HEADS OF LECTURES,

ON THE

ELEMENTS

OF

NATURAL PHILOSOPHY,

DELIVERED IN THE UNIVERSITY

OF

ST ANDREWS.

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HEADS

OF

LECTURES, &c.

NATURAL Philosophy, the science defined—Its uses—Contemplates all the material objects which Nature presents—These objects are very numerous and various; and hence the science is very extensive.

Little progress was made in this science by the antients, chiefly because of the improper manner in which they conducted their investigations—Examples in proof of this assertion.

The true method of conducting philosophical investigations.

Rules of Philosophising.

1*st*, Not to indulge in conjectures.

2*d*, Not to admit the existence of more causes than are sufficient to explain the phenomena and the effects produced.

3*d*, To afcribe fimilar effects to the fame caufe.

4*th*, Thofe qualities, which in the fame body can neither be increafed nor diminifhed, and which belong to all bodies fubject to our examination or within the fphere of our obfervation, are to be accounted the univerfal properties of all bodies.

On this laft rule is founded the method of arguing by induction—The excellency of this mode of arguing—Errors in the management of it—Directions how thefe errors are to be avoided.

The firft bufinefs of Natural Philofophy is the contemplation of natural objects—Thefe being very numerous, philofophers were induced to arrange them into claffes and orders.

Hence arofe fyftems.

The fyftem of the elements; its beauty and defects.

Material System.

Matter fundamentally the fame in all bodies—The diverfity of bodies arifes from the different modification, arrangement, and mode of cohefion of the particles of matter compofing thofe bodies.

Matter

Matter is whatever has extenſion and makes reſiſtance.

Various Properties of Matter.

1ſt, Diviſibility without end—This property admitted with difficulty on account of the finite underſtanding of man—Objected to by metaphyſicians—Their objections refuted—The great diviſibility of matter obſervable in various natural objects and operations—It can be carried to great extent by human art—Examples.

2d, Attraction—Of this there are various kinds.

a. Attraction of coheſion, which acts at ſmall and imperceptible diſtances—Strongeſt when the particles of matter are ſimilar—Many particles of matter held together by the attraction of coheſion compoſe a body—Hence the definition of a body—Denſity of a body—Denſity proportional to the quantity of matter in the body.

b. Attraction of gravitation—Equally ſtrong between particles of matter that are diſſimilar—Acts at all diſtances—Its force decreaſes as the ſquare of the diſtance increaſes. Hence gravitation

vitation $\div$ square of the diſtance reciprocally—The cauſe of bodies falling to the earth, that is, of bodies being heavy—Gravity ſynonymous with weight—Difference between gravity and gravitation—Weight the meaſure of gravitation—Hence $G \div W \div Q \div D$. Alſo $W \div B$; and univerſally $W \div DB$, and $G \div DB$. Specific gravity the ſame with denſity—The gravitation of all the different particles of matter compoſing a body ſeems to be concentrated in a certain point within the body, called the *center of gravity*—When this center of gravity is ſupported, the body is at reſt—Equilibrium—Center of ſuſpenſion and center of gravity always in the ſame perpendicular line—Stable or permanent equilibrium, and unſtable or tottering equilibrium.

c. Peculiar attractions.

d. Elective attractions—Theſe two will be explained and treated of in the ſequel.

3*d*, Inactivity, called alſo *inertia.*

4*th*, Mobility, when acted on by any force or power.

Motion, a continual and ſucceſſive change of place—All motion the effect of ſome force or power—

power—The force producing motion may be either a momentary impulfe, or a conftantly acting force.

No motion can be inftantaneous, that is, a body in motion requires a certain time to pafs over a certain fpace.

The fpace paffed over by a moving body is a line defcribed by the center of gravity of that moving body—The direction of this line is the direction of the motion; and it is always in the direction of the force.

Velocity is the rate at which the body moves; and it may be either uniform, or accelerated, or retarded, or unequable.

Impediment is any thing which either obftructs, refifts, diminifhes, or deftroys motion.

All motion ∻ the force which produced or produces the motion.

Action and reaction equal and contrary.

In confidering the circumftances of a body in motion, where the fpace defcribed is not long, and is near the furface of the earth, we may, without producing any fenfible error in our conclufions, fuppofe that, *1st*, A ſmall portion of the earth's ſurface is a plane.

2d, All bodies deſcend, or fall to the earth's ſurface, in lines parallel to each other.

3d, The ſame body is of the ſame weight at different heighths from the earth's ſurface.

Simple motion is that which is produced by a ſingle force.

Compound motion is that which is produced by two or more forces acting conjunctly at the ſame time.

Simple motion produced by a momentary impulſe is uniform.

Suppoſing, F = the force producing the motion, v = velocity, t = time ſpent during the motion, s = the ſpace paſſed over, Q = the quantity of matter in the body; in uniform motion we have the following general propoſitions:

1. $v \div F$, when the quantity of matter in the moving body is given.
2. $s \div t$, when the velocity is given.
3. $s \div v$, when the time is given.
4. $s \div tv$.
5. $F \div Q$, when the velocity is given.
6. $F \div Qv$.

A

A body in motion exerts a force againſt any impediment, which force exerted by the moving body is called the momentum of the moving body; and this momentum is always $\doteqdot$ F.

Hence momentum $\doteqdot$ Qv.

Simple motion produced by a conſtantly acting force is accelerated.

In accelerated motion we have the following propoſitions, uſing the ſame ſymbols as before, and taking m = momentum

1. $m \doteqdot Ft$.
2. $Ft \doteqdot Qv$.
3. $Qs \doteqdot Ft^2$.
4. $Fs \doteqdot Qv^2$.

In any particular caſe where any of theſe quantities are conſtant, they may be left out of the proportions; as in the caſe of falling bodies, where the quantity of matter in the falling body remains the ſame, and where the force of gravitation near the ſurface of the earth is the ſame, Q and F being left out, the propoſitions will be,

1. $m \doteqdot t$.
2. $t \doteqdot v$.
3. $s \doteqdot t^2$.
4. $s \doteqdot v^2$.

Compound

Compound motion is the reſult of two or more forces acting conjunctly upon a body: Of this there are numerous varieties.

