Burney del. Laurie sc.

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ASTRONOMICAL AND GEOGRAPHICAL ESSAYS:

CONTAINING,

I.

A COMPREHENSIVE VIEW OF THE

General Principles of Aſtronomy.

II.

THE USE OF THE

CELESTIAL AND TERRESTRIAL GLOBES,

Exemplified in a Variety of PROBLEMS, which are deſigned to illuſtrate the Phænomena of the Earth and Heavens, in the moſt eaſy and natural Manner.

III.

THE DESCRIPTION AND USE OF THE

ARMILLARY SPHERE, PLANETARIUM, TELLURIAN, AND LUNARIUM.

IV.

AN INTRODUCTION TO

PRACTICAL ASTRONOMY;

Or, the USE of the QUADRANT and EQUATORIAL.

By GEORGE ADAMS,

MATHEMATICAL-INSTRUMENT MAKER TO HIS MAJESTY, AND OPTICIAN TO HIS ROYAL HIGHNESS THE PRINCE OF WALES.

LONDON:

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M.DCC.LXXXIX.

PREFACE.

THE connection of astronomy with geography is so evident, and both in conjunction so necessary to a liberal education, that no man will be thought to have deserved ill of the republic of letters, who has applied his endeavours to diffuse more universally the knowledge of these useful sciences, or to render the attainment of them easier; for as no branch of literature can be fully comprehended without them, so there is none which impress more pleasing ideas on the mind, or that afford it a more rational entertainment.

The fifth edition of my father's treatise on the globes being out of print, I was solicited to reprint it. To obviate several objections to the form

form in which he had diſpoſed the problems, I was induced to undertake the preſent work, in which they are arranged in a more methodical manner, and a great number added to them. Such facts are alſo occaſionally introduced, and ſuch obſervations interſperſed, as it is preſumed will excite curioſity, and fix attention.

Having proceeded ſo far in this work, I found that it was eaſy to render it ſubſervient to my plan of publiſhing, from time to time, "ESSAYS, DESCRIBING THE USE OF MATHEMATICAL AND PHILOSOPHICAL INSTRUMENTS:" for the deſcription of thoſe which have been contrived to ſmooth the path to the ſcience of aſtronomy, could no where be introduced with ſo much propriety, as in a work which treated of it's elementary principles.

To further this deſign, it was neceſſary to prefix an introduction to aſtronomy. This is divided into three parts. In the firſt, the pupil is ſuppoſed to be placed in the ſun, the center of the ſolar ſyſtem; from this ſituation he conſiders the motion of the heavenly hoſt, and finds that all is regular and harmonious. In the ſecond part, his attention is directed to the appearances of the planetary bodies, as obſerved from the earth.

earth. It were to be wiſhed that the tutor would at this part exhibit to his pupil the various phænomena in the heavens themſelves; by teaching him thus to obſerve for himſelf, he would not only raiſe his curioſity, but ſo fix the impreſſions which the objects have made on his mind, that by proper cultivation they would prove a fruitful ſource of uſeful employment; and he would thereby alſo gratify that eager deſire after novelty, which continually animates young minds, and furniſh them with objects on which to exerciſe their natural activity. In the third part of this introduction, the received, or Copernican ſyſtem is explained; by this ſyſtem, the various phænomena of the heavens are rationally accounted for; it ſhews us how to reconcile the real ſtate of things, with the fallacies ariſing from the ſenſes; and teaches us that the irregularities obſervable in the motion of the heavenly bodies, are for the moſt part to be attributed to the ſituation from which they are obſerved. Aſtronomy, in common with other branches of the mathematics, while it ſtrengthens the powers of the mind, reſtrains it from raſh preſumption, and diſpoſes it to a rational aſſent.

The principles of the Copernican ſyſtem are further elucidated in the third eſſay; in which, various planetariums, lunariums, and tellurians, are defcribed. Thefe inftruments, though lefs complicated in their conftruction, and lefs expenfive to the purchafer, than thofe large ones heretofore made for the fame purpofe, are equally, perhaps better, adapted to explain the general principles of aftronomy. In defcribing them, it was neceffary to re-confider many fubjects which had been previoufly treated; but as they are here placed in another point of view, prefented to the mind under a different form, are generally defcribed in other words, and often with the addition of new matter, it is hoped that thefe repetitions, fo far from being an object of complaint, will be found to contribute to the main intention of this work, by conveying further inftruction, fixing it more deeply in the mind, and rendering that obvious, which before might be found difficult.

One part ftill feemed wanting to an introductory treatife on aftronomy, fomething that would gently lead the pupil to a knowledge of the practical part of this fcience, a branch of aftronomy to which we are indebted for our prefent knowledge of the heavens, by which geography has been improved, and by which the paffage of fhips over the tracklefs ocean is facilitated.

There is no part of mathematical ſcience more ſimple and eaſy, than the meaſurement of the relative poſitions and diſtances of inacceſſible objects. Yet to the uninſtructed, to determine the diſtance of a ſhip on the ocean, to aſcertain the height of the clouds and meteors that float in the atmoſphere, to fix the latitude and longitude of places, &c. are problems that have ever appeared to be above the reach of human art; they are, therefore, particularly calculated to engage the attention of young minds, and may be uſed to encourage diligence, and reward application.

To introduce the pupil to this branch of aſtronomy, I have deſcribed three inſtruments, each of which is ſimple in it's conſtruction, and two of them of ſmall expence. By theſe he may find the diſtance of any inacceſſible object, the height of a ſpire, a mountain, or any other elevation, learn to plot a field, aſcertain the altitude of a cloud, a fire-ball, or any other meteor, determine with accuracy the hour of the day, the latitude or longitude of a place, with many other curious problems. In the ſelection of theſe, I have to acknowledge the aſſiſtance I received from a very ingenious friend.

I had intended to ſubjoin to this preface a liſt of aſtronomical authors, that the reader might know as well where to apply for further information, as the ſources from whence I obtained my knowledge of this ſubject. But the work has ſwelled ſo much beyond my expectations, that I am conſtrained to lay aſide this deſign.

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So far as relates to the Uſe of Spectacles; pointing out the Criteria, by which every Perſon may judge when the Uſe of them will be beneficial, and how to chuſe them without injuring the Sight.

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PART I.

An Attempt to explain with Conciseness and Perspicuity the general Principles of Astronomy.

MANKIND have in all ages been desirous of forming rational conceptions of the nature and motion of those bodies that appear in the vast concave above their heads. Amidst the infinite variety of objects which surround them on every side, the heavenly bodies must have been amongst those which first attracted their attention. They are of all objects the most conspicuous, the most important, and the most beautiful.

Astronomy may be defined as the science which instructs us in the laws, or rules, that govern the heavenly host, and by which their motions are directed. It weighs and considers the powers by which they circulate in their orbs.

 It

It enables us to diſcover their ſize, determine their diſtance, explain their various phænomena, and thus correct the fallacies of the ſenſes by the light of truth.

Aſtronomy is not merely a ſpeculative ſcience; it's uſe is as extenſive, as it's reſearches are ſublime. Navigation owns it for it's guide: by it commerce has been extended, and geography improved; and thus it has co-operated with other cauſes in the greateſt of all works, the diffuſion of knowledge, and the civilization of man.

As in order to attain an accurate idea of any piece of mechaniſm, it is beſt to begin our inveſtigations by an examination of thoſe parts which give motion to the reſt, and are the primary cauſes of thoſe effects for which the machine was made; ſo the young pupil will more eaſily gain a juſt idea of the motion of the heavenly bodies, by conſidering them as ſeen from the ſun, the center of our ſyſtem, and the principal agent uſed by the Lord of nature, for conducting and regulating the planetary ſyſtem.

It will not be difficult after this, to inform him how thoſe appearances are to be accounted for, that

that ariſe from his ſituation, by which he is forced to conſider them from a point which is not in the center of the ſyſtem, and is conſequently the ſource of many apparent irregularities. It will then alſo be eaſy to prove to him, that the real and apparent motions of the heavenly bodies are frequently the reverſe of each other. For being by this means put into poſſeſſion of the univerſals of this ſcience, the knowledge of particulars will be rendered facile and clear.

OF THE SOLAR SYSTEM, AS SEEN BY A SPECTATOR, SUPPOSED TO BE PLACED IN THE SUN.

As the center of the ſyſtem is the only place from which the motion of the planets can be truly ſeen, let us ſuppoſe our obſerver placed at the center of the ſun. In this ſituation he will ſee at one view all the heavens, which will appear to him perfectly ſpherical, and the ſtars as ſo many lucid points in the concave ſurface of the ſphere; the center of which is the ſun, or, in the preſent inſtance, the eye of the obſerver.

Our ſpectator will not, however, immediately conclude from appearances, either that the heavens are really ſpherical, or that the ſun is in the center of the ſphere, or that the ſtars are all at an equal diſtance from him; having been taught by experience and obſervation, that while he remains in the ſame place, he cannot judge properly of the diſtance of ſurrounding objects, at leaſt of thoſe which are placed beyond the ordinary reach of his view: for beyond that diſtance, all the principles by which we form our general judgment fail us, and we can only tell which is neareſt, or which is furtheſt, either by our own motion, or that of the objects.

To illuſtrate this, let us ſuppoſe a number of lamps, to be placed irregularly, at different diſtances from the eye, in a dark night. Now as in this caſe, we ſuppoſe the darkneſs to be ſo complete, that no intermediate objects could be ſeen, no difference in colour diſcerned, nor any perception of a convergence towards the point of ſight, our judgment could not aſſiſt us in diſtinguiſhing the diſtance of one from the other, and they would therefore all ſeem to be at an equal diſtance from the ſpectator.

For the ſame reaſon, the ſun and moon, the ſtars and planets, appear to be all at an equal diſtance from us; though it is highly probable, that ſome of the ſtars are many millions of times

nearer

nearer to us than others. The ſun is demonſtrated to be nearer than any of the ſtars. The moon and ſome of the planets are known by ocular proof to be nearer to us than the ſun, becauſe they ſometimes come between it and our eye, and hide the whole, or a great part of his diſk, from our view. They all, however, appear equally diſtant, and to be placed in the ſurface of a ſphere, whereof our eye is the center. In whatever place, therefore, the ſpectator reſides, whether it be on this earth, in the ſun, or in the regions of Saturn, he will conſider that place as the middle point of the univerſe, and as the center of the world; for it will be to him the center of that ſpherical ſurface, in which all diſtant bodies appear to be placed.

Here the tutor will find his advantage in illuſtrating this ſubject, and extending the ideas of his pupil, by actual experiments on real objects. Young people ſhould be taught to gain as much information as poſſible from ſenſible images; by theſe their mind would be gradually led to feel it's powers, and ſoon learn to correct thoſe errors which are induced into it by appearances, derived only from the ſenſes. No man can at once convey light in the higher ſubjects to another man's underſtanding. It muſt come into the mind from it's own motions, within itſelf; and the grand art of philoſophy and education, is to ſet the mind in action, and even when we think nothing of it, to aſſiſt it in it's labour.*

The pupil may now proceed to conſider the obſervations of the ſolar ſpectator; to whom, as we have already obſerved, the heavens will appear as the ſurface of a concave ſphere, concentrical to his eye: in this ſurface he will diſcover an innumerable hoſt of fixed ſtars, which will for ſome time engage his attention, before he diſcovers that they may be diſtinguiſhed into two kinds; the one diſperſed through the whole heavens, differing in their degree of brightneſs, but remaining always at the ſame relative diſtance from each other. Theſe he will therefore call FIXED STARS, or only STARS. Beſides theſe, he will find ſome others moving among the foregoing with different velocities, which he will call WANDERING STARS, or PLANETS.

Here, however, it may be proper to obſerve, that what we call the ſky, in which the heavenly bodies ſeem as it were to be fixed, is no real

5 ſubſtance.

* Petvin's Notes to Letters on Mind.

ſubſtance. If there was no atmoſphere ſurrounding our earth, whoſe particles might reflect other rays of light to our eyes, than thoſe which come directly from the ſun, all parts of the heavens, even at mid-day, would be dark, and the ſtars be viſible at noon. But as our atmoſphere abounds with particles capable of reflecting light every way, ſome of it will fall upon our eyes whitherſoever they are directed; from the nature of this reflection, we receive the idea of colour, and the mind immediately imagines a ſubſtance wherein it may reſide; in the ſame manner, the regular reflection of light from an object in a looking glaſs, is combined by the mind into an image of that object.

Mr. de Sauſſure, when on the top of Mount Blanc, in Savoy, a mountain which is elevated 15673 feet perpendicularly above the ſea, and where conſequently the atmoſphere muſt be much rarer than our's, ſays, that the moon ſhone with the brighteſt ſplendor in the midſt of a ſky as black as ebony; while Jupiter, rayed like the ſun, roſe from behind the mountains in the eaſt.*

Of

* Appendix to vol. 74, Monthly Review.

Of the Celestial Signs and Constellations.

Having proceeded thus far, our ſpectator will endeavour to find out ſome method of diſtinguiſhing the ſtars from each other; concluding, that as they do not change their relative poſitions one to the other, he may make an exact deſcription of them, and by repeated obſervations determine the poſition and order which ſubſiſts among them.

That he may avoid confuſion in deſcription, and be able to point out any particular ſtar, without being obliged to give a name to each, he will divide them into ſeveral parcels; to each of theſe parcels he will aſſign a figure at pleaſure; theſe aſſemblages, or groupes of ſtars, he will call CONSTELLATIONS.

Thus a number of ſtars near the north pole is called the bear, becauſe the ſtars which compoſe it are at ſuch diſtances from each other, that they may fall within the figure of a bear. Another conſtellation is called the ſhip, becauſe that collection of ſtars which compoſe it, is repreſented upon a celeſtial globe as comprized within ſome part of the figure of a ſhip.

As the fixed ſtars will appear to our obſerver of different degrees of magnitude and ſplendor, he will divide them into ſix different claſſes. Thoſe which ſeem the largeſt and brighteſt, he will call ſtars of the firſt magnitude; the ſmalleſt that we can ſee with the naked eye, are called ſtars of the ſixth magnitude; and the intermediate ones, according to their different apparent ſizes, he will call of the ſecond, third, fourth, or fifth magnitudes. Thoſe ſtars which cannot be ſeen without the aſſiſtance of a teleſcope, are not reckoned in any of theſe claſſes, and are called TELESCOPIC STARS.

By a knowledge of the fixed ſtars and their poſitions, our obſerver will obtain ſo many fixed points, by which he may obſerve the motions of the planets, and the relation of theſe motions to each other. For from the ſame place, theſe motions can only be eſtimated by the angle formed at the ſpectator's eye by the ſpace which the moving body paſſes over.

To meaſure theſe ſpaces, the ſtars muſt be uſed, and conſidered as ſo many luminous points fixed in the concavity of a ſphere, whoſe radius is indefinite, and of which the obſerver's eye is the center. We may learn from hence the neceſſity

of

of forming an exact catalogue of the ſtars, and of determining their poſitions with accuracy and care. With ſuch a catalogue, the ſcience of aſtronomy begins.

Although to thoſe who are unacquainted with the nature of celeſtial obſervation, it might at firſt ſight appear almoſt impoſſible to number the ſtars; yet their relative ſituations have been ſo carefully obſerved by aſtronomers, that they have not only been numbered, but even their places in the heavens have been aſcertained with greater accuracy, than the relative ſituation of moſt places on the ſurface of the earth.

The greateſt number of ſtars that are viſible to the naked eye, may be ſeen in a winter's night, when the air is clear, and no moon appears. But even then, a good eye can ſcarce diſtinguiſh more than one thouſand at a time in the viſible hemiſphere: for though on ſuch a night they appear to be almoſt innumerable, this appearance is a deception, that ariſes from our viewing them in a tranſient and confuſed manner; whereas, if we view them diſtinctly, and only conſider a ſmall portion of the heavens at a time, and after ſome attention to the ſituation of the remarkable ſtars contained in that portion, begin to count, we

ſhall

ſhall be ſurprized at the ſmallneſs of their number, and the eaſe with which they may be counted.

Hipparchus, the Rhodian, about an hundred and twenty years before the birth of Chriſt, was the firſt among the Greeks who reduced the ſtars into a catalogue; daring, according to Pliny, "to undertake a thing, which ſeemed to ſurpaſs the power of a divinity; that is, to number the ſtars for poſterity, and to reduce them into order; having contrived inſtruments, by which he marked the place and magnitude of each ſtar. So that by theſe means we can eaſily diſcover, not only whether any of the ſtars periſh, and others grow up, but alſo whether they move, and if ſo, the direction of their motion, whether they increaſe or diminiſh; thus putting poſterity in poſſeſſion, as it were, of the heavens."

Several aſtronomers have followed Hipparchus in the ſame arduous undertaking. In 1603, J. Bayer publiſhed celeſtial charts of all the known conſtellations, and of the viſible ſtars of which they are compoſed. In theſe charts every ſtar is diſtinguiſhed by a letter. The largeſt ſtar in the conſtellation is marked with the firſt letter of the Greek alphabet; the next in apparent ſize is marked with the ſecond letter, and ſo on. If there are more ſtars in the conſtellation than there are letters in the Greek alphabet, he marks the remainder with the letters of the Roman alphabet.

When a ſtar is mentioned with the letters of the Greek or Roman alphabet, it is always with the additional name of the conſtellation to which it belongs; and thus to thoſe who are acquainted with the figures of the conſtellations, and with the catalogue of fixed ſtars, it becomes as determinate a denomination, as if the ſtar was called by a proper name, and the ſame purpoſe is anſwered in a more familiar manner, and with leſs burthen upon the memory.

The number of the ancient conſtellations was 48; in theſe were included 1022 ſtars. Many conſtellations have been added by modern aſtronomers; ſo that the catalogues of Flamſtead and De la Caille, when added together, are found to contain near five thouſand ſtars. The names of the conſtellations, their ſituation in the heavens, with other particulars, are beſt learned by ſtudying the artificial repreſentation of the heavens, a celeſtial globe.

The ſtars appear of a ſenſible magnitude to the naked eye, becauſe the retina is not only affected by the rays of light which are emitted directly from them, but by many thouſand more, which, falling upon our eye-lids, and upon the viſible aerial particles about us, are reflected into our eyes ſo ſtrongly, as to excite vibrations, not only in thoſe points of the retina, where the real images of the ſtars are formed, but alſo in other parts round about it. This makes us imagine the ſtars to be much bigger, than they would be if we ſaw them only by the few rays which come directly from them to our eyes, without being intermixed with others. Any one may be made ſenſible of this, by looking at a ſtar of the firſt magnitude, through a long narrow tube; which, though it takes in as much of the ſky as would hold a thouſand of ſuch ſtars, ſcarce renders that one viſible.

The number of the ſtars almoſt infinitely exceeds what we have yet been ſpeaking of. An ordinary teleſcope will diſcover, in ſeveral parts of the heavens, ten times as many ſtars as are viſible to the naked eye. Hooke, in his Micrographia, ſays, that with a teleſcope of twelve feet he diſcovered ſeventy-eight ſtars among the pleiades, and with a more perfect teleſcope, many more.

Galileo

Galileo reckoned eighty in the ſpace between the belt and the ſword of Orion, and above five hundred more in another part of the ſame conſtellation, within the compaſs of one or two degrees ſquare. Antonia Maria de Rheita counted in the ſame conſtellation above two thouſand ſtars. Future improvements in teleſcopes may enable us to diſcover numberleſs ſtars that are now inviſible; and many more there may be, which are too remote to be ſeen through teleſcopes, even when they have received their ultimate improvement. Dr. Herſchel, to whoſe ingenuity and aſſiduity the aſtronomical world is ſo much indebted, and of whoſe diſcoveries we ſhall ſpeak more largely in another part of this eſſay, has evinced what great diſcoveries may be made by improvements in the inſtruments of obſervation. In ſpeaking here of his diſcoveries, I ſhall uſe the words of M. de la Lande.* "In paſſing rapidly over the heavens with his new teleſcope, the univerſe increaſed under his eye; 44000 ſtars, ſeen in the ſpace of a few degrees, ſeemed to indicate that there were ſeventy-five millions in the heavens." But what are all theſe, when compared to thoſe that fill the whole expanſe, the boundleſs

* Memoires de l'Academie de Dyon, 1785.

boundlefs fields of ether; indeed, the immenfity of the univerfe muft contain fuch numbers, as would exceed the utmoft ftretch of the human imagination. For who can fay, how far the univerfe extends, or where are the limits of it? where the Creator ftayed "his rapid wheels;" or where he "fixed the golden compaffes?"

Of the Planets, as seen from the Sun.

Our folar obferver having attained a competent knowledge of the fixed ftars, will now apply himfelf to confider the planets: thefe, as we have already obferved, he will foon diftinguifh, by their motion, from the fixed ftars; the ftars always remaining in their places, but the planets would be feen paffing by them with unequal velocities. Thus on obferving the earth, for inftance, he will find it moving among the fixed ftars, and approaching nearer and nearer to the more eaftern ones; in a year's time it will complete it's revolution, and return to the fame place again.

He will find feven of thefe bodies which revolve round the fun, to each of which he will affign a name, calling the fwifteft Mercury, denominating the others in order, according to their velocities, as Venus, then the Earth, and afterwards Mars, Jupiter, Saturn, and the Georgium Sidus.

Proceeding with attention in thus exploring and examining the heavens, he will perceive that the earth is always accompanied by a ſmall ſtar, Jupiter by four, Saturn by five, and the Georgium Sidus by two: theſe ſometimes precede, at others follow; now paſs before, and then behind the planets they reſpectively attend. Theſe ſmall bodies he will call SECONDARY PLANETS, SATELLITES, OF MOONS.

The obſerver by remarking the exact time when each planet paſſes over ſome fixed ſtar, and the time they employ from their ſetting out, to their return to the ſame ſtar again, will find the times elapſing between each ſucceſſive return of the ſame planet to the ſame ſtar, to be equal; and he would ſay, that the ſeveral planets deſcribe circles in different periods; but that each of them always completes it's own circle in the ſame ſpace of time.

He will further obſerve, that there are certain bodies, which at their firſt appearance are ſmall, obſcure, ill-defined, and that move very ſlow, but which afterwards increaſe in magnitude, light, and velocity, until they arrive at a certain ſize, when they loſe theſe properties, and diminiſh in the ſame manner as they before augmented, and at laſt diſappear. To theſe bodies, which he will find in all the regions of the heavens, moving in different directions, he will give the name of COMETS.

OF THE PATHS OF THE PLANETS.

Our obſerver will take notice, that the planets run ſucceſſively through thoſe conſtellations which he has denominated, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Piſces; and that they never move out of a certain ſpace, or zone, of the heavens, which he will call the ZODIAC.

He will find, by proceeding in his obſervation, that the orbits of the planets are not all in the ſame plane, but that they croſs each other in different parts of the heavens; ſo that if he makes the orbit of any planet a ſtandard, and conſiders it as having no obliquity, he would judge the paths of all the reſt to be inclined to it; each planet having one half of it's path on one ſide, and the other half on the oppoſite ſide of the ſtandard path, or orbit. Aſtronomers generally aſſume the earth's orbit, as the ſtandard from which to compute the inclination of the others, and call it the ECLIPTIC. The points where the orbits interſect each other, are called the NODES.

The inclination of the orbits to each other, may be rendered more familiar to the imagination,* by taking as many hoops as there are planets, with a wire thruſt through each, and thereby joined to that hoop which repreſents the ecliptic; the other hoops may be then ſet more or leſs obliquely, to the repreſentative of the ecliptic.

The ſeveral orbits do not croſs or interſect the ecliptic in the ſame point, or at the ſame angles; but their nodes, or interſections, are at different parts of the ecliptic.

It ſhould, however, be obſerved here, that in ſpeaking of the orbits of the planets, nothing more is meant by this term, than the paths they paſs through in the open ſpace in which they move, and in which they are retained by a celeſtial but continuous mechaniſm.

OF

* Dr. Watts's Aſtronomy.

OF THE MOTION OF THE PLANETS ROUND THEIR AXIS.

By attentively conſidering, with a teleſcope, the ſurface of the primary planets, our ſolar obſerver will find, that ſome parts, or SPOTS, are more obſcure than others. By continued obſervation he will find, that theſe ſpots change their places, and move from one ſide of the planet to the other; then diſappear for a certain ſpace of time; after which, they again, for a while, become viſible on the ſide where they were firſt ſeen, always continuing the ſame motion nearly in an uniform manner.

The diſtance between the ſpots grows wider as they advance from the edge towards the middle of the planet, and then grows narrow again as they paſs from the middle to the other edge. The time they are ſeen on the planet's diſk, is ſomewhat leſs than the time of their diſappearance.

From theſe circumſtances he will conclude, firſt, that theſe ſpots adhere to the body of the planet, and that each planet is a globe turning on it's axis, and has conſequently two motions, one whereby it is moved round it's axis in a ſhort time, the other by which it revolves round the ſun. Theſe motions may be eaſily conceived, by only imagining a ſmall ball to roll round a large ſphere. The firſt of theſe motions, or that of a planet round it's axis, is called the DIURNAL MOTION; and the ſecond, or it's revolution round the ſun, is called the ANNUAL MOTION.

The tutor may in ſome meaſure realize to his pupil the foregoing heliocentric phænomena, by plate I. fig. 1, of the ſolar ſyſtem; or ſtill much better, by means of a planetarium: for by ſuppoſing himſelf on the braſs ball which repreſents the ſun, he will ſee that all the planets move round him in beautiful and harmonious order; on account of their diſtance, he will refer their motions to the fixed ſtars; he will ſee how readily the periods of their revolutions are diſcovered, by obſerving the time that elapſes between their ſetting out from any fixed point, or ſtar, and their returning to the ſame again. He will alſo ſee, that if the paths of the planets were in one plane, as in the inſtrument, they would all be transferred to one circle in the heavens.

When he underſtands theſe particulars, the tutor may then proceed to ſhew him that theſe motions, which are ſo regular when viewed from the

the ſun, become intricate and perplexed when viewed from the earth; and infer from thence, that whenever we "examine the works of the Deity at a proper point of diſtance, ſo as to take in the whole of his deſign, we ſee nothing but uniformity, beauty, and preciſion." Thus the heavens preſent us with a plan, which, though inexpreſſibly magnificent, is yet regular beyond the power of invention.

ESSAY I.

PART II.

ESSAY I.

PART II.

Of the Phænomena of the Heavens, as seen from the Earth.

THE various appearances of the celeſtial bodies, as ſeen from the earth, are the facts which lay the foundation of all aſtronomical knowledge. To account for, and explain them, is it's principal buſineſs: a true idea of theſe phænomena is therefore a neceſſary ſtep to a knowledge of aſtronomy.

Of the apparent Motion of the Sun.

The firſt and moſt obvious phænomenon is the daily riſing of the ſun in the eaſt, and his ſetting in the weſt; after which the moon and ſtars appear, ſtill keeping the ſame weſterly courſe, till we loſe ſight of them altogether.

This

This cannot be long obſerved, before we muſt alſo perceive, that neither the ſun nor moon always riſe exactly at the ſame point of the heavens. If we commence our obſervations of the ſun, for inſtance, in the beginning of March, we ſhall find him appear to riſe more to the northward every day, to continue longer above the horizon, to be more vertical, or higher, at mid-day; this continues till towards the end of June, when he moves backward in the ſame manner, and continues this retrograde motion till near the end of December, when it begins to move forwards, and ſo on.

It is this change in the ſun's place, that occaſions him to riſe and ſet in different parts of the horizon, at different times of the year. It is from hence that his height is ſo much greater in ſummer, than in winter. In a word, the change of the ſun's place in the heavens is the cauſe of the different length in the days and nights, and the viciſſitudes of the ſeaſons.

As the knowledge of the ſun's apparent motion is of great importance, and a proper conception of it abſolutely neceſſary, in order to form a true idea of the phænomena of the heavens, the reader will excuſe my dwelling ſomething longer upon

it.

it. If on an evening we take notice of ſome fixed ſtar near the place where the ſun ſets, and obſerve it for ſeveral ſucceſſive evenings, we ſhall find that it approaches the ſun from day to day, till at laſt it will diſappear, being effaced by his light, though but a few days before it was at a ſufficient diſtance from him. That it is the ſun which approaches the ſtars, and not the ſtars the ſun, is plain, for this reaſon; the ſtars always riſe and ſet every day at the ſame points of the horizon, oppoſite to the ſame terreſtrial objects, and are always at the ſame diſtance from each other; whereas the ſun is continually changing both the place of it's riſing and ſetting, and it's diſtance from the ſtars.

The ſun advances nearly one degree every day, moving from weſt to eaſt; ſo that in 365 days we ſee the ſame ſtar near the ſetting ſun, as was obſerved to be near him on the ſame day in the preceding year. In other words, the ſun has returned to the place from whence he ſet out, or made what we call his annual revolution.

We cannot indeed obſerve the ſun's motion among the fixed ſtars immediately, on account of the brightneſs of his light, which prevents our ſeeing thoſe ſtars that are in his neighbourhood; but

but we can obſerve the inſtant of his coming to the meridian, and his meridional altitude; we can alſo compute what point of the ſtarry heaven comes to the ſame meridian, at the ſame time, and with the ſame altitude. The ſun muſt be at that point of the ſtarry heavens thus diſcovered. Or we can obſerve that point in the heavens, which comes to the meridian at midnight, with a declination as far from the equator on one ſide, as the ſun's is on the other ſide; and it is evident, the ſun muſt be in that part of the heavens, which is diametrically oppoſite to this point. By either of theſe methods we can aſcertain a ſeries of points in the heavens, through which the ſun paſſes, forming a circle called the ECLIPTIC.*

OF THE APPARENT PHÆNOMENA OF THE MOON.

The motion of the moon through the heavens, and her appearance therein, are ſtill more remarkable than thoſe of the ſun.

At the new moon, or when ſhe firſt becomes viſible, ſhe is ſeen in the weſtern part of the heavens, at no great diſtance from the ſun. She increaſes

* The conformity of this definition of the ecliptic, with that given in page 19, will be ſeen hereafter.

increaſes every night in ſize, and removes to a greater diſtance from the ſun, till at laſt ſhe appears in the eaſtern part of the horizon, when the ſun is diſappearing in the weſtern. After this, ſhe gradually removes further and further eaſtward, till at laſt ſhe ſeems to approach the ſun as nearly in the eaſt as ſhe did before in the weſt, and riſes a little before him in the morning; whereas in the firſt part of her courſe ſhe ſet in the weſt, long after him. All theſe different appearances happen in the ſpace of a month; after which they re-commence in the ſame manner.

There is ſometimes an irregularity in theſe appearances, particularly in harveſt-time, when the moon appears for ſeveral days to be ſtationary in the heavens, and to preſerve nearly the ſame diſtance from the ſun; in conſequence of which, ſhe riſes at that ſeaſon of the year nearly at the ame hour f or ſeveral nights.

Of the apparent Motion of the Stars.

In contemplating the ſtars, it is obſerved that ſome among them have the ſingular property of neither riſing in the eaſt, nor ſetting in the weſt; but ſeem to turn round one immoveable point, near

near which is placed a ſingle ſtar, called the POLE, or POLE STAR.

This point is more or leſs elevated, according to the part of the earth from which it is viewed. Thus to the inhabitants of Lapland it is much more vertical, or elevated above the horizon, than with us: we ſee it more elevated than the inhabitants of Spain: and theſe again ſee it more elevated than thoſe of Barbary. By continually travelling ſouthward, we ſhould at laſt ſee the pole ſtar depreſſed to the horizon, and the other pole would appear in the ſouth part of the horizon, round which the ſtars in that part would revolve. There is, however, no ſtar in the ſouthern hemiſphere ſo near the pole, as that in the northern hemiſphere. Suppoſing us ſtill to travel ſouthward, the north pole would entirely diſappear, and the whole hemiſphere would ſeem to turn round a ſingle point in the ſouth, as the northern hemiſphere appears to turn round the pole ſtar.

The general appearance, therefore, of the ſtarry heavens, is that of a vaſt concave ſphere turning round two fixed points (diametrically oppoſite to each other, the one in the north, the other in the ſouth) once in twenty-four hours. Hence

Hence it is that the ſtars, though they keep the ſame relative places with reſpect to each other, yet change their ſituation very ſenſibly with reſpect to the horizon; ſome riſing above, others deſcending below it; ſome that were inviſible, now becoming viſible; while, on the other hand, many are diſappearing. Some never deſcend below the horizon; although as they turn round, they are ſometimes nearer to, at others further from it, deſcribing whole circles about a point above it. If the obſerver turns himſelf round, he will find ſome ſtars riſe only as it were to ſet again; many deſcribing ſmall arcs, and others larger ones.

The Appearances of the Planets.

Beſides the fixed ſtars, there are other bodies in the heavens, which are continually changing their places, both with reſpect to the ſtars, and one another; theſe are called PLANETS.

They move among the ſigns of the zodiac, never departing far from the ecliptic.

Their apparent motion is very irregular, confuſed, and perplexed; ſometimes they appear as going forwards, ſometimes backwards, and at others are ſtationary.

Mercury emits a bright white light, but keeps ſo near the ſun, that he is very ſeldom viſible; and when he does make his appearance, his motion towards the ſun is ſo ſwift, that he can only be diſcerned for a ſhort time. He appears a little after ſun-ſet, and again a little before ſun-riſe.

Venus is the moſt beautiful ſtar in the heavens, known by the names of the morning and evening ſtar. She alſo, like Mercury, keeps near the ſun, though ſhe recedes from him much further. She, like him, is never ſeen in the eaſtern quarter of the heavens, when the ſun is in the weſtern; but always either attends him in the evening, or gives notice of his approach in the morning.

Mars is of a red fiery colour, giving a much duller light than Venus, though he ſometimes appears almoſt equal to her in ſize. He is not ſubject to the ſame limitations in his motions as Venus and Mercury, but appears ſometimes very near the ſun, at others at a greater diſtance from him,

him, riſing when the ſun ſets, or ſetting when he riſes.

Jupiter and Saturn likewiſe often appear at great diſtances from the ſun. The former ſhines with a bright light, the latter with a pale faint one. The motion of Saturn among the fixed ſtars is ſo ſlow, that unleſs carefully obſerved, and that for ſome time, he will not be thought to move at all.

The Georgium Sidus cannot be perceived without the aſſiſtance of a teleſcope.

From the preceding obſervations, any perſon may eaſily learn to diſtinguiſh all the planets. If after ſun-ſet he ſees a planet nearer the eaſt than the weſt, he may conclude that it is neither Mercury nor Venus; and may determine whether it is Saturn, Jupiter, or Mars, by the colour and light; by which, alſo, he may diſtinguiſh between Venus and Mercury.

That the light of each planet has it's peculiar tinge; and that there are certain fixed ſtars that have the ſame tints, was known to the Chaldæans. It is an obſervation beſt verified in thoſe countries, where the air is cleareſt.

Beſides the motions which we obſerve in all the planets, their apparent magnitudes are very different, at different times. Every one muſt have obſerved, that Venus, though ſhe conſtantly appears with great ſplendor, is not always of the ſame ſize; but this difference of magnitude is moſt conſpicuous in Mars, it is remarkable in Jupiter, but leſs ſo in Saturn and Mercury.

The only phænomena viſible to the unaſſiſted ſight, beſides thoſe already deſcribed, are thoſe unexpected obſcurations of the ſun and moon, called ECLIPSES, of which we ſhall hereafter ſpeak more particularly.

We have now deſcribed thoſe appearances, which are the moſt ſtriking to every perſon who has paid the leaſt attention to what is paſſing over his head. The tutor would do well in this place, to bring his pupil acquainted with theſe appearances, and then to explain them to him by the globe, or ſome other inſtrument. It would not be amiſs, if he were now to inſtruct him by practical obſervations, and ſhew him, by a ſmall quadrant, how to meaſure the elevation of the ſtars, &c. always remembering that young minds are ever active in ſearch of impreſſions from external objects; and that theſe are more permanent than thoſe made by words: in the former the mind energizes, and is brought into action; in the latter, it is in a great degree paſſive.

ESSAY I.

PART III.

ESSAY I.

PART III.

Of the Copernican, or Solar System.

AFTER having ſtated what would be the appearances of the heavenly bodies, if we were placed at the center of the ſyſtem, and then given a general view of their phænomena, as ſeen from the earth; it will now be proper to ſhew how the irregularities that are diſcovered in one ſituation, are to be reconciled with the harmony and order that would be viſible if they were to be ſeen from the other; or in other words, to ſhew why the motions of the planets appear to us ſo different from what they really are.

One of the ends for which man was formed, is to correct appearances and errors, by the inveſtigation of truth: whoever conſiders him attentively, from infancy to manhood, and from manhood

manhood to old age, will find him ever bufy in endeavouring to attain fome reality, to fupply the place of the falfe appearances, by which he has hitherto been deceived.

It is the bufinefs of the prefent part of this effay, to correct the errors arifing from appearances, and to point out truth by a brief detail of the principal parts of the Copernican fyftem, which is now univerfally received, becaufe it rationally accounts for, and accords with the phænomena of the heavens.

"At the appointed time, when it pleafed the fupreme difpenfer of every good gift to reftore light to a bewildered world, and more particularly to manifeft his wifdom in the fimplicity, as well as in the grandeur of his works, he opened the glorious fcene with a revival of found aftronomy;"* and raifed up Copernicus to difpel the darknefs in which it was then involved.

The Copernican fyftem confifts of the fun, feven primary, twelve fecondary planets, and the comets.

The

* Pringle's Six Difcourfes to the Royal Society.

The ſeven planets, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Georgium Sidus, move round the ſun,* in orbits included one within the other, and in the order here uſed in mentioning their names, Mercury being that which is neareſt the ſun.

Theſe ſeven, which revolve round the ſun as their center, are called PRIMARY PLANETS.

The twelve ſmall planets revolve round the primary ones as a center, and are at the ſame time carried round the ſun with them; they are therefore called SECONDARY PLANETS, MOONS, or SATELLITES.

The Georgium Sidus is attended by two moons, Saturn by five, Jupiter by four, and the Earth by one; all of theſe, excepting the laſt, are inviſible to us, on account of the ſmallneſs of their ſize, and the greatneſs of their diſtance from us.

Mercury and Venus being within the Earth's orbit, are called INFERIOR PLANETS; but Mars, Jupiter,

* The ſun is not abſolutely at reſt, being ſubject to a ſmall degree of motion, which is conſidered in larger works on aſtronomy.

Jupiter, Saturn, and the Georgium Sidus, being without it, are called SUPERIOR PLANETS.

The orbits of all the planets are elliptical; but as the principal phænomena of the Copernican ſyſtem may be ſatisfactorily illuſtrated, by conſidering them as circular, the latter ſuppoſition is uſually adopted in giving a general idea of the diſpoſition and motion of the heavenly bodies.

It is clear, from a great variety of proofs, that the aſtronomers of antiquity were acquainted with the true ſolar ſyſtem, as revived by Copernicus. It was the univerſal doctrine of the Pythagorean ſchool, and is clearly marked out as ſuch by Ariſtotle: for theſe, ſays he, aſſert that fire is in the midſt of the world, and that the earth is one of the heavenly bodies. He afterwards ſpeaks of a ſet of men, who held a ſyſtem eſſentially ſimilar to that of the modern ſemitychonic. Eudemus, in his hiſtory of aſtronomy, as cited by Anatolius, ſays, that Anaximander was the firſt who diſcovered the earth to be one of the heavenly bodies, and to move round the center of the world. Ariſtarchus held that the earth is carried round the ſun, in the circumference of a circle, of which the ſun itſelf is the center; and that the ſphere of the fixed ſtars is ſo immenſe,

immenſe, that the circle of the earth's annual orbit bears no greater proportion to it, than the center of any ſphere bears to it's whole ſurface. Philolaus, and others, declared the motion of the ſun, round about the earth, to be only apparent. They ſaw and felt the importance of his globe over our's, and ſuppoſing it's influence to extend to much larger bounds than that of the earth, they placed it in the center of the univerſe. Among the Romans, we find that Numa built a temple to repreſent, as Plutarch interprets it,* the ſyſtem of the heavens, with a ſacred fire in the center of it.† Thus alſo in the Jewiſh tabernacle, the ſeven lights had a reference to the ſeven chief lights of the heavens. Hence alſo the heavens are called in ſacred writ the tabernacle of the ſun; the whole of our ſyſtem dwelling within his influence. The foregoing citations are, we preſume, ſufficient to ſhew that the ancients were not ignorant of the true ſolar ſyſtem. Thoſe that want further information on this head, may conſult the notes to Sydenham's tranſlation of the Rivals of Plato, Duten's inquiries

* Plutarch in Vita Numæ.

† Focum Veſtæ virginibus colendum dedit, UT AD SIMILITUDINEM CŒLESTIUM SIDERUM cuſtos imperii flamma vigilaret. Flor. Hiſt.

ries into the origin of the diſcoveries attributed to the moderns; Jones's eſſay on the firſt principles of natural philoſophy; Baillie hiſtoire de l'aſtronomie ancienne. But laying theſe authorities aſide, there are direct proofs to ſhew, that the moſt ancient ſages could not be ignorant of the true ſyſtem; theſe, however, muſt be left to ſome other occaſion.

We are greatly indebted to Copernicus for the revival of this ſyſtem, and being bold enough to avow it, though it was entirely oppoſed to the prejudices of the age he lived in. In praiſing of Copernicus, let us not, however, endeavour to do away the well-earned fame of Ptolemy; his ſyſtem, though erroneous, was ingenious; with it the world was content for many ages. It was then conſidered as founded upon invincible demonſtration, as a ſacred truth, that could not be weakened by the powers of controverſy, or ſhaken by the fluctuations of opinion. Being in poſſeſſion of higher truth, we ſhould not ſpeak degradingly of thoſe who preceded us. If the ground we ſtand on be firm, it will not need ſupport from the empty boaſtings of declamation, the authority of names, or the contemptuous ſneers of an affected diſdain: the writings of modern philoſophers furniſh but too many inſtan-

ces

ces of the high opinion they entertain of their own knowledge, and their contempt of thoſe who differ from them.

Let the young pupil be cautioned not to confine the idea of bigotry to the ſuperſtitious zealots of religion; for he will find as much attachment to trifles, as much blind prejudice, and as little love to truth for truth's ſake, among thoſe who are called philoſophers, as among the moſt inveterate ſectarians, or the wildeſt fanatics.

Let him, therefore, early learn to diſtinguiſh the different degrees of evidence, of which each ſubject is capable; but above all, let him ſtudiouſly avoid the improper conjunction of the demonſtrative evidence of one ſcience, with the bare probability, or unfounded aſſertions in another; leſt, like thoſe who have gone before him, he ſhould call that demonſtrated, which is often not even probable.

Before we enter into a deſcription of the ſyſtem, it may be neceſſary to define what is meant by the axis of a planet; leſt the pupil ſhould conceive them to turn on ſuch material axes, as are uſed in the machines which are contrived to repreſent the planetary ſyſtem.

The

The AXIS OF A PLANET is a line conceived to be drawn through it's center, and about which it continually turns, in the courſe of it's revolution round the ſun: the extremities of this line terminate in oppoſite points of the ſurface of the planet, and are called it's POLES; that which points towards the northern part of the heaven, is called the NORTH POLE; that which points towards the ſouthern, the SOUTH POLE.

A ball whirled from the hand into the open air, turns round upon a line within itſelf, while it is moving forward; ſuch a line as this is meant, when we ſpeak of the axis of a planet.

Fig. 1, plate I. repreſents the ſolar ſyſtem, wherein ⊙ denotes the ſun; A B the circle which the neareſt planet, Mercury, deſcribes in moving round it; C D that in which Venus moves; F G the orbit of the earth; H K that of Mars; I N that of Jupiter; O P that of Saturn; and Q R that of the Georgium Sidus; beyond this are the ſtarry heavens.

The ſun and the planets are ſometimes expreſſed by marks or characters, inſtead of writing their names at length. The characters are as follow:

follow: ☉ the ſun, ☿ Mercury, ♀ Venus, ⊕ the earth, ♂ Mars, ♃ Jupiter, ♄ Saturn.

Of the Sun.

The ſun is the center of the ſyſtem, round which the reſt of the planets revolve. It is the firſt and greateſt object of aſtronomical knowledge, and is alone enough to ſtamp a value on the ſcience, to which the ſtudy of it belongs.

The ſun is the parent of the ſeaſons; day and night, ſummer and winter, are among it's ſurprizing effects. All the vegetable creation are the offspring of it's beams; our own lives are ſupported by it's influence. Nature revives, and puts on a new face, when it approaches nearer to us in ſpring; and ſinks into a temporary death at his departure from us in the winter.

Hence it was, with propriety, called by the ancients COR CŒLI, the heart of heaven; for as the heart is the center of the animal ſyſtem, ſo is the ſun the center of our univerſe. As the heart is the fountain of the blood, and the center of heat and motion; ſo is the ſun the life and heat of the world, and the firſt mover of the mundane ſyſtem. When the heart ceaſes to beat, the circuit of life is at an end; and if the ſun ſhould ceaſe to act, a total ſtagnation would take place throughout the whole frame of nature.

"By his magnetic beam he gently warms
The univerſe, and to each inward part,
With gentle penetration, though unſeen,
Shoots inviſible virtue."

The ſun is placed near the center of the orbits of all the planets, and turns round his axis in twenty-five days. It is inclined to the ecliptic in an angle of eight degrees.

Thoſe who are not accuſtomed to aſtronomical calculation, will be ſurprized at the real magnitude of this luminary; which, on account of it's diſtance from us, appears to the eye not much larger than the moon, which is only an attendant on this earth. When looking at the ſun, they are viewing a globe, whoſe diameter is 890,000 Engliſh miles, whoſe ſurface contains 2,488,461,360,000 ſquare miles; whereas the earth is not more in diameter than 7950 miles: ſo that the ſun is about 1,392,500 times bigger than the earth. It is reckoned to be 539½ times bigger than all the planets put together. Thus as it is the fountain of light and heat to all the planets, ſo it alſo far ſurpaſſes them in it's bulk.

If

If the ſun were every where equally bright, his rotation on his axis would not be perceptible; but by means of the ſpots, which are viſible on his pure and lucid ſurface, we are enabled to diſcover this motion.

When a ſpherical body is near enough to appear of it's true figure, it is the ſhading upon the different parts of it's ſurface that cauſes it to appear of that figure to our eyes: for as a flat circular piece of board, when it is properly ſhaded by painting, will look like a ſpherical body; ſo the ſpherical body appears of it's true ſhape, for the ſame reaſon that the plane board, in the preſent inſtance, appears ſpherical. But if the ſphere is at a great diſtance, this difference of ſhading cannot be diſcerned by the eye, and conſequently the ſphere will no longer appear of it's true ſhape; the ſhading is then loſt, and it ſeems like a flat circle.

It is thus with the ſun; it appears to us like a bright flat circle, which flat circle is termed the SUN'S DISK. By the aſſiſtance of teleſcopes, dark ſpots have been obſerved on this diſk, and found to have a motion from eaſt to weſt; their velocity is greater when they are at the center, than when they are near the limb. They are ſeen firſt on one extremity, and by degrees come forwards towards the middle, and ſo paſs on, till they reach the oppoſite edge; they then diſappear; and after they have lain hid about the ſame time that they continued viſible, they will appear again as at firſt. By this motion, we diſcover not only the time the ſun employs in turning round his axis, but alſo the inclination of it's axis to the plane of the ecliptic.

The page of hiſtory informs us, that there have been periods, when the ſun has wanted of it's accuſtomed brightneſs, ſhone with a dim and obſcure light for the ſpace of a whole year. This obſcurity has been ſuppoſed to ariſe from his ſurface being at thoſe times covered with ſpots. Spots have been ſeen, that were much larger than the earth.

The ſun is ſuppoſed to have an atmoſphere round it, which occaſions that appearance which is termed the ZODIACAL LIGHT. This light is ſeen at ſome ſeaſons of the year, either a little after ſun ſet, or a little before ſun-riſe. It is faintly bright, and of a whitiſh colour, reſembling the milky way. In the morning it becomes brighter and larger, as it riſes above the horizon, till the approach of day, which diminiſhes it's ſplendor,

ſplendor, and renders it at laſt inviſible. It's figure is that of a flat or lenticular ſpheroid, ſeen in profile. The direction of it's longer axis coincides with the plane of the ſun's equator. But it's length is ſubject to great variation, ſo that the diſtance of it's ſummit from the ſun, varies from 45 to 120 degrees. It is ſeen to the beſt advantage about the ſolſtices. It was firſt deſcribed and named by Caſſini, in 1683; it was noticed by Mr. Childrey, about the year 1650.

Of the inferior Planets, Mercury and Venus.

Of Mercury. ☿

Of all the planets, Mercury is the leaſt; at the ſame time, it is that which is neareſt the ſun. It is from his proximity to this globe of light, that he is ſo ſeldom within the ſphere of our obſervation, being loſt in the ſplendor of the ſolar brightneſs. It is oftener ſeen in thoſe parts of the world, which are more ſouthward than that which we inhabit; and oftener to us than to thoſe who live nearer the north pole; for the more oblique the ſphere is, the leſs is the planet's elevation above the horizon.

Mercury never removes but a few degrees from the ſun. The meaſure of a planet's ſeparation, or diſtance, from the ſun, is called it's ELONGATION. His greateſt elongation is little more than twenty-eight degrees, or about as far as the moon appears to be from the ſun, the ſecond day after new moon. In ſome of it's revolutions, the elongation is not more than eighteen degrees.

Mercury is computed to be at 36,841,468 miles from the ſun, and to revolve round him in 87 days, 23½ hours, which is the meaſure of it's year, about one-fourth of our's. As from the nearneſs of this planet to the ſun, we neither know the time it revolves round it's axis, nor the inclination of that axis to the plane of it's orbit, we are neceſſarily ignorant of the length of it's day and night, or the variety of ſeaſons it may be liable to. Mercury is 3000 miles in diameter, and therefore contains in ſurface 28,274,400 ſquare miles. Large as Mercury, when thus conſidered, appears to be, it is but an atom, when compared with Jupiter, whoſe diameter is 94000 miles.

Mercury is ſuppoſed to move at the rate of $109{,}699\frac{16}{100}$ miles per hour. The ſun is

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26,109,963 times as big as Mercury; ſo that it would appear to the inhabitants of Mercury nearly three times larger than it does to us; and it's diſk, or face, about ſeven times the ſize we ſee it. As the other five planets are above Mercury, their phænomena will be nearly the ſame to it as to us. Venus and the earth, when in oppoſition to the ſun, will ſhine with full orbs, and afford a brilliant appearance to the Mercurian ſpectator.

Mercury, like the moon, changes it's phaſes, according to it's ſeveral poſitions with reſpect to the ſun and earth. He never appears quite round or full to us, becauſe his enlightened ſide is never turned directly towards us, except when he is ſo near the ſun, as to become inviſible. The times for making the moſt favourable obſervations on this planet, are, when it paſſes before the ſun, and is ſeen traverſing his diſk, in the form of a black ſpot. This happens in it's lower conjunction, at a particular ſituation of it's nodes; which leads us to mention their place in the ecliptic.

The angle formed by the inclination of the orbit of Mercury with the plane of the ecliptic, is 6° 54 min.; the node from which Mercury aſcends northward, above the plane of the ecliptic, is in the 14th degree of Taurus; the oppoſite one in the 14th degree of Scorpio. The earth is in theſe points on the 6th of November, and the 4th of May. If Mercury, at his inferior conjunction, comes to either of his nodes about theſe times, he will appear to TRANSIT over the diſk of the ſun. But in all other parts of his orbit his conjunctions are inviſible, becauſe he either goes above or below the ſun.

OF VENUS. ♀

Venus is the brighteſt and largeſt, to appearance, of all the planets, diſtinguiſhed from them all by a ſuperiority of luſtre; her light is of a white colour, and ſo conſiderable, that in a duſky place ſhe projects a ſenſible ſhade. Milton takes notice of her ſuperior luſtre, in deſcribing his evening in Paradiſe, thus:

" Now came ſtill Ev'ning on, and Twilight grey
Had in her ſober liv'ry all things clad;
Silence was pleas'd: NOW GLOW'D THE FIRMAMENT
WITH LIVING SAPHIRES: HESPERUS, THAT LED
THE STARRY HOST, RODE BRIGHTEST; till the moon,
Riſing in clouded majeſty, at length,

Apparent

Apparent queen, unveil'd her peerlefs light,
And o'er the dark her filver mantle threw."

The diameter of Venus is 9330 miles; fhe contains 273,472,824 fquare miles; her diftance from the fun is 68,891,486 miles; fhe goes round the fun in 224 days, 17 hours, moving at the rate of $80{,}295\frac{24}{100}$ miles per hour. It's axis is inclined to the plane of it's orbit, in an angle of 75 degrees. Her orbit makes an angle of 3° 20 min. with the ecliptic; one node is at the 14th degree of Gemini, the other in Sagittarius. Her motion round her axis has been fixed by fome at 23 hours; by others at above 24 days. She, like Mercury, conftantly attends the fun, never departing from him above 47 or 48 degrees. Like Mercury, fhe is never feen at midnight, or in oppofition to the fun, being vifible only for three or four hours in the morning, or evening, according as fhe is before or after the fun.

One would not imagine that this planet, which appears fo much fuperior to Saturn in the heavens, is fo inconfiderable when compared to it; for the diameter of Saturn is 78,000 miles; while, on the other hand, one would fcarce imagine

that

that Venus, which appears but as a lucid ſpangle in the heavens, was ſo large a globe as ſhe truly is, her diameter being 9330 miles. It is the diſtance which produces theſe effects; which gives and takes away the magnitude of things.

When this planet is in that part of it's orbit which is weſt of the ſun, that is, from her inferior conjunction to her ſuperior, ſhe riſes before him in the morning, and is called PHOSPHORUS, or LUCIFER, or the MORNING STAR. When ſhe appears eaſt of the ſun, that is, from her ſuperior conjunction to her inferior, ſhe ſets in the evening after him; or in other words, ſhines in the evening after he ſets, and is called HESPERUS, or VESPER, or the EVENING STAR.

The inhabitants of Venus will ſee the planet Mercury always accompanying the ſun; and he will be to them, by turns, an evening or a morning ſtar, as Venus is to us. To the ſame inhabitants, the ſun will appear almoſt twice as large as he does to us.

Venus, when viewed through a teleſcope, is ſeldom ſeen to ſhine with a full face; but has phaſes, juſt like the moon, from the fine thin creſcent to the enlightened hemiſphere. Her illu-

illuminated part is conſtantly turned towards the ſun; hence it's horns are turned towards the eaſt when it is a morning ſtar, and towards the weſt when it is an evening ſtar.

We are told, that, when Copernicus firſt publiſhed his account of the ſolar ſyſtem, it was objected to him that it could not be true, becauſe if it was, the inferior planets muſt have different phaſes, according to their different ſituation with reſpect to the ſun and earth; whereas they always appear round to us. The anſwer ſaid to be made by him, is, that they appear round to the eye by reaſon of their diſtance; but if we could have a nearer, or more diſtinct view of them, we ſhould ſee in them the ſame phaſes we do in the moon. The invention of teleſcopes is ſaid to have verified this prediction of Copernicus.

But it is neither probable, that a defender of the Ptolemaic ſyſtem ſhould make ſuch an objection, or Copernicus ſuch an anſwer; ſince in the Ptolemaic, as well as in the Copernican ſyſtem, the ſhape of theſe planets ought to change, juſt as the moon does; conſequently, the mere change of ſhape in the inferior planets is an argument, which, in the common way of urging

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it, proves nothing at all as to the truth or falſhood of the Copernican ſyſtem.

If, beſides the changes of ſhape made in the inferior planets, we conſider the ſituation of the planets with reſpect to the ſun, when theſe changes happen; this, indeed, will ſhew us, that the Ptolemaic ſyſtem is falſe,* as will be ſeen in a ſubſequent part of this eſſay.

Taking the times in which the planets move round the ſun, for the length of their year; and the times of their turning round their axes, for the length of their days and nights together; and aſſuming, as true, the obſervations of Bianchini, relative to the rotation of Venus round her axis; we may ſay, that a day and a night in Venus is as long as 23½ days and nights with us; her axis inclines 75 degrees from the axis of her orbit, on which account the length of her days and nights differ much more in proportion, and the variation of her ſeaſons is greater than thoſe of our earth. She very ſeldom has the forenoon and afternoon of the ſame day of an equal length. At her equator ſhe has the four ſeaſons twice every year, with other peculiarities, which are enumerated in larger treatiſes on this ſubject.

Venus

* Rutherforth's Syſtem of Natural Philoſophy, vol. 2, p. 781.

Venus is ſometimes ſeen paſſing over the diſk of the ſun, as a round dark ſpot. Theſe appearances, which are called tranſits, happen very ſeldom; there have been two within theſe few years, the one in June, 1761, the other in June, 1769; the next will be in the year 1874.

Of the Earth. ⊕

The next planet that comes before us, is the earth that we inhabit; ſmall as it really is when compared to ſome of the other planets, it is to us of the higheſt importance: we wiſh only to attain knowledge of the others, that we may find out their relation to this, and from thence learn our connection with the univerſe at large. But when viewed with an eye to eternity, it's value to us is heightened in a manner that exceeds expreſſion, and ſurpaſſes all the powers of the human mind. He alone can form ſome idea of it, who in the regions of celeſtial bliſs is become a partaker of the length and breadth, the depth and heighth, of divine love.

The orbit of the earth is placed between thoſe of Venus and Mars. The diameter of the earth is 7970 miles; it's ſurface contains 199,557,259 ſquare miles; it's diſtance from the ſun is

95,173,000 miles, and goes round him in a year, moving at the rate of 68,243$\frac{24}{100}$ miles per hour.

It turns round it's axis from WEST TO EAST, in twenty-four hours, which occafions the apparent diurnal motion of the fun, and all the heavenly bodies round it, from EAST TO WEST in the fame time; it is, of courfe, the caufe of their rifing and fetting, of day and night.

The axis of the earth is inclined 23½ degrees to the plane of it's orbit, and keeps in a direction parallel to itfelf, throughout it's annual courfe, which caufes the returns of fpring and fummer, autumn and winter. Thus his diurnal motion gives us the grateful viciffitude of night and day, and his annual motion the regular fucceffion of feafons.

OF THE MOON. ☾

Next to the fun, the moon is the moft fplendid and fhining globe in the heavens, the fatellite, or infeparable companion of the earth. By diffipating, in fome meafure, the darknefs and horrors of the night; by her various appearances, fubdividing the years into months; by regulating the flux and reflux of the fea; fhe not

only

only becomes a pleaſing, but a welcome object; an object affording much for ſpeculation to the contemplative mind, of real uſe to the navigator, the traveller, and the huſbandman.

That the moon appears ſo much larger than the other planets, is owing to her vicinity to us; for to a ſpectator in the ſun ſhe would be ſcarcely viſible, without the aſſiſtance of a teleſcope. Her diſtance is but ſmall from us, when compared with that of the other heavenly bodies; for among theſe, the leaſt abſolute diſtance, when put down in numbers, will appear great, and the ſmalleſt magnitude immenſe.

The moon is 2180 miles in diameter; her bulk is in proportion to the earth as 1 to $48\frac{6}{10}$; her diſtance from the center of the earth 240,000 miles; ſhe goes round her orbit in 27 days, 7 hours, 43 minutes, moving at the rate of $2299\frac{65}{100}$ miles per hour. The time in going round the earth, reckoning from change to change, is 29 days, 12 hours, 44 minutes.

Her orbit is inclined to the ecliptic, in an angle of 5 degrees, 18 minutes, cutting it in two points, which are diametrically oppoſite to each other; theſe points are called her nodes. The nodes have a motion weftward, or contrary to the order of the figns, making a complete revolution in about nineteen years; in which time, each node returns to that point of the ecliptic whence it before receded.

While the moon is making her revolution round the heavens, fhe undergoes great changes in her appearance. She is fometimes on our meridian at midnight, and therefore in that part of the heavens which is oppofite to the fun; in this fituation fhe appears as a complete circle, and it is faid to be FULL MOON. As fhe moves eaftward, fhe becomes deficient on the weft fide, and in about 7$\frac{1}{3}$ days comes to the meridian, at about fix in the morning, having the appearance of a femicircle, with the convex fide turned towards the fun; in this ftate, her appearance is called the HALF MOON. Moving on ftill eaftward, fhe becomes more deficient on the weft, and has the form of a crefcent, with the convex fide turned towards the fun; this crefcent becomes continually more flender, till about 14 days after the full moon, fhe is fo near the fun, that fhe cannot be feen, on account of his great fplendor. About four days after this difappearance, fhe is feen in the evening, a little to the eaftward of the fun, in the form of a fine crefcent, with

with the convex ſide turned from the ſun; moving ſtill to the eaſtward, the creſcent becomes more full; and when the moon comes to the meridian, about ſix in the evening, ſhe has again the appearance of a bright ſemicircle; advancing ſtill to the eaſtward, ſhe becomes fuller on the eaſt ſide; at laſt, in about 29½ days, ſhe is again oppoſite to the ſun, and again full.

It frequently happens, that the moon is eclipſed when at the full; that the ſun is eclipſed ſome time between the diſappearance of the moon in the morning on the weſt ſide of the ſun, and her appearance in the evening on the eaſt ſide of the ſun. The nature of theſe phænomena will be more fully conſidered, when we come to treat particularly of eclipſes.

In every revolution of the moon about the earth, ſhe turns once round upon her axis, and therefore preſents the ſame face to our view; and her day and night together are as long as our lunar month. As we ſee only one ſide of the moon, we are therefore inviſible to the inhabitants on the oppoſite ſide, without they take a journey to that ſide which is next to us, for which purpoſe ſome of them muſt travel more than 1500 miles.

As the moon illuminates the earth by a light reflected from the ſun, ſhe is reciprocally enlightened, but in a much greater degree, by the earth; for the ſurface is above 13 times greater than that of the moon; and therefore, ſuppoſing their power of reflecting light to be equal, the earth will reflect 13 times more light on the moon than ſhe receives from it. When it is what we call new moon, we ſhall appear as a full moon to the Lunarians; as it increaſes in light to us, our's will decreaſe to them: in a word, our earth will exhibit to them the ſame phaſes as ſhe does to us.

We have already obſerved, that from one half of the moon the earth is never ſeen; from the middle of the other half, it is always ſeen over head, turning round almoſt thirty times as quick as the moon does. To her inhabitants, the earth ſeems to be the largeſt body in the univerſe, about thirteen times as large to them, as ſhe does to us. As the earth turns round it's axis, the ſeveral continents and iſlands appear to the Lunarians as ſo many ſpots, of different forms; by theſe ſpots, they may determine the time of the earth's diurnal motion; by theſe ſpots, they may, perhaps, meaſure their time,—they cannot have a better dial.

Of the superior Planets.

Mars, Jupiter, Saturn, and the Georgium Sidus, are called ſuperior planets, becauſe they are higher in the ſyſtem, or farther from the center of it, than the earth is.

They exhibit ſeveral phænomena, which are very different from thoſe of Mercury and Venus; among other things, they come to our meridian both at noon and midnight, and are never ſeen croſſing the ſun's diſk.

Of Mars. ♂

Mars is the leaſt bright and elegant of all the planets; it's orbit lies between that of the earth and Jupiter, but very diſtant from both. He appears of a duſky reddiſh hue; from the dullneſs of his appearance, many have conjectured that he is encompaſſed with a thick cloudy atmoſphere.

Mars, which appears ſo inconſiderable in the heavens, is 5,400 miles in diameter, 91,608,956 ſquare miles in ſuperficial content. It's diſtance from the ſun is 145,014,148 miles. It goes round the ſun in 1 year, 321 days, 17 hours, moving at the rate of 55,287 miles per hour. It revolves round it's axis in 24 hours, 40 minutes; it's orbit is inclined to the ecliptic, at an angle of 1 deg. 52 min.; to an inhabitant in Mars, the ſun would appear one-third leſs in diameter than it does to us.

Mars, when in oppoſition to the ſun, is five times nearer to us than when in conjunction. This has a very viſible effect on the appearance of the planet, cauſing him to appear much larger at ſome periods than at others.

The axis of this planet is nearly at right angles to it's orbit. The time, therefore, the ſun is above the horizon, or the length of the natural day, will almoſt, in every part, be equal to the night, or the time the ſun is below the horizon. There will be very little change or variety of ſeaſons; but places, in different latitudes, will have very different degrees of light and cold, on account of the different inclination of the ſun's rays to the horizon.

A ſpectator in Mars will rarely, if ever, ſee Mercury, except when they ſee it paſſing over the ſun's diſk. Venus will appear to him at about the ſame diſtance from the ſun, as Mercury appears to us. The earth will appear about the ſize of Venus, and never above 48 degrees from the ſun; and will be, by turns, a morning and evening ſtar to the inhabitants of Mars.

Of Jupiter. ♃

Jupiter is ſituated ſtill higher in the ſyſtem, revolving round the ſun, between Mars and Saturn. It is the largeſt of all the planets, and eaſily diſtinguiſhed from them by his peculiar magnitude and light. To the naked eye it appears almoſt as large as Venus, but not altogether ſo bright.

Jupiter revolves round it's axis in 9 hours, 56 minutes; round the ſun in 4332 days, 12 hours, 20 minutes, or near 12 years. The diſproportion of Jupiter to the earth, in ſize, is very great; viewing him in the heavens, we conſider him as ſmall in magnitude; whereas he is in reality 94,000 miles in diameter, and 25,759,077,600 ſquare miles in ſuperficial content; his diſtance from the ſun is 494,990,976 miles; he moves at the rate of rather more than 22,101 miles per hour; his orbit is inclined to the ecliptic, at an angle of 1 deg. 20 min.

To an eye placed in Jupiter, the ſun would not be a fifth part of the ſize he appears to us, and his diſk be 25 times leſs. Though Jupiter be the largeſt of all the planets, yet it's revolution round it's axis is the ſwifteſt. The polar axis is ſhorter than the equatoreal one, and his axis perpendicular to the plane of his orbit.

Jupiter, when in oppoſition to the ſun, is much nearer the earth, than when he is in conjunction with him; at thoſe times he appears alſo larger, and more luminous than at other times.

Jupiter is attended by four ſatellites, or moons; theſe are inviſible to the naked eye; but through a teleſcope they make a beautiful appearance. As our moon turns round the earth, enlightening the nights, by reflecting the light ſhe receives from the ſun, ſo theſe alſo enlighten the nights of Jupiter, and move round him in different periods of time, proportioned to their ſeveral diſtances: and as the moon keeps company with the earth in it's annual revolution round the ſun; ſo theſe accompany Jupiter in it's courſe round that luminary.

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In ſpeaking of the ſatellites, we diſtinguiſh them according to their places, into the firſt, the ſecond, and ſo on; by the firſt, we mean that which is neareſt to the planet.

In Jupiter, the days and nights are of an equal length, each being about five hours long. We have already obſerved, that the axis of his diurnal rotation is nearly at right angles to the plane of his annual one; and here, as far as we may reaſon from analogy, we may diſcover the footſteps of that wiſdom, which is ſo conſpicuous in all the works of the Creator: for if the axis of this planet were inclined by any conſiderable number of degrees, juſt ſo many degrees round each pole would, in their turn, be almoſt ſix years in darkneſs; and as Jupiter is of ſuch an amazing ſize, in this caſe immenſe regions of land would be uninhabitable.

The outermoſt of Jupiter's ſatellites will appear almoſt as big as the moon does to us; five times the diameter, and twenty-five times the diſk of the ſun. The four ſatellites muſt afford a pleaſing ſpectacle to the inhabitants of Jupiter; for ſometimes they will riſe all together, ſometimes be all together on the meridian, ranged one under another, beſides frequent eclipſes. Notwithſtanding the diſtance of Jupiter and his ſatellites from us, the eclipſes thereof are of conſiderable uſe, for aſcertaining with accuracy the longitude of places. From the four ſatellites, the inhabitants of Jupiter will have four different kinds of months, and the number of them in their year not leſs than 4500.

An aſtronomer in Jupiter will never ſee Mercury, Venus, the earth, or Mars; becauſe, from the immenſe diſtance at which he is placed, they muſt appear to accompany the ſun, and riſe and ſet with him; but then he will have for the objects of obſervation, his own four moons, Saturn, his ring and ſatellites, and probably the Georgium Sidus.

Of Saturn. ♄

Before the diſcovery of the Georgium Sidus, Saturn was reckoned the moſt remote planet in our ſyſtem; he ſhines but with a feeble light, leſs bright than Jupiter, though leſs ruddy than Mars. The uninformed eye imagines not, when it is directed to this little ſpeck of light, that it is viewing a large and glorious globe, one of the moſt ſtupendous of the planets, whoſe diameter is 78,000 miles, whoſe ſurface contains

19,

19,113,494,400 ſquare miles. We need not, however, be ſurprized at the vaſt bulk of Saturn, and it's diſproportion to it's appearance in the heavens; for we are to conſider, that all objects decreaſe in their apparent magnitude, in proportion to their diſtance; but the diſtance of Saturn is immenſe; that of the earth from the ſun is 95,173,000 miles; of Saturn, 907,956,130 miles!

The length of a planet's year, or the time of it's revolution round it's orbit, is proportioned to it's diſtance from the ſun. Saturn goes round the ſun in 29 years, 167 days, 6 hours, moving at the rate of rather more than 22,101 miles per hour. His orbit is inclined to the ecliptic, in an angle of 2 deg. 30 min.

It has not yet been aſcertained by aſtronomical obſervation, whether Saturn revolves or not upon his axis: we are therefore ignorant of the length of his day, and of his night. The ſun's diſk will appear ninety times leſs to an inhabitant of Saturn, than it does to us; but notwithſtanding the ſun appears ſo ſmall to the inhabitants of the regions of Jupiter and Saturn, the light that he will afford them is much more than would be at firſt ſuppoſed; and calculations have been made, from

which

which it is inferred, that the ſun will afford 500 times as much light to Saturn, as the full moon to us; and 1600 times as much to Jupiter. To eyes like our's, unaſſiſted by inſtruments, Jupiter and the Georgium Sidus would be the only planets ſeen from Saturn, to whom Jupiter would ſometimes be a morning, ſometimes an evening ſtar.

There is a ſingular and curious appendage to the planet Saturn; a thin, broad, opake ring, encompaſſing the body of that planet, without touching it, like the horizon of an artificial globe, appearing double when viewed through a good teleſcope. The ſpace between the ring and the globe of Saturn, is ſuppoſed to be rather more than the breadth of the ring, and the greateſt diameter of the ring to be in proportion to that of the globe, as 7 to 3; the plane of the ring is inclined to the plane of the ecliptic, in an angle of 30 degrees, and is about 21,000 miles in breadth. It puts on different appearances to us, ſometimes being ſeen quite open, at others only as a line upon the equator. It is probable, that it will at times caſt a ſhadow over vaſt regions of Saturn's body. The ring of Saturn, conſidered as a broad flat ring of ſolid matter, ſuſpended round the body of the planet, and keeping it's place without any connection with the body, is quite different

from

from all other planetary phænomena with which we are acquainted. Of the nature of this ring, various and uncertain were the conjectures of the firft obfervers; yet they were not lefs perplexed, than thofe of the lateft. Of it's ufe to the inhabitants of Saturn, we are equally ignorant; though there are reafons for fuppofing that it would appear to them as little more than a white or bright-coloured cloud. Some of the phænomena of Saturn's ring will be treated of more particularly in another part of this effay.

Saturn is not only furnifhed with this beautiful ring, but it has alfo five attendant moons.

OF THE GEORGIUM SIDUS.

From the time of Huygens and Caffini, to the difcovery of the Georgium Sidus by Dr. Herfchel, though the intervening fpace was long, though the number of aftronomers was increafed, though affiduity in obferving was affifted by accuracy and perfection in the inftruments of obfervation, yet no new difcovery was made in the heavens, the boundaries of our fyftem were not enlarged. The inquifitive mind naturally inquires, why, when the number that cultivated the fcience was increafed, when the fcience itfelf was fo much improved,

improved, in practical discoveries it was so deficient? A small knowledge of man will answer the question, and obviate the difficulty.

The mind of man has a natural propensity to indolence; the ardour of it's pursuits, when they are unconnected with selfish views, are soon abated, small difficulties discourage, a little inconvenience fatigues him, and his reason will soon find excuses to justify, and even applaud his weakness. In the present instance, the unmanageable length of the telescopes that were in use, and the continual exposure to the cold air of the night, were the difficulties the astronomer had to encounter with; and he soon persuaded himself, that the same effects would be produced by shorter telescopes, with equal magnifying power; herein was his mistake, and here the reason why so few discoveries have been made since the time of Cassini. A similar instance of the retrogradation of science, occurs in the history of the microscope, as I have shewn in my essays on that instrument.

The Georgium Sidus was discovered by Dr. Herschel, in the year 1781; for this discovery he obtained from the Royal Society the honorary recompence of Sir Godfrey Copley's medal. He

named

named the planet in honour of his Majeſty King George III. who has taken Mr. Herſchel under his patronage, and granted him an annual ſalary.

In ſo recent a diſcovery of a planet ſo diſtant, many particulars cannot be expected. It's year is ſuppoſed to be more than 83 ſiderial years; the inclination of it's orbit 43 min. 35 ſeconds; it's bulk to that of the earth as 4,454 to 1. It's light is of a blueiſh white colour, and it's brilliancy between that of the moon and Venus.

With a teleſcope, which magnifies about 300 times, it appears to have a very well defined viſible diſk; but with inſtruments of a ſmaller power it can hardly be diſtinguiſhed from a fixed ſtar, between the ſixth and ſeventh magnitude. When the moon is abſent, it may alſo be ſeen by the naked eye.

This general view of the ſolar ſyſtem cannot, I apprehend, be better concluded than in the words of that excellent mathematician, Mr. Maclaurin.

"The view of nature, which is the immediate object of ſenſe, is very imperfect, and of ſmall extent;

extent; but by the aſſiſtance of art, and the aid of reaſon, becomes enlarged, till it loſes itſelf in infinity. As magnitude of every ſort, abſtractedly conſidered, is capable of being increaſed to infinity, and is alſo diviſible without end; ſo we find, that in nature the limits of the greateſt and leaſt dimenſions of things, are actually placed at an immenſe diſtance from each other.

"We can perceive no bounds of the vaſt expanſe, in which natural cauſes operate, and fix no limit, or termination, to the univerſe. The objects we commonly call great, vaniſh, when we contemplate the vaſt body of the earth. The terraqueous globe itſelf is loſt in the ſolar ſyſtem; the ſun itſelf dwindles into a ſtar; Saturn's vaſt orbit, and all the orbits of the comets, crowd into a point, when viewed from numberleſs places between the earth and the neareſt fixed ſtars. Other ſuns kindle to illuminate other ſyſtems, where our ſun's rays are unperceived; but they alſo are ſwallowed up in the vaſt expanſe. When we have riſen ſo high, as to leave all definite meaſures far behind us, we find ourſelves no nearer to a term, or limit.

"Our

"Our views of nature, however imperfect, ſerve to repreſent to us, in a moſt ſenſible manner, that mighty power which prevails throughout, acting with a force and efficacy that ſuffers no diminution from the greateſt diſtances of ſpace or intervals of time; and to prove that all things are ordered by infinite wiſdom, and perfect goodneſs, ſcenes which ſhould excite and animate us to correſpond with the general harmony of nature."

OF THE SHAPE OR FIGURE OF THE EARTH.

Having given a general idea of the Copernican ſyſtem, and the bodies of which it is compoſed, it will be neceſſary to enlarge theſe ideas by a more minute deſcription of the particular parts, which form this great whole; and to ſtrengthen them by the force of that evidence, on which the ſyſtem is founded.

We have already obſerved, that the appearance of the heavenly bodies is not the ſame to the inhabitants of various parts of the earth; that the ſun, the moon, and the ſtars, riſe and ſet in Greenland in a manner very different from what they do in the Eaſt Indies, and in both places very different from what they do in England:

and

and as it was natural to attribute the caufe of this change in the apparent face of the heavens, to the figure of the earth, (for appearances muft ever anfwer to the form and ftructure of the things) the nature of this figure was, therefore, one of the firft objects of inquiry among philofophers and aftronomers.

Some of the fages of antiquity concluded, that the earth muft neceffarily be of a fpherical figure, becaufe that figure was, on many accounts, the moft convenient for the earth, as an habitable world: they alfo argued, that this figure was the moft natural, becaufe any body expofed to forces, which tend to one common center, as is the cafe with the earth, would neceffarily affume a round figure. The affent, however, of the philofopher to this truth, was not determined by fpeculative reafoning; but on evidence, derived from facts and actual obfervation. From thefe I fhall felect thofe arguments, that I think will have the greateft weight with young minds.

It is known, from the laws of optics and perfpective, that if any body, in all fituations, and under all circumftances, projects a circular fhadow, that body muft be a globe.

It

It is alſo known, that eclipſes of the moon are cauſed by the ſhadow of the earth.

And we find, that whether the ſhadow be projected towards the eaſt, or the weſt, the north, or the ſouth, under every circumſtance it is circular; the body, therefore, that caſts the ſhadow, which is the earth, muſt be of a globular figure.

We ſhall obtain another convincing proof of the globular ſhape of the earth, by inquiring in what manner a perſon ſtanding upon the coaſt of the ſea, and waiting for a veſſel which he knows is to arrive, ſees that veſſel.

We ſhall find, that he firſt of all, and at the greateſt diſtance, ſees the top of the maſt riſing out of the water; and the appearance is, as if the ſhip was ſwallowed up in the water. As he continues to obſerve the object, more and more of the maſt appears; at length he begins to ſee the top of the deck, and by degrees the whole body of the veſſel. On the other hand, if the ſhip be departing from us, we firſt loſe ſight of the hull, at a greater diſtance the main ſails diſappear, and at a ſtill greater the top-ſail. But if the ſurface of the ſea were a plane, the body of the ſhip, being the largeſt part of it, would be ſeen firſt, and from the greateſt diſtance, and the maſts would not be viſible till it came nearer.

To render this, if poſſible, ſtill clearer, let us conſider two ſhips meeting at ſea, the top-maſt of each are the parts firſt diſcovered by both, the hull, &c. being concealed by the convexity of the globe which riſes between them. The ſhips may, in this inſtance, be reſembled to two men, who approach each other on the oppoſite ſides of a hill; their heads will firſt be ſeen, and gradually, as they approach, the body will come entirely in view.

This truth is fully evinced by the following conſideration; that ſhips have ſailed round the earth, have gone out to the weſtward, and have come home from the eaſtward; or in other words, the ſhips have kept the ſame courſe, and yet returned from the oppoſite ſide into the harbour whence they firſt ſailed. Now we are certain that this could not be the caſe, if the earth were a plane; for then a perſon, who ſhould ſet out from any one point, and go on ſtrait forward, without ſtopping, would be continually going further from the point from which he ſet out. This argument may be much elucidated, by referring the pupil to a terreſtrial globe, on which

which he may follow the tracks of an Anſon and a Cook round the globe.

Fig. 1 and 2, plate II. are illuſtrations of the foregoing principles. Fig. 1, ſhews that if the earth was a plane, the whole of a ſhip would be ſeen at once, however diſtant from the ſpectator, and that whether he was placed at the top or bottom of a hill. From fig. 2, it appears, that the rotundity of the earth, repreſented by the circle A B C, conceals the lower part of the ſhip *d*, while the top-maſt is ſtill viſible; and that it is not till the ſhip comes to e that the whole of it is viſible.

Obſerve any ſtar near the northern part of the horizon, and if you travel to the ſouth, it will ſeem to dip farther and farther downwards, till by proceeding, it will deſcend entirely out of ſight. In the mean time, the ſtars to the ſouthward of our traveller will ſeem to riſe higher and higher. The contrary appearances would happen, if he went to the northward. This proves that the earth is not a plane ſurface, but a curve in the direction ſouth and north. By an obſervation nearly ſimilar to this, the traveller may prove the curvature of the earth, in an eaſt and weſt direction.

The globular figure of the earth may be alſo inferred from the operation of levelling, or the art of conveying water from one place to another: for in this proceſs, it is found neceſſary to make an allowance between the true and apparent level; or in other words, for the figure of the earth. For the true level is not a ſtrait line, but a curve, which falls below the ſtrait line, about eight inches in a mile, four times eight in two miles, nine times eight in three miles, ſixteen times eight in four miles, always increaſing as the ſquare of the diſtance.

What the earth loſes of it's ſphericity by mountains and vallies, is very inconſiderable; the higheſt eminence bearing ſo little proportion to it's bulk, as to be ſcarcely equivalent to the minuteſt protuberance on the ſurface of a lemon.

It is proper, however, to acquaint the young pupil, that though we call our earth a globe, and that when ſpeaking in general terms, it may be conſidered as ſuch; yet, in the ſtrictneſs of truth, it muſt be obſerved, that it is not exactly and perfectly ſpherical, but is what we term an oblate ſpheroid, flattened a little towards the poles, and ſwelling at the equator; the equatorial diameter being about thirty-four miles longer than the diameter from pole to pole. This difference bears, however, too ſmall a proportion to the diameter, to be repreſented on globes.

OF THE DIURNAL MOTION OF THE EARTH.

Young people generally find ſome difficulty in conceiving that the earth moves; the more ſo, becauſe, in order to allow it, they muſt give up, in a great meaſure, the evidence of their exterior ſenſes, of which the impreſſions are with them exceeding ſtrong and lively. It will, therefore, be neceſſary for the tutor to prove to them, that they can by no means infer that the earth is at reſt, becauſe it appears ſo to them; and he ſhould convince them, by a variety of facts, that reaſon was given to correct the fallacies of the ſenſes. To this end we ſhall here point out ſome inſtances, where apparent motion is produced in a body at reſt, by the real motion of the ſpectator.

Let us ſuppoſe a man in a ſhip, to be carried along by a briſk gale, in a direction parallel to a ſhore, at no great diſtance from him; while he keeps his eye upon the deck, the maſt, the ſails, or any thing about him in the ſhip; that is to ſay, while he ſees nothing but ſome part of the veſſel on board of which he is, and confequently every part of which moves with him, he will not perceive that the fhip moves at all. Let him, after this, look to the fhore, and he will fee the houfes, trees, and hills, run from him in a direction contrary to the motion of the veffel; and fuppofing him to have received no previous information on this fubject, he might naturally conclude, that the apparent motion of thefe bodies was real.

In a fimilar fituation to this, we may conceive the inhabitants of the earth; who, in early times, knowing nothing of the true ftructure or laws of the univerfe, faw the fun, the ftars, and the planets, rife and fet, and perform an apparent revolution about the earth. They had no idea of the motion of the earth, and therefore all this appearance feemed reality. But as it is highly reafonable to fuppofe, that as foon as the flighteft hint fhould be given to the man, of the motion of the veffel, he would begin to form a new opinion, and conceive it to be more rational, that fo fmall a thing as the fhip fhould move, rather than all that part of the earth which was open to his view; fo, in the fame manner, no fooner was an idea formed, of the vaft extent and greatnefs of the univerfe, with refpect to this earth, than mankind began to conceive it would

be

be more rational that the earth ſhould move, than the whole fabric of the heavens.

By another familiar inſtance, it will be eaſy to ſhew the young pupil, that as the eye does not perceive it's own motion, it always judges from appearances. Let a perſon go into a common windmill, and deſire the miller to turn the mill round while he is ſitting within it, and his eyes fixed on the upright poſt in the center thereof; this poſt, though at reſt, will appear to him to turn round with conſiderable velocity, the real motion of the mill being the cauſe of the apparent motion of the ſwivel poſt. Having thus obviated the objections which ariſe from the teſtimony of the ſenſes, we may now proceed to conſider the arguments which tend more directly to prove the motion of the earth.

All the celeſtial motions will, on this ſuppoſition, be incomparably more ſimple and moderate.

This opinion is much more agreeable to our notions of final cauſes, and our knowledge of the œconomy of nature; for if the earth be at reſt, and the ſtars, &c. move round it once in 24 hours, their velocity muſt be immenſe; and it is certainly more agreeable to reafon, that one fingle body, and that one of the fmalleft, fhould revolve on it's own axis in 24 hours, than that the whole univerfe fhould be carried round it, in the fame time, with inconceivable velocity.

The rotation of the earth round it's axis is analogous to what is obferved in the fun, and moft of the planets; it being highly probable, that the earth, which is itfelf one of the planets, fhould have the fame motion as they have, for producing the fame effect: and it would be as abfurd in us to contend for the motion of the whole heavens round us in 24 hours, rather than allow a diurnal motion to our globe, as it would be for the inhabitants of Jupiter to infift that our globe, and the whole heavens, muft revolve round them in ten hours, that all it's parts might fucceffively enjoy the light, rather than grant a diurnal motion to their habitation.