1*ſt*, When the body is acted on by two forces which are momentary impulſes, the two forces may be either,

a. In the ſame direction—In this caſe the body moves in the direction of the forces; and its velocity $\doteq$ ſum of the forces.

b. In oppoſite directions—The motion is in the direction of the greater force; and velocity $\doteq$ difference of the forces—If the two forces be equal, the body is kept at reſt.

c. The one oblique to the other—In this caſe if the directions and the forces be repreſented by two ſtraight lines AB and AC, and the parallelogram ABDC be formed, the direction of the motion is the diagonal AD, and the body will move through the diagonal in the ſame time that the body would have paſſed over AB or AC if acted on by one of the forces ſeparately.

Of the compoſition and reſolution of forces.

If a body be kept at reſt by three forces acting conjunctly,

conjunctly, the forces are ∸ the fides of a triangle formed by lines drawn parallel to the directions of the three forces refpectively—Alfo each force refpectively proportional to the fine of the angle made by the directions of the other two—Alfo ∸ fides of a triangle formed by lines drawn perpendicular to the directions of the three forces refpectively.

If a body ftrikes or acts againft a plane furface, it exerts its force on the plane in a direction perpendicular to the plane; and the force exerted on the plane ∸ fine of the angle of inclination.

If the body be reflected after the ftroke, the angle of reflection equals the angle of inclination.

The three foregoing dynamical propofitions exemplified by bodies at reft on inclined planes.

If a body be held at reft on an inclined plane by a power hanging freely, and both be fet a moving, their perpendicular velocities are reciprocally ∸ quantities of matter.

If a body fall down an inclined plane, the velocity acquired by the body in any time : the velocity acquired by a body falling perpendicularly in the fame time :: CB : CA—Alfo :: fine of the plane's inclination to the horizon : radius.

The

The ſpace deſcribed by a body on an inclined plane : ſpace deſcribed by a body falling perpendicularly in the ſame time :: CB : CA.

While a body falls perpendicularly through CB, another will deſcend along the plane from C to D.

The ſpaces deſcribed on the ſame plane ≑ ſquares of the times.

The time on the plane CA : time of falling perpendicularly through CB :: CA : CB.

The times on different planes of the ſame inclination ≑ lengths of the planes.

The times in ſeveral ſucceſſive planes equals the time in one plane of the ſame heighth.

The time in a curve equals the time in a plane of the ſame heighth.

The velocity acquired by a body moving down a curve ≑ ſquare root of the heighth fallen from.

The times of deſcending through ſimilar parts of ſimilar and ſimilarly ſituated curves ≑ ſquare roots of the lengths of the curves.

The times in all chords and in the perpendicular diameter of a circle are equal.

Of Pendulums.

1ſt, If a pendulum vibrate in a very ſmall arc,

arc, the time of one vibration : time of a body falling perpendicularly through half the length of the pendulum ∷ circumference : diameter of a circle; that is, ∷ 3.1416 : 1.

Hence we learn that a body, falling to the earth, falls through 16 feet 1 inch in the firſt ſecond of its fall. We may therefore take 16 feet 1 inch to repreſent the force of gravitation at the earth's ſurface, viz. G ÷ 193 inches.

2d, The lengths of pendulums vibrating in ſimilar arcs, ÷ ſquares of the times of vibration.

3d, The lengths of pendulums vibrating in ſimilar arcs, and in the ſame time, ÷ forces of gravitation.

4th, The times of vibration of pendulums of the ſame length vibrating in ſimilar arcs ÷ ſquare roots of the forces of gravitation; and alſo reciprocally ÷ diſtances from the center of the earth.

Uſes of pendulums; for meaſuring time; for meaſuring heighths; for aſcertaining the figure of the earth.

Every part of a pendulum has a momentum peculiar to itſelf; and one certain part of the pendulum has a momentum that is the mean of all the momenta of all the ſeveral parts; and conſequently

quently the momenta of all the ſeveral parts of a pendulum ſeem to be concentrated in this point—We may therefore call this point the center of momentum—It is uſually called the center of oſcillation—The center of percuſſion identical with the center of momentum.

Method of finding the center of momentum in a pendulum of known form and weight.

The length of a pendulum is the diſtance between the point of ſuſpenſion and the center of momentum.

If the center of momentum be made the point of ſuſpenſion, the point of ſuſpenſion becomes the center of momentum reciprocally.

The general principles of dydamics illuſtrated by the ſimple machines called the mechanical powers, and by compound machines; in all of which, when the weight and power are in equilibrio, the momentum of the power equals the momentum of the weight; and to raiſe the weight as much more additional power muſt be applied as will be ſufficient to overcome the reſiſtance of the machine—The chief reſiſtance in machinery is friction—Practical rules concerning machinery.

All

All that has been advanced concerning the compound motion reſulting from the conjunct action of two momentary impulſes, is alſo applicable to the compound motion reſulting from two forces conſtantly acting.

2*d*, When one of the two forces is a momentary impulſe, and the other a force conſtantly acting, the body moves in a curve, the nature of which curve varies according to the direction of the conſtant force.

Two caſes of this compound motion conſidered : All other caſes are matters more of curioſity than utility, and may be reduced to one or other of the two following.

a. When the conſtant force acts in a direction parallel to itſelf, the curve in which the body moves is a parabola. We have examples of this motion in bodies thrown or projected near the ſurface of the earth.

The dynamical principles of projectiles applied to artillery, or the art of gunnery.

b. When the conſtant force acts towards a fixed point, the curve in which the body moves is a recurrent curve, or a curve which returns into itſelf.

The conſtant force tending to a fixed point is called the centripetal force; the momentary impulſe is called the centrifugal force; the point to which the conſtant force tends is called the center of force. The curve in which the body moves is called the orbit; the time which the body takes to paſs over the whole orbit, *i. e.* the interval of time elapſed from the departure of the body from any certain point in the orbit till its return to the ſame point, is called the revolution, or period, or periodical time.

In the caſe of bodies moving in circular orbits, if P = the periodical time, s = the ſpace which the body would move through by the action of the centripetal force F in any time t, c = 3.1416, and R = radius of the circle, we have the following propoſitions.

1*ſt*, $P = ct\sqrt{\frac{2R}{s}}$

2*d*, $P = \frac{\sqrt{R}}{\sqrt{F}}$

3*d*, $F = \frac{R}{P^2}$

4*th*,

4th, If the centripetal force be reciprocally as the ſquare of the diſtance, $P^2 \div R^3$.

In the caſe of a body moving in any other curve than a circle;

1ſt, The areas, deſcribed by radii from the center of force to the moving body,   the timesof deſcription.

2d, F $\div$ cube of the perpendicular from the center of force to the tangent.