All the phænomena relative to this fubject, are as eafily folved on the fuppofition of the earth's motion, as on the contrary hypothefis. The truth of this pofition is pleafingly illuftrated by the armillary fphere, which is fhewn, fig. 2, pl. XIII. The exterior circles reprefent the fphere of the heavens; within thefe, and in the center of the

fphere,

ſphere, is placed a little globe, ſupported by a ſteel axis. *a* and *b* are two milled nuts. By moving the nut *a*, the ſmall globe may be turned round the ſame way we ſuppoſe our earth to revolve, while the outer part, or ſphere, remains fixed; but if the nut *b* be turned the contrary way, the ſphere will move round the globe, the ſame way as the heavens appear to move.

Thus by this machine, the real motion of the earth round it's axis, within the ſphere of the heavens, or the apparent motion of the heavens round the earth, may be repreſented: and it will ſhew, that the reſult of the various problems are the ſame, whether we ſuppoſe the heavens to move round the earth, or the earth to revolve on it's axis.

Beſides the foregoing conſiderations, there are ſeveral arguments to be deduced from the higher parts of aſtronomy, which demonſtrably prove the diurnal motion of the earth.

Definitions.

Before we enter into a further explanation of phænomena, it will be neceſſary to define ſome of the principal circles of the globe. The reader

will

will comprehend more fully theſe definitions, and attain more accurate ideas of theſe circles, by placing, while he is reading them, a terreſtrial globe, or armillary ſphere, before him.

It may, however, be neceſſary to premiſe, that we are at liberty to ſuppoſe as many circles as we pleaſe, to be deſcribed on the earth; and the plane of any of theſe to be continued from the earth, until it marks a correſponding circle in the concave ſphere of the heavens.

Among theſe circles, the HORIZON is the moſt frequently named. Properly ſpeaking, there are two circles called by this name, but diſtinguiſhed from each other by added epithets, the one being called the SENSIBLE, the other the RATIONAL HORIZON.

In general terms, the HORIZON may be defined to be an imaginary circle, that ſeparates the viſible from the inviſible part of the heavens.

If a ſpectator ſuppoſes the floor or plane on which he ſtands, to be extended every way, till it reach the ſtarry heavens, this plane is his SENSIBLE HORIZON.

The

The RATIONAL HORIZON is a circle, whofe plane is parallel to the former, but paffing through the center of the earth.

The rational horizon divides the concave fphere of the heavens into equal parts, or hemifpheres; the objects that are in the upper hemifphere will be vifible; fuch as are in the lower hemifphere will be invifible to the fpectator.

Though the globe of the earth appears fo large to thofe who inhabit it, yet it is fo minute a fpeck, when compared to the immenfe fphere of the heavens, that at that diftance the planes of the rational and fenfible horizons coincide; or in other words, the diftance between them in the fphere of the heavens, is too fmall for admeafurement.

To illuftrate this, let A B C D, fig. 1, plate III. reprefent the earth; z h n o the fphere of the ftarry heaven. If an inhabitant of the earth ftands upon the point A, his fenfible horizon is *f e*, his rational one h o; the diftance between the planes of thefe two horizons is A F, the femidiameter of the earth, which is meafured in a great circle upon the fphere of the heaven, by the angle e F o, or the arc e o; this arch in fo

fmall

ſmall a circle, as z h n o would amount to ſeveral degrees, and conſequently the difference between the ſenſible and the rational horizon, would be great enough to be meaſured by obſervation. If we repreſent the ſphere of the heaven by a larger circle, the ſemidiameter of the earth A F meaſured in this circle, will amount to fewer degrees; for the arc E O is leſs than the arc e o; and the larger the ſphere of the heaven is, in proportion to the globe of the earth, the leſs ſenſible is the difference between the two horizons. Now as the ſphere of the earth is but as a point, when compared to the ſtarry heaven, the difference between the ſenſible and rational horizon will be inſenſible.

From what has been ſaid, it appears that the only diſtinction between the ſenſible and rational horizon, ariſes from the diſtance of the object we are looking at.

The ſenſible horizon is an imaginary circle, which terminates our view, when the objects we are looking at are upon the earth's ſurface. The rational horizon is an imaginary circle, which terminates our view, when the objects we are looking at are as remote as the heavenly bodies.

As

As the rational horizon divides the apparent celeſtial ſphere into two equal hemiſpheres, and ſerves as a boundary, from which to meaſure the elevation or depreſſion of celeſtial objects; thoſe in the upper, or viſible hemiſphere, are ſaid to be high, or elevated, above the horizon; and thoſe in the other hemiſphere are called low, or below the horizon.

The earth being a ſpherical body, the horizon, or limits of our view, muſt change as we change our place; and therefore, every place upon the earth has a different horizon. Thus if a man lives at A, fig. 2, plate III. his horizon is G e: if he lives at b, his horizon is H D: if at c, it is A E. From hence we obtain another proof of the ſphericity of the earth; for if it were flat, all the inhabitants thereof would have the ſame horizon.

The point in the heavens, which is directly over the head of a ſpectator, is called the ZENITH.

That point which is directly under his feet, is called the NADIR.

If a man lives at A, fig. 2, plate III. his zenith is A, his nadir E. If he lives at b, his zenith

zenith is B, his nadir F; confequently the zenith and horizon of an obferver remains fixed in the heavens, fo long as he continues in the fame place; but he no fooner changes his pofition, than the horizon touches the earth in another point, and his zenith anfwers to a different point in the heavens.

The AXIS of the earth is an imaginary line, conceived to be drawn through the center of the earth, upon which line it's revolutions are made.

The POLES of the earth are the extremities of it's axis, or thofe two points on it's furface, where it's axes terminate; one of thefe is called the NORTH, and the other the SOUTH POLE.

The poles of the heavens, or of the world, are thofe two points in the heavens, where the axis of the earth, if produced, would terminate; fo that the north pole of the heavens is exactly over the north pole of the earth, and the fouth pole of the heavens is directly over the fouth pole of the earth.

The EQUATOR is an imaginary circle, which is fuppofed to be drawn round the earth's furface, in the middle between the two poles. It divides the earth into two equal parts, one of which is called the NORTHERN, the other the SOUTHERN HEMISPHERE.

If we ſuppoſe the plane of the earth's equator to be extended all ways, as far as the heavens, it will mark there a circle, that will divide the heavens into two equal parts; this circle is called ſometimes the EQUINOCTIAL, ſometimes the CELESTIAL EQUATOR.

The meridian of any place is a circle ſuppoſed to paſs through that place, and the poles of the earth; we may therefore imagine as many meridians as there are places upon the earth, becauſe any place that is ever ſo little to the eaſt or weſt of another place, has a different meridian.

By the foregoing definition, we ſee that the meridian of any place is immoveably fixed to that place, and carried round along with it by the rotation of the earth. The meridian marks upon the plane of the horizon the north and ſouth points.

The circle which the ſun appears to deſcribe every year, in the concave ſphere of the heavens, is called the ECLIPTIC. It is thus denominated, becauſe in all eclipſes the moon is either in or

near

near the plane of it. But as the earth moves round the ſun, in the plane of the ecliptic, it is likewiſe the plane of the earth's orbit.

If we conceive a zone, or belt, about ſixteen degrees broad in the concave ſphere of the heaven, with the ecliptic paſſing through the middle of it, this zone is called the ZODIAC.

The ſtars in the zodiac are divided into TWELVE SIGNS, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Piſces.

We may imagine as many circles as we pleaſe drawn on the globe, parallel to the equator, and theſe will decreaſe in their diameter, as they approach nearer the poles.

The TROPICS are two leſſer circles of this kind, parallel to the equator, and 23½ degrees diſtant from it; one in the northern hemiſphere, which is called the TROPIC OF CANCER; the other in the ſouthern, which is called the TROPIC OF CAPRICORN. If we conceive the planes of theſe circles expanded, till they reach the ſtarry heaven, the ſun will be ſeen to move in that circle which correſponds to the tropic of cancer on the longeſt ſummer's ſummer's day, and in that circle which anſwers to the tropic of capricorn on the ſhorteſt winter's day.

The polar circles are two leſſer circles, conceived to be deſcribed at 23½ degrees diſtance from each pole.

The axis of the earth is inclined to the plane of the ecliptic, and makes with it an angle of 66½ degrees; therefore the plane of the earth's equator cannot coincide with the plane of the ecliptic, but theſe two planes make with one another an angle of 23½ degrees.

Of the annual Motion of the Earth.

The foregoing definitions being underſtood, we may now proceed in the deſcription of the phænomena of our ſyſtem. It is owing to the induſtry of modern aſtronomers, that the annual motion of the earth has been fully evinced; for though it's motion had been known to, and adopted by many among the ancient philoſophers, yet they were not able to give their opinions that degree of probability, which is attainable from modern diſcoveries, much leſs the evidence ariſing from thoſe demonſtrative proofs of which we are now in poffeffion. We fhall, therefore, enumerate fome of the reafons which induce aftronomers to believe that the earth moves round the fun.

The celeftial motions become incomparably more fimple, and free from thofe looped contortions which muft be fuppofed in the other cafe, and which are not only extremely improbable, but incompatible with what we know of motion.

This opinion is alfo more reafonable, on account of the extreme minutenefs of the earth, when compared with the immenfe bulk of the fun, Jupiter, and Saturn; and there are no known laws of motion, according to which fo great a body as the fun can revolve about fo fmall a one as the earth.

The fun is the fountain of light and heat, which it darts through the whole fyftem; it ought, therefore, to be in the center, that it's influence may be regularly diffufed through the whole heavens, and communicated in juft gradations to the whole fyftem.

When we confider the fun as the center of the fyftem, we find all the bodies moving round it, agreeable

agreeable to the univerſal laws of gravity; but upon any other conſideration we are left in the dark.

The motion of the earth round the ſun, accords with that general harmony, and univerſal law, which all the other moving bodies in the ſyſtem obſerve, namely, that the ſquares of the periodic times are as the cubes of the diſtances; but if the ſun moves round the earth, that law is deſtroyed, and the general order of ſymmetry in nature interrupted.

It is inconteſtibly proved by obſervation, a motion having been diſcovered in all the fixed ſtars, which ariſes from a combination of the motion of light with the motion of the earth in it's orbit.

It will be clearly ſhewn in it's place, that Venus and Mercury move round the ſun in orbits that are between it and the earth; that the orbit of the earth is ſituated between that of Venus and Mars; and that the orbits of Mars, Jupiter, &c. are exterior to, and include the other three.

Of the apparent Motion of the Sun, arising from the Earth's annual Motion round it.

As when a perſon ſails along the ſea coaſt, the ſhore, the villages, and other remarkable places on land, appear to change their ſituation, and to paſs by him; ſo it is in the heavens. To a ſpectator upon the earth, as it moves along it's orbit, or ſails as it were through celeſtial ſpace, the ſun, the planets, and the fixed ſtars, appear to change their places.

The apparent change of place is of two ſorts; the one is that of bodies at reſt, the change of whoſe place depends ſolely on that of the ſpectator; the other is that of bodies in motion, whoſe apparent change of place depends as well on their own motion, as on that of the ſpectator. We ſhall here conſider only that apparent change which takes place in thoſe which are at reſt, and which is owing wholly to the motion of the earth.

To ſhew that the ſun, when ſeen from the earth, will appear to move in the ſame manner, whether the ſun revolves round the earth, or whether the earth revolves round the ſun: Firſt, let us ſuppoſe the earth at reſt, without any motion

tion of it's own, and let the ſun be ſuppoſed to revolve round it in the orbit A B C D, fig. 1, plate IV. and let E F G H be a circle in the concave ſphere of the ſtarry heavens; as the ſun moves in the order of the letters A B C D in it's orbit, it will appear to a ſpectator on the earth to have deſcribed the circle E F G H. When the ſun is at A, it will appear as if it was among the fixed ſtars that are at E; when it is at B, it will appear among the fixed ſtars at F; when at C, among thoſe at H; and when it is at D, it will appear among the fixed ſtars at G. Indeed, the fixed ſtars and the ſun are not ſeen at the ſame time; but we have ſhewn, that we may tell in what part of the heavens the ſun is, or what fixed ſtars it is near, by knowing thoſe which are oppoſite to it, or come to the ſouth at midnight. Therefore, if we find that any ſet of ſtars, as thoſe at G for inſtance, come to the ſouth at midnight, we may be ſure that they are oppoſite to the ſun; and conſequently, if we could ſee the ſtars in that part of the heaven where the ſun is, we ſhould find them to be thoſe at F.

Secondly, let us ſuppoſe that S is the ſun, that it has no motion of it's own, that it reſts within the orbit A B C D, in which we ſhall now ſuppoſe the earth to move, in the order of the letters

A B C D. Upon this ſuppoſition, when the earth is at A, the ſun will appear in that part of the heavens where the ſtars H are; when the earth is at B, the ſun will appear in that part of the heavens where the ſtars G are; when the earth is at C, the ſun will appear in that part of the heavens where the ſtars E are; and as the earth revolves round the ſun, in the orbit A B C D, the ſun will appear to a ſpectator on the earth to deſcribe the circle G H E F.

Thus whether the earth is at reſt, and the ſun revolves in the orbit A B C D; or the ſun is at reſt, and the earth revolves in the ſame orbit, a ſpectator on the earth will ſee the ſun deſcribe the ſame circle E F G H, in the concave ſphere of the heavens.

Hence if the plane of the earth's orbit be imagined to be extended to the heavens, it would cut the ſtarry firmament in that very circle, in which a ſpectator in the ſun would ſee the earth revolve every year: while an inhabitant of the earth would obſerve the ſun to go through the ſame circle, in the ſame ſpace of time that the ſolar ſpectator would ſee the earth deſcribe it.

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The inhabitants of all the other planets will obſerve juſt ſuch motions in the ſun as we do, and for the very ſame reaſons; and the ſun will be ſeen from every planet to deſcribe the ſame circle, and in the ſame ſpace of time, that a ſpectator in the ſun would obſerve the planet to do. For example, an inhabitant of Jupiter would think that the ſun revolved round him, deſcribing a circle in the heavens in the ſpace of twelve years: this circle would not be the ſame with our ecliptic, nor would the ſun appear to paſs through the ſame ſtars which he does to us. On the ſame account, the ſun, ſeen from Saturn, will appear to move in another circle, diſtinct from either of the former; and will not ſeem to finiſh his period in leſs time than thirty years. Now as it is impoſſible that the ſun can have all theſe motions really in itſelf, we may ſafely affirm, that none of them are real, but that they are all apparent, and ariſe from the motions of the reſpective planets.

One phænomenon ariſing from the annual motion of the earth, which has already been ſlightly touched upon, may now be more fully explained; for as from this motion, the ſun appears to move from weſt to eaſt in the heavens, if a ſtar riſes or ſets along with the ſun at any time, it will in the courſe of a few days riſe or ſet before it, becauſe the ſun's apparent place in the heavens will be removed to the eaſtward of that ſtar. Hence thoſe ſtars which at one time of the year ſet with the ſun, and therefore do not appear at all, ſhall at another time of the year riſe when the ſun ſets, and ſhine all the night. And as any one ſtar ſhifts it's place with reſpect to the ſun, and in conſequence of that with reſpect to the hour of the night, ſo do all the reſt. Hence it is that all thoſe ſtars, which at one time of the year appear on any one ſide of the pole ſtar in the evening, ſhall in half a year appear on the contrary ſide thereof.

Of Phænomena occasioned by the annual and diurnal Motions of the Earth.

Firſt, of thoſe that ariſe from the diurnal motion. As the earth is of a ſpherical figure, that part of it which comes at any time under the confined view of an obſerver, will ſeem to be extended like a plane; and the heavens will appear as a concave ſpherical ſuperficies, divided by the aforeſaid plane into two equal parts, one of which is viſible, the other concealed from us by the opacity of the earth.

Now

Now the earth, by it's revolution round it's axis, carries the ſpectator and the aforeſaid plane from WEST TO EAST; therefore all thoſe bodies to the eaſt, which could not be ſeen becauſe they were below the plane of the horizon, will become viſible, or riſe above it, when, by the rotation of the earth, the horizon ſinks as it were below them. On the other hand, the oppoſite part of the plane, towards the weſt, riſing above the ſtars on that ſide, will hide them from the ſpectator, and they will appear to ſet, or go below the horizon.

As the earth, together with the horizon of the ſpectator, continues moving to the eaſt, and about the ſame axis, all ſuch bodies as are ſeparated from the earth, and which do not partake of that motion, will ſeem to move uniformly in the ſame time, but in an oppoſite direction, that is, from EAST TO WEST; excepting the celeſtial poles, which will appear to be at reſt. Therefore, when we ſay, that the whole concave ſphere of the heavens appears to turn round upon the axis of the world, whilſt the earth is performing one rotation round it's own axis, we muſt be underſtood to except the two poles of the world, for theſe do not partake of this apparent motion.

It is, therefore, on account of the revolution of the earth round it's axis, that the ſpectator imagines the whole ſtarry firmament, and every point of the heaven, (excepting the two celeſtial poles) to revolve about the earth from eaſt to weſt every twenty-four hours, each point deſcribing a greater or leſſer circle, as it is more or leſs remote from one of the celeſtial poles.

Although every place on the ſurface of the terraqueous globe, is illuminated by all the ſtars which are above the horizon of that place; yet when the ſun is above the horizon, his light is ſo ſtrong, that it quite extinguiſhes the faint light of the ſtars, and produces DAY. When the ſun goes below the horizon, or more properly, when our horizon gets above the ſun, the ſtars give their light, and we are in that ſtate which is called NIGHT.

Now as the earth is an opake ſpherical body, at a great diſtance from the ſun, ONE HALF of it will always be illuminated thereby, while the other half will remain in darkneſs.

The circle which diſtinguiſhes the illuminated face of the earth from the dark ſide, and is the boundary between light and darkneſs, is generally

rally called THE TERMINATOR. A line drawn from the center of the ſun to the center of the earth, is perpendicular to the plane of this circle.

When any point in the globe firſt gets into the enlightened hemiſphere, the ſun is juſt riſen to that part; when it gets half-way, or to it's greateſt diſtance from the terminator, it is then NOON; and when it leaves the enlightened hemiſphere, it is then SUN-SET; but it ſtill enjoys ſome light from the ſun, which is reflected by the atmoſphere, till it gets eighteen degrees beyond the terminator; this glimmering light is called TWILIGHT.

We have already ſhewn, that the daily motion of the ſun from eaſt to weſt, is not a real, but an apparent one, which is owing to the rotation of the earth round it's axis. Now if the ſun had no other motion but this apparent one, it would ſeem to go once round the earth, in the time of one complete rotation, or in 23 hours, 56 minutes; which is the caſe with any of the fixed ſtars, and is therefore the length of a SIDERIAL DAY.

But the ſun is found to take up a longer time to complete it's apparent revolution; for if it is

in

in the ſouth of any particular place at twelve o'clock at noon to-day, it will not complete an apparent revolution, ſo as to return to the ſouth of that place again, till twelve o'clock at noon on the next day, and conſequently the time of this apparent revolution is twenty-four hours.

This difference is owing to another apparent motion of the ſun, which is called his annual or yearly motion. For the ſun does not continue always in the ſame place in the heaven, as the fixed ſtars do; but if it is ſeen at M, fig. 2, pl. IV. one day, near the fixed ſtar R, it will have ſhifted it's place the next day, and will be near to ſome other fixed ſtar L. This motion of the ſun is from weſt to eaſt, and one entire revolution is completed in a year.

Suppoſe, therefore, that the ſun, when it is at M, near to the fixed ſtar R, appears in the ſouth of any particular place S; and then imagine the earth to turn once round upon it's axis from weſt to eaſt, or in the direction S T V W, ſo that the place may be returned to the ſame ſituation; after this rotation is completed, the ſtar R will be in the ſouth of the place as before; but the ſun having, in the mean time, moved eaſtwards, and being near to the ſtar L, or to the eaſt of R, will

will not be in the ſouth of the place S, but to the eaſtward of it: upon this account, the place S muſt move on a little farther, and muſt come to T before it will be even with the ſun again, or before the ſun will appear exactly in the ſouth.

This may be illuſtrated by an inſtance. The two hands of a watch are cloſe together, or even with one another at twelve; they both turn round the ſame way, but the minute hand turns round in a ſhorter time than the hour hand; when the minute hand has completed one rotation, and is come round to twelve, the hour hand will be before it, or will be at one; ſo that the minute hand muſt move more than once round, in order to overtake the hour hand, and be even with it again.

As this ſubject is of ſome importance, we ſhall endeavour to render it more clear, by placing it in a different point of view: the more ſo, as it may accuſtom the young pupil to reaſon on both hypotheſes, namely, the motion of the ſun, and that of the earth.

The diameter of the earth's orbit is but a phyſical point, in proportion to the diſtance of the ſtars; for which reaſon, and the earth's uniform

motion

motion on it's axis, any given meridian will revolve from any ſtar to the ſame ſtar again, in every abſolute turn of the earth upon it's axis, without the leaſt perceptible difference of time being ſhewn by a clock which goes exactly true.

If the earth had only a diurnal, without an annual motion, any given meridian would revolve from the ſun to the ſun again, in the ſame quantity of time as from any ſtar to the ſame ſtar again; becauſe the ſun would never change his place, with reſpect to the ſtars. But as the earth advances almoſt a degree eaſtward in it's orbit, in the time that it turns eaſtward round it's axis, whatever ſtar paſſes over the meridian on any day with the ſun, will paſs over the ſame meridian on the next day, when the ſun is almoſt a degree ſhort of it, that is, 3 min. 56 ſeconds ſooner. If the year contained only 360 days, the ſun's apparent place, ſo far as his motion is equable, would change a degree every day, and then the ſiderial days would be juſt four minutes ſhorter than the ſolar.

Let A B C D E F G H, fig. 3, plate IV. be the earth's orbit, in which it goes round the ſun every year, according to the order of the letters, that is, from weſt to eaſt, and turns round it's

axis

axis the ſame way, from the ſun to the ſun again in every twenty-four hours. Let S be the ſun, and R a fixed ſtar, at ſuch an immenſe diſtance, that the diameter of the earth's orbit bears no ſenſible proportion to that diſtance; N m n the earth in different points of it's orbit. Let N m be any particular meridian of the earth, and N a given point, or place, lying under that meridian.

When the earth is at A, the ſun S hides the ſtar R, which would always be hid if the earth never moved from A, and conſequently as the earth turns round it's axis, the point N would always come round to the ſun and the ſtar at the ſame time.

But when the earth has advanced through an eighth part of it's orbit, or from A to B, it's motion round it's axis will bring the point N an eighth part of a day, or three hours, ſooner to the ſtar than to the ſun. For the ſtar will come to the meridian in the ſame time as though the earth had continued in it's former ſituation at A, but the point N muſt revolve from N to n, before it can have the ſun upon it's meridian. The arc N n being therefore the ſame part of a whole circle, as the arc A B, it is plain that any ſtar which comes to the meridian at noon, with the ſun,

when

when the earth is at A, will come to it at nine o'clock in the forenoon, when the earth is at B.

When the earth has paſſed from A to C, one-fourth part of it's orbit, the point N will have the ſtar upon it's meridian, or at ſix in the morning, ſix hours ſooner than it comes round to the ſun; but the point N muſt revolve ſix hours more, before it has mid-day by the ſun: for now the angle A S D is a right angle, and ſo is N D n; that is, the earth has advanced 90 degrees on it's axis, to carry the point N from the ſtar to the ſun; for the ſtar always comes to the meridian when N m is parallel to R S A; becauſe D S is but a point in reſpect to R S. When the earth is at D, the ſtar comes to the meridian at three in the morning, at E, the earth having gone half round it's orbit; N points to the ſtar at midnight, it being then directly oppoſite to the ſun; and, therefore, by the earth's diurnal motion, the ſtar comes to the meridian twelve hours before the ſun, and then goes on, till at A it comes to the meridian with the ſun again.

Thus it is plain, that one abſolute revolution of the earth on it's axis, (which is always completed when any particular ſtar comes to be

parallel

parallel to it's ſituation at any time of the day before) never brings the ſame meridian round from the ſun, to the ſun again; but that the earth requires as much more than one turn on it's axis, to finiſh a natural day, as it has gone forward in that time, which, at a mean ſtate, is a 365th part of a circle.

From hence we obtain a method of knowing by the ſtars, whether a clock goes true or not. For if through a ſmall hole in a window-ſhutter, or in a thin plate of metal fixed to a window, we obſerve at what time any ſtar diſappears behind a chimney, or corner of a houſe, at a little diſtance; and if the ſame ſtar diſappears the next night, 3 min. 56 ſeconds, ſooner by the clock; and on the ſecond, 7 minutes, 52 ſeconds ſooner; the third night, 11 minutes, 48 ſeconds ſooner, and ſo on every night; it is an infallible ſign that the machine goes true; otherwiſe it does not, and muſt be regulated accordingly. This method may be depended on to nearly half a ſecond.

Of the Seasons of the Year.

It is our buſineſs under the preſent head to account for the phænomena of the ſeaſons, thoſe grateful viciſſitudes on which ſo much, both of the businefs and happinefs of man depends. As the feafons are applied in the hieroglyphic language of the bible, to mark the different ftages of man's progrefs in virtue, the rife, meridian glory, decline, and confummation of the church, or the different difpenfations of divine goodnefs and truth to man; we do not think the reader will be offended, if we prefent him with a few obfervations on this head, extracted from the works of an elegant moralift.

The natural advantages which arife from the pofition of the earth which we inhabit, with refpect to the other planets, afford much employment to mathematical fpeculation; by which it has been difcovered, that no other conformation of the fyftem could have given fuch commodious diftributions of light and heat, or imparted fertility and pleafure to fo great a part of a revolving fphere.

The moralift may with equal reafon obferve, that our globe feems equally fitted for the refidence of a being, placed here only for a fhort time, whofe tafk is to advance himfelf to a higher and happier ftate of exiftence, by unremitted vigilance of caution, and activity of virtue. The duties of man are fuch as human nature does not

willingly

willingly perform, and ſuch as thoſe are inclined to delay, who intend ſome time to fulfil them. It was, therefore, neceſſary, that this univerſal reluctance ſhould be counteracted, and the drowſineſs of heſitation awakened into reſolve; that the danger of procraſtination ſhould be always in view, and the fallacies of ſecurity be hourly detected. To this end, all the appearances of nature uniformly conſpire: whatever we ſee on every ſide, reminds us of the lapſe of time, and the flux of life. The day and night ſucceed each other; the rotation of the ſeaſons diverſifies the year; the ſun attains the meridian, declines and ſets; and the moon every night changes it's form.

The day may be conſidered as an image of the year, and a year as the repreſentation of life. The morning anſwers to the ſpring, and the ſpring to childhood and youth. The noon correſponds to the ſummer, and the ſummer to the ſtrength of manhood. The evening is an emblem of autumn, and autumn of declining life. The night, with it's ſilence and darkneſs, ſhews the winter, in which all the powers of vegetation are benumbed; and the winter points out the time when life ſhall ceaſe, with it's hopes and pleaſures.

He that is carried forward, however ſwiftly, by a motion equable and eaſy, perceives not the change of place, but by the variation of objects. If the wheel of life, which rolls thus ſilently along, paſſed on through undiſtinguiſhable uniformity, we ſhould never mark it's approaches to the end of the courſe. If one hour were like another; if the paſſage of the ſun did not ſhew it's waſting; if the change of ſeaſons did not impreſs upon us the flight of the year; quantities of duration, equal to days and years, would glide away unobſerved. If the parts of time were not variouſly coloured, we ſhould never diſcern their departure or ſucceſſion; but ſhould live thoughtleſs of the paſt, and careleſs of the future, without will, and perhaps without power, to compare the time which is already loſt, with that which may probably remain.

But the courſe of time is ſo viſibly marked, that it is even obſerved by nations, who have raiſed their minds very little above animal inſtinct. That theſe admonitions of nature may have their due effect; let him that deſires to ſee others happy, make haſte to give while his gift can be enjoyed; and remember, that every moment of delay takes away ſomething from the value of his benefaction. And let him who propoſes

poses his own happiness, reflect, that while he forms his purpose, the day rolls on, and the night cometh, when no man can work.

In order to explain the causes of those changes that are termed the seasons of the year, it will be necessary to premise a few considerations: First, that on account of the immense distance of the sun from the earth, the rays which proceed from it may be considered as parallel to each other. Secondly, that only one-half of a globe can be illuminated by parallel rays, and therefore only one-half of the earth will be enlightened by the sun at one time. Thirdly, that we may call the line which divides light from darkness, the terminator.

These considerations, as well as some of the following deductions, will be rendered more clear, by a survey of fig. 1, 2, and 3, pl. VI. where N Æ S Q represents the globe of the earth; N 80 S, N 70 S, &c. different meridians intersecting the equator Æ Q at right angles, and passing through the poles N and S; T T the terminator; B a brass ball, to represent the sun, with parallel rays proceeding from it.

In fig. 3, the poles coincide with the terminator.

In fig. 1, the north pole is altogether in the illuminated hemiſphere, and the ſouth pole in the dark hemiſphere.

In fig. 2, the ſouthern pole is in the enlightened part, and the north pole in the dark hemiſphere.

It is day in any given place on the globe, ſo long as that place continues in the enlightened hemiſphere; and when, by the diurnal rotation of the earth on it's axis, it is carried into the dark hemiſphere, it becomes night to that place.

The length of the day and the night depend on the poſition of the terminator, with reſpect to the axis of the earth.

If the poles be ſituated in the terminator, as in fig. 3, every parallel will be divided into two equal parts; and as the uniform motion of the earth cauſes any given place to deſcribe equal parts of it's parallel in equal times, the day and the night would be equal on every parallel of latitude;

latitude; that is, all over the globe, except at the poles, where the ſun would neither riſe nor ſet, but continue in the horizon.

But if, as in fig. 1 and 2, the axis be not placed in the plane of the terminator, the terminator will divide the equator into two equal parts, but the parallels into unequal parts; thoſe which are ſituated towards the enlightened pole, will have a greater part of their circumference in the enlightened, than in the dark hemiſphere; while ſimilar parallels toward the other pole will have the greater part of their circumference in the dark hemiſphere. Whence it follows, that the firſt-mentioned parallels will enjoy longer days than nights; and the contrary will happen to the latter, where the day will be the ſhorteſt, and the night the longeſt. All this is evident from the bare inſpection of the figures; it is alſo obſervable, that the diſproportion is greateſt in the greateſt latitude; and that thoſe places, whoſe diſtance from the pole is leſs than that of the pole from the terminator, muſt enjoy either a conſtant day, or a conſtant night; becauſe they are never carried into the oppoſite hemiſphere by the diurnal rotation of the earth. In this poſition of the axis, the inhabitants on one ſide of the equator may be ſaid to enjoy ſummer, and thoſe on the other ſide winter with reſpect to each other.

From what has been ſaid, it is plain that the viciſſitudes in the days and nights are occaſioned by the poſition of the terminator, or boundary of light and darkneſs, with the axis of the earth, or in other words, of the different aſpect of the earth with reſpect to the ſun.

We have now only to ſhew what cauſes the change of poſition in the terminator, which is, 1. The inclination of the earth's axis to the plane of the ecliptic, or orbit in which it moves. 2. That through the whole of it's annual courſe the axis of the earth preſerves it's poſition, or continues parallel to itſelf; that is, if a line be conceived as drawn parallel to the axis while the earth is in any one point of it's orbit, the axis will in every other poſition of the earth be parallel to the ſaid line.

If the axis of the earth were perpendicular to the place of it's orbit, the equator and the orbit (or ecliptic) would coincide; and as the ſun is always in the plane of the ecliptic, it would in this caſe be always over the equator, as in fig. 3, and the two poles would be in the terminator,

and

and there would be no diverſity in the days and nights, and but one ſeaſon of the year; but as this is not the caſe, we may fairly infer that the axis of the earth is not perpendicular to the plane of it's orbit.

But if the earth's axis be inclined to the plane of the ecliptic when the earth is as at fig. 1, plate VI. the pole N will be towards the ſun, and the pole S will be turned from it; but juſt the contrary will happen, when the earth by going half round the ſun has arrived at the oppoſite point in it's orbit: by this means the ſun will not be always in the equator, but at one time of the year it will appear nearer to one of the poles, and at the oppoſite time it will appear nearer to the other. To this the change of ſeaſons is owing; for when the ſun leaves the equator and approaches to one of the poles, it will be ſummer on that ſide of the equator, and when the ſun departs from thence and approaches to the other pole, then it will be winter. From the inclination of the axis, each part of the earth enjoys the benefit of ſummer in it's turn: for it is evident, from what has been ſaid already, that when it is winter towards one of the poles, on one ſide the equator, it is ſummer towards the other pole, or on the other ſide of the equator.

To

To elucidate ſtill further the changes in the ſeaſons, we ſhall beg the reader's attention to the figures in plates V. and VI. which repreſent one of the moſt ſimple inſtruments hitherto contrived for explaining them. Fig. 1, plate V. is the whole of the inſtrument. Fig. 1, 2, and 3, plate VI. two portions of it thus exhibited, in order to give a more diſtinct view of the phænomena.

If we now ſuppoſe the earth to be at Libra, as in fig. 1, plate V. then will the ſun appear to be at the oppoſite point of the ecliptic in Aries, the time of our vernal equinox. The terminator will paſs through the poles of the world, and divide every parallel to the equator into two equal parts; conſequently the nocturnal and diurnal arches, or the length of the day and night, will be equal in all places over the world. See fig. 3, plate VI.

But if you conceive the earth by it's annual motion to have moved to Capricorn, the axis keeping parallel to itſelf; the north pole will by this motion have gradually advanced into the enlightened hemiſphere, ſo that the whole northern polar circle will, when it has arrived, be in the illuminated hemiſphere, while the ſouthern pole

pole recedes into darkneſs, and all the northern parts will enjoy long days and ſummer, while the ſouthern parts will have ſhort days and winter.

Again, while the earth is deſcribing the next quarter of it's orbit, or going from Capricorn through Aquarius and Piſces to Aries, the north pole approaches the terminator in the ſame proportion that it before receded from it, and conſequently the diurnal arches gradually leſſen till it arrives at Aries, when the poles will again coincide with the terminator, and thus cauſe the days and nights to be every where equal. This is called the AUTUMNAL EQUINOX.

During the next quarter, or while the earth is going through Taurus and Gemini, the north pole will gradually recede from the light, while the ſouthern one advances into it; and the days will ſhorten in the northern hemiſphere, and lengthen in the ſouthern, until the earth is arrived at Cancer, the ſun then appearing in Capricorn, when the north pole will be juſt as far within the dark as in June it was in the enlightened hemiſphere. This time is called the WINTER SOLSTICE. The days every where in the northern hemiſphere are now at the ſhorteſt, and to the ſouthward they are at the longeſt.

From

From the winter ſolſtice to the vernal equinox the pole will approach the terminator, and the days will again lengthen in the northern hemiſphere, and at the inſtant in which the axis again coincides with the plane, the natural year, conſiſting of 365 days, 5 hours, 48½ minutes, is finiſhed.

The pupil will obſerve, by conſidering the inſtrument, that during the whole revolution of the earth, one-half of the equator is always in the light, and the other half in darkneſs; and conſequently, that under the equator the days and nights are always of an equal length.

While the earth is going from Libra to Aries, the north pole is conſtantly illuminated, and the ſouth pole all the while in darkneſs; and for the other half of the year in a contrary ſtate.

It is eaſy to perceive, by the foregoing explanation, that the inhabitants of the ſouthern hemiſphere have the ſame viciſſitudes, though not at the ſame time, it being winter in one hemiſphere while it is ſummer in the other.

There is ſtill, however, one circumſtance to be conſidered, namely, the daily apparent change in in the ſun's declination; but this will be eaſily conceived, by attending to fig. 1, 2, and 3, pl. VI. and conceiving a line to be drawn from the center of the ſun to the center of the earth, in each ſituation. This line may be called the central ſolar ray. About the 21ſt of December, when the earth is in Cancer, this ray will terminate or fall upon the ſouthern tropic, or the tropic of Capricorn; and conſequently, by the earth's rotation round her axis, the inhabitants of every part of this circle will ſucceſſively have the ſun in their zenith; or in other words, he will be vertical to them that day at noon, as the ſun appears that day to be carried round in the tropic of Capricorn.

About the 19th of March, the earth is at Aries, and the ſun will then appear in Libra; the central ſolar ray terminates upon the ſurface of the earth, in the equator, as at fig. 3; and therefore the ſun appears to be carried round in the celeſtial equator, and is ſucceſſively vertical to thoſe who live under that circle.

About the 21ſt of June, when the earth is in Capricorn, the central ſolar ray terminates on the ſurface of the earth, in the northern tropic, as at fig. 2; and for that day the ſun appears to be carried round in the tropic of Cancer,

and

and is vertical to thofe who live under that circle. About the 22nd of September, the earth is in Libra, and the fun in Aries, and the central folar ray again terminates at the equator; confequently the fun again appears in the celeftial equator, and is vertical to thofe who live under it.

We have feen, that as the fun moves in the ecliptic, from the vernal equinox to the tropic of Cancer, it gets to the north of the equator, or it's declination towards our pole increafes. Therefore, from the vernal equinox, when the days and nights are equal, till the fun comes to the tropic of Cancer, our days lengthen, and our nights fhorten; but when the fun comes to the tropic of Cancer, it is then in it's utmoft northern limit, and returns in the ecliptic to the equator again. During this return of the fun, it's declination towards our pole decreafes, and confequently the days decreafe, and the nights increafe, till the fun is arrived in the equator again, and is in the autumnal equinoctial point, when the days and nights will again be equal. As the fun moves from thence towards the tropic of Capricorn, it gets to the fouth of the equator; or it's declination towards the fouth pole increafes. Therefore, at that time of year, our days fhorten, and our nights lengthen, till the fun arrives at the tropic of Capricorn; but when the ſun is arrived there, it is then at it's utmoſt ſouthern limit, and returns in the ecliptic to the equator again. During this return, it's diſtance from our pole leſſens, and conſequently the days will lengthen, as the nights will ſhorten, till they become equal, when the ſun is come round to the vernal equinoctial point.

Our ſummer is nearly eight days longer than the winter. By ſummer is meant here the time that paſſes between the vernal and autumnal equinoxes; by winter, the time between the autumnal and vernal equinox. The ecliptic is divided into ſix northern, and ſix ſouthern ſigns, and interſects the equator at the firſt of Aries, and the firſt of Libra. In our ſummer, the ſun's apparent motion is through the ſix northern, and our winter through the ſix ſouthern ſigns; yet the ſun is 186 days, 11 hours, 51 minutes, in paſſing through the ſix firſt; and only 178 days, 17 hours, 58 minutes, in paſſing through the ſix laſt. Their difference, 7 days, 17 hours, 53 minutes, is the length of time by which our ſummer exceeds the winter.

In fig. 1, plate VII. A B C D repreſents the earth's orbit; S the ſun in one of it's foci; when the

the earth is at B, the ſun appears at H, in the firſt point of Aries; and whilſt the earth moves from B through C to D, the ſun appears to run through the ſix northern ſigns, from ♈ through ♋ to ♎ at F. When the earth is at D, the ſun appears at F, in the firſt point of Libra; and as the earth moves from D through A to B, the ſun appears to move through the ſix ſouthern ſigns, from ♎ through ♑ to Aries at H.

Hence the line F H, drawn from the firſt point of Aries through the ſun at S, to the firſt point of ♎, divides the ecliptic into two equal parts; but the ſame line divides the earth's eliptical orbit into two unequal parts. The greater part B C D is that which the earth deſcribes in the ſummer, while the ſun appears in the northern ſigns. The leſſer part is D A B, which the earth deſcribes in winter, while the ſun appears in the ſouthern ſigns. C the earth's aphelion, where it moves ſloweſt, is in the greater part; A it's perihelion, is in the leſſer part, where the ſun moves faſteſt.

There are, therefore, two reaſons why our ſummer is longer than our winter; firſt, becauſe the ſun continues in the northern ſigns, while the earth is deſcribing the greater part of it's orbit; and

and ſecondly, becauſe the ſun's apparent motion is ſlower while it appears in the northern ſigns, than whilſt it appears in the ſouthern ones.

The ſun's apparent diameter is greater in our winter than in ſummer, becauſe the earth is nearer to the ſun when at A in the winter, than it is when at C in the ſummer. The ſun's apparent diameter, in winter, is 32 min. 47 ſeconds; in ſummer, 31 min. 40 ſeconds.

But if the earth is farther from the ſun in ſummer than in winter, it may be aſked, why our winters are ſo much colder than our ſummers? To this it may be anſwered, that our ſummer is hotter than the winter, firſt, on account of the greater height to which the ſun riſes above our horizon in the ſummer; ſecondly, the greater length of the days. The ſun is much higher at noon in ſummer than in winter, and conſequently as it's rays in ſummer are leſs oblique than in winter, more of them will fall upon the ſurface of the earth. In the ſummer, the days are very long, and the nights very *ſhort*; therefore the earth and air are heated by the ſun in the day-time, more than they are cooled in the night; and upon this account, the heat will keep increaſing in the ſummer, and for the ſame reaſon will decreaſe in winter, when the days ſhorten, and the nights lengthen.

On some Appearances which depend on the Circles of the Heavens, and the Position of the Observer in Respect of them.

For the more eaſy underſtanding of theſe phænomena, it will be neceſſary to premiſe two obſervations.

1. That the inclination of an axis, or orbit, is merely relative, becauſe we compare it with ſome other axis, or orbit, which is not inclined at all. Thus our horizon being level to us, whatever place of the earth we are upon, we conſider it as having no inclination; and yet, if we travel 90 degrees from that place, we ſhall then have an horizon perpendicular to the former, but it will ſtill be level to us.

2. That half of the heavens are viſible to an inhabitant, on any part of the earth.

Of a parallel Sphere.

An inhabitant of the earth, who lives at either of the poles, has one of the celeſtial poles in his zenith,

zenith, or directly over his head; the other in his nadir, or directly under his feet. The celestial equator will coincide with the horizon; and as the polar circles, the tropics, and all the circles of daily motion, are parallel to the equator, they will also be parallel to the horizon.

It is from this position of the circles of the sphere, in respect to the horizon of a person who lives at either pole, that he is said to live in a PARALLEL SPHERE.

As all the circles of daily motion are parallel to the equator, it follows, that all the heavenly bodies, to an inhabitant at the pole, are carried round by their apparent motion, in circles which are parallel to the horizon; (thus the sun, when above the horizon, appears to revolve in a circle parallel to it, and at an altitude equal to his distance from the equator) and consequently this motion can never make those rise, which move in the circles below the horizon, nor those set which move above it.

Hence, also, an inhabitant at the north pole has the sun above his horizon, and therefore perpetual day all the time the sun is on the north side of the equator, that is, for six months together.

But the ſun is below his horizon, and it is night with him all the time the ſun is on the ſouth ſide of the equator, which is alſo for ſix months; or, in other words, the ſun will be ſeen for half a year, and then it will be day; and it will be hidden for half a year, and then it will be night.

Of a right Sphere.

If an obſerver be ſituated under the equator, he will have the celeſtial poles in his horizon, and the celeſtial equator over his head, and at right angles with his horizon; the other circles of daily motion being parallel to the equator, are alſo perpendicular, or at right angles with his horizon; therefore, in a right ſphere the riſing and ſetting of the ſun is in circles that make right angles with the horizon. It is from this poſition of theſe circles that he is ſaid to live in a RIGHT SPHERE.

In a right ſphere, the equator, and every parallel to it, is divided into two equal parts by the horizon, one half being above, the other half below it; there is, therefore, a perpetual equinox under the equator, that is, the days and nights are equal to one another at all times of the year,

year, each day being 12 hours long, and every night of the same length.

Of an oblique Sphere.

In all other positions of the sphere, except those already described, the equator, and the circles parallel to it, are inclined to the horizon. In this case, the position of the sphere is said to be OBLIQUE. This position agrees with all those people who live neither under the pole, nor under the equator. One of the poles is elevated above the horizon, the other is depressed beneath it, and the equator is inclined to the horizon.

In plate XIV. fig. 1, the terrestrial globe is in the position of the oblique sphere.

It is evident, that in this situation all the parallels to the equator are divided by the horizon into two unequal parts, but the equator into two equal parts; consequently the day and night are never equal to an inhabitant in an oblique sphere, but when the sun is in the equator, that is, twice a year, on the 20th of March, and the 22d of September. All the rest of the year the days are either longer or shorter than the nights; for the sun, which always appears to move in the ecliptic, defcribes one of the parallels to the equator, which are all cut by the horizon into two unequal parts. On the northern fide of the equator, the days are longer than the nights, as long as the fun is on the north fide of the equator; but the nights are longer than the days, when the fun is to the fouth of the equator.

The portion of the parallels above the horizon is greater in proportion as they are nearer the elevated pole; but when the diftance of the parallel from the pole becomes lefs than the elevation of the pole, then that parallel, and all thofe which are included within it, are wholly above the horizon, no part of them ever fetting or paffing under it. The contrary happens in the parallels that are fituated towards the depreffed pole, a fmaller portion of thefe being above the horizon, and the greater part lying under it. Thofe parallels which are nearer the depreffed pole, than the elevation of the pole, or latitude of the place, remain perpetually (together with the ftars included within them) under the horizon, and are never vifible to us.

In an oblique fphere there is one parallel which is as far diftant from the elevated pole, as the place is from the equator. This parallel is called the

the circle of PERPETUAL APPARITION, or the largeſt of all thoſe which conſtantly appear; the ſtars included within it never either riſe or ſet, though they are at times more elevated above the horizon than at others. Towards the other pole there is another circle, oppoſite to this, which is the circle of PERPETUAL OCCULTATION. All the ſtars that are contained within this, never riſe, but lie hid under the horizon, and are never ſeen.

AN EXPLANATION OF THE PHÆNOMENA WHICH ARISE FROM THE MOTION OF THE EARTH, AND OF THE INFERIOR PLANETS, MERCURY AND VENUS.

It will be neceſſary in this place to define more exactly ſome words which have been ſlightly explained before, and recall the reader's attention to ſome definitions that have been already given; and it is preſumed, that theſe repetitions will not be an object of complaint, becauſe they will anſwer the beneficial purpoſe of grounding the reader more firmly in the knowledge of the ſcience, to which this eſſay is intended as an introduction.

When two planets are feen together in the fame fign of the zodiac, and equally advanced therein, they are faid to be in CONJUNCTION. But when they are in oppofite figns of the zodiac, they are faid to be in OPPOSITION. Thus a planet is faid to be in oppofition to the fun, when the earth is between the fun and the planet.

The elongation of a planet is it's apparent diftance from the fun. When a planet is in conjunction with the fun, it has no elongation; when in oppofition, it's elongation is 180 degrees.

The NODES OF A PLANET'S ORBIT are thofe two points where the orbit cuts the plane of the ecliptic. We before obferved, that the orbits of all the planets are inclined to the plane of the ecliptic, and confequently crofs this plane. In fig. 3, plate III. A B C D is the plane of the ecliptic; E B F D is the orbit of a planet, in which the points B and D are the two nodes.

The LINE OF THE NODES is a line B D, fuppofed to be drawn through the fun from one node to the other. The LIMITS OF A PLANET'S ORBIT are two points in the middle between the two nodes. The point E is called the greateft northern limit, F the greateft fouthern limit.

The

The greateſt diſtance of the earth, or of any planet from the ſun, is called it's APHELION, or higher apſis; it's leaſt diſtance is called the PERIHELION, or lower apſis.

Thus in fig. 4, plate III. A is the place of the aphelion, P that of the perihelion.

The axis P A, fig. 4, of any planet's ellipſis, is called the LINE OF THE APSIDES; the extreme point of it's ſhorteſt diameter T V are the places of it's mean diſtance from the ſun; and S T, or S V, the line of it's mean diſtance.

When a planet moves according to the order of the ſigns, it's motion is ſaid to be DIRECT, or IN CONSEQUENTIA; but when it's motion is contrary to the order of the ſigns, it is ſaid to be RETROGRADE, or IN ANTECEDENTIA.

The place in the ſtarry heavens that any planet appears in, when ſeen from the center of the earth, is called it's GEOCENTRIC PLACE. The place where it would be ſeen in the celeſtial ſphere, by an obſerver ſuppoſed to be in the ſun, is called it's HELIOCENTRIC PLACE.

OF

OF THE MOTIONS OF THE INFERIOR PLANETS, VENUS AND MERCURY.

There are two different ſituations, in which an inferior planet will appear in conjunction with the ſun; one when the planet is between the ſun and the earth, the other when the ſun is between the earth and the planet. Let A, fig. 2, plate VII. be the earth in it's orbit, E the place of Venus in her orbit E H G, S the ſun, F V P Q R T D an arc in the ſtarry heavens. In this ſituation the ſun and Venus are on the ſame ſide of the earth, and will appear in the ſame point of the heavens, ſo as to be in conjunction. If the earth is at A, and Venus at G, they will alſo appear to be in conjunction.

If the earth is at A, the ſun at S, the planet at E, nearer to the earth than the ſun, it is called it's INFERIOR CONJUNCTION. But if the earth is at A, and the planet at G, farther from the earth than the ſun, this is called the SUPERIOR CONJUNCTION of the planet.

If an inferior planet is at E, the earth at A, and the ſun at S, the elongation is nothing, the planet being then in it's inferior conjunction. As the planet moves from E to y, it's elongation in-

creaſes;

creaſes; for when it is at y, it appears in the line A y P, while the ſun appears in the line A S Q; ſo that P A Q will be it's elongation. When the planet is arrived at x, it appears in the line A x V, which is a tangent to it's orbit, and then it's elongation is V A Q, which is the greateſt that can be on that ſide the ſun; for after this, the elongation decreaſes. When the planet is at K, it's elongation is P A Q; when at G, it is nothing, becauſe it is then in it's ſuperior conjunction; as the planet moves on from G, it's elongation again increaſes; for when it comes to C, it appears in the line A C R, and it's elongation is R A Q. When the planet comes to H, a line drawn from the earth through the planet is a tangent to the orbit, and the elongation is T A Q, A H T the greateſt it can have when it is on the other ſide of the ſun; for after this, the elongation again decreaſes.

Hence it is clear, that the inferior planets can never appear far from the ſun, but muſt always accompany it in it's apparent motion through the ecliptic. When we ſee either Venus or Mercury, it is either in an evening, in the weſt, ſoon after the ſun has ſet; or in a morning, a little before the ſun riſes. Venus is indeed bright enough ſometimes to be ſeen in the day-time, but then ſhe is

never

never far from the ſun. The greateſt elongation of Venus is about 48 40, and of Mercury about 28 33 degrees.

From the apparent motions of the inferior planets, we derive an argument to prove the falſity of the Ptolemaic ſyſtem. If the earth was within the orbit of Venus, as the Ptolemaic ſyſtem ſuppoſes, ſhe might be ſometimes on one ſide of the earth, whilſt the ſun is on the oppoſite ſide; or Venus might be ſometimes in oppoſition to the ſun, but Venus is never ſeen in oppoſition. Therefore, the earth is on the outſide of the orbit of Venus, and conſequently the Ptolemaic ſyſtem is not true. The ſame is alſo true of Mercury. But this, and ſome other circumſtances relative to the motions of theſe planets, will be better underſtood by a planetarium than by any diagram.

If the earth is at A, fig. 2, plate VII. when Venus appears in any part of the arc E x G, ſhe is weſtward from the ſun, and therefore riſes before him in the morning, and is called the MORNING STAR. When ſhe appears any-where in the arc G H E, ſhe is eaſtward from the ſun, and therefore ſets after him; is ſeen in the evening, and is then the EVENING STAR.

We

We have now to explain, why the inferior planets appear to move ſometimes in one direction, ſometimes in the contrary order, and at other times to be ſtationary. This is eaſily done on the Copernican ſyſtem, it being the natural reſult of the reſpective ſituations and motions of the earth and theſe planets. But on the Ptolemaic ſyſtem it is inexplicable, without calling in the aid of a very complicated hypotheſis.

When the inferior planets are paſſing from their greateſt elongation, on one ſide of the ſun, through their ſuperior conjunction, to their greateſt elongation on the other ſide, their motion, as viewed from the earth, is direct. In order to explain this propoſition, we ſhall firſt ſuppoſe the earth to be at reſt at A, fig. 2, plate VII. and correct this ſuppoſition afterwards, by ſhewing that the apparent motion of Venus, or Mercury, ſeen from the earth, is the ſame in this reſpect, whether the earth moves in it's orbit, or reſts at A.

The propoſition to be explained is this: that as Venus, for inſtance, moves from x, it's greateſt elongation on one ſide of the ſun, through G it's ſuperior conjunction, to H it's greateſt elongation on the other ſide, it will ap-

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pear to a ſpectator upon the earth to move from weſt to eaſt, according to the order of the ſigns; that is, it's geocentric motion will be direct.

The planets move round the ſun from weſt to eaſt, and conſequently if there was a ſpectator at the ſun, they would appear to him to move through the zodiac, according to the order of the ſigns; or in other words, the heliocentric motion of Venus is direct. Now if the ſun, and the earth A, are both on the ſame ſide of the planet, a ſpectator at the earth is in the ſame ſituation with reſpect to the planet and it's motion, as if he had been at the ſun: for whilſt the planet is moving from x, through G to H, a ſpectator either at A or S is on the concave ſide of the planet's orbit; and conſequently the planet will appear to move in the ſame manner from either; but the apparent motion of the planet, when ſeen from the ſun, is direct, and conſequently it's motion, when ſeen from the earth, will alſo be direct.

When Venus is at x, it appears to a ſpectator on the earth at A, to be in the line A x V, or is ſeen among the ſtars at V; when Venus has moved to K, it is ſeen among the fixed ſtars at P; when it has moved to G, it is in it's ſuperior conjunction;

junction; when it has moved to C, it appears among the fixed ftars at R; and when it is come to K, it appears among the fixed ftars at T. Thus whilft Venus has moved in it's orbit from x, it's greateft elongation on one fide of the fun, through G it's fuperior conjunction, to H it's greateft elongation on the other fide, it appears to have defcribed the arc V P Q R T in the concave fphere of the heavens; but the letters x K G C H lie from weft to eaft, becaufe they lie in the fame direction that the planet moves round the fun; and the letters V P Q R T lie in the fame direction with x K G C H. Therefore, as the planet feems to a fpectator on the earth, to defcribe the arc V P Q R T, it's apparent motion, feen from the earth, is direct, or from weft to eaft.

As the inferior planets move from their greateft elongation on one fide of the fun, through their inferior conjunction, to their greateft elongation on the other fide, their geocentric motion is RETROGRADE.

Whilft Venus, for inftance, is moving from it's greateft elongation H, plate VII. fig. 3, through it's inferior conjunction E, to it's other greateft elongation x, it appears to a fpectator upon the earth at A, to move backwards, or from eaſt to weſt, contrary to the order of the ſigns.

A ſpectator at the ſun is on the concave ſide of the planet's orbit. But whilſt Venus is moving from it's greateſt elongation H on one ſide, through E it's inferior conjunction, to x it's greateſt elongation on the other ſide, a ſpectator upon the earth is on the convex ſide of it's orbit.

Therefore, if a ſpectator at the ſun S would ſee the planet move one way, a ſpectator at the earth A will ſee it move the contrary way; or the geocentric motion will be contrary to it's heliocentric motion, and therefore retrograde; for as ſeen from the ſun, it's motion is always direct.

That two ſpectators, one at the earth, the other at the ſun, as they are on contrary ſides of the arc H E x, will ſee the planet apparently move contrary ways, may be rendered more plain by the following familiar conſideration. If two men ſtand with their faces towards each other, and a ball is rolled along upon the ground, this ball will move from the right hand of one of the men towards his left, and from the left hand of the

the other towards his right. In like manner, if one man is at the earth A, and the other at the ſun S, then whilſt the planet is deſcribing the arc H e x which is between them, it will appear to move from the right hand of the man at S towards his left, and from the left hand of the man at A towards his right.

Whilſt the motion of Venus is direct, or while it is deſcribing the arc x G H, it appears to move from V to T, among the fixed ſtars. But after it has been carried in it's orbit from H to Q, it appears in the line A z R, and is ſeen among the fixed ſtars at R. When it comes to E, it appears at Q; and when at y, it's apparent place in the heavens is at P. Thus as the planet paſſes from it's greateſt elongation H on one ſide of the ſun, through it's inferior conjunction E, to it's greateſt elongation x on the other ſide, it apparently runs back from T to V.

Venus is ſtationary, or has no apparent motion for ſome time, when it is at it's greateſt elongation; that is, when it is at H or x, and it's apparent place is either at T or V.

When either of the inferior planets, Venus for inſtance, is at it's greateſt elongation H or x, a line drawn from the earth through the planet, as A H T, or A x V, is a tangent to the orbit. Now though a right line touches a circle but in one point, yet some part of the circle greater than a point is so near to the tangent, as not to be distinguished from it. Thus the arc b d so nearly coincides with the tangent A H T, that a spectator's eye placed at A, could not distinguish the tangent from this part of the curve. Consequently, while the planet is describing this arc, no other change will be made in it's geocentric place, than if it was to move in the tangent.

But the geocentric place of the planet would not be altered, if the planet was to move in the tangent. For if it was to move from T towards A, or from A to V, the apparent place of it in the heavens would in one case be at T, in the other case at V. Therefore, while the planet is at it's greatest elongation, and is describing a small arc in it's orbit, that nearly coincides with the tangent, it's geocentric place does not alter, but it appears to continue for some time in the same part of the heavens, or is stationary.

We have hitherto supposed the earth to be at rest, and upon that supposition have explained the progress and regress, the conjunctions and

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ſtations of the inferior planets. If this ſuppoſi-tion was true, V T, or the arc which the planet at any time deſcribes in it's progreſs, and T V, the arc which it deſcribes in it's regreſs, would always be in the ſame part of the heavens. The planet, when in conjunction, would always appear at Q among the ſame fixed ſtars; and at it's elongation, or when it is ſtationary, it would always appear among the ſame fixed ſtars T on one ſide of the ſun, and at V on the other ſide.

But this ſuppoſition is not true; for the earth revolves in it's orbit A B O round the ſun. Now if the earth is at A, the time of either conjunction, the planet at this conjunction would appear among the fixed ſtars at Q, and the arcs of the greateſt elongation Q V and Q T, would be on each ſide of thoſe ſtars. But if the earth is at B, at the time of either of the conjunctions, then at the time of this conjunction, the planet will appear in the line B S T, and be ſeen among the fixed ſtars at T, and the arcs of the greateſt elongation will be on each ſide of theſe ſtars, that is, the conjunctions and elongations will happen in a different part of the heavens, when the earth is at B, from what they happen when the earth is at A; in other reſpects, the foregoing phænomena will be much the ſame, notwithſtanding the motion of the earth, only the planet will be more direct in the fartheſt part of the orbit, and leſs retrograde in the neareſt.

The inferior planets always appear very near the ſun; but by the motion of the earth in it's orbit, the ſun appears in different parts of the heavens, in different times of the year. Therefore, the inferior planets, as they are always very near the ſun, will alſo appear in different parts of the heavens, at different times of the year. And conſequently, their conjunctions and greateſt elongations will ſometimes happen when they are in one part of the heavens, and ſometimes when they are in another part. Venus ſeen from the earth, will appear to vibrate in an arc V T, half of which is on one ſide of the ſun's apparent place, and half on the other ſide.

When an inferior planet, viewed from a ſuperior, moves apparently retrograde, the ſuperior planet has alſo an apparently retrograde motion.

When a ſuperior planet, viewed from an inferior, appears ſtationary, the inferior planet viewed at the ſame time from the ſuperior, is alſo ſtationary.

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There is alſo another particular to be taken notice of, with regard to the apparent motion of the inferior planets, viz. that they do not ſeem to deſcribe the ecliptic in the heavens as the ſun does, but are obſerved to be ſometimes above, and ſometimes below it. The reaſon of this is, that their orbits are inclined to the plane of the earth's, having one-half above it, and the other below it, on which account they interſect the plane of the ecliptic, in a plane that paſſes through the center of the ſun; this line is called the line of the nodes. Theſe planets, therefore, never appear in the ecliptic, except when they are in their nodes; in all other parts of their orbit they ſeem to be more or leſs diſtant from it, according as they are ſituated with reſpect to them and the earth.

The diſtance of a planet from the ecliptic, as it would appear if ſeen from the center of the earth, is called it's GEOCENTRIC LATITUDE; as it would appear from the center of the ſun, is called it's HELIOCENTRIC LATITUDE.

OF THE SUPERIOR PLANETS.

We have already obſerved, that the greateſt elongation of either of the inferior planets is leſs than 90 degrees, or a quarter of a circle; fo that they are never far from the fun, but conftantly attend it. But the fuperior planets do not always accompany the fun, as we have fhewn that the inferior ones do; they are indeed fometimes in conjunction with it, but then they are alfo fometimes in oppofition to, or 180 degrees from it.

Let S, fig. 3, plate VII. be the fun; A B C D the orbit of any fuperior planet, Mars, for inftance; E F G the earth's orbit. If the earth be at E, the fun at S, and the planet at D, the fun and the planet will be both on the fame fide of the earth, and confequently the planet will appear in conjunction with the fun; but as the orbit of the earth is between the fun and the orbit of a fuperior planet, it is poffible for the earth to be between the fun and the planet. In this fituation the planet and the fun are on oppofite fides of the earth, or the planet is in oppofition; thus, if when the earth is at E, Mars be at A, he is then in oppofition to the fun.

A fuperior planet is in quadrature with the fun, when it's geocentric place is 90 degrees from the geocentric place of the fun; thus if the earth be at E, and Mars at B or C, he is in quadrature with

with the ſun; for the lines A E, E B, form a right angle, as do alſo the lines E A, E C.

As the earth goes round the ſun in leſs time, and in a leſs orbit than any of the ſuperior planets, it will not be amiſs to ſuppoſe a ſuperior planet to ſtand ſtill in ſome part of it's orbit, while the earth goes once round the ſun in her's, and conſider the appearances the planets would then have, which are theſe: 1. While the earth is in her moſt diſtant ſemicircle, the apparent motion of the planet would be direct. 2. While the earth is in her neareſt ſemicircle, the planet would be retrograde. 3. While the earth is near the points of contact of a line drawn from the planet, ſo as to be a tangent to the earth's orbit, the planet would be ſtationary.

Let A B C D E F G H, plate VIII. fig. 1, be the orbit of the earth, S the ſun, P Q O the orbit of Mars, L M N T an arc of the ecliptic. Let us ſuppoſe the planet Mars to continue at P, while the earth goes round in her orbit, according to the order of the letters A B C, &c. A B C D E F G H may be conſidered as ſo many ſtations, from whence an inhabitant of the earth would view Mars at different times of the year; and if ſtrait lines be drawn from each of theſe ſtations, through Mars at P, and continued to the ecliptic, they will point out the apparent place of Mars, at theſe different ſtations.

Thus ſuppoſing the earth at A, the planet will be ſeen among the ſtars at L; when the earth is arrived at B, the planet will appear at M; and in the ſame manner when at C D and E, it will be ſeen among the ſtars at N R T; therefore, while the earth moves over the large part of the orbit A B C D E, the planet will have an apparent motion from L to T, and this motion is from weſt to eaſt, or the ſame way with the earth; and the planet is ſaid to move direct, or according to the order of the ſigns. When the earth is near to A and E, the point of contact of the tangent to the earth's orbit, the planet will be ſtationary for a ſhort ſpace of time.

When the earth moves from E to H, the planet ſeems to return from T to N; and while it moves from H to A, it will be retrograde to L, where it will again be ſtationary: and ſince the part of the orbit which the earth deſcribes in paſſing from A to E, is much greater than the part E H P, though the ſpace T L which the planet deſcribes in direct and retrograde motion is the ſame, the direct motion from L to T muſt be be much ſlower than the retrograde motion from T to L.

When the earth is at C, a line drawn from C through S and P to the ecliptic, ſhews that Mars is then in conjunction with the ſun. But when the earth is at H, a line drawn from H through P, and continued to the ecliptic, would terminate in a point oppoſite to S; that is, in this ſituation Mars would be in oppoſition to the ſun. Thus it appears that the motion of Mars is direct when in conjunction, and retrograde when in oppoſition.

The retrograde motions of the ſuperior planets happen oftener, the ſlower their motions are; as the retrograde motion of the inferior planets happen oftener, the ſwifter their angular motions. Becauſe the retrograde motions of the ſuperior planets depend upon the motions of the earth; but thoſe of the inferior on their own angular motion. A ſuperior one is retrograde once in each revolution of the earth; an inferior one in every revolution of it's own.

The ſuperior planets are ſometimes nearer the earth than at other times; they alſo appear larger, or ſmaller, according to their different diſtances from

from us. Thus ſuppoſe the earth to be at C; if Mars be at P, he is the whole diameter of the earth's orbit nearer to us, than if he were at V, and conſequently his diſc muſt appear larger at V than it would at P; in other places, the diſtances of Mars from the earth are intermediate.

The diameter of the earth's orbit bears a greater ratio to the diameter of the orbit of Mars, than it does to the diameter of the orbit of Jupiter; and a greater to that of Jupiter, than of Saturn; and conſequently the difference between the greateſt and leaſt apparent diameters is greater in Mars than in Jupiter, and greater in Jupiter than in Saturn.

The ſuperior, like the inferior planets, do not always appear in the ecliptic, their orbits being inclined alſo to that of the earth; one-half is therefore above the ecliptic, the other half below it, nor are they ever ſeen in it but when they are in their nodes.

If, therefore, two planets happen to be in conjunction, at the time they come near the node of one of them, they would be ſeen from the ſun apparently to touch one another; and the fartheſt of thoſe planets from the ſun, would ſee the neareſt

neareſt moving over the face of the ſun, like a black ſpot, being then directly between the ſun and the remoter planet. So the planet Venus was obſerved from the earth, in the tranſits of the years 1761, and 1769. Alſo, ſhould an oppoſition of two planets happen near a node of one of them, the ſun being then directly between them, would hide the light of one from the other.

That the Planets are opake Bodies, and derive their Light from the Sun.

That the planets are all opake, or dark bodies, and conſequently ſhine only by the light they receive from the ſun, is plain, becauſe they are not viſible when they are in ſuch parts of their orbits as are between the ſun and earth, that is, when their illuminated ſide is turned from us.

The ſun enlightens only half a planet at once; the illuminated hemiſphere is always that which is turned towards the ſun, the other hemiſphere of the planet is dark. To ſpeak with accuracy, the ſun being larger than any of the planets, will illuminate rather more than half; but this difference, on account of the great diſtance of the ſun from any of the planets, is ſo great, that it's light

may

may be confidered as coming to them in lines phyfically parallel.

Like other opake bodies, they caft a fhadow behind them, which is always oppofite to the fun. The line in the planet's body, which diftinguifhes the lucid from the obfcure part, appears fometimes ftrait, fometimes crooked. The convex part of the curve is fometimes towards the fplendid, and the concave towards that which is obfcure, and vice verfa, according to the fituation of the eye with refpect to the planet, and of the fun which enlightens the planet.

Hence the inferior planets going round the fun in lefs orbits than our earth does, will fometimes have more, fometimes lefs of their illuminated fide towards us; and as it is the illuminated part only which is vifible to us, Mercury and Venus will, through a good telefcope, exhibit the feveral appearances of the moon, from a fine thin crefcent to the enlightened hemifphere.

If we view Venus through a telefcope, when fhe follows the fun's rays on the eaftern fide, and appears above the horizon after fun-fet, we fhall fee her appear nearly round, and but fmall; fhe is at that time beyond the fun, and prefents to us an enlightened hemiſphere. As ſhe departs from the ſun towards the eaſt, ſhe augments in her apparent ſize; and on viewing her through a teleſcope, is ſeen to alter her figure, abating of her apparent roundneſs, and appearing ſucceſſively like the moon, in the different ſtages of her decreaſe. At length, when ſhe is at her greateſt elongation, ſhe is like the moon in her firſt quarter, and appears as ſhe does when from a full ſhe has decreaſed to half a moon.

After this, as ſhe approaches (in appearance) to the ſun, ſhe appears concave in her illuminated part, as the moon when ſhe forms a creſcent; thus ſhe continues till ſhe is hid entirely in the ſun's rays, and preſents to us her whole dark hemiſphere, as the moon does in her conjunction, no part of the planet being then viſible.

After this, when ſhe departs out of the ſun's rays on the weſtern ſide, we ſee her in the morning, juſt before day-break. It is in this ſituation that Venus is called the morning ſtar, as in the other ſhe is called the evening ſtar. She at this time appears very beautiful, like a fine thin creſcent; juſt a verge of ſilver light is ſeen on her edge. From this period ſhe grows more and more enlightened every day, till ſhe is arrived at

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her greateſt digreſſion or elongation, when ſhe again appears as a half moon, or as the moon in her firſt quarter; from this time, if continued to be viewed with a teleſcope, ſhe is found to be more and more enlightened, though ſhe is all the while decreaſing in magnitude, and thus continues growing ſmaller and rounder, till ſhe is again hid or loſt in the ſun's rays.

Fig. 1 and 2, plate IX. repreſents the orbits of Venus and the earth, with the ſun in the center of them. The planet Venus is drawn in eight different ſituations, with it's illuminated hemiſpheres towards the ſun. If we ſuppoſe the earth to be at T, when Venus is at A, her dark hemiſphere is towards the earth, and ſhe is therefore inviſible, except the conjunction happens in her node, for then ſhe appears like a dark ſpot upon the diſc of the ſun. When Venus is at B, a little of her enlightened ſide is turned towards the earth, and therefore ſhe appears ſharp horned; when ſhe is at C, half her enlightened hemiſphere is turned towards the earth, and ſhe appears like an half moon; at D, more than half her enlightened hemiſphere is towards us, and ſhe appears like the moon about three days before it is full; at E, the whole enlightened hemiſphere is towards the earth, Venus is then either behind the

ſun,

ſun, or ſo very near him, that ſhe can hardly be ſeen; but if ſhe could, ſhe would appear round, like the full moon. At F ſhe is like the moon three days after the full; at G like a half moon again; at H like a creſcent, with the points of the horns turned the contrary way to what they were at B. All this is equally applicable to Mercury.

Fig. 2, plate VII. exhibits the ſeveral appearances of Venus, correſponding to their ſeveral ſituations in the foregoing figure; thus when Venus is at A, fig. 1, ſhe is quite dark, as at A, fig. 2; when ſhe is at B, fig. 1, ſhe appears as at B, fig. 2, &c.

The inferior planets do not ſhine brighteſt when they are full; thus Venus does not appear brighteſt in her ſuperior conjunction, though her illuminated hemiſphere be then turned towards us. Her ſplendor is more diminiſhed by her being at a greater diſtance from us, than the conſpicuous part of her illuminated diſc is increaſed. Dr. Halley has ſhewn, that Venus is brighteſt when her elongation from the ſun is about 40 degrees. Mercury is in his greateſt brightneſs, when very near his utmoſt elongation.

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The ſuperior planets going round the ſun in larger orbits than the earth, always turn much the greater part of their enlightened hemiſphere towards it, and therefore appear round, like the full moon, except Mars, who ſometimes appears like the moon at a little diſtance from the full.

Jupiter and Saturn are ſo remote, that they turn very nearly the ſame hemiſphere towards us that they do towards the ſun; for which reaſon, thoſe planets always appear round through the teleſcope.

Of the Moon's Motion.

It has been already obſerved, that four of the primary planets, the earth, Jupiter, Saturn, and the Georgium Sidus, are, in their revolutions round the ſun, attended by ſecondary planets. As the moon turns round the earth, enlightening our nights, by reflecting the light ſhe receives from the ſun, ſo do the other ſatellites enlighten the planets to which they belong, and move round thoſe planets at different periods of time, proportioned to their ſeveral diſtances; and as the moon keeps company with this earth, in it's annual revolution round the ſun, ſo do they ſeverally accompany the planets to which they belong in their ſeveral courſes round that luminary.

We ſhall ſpeak here only of the moon, which of all the heavenly bodies, excepting the ſun, is the moſt ſplendid and brilliant, the inſeperable companion and attendant of our earth.

If we imagine the plane of the moon's orbit to be extended to the ſphere of the heaven, it would mark therein a great circle, which may be called the moon's apparent orbit; becauſe the moon appears to the inhabitants of the earth to move in that circle, through the twelve ſigns of the zodiac, in a periodical month.

Thus let E F G H I, fig. 3, plate XI. be the orbit of the earth, S the ſun, a b c d the orbit of the moon, when the earth is at E: let A B C D be a great circle in the ſphere of the heaven, in the ſame plane with the moon's orbit. The moon, by going round her orbit according to the order of letters, appears to an inhabitant of the earth to go round in the great circle A B C D, according to the order of thoſe letters: for when the moon is at a, ſeen from the earth at E, ſhe appears at A; when the moon is got to b, ſhe appears at B; when to c, ſhe will appear at C;

when arrived at d, ſhe will appear at D. It is true, when the moon is at b, the viſual line drawn from E, through the moon, terminates in L; as it does in M, when the moon is at d; but the lines L M and D B being parallel, and not farther diſtant from each other than the diſtance of the earth's orbit, are as to ſenſe coincident, their diſtance meaſured in the ſphere of the heaven is inſenſible; for the ſame reaſon, though the earth moves from E to F, in the time that the moon goes round her orbit, ſo that at the end of a periodical month the moon will be at a, and is ſeen from the earth at F, in the line F N; the moon will, notwithſtanding, appear at A, the lines F N and E A being parallel, and as to ſenſe coincident: in like manner, in whatever part of her orbit the earth is, as at H or I, the moon, by going round in her orbit, will appear to an inhabitant of the earth to go round in the great circle A B C D.

The plane of the moon's orbit extended in the heavens, cuts the ecliptic in two oppoſite points. The two points where the moon's apparent orbit thus cuts the ecliptic, are called the MOON'S NODES. The point where the moon appears to croſs the ecliptic, as ſhe goes into north latitude, is called the moon's aſcending node, of which this

this is the character ☊; the point where the moon goes into ſouth latitude is her deſcending node, and is marked thus ☋; the moon's aſcending node is often called the dragon's head; her deſcending node is called the dragon's tail. The line of the moon's node is a line drawn from one node to the other. The moon, therefore, appears in the ecliptic only when ſhe is in one of her nodes; in all other parts of her orbit ſhe is either in north or ſouth latitude, ſometimes nearer to, ſometimes further removed from the ecliptic, according as ſhe happens to be more or leſs diſtant from the nodes.

The extremities of the line of the nodes are not always directed towards the ſame points of the ecliptic, but continually ſhift their places from eaſt to weſt, or contrary to the order of the ſigns, performing an entire revolution about the earth, in the ſpace of ſomething leſs than nineteen years.

When the place in which the moon appears to an inhabitant of the earth, is the ſame with the ſun's place, ſhe is ſaid to be in CONJUNCTION. When the moon's place is oppoſite to the ſun's place, ſhe is ſaid to be in OPPOSITION. When ſhe is a quarter of a circle diſtant from the ſun, ſhe is ſaid to be in QUADRATURE. Both the conjunction and oppoſition of the moon are termed SYZGIES.

The common lunar month, or the time that paſſes between any new moon and the next that follows it, is called A SYNODICAL MONTH, or A LUNATION.

A PERIODIC MONTH is the time the moon takes up to deſcribe her orbit; or in other words, the time in which the moon performs one entire revolution about the earth, from any point in the zodiac to the ſame again.

If the earth had no revolution round the ſun, or the ſun no apparent motion in the ecliptic, the periodical and ſynodical month would be the ſame; but as this is not the caſe, the moon takes up a longer time to paſs from one conjunction to the next, than to deſcribe it's whole orbit; or the time between one new moon and the next is longer than the moon's periodical time. The difference between thoſe two months is about 2 days, 5 hours.

The moon revolves round the earth from weſt to eaſt, and the ſun apparently revolves round the earth

earth the ſame way. Now at the new moon, or when the ſun and moon are in conjunction, they both ſet out from the ſame place, to move the ſame way round the earth; but the moon moves much faſter than the ſun, and conſequently will overtake it; and when the moon does overtake it, it will be a new moon again.

If the ſun had no apparent motion in the ecliptic, the moon would come up to it, or be in conjunction again, after it had gone once round in it's orbit; but as the ſun moves forward in the ecliptic, whilſt the moon is going round, the moon muſt move a little more than once round, before it comes even with the ſun, or before it comes to conjunction. Hence it is that the time between one conjunction, and the next in ſucceſſion, is ſomething more than the time the moon takes up to go once round it's orbit; or a ſynodical month is longer than a periodical one.

In fig. 3, plate IX. let S be the ſun, C F a part of the earth's orbit, M D a diameter of the moon's orbit when the earth is at A, and m d another diameter parallel to the former, when the earth is at B. Whilſt the earth is at A, if the moon be at D, ſhe will be in conjunction; and if the earth was to continue at A, when the moon had gone once round it's orbit, from D through M, ſo as to return to D again, it would again be in conjunction. Therefore, upon the ſuppoſition that the earth has no motion in it's orbit, the periodical and ſynodical months would be equal to one another. But as the earth does not continue at A, it will move forwards in it's orbit, during the revolution of the moon from A to B; and as the moon's orbit moves with it, the diameter M D will then be in the poſition m d; therefore, when the moon has deſcribed it's orbit, it will be at d in this diameter m d; but if the moon is at d, and the ſun at S, the moon will not be in conjunction, conſequently the periodical month is completed before the ſynodical. The moon, in order to come to conjunction, when the earth is at B, muſt be at e, in the diameter e f; or beſides going once round in it's orbit, it muſt alſo deſcribe the arc d e. The ſynodical month is, therefore, longer than the periodical, by the time the moon takes up to deſcribe the arc d e.

This may be alſo explained in another manner, by conſidering the motion of the ſun; a view of the ſubject, that may render it more eaſy to ſome young minds than the foregoing. Thus let us ſuppoſe the earth at reſt at E, fig. 4, plate IX. M the moon in conjunction with the ſun at S, while

while the moon deſcribes her orbit A B C about the earth at E, let the ſun advance by his apparent annual motion from S to D. It is plain that the moon will not come in conjunction with the ſun again, till, beſides deſcribing her orbit, ſhe hath deſcribed, over and above, the arch M F, correſponding to the arch S D.

As the moon goes round the earth in a much ſmaller orbit than that in which the earth revolves round the ſun, ſometimes more, ſometimes leſs, and ſometimes no part of her enlightened half will be towards us; hence the different phaſes and appearances of the moon.

The full moon, or oppoſition, is that ſtate in which her whole diſk is enlightened, and we ſee it all bright, and of a circular figure. The new moon is when ſhe is in conjunction with the ſun; in this ſtate, the whole ſurface turned towards us is dark, and ſhe is therefore inviſible to us.

The firſt quarter of the moon ſhe appears in the form of a ſemicircle, whoſe circumference is turned towards the weſt. At the laſt quarter, ſhe appears again under the form of a ſemicircle, but with the circumference turned towards the eaſt.

Theſe phaſes may be illuſtrated in a very pleaſing manner to the pupil, by expoſing an ivory ball to the ſun, in a variety of poſitions, by which it may preſent a greater or ſmaller part of it's illuminated ſurface to the obſerver. If it be held nearly in oppoſition, ſo that the eye of the obſerver may be almoſt immediately between it and the ſun, the greateſt part of the enlightened ſide will be ſeen; but if it be moved in a circular orbit, towards the ſun, the viſible enlightened part will gradually decreaſe, and at laſt diſappear, when the ball is held directly towards the ſun. Or to apply the experiment more immediately to our purpoſe; if the ball, at any time when the ſun and moon are both viſible, be held directly between the eye of the obſerver and the moon, that part of the ball on which the ſun ſhines, will appear exactly of the ſame figure as the moon itſelf.

The phaſes of the moon, like thoſe of Venus, may alſo be illuſtrated by a diagram; thus in fig. 1, plate XI. let S be the ſun, T the earth, A B C D E F G H the orbit of the moon. The firſt obſervation to be deduced from this figure, is, that the half of the earth and moon which is towards the ſun, is wholly enlightened by it; and the other half, which is turned from it, is totally dark.

dark. When the moon is in conjunction with the ſun at A, her enlightened hemiſphere is turned towards the ſun, and the dark one towards the earth; in which caſe, we cannot ſee her, and it is ſaid to be new moon. When the moon has moved from A to B, a ſmall portion a b of her enlightened hemiſphere will be turned towards the earth; which portion will appear of the form repreſented at B, fig. 2, plate XI. (a figure which exhibits the phaſes as they appear to us).

As the moon proceeds in her orbit, according to the order of the letters, more and more of her enlightened part is turned towards the earth. When ſhe arrives at C, in which poſition ſhe is ſaid to be in quadrature, one-half of that part towards the earth is enlightened, appearing as at C among the phaſes; this appearance is called a half moon. When ſhe comes to D, the greateſt part of that half which is towards us is enlightened; the moon is then ſaid to be gibbous, and of that figure which is ſeen at D, in fig. 2.

When the moon comes to E, ſhe is in oppoſition to the ſun, and conſequently turns all her illuminated ſurface towards the earth, and ſhines with a full face, for which reaſon ſhe is called a

full

full moon. As ſhe paſſes through the other half of her orbit, from E by F G, and H to A again, ſhe puts on the ſame faces as before, but in a contrary order or poſition.

As the moon, by reflected light from the ſun, illuminates the earth, ſo the earth does more than repay her kindneſs, in enlightening the ſurface of the moon, by the ſun's reflex light, which ſhe diffuſes more abundantly upon the moon, than the moon does upon us; for the ſurface of the earth is conſiderably greater than that of the moon, and conſequently if both bodies reflect light in proportion to their ſize, the earth will reflect much more light upon the moon, than it receives from it.

In new moon, the illuminated ſide of the earth is fully turned towards the moon, and the Lunarians will have a full earth, as we, in a ſimilar poſition, have a full moon. And from thence ariſes that dim light which is obſerved in the old and new moons, whereby, beſides the bright and ſhining horns, we can perceive the reſt of her body behind them, though but dark and obſcure. Now when the moon comes to be in oppoſition to the ſun, the earth, ſeen from the moon, will appear in conjunction with him, and it's dark ſide

ſide will be turned towards the moon, in which poſition the earth will be inviſible to the Lunarians; after this, the earth will appear to them as a creſcent. In a word, the earth exhibits the ſame appearance to the inhabitants of the moon, that the moon does to us.

The moon turns about it's own axis in the ſame time that it moves round the earth; it is on this account that ſhe always preſents the ſame face to us: for by this motion round her axis, ſhe turns juſt ſo much of her ſurface conſtantly towards us, as by her motion about the earth would be turned from us.

This motion about the axis is equable and uniform, but that about the earth is unequal and irregular, as being performed in an ellipſis, conſequently the ſame preciſe part of the moon's ſurface can never be ſhewn conſtantly to the earth; which is confirmed by a teleſcope, by which we often obſerve a little ſegment on the eaſtern and weſtern limb, appear and diſappear by turns, as if her body librated to and fro; this phænomenon is called the moon's libration. The lunar motions are ſubject to ſeveral other irregularities, which are fully diſcuſſed in the larger works on aſtronomy.

Of Eclipses.

Thoſe phænomena that are termed eclipſes, were in former ages beheld with terror and amazement, and looked upon as prodigies that portended calamity and miſery to mankind. Theſe fears, and the erroneous opinions which produced them, had their ſource in the hieroglyphical language of the firſt inhabitants of the earth. We do not, however, imagine that even the moſt ancient of theſe knew any more of the laws and motions of the heavenly bodies, than what could be diſcovered from immediate ſight; or that they knew enough of the lunar ſyſtem to calculate an eclipſe, or even that they ever attempted it.

The word ECLIPSE is derived from the Greek, and ſignifies dereliction, a fainting away, or ſwooning. Now as the moon falls into the ſhadow of the earth, and is deprived of the ſun's enlivening rays, at the time of her greateſt brightneſs, and even appears pale and languid before her obſcuration, lunar eclipſes were called LUNÆ LABORES, the ſtruggles or labours of the moon; to relieve her from theſe imagined diſtreſſes, ſuperſtition adopted methods as impotent as they were abſurd.