3d, If the body move in an ellipſe, and D = the diſtance of the body from the center of force placed in one focus of the ellipſe, then F is reciprocally $\div D^2$.

4th, The ſquares of the periods $\div$ cubes of the mean diſtances.

If a body be acted on by two or more different centripetal forces, tending to two or more different centers, by the compoſition and reſolution of forces, we can find the direction and quantity of one force equivalent to all theſe different forces, ſo that all caſes, where there are ſeveral different centripetal forces, may be reduced to the caſe of a body moved by a ſingle impulſe, and one centripetal force.

We

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We have examples of this kind of motion in the heavenly bodies.

That branch of Natural Philoſophy which contemplates the heavenly bodies, and explains the phenomena and motions obſervable among them, is called Aſtronomy.

The heavens appear to be a concave hemiſphere whoſe center is the obſerver's eye, and the earth's ſurface appears to be an extended plane which meets the concave in a circle, called the horizon.

In this concave are innumerable luminous bodies, ſome of which are ſtationary, called fixed ſtars, and others moveable, called planets. Two of theſe luminous bodies, more remarkable than any of the reſt, are called the ſun and moon.

The fixed ſtars ought firſt to be treated of, becauſe they are fixed points to which we refer the places of the planets, and fixed marks by which we meaſure their motions.

Various opinions of Philoſophers about the fixed ſtars—How the fixed ſtars may be diſtinguiſhed from one another—Neceſſity for making catalogues,

catalogues, and conſtructing maps of them—The moſt noted catalogues and maps deſcribed and explained.

The ſphere of the heavens ſeems to revolve once $23^{h}. 56^{m}. 4^{s}.$—Poles.

All the ſtars deſcribe circles which are parallel to each other, and of which one is the greateſt, viz. that which is in the middle between the two poles, and which is called the equator—Some of the ſtars are always above the horizon; others go below the horizon in the weſt, and come up again above the horizon in the eaſt; riſe, culminate, and ſet—The diviſion of the horizon into four cardinal points, and theſe ſubdivided.

Meridian, where all the ſtars culminate, is a circle perpendicular to the horizon and to the equator; paſſes through the ſouth point of the horizon, the vertex or zenith, the poles, the north point of the horizon, and the nadir.

Of the elevation of the pole, and how to find it—Different in different places.

Different methods of finding the poſition of a meridian line.

Every particular fixed ſtar culminates at the ſame

ſame altitude—The ſun does not—Tropics—Tropical year $365^{d}. 5^{h}. 48^{m}. 48^{s}$.—Diſtance between the tropics meaſured by the antients 250 years before Chriſt, and found to be $\frac{11}{83}$ of the whole circle, *i. e.* $47^{\circ}. 42'. 4''$.—Found in the the year 1800 after Chriſt to be $46^{\circ}. 55'. 52''$.—Hence this diſtance ſeems to be diminiſhing.

The ſun's diurnal revolution ſlower than that of the fixed ſtars, being about 24^{h}. varying 30^{s}. more or leſs, from 24^{h}.—The cauſe of this is a proper motion of the ſun from weſt to eaſt, making a complete revolution round the ſphere among the fixed ſtars in $365^{d}. 6^{h}. 9^{m}. 11^{s}$. called the ſidereal year, which is $20^{m}. 23^{s}$. longer than the tropical year—Heliacal riſing and ſetting of the ſtars.

The ſun's annual path through the heavens can be traced, and is found to be a circle called the ecliptic—The ecliptic croſſes the equator in two oppoſite points called the equinoxes—Obliquity of theſe two circles to each other—The equator ſometimes called the equinoctial line, and the tropics ſome times called ſolſtices.

Other imaginary great circles of the ſphere are

are two colures, circles of declination or meridians, circles of latitude, and vertical or azimuth circles.

The imaginary leſſer circles are, *1ſt*, Parallels to the equator, or parallels of declination, of which, four are diſtinguiſhed by proper names, viz. the two tropical and two polar circles; *2dly*, Parallels to the ecliptic or parallels of latitude; and, *3dly*, Parallels to the horizon, or almacantors.

Uſes of all theſe imaginary circles—Right aſcenſion and declination, longitude and latitude—Altitude and azimuth, amplitude, oblique aſcenſion and deſcenſion.

Moon's diurnal revolution—Phaſes—Lunation 29^{d}. 12^{h}. 44^{m}. 3^{s}.

Moon's proper motion among the fixed ſtars from weſt to eaſt—Lunar period 27^{d}. 7^{h}. 43^{m}. $11\frac{1}{2}{}^{s}$.—Her path an apparent circle inclined to the ecliptic—Nodes—The inclination of the moon's path to the ecliptic and the place of the nodes vary—Theſe variations irregular, but, on the whole, the place of the nodes moves retrograde.

A ſingular phenomenon ſometimes happens at the time of the new moon, viz. an eclipſe of the ſun, which is to be more fully treated of in the ſequel—Inferences from this phenomenon, 1*ſt*, The moon is a ſolid ſphere; 2*d*, The moon is between the ſun and the earth; 3*d*, The moon is not luminous in itſelf.

A ſimilar phenomenon is ſometimes obſervable at the time of the full moon, viz. an eclipſe of the moon—Inferences from this phenomenon, 1*ſt*, The earth has a ſhadow; 2*d*, The moon is enlightened by the ſun; 3*d*, The earth is a ſphere.

The earth being aſcertained to be a ſphere whoſe center was identical with the center of the ſphere of the heavens, all the imaginary points and circles of the heavens were referred to the ſurface of the globe of the earth—Hence all the circles of the ſphere have their common center at the center of the earth—Difficulty about the horizon—Real and apparent horizon—Parallaxes—Uſes of the imaginary circles on the ſurface of the globe of the earth.

All the phenomena relating to the diurnal mo-

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tion of the ſphere from eaſt to weſt are explicable on the ſuppoſition that the earth has a rotation on its axes from weſt to eaſt in 23^{h}. 56^{m}. 4^{s}.

Spherical problems—Different methods of ſolving them, 1*ſt*, Mechanically, 2*d*, Inſtrumentally, 3*d*, Arithmetically.

The ſun's motion in the ecliptic more particularly conſidered—The difference between the tropical (called alſo the equinoctial) year, and the ſidereal year is owing to the preceſſion of the equinoxes—The different methods by which this ſlow motion of the equinoxes may be aſcertained—Its quantity is 50″.227 annually.