When

When the moon, by paſſing between us and the ſun, deprived the earth of it's light and heat, the ſun was thought to turn away his face, as if in abhorrence of the crimes of mankind, and to threaten everlaſting night and deſtruction to the world. But thanks to the advancement of ſcience, which, while it has delivered us from the fooliſh fears and idle apprehenſions of the ancients, leaves us in poſſeſſion of their repreſentative knowledge, enables us to explain the appearances on which it was founded, and points out their perverſion and abuſe of it.

Any opake body that is expoſed to the light of the ſun, will caſt a ſhadow behind it. This ſhadow is a ſpace deprived of light, into which if another body comes, it cannot be ſeen for want of light; the body thus falling within the ſhadow, is ſaid to be ECLIPSED.

Hence there muſt be three bodies concerned in an eclipſe; 1. the luminous body; 2. the opake body, that caſts the ſhadow; and, 3. the body involved in the ſhadow.

OF

Of Eclipses of the Moon.

As the earth is an opake body, enlightened by the ſun, it will caſt a ſhadow towards thoſe parts that are oppoſite to the ſun, and the axis of this ſhadow will always be in the plane of the ecliptic, becauſe both the ſun and the earth are always there.

The ſun and the earth are both ſpherical bodies; if they were, therefore, of an equal ſize, the ſhadow of the earth would be cylindrical, as in fig. 5, plate IX. and would continue of the ſame breadth at all diſtances from the earth, and would conſequently extend to an infinite diſtance, ſo that Mars, Jupiter, or Saturn, might be eclipſed by it; but as theſe planets are never eclipſed by the earth, this is not the ſhape of the ſhadow, and conſequently the earth is not equal in ſize to the ſun.

If the ſun were leſs than the earth, the ſhadow would be wider, the farther it was from the earth, ſee fig. 6, plate IX. and would therefore reach to the orbits of Jupiter and Saturn, and eclipſe any of theſe planets when the earth came between the ſun and them; but the earth never eclipſes them, therefore this is not the ſhape of it's ſhadow,

ſhadow, and conſequently the ſun is not leſs than the earth.

As we have proved that the earth is neither larger nor equal to the ſun, we may fairly conclude that it is leſs; and that the ſhadow of the earth is a cone, which ends in a point at ſome diſtance from the earth, ſee fig. 7, plate IX.

The axis of the earth's ſhadow falls always upon that point of the ecliptic that is oppoſite to the ſun's geocentric place; thus if the ſun be in the firſt point of Aries, the axis of the earth's ſhadow will terminate in the firſt point of Libra. It is clear, therefore, that there can be no eclipſe of the moon but when the earth is interpoſed between it and the ſun, that is, at the time of it's oppoſition, or when it be full; for unleſs it is oppoſite to the ſun, it can never be in the earth's ſhadow: and if the moon did always move in the plane of the ecliptic, ſhe would every full moon paſs through the body of the ſhadow, and there would be a total eclipſe of the moon.

We have already obſerved, that the moon's orbit is inclined to the plane of the ecliptic, and only coincides with it in two places, which are

termed

termed the nodes. It may, therefore, be full moon * without her being in the plane of the ecliptic; ſhe may be either on the north or the ſouth ſide of it; in either of theſe caſes, ſhe will not enter into the ſhadow, but be above it in the one, below it in the other.

Let H G repreſent the orbit of the moon, E F the plane of the ecliptic, in which the center of the earth's ſhadow always moves, and N the node of the moon's orbit; A B C D four places of the ſhadow of the earth in the ecliptic. When the ſhadow is at A, and the moon at I, there will be no eclipſe; when the full moon is nearer the node, as at K, only part of her globe paſſes through the ſhadow, and that part becoming dark, it is called a PARTIAL ECLIPSE; and it is ſaid to be of ſo many digits as there are twelfth parts of the moon's diameter darkened.

When

* A planet may be in oppoſition to, or conjunction with the ſun, without being in a right line that paſſes through the ſun and the earth. Aſtronomers term it in conjunction with the ſun, if it be in the ſame part of the zodiac; in oppoſition, if it be in a part of the zodiac, 180 degrees from the ſun.

When the full moon is at M, ſhe enters into the ſhadow C, and paſſing through it becomes wholly darkened at L, and leaves the ſhadow at O; as the whole body of the moon is here immerſed in the ſhade, this is called a TOTAL ECLIPSE.

But when the moon's center paſſes through that of the ſhadow, which can only happen when ſhe is in the node at N, it is called a TOTAL AND CENTRAL ECLIPSE. There will always be ſuch eclipſes, when the center of the moon, and axis of the ſhadow, meet in the nodes.

The duration of a central eclipſe is ſo long, as to let the moon go the length of three of it's diameters totally eclipſed, which ſtay in the earth's ſhadow is computed to be about four hours; whereof the moon takes one hour from it's beginning to enter the ſhadow, till quite immerſed therein; two hours more ſhe continues totally dark; and the fourth hour is taken up from her firſt beginning to come out of the ſhadow, till ſhe is quite out of it.

In the beginning of an eclipſe, the moon enters the weſtern part of the ſhadow with the eaſtern part of her limb, and in the end of it ſhe leaves the eaſtern part of the ſhadow with the weſtern part of her limb; all the intermediate time, from her entrance to her quitting the ſhadow, is reckoned into the eclipſe; but only ſo much into the total immerſion, as paſſes while the moon is altogether obſcured.

From the magnitude of the ſun, the ſize of the earth, their diſtance from each other, the refraction of the atmoſphere, and the diſtance of the moon from the earth; it has been calculated that the ſhadow of the earth terminates in a point, which does not reach ſo far as the moon's orbit. The moon is not, therefore, eclipſed by the ſhadow of the earth alone. The atmoſphere, by refracting ſome of the rays of the ſun, and reflecting others, caſts a ſhadow, though not ſo dark a one as that which ariſes from an opake body; when, therefore, we ſay that the moon is eclipſed, by paſſing into the ſhadow of the earth, it is to be underſtood of the ſhadow of the earth, together with it's atmoſphere. Hence it is that the moon is viſible in eclipſes, the ſhadow caſt by the atmoſphere not being ſo dark as that caſt by the earth. The cone of this ſhadow is larger than the cone of the earth's ſhadow, the baſe thereof broader, the axis longer.

All

All opake bodies, when illuminated by the rays of the ſun, caſt a ſhadow from them, which is encompaſſed by a PENUMBRA, or thinner ſhadow, which every where ſurrounds the former, growing larger and larger as we recede from the body: in other words, the penumbra is all that ſpace ſurrounding the ſhadow, into which the rays of light can only come from ſome part of that half of the globe of the ſun, which is turned towards the planet, all the reſt being intercepted by the intervening body.

Let S, fig. 2, plate XI. be the ſun, E the planet, then the penumbral cone is F H G. The nearer any part of the penumbra is to the ſhadow, the leſs light it receives from the ſun; but the further it is, the more it is enlightened; thus the parts of the penumbra near M are illuminated by thoſe rays of light which come from that part of the ſun near to I, all the reſt being intercepted by the planet E; in like manner, the parts about N can only receive the light that comes from the part of the ſun near to L, whereas the parts of the penumbra at P and Q are enlightened in a much greater degree: for the planet intercepts from P only thoſe rays which come from the ſun near L, and hides from Q only a ſmall part of the ſun near I.

The moon paſſes through the penumbra before ſhe enters into the ſhadow of the atmoſphere; this cauſes her gradually to loſe her light, which is not ſenſible at firſt, but as ſhe goes into the darker part of the penumbra, ſhe grows paler; the penumbra, where it is contiguous to the ſhadow, is ſo dark, that it is difficult to diſtinguiſh one from the other.

The moon, in a total eclipſe, generally appears of a duſky reddiſh colour, eſpecially towards the edges; but of a darker towards the middle of the ſhadow.

Of Eclipses of the Sun.

The moon, when in conjunction, if near one of her nodes, will be interpoſed between us and the ſun, and will conſequently hide the ſun, or a part of him, from us, and caſt a ſhadow upon the earth: this is called an ECLIPSE OF THE SUN; it may be either partial or total.

An eclipſe of any lucid body, is a deficiency or diminution of light, which would otherwiſe come from it to our eye, and is cauſed by the interpoſition of ſome opake body.

The

The eclipſes of the ſun and moon, though expreſſed by the ſame word, are in nature very different; the ſun, in reality, loſes nothing of it's native luſtre in the greateſt eclipſes, but is all the while inceſſantly ſending forth ſtreams of light every way round him, as copiouſly as before. Some of theſe ſtreams are, however, intercepted in their way towards our earth, by the moon coming between the earth and the ſun; and the moon having no light of her own, and receiving none from the ſun on that half of the globe which is towards our eye, muſt appear dark, and make ſo much of the ſun's diſk appear ſo, as is hid from us by her interpoſition.

What is called an eclipſe of the ſun, is therefore, in reality, an eclipſe of the earth, which is deprived of the ſun's light, by the moon's coming between, and caſting a ſhadow upon it. The earth being a globe, only that half of it which at any time is turned towards the ſun, can be enlightened by him at that time; it is upon ſome part of this enlightened half of the earth, that the moon's ſhadow, or penumbra, falls in a ſolar eclipſe.

The ſun is always in the plane of the ecliptic; but the moon being inclined to this plane, and only coinciding with it at the nodes, it will not cover either the whole or a part of the ſun; or in other words, the ſun will not be eclipſed, unleſs the moon at that time is in or near one of her nodes.

The moon, however, cannot be directly between the ſun and us, unleſs they are both in the ſame part of the heavens; that is, unleſs they are in conjunction. Therefore, the ſun can never be eclipſed but at the new moon, nor even then, unleſs the moon at that time is in or near one of her nodes.

From hence it is eaſy to ſhew, that the darkneſs at our Saviour's crucifixion was not owing to an eclipſe of the ſun. For the crucifixion happened at the time of the Jewiſh paſſover, and the paſſover, by the appointment of the law, was to be celebrated at the full moon; the ſun could not, therefore, be eclipſed at the time of the paſſover. An intelligent tutor will find many opportunities of obſerving to his pupil, that nature, and philoſophy, which explains the phænomena of nature, do always agree with divine revelation.

The moon being much ſmaller than the earth, and having a conical ſhadow, becauſe ſhe is leſs than

than the ſun, can only cover a ſmall part of the earth by her ſhadow; though, as we have obſerved before, the whole body of the moon may be involved in that of the earth. Hence an eclipſe of the ſun is viſible but to a few inhabitants of the earth; whereas, an eclipſe of the moon may be ſeen by all thoſe that are on that hemiſphere which is turned towards it.

It is not neceſſary, in order to conſtitute a CENTRAL eclipſe of the ſun, that the moon ſhould be exactly in the line of the nodes, at the time of it's conjunction; for it is ſufficient to denominate an eclipſe of the ſun CENTRAL, that the center of the moon be directly between the center of the ſun, and the eye of the ſpectator; for to him, the ſun is then centrally eclipſed. But as the ſhadow of the moon can cover but a ſmall portion of the earth, it is obvious this may happen when the moon is not in one of her nodes. Further, the ſun may be eclipſed centrally, totally, partially, and not at all at the ſame time.

Thus in fig. 3, plate XI. let A B C be the ſun, M N the moon, h l g part of the cone of the moon's ſhadow, f d the penumbra of the moon: from this figure it is eaſy to perceive,

1. That thoſe parts of the earth that are within the circle repreſented by g h, are covered by the ſhadow of the moon, ſo that no rays can come from any part of the ſun into that circle, on account of the interpoſition of the moon.

2. In thoſe parts of the earth where the penumbra falls, only part of the ſun is viſible; thus between d and g, the parts of the ſun near C cannot be ſeen, the rays coming from thence towards d or g being intercepted by the moon; whereas at the ſame time, the parts between f and h are illuminated by rays coming from C, but are deprived by the moon of ſuch as come from A.

3. The nearer any part of the earth, within the penumbra, is to the ſhadow of the moon, as in places near g, l, or h, the leſs portion of the ſun is viſible to it's inhabitants; the nearer it is to the outſide of the penumbra, as towards d, e, or f, the greater portion of the ſun may be ſeen.

4. Out of the penumbra, the entire diſk of the ſun is viſible.

Of

Of Parallax and Refraction.

Aſtronomy is ſubject to many difficulties, beſides thoſe which are obvious to every eye. When we look at any ſtar in the heavens, we do not ſee it in it's real place; the rays coming from it, when they paſs out of the purer etherial medium, into our coarſer and more denſe atmoſphere, are REFRACTED, or bent in ſuch a manner, as to ſhew the ſtar higher than it really is. Hence we ſee all the ſtars before they riſe, and after they ſet; and never, perhaps, ſee any one in it's true place in the heavens.

There is another difference in the apparent ſituation of the heavenly bodies, which ariſes from the ſtations in which an obſerver views them. This difference in ſituation is called the PARALLAX of an object.

The parallaxes principally uſed by aſtronomers, are thoſe which ariſe from conſidering the object as viewed from the centers of the earth and the ſun, from the ſurface and center of the earth, and from all three compounded.

The difference between the place of a planet, as ſeen from the ſun, and the ſame as ſeen from the

the earth, is called the parallax of the annual orbit; in other words, the angle at any planet, ſubtended between the ſun and the earth, is called the parallax of the earth's or annual orbit.

The diurnal parallax is the change of the apparent place of a fixed ſtar, or planet, of any celeſtial body, ariſing from it's being viewed on the ſurface, or from the center of the earth.

The fixed ſtars have no diurnal parallax, the moon a conſiderable one; that of the planets is greater or leſs, according to their diſtances.

Let H S W, fig. 2, plate VIII. repreſent the earth, T the center thereof, o R G part of the moon's orbit, P r g part of a planet's orbit, Z a A part of the ſtarry heavens. Now to a ſpectator at S, upon the ſurface of the earth, let the moon appear in G, that is, in the ſenſible horizon of S, and it will be referred to A; but if viewed from the center T, it will be referred to the point D, which is it's true place.

The arc A D will be the moon's parallax; the angle S G T the parallactic angle; or the parallax is expreſſed by the angle under which the ſemi-

ſemidiameter T S of the earth is ſeen from the moon.

If the parallax be conſidered with reſpect to different planets, it will be greater or leſs, as thoſe objects are more or leſs diſtant from the earth; thus the parallax A D of G is greater than the parallax a d of g.

If it be conſidered with reſpect to the ſame planet, it is evident that the horizontal parallax (or the parallax when the object is in the horizon) is greateſt of all, and diminiſhes gradually, as the body riſes above the horizon, until it comes to the zenith, where the parallax vaniſhes, or becomes equal to nothing. Thus A D and a d, the horizontal parallaxes of G and g, are greater than a B and a b, the parallaxes of R and r; but the objects O and P, ſeen from S or T, appear in the ſame place Z, or the zenith.

By knowing the parallax of any celeſtial object, it's diſtance from the center of the earth may be eaſily obtained by trigonometry. Thus if the diſtance of G from T be ſought, in the triangle S T G, S T being known, and the angle S G T determined by obſervation, the ſide T G is thence known.

The

The parallax of the moon may be determined by two perſons obſerving her from different ſtations at the ſame time, ſhe being vertical to the one, and horizontal to the other. It is generally concluded to be about 57 minutes of a degree.

But the parallax moſt wanted, is that of the ſun, whereby his abſolute diſtance from the earth would be known; and hence the abſolute diſtances of all the other planets would be alſo known, from the ſecond Keplerian law.

As one of the principal objects of aſtronomy is to fix the ſituation of the ſeveral heavenly bodies, it is neceſſary, as a firſt ſtep, to underſtand the cauſes which occaſion a falſe appearance of the place of thoſe objects, and make us ſuppoſe them in a different ſituation from that which they really have. Among theſe cauſes, REFRACTION is to be reckoned. By this term is meant, the bending of the rays of light as they paſs out of one medium into another.

The earth is every where ſurrounded by an heterogeneous fluid, a mixture of air, vapour, and terreſtrial exhalations, that extend to the regions of the ſky. The rays of light from the ſun, moon, and ſtars, in paſſing to a ſpectator upon

upon earth, come through this medium, and are ſo refracted in their paſſage through it, that their apparent altitude is greater than their true altitude.

Let A C, fig. 3, plate VIII. repreſent the ſurface of the earth, T it's center, B P a part of the atmoſphere, H E K the ſphere of the fixed ſtars, A F the ſenſible horizon, G a planet, G D a ray of light proceeding from the planet to D, where it enters our atmoſphere, and is refracted towards the line D T, which is perpendicular to the ſurface of the atmoſphere; and as the upper air is rarer than that near the earth, the ray is continually entering a denſer medium, and is every moment bent towards T, which cauſes it to deſcribe a curve as D A, and to enter a ſpectator's eye at A, as if it came from E, a point above G. And as an object always appears in that line in which it enters the eye, the planet will appear at E, higher than it's true place, and frequently above the horizon A F, when it's true place is below it at G.

This refraction is greateſt at the horizon, and decreaſes very faſt as the altitude increaſes, inſomuch that the refraction at the horizon differs from the refraction at a very few degrees above

the

the horizon, by about one-third part of the whole quantity. At the horizon, in this climate, it is found to be about 33 minutes. In climates nearer to the equator, where the air is purer, the refraction is leſs; and in the colder climates, nearer to the pole, it increaſes exceedingly, and is a happy proviſion for lengthening the appearance of the light at thoſe regions ſo remote from the ſun.

Gaſſendus relates, that ſome Hollanders who wintered in Nova Zembla, in latitude 75°, were ſurprized with a ſight of the ſun 17 days before they expected him in the horizon. This difference was owing to the refraction of the atmoſphere in that latitude. To the ſame cauſe, together with the peculiar obliquity of the moon's orbit to the ecliptic, ſome of theſe very northern regions are indebted for an uninterrupted light from the moon much more than half the month, and ſometimes almoſt as long as it is capable of affording any light to other parts of the earth. Hence, in—

"Thoſe regions, where no green herb appeareth, and which for months behold not the light of the ſun, nor the chearful day:

"Infinite

"Infinite wiſdom is manifeſted, and abundant means of ſolace are offered to the contented ſoul.

"He murmureth not that the ſun is hid from him.

"He knoweth that the moon will give light for many days, and doth not fear the approach of thick darkneſs.

"To him the ſun returneth at the appointed ſeaſon; but it's approach is haſtened by the refraction of the atmoſphere." *

To this refraction we muſt attribute another curious phænomenon, mentioned by Pliny: for he relates, that the moon had been eclipſed once in the weſt, at the ſame time that the ſun appeared above the horizon in the eaſt. Mæſtlinus, in Kepler, ſpeaks of another inſtance of the ſame kind, which fell under his own obſervation.

Through this refraction we are favoured with the ſight of the ſun, about 3 minutes and ¼ before it riſes above the horizon; and alſo as much every

* King's Hymns to the Supreme Being.

every evening after it ſets below it, which in one year amounts to more than 40 hours.

It is to this property of refraction that we are alſo indebted for that enjoyment of light from the ſun when he is below the horizon, which produces the morning and evening twilight. The ſun's rays, in falling upon the higher part of the atmoſphere, are reflected back to our eyes, and form a faint light, which gradually augments till it becomes day. Had no ſuch atmoſphere exiſted, the rays of light would have come to us in ſtrait lines, and the appearance and diſappearance of the ſun would have been inſtantaneous; we ſhould have had a ſudden tranſition from the brighteſt ſunſhine, to the moſt profound darkneſs; and from thick darkneſs to a blaze of light. Thus by refraction we are prepared gradually for the light of the ſun, the duration of it's light is prolonged, and ſhades of darkneſs ſoftened.

Of the Satellites of Jupiter and Saturn.

The exiſtence of the ſatellites of any of the planets, except the moon, would have been unknown to us without the uſe of the teleſcope. The ſatellites are diſtinguiſhed according to their places, into firſt, ſecond, &c. the firſt being that

that which is neareſt to the planet. The following table ſhews the time taken by each ſatellite in it's revolution; and alſo it's mean diſtance from the primary in ſemi-diameters thereof.

JUPITER'S SATELLITES.

I.			II.			III.			IV.		
d.	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*
1	18	28	3	13	18	7	3	59	16	18	5

DISTANCE FROM JUPITER IN SEMI-DIAMETERS.

I.	II.	III.	IV.
$5\frac{2}{3}$	9	$14\frac{1}{3}$	$25\frac{1}{3}$

SATURN'S SATELLITES.

I.			II.			III.			IV.			V.		
d.	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*
1	21	18	2	17	41	3	12	25	15	22	41	79	7	48

DISTANCE FROM SATURN IN SEMI-DIAMETERS.

I.	II.	III.	IV.	V.
$8\frac{7}{8}$	$11\frac{1}{4}$	15	36	108

The ſyſtem of Jupiter and his ſatellites is very large in itſelf; yet on account of it's immenſe diſtance from us, it appears to occupy but a ſmall ſpace in the ſphere of the ſtarry heavens, and conſequently every ſatellite of Jupiter appears to us always near it's primary, and to have an oſcillatory motion, like that of a pendulum going alternately from it's greateſt digreſſion on one ſide the planet, to it's greateſt on the other, ſometimes in a ſtrait line, at others in an elliptic curve.

When a ſatellite is in it's ſuperior ſemicircle, or that half of it's orbit that is more diſtant from the earth than Jupiter, it's motion appears direct to us; when a ſatellite is in it's inferior ſemicircle, nearer to us than Jupiter is, the apparent motion of it is retrograde.

The ſatellites of Saturn revolve about it in almoſt the ſame plane, namely, that of it's ring, excepting the fifth, the plane of whoſe orbit deviates a little therefrom. Thoſe of Jupiter move alſo in a plane very nearly coincident with that in which Jupiter moves about the ſun.

The ſatellites, and their primaries, mutually eclipſe each other in the ſame manner in which it has

has been ſhewn that the earth and the moon does. But there are three caſes in which the ſatellites diſappear to us.

The one is, when the ſatellite is directly behind the body of it's primary, with reſpect to the EARTH; this is called an OCCULTATION of the planet.

Another is, when it is directly behind it's primary, with reſpect to the SUN, and ſo falls into it's ſhadow, and ſuffers an eclipſe, as the moon, when the earth is interpoſed between that and the ſun.

The laſt is, when it is interpoſed between the earth and it's primary; for then it cannot be diſtinguiſhed from the primary itſelf.

By obſerving the eclipſes of Jupiter's ſatellites, it was diſcovered that light is not propagated inſtantaneouſly, though it moves with an incredible velocity; ſo that light reaches from the ſun to us in the ſpace of eleven minutes of time, at more than the rate of 100,000 miles in a ſecond.

Of the fixed Stars.

No part of the univerſe gives ſuch enlarged ideas of the ſtructure and magnificence of the heavens, as the conſideration of the number, magnitude, and diſtance of the fixed ſtars. We admire indeed, with propriety, the vaſt bulk of our own globe; but when we conſider how much it is ſurpaſſed by moſt of the heavenly bodies, what a point it degenerates into, and how little more, even the vaſt orbit in which it revolves, would appear, when ſeen from ſome of the fixed ſtars, we begin to conceive more juſt ideas of the extent of the univerſe, and of the boundaries of creation.

Among the many diſtinctions that characterize the fixed ſtars from the other luminaries of heaven, that which is afforded by their light, or peculiar luſtre, is the moſt obvious.

The light of the planets is ſteady, becauſe it is reflected; that of the ſtars is bright and lively, and accompanied with a kind of vibration of light, which we call twinkling. This is ſuppoſed to ariſe from the nature of their light as intrinſic, and not received and reflected, and principally from the ſmallneſs of their apparent diameter.

Our atmofphere is full of innumerable little particles, which are continually floating in it; many of thefe are large enough, on coming between the eye and fuch a point as a fixed ftar, to hide that point, or take that ftar out of our view, by intercepting it's rays. But thefe atoms are in perpetual motion, fo that the ftar is no fooner hid by one of them, than it appears again, becaufe the atom has changed it's place; then another comes, and again intercepts the view: the fwift fucceffion of thefe moving particles, greatly affifts in caufing that appearance which we term twinkling.

The moft confpicuous and brighteft of the fixed ftars of our horizon is Syrius. The earth, in moving round the fun, is 190 millions of miles nearer to this ftar in one part of it's orbit, than in the oppofite; yet the magnitude of the ftar does not appear to be in the leaft altered, or it's diftance affected by it; fo that the diftance of the fixed ftars is great beyond all computation. The unbounded fpace appears filled at proper diftances with thefe ftars, each of which is probably a fun, with attendant planets rolling round it. In this view, what, and how amazing, is the ftructure of the univerfe!

Though the fixed ſtars are the only marks by which aſtronomers are enabled to judge of the courſe of the moveable ones, and we have aſſerted their relative poſitions do not vary; yet this aſſertion muſt be confined within ſome limits, for many of them are found to undergo particular changes, and perhaps the whole are liable to ſome peculiar motion, which connects them with the univerſal ſyſtem of created nature. Dr. Herſchel even goes ſo far as to ſuppoſe that there is not, in ſtrictneſs of ſpeaking, one fixed ſtar in the heavens; but that there is a general motion of all the ſtarry ſyſtems, and conſequently of the ſolar one among the reſt.

There are ſome ſtars, whoſe ſituation and place were heretofore known, and marked with preciſion, that are no longer to be ſeen; new ones have alſo been diſcovered, that were unknown to the ancients, while numbers ſeem gradually to vaniſh. There are others which are found to have a periodical increaſe and decreaſe of magnitude; and it is probable, that the inſtances of theſe changes would have been more numerous, if the ancients had poſſeſſed the ſame accurate means of examining the heavens, as are uſed at preſent.

New

New ſtars offer to the mind a phænomenon more ſurprizing, and leſs explicable, than almoſt any other in the ſcience of aſtronomy. I ſhall ſelect a few inſtances of the more remarkable ones, for the inſtruction of the young pupil: a conſideration of the changes that take place, at ſo immenſe a diſtance as the ſtars are known to be from him, may elevate his mind to conſider the immenſity of HIS power, who regulates and governs all theſe wide extended motions; "who hath meaſured the waters in the hollow of his hand, and meted out heaven with a ſpan."

It was a new ſtar, diſcovered by Hipparchus, the chief of the ancient aſtronomers, that induced him to compoſe a catalogue of the fixed ſtars, that future obſervers might learn from his labours, whether any of the known ſtars diſappear, or new ones were produced. The ſame motives engaged the illuſtrious Tycho Brahe to form, with unremitting labour and aſſiduity, another new catalogue of the ſtars.

Of new ſtars, the firſt of which we have a good account, is that which was diſcovered in the conſtellation Caſſiopea, in the month of November of the year 1572, a time when aſtronomy was ſufficiently cultivated, to enable the aſtronomers to give the account with precision. It remained visible about sixteen months; during this time, it kept it's place in the heavens, without the least variation. It had all the radiance of the fixed stars, and twinkled like them; and was in all respects like Syrius, excepting that it surpassed it in brightness and magnitude. It appeared larger than Jupiter, who was at that time in his perigee; and was scarce less bright than Venus.

It was not by degrees that it acquired this diameter, but shone forth at once of it's full size and brightness, as if of instantaneous creation. It continued about three weeks in full and entire splendor, during which time it might be seen even at noon day, by those who had good eyes, and knew where to look for it. Before it had been seen a month, it became visibly smaller, and from thence continued diminishing in magnitude till March, 1574, when it entirely disappeared. As it decreased in size, it varied in colour; at first, it's light was white, and extremely bright; it then became yellowish, afterwards of a ruddy colour, like Mars; and finished with a pale livid white, resembling that of Saturn.

In 1596, Fabricius obferved a new ftar in the neck of the Whale: he firft faw it in Auguft, and it difappeared in October of the fame year. In 1637, Phocyllides Holwarda obferved it again, and not knowing that it had been feen before, took it for a new difcovery: he watched it's place in the heavens, and faw it appear again the fucceeding year, nine months after it's difappearance. It has been fince found to be every year very regular in it's period, except that in 1672 it was miffed by Hevelius, and not feen again till 1676. Bullialdus having compared together the obfervations which had been made of it from 1638 to 1666, determined the periodical time between this ftar's appearing in it's greateft brightnefs, and returning to it again, to be 333 days; obferving further, that this ftar did not appear at once in it's full magnitude, or brightnefs, but by degrees arrived at them. He alfo framed an hypothefis, to account for thefe periodic changes.

Three changeable, or re-apparent ftars, have been difcovered in the conftellation of the Swan; the firft was feen by Janfonius, in 1600; the fecond was difcovered in 1670; the third by Kirchius, in 1686.

In

In the latter end of September, 1604, a new ſtar was diſcovered near the heel of the right foot of Serpentarius. There were in that part of the heavens, at that time, the three ſuperior planets, which ſo engaged the attention of aſtronomers, that no appearance thereabouts could have long eſcaped them. Kepler, in deſcribing it, ſays, that it was preciſely round, without any kind of hair, or tail; that it was exactly like one of the ſtars, except that in the vividneſs of it's luſtre, and the quickneſs of it's ſparkling, it exceeded any thing he had ever ſeen before. It was every moment changing into ſome of the colours of the rainbow, as yellow, orange, purple, and red; though it was generally white, when it was at ſome diſtance from the vapours of the horizon. Thoſe in general who ſaw it, agreed that it was larger than any other fixed ſtar, or even any of the planets, except Venus: it preſerved it's luſtre and ſize for about three weeks; from this time it grew gradually ſmaller. Kepler ſuppoſes that it diſappeared ſome time between October, 1605, and the February following, but on what day is uncertain.

Beſides theſe ſeveral re-apparent ſtars, ſo well characterized and eſtabliſhed by the earlieſt among the modern aſtronomers, there have been many

many discovered since, by Cassini, Maraldi, and others; Mr. Montanere speaks of having observed above one hundred changes among the fixed stars.

The star Algol, in Medusa's head, has been observed long since to appear of different magnitudes, at different times. The period of it has been lately settled by J. Goodricke, Esq. of York. It periodically changes from the first to the fourth magnitude; the time employed from one greatest diminution to the other, was anno 1783, at a mean 2 days, 20 hours, 49 minutes, 3 seconds. The changes are thus: during four hours it gradually diminishes in lustre; during the succeeding four hours, it recovers it's first magnitude by a like gradual increase; and during the remaining part of the period, namely, 2 days, 12 hours, 49 minutes, 3 seconds, it invariably preserves it's greatest lustre; after the expiration of which term, the diminution again commences.

The causes of these appearances cannot be assigned at present, with any degree of probability; perhaps they have some analogy to the spots on the sun, which at some times appear in greater numbers than at others, some of them bigger than the whole earth; or perhaps they are

owing

owing to ſome real motions of the ſtars themſelves.

There are ſeveral ſtars that appear ſingle to the naked eye, which are, on examination with a teleſcope, found to conſiſt of two, three, &c. The number of double ſtars obſerved before the time of Dr. Herſchel, was but ſmall; but this celebrated aſtronomer has noted upwards of four hundred; among theſe, ſome that are double, others that are treble, double double, quadruple, double treble, and multiple; his catalogue gives the comparative ſize of theſe ſtars, their colour as they appeared to him, with ſeveral other very curious particulars.

Beſides theſe phænomena, there are many NEBULÆ, or parts of the heavens, which are brighter than the reſt. "The moſt obvious to common notice, is that large irregular band which croſſes the ecliptic in Cancer and Capricorn, and is inclined to it in an angle of about ſixty degrees. Other nebulæ are ſeldom ſo large as to be ſeen by the naked eye, to which they appear as ſmall ſtars. Viewed by a teleſcope, they appear as ſo many luminous ſpots, of various figures, in ſome inſtances with ſtars in them; ſuch of theſe nebuloſe ſtars as are viſible to the

naked

naked eye, appear as a kind of fine white cloud. The number of nebulæ aſcertained before the time of Herſchel, are about 103." He has, however, given us a catalogue of 1000 new nebulæ; many of the nebulæ are reſolvable by the teleſcope, into cluſters of ſmall ſtars; and it is found, that teleſcopes of greater force reſolve thoſe nebulæ into ſtars, which appear as white clouds in inſtruments of leſs force. Hence then there is reaſon to conclude, that they all conſiſt of cluſters, or prodigious aggregates of ſtars. Dr. Herſchel ſays, that in the moſt crouded part of the milky way, he had fields of view, that contained no leſs than 588 ſtars, and theſe were continued for many minutes, ſo that in one quarter of an hour there paſſed no leſs than 116,000 ſtars through the field of view of his teleſcope. The blended luſtre of theſe luminous points, is the cauſe of that light and white appearance, from whence this ſpace has been denominated.

Dr. Herſchel endeavours to make it appear, both from obſervation and well grounded conjecture, 1. That the ſtarry heaven is replete with nebulæ, or ſyſtems of ſtars of various figures; and that the milky way is that particular nebula in which our ſun is placed. 2. That each nebula is compoſed of a prodigious number of ſuns,

or

or bodies, that ſhine by their own native ſplendor. 3. That each individual ſun is deſtined to give light to hundreds of worlds that revolve about it, but which can no more be ſeen by us, on account of their great diſtance, than the ſolar planets can be ſeen from the fixed ſtars. Nor is it neceſſary that in this explored and unexplorable abyſs of ſpace, the planets ſhould be of the ſame magnitude as thoſe that belong to our ſyſtem; for it is not improbable, but that planetary bodies may be diſcovered among the double and triple ſtars.

Dr. Herſchel mentions ſome other heavenly bodies diſcovered by him, which, from the ſingularity of their appearance, he finds it difficult to know how to claſs: he has termed them planetary nebulæ, for he can hardly ſuppoſe them to be nebulæ; their light is ſo uniform, as well as vivid; their diameter ſo ſmall, and well-defined; if nebulæ, they muſt conſiſt of ſtars that are compreſſed and accumulated in the higheſt degree.

OF THE TELESCOPIC APPEARANCE OF THE PLANETS.

By means of the telefcope, we are enabled, in fome meafure, to afcend into the celeftial region, and view the fun, moon, and ftars, as they would appear to us if they were brought fo many times nearer to us as the telefcope magnifies; the light proceeding from the luminary we are looking at, being diminifhed in the fame proportion.

The telefcope is one of thofe difcoveries, of which no idea could have been formed, previous to the period in which the Supreme Being was pleafed to unveil to the human mind fome of the myfterious powers of glafs: the importance of this difcovery, and the extent to which it may be carried, ftill lie hid among the fecrets of infinite wifdom.

When we look at the fun through a telefcope even of moderate power, the eye being defended by a piece of coloured or fmoked glafs, nay, even by the naked eye, when guarded in the fame manner, we difcover on his furface many black, or rather lefs bright fpots, of various fizes and fhapes. Sometimes thefe fpots will vanifh in a very fhort time after their firft appearance; fome-

times

times they travel over his whole disk, or visible surface, from west to east, when they disappear, and in twelve or thirteen days they appear again, so as to be known, by their magnitude and figure, to be those that had disappeared before. Those, however, which are of the longest continuance, do not appear to have much solidity of consistence, for in a little time they also vanish, and become bright like the rest of the surface.

These spots are more frequent at some periods than at others; in some years, the sun's disk has for many months been perfectly free from them; in others, he has for months been more or less obscured by spots: the most remarkable phænomena of these spots, as observed by Scheiner and Hevelius, are as follow: 1. Every spot, which has a nucleus, or dark part, hath also an umbra, or fainter shade, surrounding it. 2. The boundary betwixt the nucleus and umbra is always distinct and well-defined. 3. The increase of a spot is gradual, the breadth of the nucleus and umbra dilating at the same time. 4. In like manner, the decrease of a spot is gradual, the breadth of the nucleus and umbra diminishing at the same time. 5. The exterior boundary of the umbra never consists of sharp angles, but is always curvilinear, how irregular soever the outside of of the nucleus may be. 6. The nucleus of a ſpot, whilſt on the decreaſe, often changes it's figure, by the umbra incroaching irregularly upon it, inſomuch that in a ſmall ſpace of time new incroachments are diſcernible, whereby the boundary between the nucleus and the umbra is perpetually varying. 7. It often happens, that by theſe incroachments the nucleus of a ſpot is divided into two or more nuclei. 8. The nuclei of the ſpots vaniſh before the umbra. 9. Small umbræ are often ſeen without nuclei. 10. A large umbra is ſeldom ſeen without a nucleus in the middle of it. 11. When a ſpot, which conſiſted of a nucleus and an umbra, is about to diſappear, if it be not ſucceeded by a facula, or ſpot, brighter than the reſt of the diſk, the place it occupied is in a very little time not to be perceived.

In the Philoſ. Tranſ. vol. lxiv. the reader will find ſeveral curious obſervations on theſe ſpots, by Profeſſor Wilſon, and the Rev. Mr. Wolaſton. The latter gentleman ſays, he once ſaw, with a twelve-inch reflector, a ſpot burſt to pieces, while he was looking at the ſun; the appearance was to him as that of a piece of ice, when daſhed on a frozen pond, which breaks to pieces, and ſlides in various directions.

The ſpots are by no means confined to one part of the ſun's diſk, though we do not know that any have been obſerved about his polar regions. Though their direction is from eaſt to weſt, yet the paths they deſcribe in their courſe over the diſk, are exceedingly different, ſometimes being in ſtrait lines, ſometimes in curves; at one time deſcending from the northern to the ſouthern part of the diſk, at other times aſcending from the ſouthern to the northern part.

The larger ſpots, moſt of which exceed the whole earth in apparent magnitude, laſt a conſiderable time, ſometimes three months before they diſappear, at which time they are generally converted into ſpots exceeding the reſt of the ſun in brightneſs. The general opinion concerning their nature is, that they are volcanoes, or burning mountains, of immenſe ſize; and that when the eruption is nearly ended, and the ſmoke diſſipated, the fierce flames are expoſed, and appear as luminous ſpots. Dr. Wilſon ſuppoſes them, on the other hand, to be excavations in the luminous matter (or atmoſphere) that environs the body of the ſun.

"The obſervations which might with fullneſs of evidence confirm the opinion of planetary

worlds,

worlds, ſeem to be placed out of our reach, and we can ſcarce hope to make our optical inſtruments ſufficiently perfect, to render the inhabitants thereof viſible to us. All, therefore, that we can do, is to examine if the planets are accommodated with thoſe things which we are uſed to conſider as neceſſary to animal exiſtence. Lands, ſeas, clouds, vapours, and an atmoſphere, or body of air, are objects that we may expect to find on the face of an habitable world."

The moon being ſo very near us, and likewiſe in the ſame temperature as to light and heat, firſt preſents itſelf. When we look at her with the naked eye, we diſcern a great number of irregular ſpots on her diſk, diſtinguiſhed by their dark colour from the brighter or more glaring parts; but when viewed through a teleſcope, their number is prodigiouſly increaſed; and it is perceived, that many of theſe appearances are occaſioned by vaſt obſcure pits or cavities, and elevations or mountains.

Theſe mountains and cavities are known to be ſuch, from the ſhadow they caſt. In the firſt and ſecond quarters, when the light of the ſun falls obliquely upon them, the elevated parts caſt a triangular ſhadow on the ſide oppoſite to the ſun;

whereas, with refpect to the cavities, thefe have that fide which is oppofite to the fun illuminated, and that which is next the fun is dark and obfcure, the fame as would happen to a hollow bafon, placed on a table at fome diftance from a candle, in a room where there is no other light. The fhadows fhorten as the fun becomes more directly oppofed to the anterior face of the moon, and at length difappear at the time of the full. During the third and laft quarters, the fhadows appear again, but all fall towards the contrary fide of the moon, though ftill with the fame diftinction, namely, that the mountains are dark and fhady on the fide fartheft from the fun, and the pits are dark on the fide next the fun.

The full moon is a very pleafing fight through a telefcope, and has a great variety of luftre and colour; but it is not the face on which to difcover the mountains, thefe are beft feen at the increafe or decreafe; for befides the evidence derived from the fhadows, we may then fee the tops of thefe mountains catching the rays of the fun before they reach that part of the furface on which their bottoms are placed.

On April 19, 1787, Dr. Herfchel obferved fome appearance on the furface of the moon, which, judging

judging by analogy from things perceived here with us, he thought he might term volcanoes. Three of thefe he obferved in different places of the dark part of the moon; two of them appeared nearly extinct, or going to break out; the third, as an actual eruption of fire, or luminous matter. On the 20th it burnt with greater violence, and might be computed to be about three miles in diameter; the eruption refembled a piece of burning charcoal, covered by a thin coat of white afhes; all the adjacent parts of the volcanic mountain were faintly illuminated by the eruption, and were gradually more obfcure as they lay at a greater diftance from the crater. Dr. Herfchel had, in 1783, obferved an eruption, fomewhat fimilar to that of the foregoing volcano.

That the moon is furrounded by an atmofphere, is rendered probable by many obfervations of folar eclipfes, in which the edge or limb of the fun was obferved to tremble juft before the beginning. The planets are likewife obferved to change their figure from round to oval, juft before the beginning of an occultation behind the moon, which can be attributed to no other caufe than that their light is refracted by being feen through the moon's atmofphere. That we fee no clouds, will not appear furprizing, if we confider that the lunar days and nights are thirty times as long as our's; it will be eafy to conceive, that with them the phænomena of vapours may be very different from what they are with us; perhaps their clouds and rain, if any, may be condenfed into vifible quantities only during the abfence of the fun, and of courfe when they muft be invifible to us.

Mercury being at all times near the fun, we can only diftinguifh by the telefcope a variation of his figure, which is fometimes that of a half moon, fometimes a little more or lefs than half.

Venus, when in the form of a crefcent, and at her brighteft times, affords a more pleafing telefcopic view than any other of the heavenly bodies; her furface is diverfified with fpots, like thofe of the moon; by the motion of thefe, the time fhe takes up in revolving upon her axis is difcovered. With a powerful telefcope, mountains, like thofe in the moon, may be feen.

Mars appears always round and full, except at the time of the quadrature, when it's difk appears like that of the moon about three days after the full. By the fpots which are feen on it's furface, it's diurnal revolution has been afcertained.

From

From it's characteriſtic ruddineſs, and from other phænomena, it has been ſuppoſed that it's atmoſphere is nearly of the ſame denſity with our's. Dr. Herſchel has obſerved two white luminous circles ſurrounding the poles of this planet; theſe are ſuppoſed to ariſe from the ſnow lying about thoſe parts.

The appearance of Jupiter through a teleſcope, opens a vaſt field for ſpeculative inquiry. The ſurface is not equally bright, but is diſtinguiſhed by certain bands, or belts, of a duſkier colour than the reſt of the ſurface, running parallel to each other, and to the plane of it's orbit. They are not regular or conſtant in their appearance; ſometimes only one is ſeen, at other times eight have been ſeen; ſometimes one or more ſpots are formed between the belts, which increaſe till the whole is united in one large duſky band. There are alſo bright ſpots to be diſcovered on Jupiter's ſurface; theſe are rather more permanent than the belts, and re-appear after unequal intervals of time. The remarkable ſpot, by whoſe motion the rotation of Jupiter on his axis was aſcertained, diſappeared in 1694, and was not ſeen again till 1708, when it re-appeared exactly in the ſame place, and has been occaſionally ſeen ever ſince. The diſappearance and re-appearing of the ſpots is not ſo wonderful as the changes that have been obſerved in the belts; the elder Caſſini ſaw one evening five belts upon the planet, but while he was viewing them, they underwent the moſt ſurprizing change. In an hour from their fulleſt appearance there remained only three out of five, and one of theſe ſcarce perceptible.

Though the great diſtance of the planet Saturn, and the tenuity of it's light, do not permit us to diſtinguiſh the varieties of it's ſurface; yet ſome of the firſt diſcoveries made by the teleſcope were on this planet, and the ring is ſtill one of the moſt curious phænomena we are acquainted with. There is not, indeed, any thing in the whole ſyſtem of nature more wonderful than this ring, which appears nearly as bright as any part of the ſurface of the planet; by what means it is ſuſpended, or by what law ſupported; whether it is only a bright but permanent cloud, or whether it is a vaſt number of ſatellites diſpoſed in the ſame plane, whoſe blended light gives it to us the form of one continual body, we can only form crude conjecture. M. Meſſier has obſerved on the anſes of this ring, ſeveral luminous white twinkling points, differing in vivacity from each other.

OF

Of Comets.

Comets are a kind of ſtars, appearing at unexpected times in the heavens, and of ſingular and various figures, deſcending from far diſtant parts of the ſyſtem, with great rapidity, ſurprizing us with the ſingular appearance of a train, or tail; and after a ſhort ſtay, are carried off to diſtant regions, and diſappear.

They were imagined in ancient times to be prodigies hung out by the immediate hand of God in the heavens, and intended to alarm the world. Their nature being now better underſtood, they are no longer terrible. But as there are ſtill many who think them to be heavenly warnings, portents of future events, it may not be improper for the tutor to inform his pupil, that the Architect of the univerſe has framed every part according to divine order, and ſubjected all things to laws and regulations: that he does not hurl at random ſtars and worlds, and diſorder the ſyſtem of the whole glorious frame, to produce falſe apprehenſions of diſtant events, fears without foundation, and without uſe. Religion glories in the teſt of reaſon, of knowledge, and of true wiſdom; it is every way connected with, and is always elucidated by them. From

 philoſophy

philofophy we may learn, that the more the works of the Lord are underftood, the more he muft be adored; and that his fuperintendency over every portion is more clearly evinced, and more fully expreffed by their unvaried courfe, than by ten thoufand deviations.

The exiftence of an univerfal connection between all the parts of nature is now generally allowed. Comets undoubtedly form a part of this great chain; but of the part they occupy, and of the ufes for which they exift, we are equally ignorant. It is a portion of fcience whofe perfection is referved for fome diftant day, when thefe bodies and their vaft orbits may, by long and accurate obfervation, be added to the known parts of the folar fyftem.

The aftronomy of comets is very imperfect; for but little can be known with certainty, where but little can be feen. Comets afford few obfervations on which to ground conjecture, and are for the greateft part of their courfe beyond the reach of human vifion.

It is, however, now generally fuppofed, that they are planetary bodies, making part of our fyftem, revolving round the fun in extremely long elliptic

elliptic curves. That as the orbit of a comet is more or lefs excentric, the diftance to which they recede from the fun will be greater or lefs. Very great difference has been found by obfervation in this refpect, even fo great, that the fides of the elliptic orbit in fome cafes degenerate almoft into right lines.

That thofe comets which go to the greateft diftance from the fun, approach the neareft to him at their return.

Their motions in the heavens are not all direct, or according to the order of the figns, like thofe of the other planets. The number of thofe which move in a retrograde manner, is nearly equal to thofe whofe motion is direct.

The orbits of moft of them are inclined in very large angles to the plane of the ecliptic.

The velocity with which they move is variable in every part of their orbit; when they are near the fun, they move with incredible fwiftnefs; when very remote from him, their motion is inconceivably flow.

They

They differ alſo in form from the other planets, conſiſting of a large internal body, which ſhines with the reflected light of the ſun, and is encompaſſed with a very large atmoſphere, apparently of a fine matter, replete with clouds and vapours; this is called the head of the comet, and the internal part the nucleus. When a comet arrives at a certain diſtance from the ſun, an exhalation ariſes from it, which is called the tail.

The tail is always directed to that part of the heavens which is directly or nearly oppoſite to the ſun, and is greater after the comet has paſt it's perihelium, than in it's approach to it, being greateſt of all when it has juſt paſt the perihelium.

No ſatisfactory knowledge has been acquired concerning the cauſe of that train of light which accompanies the comets. Some philoſophers imagine that it is the rarer atmoſphere of the comet impelled by the ſun's rays. Others, that it is the atmoſphere of the comet, riſing in the ſolar atmoſphere by it's ſpecific levity; while others imagine that it is a phænomenon of the ſame kind with the aurora borealis; and that this earth would appear like a comet to a ſpectator placed in another planet.

The

The number of the comets is certainly very great, confiderably beyond any eftimation that might be made from the obfervations we now poffefs.

Of a Plurality of Worlds.

The fixed ftars are generally fuppofed to be of the fame nature with our fun, each of them attended by planets, which are inhabited by rational creatures like this earth.

Inftead, therefore, of one fun, and one world, we find that the region of unbounded fpace is peopled with funs, and ftars, and worlds. This opinion has been held and taught by many of the moft celebrated philofophers and aftronomers, both in ancient and modern times: in this view of things, our fyftem refembles a fingle individual of fome one fpecies of being in outward nature, diverfified from all it's fellow individuals, by differences uneffential to the kind and fpecies; but which conftitute that beauty, which arifes from uniformity amidft variety.

That the fixed ftars are funs, fhining by their own light, is probable, on account of their immenfe diftance from us; for as it is impoffible

that

that at theſe diſtances they could be ſeen by any reflection of light from the ſun, it is natural to ſuppoſe them endowed with a power of emitting light from their own bodies. By comparing the apparent diameter of objects at different diſtances, it is clear that our ſun would appear like a ſtar, were he removed to the diſtance at which they are placed ; and that therefore it is truly reaſonable to ſuppoſe, that the fixed ſtars are equal, if not ſuperior in magnitude to that which is the center of our ſyſtem ; and that they are made for the ſame purpoſes with the ſun, to beſtow light, heat, and vegetation, on a certain number of planets revolving round them.

Of their immenſe diſtance from us, and the vaſtneſs of the ſpace they occupy, the reader may form ſome idea, when he is told, that numbers amongſt them are at too great a diſtance to be adequately expreſſed by figures, and beyond the reach of admeaſurement ; and this will be heightened, if he conſiders that the ſmalleſt of the ſtars viſible to the eye are much more remote than the larger ones, and that the teleſcope diſcovers ſtars which are too diſtant to be perceptible to the naked eye. That the inſtrument, like our eyes, has it's limits ; but the extent of the heavens has no bounds.

The

The fixed ſtars being ſo far removed from, and for the moſt part inviſible to us, it can ſcarcely be conceived by the narroweſt mind, that they form a part of our ſyſtem, or were created only to give a faint glimmering light to the inhabitants of this globe; for one additional moon would have afforded us more light than the whole hoſt of ſtars; ſuch an opinion is unworthy of our reaſon, inadequate to our conceptions of the Deity. It would be alſo abſurd to ſuppoſe that the author of nature had made ſo many ſuns without planets, to be enlightened by their light, and vivified by their heat; but more ſo, to imagine ſo many habitable worlds enlightened by ſuns without inhabitants; we may, therefore, ſafely conclude, that all the planets, of every ſyſtem, are inhabited.

This reaſoning is ſtill further ſtrengthened, by conſidering the immenſity of the ſtarry heavens, in which are innumerable hoſts of ſtars, created as the means to ſome great end. From revelation we learn, that the ultimate end of creation is the peopling of heaven with men. Theſe reſplendent ſuns are clearly then the mediums of exiſtence to ſo many earths, and of men upon them, created to be happy eternally with their God, "THE ONE ETERNAL THIRST TO BLESS."

"Every

" Every ſtar is thus the center of a magnificent ſyſtem, attended by a retinue of worlds, irradiated by it's beams, and revolving round by it's active influence." Thus the greatneſs of God is magnified, and the grandeur of his empire made manifeſt. He is not glorified on one earth, or in one world, but in ten thouſand times ten thouſand. " If we could wing our way to the higheſt apparent ſtar, we ſhould there ſee other ſkies expanded, other ſuns that diſtribute their inexhauſtible beams of day; other ſtars, that gild the alternate night, and other (perhaps nobler) ſyſtems eſtabliſhed in unknown profuſion, through the boundleſs dimenſions of ſpace. Nor does the dominion of the Sovereign of all things terminate here; even at the end of this vaſt tour we ſhould find ourſelves advanced no further than the frontiers of creation, the commencement of the great JEHOVAH's kingdom."

This mode of reaſoning applies with greater force to the planets of our own ſyſtem, and gains additional ſtrength from other conſiderations. For who would venture to aſſert, that infinite love and conſummate wiſdom had formed ſuch immenſe material maſſes, ſome of which exceed our earth in ſize, convey them in revolutions round the ſun, furniſh them with moons, grant them

them the alternate changes of night and day, viciſſitudes of ſeaſons, and all this only to emit their ſcanty light on our earth.

Or who that has ſeen any engine, a windmill for inſtance, and who knows the uſe of it, if he travels into another country, and there ſees an engine of the ſame ſort, will not reaſonably conclude that it is deſigned for the ſame purpoſe? So when we know that the uſe of this planet, the earth, is for an habitation of various ſorts of animals, and we ſee other planets at a diſtance from us, ſome bigger, ſome leſs than the earth, moving periodically round, revolving on their axes, and attended with moons; is it not highly reaſonable to conclude, that they are all deſigned for the ſame uſe as this earth is, and that they are habitable worlds like that we live in.

" Who can conceive them
——————— unpoſſeſs'd
By living ſoul, deſert and deſolate,
Only to ſhine, yet ſcarce to contribute
Each orb a gleam of light?"

Or that the ALMIGHTY, who has not left with us a drop of water unpeopled, who has in every inſtance multiplied the bound of life, ſhould leave

P ſuch

ſuch immenſe bodies deſtitute of inhabitants? It is ſurely much more rational to ſuppoſe them the poſſeſſion of human beings, beings formed with capacities for knowing, loving, and ſerving their Almighty Creator; bleſt and provided with every object conducive to their happineſs, and many of them in a far greater ſtate of purity than the inhabitants of our earth, and therefore in poſſeſſion of higher degrees of bliſs, and placed in ſituations, furniſhing them with ſcenes of joy, equal to all that poetry can paint, or religion promiſe: all under the direction, indulgence, and protection of infinite wiſdom and goodneſs.

A COMPREHENSIVE SURVEY OF THE UNIVERSE.

As this work is principally intended for young minds, the following view of the univerſe, by the amiable philoſopher of Geneva, Mr. Bonnet, cannot but prove acceptable to the reader, not only becauſe it will ſerve as a recapitulation of what has gone before, but as it will tend to enlarge his ideas, and increaſe his veneration for the Father of all beings.

When the ſhades of night have ſpread their veil over the azure plains, the firmament manifeſts to our view it's grandeur and it's riches.

The ſparkling points with which it is ſown, are ſo many SUNS ſuſpended by the ALMIGHTY in the immenſity of ſpace, to give light and heat to the worlds which roll around them.

THE HEAVENS DECLARE THE GLORY OF GOD, AND THE FIRMAMENT SHEWETH HIS HANDY-WORK. The royal poet, who expreſſed himſelf with ſuch loftineſs of ſentiment, was ignorant that the ſtars he contemplated were in reality ſuns. He anticipated the times, and firſt ſung that majeſtic hymn, which future and more enlightened ages ſhould chaunt forth in praiſe to the FOUNDER OF WORLDS.

The aſſemblage of theſe vaſt bodies is divided into different ſyſtems, the number of which probably ſurpaſſes the grains of ſand which the ſea caſts on it's ſhores.

Each ſyſtem has at it's center, or focus, a ſtar, or ſun, which ſhines by it's native inherent light; and round which, ſeveral orders of opake globes revolve, reflecting, with more or leſs brilliancy, the light they borrow from it, and which renders them viſible.

Thofe globes which we perceive as wandering among the heavenly hoft, are the PLANETS; the primary, or principal ones, have the fun for the common center of their periodical revolution; while the others, which are called fecondaries, move round their primaries, accompanying them as SATELLITES in their annual revolution.

The earth has one fatellite, Jupiter four, Saturn five, and the Georgium Sidus two; Saturn has befides a luminous and beautiful ring.

We know that our folar fyftem confifts of twenty planetary bodies; we are not certain but that there may be more. Their number has been confiderably augmented fince the invention of telefcopes: more perfect inftruments, and more accurate obfervers, may further increafe their number; the difcovery of the Georgium Sidus may be looked upon as the happy prefage of future fuccefs.

Modern aftronomy has not only enriched our heavens with new planets, but it has alfo enlarged the boundaries of the folar fyftem. The comets, which from their fallacious appearance, their tail, their beard, the diverfity of their directions, their fudden appearance and difappearance, have been

been conſidered as meteors, lighted up in the air by an irritated power, are found to be a ſpecies of planetary bodies, whoſe long routes are now calculated by aſtronomers; they alſo foretel their diſtant return, determine their place, and account for their irregularities. Many of theſe bodies at preſent acknowledge the empire of our ſun, though the orbits they trace round him are ſo extenſive, that many ages are neceſſary for the completion of a revolution.

In a word, it is from modern aſtronomy that we learn that the ſtars are innumerable, and that the conſtellations, in which the ancients reckoned but a few, are now known to contain thouſands. The heavens of Thales and Hipparchus were very poor when compared to thoſe of Tycho Brahe, Flamſtead, de La Caille, and Herſchel.

The diameter of the great orbit which our earth deſcribes, is more than many millions of leagues; yet this vaſt extent vaniſhes into nothing, and becomes a mere point, when the aſtronomer wiſhes to uſe it as a meaſure, to aſcertain the diſtance of the fixed ſtars.

How great then is the real bulk of theſe luminaries, which are perceptible by us at ſuch an enormous diftance! the fun is about 1,392,500 times greater than the earth, and 539 $\frac{1}{2}$ times greater than all the planets taken together. If the ftars are funs, as we have every reafon to fuppofe, they muft either be equal to, or exceed it in fize.

Proud and ignorant mortal! lift up now thine eyes to heaven, and anfwer me: if one of thofe luminaries which adorn the ftarry heaven, fhould be taken away, would thy nights become darker? Say not then, that the ftars are made for thee; that it is for thee that the firmament glitters with effulgent brightnefs: feeble mortal! thou wert not the chief object of the liberal bounties of the Creator, when he appointed Syrius, and encompaffed it with worlds.

Whilft the planets perform their periodical revolutions round the fun, by which the courfe of their year is regulated, they turn round upon their axes, a motion by which they obtain the alternate fucceffion of day and night.

But by what means are thefe vaft bodies fufpended in the immenfity of fpace? What fecret power retains them in their orbits, and enables them to circulate with fo much regularity and harmony?

harmony? GRAVITY, OR ATTRACTION, is the powerful agent, the univerſal principle of this equilibrium, and of theſe motions. It penetrates intimately all bodies. By this power, they tend toward each other in a proportion relative to their bulk. Thus the planets tend towards the center of the ſyſtem, into which they would ſoon have been precipitated, if the Creator, when he formed them, had not impreſſed upon them a projectile or centrifugal force, which continually keeps them at a proper diſtance from the center.

The planets, by obeying at the ſame inſtant each of theſe motions, are made to deſcribe a curve. This curve is an ellipſe, of different excentricities, according to the combination of the active powers. At one of the foci of this ellipſe the ſun is placed. Thus the ſame force which determines the fall of a ſtone, is the ruling principle of the heavenly motions. Wonderful mechaniſm! whoſe ſimplicity and energy gives us unceaſing tokens of the PROFOUND WISDOM OF IT'S AUTHOR.

The earth, which ſeems ſo vaſt in the eyes of the emmets who inhabit it, and whoſe diameter is above 7970 miles, is yet near a thouſand times ſmaller than Jupiter, who appears to the naked eye as little more than a ſhining atom.

Two troops of academicians, new Argonauts, have had within this century the glory of determining the figure of the earth, and have demonſtrated it to be a ſpheroid, flattened at the poles, elevated at the equator. But Newton has acquired a ſtill greater glory, that of diſcovering, by the powers of genius, the ſame truth previous to obſervation. This figure is alſo the effect of gravity, combined with the centrifugal force. Theſe two powers acting in different proportions, on different planets, vary their figure, and change them into ſpheroids, more or leſs flat, at the ſame time that they contract or dilate their orbits.

This terraqueous globe is externally divided by land and ſeas. It is internally formed (at leaſt to a certain depth) into beds of heterogeneous matter; the beds are almoſt parallel, but of different denſities and textures.

The ſurface of the earth abounds with irregularities. In one part we find vaſt plains, interſected with hills and vallies. In another, long chains of mountains, which lift their frozen heads to the clouds; from the boſom of theſe mountains proceed rivers, which, after they have watered various countries, and produced ponds and lakes, diſcharge themſelves into the ſea, and reſtore to it what it had loſt by evaporation.

The ſea preſents to our view iſlands ſcattered in all parts of it, ſands, rocks, currents, gulphs, and ſtorms; but above all, that regular and admirable motion whereby it's waters riſe and fall twice every twenty-four hours.

The lands and ſeas are peopled with plants and animals, whoſe infinitely varied ſpecies have each their proper habitation. Mankind divided into nations, people, and families, cover the ſurface of the globe. They modify and enrich it by their various labours, and build dwellings from pole to pole, which correſpond with their manners, genius, and climate.

A rare tranſparent and elaſtic ſubſtance ſurrounds the earth to a certain height. This ſubſtance is the atmoſphere, the habitation of the winds, an immenſe reſervoir of vapours, which, when condenſed into clouds, either embelliſh our ſky by the variety of their figures, and the richneſs of their colouring; or aſtoniſh us

by

by the rolling thunder, or flashes of lightning, that escape from them; sometimes they melt away, at others are condensed into rain or hail, supplying the deficiencies of the earth with the superfluity of heaven.

The moon, the nearest of all the planets to the earth, is likewise that of which we have the most knowledge. It's globe always presents to us the same face, because it turns round upon it's axis precisely in the same space of time that it revolves round the earth.

It has it's phases, or gradual and periodical increase and decrease of light, according to it's position with respect to the sun, which enlightens it, and the earth on which it reflects the light that it has received.

The disk of the moon is divided into luminous and obscure parts. The former seems analogous to land, the latter to resemble our seas.

In the luminous spots there have been observed some parts which are brighter than the rest; these project a shadow, whose length has been measured, and their track ascertained. These parts are mountains, much higher than our's, in proportion to the ſize of the moon, whoſe tops may be ſeen gilded by the rays of the ſun, at the quadratures of the moon, and the light gradually deſcending to their feet, till they appear entirely bright. Some of theſe mountains ſtand by themſelves, while in other places there are long chains of them.

We ſhall not dwell upon the numerous particulars that may be obſerved on an attentive examination of this planet. If the author of nature has with us thought proper to vary the ſmalleſt individual, how great muſt the diverſity be, by which he has diſtinguiſhed one world from another.

Venus has, like the moon, her phaſes, ſpots, and mountains. The teleſcope diſcovers to us alſo ſpots in Mars and Jupiter. Thoſe in Jupiter form belts; conſiderable changes have been ſeen among theſe, as if of the ocean's overflowing the land, and again leaving it dry by it's retreat.

Mercury, Saturn, and the Georgium Sidus, are but little known; the firſt, becauſe he is too near the ſun; the two laſt, becauſe they are ſo remote from it.

Laſtly,

Laſtly, the ſun himſelf has ſpots, which ſeem to move with regularity, and whoſe ſize equals, and very often exceeds, our globe itſelf.

Every thing in the univerſe is ſyſtematical, all is combination, affinity, and connection.

The ſpecies and individuals have relation to the ſize of the earth; the ſize of the earth has it's relation to the place ſhe occupies in the planetary ſyſtem.

The ſun gravitates on the planets, the planets on the ſun and each other. Theſe taken together gravitate on their neighbouring ſyſtems, theſe again on more diſtant ones; while the ballance of the univerſe remains in equilibrio, in the hands of the ANCIENT OF DAYS.

From the relations which exiſt between all parts of the world, and by which they conſpire to one general end, reſults the harmony of the world.

The relations which unite all the worlds to one another, conſtitute the harmony of the univerſe.

The beauty of the world is founded in the harmonious diverſity of the beings that compoſe it, in the number, the extent, and the quality of their effects, and in the ſum of happineſs that ariſes therefrom.

ESSAY II.

PART I.

ESSAY II.

PART I.

A Treatise on the Use of the Terrestrial and Celestial Globes.

Of the Advantages of Globes in general, for illustrating the primary Principles of Astronomy and Geography; and particularly of the Advantages of the Globes, when mounted in my Father's Manner.

UNIVERSAL approbation, the opinion of thoſe that excel in ſcience, and the experience of thoſe that are learning, all concur to prove that the artificial repreſentations of the earth and heavens, on the terreſtrial and celeſtial globes, are the inſtruments the beſt adapted to convey natural and genuine ideas of aſtronomy and geography to young minds.

This ſuperiority they derive principally from their form and figure, which communicates a more juſt idea, and a more adequate repreſentation of the earth and heavens, than can be formed from any other figure.

To underſtand the nature of the projection of either ſphere in plano, requires more knowledge of geometry than is generally poſſeſſed by beginners, it's principles are more recluſe, and the ſolution of problems by them more obſcure.

The motion of the earth upon it's axis is one of the moſt important principles both in geography and aſtronomy; on it the greater part of the phænomena of the viſible world depend: there is no invention that can communicate ſo natural a repreſentation of this motion, as that of a terreſtrial globe about it's axis. By a celeſtial globe, the apparent motion of the heavens is alſo repreſented in a natural and ſatisfactory manner.

In order to convey clear ideas of the various diviſions of the earth, of the ſituation of different places, and to obtain an eaſier ſolution of problems in geography, it is neceſſary to conceive many imaginary circles to be delineated on it's ſurface, and to underſtand their relation to each other. Now on a globe theſe circles have their true form, their interſections and relative poſitions are viſible upon the moſt curſory inſpection. But in projections of the ſphere in plano, the form of theſe circles is varied, and their nature changed; they are conſequently but ill adapted to convey to young minds the elementary principles of geography.

On a globe, the appearance of the land and water is perfectly natural and continuous, and fitted to convey accurate ideas, and leave permanent impreſſions on the moſt tender minds; whereas, in planiſpheres one-half of the globe is ſeparated and disjoined from the other; and thoſe parts which are contiguous on a globe, are here ſeparated and thrown at a diſtance from each other. The celeſtial globe has the ſame ſuperiority over projections of the heavens in plano.

The globe exhibits every thing in true proportion, both of figure and ſize; while on a planiſphere the reverſe may often be obſerved.

Preſuming that theſe reaſons ſufficiently evince the great advantage of globes over either planiſpheres or maps, for obtaining the firſt principles of aſtronomical and geographical knowledge, I proceed to point out the pre-eminence of globes mounted in my father's manner, over the common, or rather the old and Ptolemaic mode of fitting them up.

The great and increafing fale of the beft globes may be looked upon at leaft as a proof of approbation from numbers; to this I might alfo add, the encouragement they have received from the principal tutors of both our univerfities, the public fanction of the univerfity of Leyden, the many editions of my father's treatife on their ufe, and it's tranflation into Dutch, &c. The recommendation of Meff. Arden, Walker,* Burton, &c. public lecturers in natural philofophy, might alfo be adduced; but leaving thefe confiderations, I fhall proceed to enumerate the reafons which give them, in my opinion, a decided preference over every other kind of mounting.

The earth, by it's diurnal revolution on it's axis, is carried round from weft to eaft. To reprefent this real motion of the earth, and to folve problems agreeable thereto, it is neceffary that the globe, in the folution of every problem, fhould be moved from WEST TO EAST; and for this purpofe, that the divifions on the large brafs circle

* An Eafy Introduction to Geography, by Mr. Walker.

circle ſhould be on that ſide which looks weſtward.* Now this is the caſe in my father's mode of mounting the globes, and the tutor can thereby explain with eaſe the rationale of any problem to his pupil. But in the common mode of mounting, the globe muſt be moved from eaſt to weſt, according to the Ptolemaic ſyſtem; and conſequently, if the tutor endeavours to ſhew how things obtain in nature, he muſt make his pupil unlearn in a degree what he has taught him, and by abſtraction reverſe the method he has inſtructed him to uſe, a practice that we hope will not be adopted by many.

The celeſtial globe being intended to repreſent the apparent motion of the heavens, ſhould be moved, when uſed, from eaſt to weſt.

Of the phænomena to be explained by the terreſtrial globe, the moſt material are thoſe which relate to the changes in the ſeaſons; all the problems connected with, or depending upon theſe phænomena, are explained in a clear, familiar, and natural manner, by the globe,

 when

* See the Rev. Mr. Hutchins's New Treatiſe on the Globes, p. 3; Adams's Treatiſe on the Globes.

when mounted in my father's mode; for on rectifying it for any particular day of the month, it immediately exhibits to the pupil the exact ſituation of the globe of the earth for that day; and while he is ſolving his problem, the reaſon and foundation of it preſents itſelf to the eye and underſtanding.

The globe may alſo be placed with eaſe in the poſition of a right ſphere, a circumſtance exceedingly uſeful, and which the old conſtruction of the globes did not admit of.

By the application of a moveable meridian, and an artificial horizon connected with it, it is eaſy to explain why the ſun, although he be always in one and the ſame place, appears to the inhabitants of the earth at different altitudes, and in different azimuths, which cannot be ſo readily done with the common globes.

On the celeſtial globe there is a moveable circle of declination, with an artificial ſun.

The braſs wires placed under the globes, ſerve to diſtinguiſh, in a natural and ſatisfactory manner, twilight from total darkneſs, and the reaſon of the length of it's duration.

The

The next point wherein they materially differ from other globes, is in the hour circle; now it muſt be confeſſed, that to every contrivance that has been uſed for this purpoſe there is ſome objection, and probably no mode can be hit upon that will be perfectly free from them. The method adopted by my father appears to me the leaſt exceptionable, and to poſſeſs ſome advantages over every other method I am acquainted with. Agreeable to the opinion of the firſt aſtronomers, among others of M. de la Lande, he uſes the equator for the hour circle, not only as the largeſt, but alſo as the moſt natural circle that could be employed for that purpoſe, and by which alone the ſolution of problems could be obtained with the greateſt accuracy. As on the terreſtrial globe, the longitude of different places is reckoned on this circle; and on the celeſtial, the right aſcenſion of the ſtars, &c. it familiarizes the young pupil with them, and their reduction to time. This method does not in the leaſt impede the motion of the globe; but while it affords an equal facility of elevating either the north or ſouth pole, it prevents the pupil from placing them in a wrong poſition; and it is alſo prevented by the horary wire from falling out of the frame.

Another circumſtance peculiar to theſe globes, is the mode of fixing the compaſs. It is ſelf-evident, that the tutor, who is willing to give correct ideas to his pupil, ſhould always make him keep the globes with the north pole directed towards the north pole of the heavens, and that, both in the ſolution of problems, and the explanation of phænomena. By means of the compaſs, the terreſtrial globe is made to ſupply the purpoſe of a tellurian, when ſuch an inſtrument is not at hand. I cannot terminate this paragraph, without teſtifying my diſapprobation of a mode of making the globe turn round upon a pin in the pillar on which it is ſupported: a mode, that while it can give but little relief to indolence, is leſs firm in it's conſtruction, and tends to introduce much confuſion in the mind of the pupil.

In order to prevent that confuſion and perplexity which neceſſarily ariſes in a young mind, when names are made uſe of which do not properly characterize the ſubject, my father found it neceſſary, with Mr. Hutchins, to term that broad wooden circle which ſupports the globe, and on which the ſigns of the ecliptic and the days of the month are engraved, the BROAD PAPER CIRCLE, inſtead of horizon, by which it had been heretofore denominated. The propriety of this change will

will be evident to all thoſe who conſider that this circle in ſome caſes repreſents that which divides light from darkneſs, in others the horizon, and ſometimes the ecliptic. For ſimilar reaſons, he was induced to call the brazen circle, in which the globes are ſuſpended, the STRONG BRASS CIRCLE.

In a word, many operations may be performed by theſe globes, which cannot be ſolved by thoſe mounted in the common manner; while all that they can ſolve may be performed by theſe, and that with a greater degree of perſpicuity; and many problems may be performed by theſe at one view, which on the other globes require ſucceſſive operations.

But as notwithſtanding their ſuperiority, the difference in price may make ſome perſons prefer the old conſtruction, it may be proper to inform them, that they may have my father's, or Senex's globes mounted in the old manner, at the uſual prices.

ESSAY II.

PART II.

ESSAY II.

PART II.

CONTAINING A DESCRIPTION OF THE GLOBES MOUNTED IN THE BEST MANNER; TOGETHER WITH SOME PRELIMINARY DEFINITIONS.

DEFINITIONS.

BEFORE we begin to deſcribe the globes, it will be proper to take ſome notice of the properties of a circle, of which a globe may be ſaid to be conſtituted.

A LINE is generated by the motion of a point.

Let there be ſuppoſed two points, the one moveable, the other fixed.

If the moveable point be made to move directly towards the fixed point, it will generate in it's motion a ſtrait line.

If

If a moveable point be carried round a fixed point, keeping always the ſame diſtance from it, it will generate a CIRCLE, or ſome part of a circle, and the fixed point will be the CENTER of that circle.

All ſtrait lines going from the center to the circumference of a circle, are equal.

Every ſtrait line that paſſes through the center of a globe, and is terminated at both ends by it's ſurface, is called a DIAMETER.

The extremities of a diameter are it's poles.

If the circumference of a ſemicircle be turned round it's diameter, as on an axis, it will generate a globe, or ſphere.

The center of the ſemicircle will be the center of the globe; and as all points of the generating ſemicircle are at an equal diſtance from it's center, ſo all the points of the ſurface of the generated ſphere are at an equal diſtance from it's center.

Description of the Globes.

There are two artificial globes; on the ſurface of one of them the heavens are delineated, this is called the CELESTIAL GLOBE. The other, on which the ſurface of the earth is deſcribed, is called the TERRESTRIAL GLOBE.

Fig. 2, plate XIV. repreſents the celeſtial; fig. 1, plate XIV. the terreſtrial globe, as mounted in my father's manner.

In uſing the celeſtial globe, we are to conſider ourſelves as at the CENTER.

In uſing the terreſtrial globe, we are to ſuppoſe ourſelves on ſome point of it's SURFACE.

The motion of the terreſtrial globe repreſents the REAL motion of the earth.

The motion of the celeſtial globe repreſents the APPARENT motion of the heavens.

The motion therefore of the celeſtial globe is a motion from EAST TO WEST.

But

But the motion of the terreſtrial globe is a motion from WEST TO EAST.

On the ſurface of each globe ſeveral circles are deſcribed, to every one of which may be applied what has been ſaid of circles in page 254.

The center of ſome of theſe circles is the ſame with the center of the globe; theſe are, by way of diſtinction, called GREAT CIRCLES.

Of theſe great circles, ſome are graduated.

The graduated circles are divided into 360 degrees, or equal parts, 90 of which make a quarter of a circle, or a quadrant.

Thoſe circles whoſe centers do not paſs through the center of the globe, are called LESSER CIRCLES.

The globes are each of them ſuſpended at the poles in a ſtrong braſs circle N Z Æ S, and turn therein upon two iron pins, which are the axis of the globe; they have each a thin braſs ſemicircle N H S, moveable about theſe poles, with a ſmall thin circle H ſliding thereon; it is quadrated each

each way, to 90 degrees from the equator to either pole.

On the terreſtrial globe this ſemicircle is a MOVEABLE MERIDIAN. It's ſmall ſliding circle, which is divided into a few of the points of the mariner's compaſs, is called a TERRESTRIAL or VISIBLE HORIZON.

On the celeſtial globe, this ſemicircle is a MOVEABLE CIRCLE OF DECLINATION, and it's ſmall braſs circle an artificial ſun, or planet.

Each globe has a braſs wire circle T W Y, placed at the limits of the crepuſculum, or twilight, which, together with the globe, is mounted in a wooden frame; the upper part B C is covered with a broad paper circle, whoſe plane divides the globe into two hemiſpheres, and the whole is ſupported by a neat pillar and claw, with a magnetic needle in a compaſs box marked M.

A Description of the Circles described on the broad Paper Circle B C; together with a general Account of it's Uses.

It contains four concentric circular ſpaces, the innermoſt of which is divided into 360 degrees, and numbered into four quadrants, beginning at the eaſt and weſt points, and proceeding each way to 90 degrees at the north and ſouth points; theſe are the four cardinal points of the horizon. The ſecond circular ſpace contains, at equal diſtances, the thirty-two points of the mariner's compaſs. Another circular ſpace is divided into twelve equal parts, repreſenting the twelve ſigns of the zodiac; theſe are again ſubdivided into 30 degrees each, between which are engraved their names and characters. This ſpace is connected with a fourth, which contains the calendar of months and days, each day on the 18 inch globes being divided into four parts, expreſſing the four cardinal points of the day, according to the Julian reckoning; by which means, the ſun's place is very nearly obtained for the common years after biſſextile, and the intercalary day is inſerted without confuſion.

In all poſitions of the celeſtial globe, this broad paper circle repreſents the plane of the horizon, and

and diſtinguiſhes the viſible from the inviſible part of the heavens; but in the terreſtrial globe it is applied to three different uſes.

1. To diſtinguiſh the points of the horizon; in this caſe it repreſents the rational horizon of any place.

2. It is uſed to repreſent the circle of illumination, or that circle which ſeparates day from night.

3. It occaſionally repreſents the ecliptic.

Of the strong Brass Circle N Æ Z S.

One ſide of this ſtrong braſs circle is graduated into four quadrants, each containing 90 degrees.

The numbers on two of theſe quadrants increaſe from the equator towards the poles; the other two increaſe from the pole towards the equator.

Two of the quadrants are numbered from the equator, to ſhew the diſtance of any point on the globe from the equator. The other two are numbered from the poles, for the more ready ſetting the globe to the latitude of any place.

The ſtrong braſs circle of the celeſtial globe is called the meridian, becauſe the center of the ſun comes directly under it at noon.

But as there are other circles on the terreſtrial globe, which are called meridians, we chuſe to denominate this the STRONG BRASS CIRCLE, or MERIDIAN.

The graduated ſide of the ſtrong braſs circle that belongs to the terreſtrial globe, ſhould face the WEST.

The graduated ſide of the ſtrong brazen meridian of the celeſtial globe ſhould face the EAST.

On the ſtrong braſs circle of the terreſtrial globe, and at about 23½ degrees on each ſide of the north pole, the days of each month are laid down according to the declination of the ſun.

Of the Horary Circles, and their Indices.

When the globes are mounted in my father's manner, we uſe the equator as the hour circle; becauſe becaufe it is not only the moft natural, but alfo the largeft circle that can be applied for that purpofe.

To make this circle anfwer the purpofe, a femicircular wire is placed over it, carrying two indices, one on the eaft, the other on the weft fide of the ftrong brafs circle.

As the equator is divided into 360°, or 24 hours, the time of one entire revolution of the earth or heavens, the indices will fhew in what fpace of time any part of fuch revolution is made among the hours which are graduated below the degrees of the equator on either globe.

As the motion of the terreftrial globe is from weft to eaft, the horary numbers increafe according to the direction of that motion; on the celeftial globe they increafe from the eaft to the weft.

Of the Quadrant of Altitude, Z A.

It is a thin, narrow, flexible flip of brafs, that will bend to the furface of the globe; it has a nut, with a fiducial line upon it, which may be readily applied to the divifions on the ftrong brafs meridian of either globe. One edge of the quadrant is divided into 90 degrees, and the divisions are continued to 18 degrees below the horizon.

Of some of the Circles that are described upon the Surface of each Globe.

We may suppose as many circles to be described on the surface of the earth as we please, and conceive them to be extended to the sphere of the heavens, marking thereon concentric circles. For as we are obliged, in order to distinguish one place from another, to appropriate names to them, so are we obliged to use different circles on the globes, to distinguish the parts, and their several relations to each other.

Of the Equator, or Equinoctial.

It goes round the globe exactly in the middle, between the two poles, from which it always keeps at the same distance; or in other words, it is every where 90 degrees distant from each pole, and is therefore a boundary, separating the northern from the southern hemisphere; hence it is frequently called the line by sailors, and when they sail over it they are said to cross the line.

It is that circle in the heavens, in which the ſun appears to move on thoſe two days, the one in the ſpring, the other in the autumn, when the days and nights are of an equal length all over the world; and hence on the celeſtial globe it is generally called the EQUINOCTIAL.

It is graduated into 360 degrees. Upon the terreſtrial globe the numbers increaſe from the meridian of London weſtward, and proceed quite round to 360. They are alſo numbered from the ſame meridian eaſtward, by an upper row of figures, to accommodate thoſe who uſe the Engliſh tables of latitude and longitude.

On the celeſtial globe, the equatorial degrees are numbered from the firſt point of Aries eaſtward, to 360 degrees.

Under the degrees on either globe is graduated a circle of hours and minutes. On the celeſtial globe the hours increaſe eaſtward, from Aries to XII at Libra, where they begin again in the ſame direction, and proceed to XII at Aries. But on the terreſtrial globe, the horary numbers increaſe by twice twelve hours weſtward from the meridian of London to the ſame again.

In turning the globe about, the equator keeps always under one point of the ſtrong braſs meridian, from which point the degrees on the ſaid circle are numbered both ways.

Of the Ecliptic.

The graduated circle, which croſſes the equator obliquely, forming with it an angle of about $23\frac{1}{2}$ degrees, is called the ecliptic.

This circle is divided into 12 equal parts, each of which contains 30 degrees. The beginning of each of theſe 30 degrees is marked with the characters of the 12 ſigns of the zodiac.

The ſun appears always in this circle; he advances therein every day, nearly a degree, and goes through it exactly in a year.

The points where this circle croſſes the equator are called the EQUINOCTIAL POINTS. The one is at the beginning of Aries, the other at the beginning of Libra.

The commencement of Cancer and Capricorn are called the SOLSTITIAL POINTS.

The

The twelve ſigns, and their degrees, are laid down on the terreſtrial globe; but upon the celeſtial globe, the days of each month are graduated juſt under the ecliptic.

The ecliptic belongs principally to the celeſtial globe.

ESSAY

ESSAY II.

PART III.

ESSAY II.

PART III.

The Use of the Terrestrial Globe, mounted in the best Manner.

Of Longitude and Latitude, and of Terrestrial Meridians.

MERIDIANS are circular lines, going over the earth's ſurface, from one pole to the other, and croſſing the equator at right angles.

Whatever places theſe circular lines paſs through, in going from pole to pole, they are the meridians of thoſe places.

There are no places upon the ſurface of the earth, through which meridians may not be conceived to paſs. Every place, therefore, is ſuppoſed to have a meridian line paſſing over it's zenith from north to ſouth, and going through the poles of the world.

Thus

Thus the meridian of Paris is one meridian; the meridian of London is another. This variety of meridians is ſatisfactorily repreſented on the globe, by the moveable meridian, which may be ſet to every individual point of the equator, and put directly over any particular place.

Whenſoever we move towards the eaſt or weſt, we change our meridian; but we do not change our meridian if we move directly to the north or ſouth.

The moveable meridian ſhews that the poles of the earth divide every meridian into two ſemi-circles, one of which paſſes through the place whoſe meridian it is, the other through a point on the earth, oppoſite to that place.

Hence it is, that writers in geography and aſtronomy generally mean by the MERIDIAN of any place the SEMICIRCLE which paſſes through that place; theſe, therefore, may be called the geographical meridians.

All places lying under the ſame ſemicircle, are ſaid to have the ſame meridian; and the ſemicircle oppoſite to it is called the oppoſite meridian,

ridian, or ſometimes the oppoſite part of the meridian.

From the foregoing definitions, it is clear that the meridian of any place is immoveably fixed to that place, and is carried round along with it by the rotation of the globe.

When the meridian of any place is by the revolution of the earth brought to point at the ſun, it is noon, or mid-day, at that place.

The plane of the meridian of any place may be imagined to be extended to the ſphere of the fixed ſtars.

When, by the motion of the earth, the plane of a meridian comes to any point in the heavens, as the ſun, moon, &c. that point, &c. is then ſaid to come to the meridian. It is in this ſenſe that we generally uſe the expreſſion of the ſun or ſtars coming to, or paſſing over the meridian.

The time which elapſes between the noon of any one day in a given place, and the noon of the day following in the ſame place, is called a natural day.

All places which lie under the ſame meridian, have their noon, and every other hour of the natural day, at the ſame time. Thus when it is one in the afternoon at London, it is alſo one in the afternoon to every place under the meridian of London.

In order to aſcertain the ſituation of any point, there muſt firſt be a ſettled part of the earth's ſurface, from which to meaſure; and as the point to be aſcertained may lie in any part of the earth's ſurface, and as this ſurface is ſpherical, the place from whence we meaſure muſt be a circle. It would be neceſſary, however, to eſtabliſh two ſuch circles, one to know how far any place may be eaſt or weſt of another, the ſecond to know it's diſtance north or ſouth of the given point, and thus determine it's preciſe ſituation.

Hence it has been cuſtomary for geographers to fix upon the meridian of ſome remarkable place, AS A FIRST MERIDIAN, OR STANDARD; and to reckon the diſtance of any place to the eaſt or weſt, or it's longitude, by it's diſtance from the firſt meridian. On Engliſh globes this firſt meridian is made to paſs through London.

THE LONGITUDE OF ANY PLACE is it's diſtance from the firſt meridian, meaſured by degrees on the equator.