The effects of the preceſſion in altering the longitudes, right aſcenſions and declinations of the fixed ſtars, but not their latitudes, and in altering the ſituation of the pole of the ſphere with reſpect to the fixed ſtars.

The ſun's motion in the ecliptic from weſt to eaſt not equable; being about the end of June, 57′. 16″ in a day, and, about the end of December, 61′. 10″ in a day.

The ſun's apparent diameter alſo varies, being the leaſt, viz. 31′. 31″. when his motion is the ſloweſt, and greateſt, viz. 32′. 35″.58, when his motion is the quickeſt.

Inference drawn from theſe two phenomena conjointly taken, that the ſun is at different diſtances from the earth at different times, viz. farther from the earth when his motion is the ſloweſt and his apparent diameter the leaſt, and nearer the earth when his motion is quickeſt and his apparent diameter greateſt.

Different hypotheſes for explaining theſe phénomena; 1*ſt*, By ſuppoſing the ſun to move in an eccentric circle; eccentricity, apſides, apogeum, perigeum, anomaly mean and true, profthapherefis or equation; 2*dly*, By ſuppoſing the ſun to move in an epicycle; 3*dly*, By ſuppoſing the ſun to move in an ellipſe—The laſt hypotheſis found to be very nearly true, *i. e.* found to explain the phenomena very nearly.

The motion of the heavenly bodies uſed as a meaſure of time—The nature of time; time can only be meaſured by uniform motion; ſidereal time; ſolar or apparent time; mean time; equation of time.

A

A year, a proper integral ſtandard, and determined by the revolution of the ſun in his orbit—Solar year and civil year.

Lunation uſed as a meaſure of time; months and weeks—Lunar year.

Difficulties of adjuſting the civil year either with the ſolar or lunar year—Julian year; Julian calendar; its defects; was reformed by Pope Gregory; Gregorian calendar; epacts, and their uſe in finding the mean new and full moons—Metonic and other cycles.

Of the planets; only five, viz. Mercury, Venus, Mars, Jupiter, and Saturn, were known before the year 1782, when a ſixth was diſcovered by Dr Herſchell, and is called by the name of the diſcoverer.

Motion of the planets among the fixed ſtars very irregular and unequal—Sometimes they move from weſt to eaſt, or directly, as do the ſun and moon; ſometimes from eaſt to weſt, or retrogradely; ſometimes they move neither directly nor retrogradely, but ſeem to ſtand ſtill, when they are ſaid to be ſtationary.

None of them ever recedes far from the ecliptic; moſt of them only a few degrees; and none

of

of them more than 10°.—Zodiac is a belt in the heavens bounded by two parallels of latitude, one on each ſide of, and 10° diſtant from, the ecliptic.

The paths of the planets croſs the ecliptic in two oppoſite points called the nodes, each planet's path having its own peculiar nodes.

Peculiarities in the motions of Mercury and Venus which are not obſervable in the other four—1*ſt*, They never recede far from the ſun—Elongation—2*d*, Sometimes they are ſeen to paſs over the ſun—Tranſit—3*d*, Always move retrogradely during a tranſit.

Peculiarities obſervable in the motions of the other four planets—1*ſt*, They are ſeen at all diſtances from the ſun—2*d*, When oppoſite to the ſun, they always move retrogradely—3*d*, When near the ſun, they always move directly; and, at that time, their motions are the quickeſt.

Several different hypotheſes or ſyſtems have been contrived for explaining the apparent motions of the planets—1*ſt*, The Ptolemaic, which is extremely defective—2*d*, The Egyptian, which fully explains the motions and phenomena of

Mercury

Mercury and Venus, but not of the other four. 3*d*, The Thyconic, which fully explains all the motions and phenomena of the planets, but it is very complex. 4*th*, The Copernican, which fully explains all the motions and phenomena of the planets, and is much more ſimple than the Thyconic.

Objections againſt the Copernican ſyſtem refuted, and the reaſons why we adopt it as the true ſyſtem—Heliocentric and geocentric places of the planets ; annual parallaxes.

The planets revolve each in an ellipſe round the ſun, which is placed in one focus common to all the ſeven ellipſes—Excentricities, apſides, periods, apheliums, periheliums.

Various methods of aſcertaining all the particulars of a planet's motions, and the form and ſituation of its orbit, by actual obſervation.

The motion of the earth in its orbit more particularly conſidered—Seaſons of the year.

Motion of the moon more particularly conſidered ; whence we conclude, that the moon moves in an ellipſe round the earth placed in one focus, and deſcribes areas proportional to the times.

Hence

Hence its motion is a compound motion reſulting from a momentary impulſe and a centripetal force—The centripetal force of the moon proved to be identical with the force of gravitation.

Jupiter has four moons revolving round him at different diſtances—The periods and diſtances of theſe moons aſcertained from obſervation; whence it appears, that the ſquares of their periods $\doteqdot$ cubes of the diſtances.

Saturn has ſeven moons, and Herſchell's planet ſix moons, all of which move round their primary planet at different diſtances, obſerving the ſame law, viz. that the ſquares of their periods $\doteqdot$ cubes of their diſtances.

Rotation of the planets on their axes, and the ſituation of their axes with reſpect to the planes of their orbits, diſcoverable by obſerving ſpots or inequalities on their ſurfaces—Peculiar phenomena of the belts of Jupiter and the ring of Saturn.

In conſequence of the rotation of the planets on their axes, they are not perfect ſpheres, but oblate ſpheroids—The figure of the earth briefly noticed—The effect of this ſpheroidical figure on the parallaxes, eſpecially on the parallax of the moon.

Eclipſes of the moon and ſun more particularly deſcribed—Methods of predicting them explained and exemplified.

Other eclipſes; occultations and tranſits—The great uſes of all theſe phenomena in chronology, geography, navigation, and aſtronomy.

Comets; different opinions about them—Like the planets, they revolve in ellipſes round the ſun in one focus.

By obſervation, all the planets and comets revolve round the ſun in ellipſes, deſcribing areas $\doteqdot$ times; the ſquares of their periods $\doteqdot$ cubes of their mean diſtances; the ſecondary planets obſerve the ſame law in revolving round their reſpective primaries: Their motion is therefore a compound motion, produced by a momentary impulſe and a centripetal force; and ſince the centripetal force of the moon has been demonſtrated to be identical with the force of gravitation, we conclude the centripetal forces of all the other ſecondary planets, and alſo of the primary planets and comets, to be the ſame, namely, gravitation.