To find the longitude of a place, is to find what degree on the equator the meridian of that place croſſes.

All places that lie under the ſame meridian, are ſaid to have the ſame longitude; all places that lie under different meridians, are ſaid to have different longitudes; this difference may be eaſt or weſt, and conſequently the difference of longitude betwen any two places, is the diſtance of their meridians from each other meaſured on the equator.

Thus if the meridian of any place cuts the equator in a point, which is fifteen degrees eaſt from that point, where the meridian of London cuts the equator, that place is ſaid to differ from London in longitude 15 degrees eaſtward.

Upon the terreſtrial globe there are 24 meridians, dividing the equator into 24 equal parts, which are the hour circles of the places through which they paſs.

The diſtance of theſe meridians from each other is 15 degrees, or the 24th part of 360 degrees; thus 15 degrees is equal to one hour.

By the rotation of the earth, the plane of every meridian points at the ſun, one hour after that meridian which is next to it eaſtward; and thus they ſucceſſively point at the ſun every hour, ſo that the plane of the 24 meridian ſemicircles being extended, paſs through the ſun in a natural day.

To illuſtrate this, ſuppoſe the plane of the ſtrong braſs meridian to coincide with the ſun, bring London to this meridian, and then move the globe round, and you will find theſe 24 meridians ſucceſſively paſs under the ſtrong braſs meridian, at one hour's diſtance from each other; till in 24 hours the earth will return to the ſame ſituation, and the meridian of London will again coincide with the ſtrong braſs circle.

By paſſing the globe round, as in the foregoing article, it will be evident to the pupil, that if one of theſe meridians, 15 degrees eaſt of London, comes to the ſtrong braſs meridian, or points at the ſun one hour ſooner than the meridian of London, a meridian that is 30 degrees eaſt, comes

comes two hours ſooner, and ſo on; and conſequently they will have noon, and every other hour, ſo much ſooner than at London: while thoſe, whoſe meridian is 15 degrees weſtward from London, will have noon, and every other hour of the day, one hour later than at London, and ſo on, in proportion to the difference of longitude. Theſe definitions being well underſtood, the pupil will be prepared not only to ſolve, but ſee the rationale of the following problems.

PROBLEM I.

To find the longitude of any place on the globe.

The reader will find no difficulty in ſolving this problem, if he recollects the definition we have given of the word longitude, namely, that it is the diſtance of any place from the firſt meridian meaſured on the equator. Therefore, either ſet the moveable meridian to the place, or bring the place under the ſtrong braſs meridian, and that degree of the equator, which is cut by either of theſe brazen meridians, is the longitude in degrees and minutes, or the hour and minute of it's longitude, expreſſed in time.

As the given place may lie either eaſt or weſt of the firſt meridian, the longitude may be expreſſed accordingly.

It appears moſt natural to reckon the longitude always weſtward from the firſt meridian; but it is cuſtomary to reckon one half round the globe eaſtward, and the other half weſtward from the firſt meridian. To accommodate thoſe who may prefer either of theſe plans, there are two ſets of numbers on our globes: the numbers neareſt the equator increaſe weſtward, from the meridian of London quite round the globe to 360°, over which another ſet of numbers is engraved, which increaſe the contrary way; by which means, the longitude may be reckoned upon the equator, either eaſt or weſt.

Example. Bring Boſton, in New England, to the graduated edge of either the ſtrong braſs, or of the moveable meridian, and you will find it's longitude in degrees to be 70½, or 4 h. 42 min. in time; Rome 12½ degrees eaſt, or 50 min. in time; Charles-Town, North America, is 79 deg. 50 min. weſt.

PROBLEM II.

To find the difference of longitude between any two places.

If the pupil underſtands what is meant by the difference of longitude, the rule for the ſolution of this problem will naturally occur to his mind. Now the difference of longitude between any two places is the quantity of an angle (at the pole) made by the meridians of thoſe places meaſured on the equator. To expreſs this angle upon the globe, bring the moveable meridian to one of the places, and the other place under the ſtrong braſs circle, and the required angle is contained between theſe two meridians, the meaſure or quantity of which is to be counted on the equator.

Example. I find the longitude of Rome to be $12\frac{1}{2}$ eaſt, that of Conſtantinople to be 29, the difference is $17\frac{1}{2}$ degrees. Again, I find Jeruſalem has 35 deg. 25 min. eaſt longitude from London; and Pekin, in China, 116 deg. 52 min. eaſt longitude, the difference is 81 deg. 27 min.; that is, Pekin is 81 deg. 27 min. eaſt longitude from Jeruſalem; or Jeruſalem is 81 deg. 27 min. weſt longitude from Pekin.

If one place is eaſt, and the other weſt of the firſt meridian, either find the longitude of both places weſtward, by that ſet of numbers which increaſe weſtward from the meridian of London to 360 deg. and the difference between the number thus found is the anſwer to the queſtion :—or,

Add the eaſt and weſt longitudes, and the ſum is the difference of longitude ; thus the longitude of Rome is 12 deg. 30 min. eaſt, of Charles-Town 79 deg. 50 min. weſt ; their ſum, 91 deg. 20 min. is the difference required.

It may be proper to obſerve here, that the difference in time is the ſame with the difference of longitude, conſequently that ſome of the following problems are only particular caſes of this problem, or readier modes of computing this difference.

PROBLEM III.

To find all thofe places where it is noon, at any given hour of the day, in another place; or in other words, (which may conduct the reader to the rationale of it's folution) to find what places have the fun upon their meridian, at any given hour of the day, in another propofed place.

As the diurnal motion of the earth, here reprefented by the terreftrial globe, is from weft to eaft, it is plain that all places which are to the eaft of any particular meridian, muft neceffarily pafs by the fun, before a meridian which is to the weft of them can arrive at it.

We fhall, therefore, divide this problem into three cafes.

1. When the given hour is at London.

2. When the given hour is in the morning, and any where but at London.

3. When the given hour is in the afternoon, but not at London.

1. When the given hour is at London.

As the firſt meridian on our globes paſſes through London, bring the given hour to the eaſt of London, if it be in the morning, to the ſtrong braſs meridian, and all thoſe places which are under it will have noon at the given hour; but bring the given hour weſt of London, if it is in the afternoon.

Example. Let it be required to know in what places it is XII o'clock, when it is ten in the morning at London. Therefore, bring that Xth hour on the equator, which is to the eaſtward of London, under the ſtrong braſs meridian, and the places that are under it's graduated edge will have the ſun upon their meridian when it is ten in the morning at London. Suppoſe the given hour at London to be three o'clock, then bring that hour on the equator which is weſtward of London, to the ſtrong braſs meridian, and thoſe places which lie under it will be noon when it is three in the afternoon at London.

2. If the given hour be in the afternoon, but not at London.

Bring

Bring the given place to the ſtrong braſs meridian, and ſet one of the hour indexes to that XII which is moſt elevated; then turn the globe from WEST TO EAST, till the index points to the given hour, and the ſtrong braſs meridian will paſs over thoſe places which have noon at the given hour in the propoſed place.

Let the hour propoſed be IV o'clock in the afternoon, at Port-Royal, in Jamaica. Bring Port-Royal to the ſtrong braſs meridian, and ſet the hour index to the moſt elevated XII; turn the globe from weſt to eaſt, until the horary index points to IV o'clock, and the ſtrong braſs meridian will paſs over thoſe places which have noon at the given hour in Jamaica.

3. IF THE GIVEN HOUR BE IN THE MORNING, BUT NOT AT LONDON.

Bring the given place to the ſtrong braſs meridian; ſet the hour index to the uppermoſt XII, and turn the globe from EAST TO WEST, until the hour index points to the given hour; then the required places are under the ſtrong braſs meridian. Let the given hour be 30 min. paſt V at Cape Paſaro, in the iſland of Sicily: bring Paſaro to the meridian, ſet the hour index

to

to the moſt elevated XII, then move the globe weſtward, till the hour index points to 30 min. paſt V, and the places under the ſtrong braſs meridian will have noon when it is 30 min. paſt V in the afternoon at Paſaro, in Sicily.

PROBLEM IV.

When it is noon at any place, to find what hour of the day it is at any other place.

Rule. Bring the place at which it is noon, to the ſtrong braſs meridian, and ſet the hour index to the uppermoſt XII, and then turn the globe about till the other place comes under the ſtrong braſs meridian, and the hour index will ſhew upon the equator the required hour.

If to the eaſtward of the place where it is noon, the hour found will be in the afternoon; if to the weſtward, it will be in the forenoon.

Thus when it is noon at London, it is 50 min. paſt XII at Rome; 32 min. paſt VII in the evening at Canton, in China; 15 min. paſt VII in the morning at Quebec, in Canada.

PROBLEM V.

At any given hour in the place where you are, to find the hour at any place propofed; or in other words, the hour where you are being given, to tell what hour it is in any other part of the world.

Rule. Bring the propofed place under the ftrong brafs meridian, fet the hour index to the given time, then turn the globe, till the place where you are is under the brafs meridian, and the horary index will point to the hour required.

Thus fuppofe we are at London at IX o'clock in the morning, what is the time at Canton, in China? Anfwer, 31 min. paft IV in the afternoon. When it is IX in the evening at London, it is about 15 min. paft IV in the afternoon at Quebec, in Canada.

Of Latitude.

We have already obferved, that the equator divides the globe into two hemifpheres, the northern and the fouthern.

The latitude of a place is it's diſtance from the equator towards the north or ſouth pole, meaſured by degrees upon the meridian of the place.

All places, therefore, that lie under the equator, are ſaid to have NO LATITUDE.

All other places upon the earth are ſaid to be in north or ſouth latitude, as they are ſituated on the north or ſouth ſide of the equator; and the latitude of any place will be greater or leſs, according as it is further from, or nearer to the equator.

Lines which keep always at the ſame diſtance from each other, are called PARALLELS.

If a circle, or circular line, be conceived keeping at the ſame diſtance from the equator, it will be a parallel to the equator.

Circles of this kind are commonly drawn on the terreſtrial, on both ſides of the equator.

A circle of this kind at 10 degrees from the equator, is called a parallel of 10 degrees.

When

When any ſuch parallel paſſes through two places on the globe's ſurface, thoſe two places have the ſame latitude.

Hence parallels to the equator are called PARALLELS OF LATITUDE.

There are four principal leſſer circles parallel to the equator, which divide the globe into five unequal parts, called ZONES.

The circle on the north ſide of the equator is called the TROPIC OF CANCER; it juſt touches the north part of the ecliptic, and ſhews the path the ſun appears to deſcribe, the longeſt day in ſummer.

That which is on the ſouth ſide of the equator, is called the TROPIC OF CAPRICORN; it juſt touches the ſouth part of the ecliptic, and ſhews the path the ſun appears to deſcribe, the ſhorteſt day in winter.

The ſpace between theſe two tropics, which contains about 47 degrees, was called by the ancients, the TORRID ZONE.

The

The two polar circles are placed at the ſame diſtance from the poles, that the two tropics are from the equator.

One of theſe is called the NORTHERN, the other the SOUTHERN POLAR CIRCLE.

Theſe include 23½ degrees on each ſide of their reſpective poles, and conſequently contain 47 degrees, equal to the number of degrees included between the tropics.

The ſpace contained within the northern polar circle, was by the ancients called the NORTH FRIGID ZONE; and that within the ſouthern polar circle, the SOUTH FRIGID ZONE.

The ſpaces between either polar circle, and it's neareſt tropic, which contain about 43 degrees each, were called by the ancients the TWO TEMPERATE ZONES.

PROBLEM VI.

To find the latitude of any place.

If the pupil comprehends the foregoing definition, he will find no difficulty in the ſolution of this and ſome of the following problems.

Rule. Bring the place to the graduated ſide of the ſtrong braſs meridian, and the degree which is over it is it's latitude. Thus London will be found to have 51 deg. 32 min. north latitude; Conſtantinople 41 deg. north latitude; and the Cape of Good Hope 34 deg. ſouth latitude.

PROBLEM VII.

To find all thoſe places which have the ſame latitude with any given place.

Suppoſe the given place to be London; turn the globe round, and all thoſe places which paſs under the ſame point of the ſtrong braſs meridian, are in the ſame latitude.

PROBLEM VIII.

To find the difference of latitude between two places.

Rule. If the places be in the ſame hemiſphere, bring each of them to the meridian, and ſubtract the latitude of one from the other. If they are in different hemiſpheres, add the latitude of one to that of the other.

Example. The latitude of London is 51 deg. 32 min.; that of Conſtantinople 41 deg.; their difference is 10 deg. 32 min. Of the difference between London, 51 deg. 32 min. north, and the Cape of Good Hope, 34 deg. ſouth, is 84 deg. 32 min.

PROBLEM IX.

The latitude and longitude of any place being known, to find that place upon the globe; or if the place be not inſerted on the globe, to find where it ought to be placed, and fix the center of the artificial horizon thereto.

Rule. Seek for the given longitude in the equator, and bring the moveable meridian to that point;

point; then count from the equator on the meridian, the degree of latitude either towards the north or ſouth pole, and bring the artificial horizon to that degree, and the interſection of it's edge with the meridian, is the ſituation required.

Example. The latitude of Smyrna, in Aſia, is 38 deg. 28 min. north; it's longitude 27 deg. 30 min. eaſt of London; therefore, bring 27 deg. 30 min. counted eaſtward on the equator, to the moveable meridian, and ſlide the diameter of the artificial horizon to 38 deg. 28 min. north latitude, and it's center will be correctly placed over Smyrna.

It may be proper in this place juſt to ſhew the pupil, that THE LATITUDE OF ANY PLACE IS ALWAYS EQUAL TO THE ELEVATION OF THE POLE OF THE SAME PLACE ABOVE THE HORIZON. The reaſon of this is, that from the equator to the pole is 90 degrees, from the zenith to the horizon is alſo 90 degrees; the diſtance of the zenith to the pole is common to both, and therefore if taken away from both, muſt leave equal remains; that is, the diſtance from the equator to the zenith, which is the latitude, is equal to the elevation of the pole.

As the finding the longitude of places forms one of the moſt important problems in geography and aſtronomy, ſome further account of it, it is preſumed, will prove entertaining and uſeful to the reader.

" For what can be more intereſting to a perſon in a long voyage, than to be able to tell upon what part of the globe he is, to know how far he has travelled, what diſtance he has to go, and how he muſt direct his courſe to arrive at the place he deſigns to viſit; theſe important particulars are all determined by knowing the latitude and longitude of the place under conſideration. When the diſcovery of the compaſs invited the voyager to quit his native ſhore, and venture himſelf upon an unknown ocean, that knowledge which before he deemed of no importance, now became a matter of abſolute neceſſity. Floating in a frail veſſel, upon an uncertain abyſs, he has conſigned himſelf to the mercy of the winds and waves, and knows not where he is." *

The following inſtance will prove of what uſe it is to know the longitude of places at ſea. The editor of Lord Anſon's voyage, ſpeaking of the iſland

* Bonnycaſtle's Aſtronomy.

iſland of Juan Fernandez, adds, "The uncertainty we were in of it's poſition, and our ſtanding in for the main on the 28th of May, in order to ſecure a ſufficient eaſting, when we were indeed extremely near it, coſt us the lives of between 70 and 80 of our men, by our longer continuance at ſea; from which fatal accident, we might have been exempted, had we been furniſhed with ſuch an account of it's ſituation, as we could fully have depended on."

The latitude of a place the ſailor can eaſily diſcover; but the longitude is a ſubject of the utmoſt difficulty, for the diſcovery of which many methods have been deviſed. It is indeed of ſo great conſequence, that the parliament of Great Britain propoſed a reward of 10,000 *l.* if it extended only to 1 degree of a great circle, or 60 geographical miles; 15,000*l.* if found to 40 ſuch miles; and 20,000*l.* to the perſon that can find it within 30 minutes of a great circle, or 30 geographical miles.

We cannot enter fully into this ſubject in theſe eſſays; it will, I hope, be deemed ſufficient, if we give ſuch an account as will enable the reader to form a general idea of the ſolution of this important problem.

From what has been ſeen in the preceding pages, it is evident that 15 degrees in longitude anſwer to one hour in time, and conſequently that the longitude of any place would be known, if we knew their difference in time; or in other words, how much ſooner the ſun, &c. arrives at the meridian of one place, than that of another. The hours and degrees being in this reſpect commenſurate, it is as proper to expreſs the diſtance of any place in time, as in degrees.

Now it is clear, that this difference in time would be eaſily aſcertained by the obſervation of any inſtantaneous appearance in the heavens, at two diſtant places; for the difference in time at which the ſame phænomenon is obſerved, will be the diſtance of the two places from each other in longitude; on this principle, moſt of the methods in general uſe are founded.

Thus if a clock, or watch, was ſo contrived, as to go uniformly in all ſeaſons, and in all places; ſuch a watch being regulated to London time, would always ſhew the time of the day at London; then the time of the day under any other meridian being found, the difference between that time, and the correſponding London time, would give the difference in longitude.

For

For ſuppoſing any perſon poſſeſſed of one of theſe time-pieces, to ſet out on a journey from London, if his time-piece be accurately adjuſted, wherever he is, he will always know the hour at London exactly; and when he has proceeded ſo far either eaſtward or weſtward, that a difference is perceived betwixt the hour ſhewn by his time-piece, and thoſe of the clocks and watches at the places to which he goes, the diſtance of thoſe places from London in longitude will be known. But to whatever degree of perfection ſuch movements may be made, yet as every mechanical inſtrument is liable to be injured by various accidents, other methods are obliged to be uſed, as the eclipſes of the ſun and moon, or of Jupiter's ſatellites. Thus ſuppoſing the moment of the beginning of an eclipſe was at ten o'clock at night at London, and by accounts from two obſervers in two other places, it appears that it began with one of them at nine o'clock, and with the other at midnight; it is plain, that the place where it began at nine is one hour, or 15 degrees eaſt in longitude from London; the other place where it began at midnight, is 30 degrees diſtant in weſt longitude from London. Eclipſes of the ſun and moon do not, however, happen often enough to anſwer the purpoſes of navigation;

and the motion of a ſhip at ſea prevents the obſervations of thoſe of Jupiter's ſatellites.

If the place of any celeſtial body be computed, for example, as in an almanack, for every day, or to parts of days, to any given meridian; and the place of this celeſtial body can be found by obſervation at ſea, the difference of time between the time of obſervation and the computed time, will be the difference of longitude in time. The moon is found to be the moſt proper celeſtial object, and the obſervations of her appulſes to any fixed ſtar is reckoned one of the beſt methods for reſolving this difficult problem.

Length of the Degrees of Longitude.

Suppoſing the earth to be a perfect globe, the length of a degree upon the meridian has been eſtimated to be 69,1 miles; but as the earth is an oblate ſpheroid, the length of a degree on the equator will be ſomewhat greater.

Whether the earth be conſidered as a ſpheroid or a globe, all the meridians interſect one another at the poles. Therefore, the number of miles in a degree muſt always decreaſe as you go north or ſouth from the equator. This is evident by in-

ſpection

ſpection of a globe, where the parallels of latitude are found to be ſmaller in proportion as they are nearer the pole.

The following TABLE ſhews how many geographical miles, and decimal parts of a mile, would be contained in a degree of longitude, at each degree of latitude from the equator to the poles, if the earth was a perfect ſphere, and the circumference of it's equinoctial line 360 degrees, and each degree 60 geographical miles.

This table enables us to determine the velocity with which places upon the globe revolve eaſtward; for the velocity is different, according to the diſtance of the places from the equator, being ſwifteſt as paſſing through a greater ſpace, and ſo by degrees ſlower towards the poles, as paſſing through a leſs ſpace in the ſame time. Now as every part of the earth is moved through the ſpace of it's circumference, or 360 degrees in 24 hours; the ſpace deſcribed in one hour is found by dividing 360 by 24, which gives in the quotient 15 degrees; and ſo many degrees does every place on the earth move in an hour. The number of miles contained in ſo many degrees in any latitude, is readily found from the table.

Thus under the equator places revolve at the rate of more than 1000 miles in an hour; at London, at the rate of about 640 miles in an hour.

TABLE

T A B L E.

LAT. Deg.	Miles.	LAT. Deg.	Miles.	LAT. Deg.	Miles.
00	60,00	31	51,43	62	28,17
1	59,99	32	50,88	63	27,24
2	59,96	33	50,32	64	26,30
3	59,92	34	49,74	65	25,36
4	59,86	35	49,15	66	24,41
5	59,77	36	48,54	67	23,45
6	59,67	37	47,92	68	22,48
7	59,56	38	47,28	69	21,50
8	59,42	39	46,62	70	20,52
9	59,26	40	45,95	71	19,54
10	59,08	41	45,28	72	18,55
11	58,89	42	44,59	73	17,54
12	58,68	43	43,88	74	16,53
13	58,46	44	43,16	75	15,52
14	58,22	45	42,43	76	14,51
15	57,95	46	41,68	77	13,50
16	57,67	47	40,92	78	12,47
17	57,37	48	40,15	79	11,45
18	57,06	49	39,36	80	10,42
19	56,73	50	38,57	81	9,38
20	56,38	51	37,76	82	8,35
21	56,01	52	36,94	83	7,32
22	55,63	53	36,11	84	6,28
23	55,23	54	35,26	85	5,23
24	54,81	55	34,41	86	4,18
25	54,38	56	33,55	87	3,14
26	53,93	57	32,68	88	2,09
27	53,46	58	31,79	89	1,05
28	52,97	59	30,90	90	0,00
29	52,47	60	30,00		
30	51,96	61	29,09		

Another

Another circumſtance which ariſes from this difference of meridians in time, muſt detain us a little before we quit this ſubject. For from this difference it follows, that if a ſhip ſails round the world, always directing her courſe eaſtward, ſhe will at her return home find ſhe has gained one whole day of thoſe that ſtayed at home; that is, if they reckon it May 1, the ſhip's company will reckon it May 2; if weſtward, a day leſs, or April 30.

This circumſtance has been taken notice of by navigators. "It was during our ſtay at Mindanao (ſays Capt. Dampier) that we were firſt made ſenſible of the change of time in the courſe of our voyage: for having travelled ſo far weſtward, keeping the ſame courſe with the ſun, we conſequently have gained ſomething inſenſibly in the length of the particular days, but have loſt in the tale the bulk or number of the days or hours.

"According to the different longitudes of England and Mindanao, this iſle being about 210 degrees weſt from the Lizard, the difference of time at our arrival at Mindanao, ought to have been about fourteen hours; and ſo much we ſhould have anticipated our reckoning, having gained it by bearing the ſun company.

"Now

" Now the natural day in every place muſt be conſonant to itſelf; but going about with, or againſt the ſun's courſe, will of neceſſity make a difference in the calculation of the civil day, between any two places. Accordingly, at Mindanao, and other places in the Eaſt Indies, we found both natives and Europeans reckoning a day before us. For the Europeans coming eaſtward, by the Cape of Good Hope, in a courſe contrary to the ſun and us, wherever we met, were a full day before us in their accounts.

" So among the Indian Mahometans, their Friday was Thurſday with us; though it was Friday alſo with thoſe that came eaſtward from Europe.

" Yet at the Ladrone iſlands we found the Spaniards of Guam keeping the ſame computation with ourſelves; the reaſon of which I take to be, that they ſettled that colony by a courſe weſtward from Spain; the Spaniards going firſt to America, and thence to the Ladrone iſlands."

It is clear, from what has been ſaid in the firſt part of this article, concerning both latitude and longitude, that if a perſon travel ever ſo far directly towards eaſt or weſt, his latitude would be

always

always the ſame, though his longitude would be continually changing.

But if he went directly north or ſouth, his longitude would continue the ſame, but his latitude would be perpetually varying.

If he went obliquely, he would change both his latitude and longitude.

The longitude and latitude of places give only their relative diſtances on the globe; to diſcover, therefore, their real diſtance, we have recourſe to the following problem.

PROBLEM X.

Any place being given, to find the diſtance of that place from another, in a great circle of the earth.

We ſhall divide this problem into three caſes.

Caſe 1. If the places lie under the ſame meridian. Bring them up to the meridian, and mark the number of degrees intercepted between them. Multiply the number of degrees thus found by 60, and they will give the number of geogra-

geographical miles between the two places. But if we would have the number of Engliſh miles, the degree before found muſt be multiplied by $69\frac{1}{2}$.

Caſe 2. If the places lie under the equator. Find their difference of longitude in degrees, and multiply as in the preceding caſe, by 60, or $69\frac{1}{2}$.

Caſe 3. If the places lie neither under the ſame meridian, nor under the equator. Then lay the quadrant of altitude over the two places, and mark the number of degrees intercepted between them. Theſe degrees multiplied as above-mentioned, will give the required diſtance.

A PARALLEL SPHERE is that poſition of the globe, in which the poles are in their zenith and nadir, it's axis at right angles to the equator and horizon, which coincide; conſequently, thoſe circles which are parallel to the equator, are alſo parallel to the horizon.

The inhabitants that anſwer to this poſition of the ſphere, if any there be, muſt live upon the two terreſtrial poles, and will have but one day and one night throughout the year, each ſix months

months long. The day, to thofe who live under the north pole, begins when the fun enters Aries, and continues till he reaches Libra, when night commences, and continues the other fix months. Thofe who live under the fouth pole, experience the direct contrary; but both enjoy a long continuance of twilight, after the fun has departed from them, and before he appears again.

For half a year, the inhabitants of the pole fee the fun moving continually round above their horizon, in a kind of fpiral line; when they firft perceive him, he fkims, as it were, their horizon, then rifes gradually higher, till he reaches the tropic, when he again defcends, till he touches the horizon, when their long and gloomy night begins.

During their fummer's day, the moon appears to them in the heavens only as a white cloud; in the winter, during her fecond and third quarters, fhe circulates above the horizon for feveral days, without fetting, being a fortnight above, and a fortnight below the horizon.

They can only fee the ftars in that hemifphere between the pole and the equator; during half a year, none of them are vifible, being fwallowed

up,

up, as it were, by the ſuperior light of the ſun. To them the ſtars never ſet, but move in circles parallel to the horizon, keeping always the ſame altitude. The planets are half their time above, and half below the horizon.

A RIGHT SPHERE is that in which the equator is at right angles to the horizon, and therefore in the zenith and nadir, and in which the poles are in the horizon.

The inhabitants that anſwer to this ſituation of the ſphere, live under the equator; their days and nights are of an equal length throughout the year, being each of them twelve hours in length.

The ſun riſes and ſets nearly perpendicular; he is half a year on one ſide their zenith, and as much on the other, paſſing over it twice a year at the equinoxes.

There is nothing uncommon in the appearance of the moon, but her riſing and ſetting like the ſun, nearly in a perpendicular direction; but there is to theſe inhabitants a moſt glorious diſplay of all the ſtars in the heavens, from pole to pole, all of them riſing and ſetting perpendicular, except the poles which lie in the horizon.

An OBLIQUE SPHERE is the poſition common to all the inhabitants of the earth, except thoſe who live at the poles, and upon the equator; it is thus named, becauſe the equator cuts the horizon obliquely.

In this ſphere the axis of the earth always makes an acute angle with the horizon; the equator is half above and half below it.

All the parallels to the equator cut the horizon alſo obliquely, and thus make the diurnal arches greater or leſs than the nocturnal ones, excepting at the time of the equinoxes.

Thoſe inhabitants of this ſphere, who live without the tropics, never have the ſun in their zenith; but under the tropics the ſun is vertical once, and between the tropics and the equator twice every year.

In this poſition the ſtars riſe and ſet obliquely; and as the moon, when at full, is always in an oppoſite ſign to the ſun, ſhe is on the ſouth ſide of the equator in ſummer, and conſequently her altitude is low, and her courſe ſhort; but in winter, when at the full, ſhe is in the northern ſigns,

ſigns, making a high long circuit, which is of great uſe in that dreary ſeaſon.

OF THE DIURNAL MOTION OF THE EARTH.

As the daily motion of the earth about it's axis, and the phænomena dependent on it, are ſome of the moſt eſſential points which a beginner ought to have in view, we ſhall now endeavour to explain it by the globes; and here, I think, the advantage of globes mounted in my father's manner, over thoſe generally uſed, will be very evident.

We have already obſerved, that in globes mounted in our manner, the motion of the terreſtrial globe about it's axis repreſents the diurnal motion of the earth, and that the horary index will point out upon the equator the 24 hours of one diurnal rotation, or any part of that time.

We ſhall now conſider the broad paper circle as the plane which diſtinguiſhes light from darkneſs; that is, the enlightened half of the earth's ſurface, from that which is not enlightened.

For when the ſun ſhines upon a globe, he ſhines only upon one half of it; that is, one half of the globe's ſurface is enlightened by him, the other not.

That the enlightened half may be that half which is above the broad paper circle, we muſt imagine the ſun to be in our ZENITH.

Or let a ſun be painted on the ceiling over the terreſtrial globe, the diameter of the picture equal to the diameter of the globe.

Then all thoſe places that are above the broad paper circle, will be in the ſun's light; that is, it will be DAY in all thoſe places.

And all places that are below this circle, will be out of the ſun's light; that is, in all thoſe places it will be NIGHT.

When any place on the earth's ſurface comes to the edge of the broad paper circle, paſſing out of the ſhade into the light, the ſun will appear RISING at that place.

And

And when a place is at the edge of the broad paper circle, going out of the light into the ſhade, the ſun will appear at that place to be SETTING.

When we view the globe in this poſition, we at once ſee the ſituation of all places in the illuminated hemiſphere, whoſe inhabitants enjoy the light of the day. One edge of the broad paper circle ſhews at what place the ſun appears riſing at the SAME time. And the oppoſite edge ſhews at what places the ſun is ſetting at the ſame time.

The horary index ſhews how long a place is moving from one edge to the other; that is, how long the day or night is at that place.

TO RECTIFY THE TERRESTRIAL GLOBE.

To rectify the terreſtrial globe, is to place it in the ſame poſition in which our earth ſtands to the ſun, at all or any given times.

That half of the earth's ſurface, which is enlightened by the ſun, is not always the ſame; it differs according as the ſun's declination differs.

To rectify then the terreſtrial globe, is to bring it into ſuch a poſition, as that the enlightened half of the earth's ſurface may be all above the broad paper circle.

On the back ſide of the ſtrong braſs meridian, and on each ſide of the north pole, the months and days of the month, are graduated in two concentric ſpaces, agreeable to the declination of the ſun.

Bring the day of the month that is graduated, on the back ſide of the ſtrong braſs meridian, to coincide with the broad paper circle, and the globe is rectified.

Thus ſet the firſt of May to coincide with the broad paper circle, and that half of the earth's ſurface which is enlightened at any time upon that day, will be all at once above the ſaid circle.

If the horary index be ſet to XII when any particular place is brought under the ſtrong braſs meridian, it will ſhew the precise time of ſun-riſing and ſun-ſetting at that place.

It

It will alſo ſhew how long any place is in moving from the eaſt to the weſt ſide of the illuminated diſc, and thence the length of the day and night.

It will alſo point out the length of the twilight, by ſhewing the time in which the place is paſſing from the twilight circle to the edge of the broad paper circle on the weſtern ſide; or from the edge of this circle on the eaſtern ſide, to the twilight wire, and thus determine the length of the whole artificial day.

N. B. The twilight wire is placed at 18 degrees from the broad paper circle.

We ſhall now proceed to exemplify upon the globes theſe particulars, at three different ſeaſons of the year, viz. the ſummer ſolſtice, the winter ſolſtice, and the time or times of the equinoxes.

PROBLEM XI.

To place the globe in the ſame ſituation, with reſpect to the ſun, as our earth is in at the time of the ſummer ſolſtice.

Rectify the globe to the extremity of the diviſions for the month of June, or $23\frac{1}{2}$ degrees north declination; that is, bring theſe diviſions on the ſtrong braſs meridian to coincide with the plane of the broad paper circle.

Then that part of the earth's ſurface, which is within the northern polar circle, will be above the broad paper circle, and will be in the light, and the inhabitants thereof will have no night.

But all that ſpace which is contained within the ſouthern polar circle, will continue in the ſhade; that is, it will there be continual night.

In this poſition of the globe, the pupil will obſerve how much the diurnal arches of the parallels of latitude decreaſe, as they are more and more diſtant from the elevated pole.

If any place be brought under the ſtrong braſs meridian, and the horary index is ſet to that XII which

which is moſt elevated, and the place be afterwards brought to the weſtern ſide of the broad paper circle, the hour index will ſhew the time of ſun-riſing; and when the place is moved to the eaſtern edge, the index points to the time of ſun-ſetting.

The length of the day is obtained by the time ſhewn by the horary index, while the globe moves from the weſt to the eaſt ſide of the broad paper circle.

Thus it will be found, that at London the ſun riſes about 15 minutes before IV in the morning, and ſets about 15 minutes after VIII at night.

At the following places, it will be nearly at the times expreſſed in the table.

	☉ Riſing.		☉ Setting		Length of day.		Twilight.	
	h.	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*
Cape Horn - -	8	44	3	16	6	32	2	35
Cape of Good Hope	7	9	4	51	9	42	1	43
Rio de Janeiro, in Brazil	6	42	5	19	10	38	1	23
Iſland of St. Thomas, near the equator -	6		6		12		1	20
Cape Lucas, California	5	12	6	48	13	36	1	35

We alſo ſee, that at the ſame time the ſun is riſing at London, it is riſing at the iſles of Sicily and Madegaſcar.

And, that at the time when the ſun ſets at London, it is ſetting at the iſland of Madeira, and at Cape Horn.

And when the ſun is ſetting at the iſland of Borneo, in the Eaſt Indies, it is riſing at Florida, in America, and many other ſimilar circumſtances relative to other places, are ſeen as it were by inſpection.

PROBLEM XII.

To explain the ſituation of the earth, with reſpect to the ſun, at the time of the winter ſolſtice.

Rectify the globe to the extremity of the diviſions for the month of December, or to $23\frac{1}{2}$ degrees ſouth declination.

When it will be apparent that the whole ſpace within the ſouthern polar circle is in the ſun's light, and enjoys continual day; whilſt that of the northern polar circle is in the ſhade, and has continual night.

If

If the globe be turned round, as before, the horary index will ſhew, that at the ſeveral places before-mentioned their days will be reſpectively equal to what their nights were at the time of the ſummer ſolſtice.

It will appear farther, that it is now ſun-ſetting at the ſame time in thoſe places, in which it was ſun-riſing at the ſame time at the ſummer ſolſtice. And on the contrary, ſun-riſing at the time it then appeared to ſet.

PROBLEM XIII.

To place the globe in the ſituation of the earth, at the times of the equinox.

The ſun has no declination at the times of the equinox, conſequently there muſt be no elevation of the pole.

Bring the day of the month when the ſun enters the firſt point of Aries, or day of the month when the ſun enters the firſt point of Libra, to the plane of the broad paper circle; then the two poles of the globe will be in that plane alſo, and the globe will be in the poſition which is called a RIGHT SPHERE.

For

For it is a right ſphere when the two poles are in the plane of the broad paper circle, becauſe then all thoſe circles which are parallel to the equator will be at right angles to that plane.

If the globe be now turned from weſt to eaſt, it will plainly appear, that all places upon it's ſurface are twelve hours above the broad paper circle, and twelve hours below it; that is, the days are twelve hours long all over the earth, and that the nights are equal to the days, whence theſe times are called the times of equinox.

Two of theſe occur in every year; the firſt in the autumnal, the ſecond the vernal equinox.

At theſe ſeaſons the ſun appears to riſe at the ſame time to all places that are on the ſame meridian. The ſun ſets alſo at the ſame time in all thoſe places.

Thus if London and Mundford, on the gold coaſt, be brought to the ſtrong braſs meridian, the graduated ſide of which is in this caſe the horary index, and they be afterwards carried to the weſtern edge of the broad paper circle, the index will ſhew that the ſun riſes at VI at both places;

places; when they are carried to the eaſtern edge, the index points to VI for the time of ſun-ſetting.

N. B. If London be not the given place, the hour index is to be ſet to the moſt elevated XII, while the place is under the graduated edge of the ſtrong braſs meridian.

Of the Artificial, or Terrestrial Horizon.

The braſs circle, which may be ſlipped from pole to pole on the moveable meridian, has been already deſcribed, page 257. The circumference of it is divided into eight parts, to which are affixed the initial letters of the mariner's compaſs.

When the center of it is ſet to any particular place, the ſituation of any other place is ſeen, with reſpect to that place; that is, whether they be eaſt, weſt, north, or ſouth of it.

It will, therefore, repreſent the horizon of that place.

We ſhall here uſe this artificial horizon, to ſhew why the ſun, although he be always in one and the ſame place, appears to the inhabitants of the

the earth at different altitudes, and in different azimuths.

PROBLEM XIV.

To exemplify the ſun's altitude, as obſerved with an artificial horizon.

The altitude of the ſun is greater or leſs, according as the line which goes from us to the ſun is nearer to, or farther off from our horizon.

Let the moveable circle be applied to any place, as London, then will the horizon of London be thereby repreſented.

The ſun is ſuppoſed, as before, to be in the zenith, that is, directly over the terreſtrial globe.

If then from London a line go vertically upwards, the ſun will be ſeen at London in that line.

At ſun-riſing, when London is brought to the weſt edge of the broad paper circle, the ſuppoſed line will be parallel to the artificial horizon, and the ſun will then be ſeen in the horizon.

As

As the globe is gradually turned from the weſt towards the eaſt, the horizon will recede from that line which goes from London vertically upwards; ſo that the line in which the ſun is ſeen, gets further and further from the horizon, that is, the ſun's altitude increaſes gradually.

When the horizon, and the line which goes from London vertically upwards, are arrived at the ſtrong braſs meridian, the ſun is then at his greateſt or meridian altitude for that day, and the line and horizon are at the largeſt angle they can make with each other.

After this, the motion of the globe being continued, the angle between the artificial horizon, and the line which goes from London vertically upwards, continually decreaſes, until London arrives at the eaſtern edge of the broad paper circle; it's horizon then becomes vertical again, and parallel to the line which goes vertically upwards. The ſun will again appear in the horizon, and will ſet.

PROBLEM XV.

Of the ſun's meridian altitude, at the three different ſeaſons.

Rectify the globe to the time of the winter ſolſtice, by problem xii. and place the center of the viſible horizon on London.

When London is at the graduated edge of the ſtrong braſs meridian, the line which goes vertically upwards makes an angle of about 15 degrees; this is the ſun's meridian altitude at that ſeaſon, to the inhabitants of London.

If the globe be rectified to the times of equinox, by problem xii. the horizon will be farther ſeparated from the line which goes vertically upwards, and makes a greater angle therewith, it being about 38½ degrees; this is the ſun's meridian altitude, at the time of equinox at London.

Again, rectify to the ſummer ſolſtice by prob. xi. and you will find the artificial horizon recede farther from the line which goes from London vertically upwards, and the angle it then makes is about 62 degrees, which ſhews the ſun's meridian altitude at the time of the ſummer ſolſtice.

Hence

Hence flows alſo the following arithmetical problem.

PROBLEM XVI.

To find the ſun's meridian altitude univerſally.

Add the ſun's declination to the elevation of the equator, if the latitude of the place, and the declination of the ſun are both on the ſame ſide.

If on contrary ſides, ſubtract the declination from the elevation of the equator, and you obtain the ſun's meridian altitude.

Thus the elevation of the equator at London is -	38°	28
The ſun's declination on the 20th of May	20	8
Their ſum, the ſun's meridian altitude that day - -	58	36

Again,

Again, to the elevation of the equator at London —	38° 28
Add the ſun's greateſt declination at the time of the ſummer ſolſtice -	23 29
The ſum is the ſun's greateſt meridian altitude at London —	61 57

PROBLEM XVII.

Of the ſun's azimuths, as compared with the artificial horizon.

The artificial horizon ſerves alſo to determine the ſun's azimuths.

An AZIMUTH of the ſun is denominated from that point of the horizon, to which the ſun, or a line going to the ſun, is neareſt.

Thus if the ſun, or a line going to the ſun, be neareſt the ſouth-eaſt point of the horizon, which point is 45 degrees diſtant from the meridian, the ſun's azimuth is an azimuth of 45 degrees, and the ſun will appear in the ſouth-eaſt.

Imagine

Imagine the ſun, as we have done before, to be placed directly over the globe.

In which caſe, a line going to the ſun from any place on the ſurface of the globe, will have a vertical direction, and will go from that place vertically upwards.

If then we apply the artificial horizon to any place, the point of this horizon to which a ver-line is neareſt, ſhews the ſun's azimuth at that time.

It is obſervable, that the point of the horizon to which ſuch a vertical line is neareſt, will be at all times that point which is moſt elevated.

To exemplify this, let the globe be in the poſition of a right ſphere, and let the artificial horizon be applied to London.

When London is at the weſtern edge of the broad paper circle, which ſituation repreſents the time when the ſun appears to riſe, the eaſtern point of the artificial horizon being then moſt elevated, ſhews that the ſun at his riſing is due eaſt.

Turn the globe, till London comes to the eaſtern edge of the broad paper circle, then the weſtern point of the artificial horizon will be moſt elevated, ſhewing that the ſun ſets due weſt.

Now place the globe in the poſition of an oblique ſphere; and if London be brought to the eaſtern or weſtern ſide of the broad paper circle, the vertical line will depart more or leſs from the eaſt and weſt points, in which caſe the ſun is ſaid to have more or leſs AMPLITUDE.

If the departure be northward, it is called northern amplitude; if ſouthward, it is called ſouthern amplitude.

In whatever poſition the globe be placed,* when London comes to the ſtrong braſs meridian, the moſt elevated part of the artificial horizon will be the ſouth point of it.

Which ſhews that at noon the ſun will always, and in all ſeaſons, appear in the ſouth.

* The globe is not ſuppoſed in this caſe, or under this view of things, ever to be elevated above the limits of the ſun's declination.

PROBLEM XVIII.

To illuſtrate the ancient diſtinction of different places on the earth, according to the diverſity of the ſhadows of upright bodies at noon.

When the ſun at noon is in the zenith of any place, the inhabitants of that place were by the ancients called ASCII; that is, without ſhadow: for the ſhadow of a man ſtanding upright, when the ſun is directly over his head, is not extended beyond that part of the earth which is directly under his body, and therefore will not be viſible.

As the ſhadow of every opake body is extended from the ſun, it follows, that when the ſun at noon is ſouthward from the zenith of any place, the ſhadow of an inhabitant of that place, and indeed of every other opake body, is extended towards the north.

But when the ſun is northward from the zenith of any place, the ſhadow falls towards the ſouth.

Thoſe are called AMPHISCII, that have both kinds of meridian ſhadows.

Thoſe whoſe meridian ſhadows are always projected one way, are termed HETEROSCII.

Rectify the globe to the ſummer ſolſtice, and move the artificial horizon to the equator, the north point will be the moſt elevated at noon.

Which ſhews, that to thoſe inhabitants who live at the equator, the ſun will at this ſeaſon appear to the north at noon, and their ſhadow will therefore be projected ſouthwards.

But if you rectify the globe to the winter ſolſtice, the ſouth point being then the uppermoſt point at noon, the ſame perſons will at noon have the ſun on the ſouth ſide of them, and will project their ſhadows northwards.

Thus they are amphiſcii, projecting their ſhade both ways, which is the caſe of all the inhabitants within the tropics.

The artificial horizon remaining as before, rectify the globes to the times of the equinox, and you will find that when this horizon is under the

ſtrong

ſtrong braſs meridian, a line going vertically upwards will be perpendicular to it, and conſequently the ſun will be directly over the heads of the inhabitants, and they will be aſcii, having no noon ſhade; their ſhadow is in the morning projected directly weſtward, in the evening directly eaſtward.

The ſame thing will alſo happen to all the inhabitants who live between the tropics of Cancer and Capricorn, ſo that they are not only aſcii, but amphiſcii alſo.

Thoſe who live without the tropics are heteroſcii; thoſe in north latitude have the noon ſhade always directed to the north, while thoſe in ſouth latitude have it always projected to the ſouth.

The inhabitants of the polar circles are called PERISCII, becauſe as the ſun goes round them continually, their ſhade goes round them likewiſe.

PROBLEM XIX.

Of the ANTŒCI, PERIŒCI, and ANTIPODES.

Theſe terms being often mentioned by geographical writers, it will be neceſſary to take ſome notice of them.

The ANTŒCI are two nations which are in or near the ſame meridian, the one in north, the other in ſouth latitude.

They have, therefore, the ſame longitude, but not the ſame latitude; oppoſite ſeaſons of the year, but the ſame hour of the day; the days of the one are equal to the nights of the other, and vice verſa; when the days of the one are at the longeſt, they are ſhorteſt at the other.

When they look towards each other, the ſun ſeems to riſe on the right hand of the one, but on the left of the other. They have different poles elevated, and the ſtars that never ſet to the one, are never ſeen by the other.

PERIŒCI are alſo two oppoſite nations, ſituated on the ſame parallel of latitude.

They have, therefore, the ſame latitude, but differ 180 degrees in longitude; the ſame ſeaſons of the year, but oppoſite hours of the day: for when it is twelve at night to the one, it is twelve at noon with the other. On the equinoctial days, the ſun is riſing to one, when it is ſetting to the other.

Antipodes are two nations diametrically oppoſite, which have oppoſite ſeaſons and latitude, oppoſite hours and longitude.

The ſun and ſtars riſe to the one, when they ſet to the other, and that during the whole year, for they have the ſame horizon.

The day of the one is the night of the other, and when the day is longeſt with the one, the other has it's ſhorteſt day.

They have contrary ſeaſons at the ſame time; different poles, but equally elevated; and thoſe ſtars that are always above the horizon of one, are always under the horizon of the other.

To exemplify theſe particulars, bring the given place to the ſtrong braſs meridian; then in the oppoſite hemiſphere, and under the ſame degree of latitude with the given place, you will find the antœci.

The given place remaining under the meridian, ſet the horary index to XII; then turn the globe, till the other XII is under the index, then will you find the periœci under the ſame degree of latitude with the given place.

Thus the inhabitants of the ſouth part of the Chili are antœci to the people of New England, whoſe periœci are thoſe Tartars who dwell on the north borders of China, which Tartars have the ſaid inhabitants of Chili for their antipodes.

This will become evident, by placing the globe in the poſition of a right ſphere, and bringing thoſe nations to the edge of the broad paper circle.

PROBLEM

PROBLEM XX.

The day of the month being given, to find all those places on the globe, over whose zenith the sun will pass on that day.

Rectify the terrestrial globe, by bringing the given day of the month on the back side of the strong brass meridian, to coincide with the plane of the broad paper circle; observe the number of degrees of the brass meridian, which corresponds to the given day of the month.

This number of degrees, counted from the equator on the strong brass meridian towards the elevated pole, is the point over which the sun is vertical; and all those places which pass under this point, have the sun directly vertical on the given day.

Example. Bring the 11th of May to coincide with the plane of the broad paper circle, and the said plane will cut 18 degrees for the elevation of the pole, which is equal to the sun's declination for that day, which being counted on the strong brass meridian towards the elevated pole, is the point over which the sun will be vertical; and all places

places that are under this degree, will have the ſun on their zenith on the 11th of May.

Hence when the ſun's declination is equal to the latitude of any place in the torrid zone, the ſun will be vertical to thoſe inhabitants that day; which furniſhes us with another method of ſolving this problem.

PROBLEM XXI.

To find the ſun's place on the broad paper circle.

Conſider whether the year in which you ſeek the ſun's place is biſſextile, or whether it is the firſt, ſecond, or third year after.

If it be the firſt year after biſſextile, thoſe diviſions to which the numbers for the days of the month are affixed, are the diviſions which are to be taken for the reſpective days of each month of that year at noon; oppoſite to which, in the circle of twelve ſigns, is the ſun's place.

If it be the ſecond year after biſſextile, the firſt quarter of a day backwards, or towards the left hand, is the day of the month for that year, againſt which, as before, is the ſun's place.

If

If it be the third year after biſſextile, then three quarters of a day backwards is the day of the month for that year, oppoſite to which is the ſun's place.

If the year in which you ſeek the ſun's place be biſſextile, then three quarters of a day backwards is the day of the month from the 1ſt of January to the 28th of February incluſive. The intercalary, or 29th day, is three-fourths of a day to the left hand from the 1ſt of March, and the 1ſt of March itſelf one quarter of a day forward, from the diviſion marked 1; and ſo for every day in the remaining part of the leap-year; and oppoſite to theſe diviſions is the ſun's place.

In this manner the intercalary day is very well introduced every fourth year into the calendar, and the ſun's place very nearly obtained, according to the Julian reckoning.

Thus,

A. D.		Sun's place.	Apr. 25.
1788	Biſſextile - -	♉	5° 35
1789	Firſt year after -	♉	5 21
1790	Second - - -	♉	5 6
1791	Third - -	♉	4 55

Upon

Upon my father's globes there are twenty-three parallels, drawn at the diſtance of one degree from each other on both ſides the equator, which, with two other parallels at 23½ degrees diſtance, include the ecliptic circle.

The two outermoſt circles are called the tropics; that on the north ſide of the equator is called the tropic of Cancer, that which is on the ſouth ſide, the tropic of Capricorn.

Now as the ecliptic is inclined to the equator, in an angle of 23½ degrees, and is included between the tropics, every parallel between theſe muſt croſs the ecliptic in two points, which two points ſhew the ſun's place when he is vertical to the inhabitants of that parallel; and the days of the month upon the broad paper circle anſwering to thoſe points of the ecliptic, are the days on which the ſun paſſes directly over their heads at noon, and which are ſometimes called their two midſummer days.

It is uſual to call the ſun's diurnal paths parallels to the equator, which are therefore aptly repreſented by the above-mentioned parallel circles; though his path is properly a ſpiral line, which he is continually deſcribing all the year long,

long, appearing to move daily about a degree in the ecliptic.

PROBLEM XXII.

To find the ſun's declination, and thence the parallel of latitude correſponding thereto.

Find the ſun's place for the given day in the broad paper circle, by the preceding problem, and ſeek that place in the ecliptic line upon the globe; this will ſhew the parallel of the ſun's declination among the above-mentioned dotted lines, which is alſo the correſponding parallel of latitude; therefore, all thoſe places through which this parallel paſſes, have the ſun in their zenith at noon on the given day.

Thus on the 23d of May the ſun's declination will be about 20 deg. 10 min.; and upon the 23d of Auguſt it will be 11 deg. 13 min. What has been ſaid in the firſt part of this problem, will lead the reader to the ſolution of the following.

PROBLEM XXIII.

To find the two days on which the ſun is in the zenith of any given place that is ſituated between the two tropics.

That parallel of declination which paſſes through the given place, will cut the ecliptic line upon the globe in two points; which denote the ſun's place, againſt which, on the broad paper circle, are the days and months required.

PROBLEM XXIV.

The day and hour at any place being given, to find where the ſun is vertical at that time.

Rectify the globe to the day of the month, ſee page 307, and you have the ſun's declination; bring the given place to the meridian, and ſet the hour index to XII; turn the globe, till the index points to the given hour on the equator; then will the place be under the degree of the declination previouſly found.

Let the given place be London, and time the 11th day of May, at 4 min. paſt V in the afternoon; bring the 11th of May to coincide with the

the broad paper circle, and oppoſite to it you will find 18 degrees of north declination; as London is the given place, you have only to turn the globe, till 4 min. paſt V weſtward of it, is on the meridian, when you will find Port-Royal, in Jamaica, under the 18th degree of the meridian, which is the place where the ſun is vertical at that time.

PROBLEM XXV.

The time of the day at any one place being given, to find all thoſe places where at the ſame inſtant the ſun is riſing, ſetting, and on the meridian, and where he is vertical; likewiſe, thoſe places where it is midnight, twilight, and dark night; as well as thoſe places in which the twilight is beginning and ending; and alſo to find the ſun's altitude at any hour in the illuminated, and his depreſſion in the obſcure, hemiſphere.

Rectify the globe to the day of the month, on the back ſide of the ſtrong braſs meridian, and the ſun's declination for that day; bring the given place to the ſtrong braſs meridian, and ſet the horary index to XII upon the equator; turn the

the globe from weſt to eaſt, until the horary index points to the given time. Then

All thoſe places which lie in the plane of the weſtern ſide of the broad paper circle, ſee the ſun riſing, and at the ſame time thoſe on the eaſtern ſide of it ſee him ſetting.

It is noon to all the inhabitants of thoſe places under the upper half of the graduated ſide of the ſtrong braſs meridian, whilſt at the ſame time thoſe under the lower half have midnight.

All thoſe places which are between the upper ſurface of the broad paper circle, and the wire circle under it, are in the twilight, which begins to all thoſe places on the weſtern ſide that are immediately under the wire circle; it's ends at all thoſe which are in the plane of the paper circle.

The contrary happens on the eaſtern ſide; the twilight is juſt beginning to thoſe places in which the ſun is ſetting, and it's end is at the place juſt under the wire circle.

And

And thoſe places which are under the twilight wire circle have dark night, unleſs the moon is favourable to them.

All places in the illuminated hemiſphere have the ſun's altitude equal to their diſtance from the edge of the enlightened diſc, which is known by fixing the quadrant of altitude to the zenith, and laying it's graduated edge over any particular place.

The ſun's depreſſion is obtained in the ſame manner, by fixing the center of the quadrant at the nadir.

PROBLEM XXVI.

To find all thoſe places within the polar circles, on which the ſun begins to ſhine, the time he ſhines conſtantly; when he begins to diſappear, the length of his abſence, as well as the firſt and laſt day of his appearance to thoſe inhabitants; the day of the month, or latitude of the place, being given.

Bring the given day of the month on the back ſide of the ſtrong braſs meridian, to the plane of the broad paper circle; the ſun is juſt then beginning to ſhine on all thoſe places which are in the parallel that juſt touches the edge of the broad paper circle, and will for ſeveral days ſeem to ſkim all around, and but a little above their horizon, juſt as it appears to us at it's ſetting; but with this obſervable difference, that whereas our ſetting ſun appears in one part of the horizon only, by them it is ſeen in every part thereof; from weſt to ſouth, thence eaſt to north, and ſo to the weſt again.

Or if the latitude be given, elevate the globe to that latitude, and on the back of the ſtrong braſs meridian, oppoſite to the latitude, you obtain the day of the month, then all the other requiſites are anſwered as above.

As the two concentric ſpaces which contain the days of the month on the back ſide of the ſtrong braſs meridian, are graduated to ſhew the oppoſite days of the year, at 180 degrees diſtance; when the given day is brought to coincide with the broad paper circle, it ſhews when the ſun begins to ſhine on that parallel, which is the firſt day of it's appearance above the horizon of that parallel.

And

And the plane of the broad paper circle cuts the day of the month on the opposite concentric space, when the sun begins to disappear to those inhabitants.

The length of the longest day is obtained by reckoning the number of days between the two opposite days found as above, and their difference from 365 gives the length of their longest night.

PROBLEM XXVII.

To make use of the globe as a tellurian, or that kind of orrery which is chiefly intended to illustrate the phænomena that arise from the annual and diurnal motions of the earth.

Describe a circle with chalk upon the floor, as large as the room will admit of, so that the globe may be moved round upon it; divide this circle into twelve parts, and mark them with the characters of the twelve signs, as they are engraved upon the broad paper circle; placing ♋ at the north, ♑ at the south, ♈ in the east, and ♎ in the west: the mariner's compass under the globe will direct the situation of these points, if the variation of the magnetic needle be attended to.

Note, At London the variation is between 23 and 24 degrees from the north weſtward.

Elevate the north pole of the globe, ſo that 66½ degrees on the ſtrong braſs meridian may coincide with the ſurface of the broad paper circle, and this circle will then repreſent the plane of the ECLIPTIC, or a plane coinciding with the earth's orbit.

Set a ſmall table, or a ſtool, over the center of the chalked circle, to repreſent the ſun, and place the terreſtrial globe upon it's circumference over the point marked ♑, with the north pole facing the imaginary ſun, and the north end of the needle pointing to the variation; and the globe will be in the poſition of the earth with reſpect to the ſun at the time of the ſummer ſolſtice, about the 21ſt of June; and the earth's axis, by this rectification of the globe, is inclined to the plane of the large chalked circle, as well as to the plane of the broad paper circle, in an angle of 66½ degrees; a line, or ſtring, paſſing from the center of the imaginary ſun to that of the globe, will repreſent a central ſolar ray connecting the centers of the earth and ſun: this ray will fall upon the firſt point of Cancer, and deſcribe that circle, ſhewing it to be the ſun's place upon the

the terreſtrial ecliptic, which is the ſame as if the ſun's place, by extending the ſtring, was referred to the oppoſite ſide of the chalked circle, here repreſenting the earth's path in the heavens.

If we conceive a plane to paſs through the center of the globe, and the ſun's center, it will alſo paſs through the points of Cancer and Capricorn, in the terreſtrial and celeſtial ecliptic; the central ſolar ray, in this poſition of the earth, is alſo in that plane; this can never happen but at the times of the ſolſtice.

If another plane be conceived to paſs through the center of the globe at right angles to the central ſolar ray, it will divide the globe into two hemiſpheres; that next the center of the chalked circle will repreſent the earth's illuminated diſc, the contrary ſide of the ſame plane will at the ſame time ſhew the obſcure hemiſphere.

The reader may realize this ſecond plane by cutting away a ſemicircle from a ſheet of card paſte-board, with a radius of about 1 $\frac{1}{2}$ tenth of an inch greater than that of the globe itſelf. *

 If

* Or he may have a plane made of wood for this purpoſe.

If this plane be applied to 66½ degrees upon the ſtrong braſs meridian, it will be in the pole of the ecliptic; and in every ſituation of the globe round the circumference of the chalked circle, it will afford a lively and laſting idea of the various phænomena ariſing from the paralleliſm of the earth's axis, and in particular the daily change of the ſun's declination, and the parallels thereby deſcribed.

Let the globe be removed from ♑ to ♒, and the needle pointing to the variation as before, will preſerve the paralleliſm of the earth's axis; then it will be plain, that the ſtring, or central ſolar ray, will fall upon the firſt point of Leo, ſix ſigns diſtant from, but oppoſite to the ſign ♒, upon which the globe ſtands; the central ſolar ray will now deſcribe the 20th parallel of north declination, which will be about the 23d of July.

If the globe be moved in this manner from point to point round the circumference of the chalked circle, and care be taken at every removal that the north end of the magnetic needle, when ſettled, points to the degree of the variation, the north pole of the globe will be obſerved to recede from the line connecting the centers of the earth and ſun, until the globe is placed upon the point

Cancer;

Cancer; after which, it will at every removal tend more and more towards the ſaid line, till it comes to Capricorn again.

PROBLEM XXVIII.

To rectify either globe to the latitude and horizon of any place.

If the place be in north latitude, raiſe the north pole; if in ſouth latitude, raiſe the ſouth pole, until the degree of the given latitude, reckoned on the ſtrong braſs meridian under the elevated pole, cuts the plane of the broad paper circle; then this circle will repreſent the horizon of that place.

PROBLEM XXIX.

To rectify for the ſun's place.

After the former rectification, bring the degrees of the ſun's place in the ecliptic line upon the globe to the ſtrong braſs meridian, and ſet the horary index to that XIIth hour upon the equator which is moſt elevated.

Or, if the ſun's place is to be retained, to anſwer various concluſions, bring the graduated edge of the moveable meridian to the degree of the ſun's place in the ecliptic, and ſlide the wire which croſſes the center of the artificial horizon thereto; then bring it's center, which is the interſection of the aforeſaid wire, and graduated edge of the moveable meridian, under the ſtrong braſs meridian as before, and ſet the horary index to that XII on the equator which is moſt elevated.

PROBLEM XXX.

To rectify for the zenith of any place.

After the firſt rectification, ſcrew the nut of the quadrant of altitude ſo many degrees from the equator, reckoned on the ſtrong braſs meridian towards the elevated pole, as that pole is raiſed above the plane of the broad paper circle, and that point will repreſent the zenith of the place.

Note, The zenith and nadir are the poles of the horizon, the former being a point directly over our heads, and the latter, one directly under our feet.

If,

If, when the globe is in this ſtate, we look on the oppoſite ſide, the plane of the horizon will cut the ſtrong braſs meridian at the complement of the latitude, which is alſo the elevation of the equator above the horizon.

Of the Solution of some Problems, in which the Broad Paper Circle is considered as the rational Horizon.

PROBLEM XXXI.

To ſhew at one view upon the terreſtrial globe for any given place, the ſun's meridian altitude, his amplitude, or point of the compaſs, on which he riſes and ſets every day in the year.

Rectify the globe to the latitude of the given place, bring that place to the ſtrong braſs meridian, and ſet the horary index to XII; ſcrew the quadrant of altitude to the zenith of the horizon, and bring it to the braſs meridian.

You will then at one view ſee the ſun's meridian altitude on every degree of the ſun's declination for the whole year, cut by the graduated edge of the quadrant of altitude, on the dotted parallels.

These

Theſe dotted parallels at the ſame inſtant alſo cut the edge of the broad paper circle, now repreſenting the horizon, in the point of the compaſs, or amplitude, on which the ſun is ſeen to riſe on the eaſt, or to ſet on the weſt ſide of the horizon, for every degree of declination throughout the year.

If you trace any of thoſe parallels to the ecliptic line, you have the ſun's place when he is upon that declination, and thence the day and month upon the horizon.

Alſo, the knowledge of the ſun's place in the ecliptic line, ſhews the ſun's declination for that time amongſt the dotted parallels.

PROBLEM XXXII.

To ſhew at one view upon the terreſtrial globe the length of the days and nights at any particular place, for all times of the year.

Rectify the globe to the latitude of the place, and the broad paper circle will repreſent the horizon; and the upper part of the dotted parallels of declination, which are here alſo parallels of latitude, will repreſent the diurnal arches.

Whence

Whence we may obtain the number of hours each of them contains, which is the ſolution of the problem. To illuſtrate this,

Elevate the globe to the poſition of a right ſphere, and you will, with one glance of the eye, ſee that all the dotted parallels of declination, as well as the equator itſelf, are cut by the horizon into two equal parts.

Therefore the inhabitants on the equinoctial line have their days and nights twelve hours long; that is, the ſun is never more, nor ever leſs than twelve hours above their horizon, during his apparent paſſage from the tropic of Cancer to the tropic of Capricorn, and thence to Cancer again.

All the fixed ſtars have the ſame apparent motion to the equatorial inhabitants; that is, they riſe and ſet, continue above, and are depreſſed below the horizon of any place upon the equator, exactly twelve hours.

Raiſe the north pole of the globe a few degrees of latitude at a time, and you will ſee the diurnal arches increaſe in length, until the pole is elevated to 66½ degrees above the horizon; then the parallel of the ſun's greateſt declination will be as far

from

from the equator as the place itſelf is from the pole; and this parallel is the tropic of Cancer, which will juſt touch the horizon in the north point.

And on the contrary, we may obſerve that the ſouthern parallels of declination continually ſhorten, as the northern ones lengthen, until they come to the tropic of Capricorn.

Rectify the globe to the latitude of London, 51½ degrees north; when the ſun is in the tropic of Cancer, the day is about 16½ hours; as he recedes from thence, the days ſhorten, as the length of the diurnal arches of the parallels ſhorten, until the ſun comes to Capricorn, and then the days are at the ſhorteſt, being of the ſame length with the nights when the ſun was in Cancer, viz. about 7½ hours.

Rectify the globe to the altitude of the northern polar circle, and you will find, when the ſun is in Cancer, he touches the horizon on that day without ſetting, being completely twenty-four hours above the horizon; and when he is in Capricorn, he once appears in the horizon, but does not riſe for the ſpace of twenty-four hours; when he is upon any other parallel of declination, the

the days are longer or ſhorter, as that parallel is nearer to, or farther from the equator.

Elevate the globe to the latitude of 80 degrees north, at which time let the ſun's declination be 10 degrees north, he then apparently ſeems to turn round above the horizon without ſetting, and never ſets from this point to Cancer, until in his return, after he has again paſſed this parallel of declination.

In the ſame manner, when his declination is 10 degrees ſouth, he is juſt ſeen at noon in the horizon, and diſappears from that time in his ſoutherly motion, till his return to the ſame point.

Elevate the north pole to 90 degrees, or in the zenith, then the globe will be in the poſition of a parallel ſphere, and the equinoctial line will coincide with the plane of the horizon; conſequently all the northern parallels are above, and all the ſouthern parallels below the horizon; therefore, the polar inhabitants, if any there be, have but one day and one night throughout the year; their day, when the ſun is in his northern, and their night, when he is in his ſouthern declination.

PROBLEM

PROBLEM XXXIII.

To find the angle of poſition of places.

The angle of poſition is that formed between the meridian of one of the places, and a great circle paſſing through the other place.

Rectify the globe to the latitude and zenith of one of the places, bring that place to the ſtrong braſs meridian, ſet the graduated edge of the quadrant to the other place, and the number of degrees contained between it and the ſtrong braſs meridian, is the meaſure of the angle ſought. Thus,

The angle of poſition between the meridian of Cape Clear, in Ireland, and St. Auguſtine, in Florida, is about 82 degrees north weſterly; but the angle of poſition between St. Auguſtine and Cape Clear, is only about 46 degrees north eaſterly.

Hence it is plain, that the line of poſition, or azimuth, is not the ſame from either place to the other, as the romb lines are.

PROBLEM XXXIV.

To find the bearing of one place from another.

The bearing of one ſea-port from another is determined by a kind of ſpiral, called a romb-line, paſſing from one to the other, ſo as to make equal angles with all the meridians it paſſeth by; therefore, if both places are ſituated on the ſame parallel of latitude, their bearing is either eaſt or weſt from each other; if they are upon the ſame meridian, they bear north and ſouth from one another; if they lie upon a romb-line, their bearing is the ſame with it; if they do not, obſerve to which romb-line the two places are neareſt parallel, and that will ſhew the bearing ſought.

Example. Thus the bearing of the Lizard point from the iſland of Bermudas, is nearly E. N. E.; and that of Bermudas from the Lizard is W. S. W. both nearly upon the ſame romb-line, but in contrary directions.

OF THE SOLUTION OF PROBLEMS, BY EXPOSING THE GLOBE TO THE SUN'S RAYS.

In the year 1679, J. Moxon publiſhed a treatiſe on what he called "THE ENGLISH GLOBE; being (ſays he) a ſtabil and immobil one, performing what the ordinary globes do, and much more; invented and deſcribed by the Right Hon. the Earl of Caſtlemaine." This globe was deſigned to perform, by being merely expoſed to the ſun's rays, all thoſe problems which in the uſual way are ſolved by the adventitious aid of brazen meridians, hour indexes, &c.

My father thought that this method might be uſeful, to ground more deeply in the young pupil's mind, thoſe principles which the globes are intended to explain; and by giving him a different view of the ſubject, improve and ſtrengthen his mind; he therefore inſerted on his globes ſome lines, for the purpoſe of ſolving a few problems in Lord Caſtlemaine's manner.

It appears to me, from a copy of Moxon's publication, which is in my poſſeſſion, that the Earl of Caſtlemaine projected a new edition of his works, as the copy contains a great number of corrections, many alterations, and ſome additions.

ditions. It is not very improbable, that at ſome future day I may re-publiſh this curious work, and adapt a ſmall globe for the ſolution of the problems.

The meridians on our new terreſtrial globes being ſecondaries to the equator, are alſo hour circles, and are marked as ſuch with Roman figures, under the equator, and at the polar circles. But there is a difference in the figures placed to the ſame hour circle; if it cuts the IIId hour upon the polar circles, it will cut the IXth hour upon the equator, which is ſix hours later, and ſo of all the reſt.

Through the great Pacific ſea, and the interſection of Libra, is drawn a broad meridian from pole to pole; it paſſes through the XIIth hour upon the equator, and the VIth hour upon each of the polar circles; this hour circle is graduated into degrees and parts, and numbered from the equator towards either pole.

There is another broad meridian paſſing through the Pacific ſea, at the IXth hour upon the equator, and the IIId hour upon each polar circle; this contains only one quadrant, or 90 degrees; the numbers annexed to it begin at the northern polar circle, and end at the tropic of Capricorn.

Here we muſt likewiſe obſerve, there are 23 concentric circles drawn upon the terreſtrial globe within the northern and ſouthern polar circles, which for the future we ſhall call polar parallels; they are placed at the diſtance of one degree from each other, and repreſent the parallels of the ſun's declination, but in a different manner from the 47 parallels between the tropics.

The following problems require the globe to be placed upon a plane that is level, or truly horizontal, which is eaſily attained, if the floor, pavement, gravel-walk in the garden, &c. ſhould not happen to be horizontal.

A flat ſeaſoned board, or any box which is about two feet broad, or two feet ſquare, if the top be perfectly flat, will anſwer the purpoſe; the upper ſurface of either may be ſet truly horizontal, by the help of a pocket ſpirit level, or plumb rule, if you raiſe or depreſs this or that ſide by a wedge or two, as the ſpirit level ſhall direct; if you have a meridian line drawn on the place over which you ſubſtitute this horizontal plane, it may be readily transferred from thence

to

to the ſurface juſt levelled; this being done, we are prepared for the ſolution of the following problems.

It will be neceſſary to define a term we are obliged to make uſe of in the ſolution of theſe problems, namely, the SHADE OF EXTUBERANCY: by this is meant that ſhade which is cauſed by the ſphericity of the globe, and anſwers to what we have heretofore named the terminator, defining the boundaries of the illuminated and obſcure parts of the globe; this circle was, in the ſolution of ſome of the foregoing problems, repreſented by the broad paper circle, but here realized by the rays of the ſun.

PROBLEM XXXV.

To obſerve the ſun's altitude (by the terreſtrial globe) when he ſhines bright, or when he can but juſt be diſcerned through a cloud.

Elevate the north pole of the globe to 66½ degrees; bring that meridian, or hour circle, which paſſes through the IXth hour upon the equator, under the graduated ſide of the ſtrong braſs meridian; the globe being now ſet upon the horizontal plane, turn it about thereon, frame and all, that the ſhadow of the ſtrong braſs meridian may fall directly under itſelf; or in other words, that the ſhade of it's graduated face may fall exactly upon the aforeſaid hour circle; at that inſtant the ſhade of extuberancy will touch the true degree of the ſun's altitude upon that meridian, which paſſes through the IXth hour upon the equator, reckoned from the polar circle, the moſt elevated part of which will then be in the zenith of the place where this operation is performed, and is the ſame whether it ſhould happen to be either in north or ſouth latitude.

Thus we may, in an eaſy and natural manner, obtain the altitude of the ſun, at any time of the day, by the terreſtrial globe; for it is very plain, when the ſun riſes, he bruſhes the zenith and nadir of the globe by his rays; and as he always illuminates half of it, (or a few minutes more, as his globe is conſiderably larger than that of the earth) therefore when the ſun is riſen a degree higher, he muſt neceſſarily illuminate a degree beyond the zenith, and ſo on proportionably from time to time.

But as the illuminated part is ſomewhat more than half, deduct 13 minutes from the ſhade of extuberancy, and you have the ſun's altitude with tolerable exactneſs.

If you have any doubt how far the ſhade of extuberancy reaches, hold a pin, or your finger, on the globe, between the ſun and point in diſpute, and where the ſhade of either is loſt, will be the point ſought.

When the ſun does not ſhine bright enough to caſt a ſhadow.

Turn the meridian of the globe towards the ſun, as before, or direct it ſo that it may lie in the ſame plane with it, which may be done if you have but the leaſt glimpſe of the ſun through a cloud; hold a ſtring in both hands, it having firſt been put between the ſtrong braſs meridian and the globe; ſtretch it at right angles to the meridian, and apply your face near to the globe, moving your eye lower and lower, till you can but juſt ſee the ſun; then bring the ſtring held as before to this point upon the globe, that it may juſt obſcure the ſun from your ſight, and the degree on the aforeſaid hour circle, which the ſtring then lies upon, will be the ſun's altitude required, for his rays would ſhew the ſame point if he ſhone out bright.

Note, The moon's altitude may be obſerved by either of theſe methods, and the altitude of any ſtar by the laſt of them.

PROBLEM XXXVI.

To place the terreſtrial globe in the ſun's rays, that it may repreſent the natural poſition of the earth, either by a meridian line, or without it.

If you have a meridian line, ſet the north and ſouth points of the broad paper circle directly over it, the north pole of the globe being elevated to the latitude of the place, and ſtanding upon a level plane, bring the place you are in under the graduated ſide of the ſtrong braſs meridian, then the poles and parallel circles upon the globe will, without ſenſible error, correſpond with thoſe in the heavens, and each point, kingdom, and ſtate, will be turned towards the real one which it repreſents.

If you have no meridian line, then the day of the month being known, find the ſun's declination as before inſtructed, which will direct you to the parallel of the day, amongſt the polar paral-

lels,

lels, reckoned from either pole towards the polar circle; which you are to remember.

Set the globe upon your horizontal plane in the ſun-ſhine, and put it nearly north and ſouth by the mariner's compaſs, it being firſt elevated to the latitude of the place, and the place itſelf brought under the graduated ſide of the ſtrong braſs meridian; then move the frame and globe together, till the ſhade of extuberancy, or term of illumination, juſt touches the polar parallel for the day, and the globe will be ſettled as before; and if accurately performed, the variation of the magnetic needle will be ſhewn by the degree to which it points in the compaſs box.

And here obſerve, if the parallel for the day ſhould not happen to fall on any one of thoſe drawn upon the globe, you are to eſtimate a proportionable part between them, and reckon that the parallel of the day. If we had drawn more, the globe would have been confuſed.

The reaſon of this operation is, that as the ſun illuminates half the globe, the ſhade of extuberancy will conſtantly be 90 degrees from the point wherein the ſun is vertical.

If the ſun be in the equator, the ſhade and illumination muſt terminate in the poles of the world; and when he is in any other diurnal parallel, the terms of illumination muſt fall ſhort of, or go beyond either pole, as many degrees as the parallel which the ſun deſcribes that day is diſtant from the equator; therefore, when the ſhade of extuberancy touches the polar parallel for the day, the artificial globe will be in the ſame poſition, with reſpect to the ſun, as the earth really is, and will be illuminated in the ſame manner.

PROBLEM XXXVII.

To find naturally the ſun's declination, diurnal parallel, and his place thereon.

The globe being ſet upon an horizontal plane, and adjuſted by a meridian line or otherwiſe, obſerve upon which, or between which polar parallel the term of illumination falls; it's diſtance from the pole is the degree of the ſun's declination; reckon this diſtance from the equator among the larger parallels, and you have the parallel which the ſun deſcribes that day; upon which if you move a card, cut in the form of a double ſquare, until it's ſhadow falls under itſelf, you will obtain the very place upon that parallel

over

over which the ſun is vertical at any hour of that day, if you ſet the place you are in under the graduated ſide of the ſtrong braſs meridian.

Note, The moon's declination, diurnal parallel and place, may be found in the ſame manner. Likewiſe, when the ſun does not ſhine bright, his declination, &c. may be found by an application in the manner of problem 35.

PROBLEM XXXVIII.

To find the ſun's azimuth naturally.

If a great circle, at right angles to the horizon, paſſes through the zenith and nadir, and alſo through the ſun's center, it's diſtance from the meridian in the morning or evening of any day, reckoned upon the degrees on the inner edge of the broad paper circle, will give the azimuth required.

METHOD I.

Elevate either pole to the poſition of a parallel ſphere, by bringing the north pole in north latitude, and the ſouth pole in ſouth latitude, into the zenith of the broad paper circle, having firſt

placed

placed the globe upon your meridian line, or by the other method before prefcribed; hold up a plumb line, fo that it may pafs freely near the outward edge of the broad paper circle, and move it fo that the fhadow of the ftring may fall upon the elevated pole; then caft your eye immediately to it's fhadow on the broad paper circle, and the degree it there falls upon is the fun's azimuth at that time, which may be reckoned from either the fouth or north points of the horizon.

METHOD II.

If you have only a glimpfe, or faint fight of the fun, the globe being adjufted as before, ftand on the fhady fide, and hold the plumb line on that fide alfo, and move it till it cuts the fun's center, and the elevated pole at the fame time; then caft your eye towards the broad paper circle, and the degree it there cuts is the fun's azimuth, which muft be reckoned from the oppofite cardinal point.

PROBLEM

PROBLEM XXXIX.

To ſhew that in ſome places of the earth's ſurface, the ſun will be twice on the ſame azimuth in the morning, twice on the ſame azimuth in the afternoon: or, in other words,

When the declination of the ſun exceeds the latitude of any place, on either ſide of the equator, the ſun will be on the ſame azimuth twice in the morning, and twice in the afternoon.

Thus, ſuppoſe the globe rectified to the latitude of Antigua, which is in about 17 deg. of north latitude, and the ſun to be in the beginning of Cancer, or to have the greateſt north declination; ſet the quadrant of altitude to the 21ſt degree north of the eaſt in the horizon, and turn the globe upon it's axis, the ſun's center will be on that azimuth at 6 h. 30 min. and alſo at 10 h. 30 min. in the morning. At 8 h. 30 min. the ſun will be as it were ſtationary, with reſpect to it's azimuth, for ſome time; as will appear by placing the quadrant of altitude to the 17th degree north of the eaſt in the horizon. If the quadrant be ſet to the ſame degrees north of the weſt, the ſun's center will croſs it twice as it approaches the horizon in the afternoon.

This

This appearance will happen more or leſs to all places ſituated in the torrid zone, whenever the ſun's declination exceeds their latitude; and from hence we may infer, that the ſhadow of a dial, whoſe gnomon is erected perpendicular to an horizontal plane, muſt neceſſarily go back ſeveral degrees on the ſame day.

But as this can only happen within the torrid zone, and as Jeruſalem lies about 8 degrees to the north of the tropic of Cancer, the retroceſſion of the ſhadow on the dial of Ahaz, at Jeruſalem, was, in the ſtricteſt ſignification of the word, miraculous.

PROBLEM XL.

To obſerve the hour of the day in the moſt natural manner, when the terreſtrial globe is properly placed in the ſun-ſhine.

There are many ways to perform this operation with reſpect to the hour, three of which are here inſerted, being general to all the inhabitants of the earth; a fourth is added, peculiar to thoſe of London, which will anſwer, without ſenſible error, at any place not exceeding the diſtance of 60 miles from this capital.

1ſt, By

1st, By a natural stile.

Having rectified the globe as before directed, and placed it upon an horizontal plane over your meridian line, or by the other method, hold a long pin upon the illuminated pole, in the direction of the polar axis, and it's shadow will shew the hour of the day amongst the polar parallels.

The axis of the globe being the common section of the hour circles, is in the plane of each; and as we suppose the globe to be properly adjusted, they will correspond with those in the heavens; therefore, the shade of a pin, which is the axis continued, must fall upon the true hour circle.

2ndly, By an artificial stile.

Tye a small string, with a noose, round the elevated pole, stretch it's other end beyond the globe, and move it so that the shadow of the string may fall upon the depressed axis; at that instant it's shadow upon the equator will give the solar hour to a minute.

But remember, that either the autumnal or vernal equinoctial colure must first be placed under the graduated side of the strong brass meridian,

ridian, before you obſerve the hour, each of theſe being marked upon the equator with the hour XII.

The ſtring in this laſt caſe being moved into the plane of the ſun, correſponds with the true hour circle, and conſequently gives the true hour.

3dly, Without any ſtile at all.

Every thing being rectified as before, look where the ſhade of extuberancy cuts the equator, the colure being under the graduated ſide of the ſtrong braſs meridian, and you obtain the hour in two places upon the equator, one of them going before, and the other following the ſun.

Note, If this ſhade be dubious, apply a pin, or your finger, as before directed.

The reaſon is, that the ſhade of extuberancy being a great circle, cuts the equator in half, and the ſun, in whatſoever parallel of declination he may happen to be, is always in the pole of the ſhade; conſequently the confines of light and ſhade will ſhew the true hour of the day.

4thly,

4thly, Peculiar to the inhabitants of London, and any place within the diſtance of ſixty miles from it.

The globe being every way adjuſted as before, and London brought under the graduated ſide of the ſtrong braſs meridian, hold up a plumb line, ſo that it's ſhadow may fall upon the zenith point, (which in this caſe is London itſelf) and the ſhadow of the ſtring will cut the parallel of the day upon that point to which the ſun is then vertical, and that hour circle upon which this interſection falls, is the hour of the day; and as the meridians are drawn within the tropics, at 20 minutes diſtance from each other, the point cut by the interſection of the ſtring upon the parallel of the day, being ſo near the equator, may, by a glance of the obſerver's eye, be referred thereto, and the true time obtained to a minute.

The plumb line thus moved, is the azimuth; which, by cutting the parallel of the day, gives the ſun's place, and conſequently the hour circle which interſects it.

From this laſt operation reſults a corollary, that gives a ſecond way of rectifying the globe to the ſun's rays.

If the azimuth and ſhade of the illuminated axis agree in the hour when the globe is rectified, then making them thus to agree, muſt rectify the globe.

COROLLARY.

Another method to rectify the globe to the ſun's rays.

Move the globe, till the ſhadow of the plumb line, which paſſes through the zenith, cuts the ſame hour on the parallel of the day, that the ſhade of the pin, held in the direction of the axis, falls upon, amongſt the polar parallels, and the globe is rectified.

The reaſon is, that the ſhadow of the axis repreſents an hour circle; and by it's agreement in the ſame hour, which the ſhadow of the azimuth ſtring points out, by it's interſection on the parallel of the day, it ſhews the ſun to be in the plane of the ſaid parallel; which can never happen in the morning on the eaſtern ſide of the globe, nor in the evening on the weſtern ſide of it, but when the globe is rectified.

This

This rectification of the globe is only placing it in ſuch a manner, that the principal great circles, and points, may concur and fall in with thoſe of the heavens.

The many advantages ariſing from theſe problems, relating to the placing of the globe in the ſun's rays, the tutor will eaſily diſcern, and readily extend to his own, as well as to the benefit of his pupil.

THE GENERAL PRINCIPLES OF

DIALLING

ILLUSTRATED BY THE

TERRESTRIAL GLOBE.

THE art of dialling is of very ancient origin, and was in former times cultivated by all who had any pretenſions to ſcience; and before the invention of clocks and watches, it was of the higheſt importance, and is even now uſed to correct and regulate them.

It teaches us, by means of the ſun's rays, to divide time into equal parts, and to repreſent on any given ſurface the different circles into which, for convenience, we ſuppoſe the heavens to be divided, but principally the hour circles.

The

The hours are marked upon a plane, and pointed out by the interpofition of a body, which receiving the light of the fun, cafts a fhadow upon the plane. This body is called the axis, when it is parallel to the axis of the world. It is called the ftyle, when it is fo placed that only the end of it coincides with the axis of the earth; in this cafe, it is only this point which marks the hours.

Among the various pleafing and profitable amufements which arife from the ufe of globes, that of dialling is not the leaft. By it the pupil will gain fatisfactory ideas of the principles on which this branch of fcience is founded; and it will reward, with abundance of pleafure, thofe that chufe to exercife themfelves in the practice of it.

If we imagine the hour circles of any place, as London, to be drawn upon the globe of the earth, and fuppofe this globe to be tranfparent, and to revolve round a real axis, which is opake, and cafts a fhadow; it is evident, that whenever the plane of any hour femicircle points at the fun, the fhadow of the axis will fall upon the oppofite femicircle.*

 Let

* Long's Aftronomy, vol. 1, page 82.

Let a P C p, fig. 1, plate XII. repreſent a tranſparent globe; a b c d e f g the hour ſemicircles; it is clear, that if the ſemicircle P a p points at the ſun, the ſhadow of the axis will fall upon the oppoſite ſemicircle.

If we imagine any plane to paſs through the center of this tranſparent globe, the ſhadow of half the axis will always fall upon one ſide or the other of this interſecting plane.

Thus let A B C D be the plane of the horizon of London; ſo long as the ſun is above the horizon, the ſhadow of the upper half of the axis will fall ſomewhere upon the upper ſide of the plane A B C D; when the ſun is below the horizon of London, then the ſhadow of the lower half of the axis E falls upon the lower ſide of the plane.

When the plane of any hour ſemicircle points at the ſun, the ſhadow of the axis marks the reſpective hour line upon the interſecting plane. The hour line is therefore a line drawn from the center of the interſecting plane, to that point where this plane is cut by the ſemicircle oppoſite to the hour ſemicircle.

Thus

Thus let A B C D, fig. 1, plate XII. the horizon of London, be the interſecting plane; when the meridian of London points at the ſun, as in the preſent figure, the ſhadow of the half axis P E falls upon the line E B, which is drawn from E, the center of the horizon, to the point where the horizon is cut by the oppoſite ſemicircle; therefore, E B is the line for the hour of twelve at noon.

By the ſame method the reſt of the hour lines are found, by drawing for every hour a line from the center of the interſecting plane, to that ſemicircle which is oppoſite to the hour ſemicircle.

Thus fig. 2, plate XII. ſhews the hour lines drawn upon the plane of the horizon of London, with only ſo many hours as are neceſſary; that is, thoſe hours, during which the ſun is above the horizon of London, on the longeſt day in ſummer.

If when the hour lines are thus found, the ſemicircles be taken away, as the ſcaffolding is when the houſe is built, what remains, as in fig. 2, will be an HORIZONTAL DIAL for London.

If, inſtead of twelve hour circles as above deſcribed, we take twice that number, we may by the points, where the interſecting plane is cut by them, find the lines for every half hour; if we take four times the number of hour circles, we may find the lines for every quarter of an hour, and ſo on progreſſively.

We have hitherto conſidered the horizon of London as the interſecting plane, by which is ſeen the method of making an horizontal dial. If we take any other plane for the interſecting plane, and find the points where the hour ſemicircles paſs through it, and draw lines from the center of the plane to thoſe points, we ſhall have the hour lines for that plane.

Fig. 3, plate XII. ſhews how the hour lines are found upon a ſouth plane, perpendicular to the horizon. Fig. 4 ſhews a ſouth dial, with it's hour lines, without the ſemicircle, by means whereof they are found.

The GNOMON of every ſun-dial repreſents the axis of the earth, and is therefore always placed parallel to it, whether it be a wire, as in the figure before us, or the edge of a braſs plate, as in a common horizontal dial.

The

The whole earth, as to it's bulk, is but a POINT, if compared to it's diſtance from the ſun; therefore, if a ſmall ſphere of glaſs be placed on any part of the earth's ſurface, ſo that it's axis be parallel to the axis of the earth, and the ſphere have ſuch lines upon it, and ſuch planes within it, as above deſcribed, it will ſhew the hour of the day as truly as if it were placed at the center of the earth, and that the ſhell of the earth were as tranſparent as glaſs.

A wire ſphere, with a thin flat plate of braſs within it, is often made uſe of to explain the principles of dialling.

From what has been ſaid, it is clear that dialling depends on finding where the ſhadow of a ſtrait wire, parallel to the axis of the earth, will fall upon a given plane, every hour, half hour, &c. the hour lines being found as above deſcribed, which we ſhall proceed to exemplify by the globe.

Every dial plane (that is, the plane ſurface on which a dial is drawn) repreſents the plane of a great circle, which circle is an HORIZON to ſome country or other.

The center of the dial reprefents the center of the earth ; and the gnomon which cafts the fhade reprefents the axis, and ought to point directly to the poles of the equator.

The planes upon which dials are delineated may be either, 1. parallel to the horizon; 2. perpendicular to the horizon ; or, 3. cutting it at oblique angles.

PROBLEM XLI.

To conftruct an horizontal dial for any given latitude, by means of the terreftrial globe.

Elevate the globe to the latitude of the place ; then bring the firft meridian under the graduated edge of the ftrong brazen one, which will then be over the hour XII, or the equator. As our globes have meridians drawn through every 15 degrees of the equator, thefe meridians will reprefent the true circles of the fphere, and will interfect the horizon of the globe, in certain points on each fide of the meridian. The diftance of thefe points from the meridian, muft be carefully noted down upon a piece of paper, as will be feen in the example. The pupil need not, however, take out into his table the diftances

further

further than from XII to VI, which is juſt 90 degrees; for the diſtances of XI, X, IX, VIII, VII, VI, in the forenoon, are the ſame from XII as the diſtances of I, II, III, IV, V, VI, in the afternoon; and theſe hour lines continued through the center will give the oppoſite hour lines on the other half of the dial.

No more hour lines need be drawn than what anſwer to the ſun's continuance above the horizon, on the longeſt day of the year, in the given latitude.

Example. Suppoſe the given place to be London, whoſe latitude is 51 deg. 30 min. north.

Elevate the north pole of the globe to 51½ degrees above the horizon; then will the axis of the globe have the ſame elevation above the broad paper circle, as the gnomon of the dial is to have above the plane thereof.

Turn the globe, till the firſt meridian (which on Engliſh globes paſſes through London) is under the graduated ſide of the ſtrong brazen meridian; then obſerve and note the points where the hour circles interſect the horizon; and as on

our

our globes the inner graduated circle, on the broad paper circle, begins from the two fixes, or eaft and weft, we fhall begin from thence, calling the hour - - VI 0° 0 we fhall find the other hours interfecting the horizon at the following degrees:

V	18°	54
IV	36	24
III	51	57
II	65	41
I	78	9

which are the refpective diftances of the above hours from VI upon the plane of the horizon.

To transfer thefe, and the reft of the hours, upon an horizontal plane, draw the parallel right lines a c and b d, fig. 5, plate XII. upon that plane, as far from each other as is equal to the intended thicknefs of the gnomon of the dial, and the fpace included between them will be the meridian, or twelve o'clock line upon the dial; crofs this meridian at right angles by the line g h, which will be the fix o'clock line; then fetting one foot of your compaffes in the interfection a, defcribe the quadrant g e with any convenient radius, or opening of the compaffes; after this, fet one foot of the compaffes in the interfection b, as a center, and with the fame radius defcribe the

the quadrant f h; then divide each quadrant into 90 equal parts, or degrees, as in the figure.

Becauſe the hour lines are leſs diſtant from each other about noon, than in any other part of the dial, it is beſt to have the centers of the quadrants at ſome diſtance from the center of the dial plane, in order to enlarge the hour diſtances near XII; thus the center of the plane is at A, but the center of the quadrants is at a and b.

Lay a rule over 78° 9′, and the center b, and draw there the hour line of I. Through b, and 65 41, gives the hour line of II. Through b, and 51 57, that of III. Through the ſame center, and 36 24, we obtain the hour line of IV. And through it, and 18 54, that of V. And becauſe the ſun riſes about four in the morning, continue the hour lines of IV and V in the afternoon, through the center b to the oppoſite ſide of the dial.

Now lay a rule ſucceſſively to the center a of the quadrant e g, and the like elevations or degrees of that quadrant, 78,9, 65,41, 51,57, 36,24, 18,54, which will give the forenoon hours of XI, X, IX, VIII, and VII; and becauſe the ſun does not ſet before VIII in the evening

evening on the longeſt days, continue the hour lines of VII and VIII in the afternoon, and all the hour lines will be finiſhed on this dial.

Laſtly, through $51\frac{1}{2}$ degrees on either quadrant, and from it's center, draw the right line a g for the axis of the gnomon a g i, and from g let fall the perpendicular g i upon the meridian line a i, and there will be a triangle made, whoſe ſides are a g, g i, and i a; if a plate ſimilar to this triangle be made as thick as the diſtance between the lines a c and b d, and be ſet upright between them, touching at a and b, the line a g will, when it is truly ſet, be parallel to the axis of the world, and will caſt a ſhadow on the hour of the day.

The trouble of dividing the two quadrants may be ſaved, by uſing a line of chords, which is always placed upon every ſcale belonging to a caſe of inſtruments.

PROBLEM

PROBLEM XLII.

To delineate a direct south dial for any given latitude, by the globe.

Let us suppose a south dial for the latitude of London.

Elevate the pole to the co-latitude of your place, and proceed in all respects as above taught for the horizontal dial, from VI in the morning to VI in the afternoon, only the hours must be reversed, as in fig. 3, plate XII.; and the hypothenuse a g of the gnomon a g f, must make an angle with the dial plane to the co-latitude of the place.

As the sun can shine no longer than from VI in the morning to VI in the evening, there is no occasion for having more than twelve hours upon this dial.

In solving this problem, we have considered our vertical south dial for the latitude of London, as an horizontal one for the complement of that latitude, or 38 deg. 30 min.; all direct vertical dials may be thus reduced to horizontal ones, in the same manner. The reason of this will be evident,

evident, if the globe be elevated to the latitude of London; for by fixing the quadrant of altitude to the zenith, and bringing it to interfect the horizon in the eaft point, it will point out the plane of the propofed dial.

This plane is at right angles to the meridian, and perpendicular to the horizon; and it is clear, from the bare infpection of the globe thus elevated, that it's axis forms an angle with this plane, which is juft the complement of that which it forms with the horizon, and is therefore juft equal to the co-latitude of the place, and that therefore it is moft fimple to rectify the globe to that co-latitude.

The north vertical dial is the fame with the fouth, only the ftyle muft point upwards, and that many of the hours from it's direction can be of no ufe.

PROBLEM XLIII.

To make an erect dial, declining from the south towards the east or west.

Elevate the pole to the latitude of the place, and screw the quadrant of altitude to the zenith.

Then if your dial declines towards the east, (which we shall suppose in the present instance) count in the horizon the degrees of declination, from the east point towards the north, and bring the lower end of the quadrant to coincide with that degree of declination at which the reckoning ends.

Then bring the first meridian under the graduated edge of the strong brazen meridian, which strong meridian will be the horary index.

Now turn the globe westward, and observe the degrees cut in the quadrant of altitude by the first meridian, while the hours XI, X, IX, &c. in the forenoon, pass successively under the brazen one; and the degrees thus cut on the quadrant by the first meridian, are the respective distances of the forenoon hours, from XII, on the plane of the quadrant.

For

For the afternoon hours, turn the quadrant of altitude round the zenith, until it comes to the degree in the horizon, oppofite to that where it was placed before, namely, as far from the weft towards the fouth, and turn the globe eaftward; and as the hours I, II, III, &c. pafs under the ftrong brazen meridian, the firft meridian will cut on the quadrant of altitude the number of degrees from the zenith, that each of the hours is from XII on the dial.

When the firft meridian goes off the quadrant at the horizon, in the forenoon, the hour index will fhew the time when the fun comes upon this dial; and when it goes off the quadrant in the afternoon, it points to the time when the fun leaves the dial.

Having thus found all the hour diftances from XII, lay them down upon your dial plane, either by dividing a femicircle into two quadrants, or by the line of chords.

In all declining dials, the line on which the gnomon ftands makes an angle with the twelve o'clock line, and falls among the forenoon hour lines, if the dial declines towards the eaft; and among the afternoon hour lines, when the dial declines

declines towards the weſt; that is, to the left hand from the twelve o'clock line in the former caſe, and to the right hand from it in the latter.

To find the diſtance of this line from that of twelve.

This may be conſidered, 1. If the dial declines from the ſouth towards the eaſt, then count the degrees of that declination in the horizon, from the eaſt point towards the north, and bring the lower end of the quadrant to that degree of declination where the reckoning ends; then turn the globe, until the firſt meridian cuts the horizon in the like number of degrees, counted from the ſouth point towards the eaſt, and the quadrant and firſt meridian will croſs one another at right angles, and the number of degrees of the quadrant, which are intercepted between the firſt meridian and the zenith, is equal to the diſtance of this line from the twelve o'clock line.

The numbers of the firſt meridian, which are intercepted between the quadrant and the north pole, is equal to the elevation of the ſtyle above the plane of the dial.

The ſecond caſe is, when the dial declines weſtward from the ſouth.

Count the declination from the eaſt point of the horizon, towards the ſouth, and bring the quadrant of altitude to the degree in the horizon, at which the reckoning ends, both for finding the forenoon hours, and the diſtance of the ſubſtile, or gnomon line, from the meridian; and for the afternoon hours, bring the quadrant to the oppoſite degrees in the horizon, namely, as far from the weſt towards the north, and then proceed in all reſpects as before.

It is preſumed, that the foregoing inſtances will be ſufficient to illuſtrate the general principles of dialling, and to give the pupil a general idea of that pleaſing ſcience; for accurate and expeditious methods of conſtructing dials, we muſt refer him to treatiſes written expreſsly on that ſubject.

NAVIGATION

EXPLAINED BY THE

GLOBE.

NAVIGATION is the art of guiding a ſhip at ſea, from one place to another, in the ſafeſt and moſt convenient manner. In order to attain this, four things are particularly neceſſary:

1. To know the ſituation and diſtance of places.

2. To know at all times the points of the compaſs.

3. To know the line in which the ſhip is to be directed from one place to the other.

4. To know, in any part of the voyage, what point of the globe the ſhip is upon.

The knowledge of the diſtance and ſituation of places, between which a voyage is to be made, implies not only a general knowledge of geography, but of ſeveral other particulars, as the rocks, ſands, ſtraights, rivers, &c. near which we are to ſail; the bending out, or running in of the ſhores, the knowledge of the times that particular winds ſet in, the ſeaſons when ſtorms and hurricanes are to be expected, but eſpecially the tides; theſe, and many other ſimilar circumſtances, are to be learned from ſea charts, journals, &c. but chiefly by obſervation and experience.

The ſecond particular to be attained, is the knowledge at all times of the points of the compaſs, where the ſhip is. The ancients, to whom the polarity of the loadſtone was unknown, found in the day-time the eaſt or weſt, by the riſing or ſetting of the ſun; and at night, the north by the polar ſtar. We have the advantage of the mariner's compaſs, by which, at any time in the wide ocean, and the darkeſt night, we know where

where the north is, and confequently the reft of the points of the compafs.

Indeed, before the invention of the mariner's compafs, the voyages of the Europeans were principally confined to coafting; but this fortunate difcovery has enabled the mariner to explore new feas, and difcover new countries, which, without this valuable acquifition, would probably have remained for ever unknown.

The third thing required to be known, is the line which a fhip defcribes upon the globe of the earth, in going from one place to another.

The fhorteft way from one place to another, is an arc of a great circle, drawn through the two places.

The moft convenient way for a fhip, is that by which we may fail from one place to another, directing the fhip all the while towards the fame point of the compafs.

A fhip is guided by fteering or directing her towards fome points of the compafs; the line wherein a fhip is directed, is called the fhip's courſe, which is named from the point towards which ſhe ſails.

Thus if a ſhip ſails towards the north-eaſt point, her courſe is ſaid to be N. E.

In long voyages, a ſhip's way may conſiſt of a great number of different courſes, as from A to B, from B to C, and from C to D, fig. 9, plate XII.; when we ſpeak of a ſhip's courſe, we conſider one of theſe at a time; the ſeldomer the courſe is changed, the more eaſily the ſhip is directed.

If two places, A and Z, fig. 7, plate XII. lie under the same meridian, the courſe from the one to the other is due north or ſouth. Thus let A Z be part of a meridian; if A be ſouth of Z, the courſe from A to Z muſt be north, and the courſe from Z to A ſouth. This is evident from the nature of a meridian, that it marks upon the horizon the north and ſouth points, and that every point of any meridian is north or ſouth from every other point of it. From hence we may deduce the following corollary: that if a ſhip ſails due north or ſouth, ſhe will continue on the ſame meridian.

If

If two places lie under the equator, the courſe from one to the other is an arc of the equator, and is due eaſt or weſt. Thus let a z, fig. 7, be a part of the equator; if a be weſt from z, the courſe from a to z is eaſt, and the courſe from z to a is weſt: for ſince the equator marks the eaſt and weſt points upon the horizon, every point of the equator lies eaſt or weſt of every other point of it, as may be ſeen upon the globe, by placing it as for a right ſphere, and bringing a or z, or any of the intermediate points, to the zenith; when it will be evident, that if we are to go from one of theſe points a, to the other z, or to any point on the equator, we muſt continue our courſe due eaſt to arrive at a, or vice verſa. From hence we may deduce this conſequence, that if a ſhip under the equator ſails due eaſt or weſt, ſhe will continue under the equator.

In the two foregoing caſes, the courſe being an arc of a great circle, (the meridian or equator) is the ſhorteſt and the moſt convenient way it can ſail.

If two places lie under the same parallel, the courſe from one to the other is due eaſt or weſt; this may be ſeen upon the globe, by the following method: bring any point of a parallel to the zenith, and ſtretch a thread over it, perpendicular to the meridian; the thread will then be a tangent to the parallel, and ſtand eaſt and weſt from the point of contact. Hence, if a ſhip ſails in any parallel, due eaſt or weſt, ſhe will continue in the ſame parallel. In this caſe, the moſt convenient courſe, though not the ſhorteſt from one to the other, is to ſail due eaſt or weſt.

If two places lie neither under the equator, nor on the same meridian, nor in the same parallel, the moſt convenient, though not the ſhorteſt, courſe from one to the other, is in a rhumb.

For if we ſhould in this caſe attempt to go the ſhorteſt way, in a great circle drawn through the two places, we muſt be perpetually changing our courſe. Thus fig 8, whatever is the bearing of Z from A, the bearings of all the intermediate points, as B, C, D, E, &c. will be different from it, as well as different from each other, as may be eaſily ſeen upon the globe, by bringing the firſt point A to the zenith, and obſerving the bearing of Z from each of them. Thus ſuppoſe when the globe is rectified to the horizon of A, the bearing of Z from A be north-eaſt, and the

the angle of poſition of Z, with regard to A, be 45 degrees; if we bring B to the zenith, we ſhall have a different horizon, and the bearing and angle of poſition from Z to B will be different from the former; and ſo on of the other points C D E, they will each of them have a different horizon, and Z will have a different bearing and angle of poſition.

From hence we may draw this corollary, that when two places lie one from the other, towards a point not cardinal, if we ſail from one place towards the point of the other's bearing, we ſhall never arrive at the other place. Thus if Z lies north-eaſt from A, if we ſail from A towards the north-eaſt, we ſhall never arrive at Z.

A RHUMB upon the globe is a line drawn from a given place A, ſo as to cut all the meridians it paſſes through at equal angles; the rhumbs are denominated from the points of the compaſs, in a different manner from the winds. Thus, at ſea, the north-eaſt wind is that which blows from the north-eaſt point of the horizon, towards the ſhip in which we are; but we are ſaid to ſail upon the N. E. rhumb, when we go towards the north-eaſt.

The

The rhumb A B C D Z, fig. 8, plate XII. paſſing through the meridians L M, N O, P Q, makes the angles L A B, N B C, P C D, equal; from whence it follows, that the direction of a rhumb is in every part of it towards the ſame point of the compaſs; thus from every point of a north-eaſt rhumb upon the globe, the direction is towards the north-eaſt, and that rhumb makes an angle of 45 deg. with every meridian it is drawn through.

Another property of the rhumbs is, that equal parts of the ſame rhumb are contained between parallels of equal diſtance of latitude; ſo that a ſhip continuing in the ſame rhumb, will run the ſame number of miles in ſailing from the parallel of 10 to the parallel of 30, as ſhe does in ſailing from the parallel of 30 to that of 50.

The fourth thing mentioned to be required in navigation, was, to know at any time what point of the globe a ſhip is upon. This depends upon four things; 1. the longitude; 2. the latitude; 3. the courſe the ſhip has run; 4. the diſtance, that is, the way ſhe has made, or the number of leagues or miles ſhe has run in that courſe, from the place of the laſt obſervation. Now any two

of

of theſe being known, the reſt may be eaſily found.

Having thus given ſome general idea of navigation, we now proceed to the problems by which the caſes of ſailing are ſolved on the globe.

PROBLEM XLIV.

Given the difference of latitude, and difference of longitude, to find the courſe and diſtance ſailed. *

Example. Admit a ſhip ſails from a port A, in latitude 38 deg. to another port B, in latitude 5 deg. and finds her difference of longitude 43 deg.

Let the port A be brought to the meridian, and elevate the globe to the given latitude of that port 38 deg. and fixing the quadrant of altitude preciſely over it on the meridian, move the quadrant to lie over the ſecond port B, (found by the given difference of latitude and longitude) then will it cut in the horizon 50 deg. 45 min. for the angle of the SHIP'S COURSE to be ſteered from

* See Martin on the Globes.

from the port A. Alſo, count the degrees in the quadrant between the two ports, which you will find 51 deg.; this number multiplied by 60, (the nautical miles in a degree) will give 3060 for the diſtance run.

PROBLEM XLV.

Given the difference of latitude and courſe, to find the difference of longitude and diſtance ſailed.

Example. Admit a ſhip ſails from a port A, in 25 deg. north latitude, to another port B, in 30 deg. ſouth latitude, upon a courſe of 43 deg.

Bring the port A to the meridian, and rectify the globe to the latitude thereof 25 deg. where fix the quadrant of altitude, and place it ſo as to make an angle with the meridian of 43 deg. in the horizon, and obſerve where the edge of the quadrant interſects the parallel of 30 deg. ſouth latitude, for that is the place of the port B. Then count the number of degrees on the edge of the quadrant interſected between the two ports, and there will be found 73 deg. which multiplied by 60, gives 4380 miles for the diſtance ſailed. As the two ports are now known, let each be

brought

brought to the meridian, and obſerve their difference of longitude in the equator reſpectively, which will be found 50 deg.

N. B. Had this problem been ſolved by LOXODROMICS, or ſailing on a rhumb, the difference of longitude would then have been 52 deg. 30 min. between the two ports.

PROBLEM XLVI.

Given the difference of latitude and diſtance run, to find the difference of longitude, and angle of the courſe.

Example. Admit a ſhip ſails from a port A, in latitude 50 deg. to another port B, in latitude 17 deg. 30 min. and her diſtance run be 2220 miles. Rectify the globe to the latitude of the place A, then the diſtance run, reduced to degrees, will make 37 deg. which are to be reckoned from the end of the quadrant lying over the port A, under the meridian; then is the quadrant to be moved, till the 37 deg. coincides with the parallel of 17 deg. 30 min. north latitude, then will the angle of the courſe appear in the arch of the horizon, intercepted between the quadrant and the meridian, which will be 32 deg.

40

40 min.; and by making a mark on the globe for the port B, and bringing the ſame to the meridian, you will obſerve what number of degrees paſs under the meridian, which will be 20, the difference of longitude required.

PROBLEM XLVII.

Given the difference of longitude and courſe, to find the difference of latitude and diſtance ſailed.

Example. Suppoſe a ſhip ſails from A, in the latitude 51 deg. on a courſe making an angle with the meridian of 40 deg. till the difference of longitude be found juſt 20 deg.; then rectifying the globe to the latitude of the port A, place the quadrant of altitude ſo as to make an angle of 40 deg. with the meridian; then obſerve in what point it interſects the meridian paſſing through the given longitude of the port B, and there make a mark to repreſent the ſaid port; then the number of degrees intercepted between that and the port A will be 28, which will give 1680 miles for the diſtance run. And the ſaid mark for the port B, being brought to the meridian, will have it's latitude there ſhewn to be 27 deg. 40 min.

PROBLEM XLVIII.

Given the courſe and diſtance ſailed, to find the difference of longitude, and difference of latitude.

Example. Suppoſe a ſhip ſails 1800 miles from a port A, 51 deg. 15 min. ſouth-weſt, on an angle of 45 deg. to another port B.

Having rectified the globe to the port A, fix the quadrant of altitude over it in the zenith, and place it to the ſouth-weſt point in the horizon; then upon the edge of the quadrant under 30 deg. (equal to 1800 miles from the port A) is the port B; which bring to the meridian, and you will there ſee the latitude; and at the ſame time, it's longitude in the equator, in the point cut by the meridian.

In all theſe caſes, the ſhip is ſuppoſed to be kept upon the ARCH OF A GREAT CIRCLE, which is not difficult to be done, very nearly, by means of the globe, by frequently obſerving the latitude, meaſuring the diſtance ſailed, and (when you can) finding the difference of longitude; for one of theſe being given, the place and courſe of

the

the ſhip is known at the ſame time; and therefore the preceding courſe may be altered, and rectified without any trouble, through the whole voyage, as often as ſuch obſervations can be obtained, or it is found neceſſary. Now if any of theſe DATA are but of the quantity of four or five degrees, it will ſuffice for correcting the ſhip's courſe by the globe, and carrying her directly to the intended port, according to the following problem.

PROBLEM XLIX.

To ſteer a ſhip upon the arch of a great circle by the given difference of latitude, or difference of longitude, or diſtance ſailed in a given time.

Admit a ſhip ſails from a port A, to a very diſtant port Z, whoſe latitude and longitude are given, as well as it's geographical bearing from A; then

Firſt, having rectified the globe to the port A, lay the quadrant of altitude over the port Z, and draw thereby the arch of a great circle through A and Z; this will deſign the intended path or tract of the ſhip.

Secondly,

Secondly, having kept the ſhip upon the firſt given courſe for ſome time, ſuppoſe by an obſervation you find the latitude of the PRESENT PLACE of the ſhip, this added to, or ſubducted from the latitude of the port A, will give the preſent latitude in the meridian; to which bring the path of the ſhip, and the part therein, which lies under the new latitude, is the true place B of the ſhip in the great arch. To the latitude of B rectify the globe, and lay the quadrant over Z, and it will ſhew in the horizon the NEW COURSE to be ſteered.

Thirdly, ſuppoſe the ſhip to be ſteered upon this courſe, till her diſtance run be found 300 miles, or 5 deg.; then, the globe being rectified to the place B in the zenith, laying the quadrant from thence over the great arch, make a mark at the 5th degree from B, and that will be the preſent place of the ſhip, which call C; which being brought to the meridian, it's latitude and longitude will be known. Then rectify the globe to the place C, and laying the quadrant from thence to Z, the new courſe to be ſteered will appear in the horizon.

Fourthly, having ſteered ſome time upon this new courſe, ſuppoſe, by ſome means or other, you come to know the difference of longitude of the preſent place of the ſhip, and of any of the preceding places, C, B, A; as B, for inſtance; then bring B to the meridian, and turn the globe about, till ſo many degrees of the equator paſs under the meridian, as are equal to the diſcovered difference of longitude, then the point of the great arch cut by the meridian, is the preſent place D of the ſhip, to which the new courſe is to be found as before.

And thus, by repeating theſe obſervations at proper intervals, you will find future places, E, F, G, &c. in the great arch; and by rectifying the courſe at each, your ſhip will be conducted on the great circle, or the neareſt way from the port A to Z, by the USE OF THE GLOBE only.

Or

OF THE GENERAL DISTRIBUTION OF LAND AND WATER IN THE TERRAQUEOUS GLOBE, WITH SOME OTHER GEOGRAPHICAL OBSERVATIONS.

Though the nature of our plan does not permit us to enter into many geographical diſquiſitions, yet we preſume the following general view will not be deemed irrelative to the ſubject; as while it tends to bring the pupil acquainted with the grand outline of the globe, it will be a pleaſing relief from the more abſtruſe part in which he has been exercifed.

If the pupil conſiders the terreſtrial globe as a map, he will find that land and water are generally contraſted to one another on the oppoſite ſide of the world; that is, if there be land on one ſide, it is anſwered by water in the antipodes. Thus for inſtance, the circumpolar parts of the northern hemiſphere conſiſt chiefly of land; but the circumpolar parts of the ſouth conſiſt almoſt entirely of water. It was formerly thought, that as there is ſo much land about the north pole, land would alſo have been found about the ſouth pole, to have ballanced it. * But the diſcoveries of our circumnavigators have ſhewn, that no ſuch land is to be met with; nor ought it

* Jones's Phyſiological Diſquiſitions.

to have been expected, for land on one fide is ballanced by water on the oppofite.

If you bring the Cape of Good Hope under the ftrong brazen meridian, this meridian will pafs through the heart of the continents of Europe and Africa; but the oppofite femicircle paffes through the middle of the great fouth fea. When the middle of the northern continent of America, about the meridian of Mexico, is examined in the fame way, the oppofite part paffes through the middle of the Indian ocean. The fouthern continent of New Holland is oppofite to the Atlantic ocean. This alternation of land and water is too regular to have been cafual; but of the reafon for it, or the benefits arifing from it, we are altogether ignorant.

There is another phænomenon which is more level to our capacity, the manifeft fuperiority of the northern hemifphere of the world over the fouthern. It has more land, more fun, more light, more heat, more arts, more fenfe, more learning, more truth, more religion. The land of the fouthern hemifphere, that is, the land which lies on the other fide of the equinoctial line, does not amount to one-fourth part of what is found on the northern fide.

The

The ſun, from the eccentricity of the earth's orbit, and the ſituation of the aphelion, makes our ſummer eight days longer than the ſummer of the other hemiſphere, which in the ſpace of 4000 years amounts to more than 87 years.

The temperature of the earth and atmoſphere in the higher northern latitudes, is much more mild and moderate than in the correſpondent ſouthern latitudes. The dreary face of Staten land, with the weather-beaten Cape of South America, a climate ſo ſevere, as ſcarcely to admit of any human inhabitant, is not nearer to the pole than the northern counties of England, while the difference in the atmoſphere and the aſpect of the earth is almoſt incredible.

The nights of the northern hemiſphere diſplay a richer canopy than thoſe of the ſouthern. The ſtars of ſuperior magnitude are more numerous on this ſide the equinoctial than on the other. When the ſun is remote from us in winter, our longeſt nights are illuminated by the principal ſtars of the firmament. When the ſun enters Capricorn, the whole conſtellation of Orion, the brighteſt in the heavens, comes to the meridian about midnight, with ſeveral other ſtars of the firſt magnitude. If the midwinter of the ſouthern hemiſphere be compared, the inferiority of the nocturnal illumination is wonderful, and will be evident to any one who examines the problem on a celeſtial globe.

The intellectual advantages of the northern hemiſphere are equally conſpicuous with the natural advantages. In the one, the arts and ſciences have always flouriſhed; but where are the poets, the hiſtorians, the orators, the philoſophers, of the ſouthern world? We may as well ſearch for the ſciences among the beaſts of the wilderneſs. There would be no end, if we were to continue the compariſon through all the ſeveral improvements which may be comprehended under the name of humanity; for here we have every thing that can adorn human life, and there they can have nothing. He that conſiders the ſubject, will find that the natural and intellectual advantages always correſpond to each other.

Every habitable latitude enjoys a heat of 60 degrees at leaſt, for two months; which heat ſeems neceſſary for the growth and maturity of corn. The quickneſs of vegetation in the higher latitudes, proceeds from the duration of the ſun over the horizon. Rain is little wanted, as the earth

earth is ſufficiently moiſtened by the melting of the ſnow that covers it during the winter: circumſtances, which, among many others, evince the wiſe diſpoſition of things by divine providence.

It is owing to the ſame provident hand that the globe of the earth is interſected with ſeas and mountains, in a manner that on it's firſt appearance ſeems altogether irregular and fortuitous, preſenting to the uninformed eye the view of an immenſe ruin; but when the effects of theſe ſeeming irregularities on the face of the globe, are carefully inſpected, they are found moſt beneficial, and even neceſſary to the welfare of it's inhabitants; for to ſay nothing of the advantages of trade and commerce, which could not exiſt without theſe ſeas, it is by them that the cold of the higher, and the heat of the lower latitude, is moderated. It is by the want of ſeas, that the interior parts of Aſia, as Siberia and Great Tartary, as well as thoſe of Africa, are rendered almoſt uninhabitable. In the ſame manner, mountains are neceſſary, not only as the ſources of rivers, but as a defence againſt heat, in the warm latitudes; without the Alps, Pyrenees, Apenine, the mountains Dauphine and Auvergne, Italy, Spain, and France, would be deprived of the mild air they now enjoy. Without the Balgate hills, or Indian Apenine, India would have been a deſert. Hence Jamaica, St. Domingo, Sumatra, and moſt other intertropical iſlands, are furniſhed with mountains, from which proceed the breezes by which they are refreſhed.*

* Kirwan on Climates.

ESSAY

ESSAY II.

PART IV.

ESSAY II.

PART IV.

Of the Use of the Celestial Globe.

THE celeſtial globe is an artificial repreſentation of the heavens, having the fixed ſtars drawn upon it, in their natural order and ſituation.

It is not to be ſuppoſed that the celeſtial globe is ſo juſt a repreſentation of the heavens as the terreſtrial globe is of the earth; becauſe here the ſtars are drawn upon a convex ſurface, whereas they naturally appear in a concave one. But ſuppoſe the globe were made of glaſs, then to an eye placed in the center, the ſtars which are drawn upon it would appear in a concave ſurface, juſt as they do in the heavens.

Or if the reader was to ſuppoſe that holes were made in each ſtar, and an eye placed in the center of the globe, it would view, through thoſe holes, the ſame ſtars in the heavens that they repreſent.

As the terreſtrial globe, by turning on it's axis, repreſents the real diurnal motion of the earth; ſo the celeſtial globe, by turning on it's axis, repreſents the apparent diurnal motion of the heavens.

For the ſake of perſpicuity, and to avoid continual references, it will be neceſſary to repeat here ſome articles which have been already mentioned.

The ecliptic is that graduated circle which croſſes the equator in an angle of about 23 ½ degrees, and the angle is called the obliquity of the ecliptic.

The circle is divided into twelve equal parts, conſiſting of 30 degrees each; the beginnings of them are marked with characters, repreſenting the twelve ſigns.

Aries

Aries ♈, Taurus ♉, Gemini ♊, Cancer ♋, Leo ♌, Virgo ♍, Libra ♎, Scorpio ♏, Sagittarius ♐, Capricornus ♑, Aquarius ♒, Piſces ♓.

Upon my father's globes, juſt under the ecliptic, the months, and days of each month, are graduated, for the readier fixing the artificial ſun upon it's place in the ecliptic.

The two points where the ecliptic croſſes the equinoctial, (the circle that anſwers to the equator on the terreſtrial globe) are called the equinoctial points; they are at the beginnings of Aries and Libra, and are ſo called, becauſe when the ſun is in either of them, the day and night is every where equal.

The firſt points of Cancer and Capricorn are called ſolſtitial points; becauſe when the ſun arrives at either of them, he ſeems to ſtand in a manner ſtill for ſeveral days; in reſpect to his diſtance from the equinoctial, when he is in one ſolſtitial point, he makes to us the longeſt day; when in the other, the longeſt night.

The

The latitude and longitude of ſtars are determined from the ecliptic.

The longitude of the ſtars and planets is reckoned upon the ecliptic ; the numbers beginning at the firſt points of Aries ♈, where the ecliptic croſſes the equator, and increaſing according to the order of the ſigns.

Thus ſuppoſe the ſun to be in the 10th degree of Leo, we ſay, his longitude, or place, is four ſigns, ten degrees ; becauſe he has already paſſed the four ſigns, Aries, Taurus, Gemini, Cancer, and is ten degrees in the fifth.

The latitude of the ſtars and planets is determined by their diſtance from the ecliptic upon a ſecondary or great circle paſſing through it's poles, and croſſing it at right angles.

Twenty-four of theſe circular lines, which croſs the ecliptic at right angles, being fifteen degrees from each other, are drawn upon the ſurface of our celeſtial globe ; which being produced both ways, thoſe on one ſide meet in a point on the northern polar circle, and thoſe on the other meet in a point on the ſouthern polar circle.

The

The points determined by the meeting of theſe circles are called the poles of the ecliptic, one north, the other ſouth.

From theſe definitions it follows, that longitude and latitude on the celeſtial globe bears juſt the ſame relation to the ecliptic, as they do on the terreſtrial globe to the equator.

Thus as the longitude of places on the earth is meaſured by degrees upon the equator, counting from the firſt meridian; ſo the longitude of the heavenly bodies is meaſured by degrees upon the ecliptic, counting from the firſt point of Aries.

And as latitude on the earth is meaſured by degrees upon the meridian, counting from the equator; ſo the latitude of the heavenly bodies is meaſured by degrees upon a circle of longitude, counting either north or ſouth from the ecliptic.

The ſun, therefore, has no latitude, being always in the ecliptic; nor do we uſually ſpeak of his longitude, but rather of his place in the ecliptic, expreſſing it by ſuch a degree and minute of ſuch a ſign, as 5 degrees of Taurus, inſtead of 35 degrees of longitude.

The diſtance of any heavenly body from the equinoctial, meaſured upon the meridian, is called it's declination.

Therefore, the ſun's declination, north or ſouth, at any time, is the ſame as the latitude of the place to which he is then vertical, which is never more than 23 ½ degrees.

Therefore all PARALLELS OF DECLINATION on the celeſtial globe are the very ſame as parallels of latitude on the terreſtrial.

Stars may have north latitude and ſouth declination, and vice verſa.

That which is called longitude on the terreſtrial globe, is called RIGHT ASCENSION on the celeſtial; namely, the ſun or ſtars diſtance from that meridian which paſſes through the firſt point of Aries, counted on the equinoctial.

Aſtronomers alſo ſpeak of OBLIQUE ASCENSION and DESCENSION, by which they mean the diſtance of that point of the equinoctial from the firſt point of Aries, which in an oblique ſphere riſes or ſets, at the ſame time that the ſun or ſtar riſes or ſets.

ASCENSIONAL difference is the difference betwixt right and oblique afcenfion. The fun's afcenfional difference turned into time, is juft fo much as he rifes before or after fix o'clock.

The celeftial figns and conftellations on the furface of the celeftial globe, are reprefented by a variety of human and other figures, to which the ftars that are either in or near them, are referred.

The feveral fyftems of ftars which are applied to thofe images, are called conftellations. Twelve of thefe are reprefented on the ecliptic circle, and extend both northward and fouthward from it. So many of thofe ftars as fall within the limits of 8 degrees on both fides of the ecliptic circle, together with fuch parts of their images as are contained within the aforefaid bounds, conftitute a kind of broad hoop, belt, or girdle, which is called the ZODIAC.

The names and the refpective characters of the twelve figns of the ecliptic may be learned by infpection on the furface of the broad paper circle, and the conftellations from the globe itfelf.

The zodiac is reprefented by eight circles parallel to the ecliptic, on each fide thereof; thefe circles are one degree diftant from each other, fo that the whole breadth of the zodiac is 16 degrees.

Amongft thefe parallels, the latitude of the planets is reckoned; and in their apparent motion they never exceed the limits of the zodiac.

On each fide of the zodiac, as was obferved, other conftellations are diftinguifhed; thofe on the north fide are called northern, and thofe on the fouth fide of it, fouthern conftellations.

All the ftars which compofe thefe conftellations, are fuppofed to increafe their longitude continually; upon which fuppofition, the whole ftarry firmament has a flow motion from weft to eaft; infomuch that the firft ftar in the conftella-tion of Aries, which appeared in the vernal interfection of the equator and ecliptic in the time of Meton the Athenian, upwards of 1900 years ago, is now removed about 30 degrees from it.

To

To represent the motion of the equinoctial points backwards, or in antecedentia, upon the celestial globe, elevate the north pole, ſo that it's axis may be perpendicular to the plane of the broad paper circle, and the equator will then be in the ſame plane; let theſe repreſent the ecliptic, and then the poles of the globe will alſo repreſent thoſe of the ecliptic; the ecliptic line upon the globe will at the ſame time repreſent the equator, inclined in an angle of $23\frac{1}{2}$ degrees to the broad paper circle, now called the ecliptic, and cutting it in two points, which are called the equinoctial interſections.

Now if you turn the globe ſlowly round upon it's axis from eaſt to weſt, while it is in this poſition, theſe points of interſection will move round the ſame way; and the inclination of the circle, which in ſhewing this motion repreſents the equinoctial, will not be altered by ſuch a revolution of the interſecting or equinoctial points. This motion is called the preceſſion of the equinoxes, becauſe it carries the equinoctial points backwards amongſt the fixed ſtars.

The poles of the world ſeem to deſcribe a circle from eaſt to weſt, round the poles of the ecliptic, ariſing from the preceſſion of the equinox. It is a very ſlow motion, for the equinoctial points take up 72 years to move one degree, and therefore they are 25,920 years in deſcribing 360 degrees, or completing a revolution.

This motion of the poles is eaſily repreſented by the above-deſcribed poſition of the globe, in which, if the reader remembers, the broad paper circle repreſents the ecliptic, and the axis of the globe being perpendicular thereto, repreſents the axis of the ecliptic; and the two points, where the circular lines meet, will now repreſent the poles of the world, whence as the globe is ſlowly turned from eaſt to weſt, theſe points will revolve the ſame way about the poles of the globe, which are here ſuppoſed to repreſent the poles of the ecliptic. The axis of the world may revolve as above, although it's ſituation, with reſpect to the ecliptic, be not altered; for the points here ſuppoſed to repreſent the poles of the world, will always keep the ſame diſtance from the broad paper circle, which repreſents the ecliptic in this ſituation of the globe.*

From

* Rutherforth's Syſtem of Nat. Philoſ. vol. ii. p. 730.

From the different degrees of brightneſs in the ſtars, ſome appear to be greater than others, or nearer to us; on our celeſtial globe they are diſtinguiſhed into ſeven different magnitudes.

OF THE USE OF THE CELESTIAL GLOBE, IN THE SOLUTION OF PROBLEMS RELATIVE TO THE SUN.

EVERY thing that relates to the ſun is of ſuch importance to man, that in all things he claims a natural preheminence. The ſun is at once the moſt beautiful emblem of the Supreme Being, and, under his influence, the foſtering parent of worlds; being preſent to them by his rays, cheering them by his countenance, cheriſhing them by his heat, adorning them at each returning ſpring with the gayeſt and richeſt attire, illuminating them with his light, and feeding the lamp of life.

To the ancients he was known under a variety of names, each characteristic of his different effects; he was their Hercules, the great deliverer, the restorer of light out of darkness, the dispenser of good, continually labouring for the happiness of a depraved race. He was the Mithra of the Persians, a word derived from love, or mercy, because the whole world is cherished by him, and feels as it were the effects of his love.

In the sacred scriptures, the original source of all emblematical writings, our Lord is called our sun, and the sun of righteousness; and as there is but one sun in the heavens, so there is but one true God, the maker and redeemer of all things, the light of the understanding, and the life of the soul.

As in scripture our God is spoke of as a shield and buckler, so the sun is characterized by this mark ⊙ representing a shield or buckler, the middle point the umbo, or boss; for it is love, or life, which alone can protect from fear and death.

His celestial rays, like those of the sun, take their circuit round the earth; there is no corner of it ſo remote as to be without the reach of their vivifying and penetrating power. As the material light is always ready to run it's heavenly race, and daily iſſues forth with renewed vigour, like an invincible champion, ſtill freſh to labour; ſo likewiſe did our REDEEMING GOD rejoice to run his glorious race, he excelled in ſtrength, and triumphed, and continues to triumph over all the powers of darkneſs, and his ever manifeſting himſelf as the deliverer, the protector, the friend, and father of the human race. *

PROBLEM L.

To rectify the celeſtial globe.

To rectify the celeſtial globe, is to put it in that poſition in which it may repreſent exactly the apparent motion of the heavens.

In different places, that poſition will vary, and that according to the different latitude of the places.

Therefore, to rectify for any place, find firſt, by the terreſtrial globe, the latitude of that place.

The

* Horne on the Pſalms.

The latitude of the place being found in degrees, elevate the pole of the celeſtial globe the ſame number of degrees and minutes above the plane of the horizon, for this is the name given to the broad paper circle, in the uſe of the celeſtial globe.

Thus the latitude of London being 51 ½ degrees, let the globe be moved till the plane of the horizon cuts the meridian in that point.

The next rectification is for the ſun's place, which may be performed as directed in pr. xxix; or look for the day of the month cloſe under the ecliptic line, againſt which is the ſun's place, place the artificial ſun over that point, then bring the ſun's place to the graduated edge of the ſtrong brazen meridian, and ſet the hour index to the moſt elevated twelve.

Thus on the 24th of May the ſun is in 3 ½ degrees of Gemini, and is ſituated near the bull's eye and the ſeven ſtars which are not then viſible, on account of his ſuperior light. If the ſun were on that day to ſuffer a total eclipſe, theſe ſtars would then be ſeen ſhining with their accuſtomed brightneſs.

Laſtly,

Laſtly, ſet the meridian of the globe north and ſouth, by the compaſs.

And the globe will be rectified, or put into a ſimilar poſition, to the concave ſurface of the heavens, for the given latitude.

PROBLEM LI.

To find the declination of the ſun for any given day in the year.

Seek the day of the month cloſe under the ecliptic line, againſt which is the ſun's place; bring that point under the ſtrong braſs meridian, and the degree that ſtands over it is the ſun's declination for that day.

Thus on the 23d of May the ſun's declination will be about 23 deg. 10 min.; and upon the 23d of Auguſt it will be 11 deg. 13 min.

PROBLEM LII.

To find the ſun's right aſcenſion.

The right aſcenſion of the ſun, &c. is an arch of the equinoctial contained between the beginning of Aries, and that point of it which comes to the meridian with it.

Therefore, bring the ſun's place to the meridian, and that point of the equinoctial which is under the meridian will ſhew the ſun's right aſcenſion.

Thus on the 11th of May the right aſcenſion will be found to be 47 deg. 10 min.

By the two laſt problems, we ſee that the right aſcenſion and declination is found after the ſame manner as the longitude and latitude of a place upon the terreſtrial globe.

Bring the ſun's place to the weſtern edge of the horizon, and the degree of the equator, cut by the horizon, is his oblique deſcenſion; carry him round to the eaſtern ſide, and you will there find his oblique aſcenſion.

PROBLEM LIII.

The latitude of the place and the ſun's place being given, to find the ſun's amplitude.

That degree from the eaſt or weſt in the horizon, wherein any object riſes or ſets, is called the AMPLITUDE.

Rectify the globe to the latitude of the place, and bring the ſun's place to the eaſtern ſide of the meridian, and the arch of the horizon intercepted between that point and the eaſtern point, will be the ſun's amplitude at riſing.

If the ſame point be brought to the weſtern ſide of the horizon, the arch of the horizon intercepted between that point and the weſtern point, will be the ſun's amplitude at ſetting.

Thus on the 24th of May the ſun riſes at four, with 36 degrees of eaſtern amplitude, that is, 36 degrees from the eaſt towards the north, and ſets at eight, with 36 degrees of weſtern amplitude.

The amplitude of the ſun at riſing and ſetting increaſes with the latitude of the place; and in very high northern latitudes, the ſun ſcarce ſets before

before he riſes again. Homer had heard ſomething of this, though it is not true of the Læſtrygones, to whom he applies it.

Six days and nights a doubtful courſe we ſteer;
The next, proud LAMOS' lofty towers appear,
And Læſtrygonia's gates ariſe diſtinct in air.
The ſhepherd quitting here at night the plain,
Calls, to ſucceed his cares, the watchful ſwain.
But he that ſcorns the chains of ſleep to wear,
And adds the herdſman's to the ſhepherd's care,
So near the paſtures, and ſo ſhort the way,
His double toils may claim a double pay,
And join the labours of the night and day.

PROBLEM LIV.

To find the ſun's altitude at any given time of the day.

Set the center of the artificial ſun to his place in the ecliptic upon the globe, and rectify it to the latitude and zenith; bring the center of the artificial ſun under the ſtrong braſs meridian, and ſet the hour index to that XII which is moſt elevated; turn the globe to the given hour, and move the graduated edge of the quadrant to the center of the artificial ſun; and that degree on the quadrant which

which is cut by the ſun's center, is the ſun's height at that time.

The artificial ſun being brought under the ſtrong braſs meridian, and the quadrant laid upon it's center, will ſhew it's meridian, or greateſt altitude, for that day.

If the ſun be in the equator, his greateſt or meridian altitude is equal to the elevation of the equator, which is always equal to the co-latitude of the place.

Thus on May 24, at nine o'clock, the ſun has about 44 degrees of altitude; and at ſix in the evening of the ſame day, his altitude will be about 20 degrees.

Of the azimuthal, or vertical Circles.

The vertical point, that is, the uppermoſt point of the celeſtial globe, repreſents a point in the heavens, directly over our heads, which is called our zenith.

From this point circular lines may be conceived croſſing the horizon at right angles.

Theſe

Theſe are called AZIMUTH or VERTICAL CIRCLES. That one which croſſes the horizon at 10 deg. diſtance from the meridian on either ſide, is called an azimuth circle of 10 deg.; that which croſſes at 20, is called an azimuth of 20 deg.

The azimuth of 90 deg. is called the PRIME VERTICAL: it croſſes the horizon at the eaſtern and weſtern points.

Any AZIMUTH CIRCLE may be repreſented by the graduated edge of the braſs quadrant of altitude, when the center upon which it turns is ſcrewed to that point of the ſtrong braſs meridian which anſwers to the latitude of the place, and the place is brought into the zenith. See prob. XXX.

If the ſaid graduated edge ſhould lie over the ſun's center or place, at any given time, it will repreſent the ſun's azimuth at that time.

If the graduated edge be fixed at any point, ſo as to repreſent any particular azimuth, and the ſun's place be brought there, the horary index will ſhew at what time of that day the ſun will be in that particular azimuth.

Here

Here it may be obſerved, that the AMPLITUDE and azimuth are much the ſame.

The amplitude ſhewing the bearing of any object WHEN IT RISES OR SETS, from the EAST and WEST points of the horizon.

The azimuth the bearing of any object when it is ABOVE THE HORIZON, either from the NORTH OR SOUTH points thereof. Theſe deſcriptions and illuſtrations being underſtood, we may proceed to

PROBLEM LV.

The latitude, the ſun's place, and his altitude, being given; to find the hour of the day, and the ſun's azimuth from the meridian.

Having rectified the globe for the latitude, the zenith, and the ſun's place, turn the globe and the quadrant of altitude, ſo that the ſun's place may cut the given degree of altitude: then the index will ſhew the hour, and the quadrant will cut the azimuth in the horizon. Thus, if at London, on the 21ſt of Auguſt, the ſun's altitude be 36 deg. in the forenoon, the hour of the day will

will be IX, and the ſun's azimuth about 58 deg. from the ſouth part of the meridian.

PROBLEM LVI.

The latitude, hour of the day, and the ſun's place being given, to find the ſun's altitude and azimuth.

Rectify the globe for the latitude, the zenith, and the ſun's place, then the number of degrees contained betwixt the ſun's place and the vertex, is the ſun's meridional zenith diſtance; the complement of which to 90 deg. is the ſun's meridian altitude. If you turn the globe about until the index points to any other given hour, then bringing the quadrant of altitude to cut the ſun's place, you will have the ſun's altitude at that hour; and where the quadrant cuts the horizon, is the ſun's azimuth at the ſame time. Thus May the 1ſt at London, the ſun's meridian altitude will be 53½ deg.; and at 10 o'clock in the morning, the ſun's altitude will be 46 deg. and his azimuth about 46 deg. from the ſouth part of the meridian.

PROBLEM LVII.

The latitude of the place, and the day of the month being given; to find the depreffion of the fun below the horizon, and the azimuth at any hour of the night.

Having rectified the globe for the latitude, the zenith, and the fun's place, take a point in the ecliptic exactly oppofite to the fun's place, and find the fun's altitude and azimnth, as by the laft problem, and thefe will be the depreffion azimuth and the altitude required.

Thus if the time given be the 1ft of November, at 10 o'clock at night, the depreffion and azimuth will be the fame as was found in the laft problem.

PROBLEM LVIII.

The latitude, the fun's place, and his azimuth being given, to find his altitude, and the hour.

Rectify the globe for the latitude, the zenith, and the fun's place; then put the quadrant of altitude to the fun's azimuth in the horizon, and turn the globe till the fun's place meets the edge of the quadrant, then the ſaid edge will ſhew the altitude, and the index point to the hour.

Thus, May 21ſt, at London, when the ſun is due eaſt, his altitude will be about 24 degrees, and the hour about VII in the morning; and when his azimuth is 60 degrees ſouth-weſterly, the altitude will be about 44 $\frac{1}{2}$ degrees, and the hour about 2 $\frac{3}{4}$ in the afternoon.

Thus the latitude and the day being known, and having beſides either the altitude, the azimuth, or the hour, the other two may be eaſily found.

PROBLEM LIX.

The latitude, the ſun's altitude, and his azimuth being given, to find his place in the ecliptic, and the hour.

Rectify the globe for the latitude and zenith, and ſet the edge of the quadrant to the given azimuth; then turning the globe about, that point of the ecliptic which cuts the altitude, will be the ſun's place. Keep the quadrant of altitude in the ſame poſition, and having brought the ſun's place to the meridian, and the hour index to 12 at noon, turn the globe about till the ſun's place cuts the quadrant of altitude, and then the index will point the hour of the day.

PROBLEM LX.

The declination and meridian altitude of the ſun, or of any ſtar being given, to find the latitude of the place.

Mark the point of declination upon the meridian, according as it is either north or ſouth from the equator; then ſlide the meridian up or down in the notches, till the point of declination be ſo far diſtant from the horizon, as is the given meridian altitude; that elevation of the pole will be the latitude.

Thus if the ſun's, or any ſtar's meridian altitude be 50 degrees, and it's declination be 11 $\frac{1}{2}$ degrees north, the latitude will be 51 $\frac{1}{2}$ degrees north.

PROBLEM LXI.

To find the length of any day in the year, in any latitude, not exceeding 66 $\frac{1}{2}$ degrees.

Elevate the celeſtial globe to the latitude, and ſet the center of the artificial ſun to his place upon the ecliptic line on the globe for the given day, and bring it's center to the ſtrong braſs meridian, placing the horary index to that XII which is moſt elevated; then turn the globe till the artificial ſun cuts the eaſtern edge of the horizon, and the horary index will ſhew the time of ſun-riſing; turn it to the weſtern ſide, and you obtain the hour of ſun-ſetting.

The length of the day and night will be obtained, by doubling the time of ſun-riſing and ſetting, as before.

PROBLEM LXII.

To find the length of the longeſt and ſhorteſt days in any latitude that does not exceed 66 $\frac{1}{2}$ degrees.

Elevate the globe according to the latitude, and place the center of the artificial ſun for the longeſt day upon the firſt point of Cancer, but for the ſhorteſt day on the firſt point of Capricorn, then proceed as in the laſt problem.

But if the place hath ſouth latitude, the ſun is in the firſt point of Capricorn on their longeſt day, and in the firſt point of Cancer on their ſhorteſt day.

PROBLEM LXIII.

To find the latitude of a place, in which it's longeſt day may be of any given length between twelve and twenty-four hours.

Set the artificial ſun to the firſt point of Cancer; bring it's center to the ſtrong braſs meridian, and ſet the horary index to XII; turn the globe till it points to half the number of the given hours and minutes; then elevate or depreſs the pole, till the artificial ſun coincides with the horizon, and that elevation of the pole is the latitude required.

PROBLEM LXIV.

To find the time of the ſun's riſing and ſetting, the length of day and night, on any place whoſe latitude lies between the polar circles; and alſo the length of the ſhorteſt day in any of thoſe latitudes, and in what climate they are.

Rectify the globe to the latitude of the given place, and bring the artificial ſun to his place in the ecliptic for the given day of the month; and then bring it's center under the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated.

Then bring the center of the artificial ſun to the eaſtern part of the broad paper circle, which in this caſe repreſents the horizon, and the horary index ſhews the time of the ſun-riſing; turn the artificial ſun to the weſtern ſide, and the horary index will ſhew the time of the ſun-ſetting.

Double the time of ſun-riſing is the length of the night, and the double of that of ſun-ſetting is the length of the day.

Thus on the 5th day of June, the ſun riſes at 3 h. 40 min. and ſets at 8 h. 20 min.; by doubling each number it will appear, that the length of this day is 16 h. 40 min. and that of the night 7 h. 20 min.

The longeſt day at all places in north latitude, is when the ſun is in the firſt point of Cancer. And,

The longeſt day to thoſe in ſouth latitude, is when the ſun is in the firſt point of Capricorn.

Wherefore, the globe being rectified as above, and the artificial ſun placed to the firſt point of Cancer, and brought to the eaſtern edge of the broad paper circle, and the horary index being ſet to that XII which is moſt elevated, on turning the globe from eaſt to weſt, until the artificial ſun coincides with the weſtern edge, the number of hours counted, which are paſſed over by the horary index, is the length of the longeſt day; their complement to twenty-four hours gives the length of the ſhorteſt night.

If twelve hours be ſubtracted from the length of the longeſt day, and the remaining hours doubled, you obtain the climate mentioned by ancient hiſtorians: and if you take half the climate, and add thereto twelve hours, you obtain the

the length of the longeſt day in that climate; this holds good for every climate between the polar circles.

A climate is a ſpace upon the ſurface of the earth, contained between two parallels of latitude, ſo far diſtant from each other, that the longeſt day in one, differs half an hour from the longeſt day in the other parallel.

PROBLEM LXV.

The latitude of a place being given in one of the polar circles, (ſuppoſe the northern) to find what number of days (of 24 hours each) the ſun doth conſtantly ſhine upon the ſame, how long he is abſent, and alſo the firſt and laſt day of his appearance.

Having rectified the globe according to the latitude, turn it about until ſome point in the firſt quadrant of the ecliptic (becauſe the latitude is north) interſects the meridian in the north point of the horizon; and right againſt that point of the ecliptic, on the horizon, ſtands the day of the month when the longeſt day begins.

And if the globe be turned about till ſome point in the ſecond quadrant of the ecliptic cuts the meridian in the ſame point of the horizon, it will ſhew the ſun's place when the longeſt day ends, whence the day of the month may be found, as before; then the number of natural days contained between the times the longeſt day begins and ends, is the length of the longeſt day required.

Again, turn the globe about, until ſome point in the third quadrant of the ecliptic cuts the meridian in the ſouth part of the horizon; that point of the ecliptic will give the time when the longeſt night begins.

Laſtly, turn the globe about, until ſome point in the fourth quadrant of the ecliptic cuts the meridian in the ſouth point of the horizon; and that point of the ecliptic will be the place of the ſun when the longeſt night ends.

Or, the time when the longeſt day or night begins, being known, their end may be found by counting the number of days from that time to the ſucceeding ſolſtice; then counting the ſame number of days from the ſolſtitial day, will give the time when it ends.

OF THE EQUATION OF TIME.

It is not poſſible in a treatiſe of this kind to enter into a diſquiſition of the nature of time. It is ſufficient to obſerve, that if we would with exactneſs eſtimate the quantity of any portion of infinite duration, or convey an idea of the ſame to others, we make uſe of ſuch known meaſures as have been originally borrowed from the motions of the heavenly bodies. It is true, none of theſe motions are exactly equal and uniform, but are ſubject to ſome ſmall irregularities, which, though of no conſequence in the affairs of civil life, muſt be taken into the account; in aſtronomical calculation, there are other irregularities of more importance, one of which is the inequality of the natural day.

It is a conſideration that cannot be reflected upon without ſurprize, that wherever we look for commenſurabilities and equalities in nature, we are always diſappointed. The earth is ſpherical, but not perfectly ſo; the ſummer is unequal, when compared with the winter; the ecliptic diſagrees with the equator, and never cuts it twice in the ſame equinoctial point. The orbit of the earth has an eccentricity more than double in proportion to the ſpheroidity of it's globe: no number

number of the revolutions of the moon coincide with any number of the revolutions of the earth in it's orbit: no two of the planets meaſure one another: and thus it is wherever we turn our thoughts, ſo different are the views of the Creator from our narrow conception of things; where we look for commenſuration, we find variety and infinity.

Thus ancient aſtronomers looked upon the motion of the ſun to be ſufficiently regular for the menſuration of time; but by the accurate obſervations of later aſtronomers, it is found that neither the days, nor even the hours, as meaſured by the ſun's apparent motion, are of an equal length on two accounts.

1ſt, A natural or ſolar day of 24 hours, is that ſpace of time the ſun takes up in paſſing from any particular meridian to the ſame again; and one revolution of the earth, with reſpect to a fixed ſtar, is performed in 23 hours, 56 minutes, 4 ſeconds; therefore, the unequal progreſſion of the earth through her elliptical orbit, (as ſhe takes almoſt eight days more to run through the northern half of the ecliptic, than ſhe does to paſs through the ſouthern) is the reaſon that the length of the day is not exactly equal to the time in which

which the earth performs it's rotation about it's axis.

2dly, From the obliquity of the ecliptic to the equator, on which laſt we meaſure time; and as equal portions of one do not correſpond to equal portions of the other, the apparent motion of the ſun would not be uniform; or, in other words, thoſe points of the equator which come to the meridian, with the place of the ſun on different days, would not be at equal diſtances from each other.

PROBLEM LXVI.

To illuſtrate, by the globe, the cauſes of the equation of time.

This laſt is eaſily ſeen upon the globe, by bringing every tenth degree of the ecliptic to the graduated ſide of the ſtrong braſs meridian, and you will find that each tenth degree on the equator will not come thither with it, but in the following order from ♈ to ♋, every tenth degree of the ecliptic comes ſooner to the ſtrong braſs meridian than their correſponding 10ths on the equator; thoſe in the ſecond quadrant of the ecliptic, from ♋ to ♎, come later, from ♎ to ♑ ſooner, and from ♑ to Aries later, whilſt thoſe at the beginning of each quadrant come to the meridian at the ſame time; therefore the ſun and clock would be equal at theſe four times, if the ſun was not longer in paſſing through one-half of the ecliptic than the other, and the two inequalities joined together, compoſe that difference which is called the equation of time.

Theſe cauſes are independent of each other, ſometimes they agree, and at other times are contrary to one another.

The inequality of the natural day is the cauſe that clocks or watches are ſometimes before, ſometimes behind the ſun.

A good and well-regulated clock goes uniformly on throughout the year, ſo as to mark the equal hours of a natural day, of a mean length: a ſun-dial marks the hours of every day in ſuch a manner, that every hour is a 24th part of the time between the noon of that day, and the noon of the day immediately following. The time meaſured by a clock is called equal or true time, that meaſured by the ſun-dial apparent time.

Of the Use of the Celestial Globe, in Problems relative to the Planets.

The ſituation of the fixed ſtars being always the ſame with reſpect to one another, they have their proper places aſſigned to them on the globe.

But to the planets no certain place can be aſſigned, their ſituation always varying.

That ſpace in the heavens, within the compaſs of which the planets appear, is called the zodiac.

The latitude of the planets ſcarce ever exceeding 8 degrees, the zodiac is ſaid to reach about 8 degrees on each ſide of the ecliptic.

Upon the celeſtial globe, on each ſide of the ecliptic, are drawn eight parallel circles, at the diſtance of one degree from each other, including a ſpace of 16 degrees; theſe are croſſed at right angles, with ſegments of great circles at every 5th degree of the ecliptic; by theſe, the place of a planet on the globe, on any given day, may be aſcertained with accuracy.

PROBLEM LXVII.

To find the place of any planet upon the globe, and by that means to find it's place in the heavens; alſo, to find at what hour any planet will riſe or ſet, or be on the meridian, on any day in the year.

Rectify the globe to the latitude and ſun's place, then find the planet's longitude and latitude in an ephemeris, and ſet the graduated edge of the moveable meridian to the given longitude in the ecliptic, and counting ſo many degrees amongſt the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or ſouth; and ſet the center artificial ſun to that point, and the center will repreſent the place of the planet for that time.

Or fix the quadrant of altitude over the pole of the ecliptic, and holding the globe faſt, bring the edge of the quadrant to cut the given degree of longitude on the ecliptic; then ſeek the given latitude on the quadrant, and the place under it is the point ſought.

While

While the globe moves about it's axis, this point moving along with it will repreſent the planet's motion in the heavens. If the planet be brought to the eaſtern ſide of the horizon, the horary index will ſhew the time of it's riſing. If the artificial ſun is above the horizon, the planet will not be viſible: when the planet is under the ſtrong brazen meridian, the hour index ſhews the time it will be on that circle in the heavens: when it is at the weſtern edge, the time of it's ſetting will be obtained.

PROBLEM LXVIII.

To find directly the planets which are above the horizon at ſun-ſet, upon any given day and latitude.

Find the ſun's place for the given day, bring it to the meridian, ſet the hour index to XII, and elevate the pole for the given latitude: then bring the place of the ſun to the weſtern ſemicircle of the horizon, and obſerve what ſigns are in that part of the ecliptic above the horizon, then caſt your eye upon the ephemeris for that month, and you will at once ſee what planets poſſeſs any of thoſe elevated ſigns; for ſuch will be viſible, and fit for obſervation on the night of that day.

PROBLEM LXIX.

To find the right aſcenſion, declination, amplitude, azimuth, altitude, hour of the night, &c. of any given planet, for a day of a month and latitude given.

Rectify the globe for the given latitude and day of the month; then find the planet's place, as before directed, and then the right aſcenſion, declination, amplitude, azimuth, altitude, hour, &c. are all found, as directed in the problems for the ſun; there being no difference in the proceſs, no repetition can be neceſſary.

OF THE USE OF THE CELESTIAL GLOBE, IN PROBLEMS RELATIVE TO THE MOON.

From the ſun and planets we now proceed to thoſe problems that concern the moon, the brilliant ſatellite of our earth, which every month enriches it with it's preſence; by the mildneſs of it's light ſoftening the darkneſs of night; by it's influence affecting the tide; and by the variety of it's aſpects, offering to our view ſome very remarkable phænomena.

As the orbit of the moon is conſtantly varying in it's poſition, and the place of the node always changing, as her motion is even variable in every part of her orbit, the ſolution of the problems which relate to her, are not altogether ſo ſimple as thoſe which concern the ſun.

The moon increaſes her longitude in the ecliptic every day, about 13 degrees, 10 minutes, by which means ſhe croſſes the meridian of any place about 50 minutes later than ſhe did the preceding day.

Thus if on any day at noon her place (longitude) be in the 12th degree of Taurus, it will be 13 deg. 10 min. more, or 25 deg. 10 min. in Taurus on the ſucceeding noon.

It is new moon when the ſun and moon have the ſame longitude, or are in or near the ſame point of the ecliptic.

When they have oppoſite longitudes, or are in oppoſite points of the ecliptic, it is full moon.

To aſcertain the moon's place with accuracy, we muſt recur to an ephemeris; but as even in moſt ephemerides the moon's place is only ſhewn at the beginning of each day, or XII o'clock at noon, it becomes neceſſary to ſupply by a table this deficiency, and aſſign thereby her place for any intermediate time.

In the nautical ephemeris, publiſhed under the authority of the Board of Longitude, we have the moon's place for noon and midnight, with rules for accurately obtaining any intermediate time; but as this ephemeris may not always be at hand, we ſhall inſert, from Mr. Martin's treatiſe on the globes, a table for finding the hourly motion of the moon. In order, however, to uſe this table, it will be neceſſary firſt TO FIND THE QUANTITY OF THE MOON'S DIURNAL MOTION

MOTION IN THE ECLIPTIC, for any given day; for the quantity of the moon's diurnal motion varies from about 11 deg. 46 min. the leaſt, to 15 deg. 16 min. when greateſt.

The following tables are calculated from the leaſt of 11 deg. 46 min. to the greateſt of 15 deg. 16 min. every column being increaſing 10 minutes; upon the top of the column is the quantity of the diurnal motion, and on the ſide of the table are the 24 hours, by which means it will be eaſy to find what part of the diurnal motion of the moon anſwers to any given number of hours.

Thus ſuppoſe the diurnal motion to be 12 32, look on the top column for the number neareſt to it, which you will find to be 12 36, in the ſixth column; and under it, againſt 9 hours, you will find 4 deg. 43 min. which is her motion in the ecliptic in the ſpace of 9 hours for that day. The quantity of the diurnal motion for any day is found by taking the difference between it and the preceding day.

Thus let the diurnal motion for the 11th of May, 1787, be required.

	SIGNS.	DEG.	MIN.
On the 11th of May her place was	11	2	35
On the 10th of May -	10	19	47
The diurnal motion ſought		12	48

TABLES

TABLES

FOR FINDING THE HOURLY MOTION OF THE MOON, AND THEREBY HER TRUE PLACE AT ANY TIME OF THE DAY.

TABLE I.

HOURS.	11 46	11 56	12 6	12 16	12 26	12 36	12 46	12 56	13 6	13 16	13 26
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m	d. m	d. m.	d. m.	l. m.	d. m.
1	0 29	0 30	0 30	0 30	0 31	0 31	0 32	0 32	0 33	0 33	0 34
2	0 59	1 0	1 0	1 1	1 2	1 33	1 4	1 5	1 5	1 6	1 43
3	1 28	1 20	1 31	1 32	1 33	1 3[illegible]	1 36	1 37	1 38	1 39	1 41
4	1 58	1 59	2 1	2 3	2 4	2 6	2 8	2 9	2 11	2 13	2 14
5	2 27	2 29	2 31	2 34	2 35	2 37	2 40	2 42	2 44	2 46	2 48
6	2 57	2 59	3 1	3 4	3 6	3 9	3 11	3 14	3 16	3 19	3 21
7	3 26	3 29	3 32	3 35	3 38	3 40	3 43	3 46	3 49	3 52	3 55
8	3 55	3 59	4 2	4 6	4 9	4 12	4 15	4 19	4 22	4 25	4 20
9	4 25	4 28	4 32	4 36	4 40	4 43	4 47	4 51	4 55	4 58	5 2
10	4 54	4 58	5 3	5 7	5 11	5 1	5 19	5 23	5 27	5 32	5 56
11	5 24	5 28	5 33	5 37	5 42	5 4	5 51	5 56	6 0	6 3	6 9
12	5 53	5 58	6 3	6 8	6 13	6 18	6 23	6 28	6 33	6 38	6 43
13	6 22	6 28	6 33	6 39	6 44	6 49	6 55	7 0	7 6	7 11	7 17
14	6 52	6 58	7 3	7 9	7 15	7 21	7 2	7 33	7 38	7 44	7 50
15	7 21	7 27	7 34	7 40	7 46	7 52	7 59	8 5	8 11	8 17	8 24
16	7 51	7 57	8 4	8 11	8 17	8 24	8 31	8 37	8 44	8 51	8 57
17	8 20	8 27	8 34	8 41	8 48	8 55	9 3	9 10	9 17	9 24	9 31
18	8 49	8 57	9 4	9 12	9 19	9 27	9 34	9 42	9 49	9 57	10 4
19	9 19	9 26	9 35	9 43	9 51	9 58	10 6	10 14	10 22	10 30	10 38
20	9 48	9 56	10 5	10 13	10 21	10 30	10 38	10 47	10 55	11 3	11 12
21	10 17	10 26	10 36	10 44	10 53	11 1	11 10	11 19	11 27	11 36	11 43
22	10 47	10 56	11 6	11 15	11 21	11 33	11 42	11 51	12 0	12 10	12 19
23	11 17	11 26	11 36	11 46	11 55	12 4	12 14	12 24	12 33	12 43	12 52
24	11 46	11 56	12 6	12 16	12 26	12 36	12 46	2 56	13 6	13 16	13 26

TABLE II.

HOURS.	13 30	13 40	13 50	14 6	14 16	14 26	14 36	14 46	14 56	15 6	15 16
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	0 31	0 34	0 35	0 36	0 36	0 36	0 36	0 37	0 37	0 38	0 38
2	1 8	1 9	1 16	1 10	1 11	1 12	1 13	1 14	1 15	1 15	1 16
3	1 42	1 42	1 46	1 46	1 47	1 48	1 49	1 51	1 51	1 53	1 54
4	2 16	2 8	2 19	2 21	2 22	2 24	2 26	2 28	2 20	2 31	2 33
5	2 50	2 52	2 54	2 56	2 58	3 0	3 3	3 5	3 7	3 9	3 11
6	3 24	3 26	3 29	3 31	3 34	3 39	3 39	3 41	3 45	3 46	3 9
7	3 58	4 1	4 4	4 7	4 10	4 10	4 15	4 18	4 21	4 24	4 7
8	4 32	4 35	4 39	4 42	4 45	4 49	4 52	4 55	4 59	5 2	5 5
9	5 6	5 10	5 13	5 17	4 21	5 25	5 28	5 32	5 36	5 40	5 43
10	5 40	5 42	5 48	5 52	5 57	6 1	6 5	6 9	6 13	6 17	6 22
11	6 14	6 19	6 23	6 28	6 32	6 37	6 41	6 46	6 51	6 55	7 0
12	6 48	6 53	6 58	7 3	7 8	7 13	7 28	7 23	7 28	7 33	7 28
13	7 22	7 27	7 33	7 38	7 44	7 49	7 54	8 6	8 5	8 11	8 10
14	7 56	8 0	8 8	8 13	8 19	8 25	8 31	8 37	8 43	8 48	8 54
15	8 30	8 36	8 42	8 49	8 55	9 1	9 7	9 14	9 20	9 26	9 32
16	9 4	9 11	9 17	9 21	9 12	9 37	9 44	9 51	9 57	10 4	10 11
17	9 38	9 45	9 52	9 59	10 20	10 13	10 20	10 28	10 33	10 42	10 49
18	10 12	10 19	10 27	10 34	10 42	10 49	10 57	11 4	11 12	11 19	11 27
19	10 46	10 54	11 5	11 10	11 18	11 26	11 34	11 41	11 49	11 57	12 5
20	11 29	11 38	11 37	11 24	11 8	12 2	12 10	12 18	12 17	12 35	12 42
21	11 55	12. 3	12 11	12 20	12 9	12 38	12 40	12 55	13 4	13 13	13 21
22	12 28	12 37	12 46	12 55	13 5	13 14	13 23	13 33	13 41	13 50	13 50
23	13 2	13 12	13 21	13 31	13 43	13 59	13 59	14 9	14 10	14 28	14 38
24	13 36	13 46	13 56	14 6	14 16	14 26	14 36	14 46	14 56	15 6	15 16

The

The moon's path may be reprefented on the globe in a very pleafing manner, by tying a filken line over the furface of the globe, exactly on the ecliptic; then finding, by an ephemeris, the place of the nodes for the given time, confine the filk at thefe two points, and at 90 degrees diftance from them elevate the line about 5¼ deg. from the ecliptic, and deprefs it as much on the other, and it will then reprefent the lunar orbit for that day.

PROBLEM LXX.

To find the moon's place in the ecliptic, for any given hour of the day.

Firft, without an ephemeris, only knowing the age of the moon, which may be obtained from every common almanack.

Elevate the north pole of the celeftial globe to 90 degrees. and then the equator will be in the plane of, and coincide with the broad paper circle; bring the firft point of Aries, marked ♈ on the globe, to the day of the new moon on the faid broad paper circle, which anfwers to the fun's place for that day; and the day of the moon's age will ftand againft the fign and degree of the moon's moon's mean place; to which place apply a ſmall patch, to repreſent the moon.

But if you are provided with an ephemeris,* that will give the moon's latitude and place in the ecliptic; firſt note her place in the ecliptic upon the globe, and then counting ſo many degrees amongſt the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or ſouth upon the given day, and that will be the point which repreſents the true place of the moon for that time, to which apply the artificial ſun, or a ſmall patch.

Thus on the 11th of May, 1787, ſhe was at noon in 2 deg. 35 min. of Piſces, and her latitude was 4 deg. 18 min.; but as her diurnal motion for that day is 12 48 in nine hours, ſhe will have paſſed over 4 deg. 47 min. which added to her place at noon, gives 7 h. 22 m. for her place on the 11th of May, at nine at night.

PROBLEM

* The nautical almanack is the beſt Engliſh ephemeris.

PROBLEM LXXI.

To find the moon's declination for any given day or hour.

The place in her orbit being found, by prob. lxx. bring it to the brazen meridian; then the arch of the meridian contained between it and the equinoctial, will be the declination fought.

PROBLEM LXXII.

To find the moon's greateft and leaft meridian altitudes in any given latitude, that of London for example.

It is evident, this can happen only when the afcending node of the moon is in the vernal equinox; for then her greateft meridian altitude will be 5 deg. greater than that of the fun, and therefore about 67 deg.; alfo her leaft meridian altitude will be 5 deg. lefs than that of the fun, and therefore only 10 deg.: there will therefore be 57 deg. difference in the meridian altitude of the moon; whereas that of the fun is but 47 deg.

N. B.

N. B. When the ſame aſcending node is in the autumnal equinox, then will her meridian altitude differ by only 37 deg.; but this phænomenon can ſeparately happen but once in the revolution of a node, or once in the ſpace of nineteen years: and it will be a pleaſant entertainment to place the ſilken line to croſs the ecliptic in the equinoctial points alternately; for then the reaſon will more evidently appear, why you obſerve the moon ſometimes within 23 deg. of our zenith, and at other times not more than 10 deg. above the horizon, when ſhe is full ſouth.

PROBLEM LXXIII.

To illuſtrate, by the globe, the phænomenon of the harveſt moon.

About the time of the autumnal equinox, when the moon is at or near the full, ſhe is obſerved to riſe almoſt at the ſame time for ſeveral nights together; and this phænomenon is called the HARVEST MOON.

This circumſtance, with which farmers were better acquainted than aſtronomers, till within theſe few years, they gratefully aſcribed to the goodneſs of God, not doubting that he had ordered

ordered it on purpofe to give them an immediate fupply of moon-light after fun-fet, for their greater conveniency in reaping the fruits of the earth.

In this inftance of the harveft moon, as in many others difcoverable by aftronomy, the wifdom and beneficence of the Deity is confpicuous, who really fo ordered the courfe of the moon, as to beftow more or lefs light on all parts of the earth, as their feveral circumftances and feafons render it more or lefs ferviceable.*

About the equator, where there is no variety of feafons, moon-light is neceffary for gathering in the produce of the ground; and there the moon rifes about 50 minutes later every day or night than on the former.

At confiderable diftances from the equator, where the weather and feafons are more uncertain, the autumnal full moons rife at fun-fet from the firft to the third quarter.

At the poles, where the fun is for half a year abfent, the winter full moons fhine conftantly without

* Fergufon's Aftronomy.

without ſetting, from the firſt to the third quarter.

But this obſervation is ſtill further confirmed, when we conſider that this appearance is only peculiar with reſpect to the full moon, from which only the farmer can derive any advantage; for in every other month, as well as the three autumnal ones, the moon, for ſeveral days together, will vary the time of it's riſing very little; but then in the autumnal months this happens about the time when the moon is at the full; in the vernal months, about the time of new moon; in the winter months, about the time of the firſt quarter; and in the ſummer months, about the time of the laſt quarter.

Theſe phænomena depend upon the different angles made by the horizon, and different parts of the moon's orbit, and that the moon can be full but once or twice in a year, in thoſe parts of her orbit which riſe with the leaſt angles.

The moon's motion is ſo nearly in the ecliptic, that we may conſider her at preſent as moving in it.

The different parts of the ecliptic, on account of it's obliquity to the earth's axis, make very different angles with the horizon as they riſe or ſet. Thoſe parts, or ſigns, which riſe with the ſmalleſt angles, ſet with the greateſt, and vice verſa. In equal times, whenever this angle is leaſt, a greater portion of the ecliptic riſes, than when the angle is larger.

This may be ſeen, by elevating the globe to any conſiderable latitude, and then turning it round it's axis in the horizon.

When the moon, therefore, is in thoſe ſigns which riſe or ſet with the ſmalleſt angles, ſhe will riſe or ſet with the leaſt difference of time, and with the greateſt difference in thoſe ſigns which riſe or ſet with the greateſt angles.

Thus in the latitude of London, at the time of the vernal equinox, when the ſun is ſetting in the weſtern part of the horizon, the ecliptic then makes an angle of 62 deg. with the horizon; but when the ſun is in the autumnal equinox, and ſetting in the ſame weſtern part of the horizon, the ecliptic makes an angle but of 15 deg. with the horizon; all which is evident by a bare inſpection of the globe only.

Again,

Again, according to the greater or leſs inclination of the ecliptic to the horizon, ſo a greater or leſs degree of motion of the globe about it's axis will be neceſſary to cauſe the ſame arch of the ecliptic to paſs through the horizon; and conſequently the time of it's paſſage will be greater or leſs, in the ſame proportion; but this will be beſt illuſtrated by an example.

Therefore, ſuppoſe the ſun in the vernal equinox, rectify the globe for the latitude of London, and place of the ſun; then bring the vernal equinox, or ſun's place, to the weſtern edge of the horizon, and the hour index will point preciſely to VI; at which time, we will alſo ſuppoſe the moon to be in the autumnal equinox, and conſequently at full, and riſing exactly at the time of ſun-ſet.

But on the following day, the ſun, being advanced ſcarcely one degree in the ecliptic, will ſet again very nearly at the ſame time as before; but the moon will, at a mean rate, in the ſpace of one day, paſs over 13 deg. in her orbit; and therefore, when the ſun ſets in the evening after the equinox, the moon will be below the horizon, and the globe muſt be turned about till 13 deg. of Libra come up to the edge of the horizon, and

and then the index will point to 7 h. 16 m. the time of the moon's rifing, which is an hour and ¾ after fun-fet for dark night. The next day following, there will be 2½ hours, and fo on fucceffively, with an increafe of 1¾ h. dark night each evening refpectively, at this feafon of the year; all owing to the very great angle which the ecliptic makes with the horizon at the time of the moon's rifing.

On the other hand, fuppofe the fun in the autumnal equinox, or beginning of Libra, and the moon oppofite to it in the vernal equinox, then the globe (rectified as before) being turned about till the fun's place comes to the weftern edge of the horizon, the index will point to VI, for the time of his fetting, and the rifing of the full moon on that equinoctial day. On the following day, the fun will fet nearly at the fame time; but the moon being advanced (in the 24 hours) 13 deg. in the ecliptic, the globe muft be turned about till that arch of the ecliptic fhall afcend the horizon, which motion of the globe will be very little, as the ecliptic now makes fo fmall an angle with the horizon, as is evident by the index, which now points to VI h. 17 deg. for the time of the moon's rifing on the fecond day, which is but about ¼ of an hour after fun-fet. The third day, the moon will riſe within ½ an hour; on the fourth, within ¾ of an hour, and ſo on; ſo that it will be near a week before the nights will be an hour without illumination; and in greater latitudes, this difference will be ſtill greater, as you will eaſily find by varying the caſe, in the practice of this celebrated problem, on the globe.

This phænomenon varies in different years; the moon's orbit being inclined to the ecliptic about 5 degrees, and the line of the nodes continually moving retrograde, the inclination of her orbit to the equator will be greater at ſome ſeaſons than it is at others, which prevents her haſtening to the northward, or deſcending ſouthward, in each revolution, with an equal pace.

Of the Tides.

A tide is that motion of the water in the ſea and rivers, by which they are found regularly to riſe and fall.

The general cauſe of the tides was diſcovered by Sir Iſaac Newton, and are deduced from the following conſiderations.

We find, by conſtant experience, that all bodies fall down to the earth's ſurface in perpendicular lines; and as lines perpendicular to the ſurface of a ſphere, tend towards the center, therefore the lines, along which all heavy bodies fall, are directed towards the earth's center.

As theſe bodies apparently fall by their weight or gravity, the law by which they fall is called the law of gravitation.

Now as bodies, by their gravity, fall towards the earth, it has not been deemed improper to ſay, that the earth attracts thoſe bodies, and therefore, in reſpect to the earth, the word GRAVITATION and ATTRACTION may be uſed one for the other, as by them is meant no more than the

 power,

power, or law, by which bodies tend towards it's center.

Sir Isaac Newton, by a sagacity peculiar to himself, discovered from many observations, that this law of gravitation or attraction was universally diffused throughout the solar system, and that the regular motions observed among the heavenly bodies, were governed by the same principle; so that the earth and moon attracted each other, and were both of them attracted by the sun. Also, that the force of attraction, exerted by these bodies one on the other, was less as the distance increased, in proportion to the squares of those distances.

It is not in the motion of the celestial bodies only, that the effects of this mutual gravitation is visible; we are now to explain by the same principle, a phænomenon which passes upon the earth, the ebbing and flowing of the sea.

As the earth is attracted by the sun and moon, the parts of the earth will not gravitate towards it's center in the same manner as if those parts were not affected by such attractions.

It

It is alſo very evident, that if the earth was entirely free from theſe actions of the ſun and moon, the oceans would then be equally attracted towards it's center, on all ſides, by the force of gravity, and would continue in perfect ſtagnation, without ever ebbing or flowing.

But as the ocean is not free from theſe actions, it muſt needs riſe higher in thoſe places where the ſun and moon diminiſh it's gravity, or where the ſun and moon have the greateſt attraction.

As the force of gravity will be moſt diminiſhed in thoſe parts of the earth where her attraction is moſt powerful, (which muſt be when ſhe is neareſt to, or in the zenith of thoſe places) the waters in thoſe parts will riſe higheſt, and it will be FULL SEA, or FLOOD, in ſuch places.

The parts of the earth directly under the moon, and thoſe alſo in their nadir, or ſuch places as are diametrically oppoſite to thoſe where the moon is in the zenith, will have the flood, or high water, at the ſame time.

For either hemiſphere of the earth would gravitate equally towards the other half, were they free from all external attraction.

But by the action of the moon, the gravitation of one hemifphere towards the center is diminifh-ed, and that of the other is increafed.

Now in the hemifphere next the moon, the parts in the zenith being moft attracted, and thereby their gravitation towards the earth's cen-ter diminifhed ; confequently, the waters in thofe parts muft be higher than in any other part of this hemifphere.