The general concluſions are,

1st, That the world had a beginning, namely, when the momentary impulſe was firſt given.

2d, That it is held in exiſtence by a conſtantly acting force or power.

3d, That it muſt ceaſe whenever this power is withdrawn.

4th, That the whole ſyſtem is the conſequence of deſign, in which there is a diſplay of wiſdom and power far exceeding the utmoſt ſtretch of human thought.

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The ſyſtem, however, muſt be examined ſtill farther. The ſun, which is the center of the ſyſtem, is the ſource of all the light and heat which we enjoy. Light and heat muſt therefore be inquired into.

That branch of Natural Philoſophy which treats of the nature of viſion, is called optics; but as there can be no viſion without light, it is uſual to treat of the nature and properties of light in this branch.

Light is moſt probably a body; and it moves naturally always in ſtraight lines.

The motion of light proved by obſervations on the

the eclipſes of Jupiter's Satellites; and its velocity thence aſcertained to be very great, viz. $16\frac{1}{4}$ minutes in traverſing the longer axis of the earth's orbit.

Definitions of a ray; a beam; pencil, converging or diverging; medium.

If a ray of light fall on any ſurface, it is turned out of its ordinary ſtraight courſe in two ways.

1ſt, If the ſurface be not diſpoſed to let the light paſs through it, the ray is reflected.

2d, If the ſurface be the ſurface of a perfectly tranſparent medium, the ray paſſes through the medium, after having been bent or refracted at the ſurface.

If the ſurface be the ſurface of an imperfectly tranſparent medium, part of the ray is reflected, and the other part is refracted at the ſurface.

Definitions—Incident ray; incident point; reflected ray; refracted ray; angle of incidence; angle of reflection; angle of refraction.

General law of reflection—The angle of reflection equals the angle of incidence.

General laws of refraction.

1ſt, If the ray paſſes out of a rare into a denſer medium, it is refracted towards the perpendicular.

2*d*, If the ray paſſes out of a denſe into a rarer medium, it is refracted from the perpendicular.

3*d*, In any two media, the ſine of the angle of refraction ∻ ſine of the angle of incidence.

4*th*, Different media have different refracting powers; thus, if the medium out of which the ray paſſes be air, and the medium into which it paſſes be water, then the ſine of the angle of incidence : ſine of the angle of refraction :: 4 : 3. Out of air into glaſs :: 31 : 20, or 3 : 2. Out of air into diamond :: 12 : 5.

No law yet diſcovered reſpecting the different refractive powers of different media; theſe powers are therefore to be aſcertained by experiment.

5*th*, If a ray of light fall perpendicularly on the ſurface of a refracting medium, it will not be fracted.

6*th*, No ray paſſing out of a denſe into a rarer medium can be refracted, if the angle of incidence be greater than a certain limit, which limit varies for different media: And, if the angle of incidence be greater than this limit, no part of

the

the ray will be refracted, but the whole of it will be reflected.

7th, A ray, after refraction, is divided into seven differently coloured rays; viz. red, orange, yellow, green, blue, indigo, and violet, forming an oblong image. Different degrees of refrangibility in the differently coloured parts of the original ray; the violet being moſt refracted, and the red the leaſt. Ratios of the ſines of the angles of incidence to the ſines of the angles of refraction for each.

Luminous objects are ſeen by their own or native light. Opake objects ſeen by light being reflected from them; and objects appear to be of different colours becauſe they are diſpoſed to reflect or tranſmit only ſome peculiar parts of light, *i. e.* only ſome peculiar colour.

The rays of light iſſuing from, or reflected from every point of an object, carry with them the image of that point. And all the images of all the different points of an object may be collected ſo as to form a complete image of the whole object—Peculiar circumſtances of this phe-

nomenon—

nomenon—Difference between diftinctnefs and brightnefs of an image or of an object.

If parallel rays be reflected or refracted by one plane furface, or by feveral plane furfaces that are parallel to each other, they will remain parallel after the reflection or refraction.

If parallel rays be reflected or refracted by two or more plane furfaces not parallel to each other, they will not remain parallel after the refraction or reflection, but will be either diverging or converging.

Parallel rays, after reflection or refraction, by a curved furface, become, in fome inftances, diverging, and in others converging, according to the nature of the curved furface.

Focus is a point in which converging rays meet, or from which diverging rays feem to diverge, after reflection or refraction—Diftinction between principal focus, conjugate focus, and virtual focus.

Parallel rays reflected to a focus by a parabolical concave furface.

Diverging rays reflected to a focus by an elliptical concave furface, the two foci of the ellipfe being the conjugate foci.

Any

Any other concave curved ſurface than the two above mentioned, reflect rays ſo as to make them croſs each other in many different points, ſo that a great number of imperfect foci are formed: Theſe imperfect foci are arranged in a curve called the catacauſtic curve, which varies according to the nature of the reflecting curved ſurface.

Since a ſmall portion of a ſpherical ſurface nearly coincides with a parabolical and with an elliptical ſurface, ſmall portions of ſpherical ſurfaces may be, and commonly are, uſed inſtead of either parabolical or elliptical ſurfaces.

Mirrors are either plane, or convex ſpherical, or concave ſpherical ſurfaces.

In a plane mirror, the focus is virtual.

In a convex ſpherical mirror, the focus is alſo virtual.

In a concave ſpherical mirror, the focus is real, being ſometimes principal, and ſometimes conjugate.

To find the focus in plane mirror.

To find the focus in a ſpherically convex or concave mirror. *1ſt*, Mathematically. *2d*, Mechanically.

Curved

Curved ſurfaces of a peculiar kind refract parallel or diverging rays to a focus; but as theſe peculiar curved ſurfaces are difficult to form by art, and as ſmall portions of ſpherical ſurfaces refract parallel and diverging rays nearly to a focus, theſe laſt are generally uſed in practice.

Focus by a convex ſpherical ſurface, ſometimes virtual, principal, or conjugate.

Focus by a concave ſpherical ſurface, always virtual.

Lenſes, different ſpecies of them: Axis of a lenſe: Vertex: Curvature: Diameter or aperture.

Problems for determining the focus in every different ſpecies of lenſe. *1ſt*, Mathematically. *2d*, Mechanically.

Of images formed in the foci of mirrors and lenſes.

Of diſtorted images.

Image of the object formed on the retina is the cauſe of viſion.

The ſtructure of the eye exhibited by diſſection, and explained.