But in the hemifphere which is moft remote from the moon, the nadir, or moft diftant point, being lefs attracted by the moon than thofe parts that are nearer, is left as it were behind, while all the other parts, and even the center itfelf, is more attracted towards her, and confequently the water will be higher in that point than at any other part of this hemifphere.

The two middle points will therefore be higheft in their refpective hemifpheres; the one being really more ELEVATED, the other lefs DEPRESSED by the moon's attraction, than the adjacent parts.

Thoſe parts of the earth where the moon appears in the horizon, or is 90 degrees diſtant from the zenith and nadir, will have the ebbs or loweſt waters.

For as the waters in the zenith and nadir riſe at the ſame time, the waters in their neighbourhood will preſs towards thoſe places, to maintain the equilibrium; and to ſupply the place of theſe, others will move the ſame way, and ſo on to places at 90 degrees diſtant from the zenith and nadir; conſequently, in thoſe places where the moon appears in the horizon, the waters will have more liberty to deſcend towards the center, and therefore in thoſe places they will be the loweſt.

Hence it plainly follows, that if the ſurface of the earth was covered with water, it would put on a ſpheroidal, or egg-like figure, whoſe longeſt diameter would paſs through the place where the moon is vertical, and the ſhorteſt diameter will be where ſhe is in the horizon; and as the moon apparently ſhifted her poſition from eaſt to weſt, in going round the earth every day, the longer diameter of the ſpheroid would follow her motion, and thus occaſion the two floods and ebbs

 obſervable

obſervable in about every 25 hours, which is about the length of a lunar day.

Hence in any place, the greater the moon's mid-day altitude, the greater the evening tides will be; and the greater the midnight depreſſion, the greater the tides will be.

The ſummer evening and the winter morning tides are higheſt, becauſe the moon's ſummer altitude, and winter depreſſion, are greateſt, eſpecially when her declination is north in ſummer, and ſouth in winter.

The time of high water is not preciſely at the time of the moon's coming to the meridian, but about an hour or two after.

For the moon acts with ſome force after ſhe has paſt the meridian, and thereby adds to the libration, or waving motion, which ſhe has put the water into, whilſt ſhe was in the meridian, in the ſame manner as a ſmall force applied upwards to a ball already raiſed to ſome height, will raiſe it ſtill higher.

The

The tides are greater than ordinary twice every month, that is, about the times of new and full moon; they are called SPRING TIDES.

For at theſe times the actions of both ſun and moon concur to draw in the ſame right line; and therefore the ſea muſt be moſt elevated. In conjunction, or when the ſun and moon are on the ſame ſide of the earth, they both conſpire to raiſe the water in the zenith, and conſequently in the nadir. And when the ſun and moon are in oppoſition, that is, when the earth is between them, whilſt one makes high water in the zenith and nadir, the other does the ſame in the nadir and zenith.

The tides are leſs than ordinary twice every month, that is, about the times of the firſt and laſt quarters of the moon; and theſe are called NEAP TIDES.

Becauſe in theſe quarters of the moon, the ſun raiſes the waters where the moon depreſſes it; and depreſſes where the moon raiſes; ſo that the tides are made only by the difference of their actions.

It is to be obſerved, that the ſpring tides do not happen directly on the new and full moons, but rather a day or two after, when the action of the ſun and moon have conſpired together for a conſiderable time. In like manner, the neap tides happen a day or two after the quarters.

When the moon is in her perigæum, or neareſt approach to the earth, the tides increaſe more in the ſame circumſtances than at other times.

The ſpring tides are greateſt about the times of the equinoxes, that is, about the latter end of March and September, than at any other times of the year, and the neap tides are the leſs.

Becauſe the longer diameter of the ſpheroid will at that time be in the earth's equator, and conſequently deſcribe a great circle of the earth, by whoſe diurnal rotation the floods will move ſwifter, as deſcribing a great circle in the ſame time they uſed to deſcribe a leſſer circle, by which means the waters will be thrown more forcibly againſt the ſhores, and muſt riſe higher.

The circumſtances hitherto explained, would always take place, if the whole ſurface of the earth was covered with ſea ; but ſince it is not ſo, there ariſe a great many different appearances, which require particular ſolutions, in which the ſituation of the ſhores, &c. muſt be conſidered ; for theſe, we muſt refer the reader to larger works on aſtronomy.

Small inland ſeas, ſuch as the Mediterranean and the Baltic, are but little ſubject to tides ; becauſe the action of the ſun and moon is nearly equal at both extremities. In very high latitudes the tides are alſo very inconſiderable ; for the ſun and moon always acting near the equator, and raiſing the water towards the torrid zone, the neighbourhood of the poles muſt be conſequently deprived of thoſe waters, and the ſea muſt be low, relative to other parts.

PROBLEM LXXIV.

To find what azimuth the moon is upon at any place when it is flood, or high water ; and thence the high tide for any day of the moon's age at the ſame place.

Having obſerved the hour and minute of high water, about the time of new or full moon, rectify the globe to the latitude and ſun's place ; find the

moon's

moon's place and latitude in an ephemeris, to which ſet the artificial moon,* and ſcrew the quadrant of altitude in the zenith; turn the globe till the horary index points to the time of flood, and lay the quadrant over the center of the artificial moon, and it will cut the horizon in the point of the compaſs upon which the moon was, and the degrees on the horizon contained between the ſtrong braſs meridian and the quadrant, will be the moon's azimuth from the ſouth.

To find the time of high water at the ſame place.

Rectify the globe to the latitude and zenith, find the moon's place by an ephemeris for the given day of her age, or day of the month, and ſet the artificial moon to that place in the zodiac; put the quadrant of altitude to the azimuth before found, and turn the globe till the artificial moon is under it's graduated edge, and the horary index will point to the time of the day on which it will be high water.

THE

* Or patch repreſenting the moon.

THE USE OF THE CELESTIAL GLOBE IN THE SOLUTION OF PROBLEMS ASCERTAINING THE PLACES AND VISIBLE MOTIONS OR ORBITS OF COMETS.*

There is another claſs, or ſpecies of planets, which are called COMETS. Theſe move round the ſun in regular and ſtated periods of times, in the ſame manner, and from the ſame cauſe, as the reſt of the planets do; that is, by a centripetal force, every where decreaſing as the ſquares of the diſtances increaſe, which is the general law of the whole planetary ſyſtem. But this centripetal force in the comets being compounded with the projectile force, in a very different ratio from that which is found in the planets, cauſes their orbits to be much more ecliptical than thoſe of the planets, which are almoſt circular.

But whatever may be the form of a comet's orbit in reality, their geocentric motions, or the apparent paths which they deſcribe in the heavens among the fixed ſtars, will always be circular, and therefore may be ſhewn upon the ſurface of a celeſtial globe, as well as the motions and places of any of the reſt of the planets.

To

* Martin's Deſcription and Uſe of the Globes.

To give an inſtance of the cometary praxis on the globe, we ſhall chuſe that comet, for the ſubject of theſe problems, which made it's appearance at Boſton, in New England, in the months of October and November, 1758, in it's return to the ſun; after which, it approached ſo near the ſun, as to ſet HELIACALLY, or to be loſt in it's beams for ſome time, ſpent in paſſing the perihelion. Then afterwards emerging from the ſolar rays, it appeared retrograde in it's courſe from the ſun towards the latter end of March, and ſo continued the whole month of April, and part of May, in the Weſt Indies, particularly in Jamaica, whoſe latitude rendered it viſible in thoſe parts, when it was, for the greateſt part of the time, inviſible to us, by reaſon of it's ſouthern courſe through the heavens.

When two obſervations can be made of a comet, it will be very eaſy to aſſign it's courſe, or mark it out upon the ſurface of the celeſtial globe. Theſe, with regard to the above-mentioned comet, we have, and they are ſufficient for our purpoſe in regard to the ſolution of cometary problems.

By an obſervation made at Jamaica on the 31ſt of March, 1759, at V o'clock in the morning, the

the comet's altitude was found to be 22 deg. 50 min. and it's azimuth 71 deg. ſouth-eaſt. From hence we ſhall find it's place on the ſurface of the globe, by the following problem.

PROBLEM LXXV.

To rectify the globe for the latitude of the place of obſervation in Jamaica, latitude 17 deg. 30 min. and given day of the month, viz. March 31ſt.

Elevate the north pole to 17 deg. 30 min. above the horizon, then fix the quadrant of altitude to the ſame degree in the meridian, or zenith-point. Again, the ſun's place for the 31ſt of March is in 10 deg. 34 min. ♈, which bring to the meridian, and ſet the hour index at XII, and the globe is then rectified for the place and time of obſervation.

PROBLEM LXXVI.

To determine the place of a comet on the ſurface of the celeſtial globe from it's given altitude, azimuth, hour of the day, and latitude of the place.

The

The globe being rectified to the given latitude, and day of the month, turn it about towards the east, till the hour index points to the given time, viz. V o'clock in the morning; then bring the quadrant of altitude to intersect the horizon in 71 deg. the given azimuth in the south-east quarter; then, under 22 deg. 50 min. the given altitude, you will find the comet's place, where you may put a small patch to represent it.

PROBLEM LXXVII.

To find the latitude, longitude, declination, and right ascension of the comets.

In the circles of latitude contained in the zodiac, you will find the latitude of the comet to be about 3 deg. 30 min. from the ecliptic; the same circle of latitude reduces it's place to the ecliptic in 26 deg. 30 min. of ♒, which is it's longitude sought. Then bring the cometary patch to the brazen meridian, and it's declination will be shewn to be 9 deg. 15 min. south. At the same time, it's right ascension will be 327 deg. 30 min.

PROBLEM LXXVIII.

To ſhew the time of the comet's riſing, ſouthing, ſetting, and amplitude, for the day of the obſervation at Jamaica.

Bring the place of the comet into the eaſtern ſemi-circle of the horizon, (the globe being rectified as directed) the index will point to III hours 15 min. which is the time of it's riſing in the morning at Jamaica, the amplitude 10 deg. very nearly, to the ſouth. The patch being brought to the meridian, the index points to IX o'clock 10 min. for the time of culminating, or being ſouth to them. Laſtly, bring the patch to touch the weſtern meridian, and the index will point to III in the afternoon, for the time of the comet's ſetting, with 10 deg. of ſouthern amplitude, of courſe.

PROBLEM LXXIX.

From the comet's place being given, to find the time of it's riſing in the horizon of London, on the 31ſt day of March, 1759.

For this purpose, you need only rectify the globe for the given latitude of London, and bring the cometary patch to the eastern horizon, and the index points to III hours, 45 min. for the time of it's rising at London, with about 14 deg. of south amplitude; then turn the patch to the western horizon, and the index points to II h. 25 min. the time of it's setting.

N. B. From hence it appears, the comet rose soon enough that morning to have been observed at London, had the heavens been clear, and the astronomers been before-hand apprized of such a phænomenon.

PROBLEM LXXX.

To determine another place of the same comet, from an observation made at London on the 6th day of May, at X in the evening.

On the 6th day of May, 1759, at X at night, the place of the comet was observed, and it's distance measured with a micrometer, from two fixed stars marked μ and ν in the constellation called HYDRA, and it's altitude was found to be 16 deg. and it's azimuth 37 deg. south-west, from whence it's place on the surface

ſurface of the globe is exactly determined, as in prob. lxxvi. and having ſtuck a patch thereon, you will have the two places of the comet on the ſurface of the globe, for the two diſtant days and places of obſervation, as required.

PROBLEM LXXXI.

From two given places of a comet, to aſſign it's apparent path among the fixed ſtars in the heavens.

The two places of the comet being determined by the obſervations on the 31ſt of March, 1758, and the 6th of May following, and denoted by two patches reſpectively, you muſt move the globe up and down, in the notches of the horizon, till ſuch time you bring both the patches to coincide with the horizon; then will the arch of the horizon between the two patches ſhew, upon the celeſtial globe, the apparent place of the comet in the interval between the two obſervations, and by drawing a line with a black lead pencil along by the frame of the horizon, it's path on the ſurface of the globe will be delineated, as required. And here it may be obſerved, that it's apparent path lay through the following ſouthern conſtellations, viz. the tail of Capricorn, the tail of Piſces Auſtralis, by the head of Indus, the neck and body of Pavo, through the neck of Apus, below Triangulum Auſtrale, above Muſca, by the lowermoſt of the Croſiers, acroſs the hind legs and through the tail of Centaurus, from thence between the two ſtars in the back of the Hydra before-mentioned; after this, it paſſed on to Sextans Uraniæ, and then to the ecliptic near Cor Leonis; ſoon after which, it totally diſappeared.

PROBLEM LXXXII.

To eſtimate the apparent velocity of a comet, two places thereof being given by obſervation.

Let one place be aſcertained near the beginning of it's appearance, and the other towards the end thereof; then bring theſe two places to the horizon, and count the number of degrees interſected between them, which being the ſpace apparently deſcribed in a given time, will be the velocity required. Thus, in the caſe of the above-mentioned comet, you will find, that it deſcribed more than 150 deg. in the ſpace of 36 days, which is more than 4 deg. per day.

PROBLEM

PROBLEM LXXXIII.

To represent the general phænomena of the comet, for any given latitude.

Bring the visible path of the comet to coincide with the horizon, by which it was drawn, and then observe what degree of the meridian is in the north point of the horizon, which, in the case of the foregoing comet, will be the 23 deg. This will shew the greatest latitude in which the whole path can be visible in any latitude less than this, as that of Jamaica; where, for instance, the most southern part of the path will be elevated more than 5 deg. above the horizon, and the comet visible through the whole time of it's apparition. But rectifying the globe for the latitude of London, the path of the said comet will be for the most part invisible, or below the horizon; and therefore it could not have been seen in our latitude, but at times very near the beginning and end of it's appearance; because, by bringing the comet's path on one part to the south point of the horizon, it will immediately appear in what part the comet ceases to be visible; and then bringing the other part of the path to the point, it will appear in what part it will again become viſible.

After this manner may the problems relating to any other comets be performed; and thus the paths of the ſeveral comets, which have hitherto been obſerved, may be ſeverally delineated on the celeſtial globe, and their various phænomena in different latitudes be thereby ſhewn.

The Use of the Celestial Globe, in Problems relative to the fixed Stars.

The uſe of the celeſtial globe is in no inſtance more conſpicuous, than in the problems concerning the fixed ſtars. Among many other advantages, it will, if joined with obſervations on the ſtars themſelves, render the practice and theory of other problems eaſy and clear to the pupil, and vaſtly facilitate his progreſs in aſtronomical knowledge.

The heavens are as much ſtudded over with ſtars in the day, as in the night; only that they are then rendered inviſible to us, by the brightneſs of the ſolar rays. But when this glorious luminary deſcends below the horizon, they begin gradually

gradually to appear. When the ſun is about 12 degrees below the horizon, ſtars of the firſt magnitude become viſible: when he is 13 degrees, thoſe of the ſecond are ſeen: when 14 degrees, ſtars of the third magnitude appear: when 15 degrees, thoſe of the fourth preſent themſelves to view: when he is deſcended about 18 degrees, the ſtars of the fifth and ſixth magnitude, and thoſe that are ſtill ſmaller, become conſpicuous, and the azure arch ſparkles with all it's glory.

PROBLEM LXXXIV.

To find the right aſcenſion and declination of any given ſtar.

Bring the given ſtar to the meridian, and the degree under which it lies is it's declination; and the point in which the meridian interſects the equinoctial is it's right aſcenſion. For inſtance, let Arcturus be the given ſtar; this brought to the meridian will be ſeen under the 20 deg. 20 min. which is therefore it's declination, north; and it's right aſcenſion is, at the ſame time, ſhewn in the equinoctial to be 211 deg. Again, another inſtance may be Sirius, the dog-ſtar,

 which,

which, brought to the meridian, will be feen under the 16 deg. 30 min. which is his declination, fouth; and it's right afcenfion 98 deg. 20 min. in the equinoctial line.

PROBLEM LXXXV.

To find the latitude and longitude of a given ftar.

Bring the pole of the ecliptic to the meridian, over which fix the quadrant of altitude, and holding the globe very fteady, move the quadrant to lie over the given ftar, and it will cut that degree in the edge, as will fhew it's latitude from the ecliptic, and in the ecliptic the quadrant will cut that degree which is called it's place REDUCED TO THE ECLIPTIC, or longitude, from the beginning of Aries. Thus, with refpect to Arcturus, it's latitude from the ecliptic will be found 30 deg. 30 min. and it's longitude in the ecliptic about 20 deg. 20 min. of Libra. This problem regards either pole, as the ftars are in the northern or fouthern hemifpheres, refpectively.

PROBLEM LXXXVI.

The right aſcenſion and declination of a ſtar being given, to find it's place on the globe.

Turn the globe till the meridian cuts the equinoctial in the degree of right aſcenſion. Thus, for example, ſuppoſe the right aſcenſion of Aldebaran to be 65 deg. 30 m. and it's declination to be 16 deg. north, then turn the globe about till the meridian cuts the equinoctial in 65 deg. 30 min. and under the 16 deg. of the meridian, on the northern part, you will obſerve the ſtar Aldebaran, or the bull's eye.

PROBLEM LXXXVII.

To find the time of the riſing, ſouthing, ſetting, amplitude, &c. of any ſtar, in a given latitude and day of the year.

The precept is the ſame as in the problems for the ſun. Thus, let it be required to know at what time the Pleiades (or ſeven ſtars) riſe, ſet, &c. in the latitude of London, on the 11th of May. The globe being rectified for the latitude of London, and the ſun's place for the given day,

turn

turn the globe about till you bring the Pleiades into the eaftern femi-circle of the horizon, and the index will point to 34 deg. 45 min. the time of their rifing in the morning. Then bring the faid clufter of ftars to the meridian, and the index will point to about ½ after XII for the time of their culminating, or being upon the meridian. Laftly, bring them into the weftern horizon, and the index will point to VIII 40 min. which fhews the time of their fetting in the evening of that day. It will alfo appear, on the circle of the horizon, that they rife with about 40 deg. of amplitude to the north, and fet with the fame amplitude from the weft.

PROBLEM LXXXVIII.

To find what conftellation any remarkable ftar, feen in the firmament, belongs to.

Bring the fun's place in the ecliptic for that day to the ftrong brafs meridian, and fet the horary index to that XII which is moft elevated; the celeftial globe being rectified to the latitude, turn the globe till it points to the prefent hour; and by the help of the mariner's compafs, and attending to the variation, which at London is nearly

nearly 24 degrees from the north, weſtward, ſet the north pole of the globe towards the north pole of the heavens.

The ſtar upon the globe (if you conceive yourſelf in the center) which directs towards that point in the heavens, in which the ſtar you want to know is ſeen, is the ſtar required.

At the ſame time, by comparing the ſtars in the heavens with thoſe upon the globe, the other ſtars and their conſtellations may be eaſily known; whereby you will be enabled, any ſtar-light night, to point out many of thoſe ſtars called correſpondents to various places on the earth.

PROBLEM LXXXIX.

To find at what hour any known ſtar paſſes the meridian on any day in the year.

Rectify the globe to the latitude, and ſet the artificial ſun to his place in the ecliptic; bring it's center under the ſtrong braſs meridian, and ſet the horary index to XII; then turn the globe till the ſtar comes to the meridian, and the horary index will point upon the equator to the hour

on

on which that ſtar will be upon the ſouth part of the meridian.

If you turn the globe on till the center of the artificial ſun is under that graduated ſide of the braſs meridian, which is below the elevated pole, all thoſe ſtars, which are then cut by that ſide of the meridian above the ſaid pole, will paſs the meridian at midnight.

PROBLEM XC.

To find on what day of the year any ſtar paſſes the meridian at any propoſed hour of the night.

Bring the ſtar to the ſtrong braſs meridian, and ſet the horary index to the propoſed hour; then turn the globe till the index points to XII, and that degree on the ecliptic, which is cut by the meridian, is the ſun's place, againſt which, in the calendar upon the broad paper circle, is the day of the month.

PROBLEM

PROBLEM XCI.

To trace the circles of the ſphere in the ſtarry firmament.

We ſhall ſolve this problem for the time of the autumnal equinox; becauſe that interſection of the equator and ecliptic will be directly under the depreſſed part of the meridian about midnight; and then the oppoſite interſection will be elevated above the horizon; and alſo becauſe our firſt meridian upon the terreſtrial globe paſſing through London, and the firſt point of Aries, when both globes are rectified to the latitude of London, and to the ſun's place, and the firſt point of Aries is brought under the graduated ſide of each of their meridians, we ſhall have the correſponding face of the heavens and the earth repreſented, as they are with reſpect to each other at that time, and the principal circles of each ſphere will correſpond with each other.

The horizon is then diſtinguiſhed, if we begin from the north and count weſtward, by the following conſtellations; the hounds and waiſt of Bootes, the northern crown, the head of Hercules, the ſhoulders of Serpentarius, and Sobieſki's eſki's ſhield; it paſſes a little below the feet of Antinous, and through thoſe of Capricorn, through the Sculptor's frame, Eridanus, the ſtar Rigell in Orion's foot, the head of Monoceros, the crab, the head of the little lion, and lower part of the great bear.

The meridian is then repreſented by the equinoctial colure, which paſſes through the ſtar marked δ in the tail of the little bear, under the north pole, the pole ſtar, one of the ſtars in the back of Caſſiopea's chair marked β, the head of Andromeda, the bright ſtar in the wing of Pegaſus marked γ, and the extremity of the tail of the whale.

That part of the equator which is then above the horizon, is diſtinguiſhed on the weſtern ſide by the northern part of Sobieſki's ſhield, the ſhoulder of Antinous, the head and veſſel of Aquarius, the belly of the weſtern fiſh in Piſces; it paſſes through the head of the whale, and a bright ſtar marked δ in the corner of his mouth, and thence through the ſtar marked δ in the belt of Orion, at that time near the eaſtern ſide of the horizon.

That

That half of the ecliptic which is then above the horizon, if we begin from the weſtern ſide, preſents to our view Capricornus, Aquarius, Piſces, Aries, Taurus, Gemini, and a part of the conſtellation Cancer.

The ſolſtitial colure, from the weſtern ſide, paſſes through Cerberus, and the hand of Hercules, thence by the weſtern ſide of the conſtellation Lyra, and through the dragon's head and body, through the pole point under the polar ſtar, to the eaſt of Auriga, through the ſtar marked η in the foot of Caſtor, and through the hand and elbow of Orion.

The northern polar circle, from that part of the meridian under the elevated pole, advancing towards the weſt, paſſes through the ſhoulder of the great bear, thence a little to the north of the ſtar marked α in the dragon's tail, the great knot of the dragon, the middle of the body of Cepheus, the northern part of Caſſiopea, and baſe of her throne, through Camelopardalus, and the head of the great bear.

The tropic of Cancer, from the weſtern edge of the horizon, paſſes under the arm of Hercules, under the vulture, through the gooſe and

fox,

ſox, which is under the beak and wing of the ſwan, under the ſtar called Sheat, marked β in Pegaſus, under the head of Andromeda, and through the ſtar marked ϕ in the fiſh of the conſtellation Piſces, above the bright ſtar in the head of the ram marked α, through the Pleiades, between the horns of the bull, and through a group of ſtars at the foot of Caſtor, thence above a ſtar marked δ, between Caſtor and Pollux, and ſo through a part of the conſtellation Cancer, where it diſappears by paſſing under the eaſtern part of the horizon.

The tropic of Capricorn, from the weſtern ſide of the horizon, paſſes through the belly, and under the tail of Capricorn, thence under Aquarius, through a ſtar in Eridanus marked c, thence under the belly of the whale, through the baſe of the chemical furnace, whence it goes under the hare at the feet of Orion, being there depreſſed under the horizon.

The ſouthern polar circle is inviſible to the inhabitants of London, by being under our horizon.

Arctic and antarctic circles, or circles of perpetual apparition and occultation.

The largeſt parallel of latitude on the terreſtrial globe, as well as the largeſt circle of declination on the celeſtial, that appears entire above the horizon of any place in north latitude, was called by the ancients the arctic circle, or circle of perpetual apparition.

Between the arctic circle and the north pole in the celeſtial ſphere, are contained all thoſe ſtars which never ſet at that place, and ſeem to us, by the rotative motion of the earth, to be perpetually carried round above our horizon, in circles parallel to the equator.

The largeſt parallel of latitude on the terreſtrial, and the largeſt parallel of declination on the celeſtial globe, which is entirely hid below the horizon of any place, was by the ancients called the antarctic circle, or circle of perpetual occultation.

This circle includes all the ſtars which never riſe in that place to an inhabitant of the northern hemiſphere, but are perpetually below the horizon.

All arctic circles touch their horizons in the north point, and all antarctic circles touch their horizons in the ſouth point; which point, in the terreſtrial and celeſtial ſpheres, is the interſection of the meridian and horizon.

If the elevation of the pole be 45 degrees, the moſt elevated part either of the arctic or antarctic circle, will be in the zenith of the place.

If the pole's elevation be leſs than 45 degrees, the zenith point of thoſe places will fall without it's arctic or antarctic circle; if greater, it will fall within.

Therefore, the nearer any place is to the equator, the leſſer will it's arctic and antarctic circles be; and on the contrary, the farther any place is from the equator, the greater they are. So that,

At the poles, the equator may be conſidered as both an arctic and antarctic circle, becauſe it's plane is coincident with that of the horizon.

But at the equator (that is, in a right ſphere) there is neither arctic nor antarctic circle.

They

They who live under the northern polar circle, have the tropic of Cancer for their arctic, and that of Capricorn for their antarctic circle.

And they who live on either tropic, have one of the polar circles for their arctic, and the other for their antarctic circle.

Hence, whether these circles fall within or without the tropics, their diftance from the zenith of any place is ever equal to the difference between the pole's elevation, and that of the equator above the horizon of that place.

From what has been faid, it is plain there may be as many arctic and antarctic circles, as there are individual points upon any one meridian, between the north and fouth poles of the earth.

Many authors have miftaken thefe mutable circles, and have given their names to the immutable polar circles, which laft are arctic and antarctic circles, in one particular cafe only, as has been fhewn.

PROBLEM XCII.

To find the circle, or parallel of perpetual apparition, or occultation of a fixed ſtar in a given latitude.

By rectifying the globe to the latitude of the place, and turning it round on it's axis, it will be immediately evident, that the circle of perpetual apparition is that parallel of declination which is equal to the complement of the given latitude northward; and for the perpetual occultation, it is the ſame parallel ſouthward, that is to ſay, in other words, all thoſe ſtars, whoſe declinations exceed the co-latitude, will always be viſible, or above the horizon; and all thoſe in the oppoſite hemiſphere, whoſe declination exceeds the co-latitude, never riſe above the horizon.

For inſtance; in the latitude of London 51 deg. 30 min. whoſe co-latitude is 38 deg. 30 min. gives the parallels deſired; for all thoſe ſtars which are within the circle, towards the north pole, never deſcend below our horizon; and all thoſe ſtars which are within the ſame circle, about the ſouth pole, can never be ſeen in the latitude of London, as they never aſcend above it's horizon.

PROBLEM

PROBLEM XCIII.

To represent the face of the heavens on the globe for a given hour on any day of the year.

Rectify the globe to the given latitude of the place and day of the month, setting it due north and south by the needle; then turn the globe on it's axis till the index points to the given hour of the night; then all the upper hemisphere of the globe will represent the visible face of the heavens for that time, by which it will be easily seen what constellations and stars of note are then above our horizon, and what position they have with respect to the points of the compass. In this case, supposing the eye was placed in the center of the globe, and holes were pierced through the centers of the stars on it's surface, the eye would perceive through those holes the various corresponding stars in the firmament; and hence it would be easy to know the various constellations at sight, and to be able to call all the stars by their names.

The use of this problem is most extensive, as it acquaints us at any time with the apparent face or state of the heavens, and shews us when the moon, or any of the planets, may be seen, or fit for examination by the telefcope. We can alfo from hence learn, when any of thofe curious and wonderful objects, called NEBULOUS STARS, may be feen, and which ftrike the mind of the obferver with amazement, by prefenting to his view an indefinite number of the fmalleft fixed ftars through the whole field of view in his telefcope.

From hence alfo, the pofition of that very extraordinary phænomenon called the GALAXY, or MILKY WAY, is at any time known.

This fingle problem, therefore, may be confidered in itfelf as fufficient to recommend the ufe of the celeftial globe, to every ftudious and rational mind, as the moft neceffary inftrument of his celeftial tuition.

PROBLEM XCIV.

The latitude of the place, the fun's place, and the hour of the night being given, to find the azimuth and altitude of any known fixed ftar.

Rectify the globe for the latitude of the place, and the fun's place; turn the globe till the hour index points to the given hour; then fix the quadrant

drant of altitude in the zenith, and lay it over the ſtar, and it will ſhew the altitude and azimuth of it.

It was by obſerving the times of the riſings and ſettings of the fixed ſtars, or the times of their culminating or paſſing the meridian, that the ancients determined the hour or time of night.

PROBLEM XCV.

The latitude of the place, the ſun's place, and the azimuth of any known ſtar being given, to find the hour of the night.

Having rectified the globe for the latitude of the place and the ſun's place, if the given ſtar be due north or ſouth, bring it to the meridian, and the index will ſhew the hour of the night.

If the ſtar be in any other direction, fix the quadrant of altitude in the zenith, and ſet it to the ſtar's azimuth in the horizon; turn the globe about until the quadrant cuts the center of the ſtar, and then the horary index will ſhew the hour of the night.

But as it may poſſibly happen that we may ſee a ſtar, and would be glad to know what ſtar it is, or whether it may not be a new ſtar, or a comet; how that may be diſcovered, will be ſeen under the following

PROBLEM XCVI.

The latitude of the place, the ſun's place, the hour of the night, and the altitude and azimuth of any ſtar being given, to find the ſtar.

Rectify the globe for the latitude of the place, and the ſun's place; fix the quadrant of altitude in the zenith, and turn the globe till the hour index points to the given hour, and ſet the quadrant of altitude to the given azimuth; then the ſtar that cuts the quadrant in the given altitude, will be the ſtar ſought.

Though two ſtars, that have different right aſcenſions, will not come to the meridian at the ſame time, yet it is poſſible that in a certain latitude they may come to the ſame vertical circle at the ſame time; and that conſideration gives the following

PROBLEM XCVII.

The latitude of the place, the ſun's place, and two ſtars, that have the ſame azimuth, being given, to find the hour of the night.

Rectify the globe for the latitude, the zenith, and the ſun's place; then turn the globe, and alſo the quadrant about, till both the ſtars coincide with it's edge; the hour index will ſhew the hour of the night, and the place where the quadrant cuts the horizon, will be the common azimuth of both ſtars.

What hath been obſerved above, of two ſtars that have the ſame azimuth, will hold good likewiſe of two ſtars that have the ſame altitude; from whence we have the following

PROBLEM XCVIII.

The latitude of the place, the ſun's place, and two ſtars, that have the ſame altitude, being given, to find the hour of the night.

Rectify the globe for the latitude of the place, the zenith, and the ſun's place; turn the globe, ſo that the ſame degree on the quadrant ſhall cut

both

both ſtars, then the hour index will ſhew the hour of the night.

In the former propoſitions the latitude of the place is ſuppoſed to be given, or known. But as it is frequently neceſſary to find the latitude of the place, and eſpecially at ſea, how this may be found, in a rude manner at leaſt, having the time given by a good clock, or watch, will be ſeen in the following

PROBLEM XCIX.

The ſun's place, the hour of the night, and two ſtars, that have the ſame azimuth, or altitude, being given, to find the latitude of the place.

Rectify the globe for the ſun's place, and turn it, till the index points to the given hour of the night; keep the globe from turning, and move it up and down in the notches, till the two given ſtars have the ſame azimuth, or altitude; then the braſs meridian will ſhew the height of the pole, and conſequently the latitude of the place.

PROBLEM

PROBLEM C.

Two ſtars being given, one on the meridian, and the other on the eaſt and weſt part of the horizon, to find the latitude of the place.

Bring the ſtar obſerved on the meridian to the meridian of the globe; then keeping the globe from turning round it's axis, ſlide the meridian up or down in the notches, till the other ſtar is brought to the eaſt or weſt part of the horizon; and that elevation of the pole will be the latitude of the place ſought.

OBSERVATION.

From what hath been ſaid, it appears, that if, of theſe five things, 1. the latitude of the place; 2. the ſun's place in the ecliptic; 3. the hour of the night; 4. the common azimuth of two known fixed ſtars; 5. the equal altitude of two known fixed ſtars; any THREE of them be given, the remaining TWO will eaſily be found.

There are three ſorts of riſings and ſettings of the fixed ſtars, taken notice of by ancient authors, and commonly called POETICAL RISINGS and

SETTINGS,

SETTINGS, becauſe moſtly taken notice of by the poets.

Theſe are the COSMICAL, ACHRONICAL, and HELIACAL.*

They are to be found in moſt authors that treat on the doctrine of the ſphere, and are now chiefly uſeful in comparing and underſtanding paſſages in the ancient writers; ſuch are Heſiod, Virgil, Columella, Ovid, Pliny, &c. How they are to be found by calculation, may be ſeen in Petavius's Uranologion, and Dr. Gregory's aſtronomy.

DEFINITION.

When a ſtar riſes or ſets at ſun-riſing, it is ſaid to riſe or ſet COSMICALLY.

From whence we ſhall have the following

PROBLEM CI.

The latitude of the place being given, to find, by the globe, the time of the year when a given ſtar riſes or ſets coſmically.

Let

* Coſtard's Hiſtory of Aſtronomy.

Let the given place be Rome, whoſe latitude is 42 deg. 8 min. north; and let the given ſtar be the Lucida Pleiadum. Rectify the globe for the latitude of the place; bring the ſtar to the edge of the eaſtern horizon, and mark the point of the ecliptic riſing along with it; that will be found to be Taurus, 18 deg. oppoſite to which, on the horizon, will be found May the 8th. The Lucida Pleiadum, therefore, riſes coſmically May the 8th.

If the globe continues rectified as before, and the Lucida Pleiadum be brought to the edge of the weſtern horizon, the point of the ecliptic, which is the ſun's place, then riſing on the eaſtern ſide of the horizon, will be Scorpio, 29 deg. oppoſite to which, on the horizon, will be found November the 21ſt. The Lucida Pleiadum, therefore, ſets coſmically November the 21ſt.

In the ſame manner, in the latitude of London, Sirius will be found to riſe coſmically Auguſt the 10th, and to ſet coſmically November the 10th.

It is of the coſmical ſetting of the Pleiades, that Virgil is to be underſtood in this line,

ANTE TIBI EOÆ ATLANTIDES ABSCONDANTUR,*

and not of their SETTING IN THE EAST, as ſome have imagined, where ſtars riſe, but never ſet.

DEFINITION.

When a ſtar riſes or ſets at ſun-ſetting, it is ſaid to riſe or ſet ACHRONICALLY.

Hence, likewiſe, we have the following

PROBLEM CII.

The latitude of the place being given, to find the time of the year when a given ſtar will riſe or ſet achronically.

Let the given place be Athens, whoſe latitude is 37 deg. north, and let the given ſtar be Arcturus.

Rectify the globe for the latitude of the place, and bringing Arcturus to the eaſtern ſide of the horizon, mark the point of the ecliptic then ſetting on the weſtern ſide; that will be found Aries,

12

* Georg. l. 1, v. 221.

12 deg. oppofite to which, on the horizon, will be found April the 2d. Therefore, Arcturus rifes at Athens achronically April the 2d.

It is of this rifing of Arcturus that Hefiod fpeaks in his Opera & Dies.*

When from the SOLSTICE fixty days are paft,
At eve ARCTURUS rifes in the eaft.

If the globe continues rectified to the latitude of the place, as before, and Arcturus be brought to the weftern fide of the horizon, the point of the ecliptic fetting along with it will be Sagittary, 7 deg. oppofite to which, on the horizon, will be found November the 29th. At Athens, therefore, Arcturus fets achronically November the 29th.

In the fame manner Aldebaran, or the bull's eye, will be found to rife achronically May the 22d, and to fet achronically December the 19th.

DEFINITION.

* Lib. ii. ver. 185.

DEFINITION.

When a ſtar firſt becomes viſible in the morning, after it hath been ſo near the ſun as to be hid by the ſplendor of his rays, it is ſaid to riſe HELIACALLY.

But for this there is required ſome certain depreſſion of the ſun below the horizon, more or leſs, according to the magnitude of the ſtar. A ſtar of the firſt magnitude is commonly ſuppoſed to require that the ſun be depreſſed 12 deg. perpendicularly below the horizon.

This being premiſed, we have the following

PROBLEM CIII.

The latitude of the place being given, to find the time of the year when a given ſtar will riſe heliacally.

Let the given place be Rome, whoſe latitude is 42 deg. north, and let the given ſtar be the bright ſtar in the bull's horn.

Rectify

Rectify the globe for the latitude of the place, ſcrew on the braſs quadrant of altitude in it's zenith, and turn it to the weſtern ſide of the horizon. Bring the ſtar to the eaſtern ſide of the horizon, and mark what degree of the ecliptic is cut by 12 deg. marked on the quadrant of altitude; that will be found to be Capricorn, 3 deg. the point oppoſite to which is Cancer, 3 deg. and oppoſite to this will be found, on the horizon, June the 25th. The bright ſtar, therefore, in the bull's horn, in the latitude of Rome, riſes heliacally June the 25th.

Theſe kinds of riſings and ſettings are not only mentioned by the poets, but likewiſe by the ancient phyſicians and hiſtorians.

Thus Hippocrates, in his book De Ære, ſays, "one ought to obſerve the heliacal riſings and ſettings of the ſtars, eſpecially the DOG STAR, and ARCTURUS; likewiſe the COSMICAL ſetting of the PLEIADES."

And Polybius, ſpeaking of the loſs of the Roman fleet, in the firſt Punic war, ſays, "it was not ſo much owing to fortune, as to the obſtinacy of the conſuls, in not hearkening to their pilots, who diſſuaded them from putting to ſea

 at

at that ſeaſon of the year, which was between the riſing of ORION and the DOG STAR; it being always dangerous, and ſubject to ſtorms." *

DEFINITION.

When a ſtar is firſt immerſed in the evening, or hid by the ſun's rays, it is ſaid to ſet heliacally.

And this again is ſaid to be, when a ſtar of the firſt magnitude comes within 12 degrees of the ſun, reckoned in the perpendicular.

Hence again we have the following

PROBLEM CIV.

The latitude of the place being given, to find the time of the year when a given ſtar ſets heliacally.

Let the given place be Rome, in latitude 42 deg. north, and let the given ſtar be the bright ſtar in the bull's horn. Rectify the globe for the latitude of the place, and bring the ſtar to the edge of the weſtern horizon; turn the quadrant of altitude, till 12 deg. cut the ecliptic on the

* Lib. i. p. 53.

the eaſtern ſide of the meridian. This will be found to be 7 deg. of Sagittary, the point oppoſite to which, in the ecliptic, is 7 deg. of Gemini; and oppoſite to that, on the horizon, is May the 28th, the time of the year when that ſets heliacally in the latitude of Rome.

Of the Precession of the Equinox.

We have already taken notice of and illuſtrated in page 419, that apparent ſlow motion of the fixed ſtars forwards, which is cauſed by the like ſlow motion of the equinoctial points backwards; and ſhewn that this is owing to the revolution of the axis of the equator about the axis of the ecliptic, the pole of the equator deſcribing in the heavens a circle about the axis of the ecliptic. By this motion they are found to recede from their ancient ſtations, at the rate of 50 ſeconds every year, making a degree in 72 years, and 25,920 years to perform one revolution.

Hence it is, that though the ſigns or conſtellations in the zodiac are called by the ſame names with thoſe in the ecliptic, yet the ſigns in one do not anſwer to thoſe in the other; the ſign called Aries, for inſtance, in the ecliptic, is not in that part of it which anſwers to the figure or conſtellation of Aries in the zodiac; the ſame is equally true of all the other ſigns. This is made very plain upon the celeſtial globe; for the reader will find there that the mark ♈ and the 30 deg. reckoned from it, which make the ſign Aries in the ecliptic, are not within the figure or conſtellation of the ram. This motion in their longitude does not, however, vary their latitude.

Hence their places being once determined to a known year, their longitudes may be aſcertained for any time paſt or to come, by the ſole ſubtraction or addition of ſo many times 50 ſeconds, as there are years between that to which the given ſtar is rectified, and that to which it is required; or knowing the quantity of preceſſion from any former period, the diſtance thereof in time may be obtained, by reducing it into ſeconds, and dividing the reſult by 50, the quotient will give the number of years, as in the following examples.

EXAMPLE I.

Given, 1908 years. To find the quantity of the preceſſion for that time.

1908

1908 years
Multiply by - 50 seconds

60) 95400

60) 1590

Answer - - 26° 30′ preceſſion in 1908 years.

EXAMPLE II.

Given, 26° 30′, the quantity of the preceſſion, to find the time.

26° 30′
Multiply by 60

1590 minutes
Multiply by 60

Divide by 50) 95400 ſeconds

Anſwer - 1908 years.

The regular change in the preceſſion of the fixed ſtars, or rather the conſtant retrogreſſion of the equinoctial points, ſeems to cauſe an irregular variation in their right aſcenſions and declinations, more or leſs, according to their diſtances from the pole of the ecliptic. Whence it may

 not

not be improper to ſhew how theſe may be found, as the coſmical, achronical, and heliacal riſings and ſettings of the fixed ſtars, found by the preceding problems, have reſpect only to the preſent age; and the following problem will ſhew the reader how to determine the ancient place of any ſtar agreeable to the time of ancient authors, if their authority may be depended on.

PROBLEM CV.

Given, the latitude and ancient longitude of a fixed ſtar, to find it's right aſcenſion and declination.

Elevate the celeſtial globe to $66\frac{1}{2}$ degrees, bring the pole of the ecliptic into the zenith, and there fix the quadrant of altitude; apply it's graduated edge to the given ſtar, and it will cut it's preſent longitude, either on the ecliptic or broad paper circle, which in this poſition of the globe coincide with each other: make a mark on the quadrant, at the latitude of the given ſtar, and remove it to it's ancient longitude, as found above; then bring the graduated edge of the moveable meridian to the mark juſt made upon the quadrant of altitude, and ſet the center of the artificial ſun to that point which will then repre-

ſent

ſent the ancient place of the given ſtar. That point of the moveable meridian, upon which the center of the artificial ſun was placed, is it's ancient declination; and that point of the equator, cut by it's graduated edge, is it's ancient right aſcenſion.

The globe being thus rectified to the place and preceſſion of any particular ſtar, as given us by ancient authors, the times of the year when ſuch ſtar roſe or ſet, either coſmically, achronically, or heliacally, may be thus obtained by the preceding problems, agreeable to the period of the author under conſideration. The reader, who wiſhes to purſue this ſubject further, will find it illuſtrated by many curious and learned examples in the Rev. Mr. Coſtard's Hiſtory of Aſtronomy.

Of the Correspondence of the Celestial and Terrestrial Spheres.*

That the reader may thoroughly underſtand what is meant by the correſpondence between the two ſpheres, let him imagine the celeſtial globe to be delineated upon glaſs, or any other tranſparent matter, which ſhall inveſt or ſurround the terreſtrial globe, but in ſuch a manner,

 that

* Adams's Treatiſe on the Globes.

that either may be turned about upon the poles of the globe, while the other remains fixed; and ſuppoſe the firſt point of Aries on the inveſting globe to be placed upon the firſt point of Aries on the terreſtrial globe, (which point is in the meridian of London) then every ſtar in the celeſtial ſphere will be directly over thoſe places, to which it is a correſpondent. Each ſtar will then have the degree of it's right aſcenſion directly upon the correſponding degree of terreſtrial longitude; their declination will alſo be the ſame with the latitude of the places to which they anſwer; or in other words, when the declination of a ſtar is equal to the latitude of a place, ſuch ſtar, within the ſpace of 24 hours, will paſs vertically over that place, and all others that have the ſame latitude.

If we conceive the celeſtial inveſting globe to be fixed, and the terreſtrial globe to be gradually turned from weſt to eaſt, it is clear, that as the meridian of London paſſes from one degree to another, under the inveſting ſphere, every ſtar in the celeſtial ſphere becomes correſpondent to another place upon the earth, and ſo on, until the earth has completed one diurnal revolution; or till all the ſtars, by their apparent daily motion, have paſſed over every meridian of the terreſtrial

terreſtrial globe. From this view of the ſubject, an amazing variety, uniting in wonderful and aſtoniſhing harmony, preſents itſelf to the attentive reader; and future ages will find it difficult to inveſtigate the reaſons that ſhould induce the preſent race of aſtronomers to neglect a ſubject ſo highly intereſting to ſcience, even in a practical view, but which in theory would lead them into more ſublime ſpeculations, than any that ever yet preſented themſelves to their minds.

A general Description of the Passage of the Star marked γ in the Head of the Constellation Draco, over the Parallel of London.

The ſtar γ, in the head of the conſtellation Draco, having 51 deg. 32 min. north declination, equal to the latitude of London, is the correſpondent ſtar thereto. To find the places which it paſſes over, bring London to the graduated ſide of the braſs meridian, and you will find that the degree of the meridian over London and the repreſentative of the ſtar, paſſes over from London, the road to Briſtol, croſſes the Severn, the Briſtol channel, the counties of Cork and Kerry in Ireland, the north part of the Atlantic ocean, the Streights of Belleiſle, New Britain, the north

north part of the province of Canada, New South Wales, the ſouthern part of Kamſchatka, thence over different Tartarian nations, ſeveral provinces of Ruſſia, over Poland, part of Germany, the ſouthern part of the United Provinces, when croſſing the ſea, it arrives again at the meridian of London.

When the ſaid ſtar, or any other ſtar, is on the meridian of London, or any other meridian, all other ſtars, according to their declination and right aſcenſion, and difference of right aſcenſion, (which anſwers to terreſtrial latitude, longitude, and difference of longitude) will at the ſame time be on ſuch meridians, and vertical to ſuch places as correſpond in latitude, longitude, and difference of longitude, with the declination, &c. of the reſpective ſtars.*

From the ſtars, therefore, thus conſidered, we attain a copious field of geographical knowledge, and may gain a clear idea of the proportionable diſtances, and real bearings, of remote empires, kingdoms, and provinces, from our own zenith, at the ſame inſtant of time; which may be found in

* Fairman's Geography.

in the ſame manner as we found the place to which the ſun was vertical at any propoſed time.

Many inſtances of this mode of attaining geographical knowledge, may be found in my father's treatiſe on the globes.

OF THE

USE

OF THE

TERRESTRIAL GLOBE,

WHEN MOUNTED IN THE COMMON MANNER.

ALTHOUGH I have, in the firſt part of this eſſay, laid before my readers the reaſons which induce me to prefer my father's manner of mounting the globes, to the old or Ptolemaic form, yet as many may be in poſſeſſion of globes mounted in the old form, and others may have been taught by thoſe globes, I thought it would render theſe eſſays more complete, to give an account of ſo many of the leading problems, ſolved on the common globes, as would enable them to apply the remainder of thoſe heretofore

tofore ſolved, to their own uſe. This is the more expedient, as ſince the publication of my father's treatiſe, there have been a few attempts to do away ſome of the inconveniences of the ancient form, particularly that of the old hour circle, which is now generally placed under the meridian.

I cannot, however, refrain from again obſerving to the pupil, that the ſolution of the problems on the old globes depends upon appearances; that therefore, if he means to content himſelf with the mere mechanical ſolution of them, the Ptolemaic globes will anſwer his purpoſe; but if he wiſhes to have clear ideas of the rationale of thoſe problems, he muſt uſe thoſe mounted in my father's manner.

The celeſtial globe is uſed the ſame way in both mountings, excepting, that in my father's mounting it has ſome additional circles; but the difference is ſo trifling, that it is preſumed the pupil can find no difficulty in applying the directions there as given to the old form.

PROBLEM I.

To find the latitude and longitude of any given place on the globe.

Bring the place to the eaſt ſide of the braſs meridian, then the degree marked on the meridian over it ſhews it's latitude, and the degree of the equator, under the meridian, ſhews it's longitude.

Hence, if the longitude and latitude of any place be given, the place is eaſily found, by bringing the given longitude to the meridian; for then the place will lie under the given degree of latitude upon the meridian.

PROBLEM II.

To find the differences of longitude between any two given places.

Bring each of the given places ſucceſſively to the brazen meridian, and ſee where the meridian cuts the equator each time; the number of degrees contained between thoſe two points, if it be leſs than 180 deg. otherwiſe the remainder to

360 deg. will be the difference of longitude required.

PROBLEM III.

To rectify the globe for the latitude, zenith, and ſun's place.

Find the latitude of the place (by prob. I.) and if the place be in the nothern hemiſphere, elevate the north pole above the horizon, according to the latitude of the place. If the place be in the ſouthern hemiſphere, elevate the ſouth pole, above the ſouth point of the horizon, as many degrees as are equal to the latitude.

Having elevated the globe according to it's latitude, count the degrees thereof upon the meridian from the equator towards the elevated pole, and that point will be the zenith, or the vertex of the place; to this point of the meridian faſten the quadrant of altitude, ſo that the graduated edge thereof may be joined to the ſaid point.

Having brought the ſun's place in the ecliptic to the meridian, ſet the hour index at twelve at noon,

noon, and the globe will be rectified to the ſun's place.

PROBLEM IV.

The hour of day at any place being given, to find all thoſe on the globe, where it is noon, midnight, or any given hour at that time.

On the globes, when mounted in the common manner, it is now cuſtomary to place the hour circle under the north pole; it is divided into twice twelve hours, and has two rows of figures, one running from eaſt to weſt, the other from weſt to eaſt; this circle is moveable, and the meridian anſwers the purpoſe of an index.

Bring the given place to the brazen meridian, and the given hour of the day on the hour circle; this done, turn the globe about, till the meridian points at the hour deſired; then, with all thoſe under the meridian, it is noon, midnight, or any given hour at that time.

PROBLEM V.

The hour of the day at any place being given, to find the correſpondent hour (or what o'clock it is at that time) in any other place.

Bring the given place to the brazen meridian, and ſet the hour circle to the given time; then turn the globe about, until the place where the hour is required comes to the meridian, and the meridian will point out the hour of the day at that place.

Thus, when it is noon at London, it is

		H.	M.	
At	Rome - -	0	52	P. M.
	Conſtantinople	2	7	P. M.
	Vera Cruz -	5	30	A. M.
	Pekin in China -	7	50	P. M.

PROBLEM VI.

The day of the month being given, to find all thoſe places on the globe where the ſun will be vertical, or in the zenith that day.

Having found the ſun's place in the ecliptic for the given day, bring the ſame to the brazen meridian,

meridian, obſerve what degree of the meridian is over it, then turn the globe round it's axis, and all places that paſs under that degree of the meridian will have the ſun vertical, or in the zenith that day, i. e. directly over the head of each place at it's reſpective noon.

PROBLEM VII.

A place being given in the torrid zone, to find thoſe two days of the year on which the ſun will be vertical to that place.

Bring the given place to the brazen meridian, and mark the degree of latitude that is exactly over it on the meridian; then turn the globe about it's axis, and obſerve the two points of the ecliptic, which paſs exactly under that degree of latitude, and look on the horizon for the two days of the year in which the ſun is in thoſe points or degrees of the ecliptic, and they are the days required; for on them, and none elſe, the ſun's declination is equal to the latitude of the given place.

PROBLEM

PROBLEM VIII.

To find the antœci, periœci, and antipodes of any given place.

Bring the given place to the brazen meridian, and having found it's latitude, keep the globe in that poſition, and count the ſame number of degrees of latitude on the meridian, from the equator towards the contrary pole, and where the reckoning ends, that will give the place of the antœci upon the globe. Thoſe who live at the equator have no antœci.

The globe remaining in the ſame poſition, bring the upper XII on the horary circle to the meridian, then turn the globe about till the meridian points to the lower XII; the place which then lies under the meridian, having the ſame latitude with the given place, is the periœci required. Thoſe who live at the poles, if any, have no periœci.

As the globe now ſtands (with the index at the lower XII, the antipodes of the given place are under the ſame point of the brazen meridian where it's antœci ſtood before.

PROBLEM IX.

To find at what hour the ſun riſes and ſets any day in the year; and alſo upon what point of the compaſs.

Rectify the globe for the latitude of the place you are in; bring the ſun's place to the meridian, and bring the XII to the meridian; then turn the ſun's place to the eaſtern edge of the horizon, and the meridian will point out the hour of riſing; if you bring it to the weſtern edge of the horizon, it will ſhew the ſetting.

Thus on the 16th day of March, the ſun roſe a little paſt ſix, and ſet a little before ſix.

Note: In the ſummer the ſun riſes and ſets a little to the northward of the eaſt and weſt points, but in winter, a little to the ſouthward of them. If, therefore, when the ſun's place is brought to the eaſtern and weſtern edges of the horizon, you look on the inner circle, right againſt the ſun's place, you will ſee the point of the compaſs upon which the ſun riſes and ſets that day.

PROBLEM X.

To find the length of the day and night at any time of the year.

Only double the time of the ſun's riſing that day, and it gives the length of the night; double the time of his ſetting, and it gives the length of the day.

This problem ſhews how long the ſun ſtays with us any day, and how long he is abſent from us any night.

Thus on the 26th of May the ſun riſes about four, and ſets about eight; therefore, the day is ſixteen hours long, and the night eight.

PROBLEM XI.

To find the length of the longeſt or ſhorteſt day, at any place upon the earth.

Rectify the globe for that place, bring the beginning of Cancer to the meridian; bring XII to the meridian, then bring the ſame degree of Cancer to the eaſt part of the horizon, and the meridian will ſhew the time of the ſun's riſing.

If the ſame degree be brought to the weſtern ſide, the meridian will ſhew the ſetting, which doubled (as in the laſt problem) will give the length of the longeſt day and ſhorteſt night.

If we bring the beginning of Capricorn to the meridian, and proceed in all reſpects as before, we ſhall have the length of the longeſt night and ſhorteſt day.

Thus in the Great Mogul's dominions, the longeſt day is 14 hours, and the ſhorteſt night 10 hours. The ſhorteſt day is 10 hours, and the longeſt night 14 hours.

At Peterſburgh, the ſeat of the Empreſs of Ruſſia, the longeſt day is about 19½ hours, and the ſhorteſt night 4½ hours; the ſhorteſt day 4½ hours, and longeſt night 19½ hours.

Note: In all places near the equator, the ſun riſes and ſets at ſix the year round. From thence to the polar circles, the days increaſe as the latitude increaſes; ſo that at thoſe circles themſelves, the longeſt day is 24 hours, and the longeſt night juſt the ſame. From the polar circles to the poles, the days continue to lengthen into weeks and months; ſo that at the very pole, the

the ſun ſhines for ſix months together in ſummer, and is abſent from it ſix months in winter.

Note: That when it is ſummer with the northern inhabitants, it is winter with the ſouthern, and the contrary; and every part of the world partakes of an equal ſhare of light and darkneſs.

PROBLEM XII.

To find all thoſe inhabitants to whom the ſun is this moment riſing or ſetting, in their meridian or midnight.

Find the ſun's place in the ecliptic, and raiſe the pole as much above the horizon as the ſun (that day) declines from the equator; then bring the place where the ſun is vertical at that hour to the braſs meridian; ſo will it then be in the zenith or center of the horizon. Now ſee what countries lie on the weſtern edge of the horizon, for in them the ſun is riſing; to thoſe on the eaſtern ſide he is ſetting; to thoſe under the upper part of the meridian it is noon day; and to thoſe under the lower part of it, it is midnight.

Thus on the 25th of April, at ſix o'clock in the evening, at Worceſter,

The ſun is riſing at New Zealand; and to thoſe who are ſailing in the middle of the Great South Sea.

The ſun is ſetting at Sweden, Hungary, Italy, Tunis, in the middle of Negroland and Guinea.

In the meridian (or noon) at the middle of Mexico, Bay of Honduras, middle of Florida, Canada, &c.

Midnight at the middle of Tartary, Bengal, India, and the ſeas near the Sunda iſles.

PROBLEM XIII.

To find the beginning and end of twilight.

The twilight is that faint light which opens the morning by little and little in the eaſt, before the ſun riſes; and gradually ſhuts in the evening in the weſt, after the ſun is ſet. It ariſes from the ſun's illuminating the upper part of the atmoſphere, and begins always when he approaches within

within 18 degrees of the eaſtern part of the horizon, and ends when he deſcends 18 degrees below the weſtern; when dark night commences, and continues till day breaks again.

To find the beginning of twilight, rectify the globe; turn the degree of the ecliptic, which is oppoſite to the ſun's place, till it is elevated 18 degrees in the quadrant of altitude above the horizon on the weſt, ſo will the index point the hour twilight begins.

This ſhort ſpecimen of problems by the old globes, it is preſumed, will be ſufficient to enable the pupil to ſolve any other.

ESSAY

ESSAY III.

PART I.

ESSAY III.

PART I.

A DESCRIPTION OF SEVERAL INSTRUMENTS,

WHICH ARE DESIGNED TO ILLUSTRATE THE GENERAL PRINCIPLES OF ASTRONOMY.

IN purſuance of my original plan, I proceed to deſcribe thoſe inſtruments that have been contrived to facilitate the progreſs of aſtronomy and geography. By their aſſiſtance, the lecturer and teacher are enabled to impreſs more ſtrongly on their pupils, the principles deſigned to be cultivated. The pupil, by reſolving a problem, or explaining any particular phænomenon by an inſtrument, ſtrengthens the faculties of his mind, and

and realizes to himſelf by the eye and the touch, what would otherwiſe have left but a faint and imperfect trace upon his memory.

To repreſent by machines the motion and various aſpects of the heavenly bodies, to ſhew by them the parallelíſm of the earth's axis, together with it's diurnal and annual motions ; and by this means to explain the beautiful variety of the ſeaſons, and other celeſtial and terreſtrial phænomena, has ever been conſidered as one of the nobleſt efforts of mechanical genius.

It is the buſineſs of this eſſay to deſcribe the moſt modern inſtruments that have been contrived for this purpoſe. But among the various methods that have been imagined, to exhibit to the uninformed eye the motion of the heavenly bodies, there is none whoſe effect is ſo ſtriking as the Eidouranion of Mr. Walker ; and I muſt own, I do not remember ever to have received more pleaſure than I did upon ſeeing the curtain draw up, and beholding the planetary bodies in motion, in this beautiful machine. A deſcription of it does not come within the limits of this eſſay, as it's effects are only ſtriking when it is made upon a very large ſcale.

The

The three firſt that I ſhall deſcribe are repreſented in plate V. plate XV. and plate XVI: the one is a manual planetarium, the other a ſimple tellurian, the third a lunarium: theſe three ought to accompany every pair of globes; they are rendered as ſimple as poſſible, in order to reduce the price, that much real knowledge may be attained at an eaſy rate.

Plate XVII. fig. 1, and plate XVIII. fig. 1 and 2, repreſent what I deem to be the completeſt inſtrument of the kind: it is ſo contrived as to exhibit, with the greateſt accuracy and perſpicuity, the phænomena of the earth and heavens; being the moſt comprehenſive, and at the ſame time the leaſt defective.

Plate XIX. repreſents an elegant and neat planetarium, tellurian, and lunarium, in one inſtrument, the whole moving by wheel-work.

Fig. 1 and 2, plate XIII. two armillary ſpheres; a planetarium is included in that of fig. 1, plate XIII. fig. 2 is an armillary ſphere, by which the real and apparent motion of the earth and heavens may be illuſtrated and explained.

A De-

A Description of the three Instruments represented in Plate V. Plate XV. and Plate XVI.

In this part we ſhall ſuppoſe the reader to be acquainted with thoſe definitions that we have had occaſion to introduce in the preceding parts of this work; theſe being remembered, he will meet with little or no difficulty in the following pages.

Plate XV. repreſents a manual planetarium, or one in which the planets muſt be moved by hand, without the aſſiſtance of wheel-work.

First. A Description of the Planetarium, represented at Plate XV.

A planetarium may be conſidered as a diametrical ſection of our univerſe, in which the upper and lower hemiſpheres are ſuppreſſed: the ſun is repreſented by a braſs ball ☉ placed in the center of the inſtrument; round about, but at different diſtances, the planets are placed thus on the ſtem; near the ſun is Mercury ☿, then Venus ♀, the Earth ⊕, Mars ♂, Jupiter ♃, and laſtly Saturn ♄.

The

The fecondary ones are placed about the primary ones; thus about the earth there is one little ball to reprefent the moon, about Jupiter four, and about Saturn are five befides his ring.

Upon the plate of the planetarium are placed, in two oppofite circles, the ecliptic, and the calendar of months, by which means the planets may be fet to their mean places in the ecliptic for any day of the year.

Imperfect as this inftrument may appear, it will greatly affift the tutor in communicating to his pupil general ideas of the order, number, phafes, relative pofitions, and motion of the celeftial bodies.

You may turn either of the planets round by laying hold of, and removing the brafs bar which fupports them. In thus imitating their different revolutions, it will be very obvious that if each of them left a trace behind of their motions, there would be fix concentric circles defcribed about the brafs ball reprefenting their different orbits.

A fecond obfervation may be very properly that, which has been infifted on in the firft effay of this work, page 17, namely, that the motions of the planets are regular and harmonious as ſeen from the ſun; the pupil, by ſuppoſing himſelf ſituated on the braſs ball, and viewing the motion of the planets from thence, will find the idea pleaſingly and fully illuſtrated.

Let him afterwards ſuppoſe himſelf to be ſituated on the earth, and he will ſoon find, that it is his ſituation which is the ſource of apparent irregularity. If he conſiders the motions of the planets Venus and Mercury, he will find that in one part of their orbit, they paſs between us and the ſun: this is called their inferior conjunction, while in the oppoſite part they paſs on beyond, or on the other ſide of the ſun, which is called their ſuperior conjunction.

Here alſo it becomes very evident, that neither of theſe planets can ever appear at a great diſtance from the ſun. The tutor may eaſily explain this, and what is alſo meant by the elongation of a planet, by applying the doubled end of a piece of thread to the globe that repreſents the earth; one of the ends of the thread cloſe to the ſtem of the ſun, and the other end to that of Venus and Mercury; he will then find on moving the planets round, that they can never appear

far

far from the ſun, and that Mercury recedes leſs from him than Venus; the angle obſerved by this means would coincide exactly with that of the heavens, if the arms of the planetarium were at a ſufficient length to repreſent the proportional diſtances of the planets from each other. It is becauſe Mercury removes ſo little from the ſun, that he is ſo ſeldom ſeen.

The pupil will find that the ſuperior planets, Mars, Jupiter, or Saturn, are ſometimes ſeen in direct oppoſition to the ſun, having the earth between them and it; they are at other times ſeen in conjunction with the ſun, or on the contrary ſide of it.

The phaſes of the planets are illuſtrated by placing a ſmall lamp, or a piece of candle, in the center of the machine, inſtead of the braſs ball that repreſents the ſun.

The planets when moving, are continually varying their diſtances from the earth, and conſequently cannot appear to move with an uniform velocity; for they will be ſeen to move faſteſt when they are neareſt the earth, and ſloweſt when they are moſt remote from it; hence alſo they appear much larger at one time than at another.

The teacher may by this inftrument make it obvious to his pupil, why the planets appear to move fometimes direct, at others ftationary or retrograde; by extending a ftring from the earth over either of the planets, and to fome diftance beyond them, and keeping it over them during a revolution.

By the planetarium, the pupil will receive the moft fatisfactory evidence of the truth of the Copernican, and the errors of the Ptolemaic fyftem. For on removing the brafs ball from the center, and placing in it's ftead a fmall ivory one to reprefent the earth, and placing a fmall brafs ball inftead of the ivory earth, the inftrument will then exhibit the fituation of the planetary bodies according to the Ptolemaic fyftem.

It is plain, that in this fyftem, in which the earth is made the center of the motion of the heavenly bodies, 1. That their motions would all have been the fame way, or from weft to eaft continually; whereas in the heaven they are feen to move fometimes from weft to eaft, at others from

from eaſt to weſt, while at other times they are ſtationary. 2. They would in this caſe appear to move with an uniform velocity; whereas they are always obſerved to move with a variable one. 3. On the ſuppoſition that the earth was the center of the ſyſtem, it is evident from the inſtrument, that any of the planets might be ſeen at all diſtances from the ſun, or that Mercury or Venus might be ſeen when the ſun is ſetting, not only in the ſouth, but even in the eaſt, ſituations in which they were never ſeen by any obſerver. 4. The planets Venus and Mercury being, according to this hypotheſis, within the orbit of the ſun, could never be ſeen to go behind or beyond; but from obſervation we find them as often behind as before the ſun. To remedy theſe imperfections in his ſyſtem, and reconcile it with nature, Ptolemy was obliged to introduce various circles, into which he ſuppoſed the planets to deviate in their revolutions round the earth; thus multiplying cauſes without neceſſity, and rendering that perplexed, which, when rightly conſidered, is found to be ſimple.

Description of the Tellurian represented at Fig. 1, Plate V.

This is the moſt ſimple tellurian that is made; my endeavours in conſtructing it have been to form an inſtrument that ſhould render the phænomena of the ſeaſons clear to the youngeſt pupil.

It conſiſts of four ſmall globes, A, B, C, D, deſigned to repreſent our earth at the four principal ſeaſons of the year, ſummer and winter, ſpring and autumn. Theſe globes are all inclined in an angle of 66½ degrees to the plane of the ecliptic; in the center of the inſtrument a braſs ball is placed, to repreſent the ſun; there is alſo a ſmall pillar, on the top of which are placed ſeveral wires, parallel to each other, to repreſent parallel rays proceeding from the ſun; to each globe there is a black hemiſphere, placed oppoſite to the ſun, dividing the enlightened from the unenlightened parts of the globe; one of theſe black hemiſpheres may be taken off occaſionally, and the globe be removed from it's ſituation. There is alſo a circle, which is not repreſented in the plate; this circle is placed at the height of the earth's center, and is intended to repreſent the orbit of the earth; four pieces of wire are placed at the four quarters of this circle, having the ſame

ſame inclination to it that the axis of the earth has to the plane of it's orbit, to give a clear idea of what is meant by the inclination of the axis of the earth, and what by it's parallelifm.

To explain the required phænomena by this inſtrument, the tutor has only to aſſume two propoſitions: 1. That a globular luminous body ſending out parallel rays, will only enlighten one half of another globe, and conſequently that hemiſphere only is illuminated which is turned towards the luminous body. 2. That the globe moves round the luminous body in ſuch a manner, that in all parts of it's orbit, it's axis may be parallel to itſelf, and have a certain inclination to the plane of the orbit.

When the earth is in the firſt point of Capricorn, the ſun will appear in the firſt point of Cancer; in this ſituation, which is that of the ball A, fig. 1, plate V. the north pole is turned towards the ſun, and that part of the globe ſituated within the arctic circle, lies wholly in the enlightened hemiſphere, and has no night; while the ſouth pole, and it's polar circle, being totally turned from the ſun, are quite involved in darkneſs.

In this poſition of the earth, the inhabitants of the northern hemiſphere will have their days at the longeſt, and their nights at the ſhorteſt; and the length of the longeſt days are greater, according as the place is further removed from the equator, till it reaches the polar circle, from whence to the pole there is at this ſeaſon continual day, and the ſeaſon is that of ſummer: while all the inhabitants on the ſouth ſide of the equator will have their nights the longeſt, and their days the ſhorteſt; becauſe the greateſt portion of the parallels which they deſcribe by the diurnal motion of the earth, are in darkneſs, and the leaſt in the light; the ſeaſon of the year to them at this time is winter.

To render this ſubject clearer to the pupil, let the tutor now refer him to the oppoſite ſituation of the globe at C, when the earth is in the firſt point of Cancer, and the ſun is ſeen in the firſt point of Capricorn. Here the northern polar circle is all involved in darkneſs, and has no day; while the ſouthern is entirely within the light, and to the inhabitants thereof there is no night. It is now winter in the northern hemiſphere, and the days are ſhorter than the night; while in the ſouthern hemiſphere, the days are at the longeſt. If the hemiſphere be now removed from

from the globe which is at Capricorn, and the globe itſelf be taken out, and brought near to that at Cancer, keeping the axis parallel to it's former ſituation, the young mind will immediately perceive how the beautiful viciſſitude in the ſeaſons is effected, merely by the inclination of the earth's axis to the plane of it's orbit, and the paralleliſm of it's axis during it's annual courſe.

When the globe is at the firſt point of Aries, as at D, and the ſun appears to be in the firſt point of Libra; the circle of illumination touches both poles, and the ſun is vertical to the equator; the axis inclines ſideways to the ſun, ſo that the earth is enlightened from pole to pole, and the days and nights are equal at all places of the earth, and the ſeaſon is that of the vernal equinox.

When the earth is at Libra, the ſun appears in Aries; the earth is again enlightened from pole to pole, and the days and nights are again every where equal.

As there are 24 meridian ſemicircles drawn on each of the globes, all meeting at their poles, and as one rotation of the earth on it's axis is performed in 24 hours, each of theſe meridians is an hour diſtant from the other in every parallel of latitude. You may, therefore, find how long the day is at any place of the earth, in either of the four ſituations, by counting how many of theſe meridians are in the light in the parallel of latitude of the given place; this number being ſubtracted from 24 hours, will give the length of the night.

In all poſitions of the earth, half the equator is always in the light, and half in darkneſs; therefore, at the equator the days and nights are all equal.

If you take off the cap of the globe which is moveable, then remove it from it's place, and hold it in the four cardinal ſituations in which the others are fixed, but with the axis perpendicular to the plane of the ecliptic; you will find that the ſeaſons would, in this caſe, have been always the ſame, without any alteration, and the days and nights of the ſame length at all places, throughout the whole year: only at the poles there would be hardly either day or night, the ſun neither riſing above, nor ſetting below the horizon, but going round the ſame continually, with one-half of his diſc in view. This is what would really happen,

happen, if the axis of the earth did not incline to the plane of it's orbit.

Description of the Lunarium, which is represented at Fig. 1, Plate XVI.

A B is the baſe of the inſtrument, on which there are two circles, one with the ſigns of the ecliptic, the other with the days of the month correſponding thereto, for the readier ſetting the moon or her nodes to their reſpective places.

C D E F an inclined braſs plane, G H I K another plane parallel to the former, and ſupported by two braſs props; the inner edge of this ring nearly touches the artificial moon, and repreſents the plane of the moon's orbit.

The moon is ſometimes on the north ſide, and ſometimes on the ſouth ſide of the ecliptic, which is called her latitude; the degrees and parts thereof are engraved from each node to the higheſt and loweſt part of her orbit, which is 5 deg. 18 min. on each ſide of the nodes.

The two nodes lie in the plane of the ecliptic, in thoſe parts of the moon's orbit where the wires that ſupport it are fixed. That from which the

the moon begins to aſcend northward, above the ecliptic, is called the aſcending or north node, as the oppoſite one from which the moon deſcends ſouthward, below the ecliptic, is called her deſcending node. They always keep oppoſite to each other, and move backward through all the ſigns of the ecliptic, in about nineteen years; on each ſide of them both is engraved a ſmall ſun at 18 degrees, and a ſmall moon 12 degrees diſtant from them; theſe are the limits of eclipſes, the firſt of the ſun, and the other of the moon. In uſing this inſtrument, the braſs ball repreſenting the ſun, is ſuppoſed to be on the table, oppoſite to it's place in the ecliptic, for the given time; and that the moon's nodes are alſo ſet to their place in the ecliptic.

If the moon's orbit coincided with the plane of the ecliptic, there would be an eclipſe of the ſun at every new moon; becauſe the moon's ſhadow then paſſing over ſome parts of the earth, would deprive them of the ſun's light; but becauſe the ſun is a great luminous body, and the moon a ſmall opake one, her ſhadow will be conical, and can only cover a ſmall part of the earth at once; and therefore there would be ſeveral ſuch eclipſes inviſible, though at noon day, to a great many places on the earth. The

moon

moon would alſo, every time ſhe was oppoſite to the ſun, paſs through the ſhadow of the earth, and undergo a total eclipſe to all thoſe inhabitants of the earth to whom it was viſible.

But as the ſun and the earth are always in the plane of the ecliptic, and the moon's orbit is inclined to it, and cuts it only in the nodes, it is plain there can be no eclipſes, but when a right line paſſing through the nodes would, if continued, run either through, or nearly by the ſun, at the time of new or full moon; and from the time that this happens till it does ſo again, is about 173 days, or near half a year, ſave what allowance is to be made of 18 degrees on either ſide of the nodes, within which the ſun may be eclipſed; and of 12 degrees, within which the moon may ſuffer an eclipſe.

The foregoing circumſtances are rendered evident to the ſenſes and the mind, by means of the lunarium; particularly ſo, when a candle, or lamp, is ſubſtituted in the place of the braſs ſun fig. 2.

OF THE

USE AND APPLICATION

OF THE MOST IMPROVED

PLANETARIUM, LUNARIUM,

AND

TELLURIAN.

THE defcription of the preceding inftruments is in a great degree applicable to this improved planetarium; but as the conftruction of this is more perfect, and as it is alfo more extenfive in it's ufe, a fuller defcription is neceffary, which I give the more readily, as the defcription of this will ferve, with very few alterations, for the greater part of orreries, &c.

It feems highly probable, that the ancients were not unacquainted with planetary machines, and

and that the ſame powers of genius which led them to contemplate and reaſon upon the motion of the heavenly bodies, induced them to realize their ideas, and form inſtruments for explaining them; and we may fairly preſume, that theſe were carried to no ſmall degree of perfection, when we conſider that of one Archimedes was the maker, and Cicero the encomiaſt.

The inſtrument now to be deſcribed, was invented by the celebrated HUYGENS; though ſince his time it has been aſcribed to almoſt as many inventors as makers; each deviation in form, the mounting it in this mode or the other, the addition of a zodiac, or ſome ſuch ſlight changes, have been deemed by many of ſufficient importance to give them a claim to the title of inventors;—be it ſo. Let the friend of ſcience encourage every humble effort to improve it, and let him beſtow a name which, though it may in ſome meaſure gratify vanity, yet incites to labour, rather than by contempt check the ardour, or diſcourage the talents which, when called forth, may be of the greateſt ſervice to ſociety.

Fig. 1, plate XVII. repreſents the planetarium, the box in which the wheel-work is contained

contained that moves the ſix primary planets round the ſun, in their proper periods of time, this motion being communicated to them by turning the handle.

On the upper plate of the planetarium, there are placed in two oppoſite circles, correſponding to each other, the ſigns of the ecliptic, and the days of the month, by means whereof the planets may be eaſily ſet to their mean places in the ecliptic for any day in the year.

Through the center of the plate there paſſes a ſtrong ſtem, on which the braſs ball ☉ is placed, which repreſents the ſun; round the ſtem are the different ſockets, which carry the arms, by which the balls repreſenting the planets are ſupported.

The planets are ivory balls, having the hemiſphere which is next the ſun white, the other black, to exhibit their reſpective phaſes to each other. The planets may be eaſily put on or taken off their ſockets, as occaſion requires.

About the primary planets are placed the ſecondary planets, or moons, which are in this inſtru-

instrument only moveable by hand; but when the inſtrument is fitted up on a large ſcale, and in a more expenſive form, even theſe are put in motion by the wheel-work.

The planets are diſpoſed in the following order: in the center is the braſs ball ☉ to repreſent the ſun, then Mercury ☿, Venus ♀, the earth ⊕, Mars ♂, Jupiter ♃, and Saturn ♄; the Georgium Sidus is not inſerted, becauſe it would not only enhance the expence, but it's motion would be ſo ſlow, as to render it incapable of affording either amuſement or inſtruction. By turning the handles, they all move about the ſun from weſt to eaſt, with the ſame relative velocities and periodical times that they have in the heavens.

When the pupil has been gratified by putting the inſtrument in motion, and making his own obſervations on thoſe motions, it will be proper to acquaint him with the names of the different planets, and of their diviſion into primary and ſecondary, to ſhew him how they were firſt diſtinguiſhed from the fixed ſtars, and how the length of their periodic revolution was diſcovered. Here it will be proper to obſerve that the annual motion of the earth, or the time it takes to per-

 form

form it's period round the ſun, is made the baſis to which the others are compared; and this is one of the reaſons why the months, and days of our months, are engraved on the circle. Having obſerved this, the planets may be put in motion, and they will be found to revolve round the repreſentative of the ſun in their proportionable times, each planet always completing it's revolution in the ſame ſpace of time, in periods regulated and proportioned to their diſtance from the ſun: the curves which they deſcribe in their revolution, is what is termed their orbit.

In order to aſſiſt the imagination in forming an idea of the vaſt diſtances of the planets from the ſun, the following ſuppoſitions have been made: That if a body projected from the ſun, ſhould fly with the ſwiftneſs of a cannon ball, that is, 480 miles every hour, this body would reach the orbit of Mercury in about 8 years, 276 days; of Venus in 16 years, 136 days; of the earth in 22 years, 226 days; of Mars in 34 years, 170 days; of Jupiter in 117 years, 234 days; and the orbit of Saturn in 215 years, 286 days.

If the reader ſhould think this idea too extenſive, he may contract it in the following manner,

in

in which the proportional bulks and diſtances of the ſun and planets are conſidered.

The dome of St. Paul's is 145 feet in diameter. Suppoſe a globe of this ſize to repreſent the ſun, then a globe of $9\frac{7}{10}$ inches will repreſent Mercury; one of $17\frac{9}{10}$ inches Venus; one of 18 inches the earth; one of 5 inches diameter the moon; one of 10 inches Mars; one of 15 feet Jupiter; one of $11\frac{1}{2}$ Saturn, with his ring 4 feet broad, and at the ſame diſtance from his body all around.

In this proportion, ſuppoſe the ſun to be at St. Paul's, Mercury might be at the Tower of London, Venus at St. James's palace, the earth at Mary-le-bone, Jupiter at Hampton-Court, and Saturn at Cliefden.*

As the general phænomena of the planetary ſyſtem will be beſt underſtood by an induction of particulars, I ſhould adviſe the tutor to remove all the planets but thoſe whoſe motion he is going to explain. For inſtance, let us ſuppoſe him to leave only the earth, Mars, and Venus. Now as each planet moves with a different degree of velocity,

 they

* Ferguſon's Tables and Tracts, p. 136.

they are continually changing their relative pofitions. Thus on turning the handle of the machine, he will find, 1ft, that the earth moves twice as faft as Mars, making two revolutions while he makes one; and Venus, on the other hand, moves much fafter than the earth. Secondly, that in each revolution of the earth thefe planets continually change their relative pofitions, correfponding fome times with the fame point of the ecliptic, but much oftener with different points.

We may now proceed to make fome obfervations on the motions of Venus, as obferved in the planetarium. If confidered as viewed from the fun, we fhall find that Venus would appear at one time nearer to the earth than at another; that fometimes fhe would appear in the fame part of the heavens, and at others in oppofite parts thereof.

As the planets, when feen from the fun, change their pofition with refpect to the earth, fo do they alfo, when feen from the earth, change their pofition with refpect to the fun, being fometimes nearer to, at others farther from, and at times in conjunction with him.

But

But the conjunctions of Venus or Mercury, ſeen from the earth, not only happen when they are ſeen together from the ſun, but alſo when they appear to be in oppoſition to the ſolar ſpectator. To illuſtrate this, bring the earth and Venus to the firſt point of Capricorn; then by applying a ſtring from the ſun over Venus and the earth, you will find them to be in conjunction, or on the ſame point of the ecliptic.

Whereas if you turn the handle till the ſun is between Venus and the earth, a ſpectator in the ſun will ſee Venus and the earth in oppoſition; but an inhabitant of the earth will ſee Venus, not in oppoſition to the ſun, but in conjunction with him.

In the firſt conjunction Venus is between the ſun and earth; this is called the inferior conjunction. In the ſecond, the ſun is ſituated between the earth and Venus; this is called the ſuperior conjunction.

After either of theſe conjunctions, Venus will be ſeen to recede daily from the ſun, but never departing beyond certain bounds, never appearing oppoſite to the ſun; and when ſhe is ſeen at the greateſt diſtance from him, a line joining her center with the center of the earth, will be a tangent to the orbit of Venus.

To illuſtrate this, take off the ſun from it's ſupport, and the ball of Venus from it's ſupporting ſtem; place the wire, fig. 2, plate XVII. ſo that the part P may be on the ſtem that ſupports the earth, and a ſimilar ſocket, fig. 3, on the pin which ſupports the ball of Venus; the wire F is to lie in a notch at the top of the ſocket, which has been put upon the ſupporting ſtem of Venus; then will the wire repreſent a viſual ray going from an inhabitant of the earth to Venus. By turning the handle, you will now find that the planet never departs further than certain limits from the ſun, which are called it's greateſt elongations, when the wire becomes a tangent to the orbit; after which, it approaches the ſun, till it arrives at either the inferior or ſuperior conjunction.

It will alſo be evident from the inſtruments, that Venus, from her ſuperior conjunction, when ſhe is furtheſt from the earth, to the time of her inferior conjunction, when ſhe is neareſt, ſets later than the ſun, is ſeen after ſun-ſet, and is, as it were, the forerunner of night and darkneſs. But from the inferior conjunction, till ſhe comes the fuperior one, fhe is always feen weftward of the fun, and muft confequently fet before him in the evening, and rife before him in the morning, foretelling that light and day are at hand.

Bring Venus and the earth to the beginning of Aries, when they will be in conjunction; and turn the handle for nearly 225 days, and as Venus moves fafter than the earth, fhe will be come to Aries, and have finifhed her courfe, but will not have overtaken the earth, who has moved on in the mean time; and Venus muft go on for fome time, in order to overtake her.

Therefore, if Venus fhould be this day in conjunction with the fun, in the inferior part of her orbit, fhe will not come again to the fame conjunction till after 1 year, 7 months, and 12 days.

It is alfo plain, by infpection of the planetarium, that though Venus does always keep nearly at the fame diftance from the fun, yet fhe is continually changing her diftance from the earth; her diftance is greateft when fhe is in her fuperior, and leaft when fhe is in her inferior conjunction.

As Venus is an opake globe, and only ſhines by the light ſhe receives from the ſun, that face which is turned towards the ſun will always be bright, while the oppoſite one will be in darkneſs; conſequently, if the ſituation of the earth be ſuch, that the dark ſide of Venus be turned towards us, ſhe will then be inviſible, except ſhe appear like a ſpot on the diſk of the ſun. If her whole illuminated face is turned towards the earth, as it is in her ſuperior conjunction, ſhe appears of a circular form, and according to the different poſitions of the earth and Venus, ſhe will have different forms, and appear with different phaſes, undergoing the ſame changes of form as the moon. Theſe different phaſes are ſeen very plain in this inſtrument, as the ſide of the planet which is oppoſite to the ſun, is blackened; ſo that in any poſition, a line drawn from the earth to the planet, will repreſent that part of her diſk which is viſible to us.

The irregularities in the apparent motions of the planets, is a ſubject that this inſtrument will fully elucidate; and the pupil will find that they are only apparent, taking their riſe from the ſituation and motion of the obſerver. To illuſtrate this, let us ſuppoſe the above-mentioned wire, when connected with Venus and the earth, to

be

be the viſual ray of an obſerver on the earth, it will then point out how the motions of Venus appear in the heavens, and the path ſhe appears to us to deſcribe among the fixed ſtars.

Let Venus be placed near her ſuperior conjunction, and the inſtrument in motion, the wire will mark out the apparent motion of Venus in the ecliptic. Thus Venus will appear to move eaſtward in the ecliptic, till the wire becomes a tangent to the orbit of Venus, in which ſituation ſhe will appear to us to be ſtationary, or not to advance at all among the fixed ſtars; a circumſtance which is exceeding viſible and clear upon the planetarium.

Continue turning, till Venus be in her ſuperior conjunction, and you will find by the wire, or viſual ray, that ſhe now appears to move backward in the ecliptic, or from eaſt to weſt, till ſhe is arrived to that part where the viſual ray again becomes a tangent to her orbit. In which poſition, Venus will again appear ſtationary for ſome time; after which, ſhe will commence anew her direct motion.

Hence when Venus is in the ſuperior part of her orbit, ſhe is always ſeen to move directly,

according

according to the order of the ſigns; but when ſhe is in the inferior part, ſhe appears to move in a contrary direction.

What has been ſaid concerning the motions of Venus, is applicable to thoſe of Mercury; but the conjunctions of Mercury with the ſun, as well as the times of his being direct ſtationary or retrograde, are more frequent than thoſe of Venus.

If the tutor wiſhes to extend his obſervations on the inſtrument to Mars, he will find by the viſual ray, that Mars, when in conjunction, and when in oppoſition, will appear in the ſame point of the ecliptic, whether it is ſeen from the ſun or the earth; and in this ſituation only is it's real and apparent place the ſame, becauſe then only the ray proceeds as if it came from the center of the univerſe.

He will obſerve, that the direct motion of the ſuperior planets is ſwifter the nearer it is to the conjunction, and ſlower when it is nearer to quadrature with the ſun; but that the retrograde motion of a ſuperior planet is ſwifter the nearer it is to oppoſition, and ſlower the nearer it is to quadra-

quadrature; but at the time of change from direct to retrograde, it's motion becomes insensible.

Of all the prejudices which philosophy contradicts, there is none so general as that the earth keeps it's place unmoved. This opinion seems to be universal, till it is corrected by instruction, or by philosophical speculation. Those who have any tincture of education, are not now in danger of being held by it; but they find at first a reluctance to believe that there are antipodes, that the earth is spherical, and turns round it's axis every day, and round the sun every year. They can recollect the time when reason struggled with prejudice upon these points, and prevailed at length, but not without some efforts.*

The planetarium gives ocular demonstration of the motion of the earth about the sun, by shewing that it is thus only that the celestial phænomena can be explained, and making the absurdity of the Ptolemaic system evident to the senses of young people. For this purpose, take off the brass ball which represents the sun, and put on the small ivory ball which accompanies the instrument in it's place, to represent the

* Reid's Essays on the Intellectual Powers of Man.

the earth, and place a ſmall braſs ball for the ſun, on that arm which carries the earth.

The inſtrument in this ſtate will give an idea of the Ptolemaic ſyſtem, with the earth immoveable in the center, and the heavenly bodies revolving about in the following order: Mercury, Venus, THE SUN, Mars, Jupiter, and Saturn. Now in this diſpoſition of the planets, ſeveral circumſtances are to be obſerved, that are contrary to the real appearances of the celeſtial motions, and which therefore prove the falſity of this ſyſtem.

It will appear from the inſtrument, that on this hypotheſis Mercury and Venus could never be ſeen to go behind the ſun, from the earth, becauſe the orbits of both of them are contained between the ſun and the earth; but theſe planets are ſeen to go as often behind the ſun as before it; we may, therefore, from hence conclude, that this ſyſtem is erroneous.

It is alſo apparent in the planetarium, that on this ſcheme theſe planets might be ſeen in conjunction with, or in oppoſition to the ſun, or at any diſtance from it. But this is contrary to experience; for they are never ſeen in oppoſition

to

to the ſun, nor ever recede from it beyond certain limits.

Again, on the Ptolemaic ſyſtem all the planets would be at an equal diſtance from the earth, in all parts of their orbits, and would therefore neceſſarily appear always of the ſame magnitude, and moving with equal and uniform velocities in one direction; circumſtances which are known to be repugnant to obſervation and experience.

To use the Instrument as a Tellurian, Plate XVIII. Fig. 1.

The ſun, the earth, and the moon, are bodies, which, from our connection with them, are ſo intereſting to us, that it is neceſſary to enter into a minute detail of their reſpective phænomena. To render this inſtrument a tellurian, all the planets are firſt to be taken off, the piece of wheelwork A B is to be placed on in their ſtead, in ſuch a manner, that the wheel c may fall into the teeth that are cut upon the edge of the ecliptic. The milled nut D is then to be ſcrewed on, to keep the wheel-work firmly in it's place. It is beſt to place this wheel-work in ſuch a manner, that the index E may point to the firſt of June,

and

and then to move the globe, ſo that the north pole may be turned towards the ſun.

The inſtrument is now ready to ſhew, in an accurate and clear manner, all the phænomena ariſing from the annual and diurnal motion of the earth; as the globe is of 3 inches diameter, all the continents, ſeas, kingdoms, &c. may be diſtinctly ſeen; the equator, the ecliptic, tropics, and other circles, are very viſible, ſo that the problems relative to peculiar places, may be ſatisfactorily ſolved. The axis of the earth is inclined to the ecliptic in an angle of 66½ degrees, and preſerves it's paralleliſm during the whole of it's revolution. About the globe there is a circle, to repreſent the TERMINATOR, or boundary between light and darkneſs, dividing the enlightened from the dark hemiſphere. At N O is an hour circle, to determine the time of ſun riſing or ſetting.

The braſs index G repreſents a central ſolar ray; it ſerves to ſhew when it is noon, or when the ſun is upon the meridian at any given place; it alſo ſhews what ſign and degree of the ecliptic on the globe the ſun deſcribes on any day, and the parallel it deſcribes.

The

The plane of the terminator H I paſſes through the center of the earth, and is perpendicular to the central ſolar ray. The index E points out the ſun's place in the ecliptic of the inſtrument for any given day in the year.

The firſt thing to be done, is to rectify the tellurian; or in other words, to put the globe into a poſition ſimilar to that of the earth, for any given day. Thus to rectify the tellurian for the 21ſt of June, turn the handle till the annual index comes to the given day; then move the globe by the arm K L, ſo that the north pole may be turned towards the ſun; and adjuſt the terminator, ſo that it may juſt touch the edge of the arctic circle. The globe is then in the ſituation of the earth for the longeſt day in our northern hemiſphere, the annual index pointing to the firſt point of Cancer and the 21ſt of June; bring the meridian of London to coincide with the central ſolar ray, and move the hour circle N O, till the index L points to XII; we then have the ſituation of London with reſpect to the longeſt day.

Now on gently turning the handle of the machine, the point repreſenting London will, by the rotation of the earth, be carried away

to,

towards the eaſt, while the ſun ſeems to move weſtward; and when London has arrived at the eaſtern part of the terminator, the index will point on the hour circle the time of ſun-ſetting for that day; continue to turn on, and London will move in the ſhaded part of the earth, on the other ſide of the terminator; when the index is again at XII, it is midnight at London; by moving on, London will emerge from the weſtern ſide of the terminator, and the index will point out the time of ſun-riſing, the ſun at that inſtant appearing to riſe above the horizon in the eaſt, to an inhabitant of London.

It will be evident by the inſtrument, while in this poſition, that the central ſolar ray, during the whole revolution of the earth on it's axis, only points to the tropic of Cancer, and that the ſun is vertical to no other part of the earth, but thoſe that are under this tropic.

By obſerving how the terminator cuts the ſeveral parallels of the globe, we ſhall find that all thoſe between the northern and ſouthern polar circles (except the equator) are divided unequally into diurnal and nocturnal arches, the former being greateſt on the north ſide of the equator, and the latter on the ſouth ſide of it.

In

In this poſition, the northern polar circle is wholly on that ſide the terminator which is neareſt the ſun, and therefore altogether in the enlightened hemiſphere, and the inhabitants thereof enjoy a continual day. In the ſame manner, the inhabitants of the ſouthern polar circle continue in the dark at this time, notwithſtanding the diurnal revolution of the earth; it is the annual motion only which can relieve them from this ſituation of perpetual darkneſs, and bring to them the bleſſings of day, and the enjoyments of ſummer; while in this ſtate the inhabitants in north latitude are neareſt to the central ſolar ray, and conſequently to the ſun's perpendicular beams, and of courſe a greater number of his rays will fall upon any given place, than at any other time; the ſun's rays do now alſo paſs through a leſs quantity of the atmoſphere, which, together with the length of the day, and the ſhortneſs of the night, are the reaſons of the increaſe of heat in ſummer, together with all it's other delightful effects.

While the earth continues to turn round on it's own axis once a day, it is continually advancing from weſt to eaſt, according to the order of the ſigns, as is ſeen by the progreſs of the annual index E, which points ſucceſſively to all the ſigns and degrees of the ecliptic; the ſun in the mean time ſeems to deſcribe the ecliptic alſo, going from weſt to eaſt, at the diſtance of ſix ſigns from the earth, that is, when the earth really ſets out from the firſt point of Capricorn, the ſun ſeems to ſet out from the firſt point of Cancer, as is plain from the index.

But as during the annual revolution of the earth, the axis always remains parallel to itſelf, the ſituation of this axis, with reſpect to the ſun, muſt be continually changing.

As the earth moves on in the ecliptic, the northern polar circle gets gradually under the terminator, ſo that when the earth is arrived at the firſt point of Aries, and the annual index is at the firſt point of Libra on the 22d of September, this circle is divided into two equal parts by the terminator, as is alſo every other parallel circle, and conſequently the diurnal and nocturnal arches are equal; this is called the time of equinox, the days and nights are then equal all over the earth, being each of them 12 hours long, as will be ſeen by the horary index L. The central ſolar ray G having ſucceſſively pointed to all the parallels that may be ſuppoſed to be between the equator and the tropic of Cancer,

Cancer, is at this period perpendicular to the inhabitants that live at the equator.

By continuing to turn the handle, the earth advances in the ecliptic, and the terminator ſhews how the days are continually decreaſing, and the diurnal arches ſhortening, till by degrees the whole ſpace contained by the northern polar circle is on that ſide of the terminator which is oppoſite to the ſun, which happens when the earth is got to the firſt point of Cancer, and the annual index is at the firſt point of Capricorn, on the 21ſt of December. In this ſtate of the globe, the northern polar circle, and all the country within that ſpace have no day at all; whilſt the inhabitants that live within the ſouthern polar circle, being on that ſide of the terminator which is next the ſun, enjoy perpetual day. By this and the former ſituation of the earth, the pupil will obſerve that there are nations to whom a great portion of the year is darkneſs, who are condemned to paſs weeks and months without the benign influence of the ſolar rays. The central ſolar ray is now perpendicular to the tropic of Capricorn; the length of the days is inverſly what it was when the ſun entered Cancer, the days being now at their ſhorteſt, and the nights longeſt in the northern hemiſphere;

the length of each is pointed out by the horary index.

The earth being again carried on till it enters Libra, and the ſun Aries, we ſhall again have all the phænomena of the equinoctial ſeaſons. The terminator will divide all the parallels into two equal parts; the poles will again be in the plane of the terminator, and conſequently as the globe revolves, every place from pole to pole will deſcribe an equal arch in the enlightened and obſcure hemiſpheres, entering into and going out of each exactly at ſix o'clock, as ſhewn by the hour index.

As the earth advances, more of the northern polar circle comes into the illuminated hemiſphere, and conſequently the days increaſe with us, while thoſe on the other ſide the equator decreaſe, till the earth arrives at the firſt point of Capricorn, the place from which we firſt began to make our obſervations.

Take off the globe and it's terminator, and put on in it's place the globe which accompanies the inſtrument, and which is furniſhed with a meridian, horizon, and quadrant of altitude; the edge of the horizon is graduated from the eaſt and

and weſt, to the north and ſouth points, and within theſe diviſions are the points of the compaſs to the under ſide of this horizon; but at 18 degrees from it another circle is affixed, to repreſent the twilight circle; the meridian is graduated like the meridian of a globe; the quadrant of altitude is divided into degrees, beginning at the zenith, and finiſhing at the horizon.

This globe, if the horizon be differently ſet with reſpect to the ſolar ray, will exhibit the various phænomena ariſing from the ſituation of the horizon with reſpect to the ſun, either in a right, a parallel, or an oblique ſphere; or having ſet the horizon to any place, you will ſee by the central ſolar ray how long the ſun is above or below the horizon of that place, and at what point of the compaſs he riſes, his meridian altitude, and many other curious particulars, of which we ſhall give a few examples.

Set the horizon to coincide with the equator, and place the earth in the firſt point of Libra; then will the globe be in the poſition of a parallel ſphere, and of the inhabitants of the poles at that ſeaſon of the year, which inhabitants are repreſented by the pin at the upper part of the quadrant of altitude; the handle being turned round gently, the earth will revolve upon it's axis, and the solar ray will coincide with the horizon, without deviating in the least to the north or south; shewing, that on the 21st of March the sun does not appear to rise or set to the terrestrial poles, but passes round through all the points of the compass, the plane of the horizon bisecting the sun's disk.

Now place the horizon, so that it may coincide with the poles, and the pin representing an inhabitant be over the equator, the globe in this position is said to be in that of a right sphere; the equator, and all the parallels of latitude, are at right angles, or perpendicular to the horizon; by turning the handle till the earth has completed a year, or one revolution about the sun, we shall perceive all the solar phænomena as they happen to an inhabitant at the equator, which are, 1. That the sun rises at six, and sets at six, throughout the year, so that the days and nights there are perpetually equal. 2. That on the 21st of March, and 22d of September, the sun is in the zenith, or exactly over the heads of the inhabitants. That one half of the year between March and September, the sun is every day full north, and the other half between September and

and March, is full ſouth of the equator, his meridian altitude being never leſs than $66\frac{1}{2}$ degrees.

If the pin repreſenting an inhabitant be now removed out of the equator, and ſet upon any place between it and the poles, the horizon will not then paſs through either of the poles, nor coincide with the equator, but cut it obliquely, one-half being above, the other half below the horizon; the globe in this ſtate is ſaid to be in that of an oblique ſphere, of which there are as many varieties as there are places between the equator and either pole. But one example will be ſufficient; for whatever appearance happens to one place, the ſame, as to kind, happens to every other place, differing only in degree, as the latitudes differ. Bring the pin, therefore, over London, then will the horizon repreſent the horizon of London, and in one revolution of the earth round the ſun, we ſhall have all the ſolar appearances through the four ſeaſons clearly exhibited, as they really are in nature; that is, the earth ſtanding at the firſt degree of Libra, and the ſun then entering into Aries, the meridian turned to the ſolar ray, and the hour index ſet to XII, you will then have the globe ſtanding in the ſame poſition towards the ſun, as our earth does at noon on the 21ſt of March. If the handle be turned round, when the ſolar ray comes to the weſtern edge of the horizon, the hour index will point VI, which ſhews the time of ſun-ſetting; London then paſſes into, and continues in darkneſs, till the hour index having paſſed over XII hours, comes again to VI, at which time the ſolar ray gains the eaſtern edge of the horizon, thereby defining the time of ſun-riſing; ſix hours afterwards the meridian again comes to the ſolar ray, and the hour index points to XII, thereby evidently demonſtrating the equality of the day and night, when the ſun is in the equinoctial; you may then alſo obſerve, that the ſun riſes due eaſt, and ſets due weſt.

Continuing to move the handle, you will find that the ſolar ray declines from the equator towards the north, and every day at noon riſes higher upon the graduations of the meridian than it did before, continually approaching to London, the days at the ſame time growing longer and longer, and the ſun riſing and ſetting more and more towards the north, till the 21ſt of June, when the earth gets into the firſt degree of Capricorn, and the ſun appears in the tropic of Cancer, riſing about 40 minutes paſt III in the morning, and ſetting about 20 minutes paſt VIII in the evening; and after continuing about ſeven

hours

hours in the nether hemifphere, appears rifing in the north-eaft as before. From the 21ft of June to the 22d of September, the fun recedes to the fouth, and the days gradually decreafe to the autumnal equinox, when they again become equal.

During the three fucceeding months, the fun continues to decline towards the fouth pole, till the 21ft of December, when the fun enters the tropic of Capricorn, rifing on the fouth-eaft point of the compafs about 20 minutes paft VIII in the morning, and fetting about 40 minutes paft III in the evening, at the fouth-weft point upon the horizon; after which, the fun continues in the dark hemifphere for 17 hours, and then appears again in the fouth-eaft, as before. From the 21ft of December the fun returns towards the north, and the days continually increafe in length till the vernal equinox, when all things are reftored in the fame order as at the beginning.

Thus all the varieties of the feafons, the time of fun rifing and fetting, and at what point of the compafs; as alfo the meridian altitude and declination every day of the year, and duration of twilight, and to what place the fun is at any time

vertical,

vertical, are fully exemplified by this globe and it's apparatus.

Before we quit the phænomena particularly arising from the motion and position of the earth, let the globe, with the meridian and horizon, be removed, and the ivory ball which fits upon the pin be placed thereon, to represent the earth.

As the axis of this globe stands perpendicular to the plane of the ecliptic, you will find that the solar ray continually points at the equator of this little ball, and will never deviate to the north or south; though by turning the handle, the ball is made to complete a revolution round the sun. This shews that the earth in this position would have the days and nights equal in every part of the globe, all the year long; and that the variety of the seasons is owing to it's axis being inclined to the plane of it's orbit.

Of the Lunarium, Fig. 2, Plate XVIII.

Having thus illustrated the phænomena, which arise particularly from the inclination of the earth's axis to the plane of the ecliptic, from it's rotation round it's axis, and revolution round the

sun;

fun; we now proceed to explain, by this inftrument, the phænomena of the moon; but in order to this, it will be neceffary to fpeak firft of the inftrument, which is put in motion like the preceding one, by the teeth on the fixed wheel; it is alfo to be placed upon the fame focket as the tellurian, and confined down by the fame milled nut; the floping ring P Q reprefents the plane of the moon's orbit, or path, round the earth; fo that the moon in her revolution round the earth does not move parallel to the plane of the ecliptic, but on this inclined plane; the two points of this plane, that are connected by the brafs wire, are the nodes, one of which is marked ☊, for the afcending node, the other ☋ for the defcending node. As the moon is fometimes on the north, and fometimes on the fouth fide of the ecliptic, which deviations from the ecliptic are called her north or fouth latitude; her greateft deviation, which is when fhe is at her higheft and loweft points, called her limits, is 5 deg. 18 min.; this, with all the other intermediate degrees of latitude, are engraved on this ring, beginning at the nodes, and numbered both ways from them. At each fide of the nodes we find, at about 18 degrees diftance from them, a fun ☉, and at about 12 degrees a moon ☽, to indicate that when the full moon is got as far from the nodes as the mark ☽,

there

there can then be no eclipſe of the moon, nor any eclipſe of the ſun; when the new moon has paſſed the mark ⊙, theſe points are generally termed the limits of eclipſes.

The nodes of the moon do not remain fixed at the ſame point of the ecliptic, but have a motion contrary to the order of the ſigns. T V is a ſmall circle parallel to the ecliptic; it is divided into 12 ſigns, and each ſign into 30 degrees; this circle is moveable in it's ſocket, and is to be ſet by hand, ſo that the ſame ſign may be oppoſite to the ſun, that is marked out by the annual index. The moon's nodes are to be ſet to their place in this ſmall ecliptic, which place is to be found by an ephemeris; R S is a circle, on which are divided the days of the moon's age; X Y is an ellipſis, to repreſent the moon's elliptical orbit, the direct motion of the apogee, or the line of the apſides, with the ſituation of the elliptical orbit of the moon, and place of the apogee in the ecliptic at all times.

Having rectified the lunarium for uſe, on putting it into motion it will be evident,

1. That the moon, by the mechaniſm of the inſtrument, always moves in an orbit inclined to that of the ecliptic, and conſequently in an orbit analogous to that in which the moon moves in the heavens.

2. That ſhe moves from weſt to eaſt.

3. That the white or illuminated face of the moon is always turned towards the ſun.

4. That the nodes have a revolution contrary to the order of the ſigns, that is, from Aries to Piſces; that this revolution is performed in about nineteen years, as in nature.

5. That the moon's rotation upon her axis is effected and completed in about $27\frac{1}{2}$ days; whereas it is $29\frac{1}{2}$ days from one conjunction with the ſun to the next.

6. That every part of the moon is turned to the ſun, in the ſpace of her monthly or periodic revolution.

To be more particular. On turning the handle, you will obſerve another motion of the earth, which has not yet been ſpoken of, namely, it's monthly motion about the common center of gravity, between the earth and moon, which center of gravity is reprefented by the pin Z. From hence we learn, that it is not the center of the earth which defcribes what is called the annual orbit, but the center of gravity between the earth and moon, and that the earth has an irregular, vermicular, or fpiral motion about this center, fo that it is every month at one time nearer to, at another further from the fun. It is evident from the inftrument, that the moon does not regard the center of the earth, but the center of gravity as the center of her proper motion. That the center of the earth is furtheft from the fun at new moon, and neareft at the full moon; that in the quadratures the monthly parallax of the earth is fo fenfible, as to require a particular equation in aftronomical tables. Thefe particulars were firft applied to the orrery, by the late ingenious Mr. Benjamin Martin.

The phafes of the moon are clearly exhibited in this inftrument; for we here fee that half which is oppofite to the fun is always dark, while that which is next to the fun is white, to reprefent the illuminated part. Thus when it is new moon, you will fee the whole white part next the fun, and the dark part turned towards the earth, fhewing ſhewing thereby it's diſappearance, or the time of it's conjunction and change: on turning the handle, a ſmall portion of the white part will begin to be ſeen from the earth, which portion will increaſe towards the end of the 7th day, when you will perceive that half of the light, and half of the dark ſide, is turned towards the earth, thus illuſtrating the appearance of the moon at the firſt quarter. From hence the light ſide will continually ſhew itſelf more and more in a gibbous form, till at the end of fourteen days the whole white ſide will be turned towards the earth, and the dark ſide from it, the earth now ſtanding in a line between the ſun and moon; and thus the inſtrument explains the oppoſition, or full moon. On turning the handle again, ſome of the ſhaded part will begin to turn towards the earth, and the white ſide to turn away from it, decreaſing in a gibbous form till the laſt quarter, when the moon will appear again as a creſcent, which ſhe preſerves till ſhe has attained another conjunction.

In this lunarium the moon has always the ſame face or ſide to the earth, as is evident from the ſpots delineated on the ſurface of the ivory ball, revolving about it's axis in the courſe of one revolution round the earth; in conſequence

of

of which, the light and dark part of the moon appear permanent to us, and the phafes are fhewn as they appear in the heavens.

The tutor will be enabled by this inftrument to explain fome other circumftances to his pupil; namely, that as the earth turns round his axis once in 24 hours, it muft in that time exhibit every part of it's furface to the inhabitants of the moon, and therefore it's luminous and opake parts will be feen by them in conftant rotation. As that half of the earth which is oppofed to the fun is always dark, the earth will exhibit the fame phafes to the lunarians that we do to them, only in a contrary order, that when the moon is new to us, we fhall be full to them, and vice verfa. But as one hemifphere only of the moon is ever turned towards us, it is only to thofe that are in this hemifphere who can fee us; our earth will appear to them always in one place, or fixed in the fame part of the heavens; the lunarians in the oppofite hemifphere never fee our earth, nor do we ever view the part of the moon that they inhabit. The moon's apparent diurnal motion in the heavens is produced by the daily revolution of our earth.

If

If we conſider the moon with reſpect to the ſun, the inſtrument ſhews plainly that one-half of her globe is always enlightened by the ſun; that every part of the lunar ball is turned to the ſun, in the ſpace of her monthly or periodical revolution, and that therefore the length of the day and night in the moon is always the ſame, and equal to $14\frac{3}{4}$ of our day. When the ſun ſets to the lunarians in that hemiſphere next the earth, the terreſtrial moon riſes to them, and they can therefore never have any dark night; while thoſe in the other hemiſphere can have no light by night, but what the ſtars afford.

The difference between the periodical month, in which the moon exactly deſcribes the ecliptic, and the ſynodical, or time between any two new moons, is here rendered very evident. To ſhew this difference, obſerve at any new moon her place in the ecliptic, then turn the handle, and when the moon has got to the ſame point in the ecliptic, you will ſee that the dial ſhews $27\frac{1}{3}$ days, and the moon has finiſhed her periodic revolution. But the earth at the ſame time having advanced in it's annual path about 27 degrees of the ecliptic, the moon will not have got round in a direct line with the ſun, but will require 28 days and 4 hours more, to bring it into conjunction with the ſun again.

There is nothing in aſtronomy more worthy of our contemplation, nor any thing more ſublime in natural knowledge, than rightly to comprehend thoſe ſudden obſcurations of the heavenly bodies, that are termed eclipſes, and the accuracy with which they are now foretold. One of the chief advantages derived by the preſent generation, from the improvement and diffuſion of philoſophy, is delivery from unneceſſary terror, and exemption from falſe alarms. The unuſual appearances, whether regular or accidental, which once ſpread conſternation over ages of ignorance, are now the recreations of inquiſitive ſecurity. The ſun is no more lamented when it is eclipſed, than when it ſets; and meteors play their corruſcations without prognoſtic or prediction.

We have already obſerved, that the ſun is the only real luminary in the ſolar ſyſtem, and that none of the other planets emit any light but what they have received from the ſun; that the hemiſphere which is turned towards the ſun is illuminated by his rays, while the other ſide is involved in in darkneſs, and projects a ſhadow, which ariſes from the luminous body.

When the ſhadow of the earth falls upon the moon, it cauſes an eclipſe of the moon; when the ſhadow of the moon falls upon the earth, it cauſes an eclipſe of the ſun.

An eclipſe of the moon, therefore, never happens but when the earth's opake body interpoſes between the ſun and the moon, that is, at the full moon; and an eclipſe of the ſun never happens but when the moon comes in a line between the earth and the ſun, that is, at the new moon.

From what we have already ſeen by the inſtrument, it appears that the moon is once every month in conjunction, and once in oppoſition; from hence it would appear, that there ought to be two eclipſes, one of the ſun, the other of the moon, every month; but this is not the caſe, and for two reaſons, firſt, becauſe the orbit of the moon is inclined in an angle of about 5 degrees to the plane of the ecliptic; and ſecondly, becauſe the nodes of this orbit have a progreſſive motion, which cauſes them to change their place every lunation. Hence it often happens, that at the times of oppoſition or conjunction the moon has ſo much latitude, or what is the ſame thing, is ſo much below or above the plane of the ecliptic, that the light of the ſun will in the firſt caſe reach the moon, without any obſtacle, and in the other the earth; but as the nodes are not fixed, but run ſucceſſively through all the ſigns of the ecliptic, the moon is often, both at the times of conjunction and oppoſition, in or very near the plane of the ecliptic; in theſe caſes an eclipſe happens, either of the ſun or moon, according to her ſituation. The whole of this is rendered clear by the lunarium, where the wire projecting from the earth, ſhews when the moon is above, below, or even with the earth, at the times of conjunction and oppoſition, and thus when there will be, or not, any eclipſes.

The diſtance of the moon from the earth varies ſenſibly with reſpect to the ſun; it does not move in a circular, but in an elliptic orbit * round us, the earth being at one of the foci of this curve. The longer axis of the lunar orbit is not always directed

* That point of her orbit wherein ſhe is neareſt the earth, is called her PERIGEE; the oppoſite point, in which ſhe is fartheſt off, is called her APOGEE. Theſe two points are called her APSIDES, the apogee is the higher, the perigee the lower apſis.

directed to the ſame point of the heavens, but has a movement of it's own, which is not to be confounded with that of the nodes; for the motion of the laſt is contrary to the order of ſigns, but that of the line of apſides is in the ſame direction, and returns to the ſame point in the heavens in about nine years. This motion is illuſtrated in the lunarium by means of the braſs ellipſis X Y, which is carried round the earth in little leſs than nine years: thus ſhewing the ſituation of the elliptical orbit of the moon, and the place of the apogee in the ecliptic.

Thoſe who wiſh to extend the application of the inſtrument further, may have an apparatus applied to it for explaining the Jovian and Saturnian ſyſtems, illuſtrating the motion of their ſatellites, and of the ring of Saturn. But as this application would extend the price of the inſtrument beyond the reach of moſt purchaſers, I have thought it would be unneceſſary to deſcribe them; the more ſo, as the phænomena they are intended to explain are accurately and clearly deſcribed in ſeveral introductory works of aſtronomy.

Of the Planetarium, Tellurian, and Lunarium, represented in Plate XIX.

It is unneceſſary to enter into a minute deſcription of this inſtrument, as what has been ſaid upon the laſt will apply to this, the difference being but ſmall, and that calculated to render the inſtrument leſs expenſive.

It differs from that delineated in plates XVII. and XVIII. in the following particulars:

1. That the parts do not take off, as in the other, for exhibiting the particular phænomena; but the whole is put in motion at the ſame time.

2. That the part, which anſwers the purpoſe of the tellurian, is upon a much ſmaller ſcale than that of plate XVIII.

3. The lunarium only exhibits the monthly motion of the moon round the earth, the inclination of the nodes, and the phaſes.

To leſſen the price ſtill more, ſome of theſe inſtruments are conſtructed with no diurnal motion to the earth.

OF THE ARMILLARY SPHERE, FIG. I, PLATE XIII.

This inſtrument repreſents a planetarium, as combined, or rather as inſerted within an armillary ſphere. The planetarium exhibits the motion of the earth, and all the primary planets, round the ſun; the parallelifm of the earth's axis, and the moon's motion round the earth, the ſeaſons, &c. may therefore be explained by it; the propriety of placing them in a ſphere, is too obvious to need explanation; the deſcription of the foregoing inſtrument will enable the tutor to uſe this with eaſe to himſelf, and ſatisfaction to his pupil.

DESCRIPTION AND USE OF THE ARMILLARY SPHERE, FIG. I, PLATE XIII.

Whoever has ſeen a common armillary ſphere, and underſtands how to uſe it, muſt be ſenſible that the machine here referred to, is of a very different, and much more advantageous conſtruction. And whoever has ſeen the curious glaſs ſphere, invented by Dr. Long, or the figure of it in his aſtronomy, muſt know that the furniture of the terreſtrial globe in this machine, the manner of turning either the earthly globe, or the circles which ſurround it, are all copied from the doctor's glaſs ſphere; and that the only difference is, a parcel of rings inſtead of a glaſs celeſtial globe; and all the additions are, a moon within the ſphere, and a ſemicircle upon the pedeſtal.*

The exterior parts of this machine are a compages of braſs rings, which repreſent the principal circles of the heaven, viz. 1. The equinoctial, which is divided into 360 degrees, (beginning at it's interſection with the ecliptic in Aries) for ſhewing the ſun's right aſcenſion in degrees; and alſo into 24 hours, for ſhewing his right aſcenſion in time. 2. The ecliptic B B, which is divided into 12 ſigns, and each ſign into 30 degrees, and alſo into the months and days of the year, in ſuch a manner, that the degree or point of the ecliptic in which the ſun is, on any given day, ſtands over that day in the circle of months. 3. The tropic of Cancer C C. 4. The arctic circle E, and the antarctic circle F, each $23\frac{1}{2}$ degrees from it's reſpective pole at N and S. 5. The equinoctial colure G G paſſing through the north and ſouth poles of the heaven at N and S, and through the equinoctial points Aries and Libra, in the ecliptic. 6. The ſolſtitial colure H H paſſing through the poles of the heaven, and

* Ferguſon's Lectures, p. 194.

and through the solstitial points Cancer and Capricorn, in the ecliptic. Each quarter of the former of these colures is divided into 90 degrees, from the equinoctial to the poles of the world, for shewing the declination of the sun, moon, and stars; and each quarter of the latter, from the ecliptic to it's poles, for shewing the latitudes of the stars.

In the north pole of the ecliptic is a nut b, to which is fixed one end of a quadrantal wire, and to the other end a small sun Y, which is carried round the ecliptic B B, by turning the nut; and in the south pole of the ecliptic is a pin at d, on which is another quadrantal wire, with a small moon Z upon it, which may be moved round by hand; but there is a particular contrivance for causing the moon to move in an orbit which crosses the ecliptic at an angle of 5⅓ degrees, in two opposite points, called the moon's nodes; and also for shifting these points backward in the ecliptic, as the moon's nodes shift in the heaven.

Within these circular rings is a small terrestrial globe I, fixed on an axis K K, which extends from the north and south poles of the globe, to those of the celestial sphere at N and S: on this axis is fixed the flat celestial meridian L, which may be ſet directly over the meridian of any place on the globe, and then turned round with the globe, ſo as to keep over the ſame meridian upon it: this flat meridian is graduated the ſame way as the braſs meridian of a common globe, and it's uſe is much the ſame. To this globe is fitted the moveable horizon M M, ſo as to turn upon two ſtrong wires proceeding from it's eaſt and weſt points to the globe, and entering the globe at oppoſite points of it's equator, which is a moveable braſs ring let into the globe in a groove all around it's equator: the globe may be turned by hand within this ring, ſo as to place any given meridian upon it, directly under the celeſtial meridian L. The horizon is divided into 360 degrees all around it's outermoſt edge, within which are the points of the compaſs, for ſhewing the amplitude of the ſun and moon, both in degrees and points. The celeſtial meridian L L paſſes through two notches in the north and ſouth points of the horizon, as in a common globe; but here, if the globe be turned round, the horizon and meridian turn with it. At the ſouth pole of the ſphere is a circle of 24 hours, fixed to the rings, and on the axis is an index which goes round that circle, if the globe be turned round it's axis.

The

The whole fabric is ſupported on three feet, and may be elevated or depreſſed upon the joint O, to any number of degrees from o to q o, by means of the arc P, which is fixed into the ſtrong braſs arm Q, and ſlides in the upright piece R, in which is a ſcrew at r, to fix it at any proper elevation. In the box T are two wheels (as in Dr. Long's ſphere) and two pinions, whoſe axes come out at a and b; either of which may be turned by the milled nuts affixed to them. When the nut b is turned, the terreſtrial globe, with it's horizon and celeſtial meridian, keep at reſt; and the whole ſphere of circles turns round from eaſt, by ſouth, to weſt, carrying the ſun Y, and moon Z, round the ſame way, and cauſing them to riſe above and ſet below the horizon; but when the nut a is turned forward, the ſphere, with the ſun and moon, keep at reſt; and the earth, with it's horizon and meridian, turn round from weſt, by ſouth, to eaſt; and bring the ſame points of the horizon to the ſun and moon, to which theſe bodies came when the earth kept at reſt, and they were carried round it, ſhewing that they riſe and ſet in the ſame points of the horizon, and at the ſame times in the hour circle, whether the motion be in the earth, or in the heaven. If the earthly globe be turned, the hour index goes round it's hour circle;

cle; but if the ſphere be turned, the hour circle goes round below the index.

And ſo, by this conſtruction, the machine is equally fitted, to ſhew either the real motion of the earth, or the apparent motion of the heaven.

To rectify the ſphere for uſe, firſt ſlacken the ſcrew r in the upright ſtem R, and taking hold of the arm Q, move it up or down until the given degree of latitude for any place be at the ſide of the ſtem R, and then the axis of the ſphere will be properly elevated, ſo as to ſtand parallel to the axis of the world, if the machine be ſet north and ſouth by a ſmall compaſs: this done, count the latitude from the north pole, upon the celeſtial meridian L, down towards the north notch of the horizon, and ſet the horizon to that latitude; then turn the nut b, until the ſun Y comes to the given day of the year in the ecliptic, and the ſun will be at it's proper place for that day: find the place of the moon's aſcending node, and alſo the place of the moon, by an ephemeris, and ſet them right accordingly. Laſtly, turn the nut b until either the ſun comes to the meridian L, or until the meridian comes to the ſun, (according as you want the ſphere or earth to move)

move) and ſet the hour index to the XII marked noon, and the whole machine will be rectified.

Then turn the nut a, and obſerve when the ſun or moon riſe and ſet in the horizon, and the hour index will ſhew the times thereof for the given day.

Thoſe who underſtand the uſe of the globes, will be at no loſs to work many other problems by this ſphere.

ESSAY

ESSAY IV.

ESSAY IV.

AN INTRODUCTION TO PRACTICAL ASTRONOMY.

THERE is no part of mathematical ſcience more truly calculated to intereſt and ſurprize mankind, than the meaſurement of the relative poſitions and diſtances of inacceſſible objects. To determine the diſtance of a ſhip, ſeen on a remote ſpot of the unvaried face of the ocean; to aſcertain the height of the clouds and meteors which float in the inviſible fluid above our heads; or to ſhew with certainty the wonderful dimenſions of the ſun and other bodies in the heavens, are among the numerous problems which to the vulgar appear far beyond the reach of human art, but are neverthelefs truly refolved by the incontrovertible principles of the mathematics. Thefe principles, fimple in themfelves, and eafy to be underftood, are applied to the conftruction of a variety of inftruments; and the following pages contain an account of their ufe in the quadrant and the equatorial.

The pofition of any object, with regard to a fpectator, can be confidered in no more than two ways; namely, as to it's diftance, or the length of a line fuppofed to be drawn from the eye to the object; and as to it's direction, or the fituation of that line with refpect to any other lines of direction: or in other words, whether it lies to the right or left, above or below thofe lines. The firft of thefe two modes bears relation to a line abfolutely confidered, and the fecond to an angle. It is evident that the diftance can be directly come at by no other means than by meafuring it, or fucceffively applying fome known meafure along the line in queftion; and therefore, that in many cafes the diftance cannot be directly found; but the pofition of the line, or the angle it forms, with fome other affumed line, may be readily afcertained, provided this laft line do likewife terminate in the eye of the fpectator. Now the whole

whole artifice of meaſuring inacceſſible diſtances, conſiſts in finding their lengths, from the conſideration of angles, obſerved about ſome other line, whoſe length can be ſubmitted to actual menſuration. How this is done I ſhall proceed to ſhew.

Every one knows the form of a common pair of compaſſes. If the legs of this inſtrument were mathematical lines, they would form an angle greater or leſs, in proportion to the ſpace the points would have paſſed through in their opening. Suppoſe an arc of a circle to be placed in ſuch a manner, as to be paſſed over by theſe points, then the angles will be in proportion to the parts of the arc paſſed over; and if the whole circle be divided into any number of equal parts, as for example, 360, the number of theſe comprehended between the points of the compaſſes, will denote the magnitude of the angle. This is ſufficiently clear; but there is another circumſtance which beginners are not often ſufficiently aware of, and which therefore requires to be well attended to: it is, that the angle will be neither enlarged nor diminiſhed by any change in the length of the legs, provided their poſition remains unaltered; becauſe it is the inclination of the legs, and not their diſtance from each, or the ſpace between them, which conſtitutes the angle. So that if a pair of compaſſes, with very long legs, were opened to the ſame angle as another ſmaller pair, the intervals between their reſpective points would be very different; but the number of degrees on the circles, ſuppoſed to be applied to each, would be equal, becauſe the degrees themſelves on the ſmaller circle would be exactly proportioned to the ſhortneſs of the legs. This property renders the admeaſurement of angles very eaſy; becauſe the diameter of the meaſuring circle may be varied at pleaſure, as convenience requires. In practice, however, the magnitude of inſtruments is limited on each ſide. If they be made very large, they are difficult to manage, and their weight bearing a high proportion to their ſtrength, renders them liable to change their figure, by bending when their poſition is altered; but on the contrary, if they are very ſmall, the errors of conſtruction and graduation amount to more conſiderable parts of the diviſions on the limbs of the inſtrument.

Of the Quadrant and it's Uses.

Every circle being ſuppoſed to be divided into 360 equal parts, or degrees, it is evident that 90 degrees, or one-fourth part of a circle, will be ſufficient

ſufficient to meaſure all angles formed between a fine perpendicular to the horizon, and other lines which are not directed to points below the level. Fig. 1, pl. XX. is a drawing of a very ſimple and uſeful inſtrument of this kind. A B C is a quadrant mounted on an axis and pedeſtal: by means of the axis, it may be immediately placed in any vertical poſition, and the pedeſtal being moveable in the axis of the circle E F, ſerves to place it in the direction of any azimuth, or towards any point of the compaſs. The limb A B is divided into degrees and halves, numbered from A; and upon the radius B C are fixed two ſights, of which B is perforated with a ſmall hole, and is provided with a dark glaſs, to defend the eye from the ſun's light; and the other ſight C has a larger hole, furniſhed with croſs wires, and alſo a ſmaller, which is of uſe to take the ſun's altitude by the projection of the bright image of that luminary upon the oppoſite ſight. From the center C hangs a plumb line C P. The horizontal circle F E is divided into four quadrants of 90 degrees; and an arm E, connected with the pedeſtal, moves along the limb, and conſequently ſhews the poſition of the place of the quadrant, as will hereafter be more minutely explained. Laſtly, the ſcrews G, H, I, render it very eaſy to ſet the whole inſtrument ſteadily and accurately in it's proper poſition, notwithſtanding any irregularity in the table or ſtand it may be placed upon.

The rationale of this inſtrument is very clear and obvious. It is uſed to meaſure the angular diſtance of any body, or appearance, either from the zenith or point immediately above our heads, or from the horizon or level. The plumb line C P, if continued upwards from C, would be directed to the zenith Z; and the line C L, ſuppoſed to be drawn from the center of the quadrant to an object L, will form an angle L C Z, which is the zenith diſtance, and is equal to the angle B C P, formed between the oppoſite parts of the ſame lines. We ſee, therefore, that the degrees on the arc, comprehended on the limb of the quadrant, between the plumb line and the extremities next the eye, meaſure the angle of zenith diſtance.

Again, the line C K (forming a right angle with the perpendicular C Z) is level, or horizontal; the angle L C K muſt therefore be the altitude or elevation of L above the horizon: and this laſt angle muſt be equal to the angle meaſured between the plumb line and the end A fartheſt from the eye; becauſe both theſe are

equal

equal to the quantity which would be left, after taking the zenith diſtance from a right angle, or the whole quadrant.

The determination of the altitude or zenith diſtance of an object is not ſufficient to aſcertain it's place, becauſe the object may be placed in any direction with reſpect to azimuth, or the points of the compaſs, without increaſe or diminution of it's altitude. Hence it is that an horizontal graduated circle is a neceſſary addition to a quadrant which is not intended to be always uſed in the ſame plane. The bearing or poſition of an object relative to the cardinal points, together with the altitude, is ſufficient to aſcertain the place of any object or phænomenon.

After this ſhort account of the general principles of the quadrant, I ſhall proceed to ſhew ſome of the leading problems reſolved by it.

PROBLEM I.

To adjuſt the quadrant for obſervation.

The quadrant is adjuſted for obſervation when it's plane continues perpendicular to the horizon, in all poſitions of the line of ſight. For this purpofe, bring the index to 90° on the horizon, and turn one or both of the fcrews which are fixed oppofite 60°, till the plumb line lightly touches the plane of the quadrant. Then turn the index to 0°, and make the fame adjuftment, by means of the fcrew at 0°, and the quadrant is ready for obfervation.

Or otherwife, fet the index at 0°, and obferve the degree marked by the plumb line on the limb; then turn the index to the other 0° which is diametrically oppofite, and obferve the degree marked by the plumb line: if it be the fame as before, there will be no occafion to alter the fcrews at 60°; but if otherwife, one or both of thofe fcrews muft be turned, till the plumb line interfects the middle degree (or part) between the two. After this operation, the degree marked by the plumb line muft be obferved, as before, by fetting the index at both the 90°, and the adjuftment of the plumb line to the middle diftance muft be made by the fcrew at O, taking care not to touch the other fcrews.

The

The latter method of adjuſtment being more accurate in practice, may be uſed after the former.*

PROBLEM II.

To find the diſtance of an object on the earth, by obſervations made from two ſtations on the ſame level.

OBSERVATIONS.

Chuſe two ſtations, between which the ground is level, and place a viſible mark on each. The diſtance between them ought not to be leſs than the ſeventh or eighth part of the eſtimated diſtance of the object; and neither ſtation ought to be conſiderably nearer the object than the other. Meaſure the diſtance between the ſtations, by means of meaſuring poles, a chain, or a piece of ſtretched cork. From one ſtation direct

* The larger or more expenſive inſtruments have apparatus for ſetting the axes of motion at right angles to the planes of the horizontal circle and quadrant, the line of ſight or collimation parallel to the radius paſſing through 90°, &c. &c. In the ſmall inſtruments, deſcribed in the text, theſe adjuſtments are made by the workman.

direct the quadrant to the object, by looking through the hole in one ſight, and moving the upright axis about, till the object is ſeen through the hole in the other, exactly at the interſection of the croſs wires. Obſerve the degrees and parts ſhewn by the index on the horizontal circle; then direct the quadrant in the ſame manner to the mark of the other ſtation, and obſerve the degrees and parts ſhewn by the index. The number of degrees and parts intercepted between this and the former poſition of the index, is the angle at the firſt ſtation. The ſame operations repeated at the ſecond ſtation, will give the angle at that ſtation.

SOLUTION.

Take the ſum of the two obſerved angles from 90°, and the remainder will be the angle under which the two ſtation-marks would be ſeen from the object. Then

As the ſine of the angle at the object
Is to the ſine of the angle at one ſtation;
So is the diſtance between the ſtations
To the diſtance of the object from the other ſtation.

These,

Theſe, and all other proportions, may be ſolved by the logarithms, or more ſpeedily by the Gunter's rule.

SOLUTION OF THE PROBLEM BY PROTRACTION.

From a ſcale of equal parts lay down a right line, to repreſent the meaſured baſe.

By means of the protractor, or by the compaſſes and line of chords, draw a line from each extremity of the baſe, reſpectively forming angles equal to thoſe actually obſerved.

Continue theſe lines till they interſect.

The interval between the point of interſection, and one extremity of the baſe, being taken between the compaſſes, and applied to the line of equal parts, will ſhew the diſtance between the object and the ſtation repreſented by that extremity.

This problem may, in caſes of ſmall diſtance, be conveniently applied to a baſe line meaſured within a room, and the obſervations taken out at the windows.

PROBLEM

PROBLEM III.

To find the diſtance of the foot of a tower, by obſervations made on the upper part.

The ſolution of this problem conſiſts in making obſervations on the ſummit, in the ſame manner as in the foregoing problem. The diſtance deduced from the horizontal angles will be that of a point in the horizon, immediately beneath the part on which the obſervations were made.

PROBLEM IV.

To find the height of a ſpire, a mountain, or any other elevation.

Caſe 1. When the diſtance of the point immediately beneath the ſummit can be meaſured.

Obſerve the angle of altitude with the quadrant, by viewing the ſummit through the ſights, and noting the degrees and parts indicated by the interſection of the plumb line. Meaſure alſo the horizontal diſtance.

Then,

Then,

As the co-ſine of the obſerved angle
Is to the ſine of the obſerved angle ;
So is the meaſured diſtance
To the height required.

Or by conſtruction. Draw a right line equal to the meaſured baſe, taken from a ſcale of equal parts.

Erect a perpendicular from one extremity, and from the other draw a line inclined towards the perpendicular, and forming an angle with the baſe, equal to the obſerved angle.

The interval between the interſection of this laſt line, and the perpendicular, and the lower extremity of the perpendicular itſelf, being taken in the compaſſes, and applied to the line of equal parts, will ſhew the height required.

Caſe 2. When the diſtance of the point immediately beneath the ſummit cannot be meaſured.

Find

Find the diſtance by prob. iii. and the height by caſe 1, of the preſent problem: or otherwiſe,

Meaſure a baſe line directly towards the object, and take the altitude from each end of the baſe.

Then,

As the ſines of the difference between the ſum of
the two altitudes, and 180°,
Are to the ſine of the leſs altitude;
So is the baſe line
To the direct diſtance between the ſummit and
the nearer end of the baſe line.

And,

As radius
Is to the ſine of the greater altitude;
So is the diſtance laſt found
To the height required.

Or by conſtruction. Set off the baſe line, and from it's extremities draw lines inclined to the baſe in the reſpective angles obſerved, but in ſuch a manner, as that the leſs angle may be formed by the

the baſe itſelf, and the greater by the prolongation of the baſe.

Theſe lines will interſect.

From the point of interſection let fall a perpendicular on the prolongation of the baſe, and it will give the height required.

The firſt method of ſolving this caſe is in general the beſt in practice. It is for the moſt part much more eaſy to find a baſe ſufficiently long and level between two ſtations, nearly equi-diſtant from the eminence, as the firſt requires, than in a direction towards it, becauſe the ground uſually riſes irregularly towards mountains. And in the latter caſe alſo, if the difference between the two altitudes be not very conſiderable, the reſult will be rendered erroneous by a very ſmall inaccuracy of obſervation.

PROBLEM V.

To plot a field by a baſe line meaſured in the middle.

Set

Set up marks in the corners or angles, and meaſure a line in the field in ſuch a direction, as that it may be as far as poſſible from pointing towards any of the angles. Direct the ſights from one end of the baſe to each of the angles ſucceſſively, and alſo to the other extremity of the baſe, carefully noting the degrees and parts of the horizontal circle, indicated by the index. Repeat the like operations at the other end of the baſe line.

Conſtruction. Draw a faint line upon paper, upon which ſet off, from a ſcale of equal parts, the meaſured baſe. From it's extremities draw lines, forming the reſpective angles obſerved. The interſections of thoſe lines will ſhew the cornus, or angles, of the field, and muſt be joined by right lines.

This problem being nothing more than a determination of the poſition of the angular points with reſpect to the baſe line, by prob. 1, will be more accurate in practice, the more nearly the conditions there expreſſed are adhered to. If a baſe line cannot be had in view of all the angles, and in a convenient poſition, two or more baſe lines may be meaſured, and connected together

by

by the obſervation of the requiſite angles; or the three ſides of a triangle may be meaſured in the field, according to the diſcretion of the ingenious learner, and the bearings of the corners of the field taken from ſuch extremities of any of theſe meaſured lines, as are beſt adapted to the purpoſe.*

As this method is very far from being laborious, the practitioner will do well to meaſure the field twice, from a different baſe each time.

PROBLEM

* It may be proper to obſerve, for the uſe of ſuch as are unacquainted with ſurveying of land, that the Engliſh acre is 4840 ſquare yards, and that land is moſt conveniently meaſured by the Gunter's chain of 22 yards in length, divided into 100 links; becauſe the ſquare chain, or 22 multiplied by 22, equal to 484, is exactly the tenth part of an acre. If the plot of a field meaſured in chains and links, be therefore made upon paper, and divided into a number of triangles, by drawing right lines within it, the baſe and perpendicular of each triangle may be meaſured from the ſcale of equal parts, and half their product will be the area of the triangle in ſquare chains; the ſum of all the areas of the triangles will be the area of the field, which divided by 10, will ſhew the number of acres; the remaining decimal fraction multiplied by 4, gives the roods; and the decimal part of this laſt product multiplied by 40, gives the perches.

PROBLEM VI.

To plot a field, by meaſuring the ſides and angles.

Set up marks at each of the angles, and at every one of theſe marks direct the quadrant to the two adjacent marks on each ſide. The number of degrees and parts between the two poſitions of the index on the horizontal circle, will ſhew the angle at the ſtation where the obſervation is made. Meaſure the diſtance to the next ſtation, and obſerve the angle there in the ſame manner. And thus proceed completely round the field.

Conſtruction. From the ſcale of equal parts draw a line equal to the firſt meaſured ſide, and from it's extremities draw two lines, forming angles equal to thoſe actually obſerved.

Make theſe laſt lines equal to the ſides they repreſent, and from their extremities draw two other lines at angles reſpectively found by obſervation.

Proceed thus, till the whole field is plotted.

When

When all the angles of a field are thus meaſured, their ſum, if the operation has been truly made, will be equal to twice as many right angles, deducting four, as there are angles in all, provided they be all inward angles. But if any of them be outward angles, their reſpective ſupplements to 360° muſt be taken in making up the ſum, inſtead of the angles themſelves. When the ſum proves either greater or leſs than juſt the figure, it will not anſwer on paper; and as obſervations made with ſmall inſtruments cannot be expected to be free from perceptible errors, it will be expedient to correct the angles by adding or ſubtracting ſuch defect or exceſs, to or from all the angles, in proportion to their magnitude, or more readily in equal proportions among them.

This way of meaſuring is much uſed in America, by the meaſuring wheel and mariner's compaſs, and is applicable to extenſive woody or mountainous tracts of land, where great accuracy is not required. It may alſo be uſed in conjunction with other methods, for delineating a ſea-coaſt, &c.

PROBLEM VII.

To find the altitude and height of fire balls, and other meteors, in the atmoſphere.

Though the extreme velocity and tranſient nature of fiery meteors in the atmoſphere in a great meaſure prevents the making of ſuch obſervations as might tend to aſcertain their diſtance, yet they form a ſubject of inquiry ſo curious and intereſting, as renders ſuch as can be made of great value. An obſerver, who perceives an appearance of this kind, ought carefully to note the buildings, trees, ſtars, &c. near which it paſſes; and as ſoon afterwards as convenient take their altitude and bearings. If two ſuch obſervations be taken by perſons at different places, ſufficiently diſtant from each other, the diſtance on the earth may be conſidered as the baſe, and from this and the two obſerved angles the height of the meteor may be found by problem ii.

By obſervations of this kind it has been found, that the larger fire balls are elevated about 60 miles above the earth's ſurface, and that ſome of them are near five miles in diameter.

PROBLEM VIII.

To find the height of a cloud, by obſervation of a flaſh of lightning.

If the altitude of that part of a cloud from which a flaſh of lightning has iſſued, be immediately taken with the quadrant, and the number of ſeconds of time elapſed between the inſtant of the flaſh, and the firſt arrival of the thunder be reckoned, theſe data will be ſufficient to determine the height of the thunder cloud. For ſound is admitted to paſs through 1142 feet in a ſecond; but light has ſuch an extreme velocity, that it paſſes through thirty-five thouſand miles in a ſecond, and may therefore be reckoned inſtantaneous in all obſervations upon the earth. Hence it follows, that the number of ſeconds obſerved, multiplied by 1142, will give the diſtance of the cloud in feet; and

As radius
Is to the ſine of the obſerved angle;
So is the diſtance of the cloud
To it's height.

Or by conſtruction. From a point in any right line, draw another right line, forming the obſerved angle. Set off on this left line, from the angular point, the diſtance of the cloud, taken from a ſcale of equal parts. From the extreme of the laſt-mentioned line let fall a perpendicular on the other line; and this perpendicular will be the height required.

If the flaſh of lightning ſtrike directly down, the height of the cloud will alſo be the length of the flaſh. But this is not often the caſe.

PROBLEM IX.

To determine the height of a cloud, by obſervations on it's altitude and velocity.

When the ſky abounds with detached clouds, moving with conſiderable velocity, it is eaſy to determine the degree of ſwiftneſs, by obſerving the progreſs of their ſhadows which paſs along the ground. For this purpoſe, nothing more is neceſſary, than to note the inſtants of time when one of theſe ſhadows paſſes over two objects, ſuch as hedges, trees, &c. lying in it's direction; and to meaſure the interval paſſed over, during the intermediate time. When this velocity is thus

thus found, place the plane of the quadrant in the direction of the wind, and setting the sights to a considerable altitude, to be written down, take notice of some remarkable edge of a cloud, which passes across the wire in the aperture of the farthest sight, giving notice at the same instant to an assistant to note the time. Then move the quadrant on it's axis twenty or thirty degrees, and give the like notice to the assistant when the same part of the cloud passes the wire; write down this last altitude. The perpendicular height of the cloud will be found by the following proportions.

As the number of seconds observed when the shadow of the former cloud was seen on the ground

Is to the number of seconds elapsed between the two observations with the quadrant;

So is the distance measured on the ground

To the distance passed through by the cloud (whose altitude was taken) during the time of observation.

Then,

As the ſine of the difference between the ſum of the two altitudes and 180°
Is to the ſine of the leſs altitude ;
So is the diſtance paſſed over by the cloud
To it's diſtance from the obſerver, when the greater altitude was taken.

And laſtly,

As radius
Is to the ſine of the greater altitude ;
So is the diſtance laſt found
To the perpendicular height of the cloud.

PROBLEM X.

To find the altitude of the ſun, or any other celeſtial body.

This conſiſts in the ſimple application of the quadrant to a celeſtial body, in the ſame manner as has already been ſhewn with regard to terreſtrial objects. The quadrant being rectified or adjuſted by problem 1, as it muſt be in all caſes previous to it's uſe, the celeſtial body muſt be viewed through the ſights, and the plumb-line will ſhew it's it's altitude on the graduated limb of the inſtrument. If the obſervation be made on the ſun, the dark glaſs muſt be uſed to defend the eye, or the luminous ſpot formed by the ſmaller hole of that ſight which carries the croſs wires, muſt be made to fall on the mark on the other ſight which lies immediately beneath the eye-hole.

PROBLEM XI.

To find the latitude of the place of obſervation.

When the ſun, or a ſtar, is nearly on the meridian, or a few minutes before twelve at noon, take it's altitude, and repeat this operation at ſhort intervals of time, till it is found not to increaſe, but diminiſh. This laſt or greateſt altitude is the meridian altitude.

In places where the ſun does not ſet, the leaſt altitude is the meridian altitude beneath the pole.

The rule for finding the latitude by the meridian altitude of an object not beneath the pole, is as follows:

If the co-altitude and declination * be of the ſame name, (that is, either both north, or both ſouth) their difference will be the latitude; if of different names, their ſum will be the latitude. And the latitude will always be of the ſame name with the declination, excepting when the declination has been ſubtracted from the co-latitude.

But when the altitude is beneath the pole, the following is the rule:

Add the altitude and the co-declination together, and the ſum will be the latitude of the ſame name with the declination.

PROBLEM XII.

To find the time by equal altitudes of the ſun.

Obſerve the ſun's altitude in the morning, and alſo the time by a clock or watch. Leave the quadrant in the ſame ſituation, taking care that it's poſition be not altered by any accident; and in the afternoon direct it to the ſun, by moving the index of the horizontal circle only. Add the time

* The declination of the ſun, and moſt other moveable celeſtial bodies, is to be found in the ephemerides.

time when the ſun's altitude correſponds with that to which the quadrant was ſet in the morning. The middle inſtant between the two times of obſervation, is the time of apparent noon. Correct this, by adding or ſubtracting the equation of time, and it will ſhew the time of true noon. If it be preciſely XII, the clock is right; but if it differ, the clock is faſter or ſlower, by the quantity of the difference greater or leſs than XII.

PROBLEM XIII.

To draw a meridian line, or to find the cardinal points of the compaſs, by equal altitudes of the ſun, or a ſtar.

If equal altitudes of the ſun be taken as directed in the foregoing problem, and the place of the index on the horizon circle be carefully noted at each time of obſervation, the middle degree or part between each will be the place where the index will ſtand when the ſights of the quadrant are directed to the ſouth, or north, according as the ſun is to the ſouthward or northward of the place of obſervation at noon. Set the index to this middle point, and direct the ſights

ſights of the quadrant to ſome remote and fixed object on the earth. This object will be a ſouth meridian mark, and will ſerve to ſet the quadrant at any future time. Then take up the inſtrument, and after ſetting the index to 0, place it again on the table, or ſupport, and move the whole inſtrument, not by any of it's parts, but entirely about upon the table, till the ſights are truly directed to the meridian mark. Adjuſt the horizontal circle by prob. 1, and the index will then ſerve to ſhew the true bearing of any object; becauſe the diameter joining the two zeros, or 00's, anſwers to the meridian line.

If the table, or ſupport, be immoveable, it will be proper to make three marks, or indentations, to receive the points of the ſcrews; by which means the horizontal circle may be inſtantly, at any time, ſet in it's proper poſition, with reſpect to the cardinal points of the horizon.

Obſervations of equal altitude are, generally ſpeaking, better, the greater the interval is between them, not exceeding 12 hours; and theſe obſervations on the ſun require ſome correction, on account of the change of it's declination during the time of obſervation. The young aſtronomer with ſmall inſtruments may, however, neglect

neglect this; and indeed it is of little confequence about the folftices, when the fun's declination changes very flowly.

It often happens that there is not any window in a houfe, from which the fun can be feen morning and evening. In this cafe, the meridian may be determined by obfervations of equal altitude of the pole ftar, or any other near the pole.

PROBLEM XIV.

To find the time by the fun's tranfit over the meridian.

Adjuft the quadrant to the cardinal points by the laft problem, a fhort time before noon. Set the index to o, and elevate the quadrant, fo that the fhadow of the fight with the crofs wires may fall upon the other. As the inftant of apparent noon approaches, the bright fpot formed by the fun's light through the lower hole in the former fight, will be feen approaching the mark on the latter. If the obferver chufes to look at the fun, he muft now put up the dark glafs, and apply to the obfervations. The inftants when the firft limb or edge of the fun appears to touch the perpendicular wire, and alfo when the latter limb

appears

appears to leave it, muſt be noted by the clock or watch. The middle time is the apparent noon. Or if he chuſes to obſerve by the bright ſpot only, the inſtant when the ſpot is ſeen upon the mark is the apparent noon. And this corrected by the equation of time, as directed in prob. xii. will ſhew how much the clock is faſt or ſlow.

PROBLEM XV.

To find the time by an obſervation of the ſun's altitude and azimuth.

Adjuſt the inſtrument to the cardinal points, and obſerve the ſun's altitude. Take notice likewiſe of the angle of azimuth from the meridian, as ſhewn by the index.

Then,

As the ſine complement of the ſun's declination
Is to the ſine complement of the altitude ;
So is the ſine of the azimuth
To the ſine of the ſun's horary angle.

Which laſt being reduced into time, by allowing fifteen degrees to one hour, and in proportion for the other parts, gives the apparent time,

if

if afternoon ; but if before noon, it muſt be deducted from 12 hours, to give the time. This apparent time muſt be corrected by the equation, as in problem xii.

OF THE EQUATORIAL, OR UNIVERSAL SUN-DIAL, AND IT'S USES.

The plumb-line, or direction in which gravity acts, being the only line we can at all times have immediate recourſe to, for determining the poſitions of objects, is the chief particular to which the circles in the inſtrument laſt deſcribed are adapted ; and accordingly, their planes are placed the one parallel, and the other perpendicular to that line. But as there are few places on the earth whoſe vertical or horizontal circles correſpond with thoſe in which the celeſtial motions are performed, it was found neceſſary, at a very early period, to conſtruct inſtruments adapted not only to the meaſurement of altitudes and azimuths, but alſo to follow the heavenly bodies in their reſpective paths, and determine their right aſcenſions and declinations, more immediately than can be done by the quadrant and horizontal circle. The equatorial is the moſt approved modern inſtrument for this purpoſe.

It confifts of the following parts:

An horizontal circle E F, plate XX. fig. 2, divided, like that of the former inftrument, into four quadrants, of 90° each. But inftead of a moveable index there is a fixed nonius plate at E, and the circle itfelf may be turned on it's axis.

In the center of the horizontal circle is fixed a ftrong upright pillar, which fupports the center of a vertical femicircle A B, divided into two quadrants of 90° each. This is called the femicircle of altitude, and fupplies the place of the quadrant in the former inftrument, but it is more extenfively ufeful, becaufe one quadrant ferves to meafure altitudes, and the other depreffions. It has no plumb-line, but a nonius plate at K.

At right angles to the plane of this femicircle, the equatorial circle M N is firmly fixed. It reprefents the equator, and is divided into twice twelve hours, every hour being divided into twelve parts, of five minutes each.

Upon the equatorial circle moves another circle, with a chamfered edge, carrying a nonius, by which the divifions on the equatorial may be read

3

read off to ſingle minutes; and at right angles to this moveable circle is fixed the ſemicircle of declination D, divided into two quadrants of 90° each.

The piece which carries the ſights O P is fixed to an index moveable on the ſemicircle of declination, and carrying a nonius at Q. The ſight O, to which the eye is to be applied, has two ſmall holes, and a dark glaſs for covering either occaſionally; and the ſight P has two pieces ſcrewed on, the lower having a ſmall hole to admit the ſolar ray, and the upper carries two croſs wires.

Laſtly, there are two ſpirit levels fixed on the horizontal circle at right angles to each other.

The following are among the many problems which may be ſolved with peculiar facility, by means of this uſeful inſtrument.

PROBLEM XVI.

To adjuſt the equatorial for obſervation.

Set the inſtrument on a firm ſupport. Firſt, to adjuſt the levels, and the horizontal or azimuth circle. Turn the horizontal circle, till the beginning O of the divisions coincides with the middle stroke of the nonius, or near it. In this situation, one of the levels will be found to lie either in a right line joining the two feet screws which are nearest the nonius, or else parallel to such a right line. By means of the two last-mentioned screws, cause the bubble in the level to become stationary in the middle of the glass; then turn the horizontal circle half round, by bringing the other O to the nonius; and if the bubble remains in the middle, as before, the level is well adjusted; if it does not, correct the position of the level, by turning one or both of the screws which pass through it's ends, (by means of a turn-screw) till the bubble has moved half the distance it ought to come to reach the middle; and cause it to move the other half, by turning the foot-screws already mentioned. Return the horizontal circle to it's first position, and if the adjustments have been well made, the bubble will remain in the middle; if otherwise, the process of altering the level and the foot-screws, with the reversing, must be repeated till it bears this proof of it's accuracy. Then turn the horizontal circle till 90° stands opposite to the nonius; and by the foot-screw, immediately opposite the other 90°, (without touching the others)

others) cauſe the bubble of the ſame level to ſtand in the middle of the glaſs. Laſtly, by it's own proper ſcrews ſet the other level (not yet attended to) ſo that it's bubble may occupy the middle of it's glaſs.

Secondly, to adjuſt the line of ſight. Set the nonius on the declination ſemicircle at O; the nonius on the horary circle at VI; and the nonius on the ſemicircle of altitude at 90°. Look through the ſights towards ſome part of the horizon, where there is a diverſity of remote objects. Level the horizontal circle, and then obſerve what object appears on the center of the croſs wires. Reverſe the ſemicircle of altitude, ſo that the other 90° may apply to the nonius; taking care, at the ſame time, that the other three noniuſes continue at the ſame parts of their reſpective graduations as before. If the remote object continues to be ſeen on the center of the croſs wires, the line of ſight is truly adjuſted; but if not, unſcrew the two ſcrews which carry the frame of the croſs wires, and move the frame till the interſection appears to lie on a new object, half way between the object firſt obſerved, and that to which the wires are applied in the laſt poſition. Return the ſemicircle of altitude to it's original poſition: if the interſection of the wires be then found to be on the object to which they were laſt directed, the line of ſight is truly adjuſted; but if not, the frame muſt be again altered as before: and the ſame general operation muſt be repeated, till the croſs wires in both poſitions apply to the ſame object.

Beſides this adjuſtment of the center of interſection, it is neceſſary that one of the wires ſhould be in the plane of the declination ſemicircle, and the other at right angles to that plane. As the wires are fixed at right angles to each other, the adjuſtment of one of them will be ſufficient. For this purpoſe, obſerve any ſmall object on one of the wires: if it be the vertical wire, move the index of the ſemicircle of declination; or if the other, move the laſt-mentioned ſemicircle on the axis of the equatorial circle. In either caſe the object will coincide with the wire during it's motion, if the poſition be right; if not, alter that poſition, taking care not to diſplace the center from it's adjuſtment.

To adjuſt the piece which carries the hole for forming the ſolar ſpot, direct the ſights to the ſun, ſo that the center of the luminous circle formed by the aperture which carries the croſs wires, may fall preciſely on the upper ſight hole.

Then

Then move the frame, with the ſmall perforation, till the ſolar ſpot falls exactly on the lower ſight-hole.

Thirdly, to find the correction to be applied to obſervations by the ſemicircle of altitude. Set the nonius on the declination ſemicircle to O; and the nonius on the horary circle to XII. Direct the ſights to any fixed and diſtinct object, by moving the horizontal circle and ſemicircle of altitude, and nothing elſe. Note the degree and minute of altitude or depreſſion. Reverſe the declination ſemicircle, by directing the nonius on the horary circle to the oppoſite XII. Direct the ſights again to the ſame object, by means of the horizontal circle and ſemicircle of altitude, as before. If it's altitude, or depreſſion, be the ſame as was obſerved in the other poſition, no correction will be required; but if otherwiſe, half the difference of the two angles is the correction to be added to all obſervations or rectifications made with that quadrant, or half of the ſemicircle, which ſhewed the leaſt angle; or to be ſubtracted from all obſervations or rectifications made with the other quadrant, or half.

When the levels and croſs wires are once truly ſet, they will preſerve their adjuſtment a long

 time,

time, if not deranged by violence; and the correction to be applied to the ſemicircle of altitude, is a conſtant quantity.

PROBLEM XVII.

To meaſure angles, either of azimuth, altitude, or depreſſion.

Set the middle mark of the nonius on the declination at O, and fix it by means of the milled ſcrew behind. Set the horary circle at XII on the equator, and the inſtrument (previouſly adjuſted) is ready for obſervation. Then if the ſights be directed ſucceſſively to any two objects, the degrees and minutes contained between the two poſitions of the nonius, on the limb of the horizontal circle, will ſhew the horizontal angle in the ſame manner as has been deſcribed at prob. ii. of the quadrant. And likewiſe, if the ſights be directed to any object, by moving the horizontal circle and ſemicircle of altitude, the degree and minute marked by the nonius on the laſt-mentioned ſemicircle will be the angle of altitude, if on the quadrant or part neareſt the eye, or of depreſſion, if on the remoter quadrant.

Remark.

Remark. It is proper in this place to defcribe the nature and ufe of the admirable contrivance commonly called a nonius. It depends on the fimple circumftance, that if any line be divided into equal parts, the length of each part will be greater, the fewer the divifions; and contrariwife, it will be lefs in proportion as thofe divifions are more numerous. Thus it may be obferved, that the diftance between the two extreme ftrokes on the nonius, in the equatorial before us, is exactly equal to 11 degrees on the limb, but that it is divided into 12 equal parts. Each of thefe laft parts will therefore be fhorter than the degree in the proportion of 11 to 12; that is to fay, it will be one-twelfth part, or 5 minutes fhorter. Confequently, if the middle ftroke be fet precifely oppofite to any degree, the relative pofitions of the nonius and the limb muft be altered 5 minutes of a degree, before either of the two adjacent ftrokes next the middle, on the nonius, can be brought to coincide with the neareft ftroke of a degree; and fo likewife, the fecond ftrokes on the nonius will require a change of 10 minutes; the third, of fifteen, and fo forth to thirty, when the middle line of the nonius will be feen to be equi-diftant between two of the ftrokes on the limb; after which, the lines on the oppofite fide of the nonius will coincide in fucceffion with the ftrokes on the limb.

It is clear from this, that whenever the middle ftroke of the nonius does not ftand precifely oppofite to any degree, the odd minutes, or diftance between it and the degree immediately preceding, may be known by the number of the ftroke on the nonius, which coincides with any of the ftrokes on the limb. It muft be obferved, however, that as the degrees in the feveral quadrants are reckoned in oppofite directions, fo likewife the nonius has two fets of numbers; for the ufe of which, it need only be remembered, that they always begin from the middle, and go to 30 minutes, and thence from the oppofite 30 minutes in the fame direction, to the middle; and that they muft always be reckoned in the oppofite direction to the degrees on the limb.*

PROBLEM

* In this inftrument they muft be read in the oppofite direction; but when the nonius plate has it's divifions fewer than the number of parts on the limb to which it is equal, they coincide fucceffively in the fame direction as that of the motion of the index.

PROBLEM XVIII.

To find the diſtance of an object on the earth, by obſervations made at two ſtations.

This may be done by meaſuring a baſe line and the horizontal angles, and proceeding as directed at problem ii. But as the equatorial meaſures angles of depreſſion, as well as elevation, the ſtations may not only be on the ſame level, but may be vertically the one above the other. For example, if the altitude of any object be taken from a lower window of any building, and it's depreſſion from a window immediately above, and the diſtance of the two ſtations of the inſtrument be accurately meaſured,

Then,

As the ſine of the ſum of the angles of altitude
and depreſſion (or of the difference, if
both be altitude, or both depreſſion)
Is to the ſine of the angle at the upper ſtation;
So is the diſtance between the ſtations
To the diſtance of the object from the lower
ſtation.

PROBLEM XIX.

To meaſure heights and diſtances.

As the ſemicircle of altitude anſwers every purpoſe of the quadrant, in the inſtrument before deſcribed, and the horizontal circle is common to both, it will be eaſy for the intelligent learner to perform the problems iii. iv. vii. viii. and ix. by the equatorial, from the inſtructions given under each reſpectively.

PROBLEM XX.

To plot a piece of land.

The problems v. and vi. with all others which are ſolved by the menſuration of horizontal angles, may likewiſe be performed with great facility by the equatorial.

PROBLEMS XXI. XXII. XXIII. and XXIV.

Under this title it may be obſerved, that the problems xi. xii. xiii. xiv. and xv. for finding the latitude, the time by equal altitudes, the poſition of the cardinal points, and the time by the ſun's tranſit over the meridian, or by it's altitude and

and azimuth, may be performed with equal eaſe, and greater accuracy, by the horizontal circle and ſemicircle of altitude, in the inſtrument before us, as by the quadrant treated of under thoſe problems.

I ſhall now proceed to ſome of the problems, to which the equatorial is more peculiarly adapted.

PROBLEM XXV.

To find the latitude of a place, the ſun's declination being known.

Place the adjuſted equatorial, a ſhort time before noon, in ſuch a poſition, that the planes of the ſemicircles of altitude and declination may be as near the meridian as eſtimation will allow; and let the ſight which carries the croſs wires be turned to the point of the compaſs, (either north or ſouth) to which the ſun will come at noon. Set the index on the declination ſemicircle to the degree and minute of the ſun's declination, either to the north or ſouth ſide of O, as the caſe may be. Then by means of the horizontal circle and ſemicircle of altitude, without touching the declination ſemicircle, cauſe the ſolar ſpot to fall on the mark in the oppoſite ſight, (or obſerve the ſun itſelf by the croſs wires). Keep the ſights in this manner directed to the ſun, till his altitude begins to diminiſh. The degree and minute on the ſemicircle of altitude is the co-latitude, and the latitude will be north, if that degree and minute be upon the northermoſt quadrant; but if otherwiſe, ſouth.

PROBLEM XXVI.

To find the meridian line, and the time, from one obſervation of the ſun, when it's declination and the latitude of the place are known.

This problem requires that both the azimuth and altitude of the ſun ſhould alter quickly; and this is, generally ſpeaking, the caſe, more eminently, the farther that luminary is from the meridian. Therefore,

At the diſtance of ſeveral hours, either before or after noon, adjuſt the horizontal circle; ſet the ſemicircle of altitude, ſo that it's nonius may ſtand at the co-latitude; lay the plane of the laſt-mentioned ſemicircle in the meridian, by eſtimation, it's O being directed towards the depreſſed pole; place the nonius of the declination ſemicircle

circle to the declination, whether north or fouth. Then direct the line of fight towards the fun, partly by moving the declination femicircle on the axis of the equatorial circle, and partly by moving the horizontal circle on it's own axis. There is but one pofition of thefe which will admit of the folar fpot falling directly on the mark on the oppofite fight. When this pofition is obtained, the nonius on the equatorial, or horary circle, fhews the apparent time, and the circle of altitude is in the plane of the meridian.

PROBLEM XXVII.

To find the time, when the latitude, the fun's declination, and the meridian are known.

The meridian being found by equal altitudes of the fun, or a ftar, which is the beft method, and fettled by a meridian mark, or by indentations, to fet the fcrews in, (prob. xiii.) place the equatorial accordingly, and adjuft it by the levels. Set the femicircle of altitude to the latitude of the place, and the index of the line of fight, to the declination of the fun. Turn this laft femicircle, till the fights are accurately directed to the fun. The nonius will fhew the time on the horary circle.

This

This problem is more accurate than the foregoing, and may be applied at all times when the ſun is viſible.

PROBLEM XXVIII.

To find the meridian line, when the time, the ſun's declination, and the latitude of the place are known.

Adjuſt the inſtrument. Set the ſemicircle of altitude to the latitude, and the nonius of the declination ſemicircle to the declination; and ſet the nonius of the horary circle to the apparent time. Turn the horizontal circle till the ſights are directed to the ſun. The ſemicircle of altitude is then in the plane of the meridian.

This problem gives the poſition of the meridian more accurately than problem xxvi. It is much more ready where the time can be had, than the method of equal altitudes, and it is near enough to the truth for ſmall inſtruments. The nearer the obſervation is made to the time of noon, the better, becauſe the ſun then changes it's azimuth the quickeſt.

PROBLEM XXIX.

To find the declination of the ſun, or any celeſtial object, when the latitude of the place, and poſition of the meridian, are known.

Rectify the inſtrument for the latitude, as in the foregoing problem; and place the ſemicircle of altitude in the meridian. Then direct the ſights to the object, partly by moving the declination ſemicircle on the axis of the equatorial circle, and partly by moving the nonius of the ſemicircle laſt-mentioned. This nonius will then ſhew the declination.

PROBLEM XXX.

To find the right aſcenſion of any celeſtial object, when the time, the latitude, and the poſition of the meridian, are known.

Perform the operations directed in prob. xxix. Place the ſight ſo that the vertical wire may be a little to the weſtward of the object; and obſerve by a clock, or watch, the apparent or ſolar time when it croſſes the wire. The ſhorteſt interval between the time of obſervation and the time marked on the equatorial circle, by the nonius, is the difference between the times of each luminary coming to the window.

If the ſtars precede the ſun, this difference muſt be ſubtracted from, or if otherwiſe, added to the ſun's right aſcenſion; and the difference, or ſum, will be the ſtar's right aſcenſion, provided it do not exceed 24 hours; if it do, the exceſs is the right aſcenſion.

If the ſun's right aſcenſion ſhould be too ſmall to admit of taking the difference from it, it muſt itſelf be taken from the difference; and the ſupplement of the remainder to 24 hours, will be the ſtar's right aſcenſion.

PROBLEM XXXI.

To direct the line of ſight to any ſtar or planet.

Adjuſt the inſtrument to the latitude and meridian, and ſet the nonius on the declination circle to the declination of the ſtar. Then take the difference between the right aſcenſion of the ſun and ſtar; and if the right aſcenſion of the ſtar be greater than that of the ſun, ſubtract the difference; if not, add it to the time of obſervation.

The

The remainder, or ſum, will be the hour and minute to which the nonius on the horary circle is to be ſet; which being done, the ſights will point to the ſtar or planet ſought.

If the time be too ſmall to admit of having the difference taken from it, borrow 24 hours, and reckon the remainder from XII at noon.

When the ſtar or planet has, by the diurnal motion of the earth, been carried out of the field of view, in which the croſs wires are placed, it may be readily overtaken, by moving the declination ſemicircle on the equatorial circle.

There are many other pleaſant and uſeful problems, both terreſtrial and aſtronomical, which may be ſolved by theſe inſtruments; but they cannot here be enlarged on, conſiſtently with the intended limits of the preſent work. The intelligent ſtudent will diſcover ſome of them himſelf, and for the reſt he may conſult Atwood's Analyſis of a Courſe of Lectures, De La Lande's Aſtronomie, and other approved authors. It will be ſeen, likewiſe, that I have not entered into the minute conſiderations of refractions, the variation of declinations, and other elements for parts of days, &c. neither have I deſcribed any of the ingenious artifices, by which the errors of inſtruments are either corrected or allowed for. In this, alſo, I think the judicious teacher will join me in opinion, that though they are deſervedly eſteemed of the higheſt importance in the accurate operations of modern aſtronomy, yet it would not have been adviſeable to have diverted the attention of the learner, before his curioſity was excited by a diſplay of the leading particulars, even on the ſuppoſition that my plan could have allowed room for entering into ſuch a detail.

The learner need not, however, be too diffident in attempting to diſcover them by his own reflections, after he has acquired a perfect knowledge of the contents of the foregoing pages. There is no doubt but he will then ſee with that pleaſure which attends ſucceſsful inveſtigation, the excellence of the equatorial, and the numerous methods by which it's parts may be made to cooperate, in producing much more accurate reſults than it's ſize may ſeem to promiſe. In the mean time I ſhall conclude this article with a deſcription of an improved equatorial, in which every endeavour has been uſed to unite ſimplicity of conſtruction with delicacy and preciſion of workmanſhip.

DESCRIP-

Description of the Improved Equatorial.

The leading requiſites in good aſtronomical inſtruments, are, 1. the parts muſt be firmly connected, ſo that they may always preſerve the ſame figure; 2. the arcs muſt be truly centered, and accurately graduated; and 3. the extremity of the line of ſight muſt in all ſimple motions deſcribe a true circle. The two former either are or ought to be found in all inſtruments, whatever may be their form; but the latter property requires a particular conſtruction. It is obvious, that when the line of ſight, or teleſcope, is moved on the ſurface of one of the circles of an inſtrument, it's motion will be affected by every irregularity or deviation of that ſurface from a true plane; but on the contrary, if the motions be performed about axes well fitted, the extremity of the line of ſight will in all ſituations remain directed to ſome point in the circle, in which it may be placed. The difficulty of obtaining and preſerving the true ſurface in the former caſe, has induced all aſtronomers to give the preference to axes of motion, in ſuch inſtruments as are intended to be uſed in obſerving tranſits of the celeſtial bodies, acroſs the plane of the circle in which the line of ſight is moved; and as a great part of the obſervations made with the equatorial, are of the nature of thoſe tranſits, it is a very deſirable quality that all it's movements ſhould be made upon axes, inſtead of their being governed by the planes of the circles it is compoſed of.

In the preſent inſtrument (plate XXI.) this circumſtance is particularly attended to. E F is the horizontal circle firmly connected to another circular piece by ſix vertical pillars. The diſtance between theſe two circles affords a convenient ſituation for a ſtrong upright axis, on which the whole of the upper part of the inſtrument may be horizontally turned. The circular piece, which is ſcrewed upon the head of the vertical axis, carries a ſpirit level. It alſo has an adjuſting ſcrew on one of it's edges, and a nonius plate on the other, which ſhews minutes. This piece ſupports the two uprights, upon which the axis of the ſemicircle of altitude A B turns. At right angles to the ſemicircle of altitude is fixed the equatorial or horary circle, from the center of which laſt proceeds a ſtrong axis, that carries the apparatus for ſupporting the teleſcope. The horary motion of the teleſcope is performed by an adjuſting ſcrew, connected with an index that carries a nonius, for dividing the hours into portions of ten ſeconds each. The teleſcope has a ſtrong but light axis, whoſe circular ends turn in moveable

moveable ſockets of hard metal, one of which is capable of a vertical, and the other of an horizontal adjuſtment. One end of the axis is perforated, and has a ſmall convex lens ſet in the opening, through which, by the help of a reflector within, the croſs wires may be illuminated for making obſervations on the ſtars at night. The ſemicircle of declination D is affixed to the teleſcope, and paſſes very near a nonius Q, which ſhews minutes on the limb. I ſhall now proceed to deſcribe the method of adjuſtment and obſervation, which will render a more minute enumeration of the parts unneceſſary, and will at the ſame time ſhew their uſe much better than can be done by mere deſcription.

An attentive view of the inſtrument, or drawing, compared with what has been ſaid before, at problem xvi. will ſhew that it's perfect adjuſtment conſiſts in the following particulars. 1. The horizontal circle E F muſt be truly level. 2. The plane of the ſemicircle of altitude A B muſt be truly perpendicular to the horizon, or it's axis muſt be level. 3. The horary circle M N muſt be parallel to the horizontal circle E F, when the nonius of the ſemicircle of altitude marks o degrees; or at leaſt the error of the poſition of the nonius muſt be found. 4. The axis of the horary circle, or the polar axis, muſt be at right angles to the plane of that circle. 5. The line of ſight, or optical axis of the teleſcope, muſt be at right angles to it's axis of motion. 6. The croſs axis of the teleſcope muſt be parallel to the plane of the horary circle; and (7.) parallel to that of the ſemicircle of altitude, when the nonius marks the hour of VI. Laſtly, the line of ſight muſt be parallel to the horary circle, when the nonius of the ſemicircle of declination marks 0 degrees.