Of

Of the nature of viſion—Perfect or diſtinct viſion—Imperfect or indiſtinct viſion depends on ſeveral different circumſtances—The imperfections known by the names of ſhort-ſightedneſs and long-ſightedneſs particularly conſidered, and the methods of remedying theſe imperfections—Illuſions in viſion.

Of viſion by glaſſes—Optical illuſions—Optical inſtruments; viz. Camera obſcura; different conſtruction of this inſtrument for different purpoſes—Reading glaſſes—Microſcopes, ſingle, double, ſolar, reflecting—Teleſcopes; refracting teleſcopes of different kinds; reflecting teleſcopes of different kinds: Of the imperfections of teleſcopes, and how theſe imperfections may, in ſome meaſure, be obviated—Hadley's inſtrument for meaſuring angles by means of two reflecting plane mirrors; the great utility of this inſtrument; practical directions for adjuſting it, and how to uſe it—Various other optical inſtruments.

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When rays of light fall on any ſurface, and are neither reflected nor refracted, but are abſorbed, then heat is produced.

Various

Various opinions about the nature of heat; but chiefly,

1st, Lord Bacon's opinion, (which was adopted by Mr Boyle, Sir Isaac Newton, and others,) that heat consists in a motion among the parts of the heated body—The grounds of this opinion.

2d, Professor Rickman's opinion, that heat is a body sui generis—The grounds of this opinion.

The most obvious property of heat is its disposition to diffuse itself equally through all substances whatsoever—Equilibrium of heat, or rather equilibrium of temperature.

Of the equal distribution of heat through fluids, and the impossibility of heating one part of a fluid mass more than any other part of the same mass.

Of the unequal distribution of heat through the atmosphere—Several phenomena explained.

The general effects of heat are,

1st, Expansion—The general laws of expansion by heat not yet ascertained—Inconveniencies of expansion on several occasions, and how these inconveniencies may be, in some cases, obviated—Uses to which expansion may be applied—Thermometers—The history of their invention—Description

ſcription of the method of conſtructing thermometers, and adapting ſcales to them; different ſcales deſcribed and explained, viz. Farenheit's, Reaumur's, &c.—Different kinds of thermometers for different purpoſes—Exceptions to expanſion, viz. that ſome few ſubſtances contract by being heated, and expand by being cooled—Several phenomena explained by means of the principles above delivered.

2*d*, Fluidity—Definition of a fluid—All ſolids become fluid by being heated—The phenomena, obſervable when a ſolid is changed into a fluid by means of heat, are, 1*ſt*, The change is ſlow; 2*d*, The temperature of the maſs is always the ſame during the whole time of the change; 3*d*, Different ſubſtances require very different degrees of heat to change them from a ſolid to a fluid ſtate.

Former opinions reſpecting the nature and cauſe of fluidity—The hypotheſis of Profeſſor Muſchenbrook, concerning frigorific particles, examined and refuted—The doctrine of latent heat explained and examined—This doctrine proceeds on the ſuppoſition that heat is a material ſubſtance ; doubts whether heat be really a ſubſtance *ſui generis*—The doctrine of latent heat does not explain all the phenomena obſervable in the melting and congealing of bodies—Explanation of the phenomena on the ſuppoſition that heat is a condition of the heated body, and conſiſts in a motion among the particles of matter compoſing the body—This doctrine of fluidity explains many phenomena concerning the melting and congealing of bodies which the doctrine of latent heat does not.

3*d*, Evaporation—Definition of vapour—Phenomena attending the converſion of a body into vapour ſimilar to thoſe attending the converſion of a ſolid into a fluid—1*ſt*, The converſion is ſlow—2*dly*, The temperature of the maſs is always the ſame during the whole time of the converſion—3*dly*, Different ſubſtances require very different temperatures for their converſion into vapour.

Former opinions reſpecting the formation of vapour—The doctrine of latent heat inſufficient for explaining all the phenomena—Explanation of all the phenomena on the ſuppoſition that heat conſiſts in a motion among the particles of matter compoſing the body.

Farther

Farther confiderations refpecting the different ftates or forms in which a fubftance exifts, viz. in a folid ftate, in the ftate of a fluid, and in the ftate of vapour. Moft fubftances, by the application of heat, pafs through the intermediate ftate of fluidity before they are converted into vapour; and the very few fubftances which do not, may be made to do fo by proper management—This phenomenon inexplicable by the doctrine of latent heat; but fully explicable on the fuppofition that heat confifts in a motion among the particles of matter compofing the body.

4th, Ignition—The connection between light and heat.

5th, Inflammation—This effect of heat is confined to a certain clafs of fubftances called inflammable fubftances—No inflammation can take place without the action of the air—Farther confiderations refpecting inflammation referved till we have treated of air.

* * *

More particular confideration of fluidity—That branch of Natural Philofophy which confiders

fiders and treats of the nature and general properties of fluids is called Hydroftatics.

Hydraulics is the art of raifing and conveying fluids ; and this art is founded on the principles which the fcience of hydroftatics teaches.

The furface of a fluid at reft is a plane parallel to the horizon ; but if the furface be very extenfive, then it is fpherical.

The furface of a fluid ftands at the fame horizontal heighth or level in veffels that communicate by pipes or channels—This property of fluids applied to many ufeful purpofes ; levels, artificial horizon, conducting water into towns, &c.

If a fluid be at reft in a veffel, whofe bafe is parallel to the horizon, then equal parts of the bafe are equally preffed by the fluid.

The preffure of a fluid at any depth is proportional to the depth, and is equal in all manner of directions.

The preffure of a fluid on the horizontal bafe of the containing veffel ÷ the bafe (when the depth of the fluid is the fame) whatever be the fhape of the veffel.

And univerfally the preffure $\doteqdot$ depth of the fluid, and the bafe of the containing veffel conjointly.

Of fpouting fluids—The path defcribed by a fpouting fluid is a parabola, except when fpouting perpendicularly. A fluid fpouting perpendicularly upwards rifes nearly as high as the furface of the fluid in the refervoir.

The velocities of fpouting fluids $\doteqdot$ fquare roots of the depths of the aperture below the furface.

The quantities difcharged $\doteqdot$ fquare roots of the depths.

The quantity difcharged $\doteqdot$ the area of the aperture; and if the aperture be circular $\doteqdot$ fquare of the diameter of the aperture.

And univerfally, the quantity difcharged $\doteqdot$ fquare root of the depth and the area of the aperture conjointly.

If d = the depth of the aperture below the furface, b = the diameter of the circular aperture, both in inches, then the abfolute quantity difcharged in a fecond of time $= 0.7854\, b^2 \sqrt{386\, d}$. cubic inches, or $= 4\, b^2 \sqrt{d}$. gallons Englifh wine meafure.

The

The ſame principles applied for aſcertaining the quantity of a fluid that flows through a ſlit of known dimenſions, in the ſide of a full veſſel.

Application of the two laſt propoſitions to the practice of meaſuring the quantity of water diſcharged by a ſpring, or the efflux of a mill-dam, or other ſtream.

If a fluid runs through a pipe, the velocities in different parts of the pipe ∻ tranſverſe ſections of the pipe in theſe parts reciprocally; and if the pipe be cylindrical ∻ ſquares of the diameters reciprocally.

The quantities of a fluid running with the ſame velocity through cylindrical pipes of different diameters ∻ ſquares of the diameters.

Of the motion of fluids in channels, rivers, mill-leads, &c.

The figure of a fluid globe at reſt is perfectly ſpherical; but if the fluid globe has a rotation on an axis, then the perfect ſphere is changed into an oblate ſpheroid.

Inveſtigation of the ratio of the polar and equatorial radius of the earth, according to the dynamical

mical principles formerly delivered. This ratio ascertained to be 229 : 230.

Other methods of finding the equatorial and polar radii of the earth, by pendulums, or the going of pendulum clocks, and by actual measurement; whence

The equatorial radius = 20993530 feet.

The polar radius = 20895806.

The mean radius = 20944668.

The disturbance of the oblate spheroidical figure of a rotatory fluid globe, by the attractive forces of other bodies.

The phenomena of the tides explained by the principles established in the foregoing proposition.

When a solid body is immersed in a fluid, it displaces a quantity of the fluid equal to its own bulk.

If the solid is capable of sinking in the fluid, it loses a part of its weight by being immersed in the fluid.

The loss of weight which the solid sustains is equal to the weight of a quantity of the fluid of the same bulk with the immersed solid.

This

This property of bodies immerſed in fluids applied to the purpoſe of aſcertaining the ſpecific gravities of bodies.

Of the conſtruction of tables of the ſpecific gravities of bodies; and why pure water is aſſumed as the general ſtandard in theſe tables.

Different methods of finding the ſpecific gravities of ſolid bodies.

1ſt, If the ſolid be heavier than water.

2d, If the ſolid be lighter than water.

3d, If the ſolid be liable to be diſſolved by water.

Different methods of finding the ſpecific gravities of bodies in the form of powder, as ſand, earth, &c.

Different methods of finding the ſpecific gravities of fluids.

Utility of the tables of ſpecific gravities of bodies.

Several problems ſolved by the principles derived from the doctrine of ſpecific gravities.

Of floating bodies—They diſplace a quantity of fluid equal to their own weight—Floating bodies applied to aſcertain the ſpecific gravity of bodies

dies, either ſolid or fluid; to weigh cargoes of boats and ſhips.

On the equilibrium of floating bodies.

The center of gravity of the whole floating body, and the center of gravity of the immerſed part of the floating body, are always in the ſame perpendicular line to the horizon.

The equilibrium can only be permanent when the diſtance between theſe two centers of gravity is the leaſt poſſible.

Practical rules concerning the form of bodies intended to float.

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A more particular conſideration of vapours, or elaſtic fluids.

That branch of Natural Philoſophy which treats of the nature and general properties of elaſtic fluids, is called pneumatics.

The moſt abundant elaſtic fluid in nature is the air in which we live, and which, ſurrounding the globe of the earth, forms the atmoſphere.

Air is heavy—Is capable of being weighed—Its ſpecific gravity is 0.001222, that of pure water being unity.

The air capable of being taken out of a veſſel by ſeveral means; but moſt conveniently by means of an inſtrument called an air-pump.

This inſtrument deſcribed, and its conſtruction exhibited and explained. Its imperfections. It can never make a perfect vacuum, but only approximates to a vacuum.

The elaſticity of the air conſidered, and proved by many experiments.

The preſſure of the atmoſphere very great—Method of aſcertaining the quantity of this preſſure, which is found to be between 14 and 15 pounds avoirdupoize weight on every ſquare inch of ſurface—The atmoſphere, like all other fluids, preſſes equally in all manner of directions.

The barometer, which ſhews and meaſures the weight or preſſure of the atmoſphere, is a uſeful inſtrument—Different conſtructions of this inſtrument, with their reſpective advantages and defects.

The preſſure of the atmoſphere is not always the ſame, and ſeems to have ſome ſort of connection with the ſtate of the weather, and hence the barometer is a weather-glaſs.

Practical

Practical directious for judging of the ſtate of the weather by the riſing and falling of the quickſilver in the barometer.

The denſity of the air varies as the preſſure varies; hence the denſity ∻ the weight of all the ſuperincumbent air.

Hence alſo the denſity of the air is different at different heighths from the ſurface of the earth.

The logarithm of the denſity ∻ heighth above the ſurface of the earth.

The denſity of the air reciprocally ∻ the heat or temperature.

Hence univerſally the denſity ∻ preſſure directly, and the temperature reciprocally.

The preſſure is meaſured by the barometer, and the temperature is meaſured by the thermometer. Hence by theſe two inſtruments we can meaſure the denſity; and hence alſo the barometer and thermometer are capable of being employed for meaſuring heighths.

Practical directions for meaſuring heighths by means of the barometer and thermometer.

Several phenomena explained which are cauſed by the preſſure of the atmoſphere.

The

The preſſure of the atmoſphere, being a very great force, is frequently applied to ſeveral uſeful purpoſes—The ſyphon and its manner of operation explained.

The principles of the common pump explained, and its conſtruction conſidered—Forcing, lifting, and other pumps—Water engines.

The fire engine deſcribed, and its general principles explained—Hiſtory of the various improvements which this uſeful machine has received.

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Hiſtory of the diſcovery made by Mr Boyle, that air is ſometimes found combined with other ſubſtances; in which ſtate it is void of elaſticity, and was called fixed air. Dr Hales firſt obſerved fixed air to be different from the air of the atmoſphere.

Fixed air can be ſeparated from the ſubſtances which contain it, and, when ſeparated, it always recovers its elaſticity.