The manner of making theſe adjuſtments may be as follows. 1. Level the horizontal circle as deſcribed in problem xvi. 2. The plane of the ſemicircle of altitude is adjuſted in the original conſtruction of the inſtrument. 3. Set the horary index at XII, and direct the teleſcope to a remote object; ſet the index to the oppoſite XII, and turn the horizontal moveable circle half round. If the teleſcope then points to the ſame object, the horary circle is parallel to the horizon; if not, alter the poſition of the ſemicircle of altitude, till the teleſcope continues to point to one ſingle object in both poſitions of the horary index. When this adjuſtment is made, take notice of the ſituation of the nonius of the ſemicircle of altitude; if it cuts at 0 degrees, it is rightly placed;

placed; if not, note the difference, to be applied as a correction of all obſervations made with that ſemicircle. 4. The axis of the horary circle is truly placed in the conſtruction. 5. Cauſe the vertical croſs wire of the teleſcope to interſect a remote object, the adjuſting ſcrews of the horizontal and horary circles being previouſly made faſt; then reverſe the poſition of the axis, ſo that the ſemicircle of declination may be upwards inſtead of downwards. By the motion on the axis it will be ſeen whether the ſame croſs wire interſects the object ſeen in the former poſition; if it do, the line of ſight is at right angles to the axis of motion; but if not, alter the poſition of the croſs wires, by means of the two ſmall ſcrews near the eye end of the teleſcope, one of which muſt be unſcrewed a little, and the other ſcrewed up, till the deſired proof, the accuracy of the poſition of the teleſcope, be attained. 6. Hook the arms of the hanging levels upon the ends of the axis of the teleſcope, having previouſly placed the horizontal and horary circles level. By means of the ſmall capſtan ſcrew beneath one end of the axis, cauſe the bubble of the hanging level to occupy the middle of it's glaſs. Unhook the level, and hang it again on the axis, but in a contrary poſition, ſo that it's right-hand end may now be placed to the left. If the bubble ſtill continues to occupy the middle of the glaſs, the axis of the teleſcope is truly level or parallel to the horary circle; if not, alter the adjuſtment of the axis by the capſtan ſcrew, and of the level by it's own ſcrews, till the bubble ſtands in the middle in both poſitions. 7. Set the ſemicircle of altitude to 90°, and fix it there; ſet the declination ſemicircle to 0°, and the horary index to VI. Direct the teleſcope to a remote object. Then move the horizontal circle half round, and ſet the horary index preciſely at the oppoſite VI. If the ſame object be ſeen at the interſection of the croſs wires, the line of ſight is rightly placed, with reſpect to the horary index; if not, correct the axis of the teleſcope by the ſide capſtan ſcrew, ſo that the croſs wires may cover an object half-way between the former object and that laſt ſeen. Laſtly, make the horizontal and horary circles parallel to each other, and direct the teleſcope to a remote object, obſerving the degree and minute ſhewn by the nonius of the declination ſemicircle. Turn the horizontal circle 180°, and the horary index likewiſe 180°, and obſerve the ſame object. If the degrees and minutes on the declination ſemicircle be the ſame as before, the nonius is rightly placed; if not, take half the ſum of the two altitudes, or depreſſions, which

will

will be the true altitude or depreſſion of the object, with reſpect to the horary circle; then looſen the ſcrews of the declination nonius, and move it till the object ſeen at the interſection of the croſs wires gives the true quantity on the declination ſemicircle.

The problems wrought by the former inſtruments, with every other in aſtronomy, ſurveying, and menſuration, may be performed with ſingular accuracy by this equatorial.

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Complete equatorial inſtruments, from 50 gs. to	500	0	0
Tranſit inſtruments, aſtronomical quadrants, circular inſtruments, according to their ſizes, the variety and accuracy of their adjuſtments.			

Mathematical Inſtruments, for Geometry, Drawing, &c.

Plain compaſſes for meaſuring lines, from 1s. to	0	5	0
Drawing compaſſes with moveable points, from 5s. 6d. to —— ——	3	3	0
Drawing pens, from 1s. to — —	0	5	0
Bow compaſſes for deſcribing ſmall circles, from 3s. to — — —	0	5	0
Hair compaſſes for taking extents with accuracy	0	7	6
Beam compaſſes for deſcribing large circles, laying down diviſions, &c.			
Triangular compaſſes for transferring three points at once from any plan or drawing, from 18s. to	1	1	0
Proportionable compaſſes for diminiſhing plans or drawing in any aſſigned proportions —	1	11	6
Elliptical compaſſes with friction rollers, for drawing ellipſes — —	4	4	0

	£.	s.	d.
Elliptical compaſſes on a different conſtruction, anſwering at the ſame time the purpoſes of beam and calliper compaſſes ——	4	4	0
Spiral compaſſes for deſcribing ſpirals, anſwering alſo as beam and elliptical compaſſes, from 6l. 6s. to —— ——	11	11	0
Parallel rules of various conſtructions			
A new-invented parallel rule, which for facility in application, and accuracy, exceeds any other kind, from 8s. 6d. to —— —	1	1	0
Ditto with a protractor			
An inſtrument for drawing lines inclined in a given angle to each other, though the angular point is at an immenſe diſtance, a rule exceedingly uſeful in perſpective			
Various inſtruments for the purpoſe of dividing lines, or transferring diviſions on paper			
A cyclograph, or an inſtrument by which circles may be deſcribed, from 4 or 6 inches radius to one as large as the orbit of the Georgium Sidus	6	6	0
Plain ſcales and ſectors of different ſizes			
Square protractors, ſemicircular and circular			
Pocket caſes of drawing inſtruments, from 7s. 6d. to	5	15	6
Magazine, or complete collection of drawing inſtruments, at 11l. 11s. at 17l. 17s. and from thence to —— ——	50	0	0
Perſpective compaſſes for aſcertaining the relative proportion of objects — —	0	18	0
Dr. Hirſt's inſtrument for drawing in perſpective	5	5	0
A new invented inſtrument for the ſame purpoſe, which will facilitate the operations of the artiſt, and greatly aſſiſt beginners			
An inſtrument for facilitating drawing from nature, by aſcertaining a number of points			
Concave lenſes with ſquares for eye drafts			
Drawing glaſſes, or glaſſes with a ſight to aſſiſt draftſmen			
Pantographers for copying, reducing, and enlarging drawings, from 2l. 12s. 6d. to ——	6	6	0

Surveying

Surveying Inftruments.

	£.	s.	d.
Cafes of drawing inftruments			
Parallel rules			
Plotting fcales			
Sets of plotting fcales			
A new-invented parallel rule, with plotting fcales			
A parallel rule and protractor			
A plotting fcale, in form of a beam compafs			
Protractors for laying down angles			
Ditto with a nonius and moveable limb —	2	12	6
Ditto rendered more accurate, as the limb is made to move with a tooth and pinion —	4	14	6
Meafuring wheels — —	6	16	6
Pedometers for meafuring a given diftance in walking.			
Meafuring chains of 50 and 100 feet			
Gunter's chain — — —	0	7	6
Tape boxes, according to the length			
Surveying crofs or fquare — —	1	11	6
Plain tables, with an index and fights; by thefe the plan is taken on the fpot, and does not require a future protraction — —	3	13	6
Beighton's improved plain table, with an index of a peculiar make; in this inftrument the line of fight is always over the center of the table, the ftation lines are alfo drawn parallel to thofe meafured on the ground — —	14	1	0
Theodolites, or inftruments for meafuring angles, diftances, &c. are made in various ways, fome being more fimple and portable, others more accurate, and with a greater number of adjuftments.			
Theodolites, with four plain fights, and a compafs box, from 5l. 5s. to — —	5	15	6
A fmall theodolite, with telefcopic fights and vertical arch — — —	9	9	0
A larger ditto, in which the limb of the theodolite is made to ferve occafionally the purpofe of a protractor — — —	14	14	0
A ditto of the fame fize, on a different conftruction, the vertical arch being affixed to a long axis; the limb does not ferve for a protractor	14	14	0
A larger ditto, like the preceding, only moving with rack-work — — —	21	0	0

U u The

	£.	s.	d.
The lateſt improved theodolite, with double teleſcope, and every requiſite adjuſtment			
Circumferenters, the principal inſtrument uſed in America, from 2l. 2s. to —	4	14	6
An improved circumferenter, ſo contrived, that the operator need not reſt the truth of his work entirely on the needle; it may be alſo uſed to take altitudes			
Air or ſpirit levels with teleſcopic ſights, from 4l. 14s. 6d. to — ——	12	12	0
Air or ſpirit levels with plain ſights —	1	11	6
Station ſtaves with ſliding vanes for levelling	1	16	0
A ſmall ſurveying compaſs, with ſights, a nonius diviſion, and three-legged ſtaff —	4	14	6
A ſmall ſurveying compaſs and ſingle ſtick	2	2	0
(The two foregoing inſtruments are portable and light, and may be put with eaſe in the pocket)			
Miners compaſſes, uſed for carrying on works under-ground, from 10s. 6d. to —	1	1	0
Ditto with a ſmall teleſcope fixed to one ſide	1	11	6
Green's teleſcope and tangent board, for meaſuring diſtances at one ſtation: (it is obvious, that on the meaſuring of a ſtrait line with accuracy, the whole buſineſs of ſurveying depends; Mr. Green's method is certainly more expeditious than any other, and is not liable to objections which may be made to them)			
Optical ſquare, a ſmall inſtrument for ſurveying by right angles; it requires no ſtaff, and may be eaſily corrected or adjuſted — —	1	16	0
An optical inſtrument for determining with accuracy when objects are in a ſtrait line -	1	7	0

Military Inſtruments.

Gunners levels or perpendiculars
Gunners callipers
Beam callipers
Shot guages
Shell ditto
Gunners quadrants with a plummet
Ditto with a level

Ditto

	£.	s.	d.
Ditto with an adjuſting ſcrew			
Ditto and perpendicular combined together			
General Williamſon's inſtruments for howitzers, mortars, &c.			
Surveying compaſſes, ſurveying croſſes, caſes of inſtruments, teleſcopes, plain tables, theodolites, &c.			
A complete apparatus for an officer, in a box	21	0	0

Inſtruments for Navigation.

Caſes of Inſtruments, and teleſcopes of different kinds, ſizes, and prices			
Night teleſcopes, from 1l. 11s. 6d. to	2	2	0
Opera glaſs for the ſame purpoſe —	1	11	6
A teleſcope with an eye-glaſs micrometer, for determining the diſtance of a ſhip at ſea			
Hadley's quadrants in mahogany frames —	2	2	0
Ditto in black ebony frames — —	3	3	0
Hadley's ſextant in wood —	6	16	6
Ditto in braſs, on the moſt improved plan, from 11l. 11s. to — — —	15	15	0
Knight's ſteering compaſs, with improvements	2	12	6
Knight's azimuth ditto — —	5	15	6
Ditto on friction wheels —	10	10	0
Marine barometers; by theſe ſtorms have been foretold at ſea ſome hours before they happened			
Circular inſtruments, to anſwer the purpoſe of the ſextant			
Dipping needles, from 12l. 12s. to —	31	10	0

Inſtruments for Electricity.

A ſmall electrical machine, with a ſelect apparatus	8	8	0
An electrical machine and medical apparatus in a box; the machine is mounted in a plain but ſtrong manner, and ſo as to act with power; the apparatus is the moſt convenient and ſimple hitherto contrived for medico-electrical purpoſes	6	16	6

	£.	s.	d.
Ditto with an additional apparatus lately contrived for more eafily giving partial fhocks —	7	17	6
Improved electrical machines, from 3l. 13s. 6d. to	40	0	0
Electrical batteries, from 2l. 12s. 6d. to			
Electrical jars of different fizes			
Ditto with an electrometer affixed to them	0	18	0
Medical bottles, with a tube for qualifying the fhock — — —	0	7	6
Ditto mounted with a difcharging rod, and an electrometer, on an improved plan, for giving the electric fhock —— ——	1	1	0
Directors with glafs handles for medical purpofes	0	10	6
Jointed difchargers with glafs handles —	0	10	6
Plain difcharging rods — —	0	3	0
An univerfal difcharger and prefs —	1	11	6
Kinnerfly's electrical thermometer ——	1	1	0
Quadrant electrometer — —	0	10	6
Cavallo's atmofpheric electrometer, from 15s. to	1	1	0
Ditto with additions by De Sauffure —	1	11	6
Bennet's gold leaf electrometer —	0	18	0
An apparatus for making Canton's and Wilfon's experiments on electric attraction, &c.			
Compound apparatus, fig. 49, plate III. of my effays on electricity; by this apparatus a great number of neat and fatisfactory experiments may be performed — —	3	3	0
Ditto without the exhaufted flafk and conductor	1	11	6
Leyden vacuum —— —	0	10	6
Luminous conductors ———	1	1	0
Spiral tubes, from 4s. 6d. to ——	0	10	6
Coloured fpirals — — —	0	9	0
Sets of fpirals, fee plate V. fig. 98, of my effays on electricity — —	1	11	6
Luminous words, from 10s. 6d. to —	1	11	6
Spotted bottle — - —	0	9	0
Belted bottle, plate III. fig. 46 — —	1	1	0
Double bottle, a pleafing and ufeful part of an electrical apparatus, to gain a clear idea of the Franklinian theory ———	0	18	0
Plates and ftand for dancing images, pith images, and pith balls			
An artificial fpider			
A fmall head with hair			
An electrical piftol for inflammable air —	0	7	6
Ditto mounted in fets			

	£.	s.	d.
An electrical cannon for gunpowder			
A thunder houſe	0	6	6
Ditto with a drawer	0	8	6
A powder houſe, fig. 89, plate V.	0	16	0
A pyramid, fig. 90, plate V.	0	15	0
Nicholſon's revolving doubler	3	3	0
A bone ball and a ball of box wood fitted on braſs wires			
Electric flyer and points			
A plain ſet of bells, fig. 17, plate II.	0	9	0
Five bells mounted on a ſtand, fig. 18, plate II.	0	18	0
A ſet of muſical bells, fig. 19, plate II.	1	7	0
Magic picture	0	10	6
Electrical ſtools, from 8s. 6d. to			
An electrophorus, from 10s. 6d. to			

Apparatus for Experiments on Magnetiſm.

An apparatus for explaining the principal phænomena of magnetiſm, from 3l. 3s. to	15	15	0
Magnets			
Small compound magnets			
Horſeſhoe magnets			
Compound ditto, from 15s. to	21	0	0
Dipping needles from 12l. 12s. to	31	10	0
Variation compaſſes, from 2l. 12s. 6d. to	21	0	0

Inſtruments for Experiments on Pneumatics.

A ſmall ſingle-barrel air-pump	2	12	6
A ſmall double-barrel ditto	4	14	6
A larger ditto	6	16	6
A table air pump	10	10	0
The American double barrelled air pump, the lateſt improvement on this inſtrument, in which the air receives no impediment from the action of valves or cocks, exceeding Smeaton's in accuracy and ſimplicity, and far ſuperior in both reſpects to ſeveral later contrivances			

	£.	s.	d.
A condenſing engine; this may be, if deſired, combined with the former, but the rational and practical experimentaliſt will find many advantages in having them detached from one another			

Apparatus for an Air Pump.

The magdeburg hemiſpheres, from 12s. to	1	11	6
A flat plate and collar of leathers for placing on open receivers —— ——	0	15	6
Guinea and feather apparatus, for experiments on the reſiſtance of the air, from 18s. to	1	11	6
A ſet of mills for ditto —— —	1	11	6
A ditto on a better conſtruction ——	4	4	0
Bell apparatus, for ſhewing that a vacuum does not communicate ſound —— ——	0	5	6
Ditto on a better conſtruction			
Ditto with wheel-work, by which the bell may be put in motion or ſtopped at pleaſure —	3	13	6
A new apparatus for ſtriking flint and ſteel in vacuo			
An apparatus for firing gunpowder in vacuo			
A copper bottle, beam and ſtand, for weighing of air	2	16	0
A box bladder and lead weights, to ſhew the elaſtic power of the air —— —	0	15	6
Ditto on an improved plan ——	0	18	0
A model of a pump, illuſtrating at the ſame time the nature of pumps, and proving that there is no ſuch thing as ſuction ——	1	5	0
A ſmall receiver and plate, which clearly evinces that receivers are kept on the pump by preſſure, not ſuction — — ——	0	12	0
A filtering cup — —	0	5	6
A plate and piece of wood ——	0	4	6
(The two laſt articles are for ſhewing the poroſity of vegetables)			
The torricellian experiment			
Fountain in vacuo — —	0	5	6
Ditto on a different conſtruction —	0	18	0
Lungs glaſs — —	0	5	6
Ditto on a different conſtruction			
A ſingle transferer plate and pipe for a fountain	0	15	6

A double

	£.	s.	d.
A double transferer, for communicating a vacuum from one receiver to another —	3	3	0
A burnt air pipe, for experiments on infected air	0	18	0
An apparatus to illustrate the lateral pressure of the air			
Breaking square and cage			
A small bladder and lead weight			
A small ballance beam and stand —	0	7	6
Ditto on an improved construction			
Receivers of different sizes			

Meteorological Instruments.

A plain portable barometer —	2	2	0
Ditto with a thermometer —	3	3	0
A plain barometer, covered frame and glass door	2	12	6
Ditto with a thermometer —	3	13	6
A barometer with a long cylindric thermometer	4	4	0
A ditto with ditto, and De Luc's hygrometer	7	7	0
A barometer and thermometer, with a guage, the indexes moving by rack-work —	5	15	6
A barometer for measuring the altitude of mountains, &c.			
Marine barometers			
Diagonal, wheel, and statical barometers			
Fahrenheit's thermometers, from 1l. 1s. to	2	12	6
Ditto for botanic purposes —	0	18	0
Ditto for the brewery — —	1	1	0
De Luc's hygrometer; these are the only instruments by which comparative observations can be made on the dryness and moisture of the air, from 3l. 3s. to — —	7	7	0
Rain guages			
Dr. Lind's wind guage			
Hygrometers with the beard of the wild oat	0	10	6
Fontana's eudiometer for ascertaining the purity of the air — —	2	5	0

Instru-

Inſtruments for illuſtrating the Mechanic Powers, the Laws of Motion, &c.

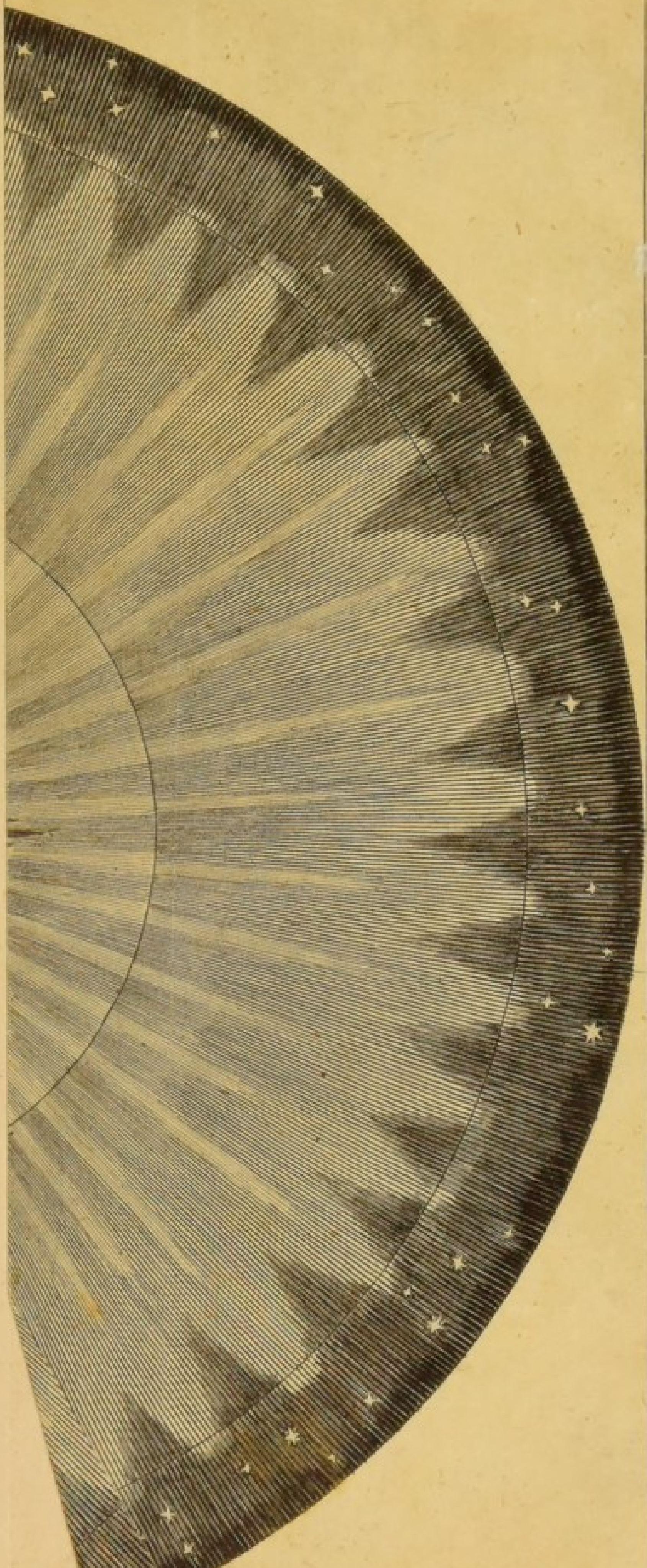
	£.	s.	d.
A conciſe apparatus for illuſtrating the nature of the ballance, the pulley, the different kinds of levers, the inclined plane, the wheel and axle, the ſcrew, a compound engine, and a compound lever; alſo, a double cone to move up an inclined plane, and other pieces to ſhew the properties of the center of gravity, from 21l. to	26	5	0
A ditto on a more enlarged ſcale			
Atwood's apparatus for demonſtrating with accuracy the laws of accelerated and retarded motion. It is one of the moſt pleaſing and ſcientific inſtruments in mechanics, as well from the variety of experiments that may be made with it, as the accuracy with which they are performed	26	5	0
A machine for illuſtrating the theory of central forces; in this machine the times are marked by ſound, the ſpaces are ſhewn by an index, the errors ariſing from friction are ſo far leſſened as to be ſcarcely ſenſible ———	31	10	0
Pullies of various combinations and conſtructions			
A ſmall carriage, inclined plane, wheels of different ſizes, &c. for experiments on wheel carriages			
Roberval's paradoxical ballance			
Cycloidal lever, ſee Emerſon's Mechanics, prop. 20, 25.			
Compound ſteelyard			
An apparatus for experiments on colliſion			
Ditto for illuſtrating the compoſition and reſolution of motion			
Pyrometers on various conſtructions			

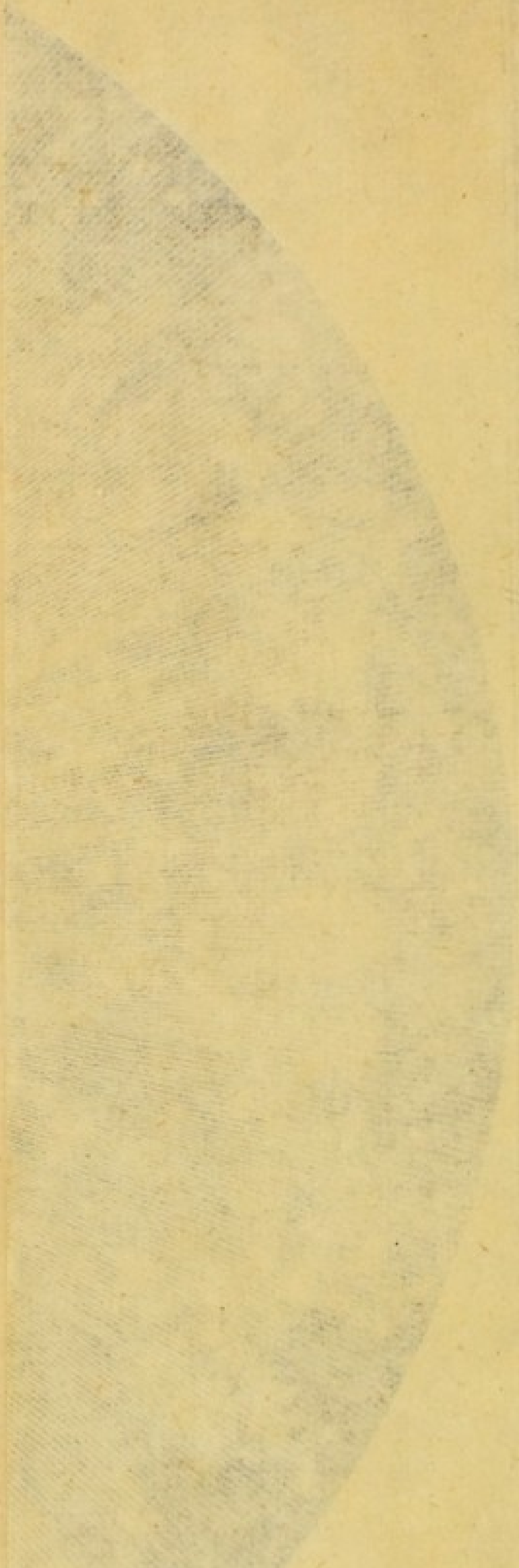
With many other articles and models for experiments on friction, pendulums, &c. too numerous to be comprized in a ſmall catalogue

Inſtru-

Inſtruments for Experiments in Hydroſtatics and Hydraulics.

	£.	s.	d.
Hydroſtatic ballances, from 2l. 2s. to —	10	10	0
Nicholſon's improved hydrometers, for aſcertaining the ſpecific gravity of bodies			
Ditto for examining of coin			
A conciſe apparatus for experiments on hydroſtatics	21	10	0
An apparatus for ſhewing that fluids have weight			
Ditto for ſhewing that the particles of fluids exerciſe their preſſure independently one of the other			
Ditto to ſhew that fluids preſs in every direction			
Ditto to demonſtrate the lateral preſſure of fluids			
Ditto to ſhew that, *cæteris paribus*, the preſſure of fluids is as their perpendicular height			
The hydroſtatic paradox			
The hydroſtatic bellows			
Apparatus for illuſtrating the laws of preſſure and equilibrium between heterogeneous fluids			
Ditto for illuſtrating the action of fluids upon bodies immerſed in them			
An apparatus for experiments on ſpouting fluids			
Hydrometers for proving ſpirits, from 1l. 11s. 6d. to	4	14	6
An apparatus for making experiments on capillary tubes			
The model of the diving bell			
A glaſs model of the lifting pump			
A ditto of the lifting and forcing pump			
Hiero's fountain in copper japanned			
Ditto double			
Fountain of command			
A japanned copper fountain to act by condenſed air with a variety of jets			
Apparatus for experiments on ſyphons.			





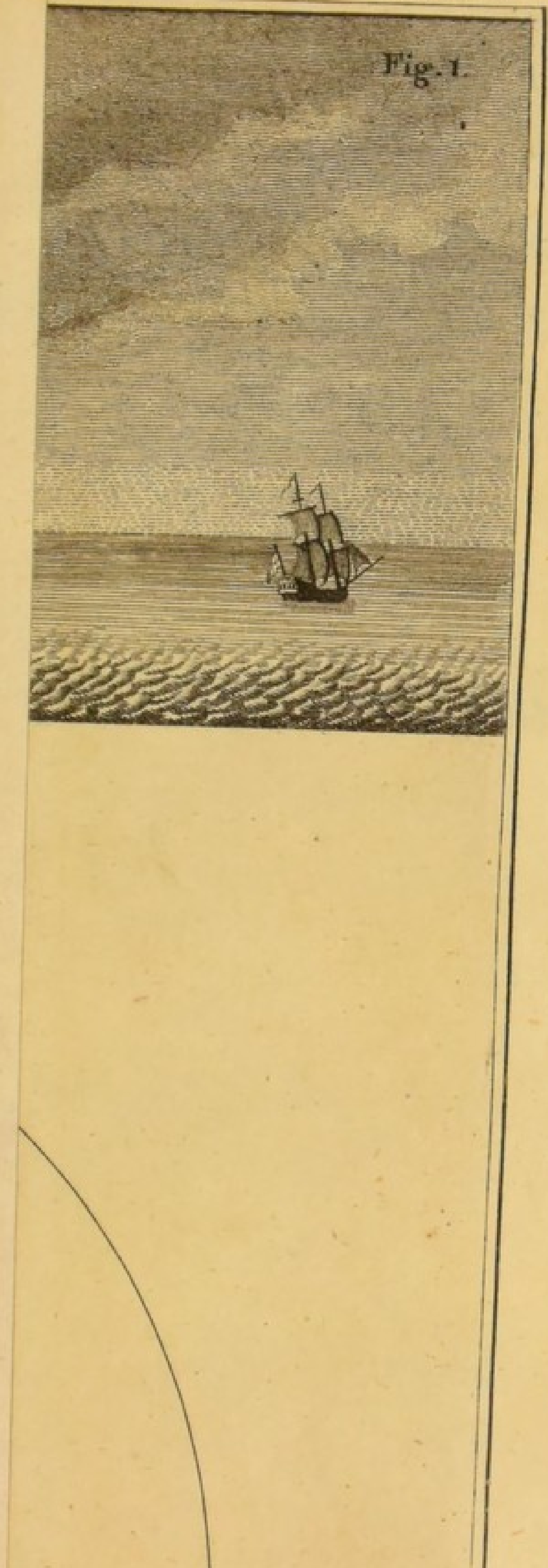


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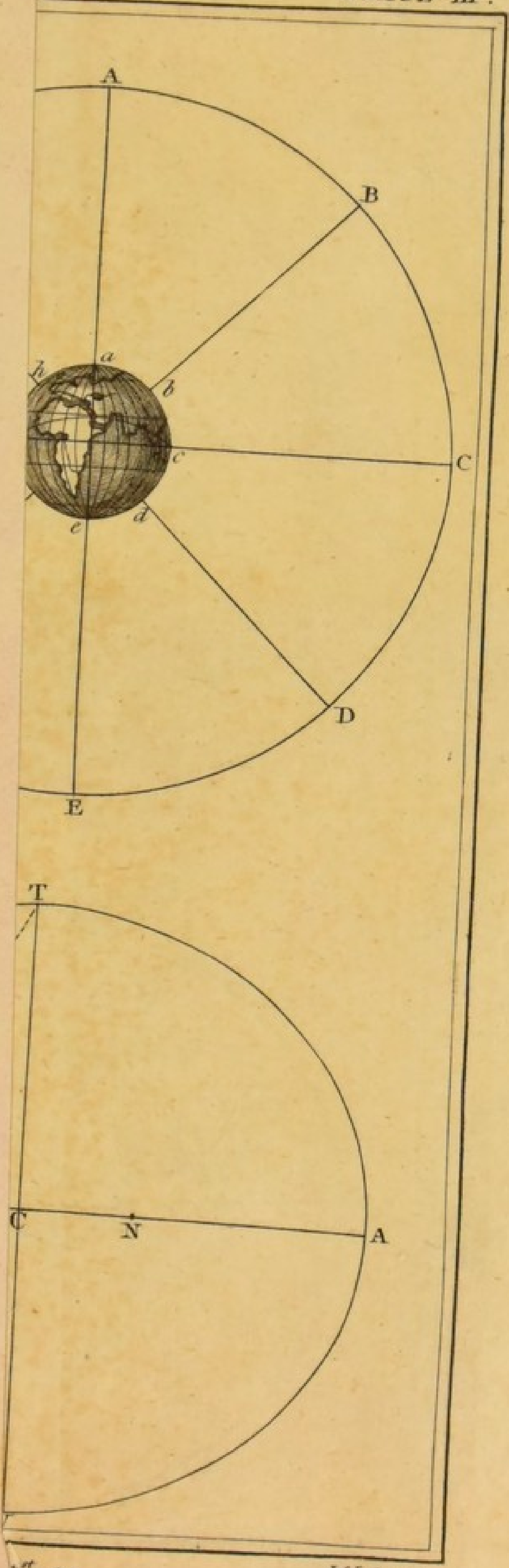
PLATE III.



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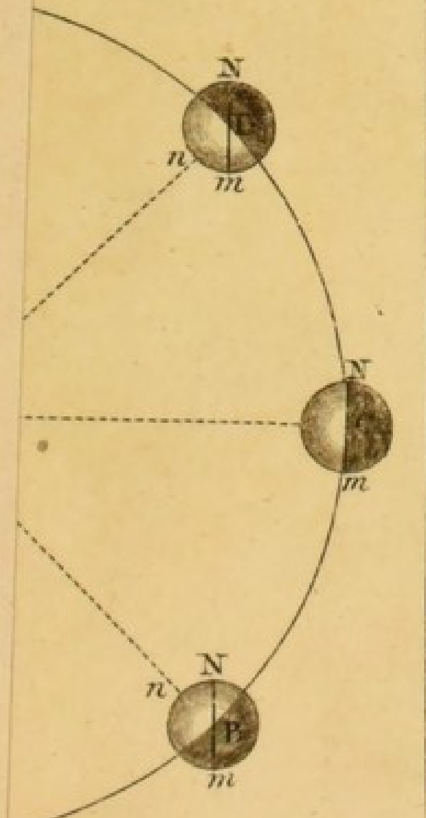

Fig. 3.

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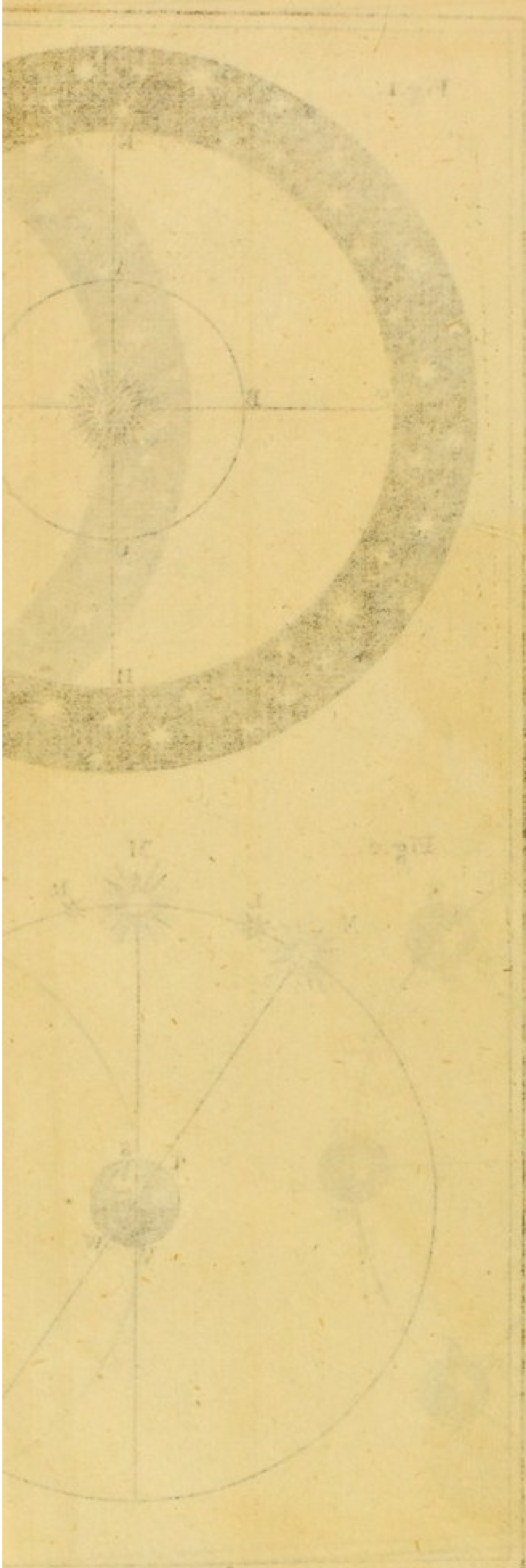

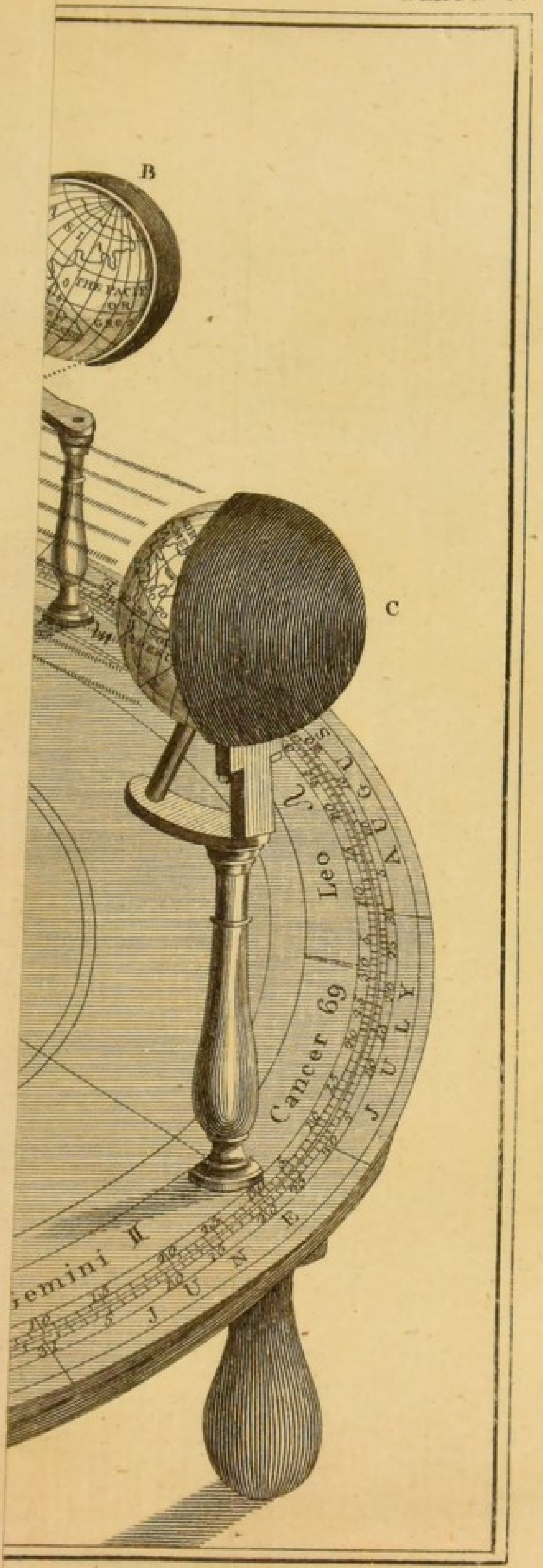

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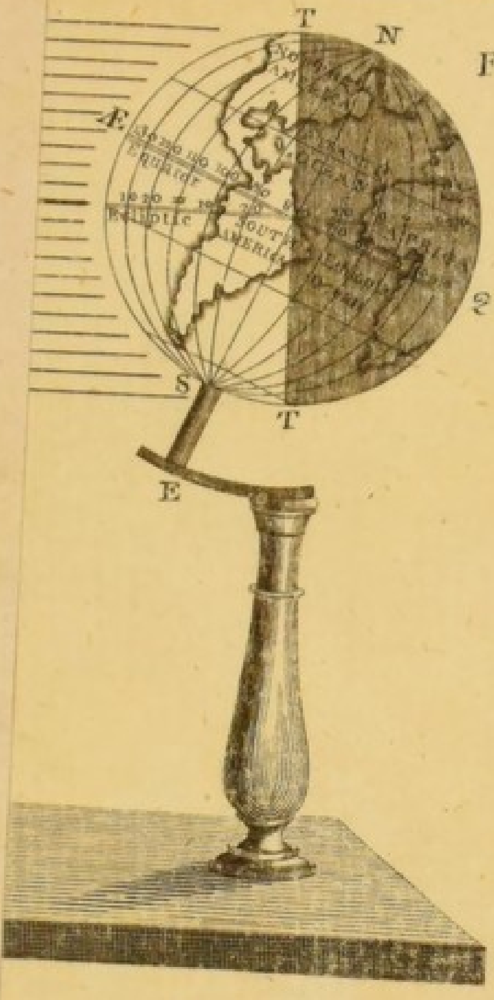
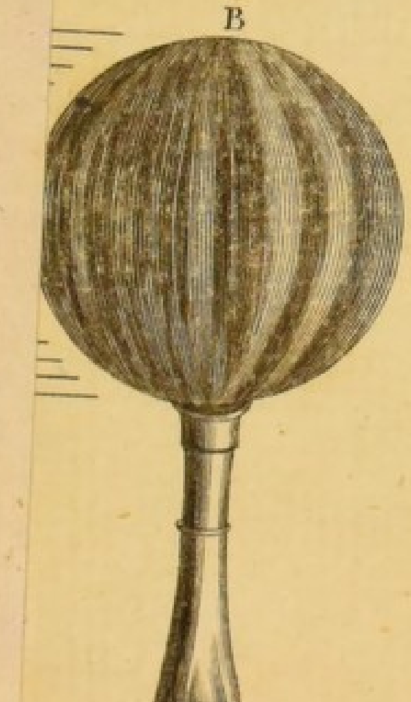
Fig. 2.





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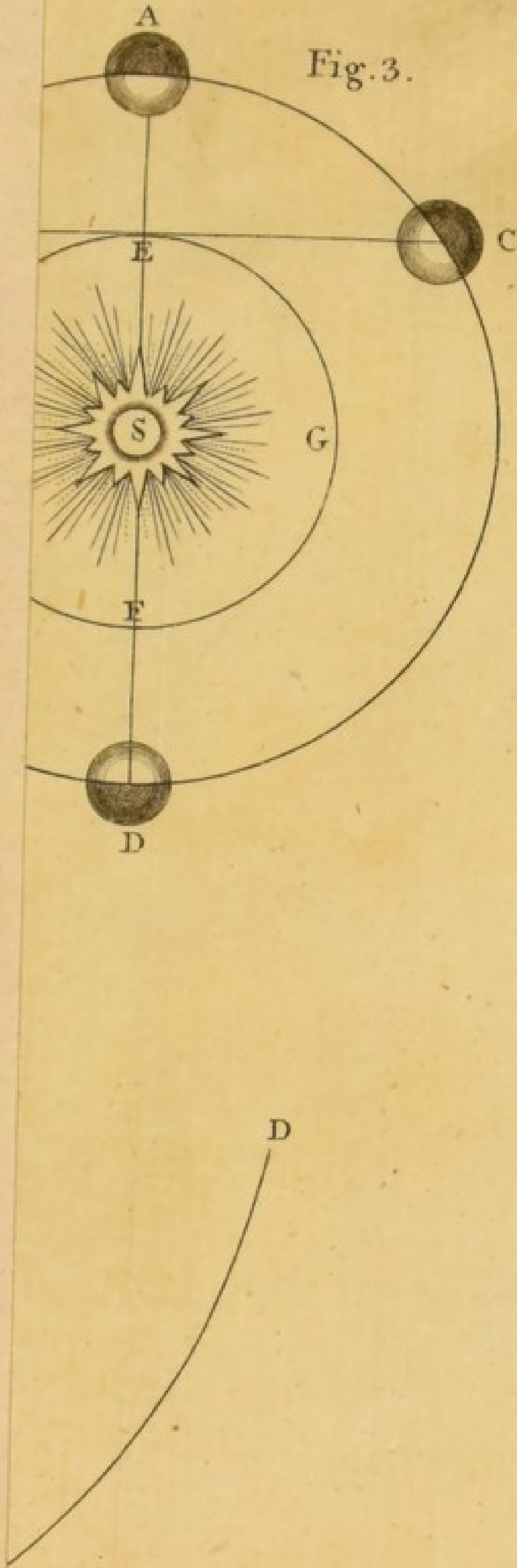

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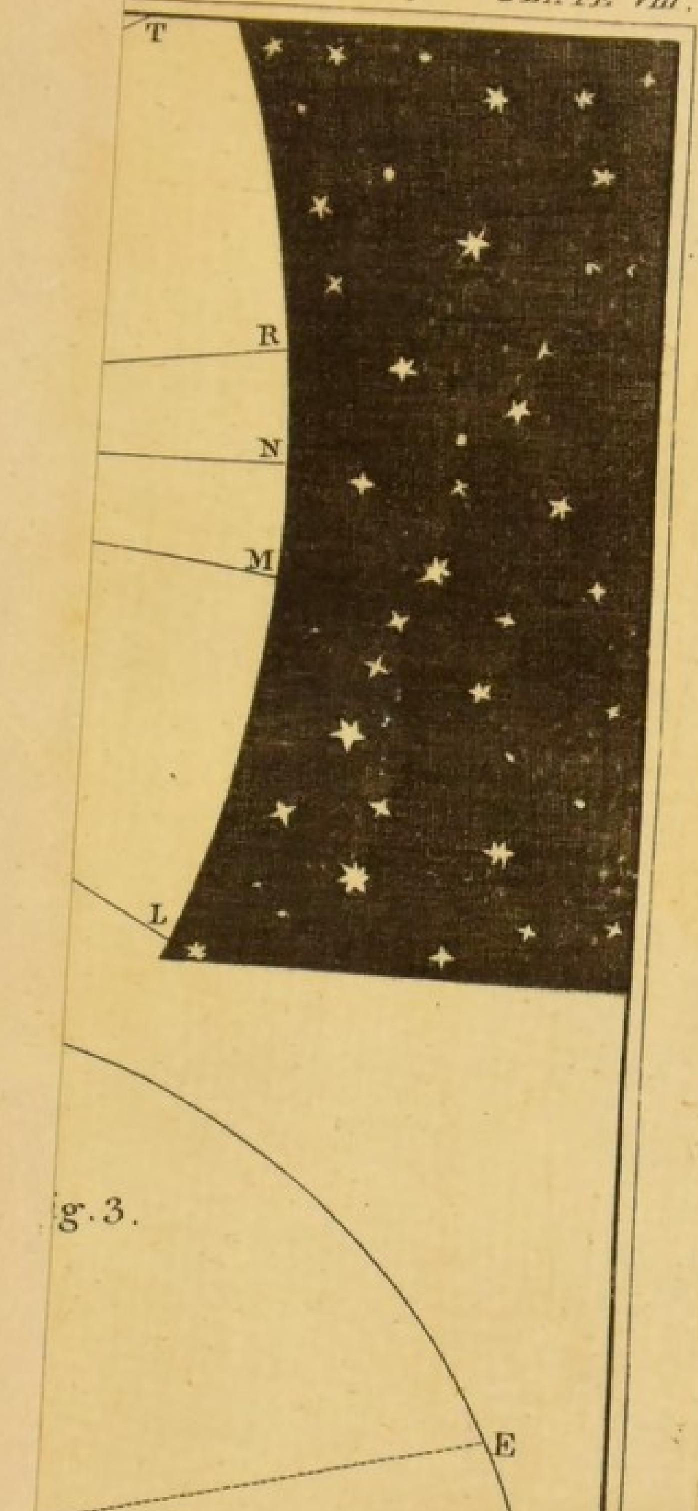

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Fig. 2.

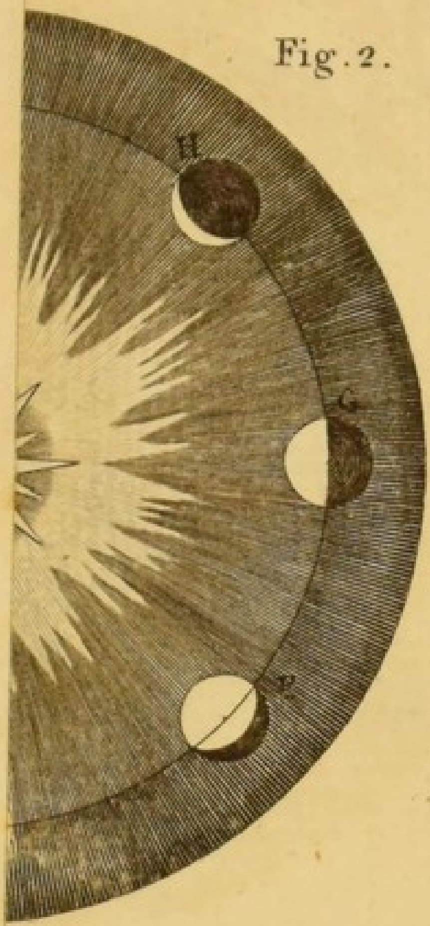
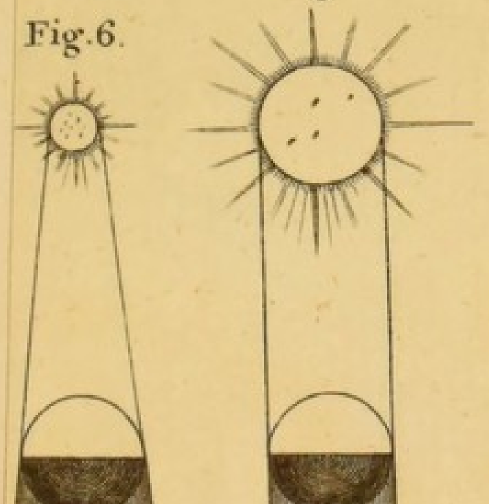


Fig. 5.

Fig. 6.



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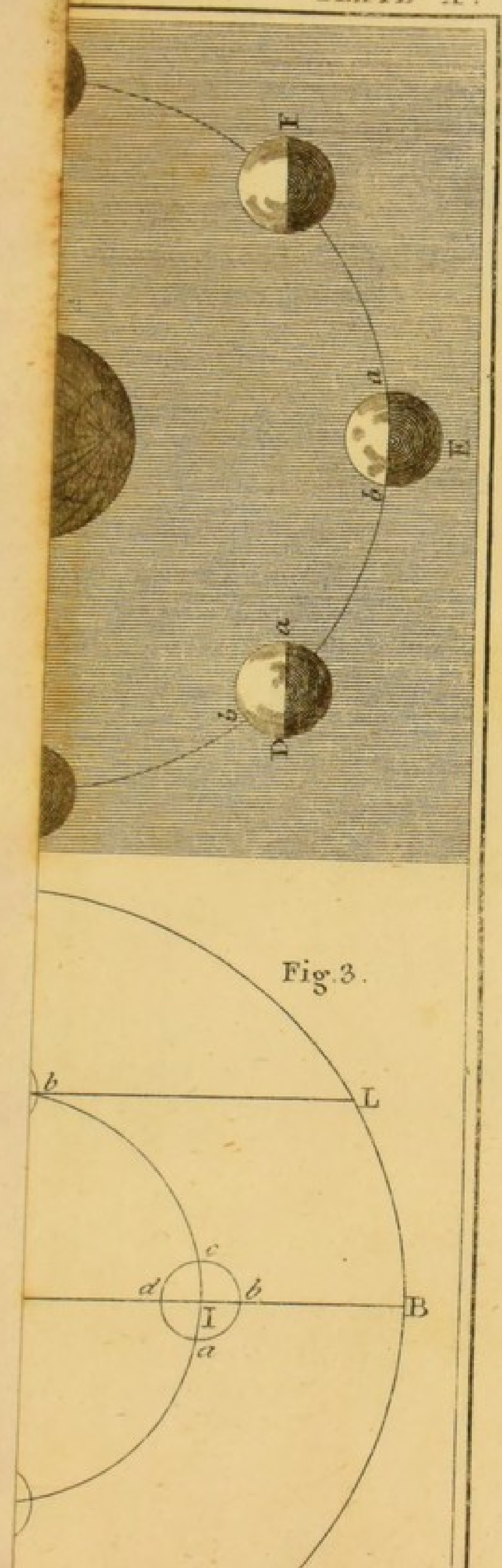

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PLATE XI.

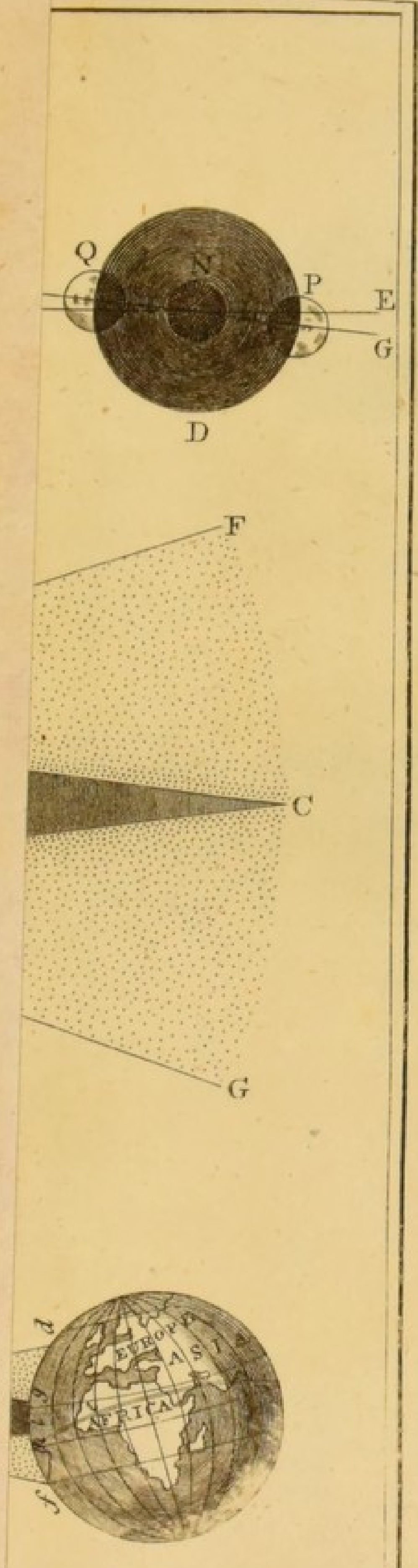

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Fig. 6.

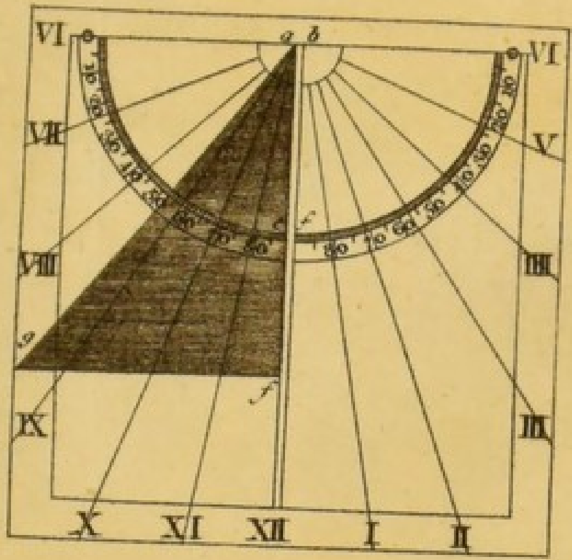
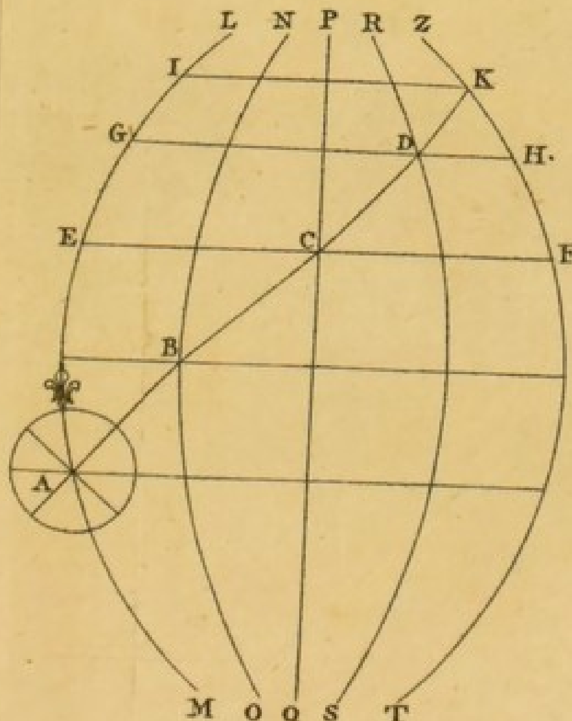
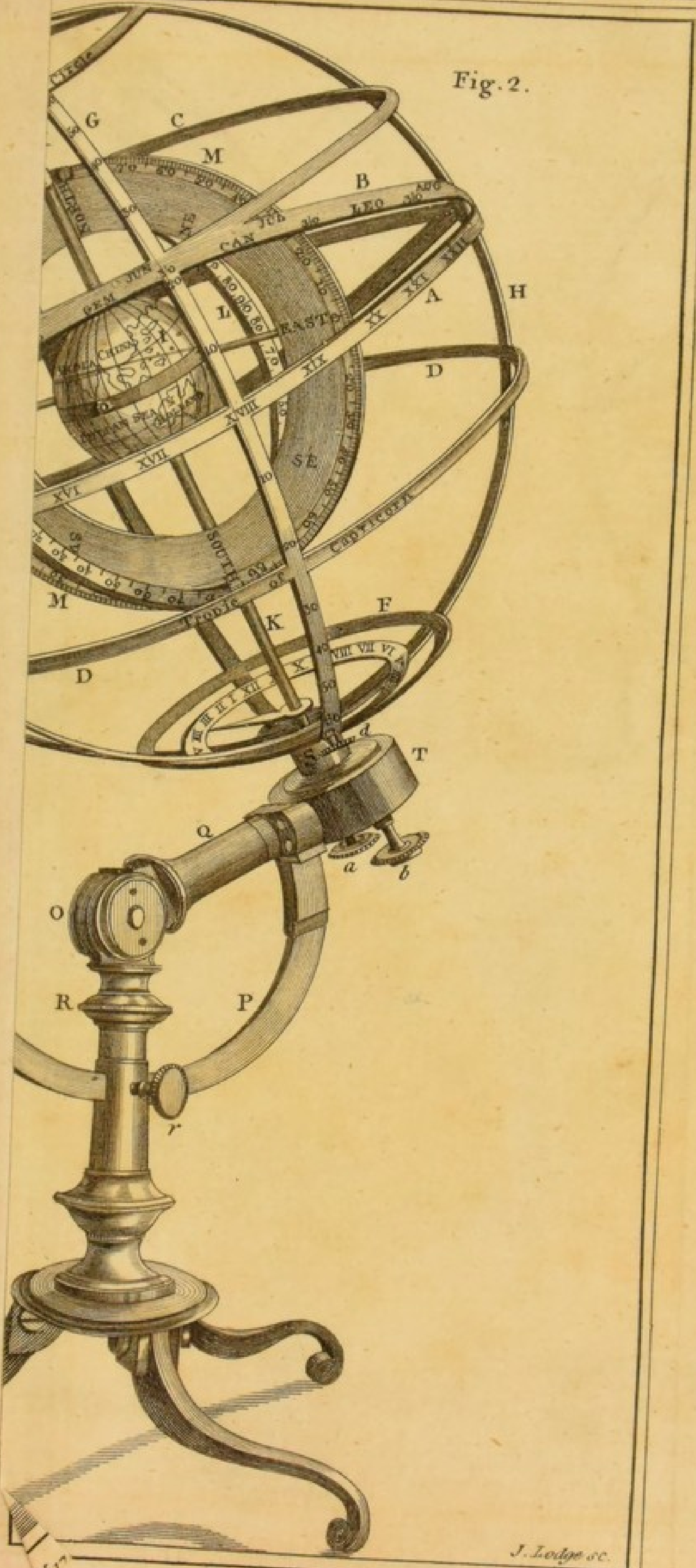


Fig. 8.



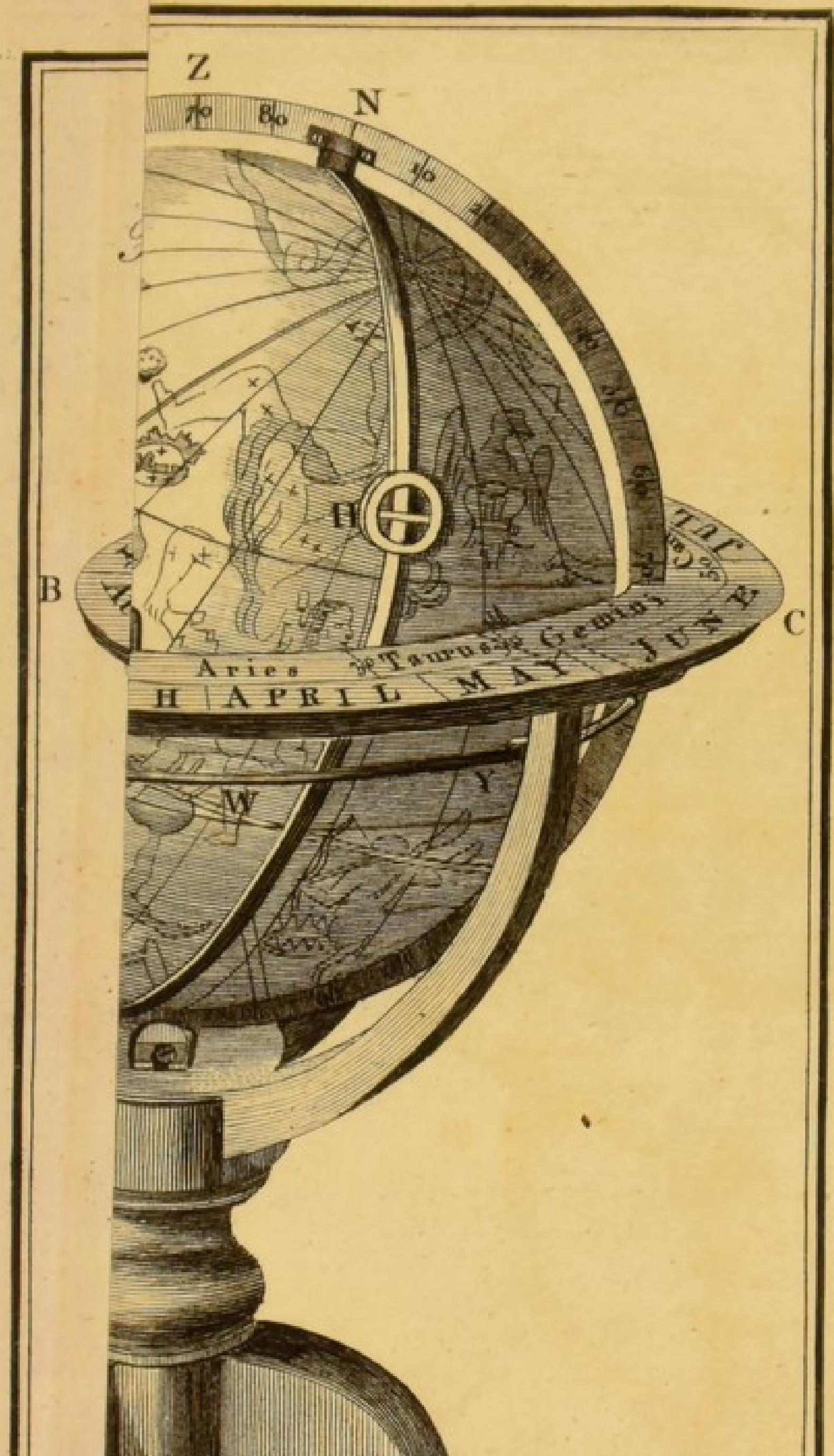
1788. Jn.º Lodge sc.

Fig. 2.

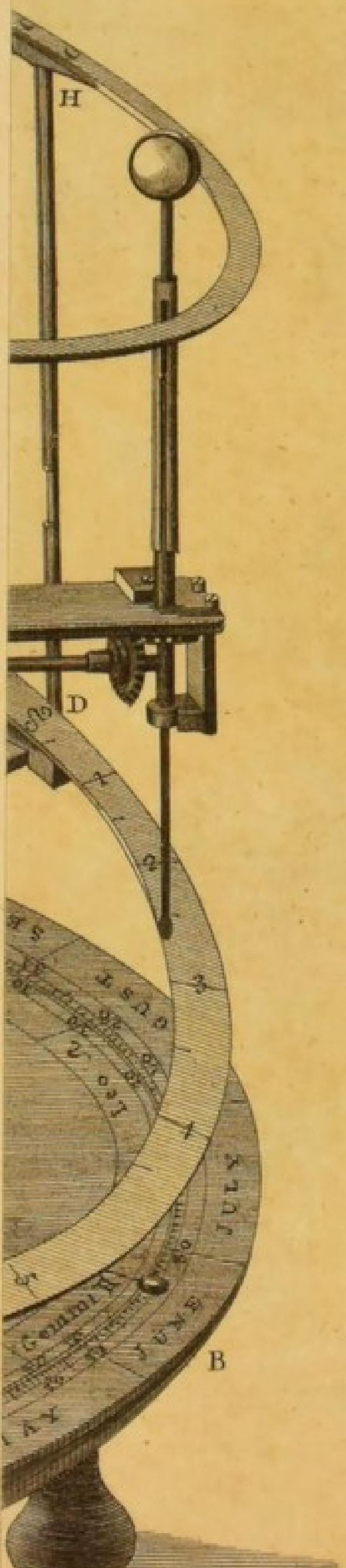


J. Lodge sc.

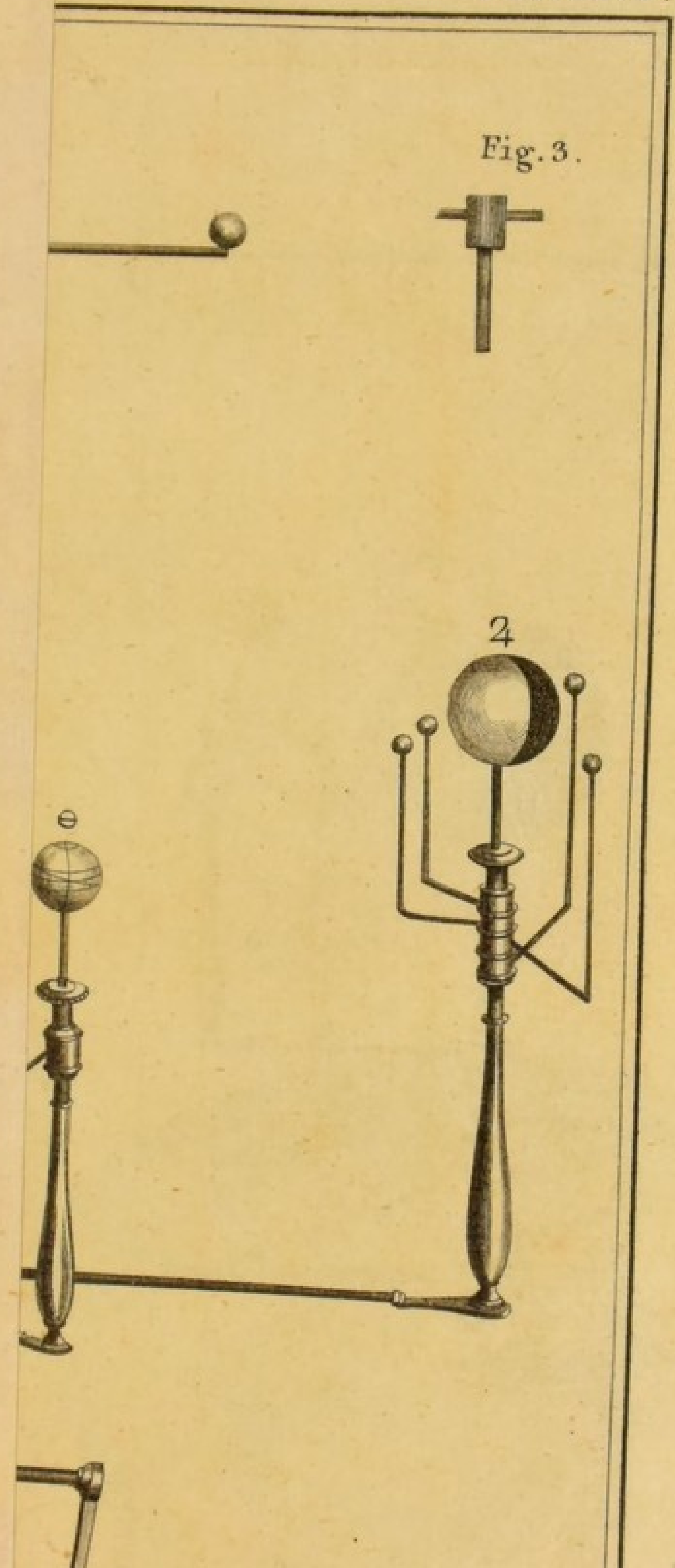
Plate XIV



T. Milne



Jn.° Lodge sc.



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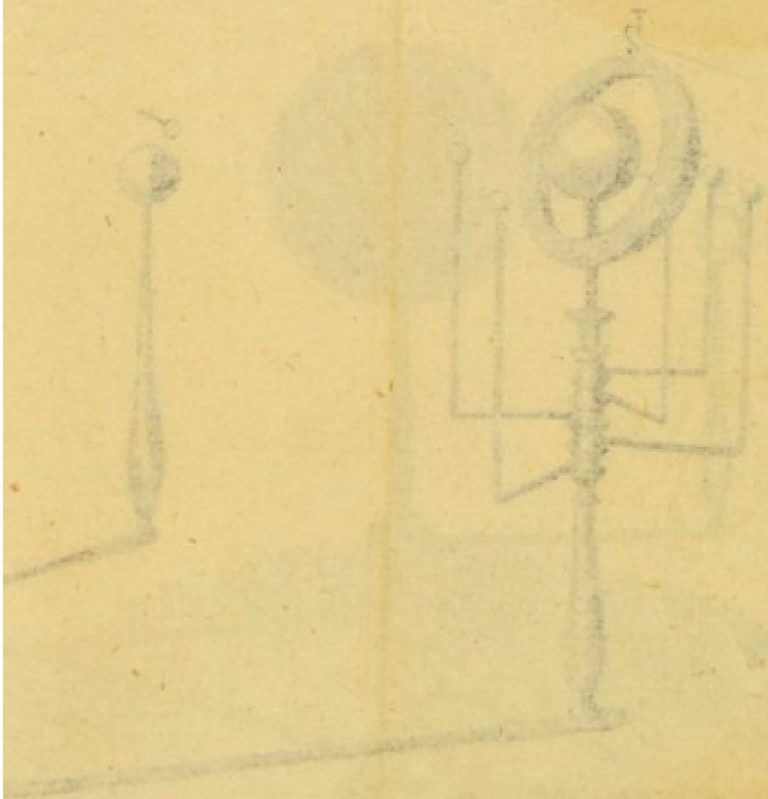
Jn.º Lodge sc.



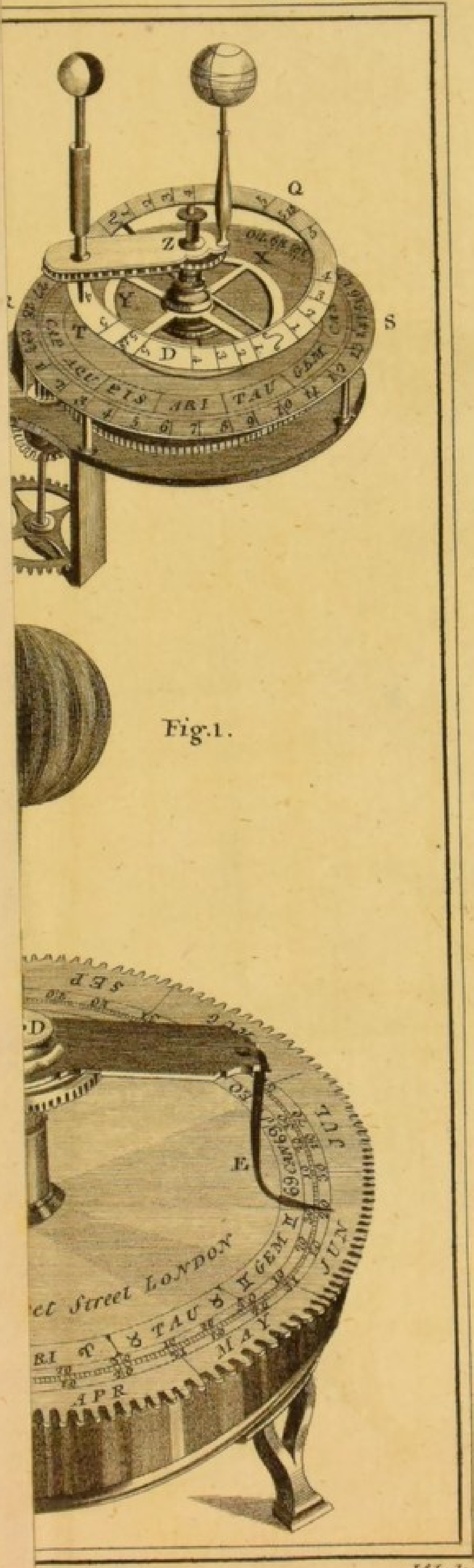
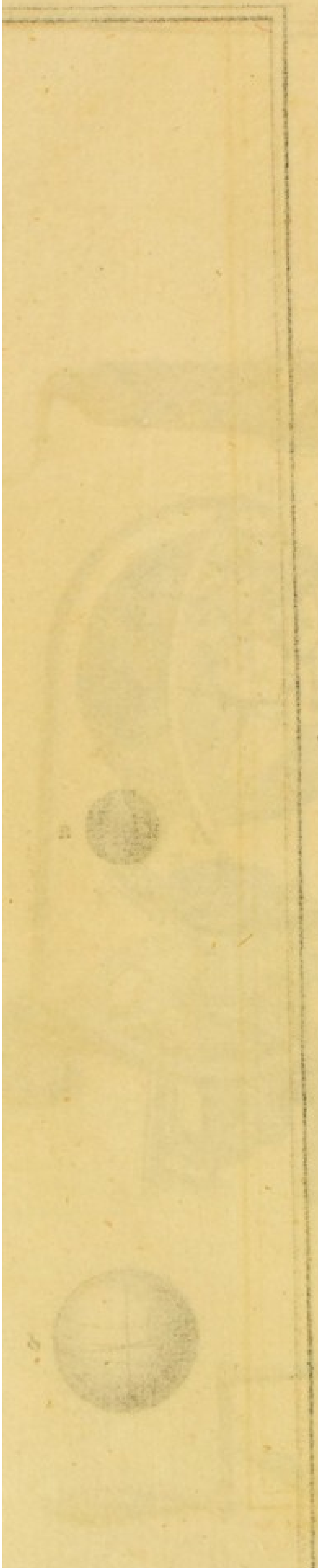
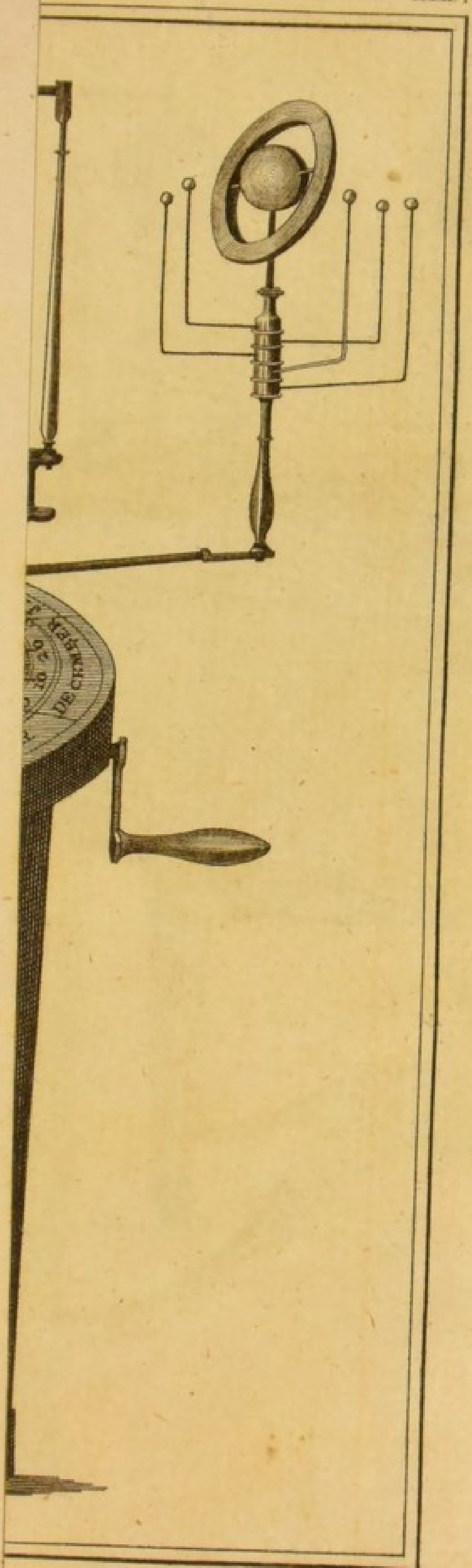


Fig.1.

J.H. Lodge sc.





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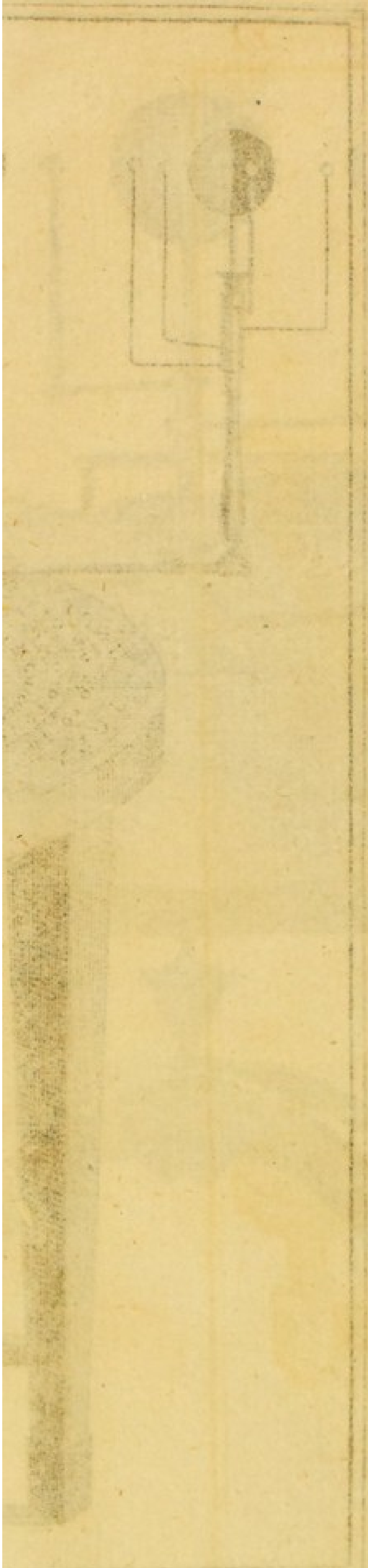


Fig. 1.

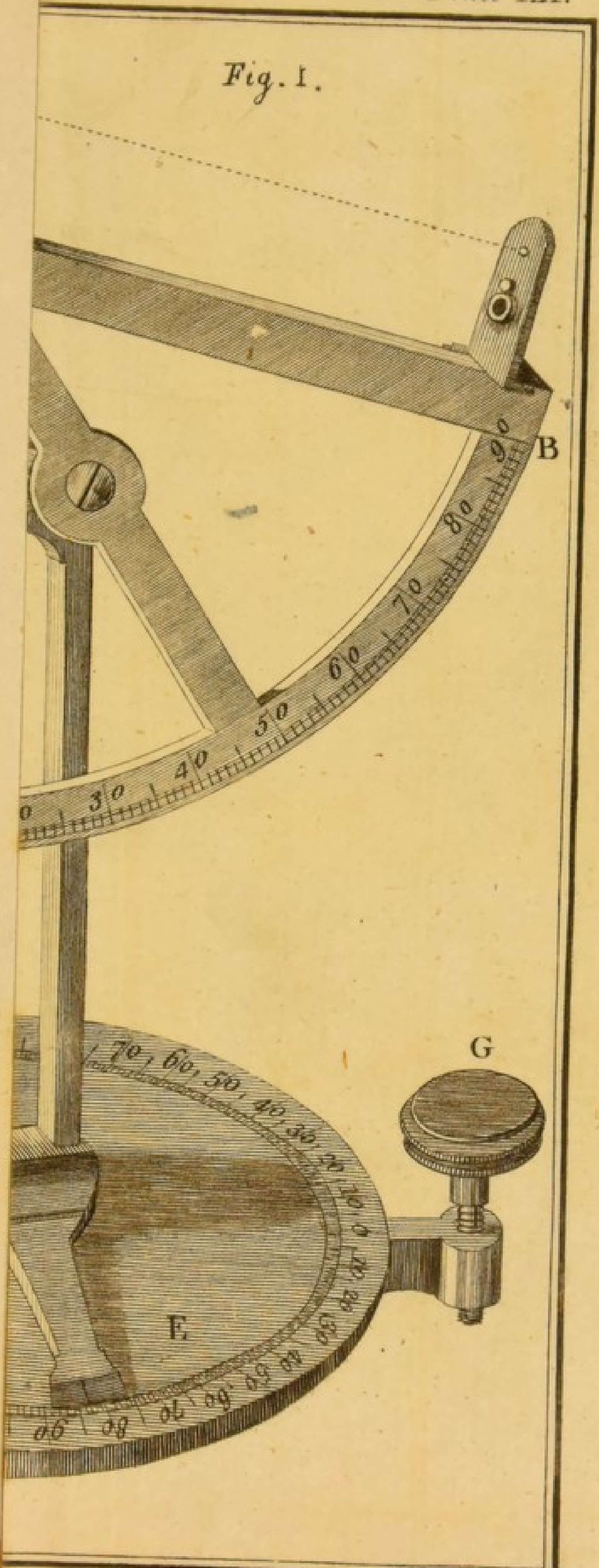
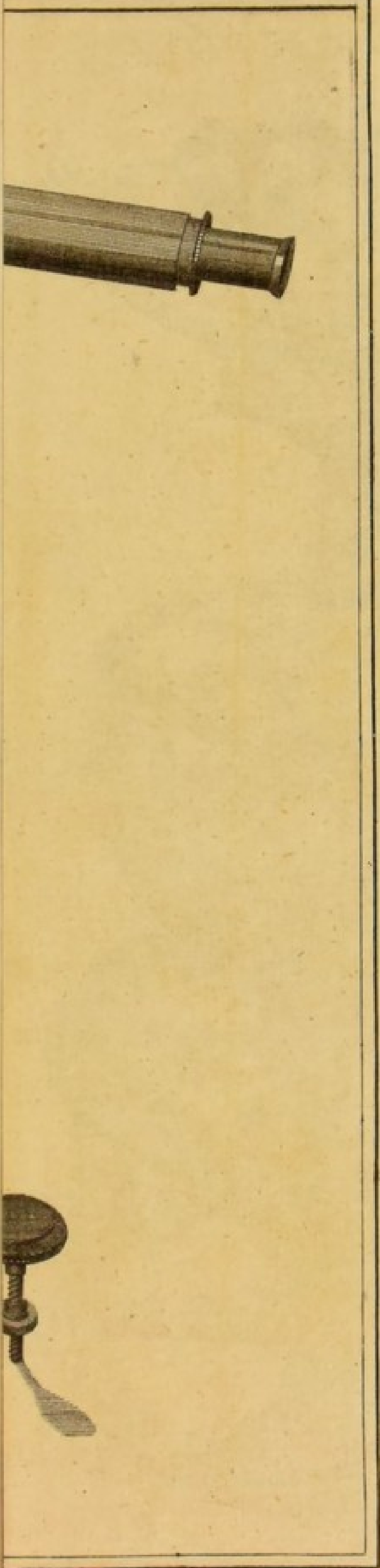


PLATE XXI.



J. Lodge sc.

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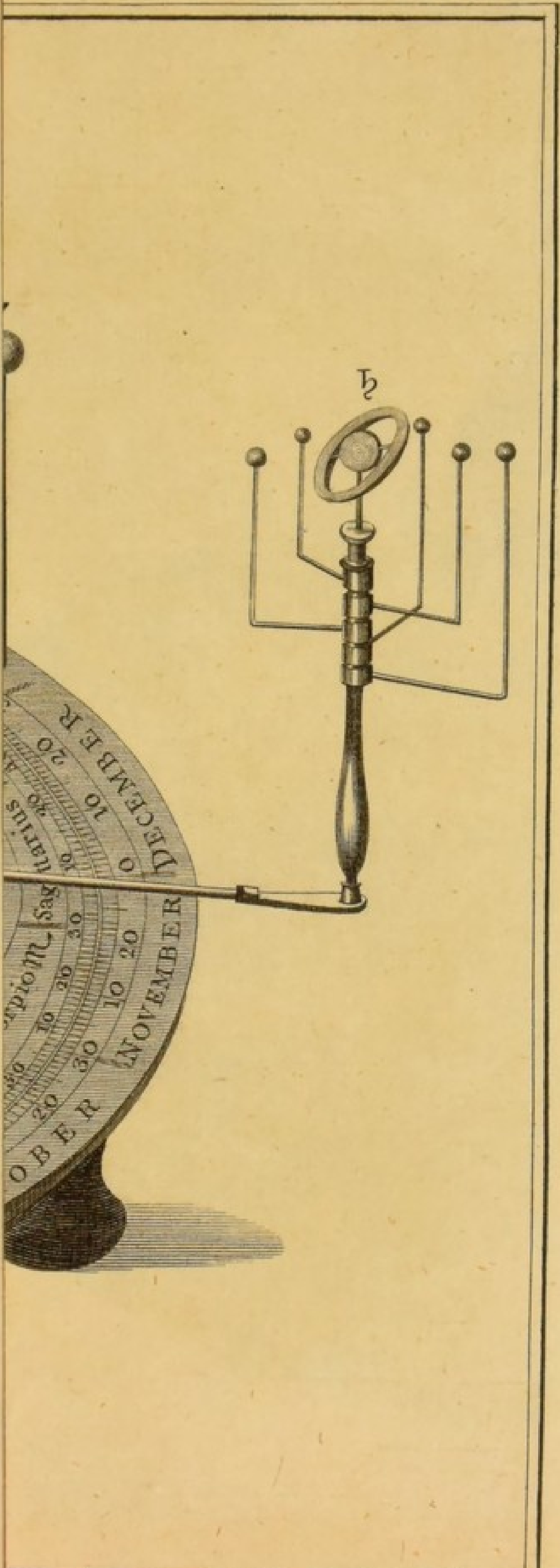

Jn.o Lodge sc.