It may be ſeparated from the ſubſtances which contain it. *1ſt*, By removing the preſſure of the atmoſphere. *2dly*, By the application of heat. *3dly*, 3*d*, By mixing the ſubſtance containing it with other ſubſtances.

The firſt method is practicable only in a very few caſes—Examples.

By the ſecond method, the fixed air is moſt commonly ſeparated ſuddenly; and, with violence, producing exploſions—Examples.

By the third method, the air is ſeparated, except in a few caſes, gradually—Examples.

On the general nature of mixture, and the phenomena obſervable when ſubſtances are mixed with each other.

Elective attractions conſidered.

Air extricated from chalk by mixing the chalk with an acid.

When this air is examined, it is found to have many properties by which it differs from common or atmoſpheric air—1*ſt*, It is heavier than atmoſpheric air—2*dly*, It extinguiſhes flame immerſed in it—3*dly*, It kills animals that breath it—4*thly*, It unites with water, imparting to the water an acid taſte and a peculiar briſkneſs,

Natural hiſtory of this air—It occurs frequently in a ſeparate ſtate; is contained in various other

other ſubſtances beſides chalk; is extricated or produced by ſeveral natural operations—Its various names.

Another peculiar kind of air extracted from water, by mixing the water with a metal and the acid of ſulphur—The general properties of this air—Its natural hiſtory and various denominations.

Another peculiar kind of air, called nitrous air, extracted from nitrous acid, by mixing the acid with a metal—The properties of this air are, 1*ſt*, It is noxious to animals—2*d*, It extinguiſhes flame—3*d*, When mixed with four times its bulk of atmoſpheric air, red fumes are produced, which, being condenſed, are found to be nitrous acid; the five bulks of air are reduced to three; and the air thus leſſened is unfit for the ſupport of animal life, or of combuſtion, and has hence been called Azot.

If animals breath in a portion of confined atmoſpheric air, the animals die, and the bulk of the air is reduced to about three-fourths of its original bulk, the remainder being azot, or the ſame kind of air as that which is obtained by

mixing

mixing atmospheric air with a certain portion of nitrous air.

Inflammable substances burning in confined atmospheric air produce the same effect.

The conclusion drawn from these phenomena is that the atmosphere consists of two distinct kinds of air; the one of which, being about the fourth part of the whole, is employed for the support of animal life and of combustion, and that the other three-fourths is unfit for these purposes—The first has therefore been called vital air, empyreal air, or pure air, and the other azotic air or simply azot.

Another conclusion drawn from these phenomena is, that the nitrous acid is a compound consisting of pure air and nitrous air.

Pure air separated from nitre—Its properties more particularly considered, and the contents of the atmosphere determined to be,

Vital or pure air, -	27 parts	in the hundred.
Azotic air, - - -	72 parts	
Chalk air, - - -	1 part	

When inflammable substances are burnt in pure air, all the air disappears; and, if the combustion

buſtion be ſo managed that nothing eſcapes, we find the produce to be equal in weight to the ſum of the weights of the inflammable ſubſtance and of the air: And ſince, in moſt caſes, the produce, after combuſtion, is an acid, pure air has been called oxygene.

Farther conſideration of the union of pure air with other ſubſtances.

Pure air being neceſſary for ſupporting animal life and combuſtion, a great quantity of it is continually expended in theſe natural proceſſes; hence all of it would in a ſhort time be conſumed, had not nature provided means for reproducing it—The different proceſſes of Nature by which this reproduction of vital air is effected—General inference that there is a diſplay of wiſdom, deſign, and contrivance, for continuing and preſerving the world in its preſent ſtate.

* * *

Beſides the uſes of air, above enumerated, we find it to be the cauſe of ſound.

Sound is produced on the following occaſions, *1ſt*, When air ruſhes violently into a vacuum—

2d,

2*d*, When condenſed air ruſhes violently out of its confinement—3*d*, When a ſolid is quickly moved through the air—4*th*, When air paſſes quickly through a parcel of ſolids, or through holes—5*th*, When ſolid elaſtic bodies are ſtruck againſt one another in air. Air, therefore, is always neceſſary.

Cauſe of ſound more particularly conſidered.

Velocity of ſound 1142 feet in a ſecond.

Echoes, ſimple and multiplied.

Sounds vary in tone, and are either grave or acute; a grave tone from ſlow vibrations, an acute tone from quick vibrations.

Of the nature of the vibrations of a muſical ſtring.

The number of vibrations in ſtrings of the ſame materials and diameter ∻ ſquare root of the tenſion with which they are ſtretched.

The number of vibrations in ſtrings of the ſame materials and diameter ∻ lengths reciprocally.

And univerſally, the number of vibrations ∻ ſquare root of the tenſion directly, and the length of the ſtring reciprocally.

Of concords, diſcords, and harmony.

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Of currents in the atmoſphere, commonly called winds.

They are either, *1ſt*, perennial or conſtant winds, as the trade winds between the tropics. Or, *2dly*, periodical or ſtated winds, as the monſoons, in large bays and gulfs. Or, *3dly*, variable winds.

Of the general cauſe of winds; how this cauſe is ſo modified as to produce all the effects above mentioned.

Whirlwinds conſidered, and their cauſe explained.

Rain; its formation—Miſts, dews, and clouds.

Various phenomena accompanying miſts and rain—Rainbow, weathergalls, halos, parhelia, &c.

Of atmoſpherical refractions.

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Of the reſiſtance which the air and other fluids make againſt bodies moving in them.

Reſiſtance ∻ ſquare of the velocity of the moving body.

Reſiſtance

Reſiſtance ∻ ſquare of the diameter of the moving body.

Reſiſtance ∻ denſity of the fluid in which the body moves. This laſt propoſition ſuppoſes the fluid to be perfect, *i. e.* whoſe particles of matter have no attraction of coheſion, or a fluid which has no tenacity.

Univerſally, the reſiſtance ∻ ſquare of the velocity, ſquare of the diameter of the moving body, and the denſity of the fluid conjointly.

In the caſe of falling bodies, when they have acquired a certain velocity, the reſiſtance becomes equal to the accelerating force, and the body falls, not with an accelerated, but with an uniform velocity.

What relates to the reſiſtance which bodies meet with when they move in fluids holds good with reſpect to the reſiſtance which a body at reſt exerts againſt a moving fluid; or to the force which a moving fluid exerts on a body at reſt.

Theſe principles applied for aſcertaining the action of a ſtream of water againſt piers and bulwarks, and alſo againſt the float-boards of mill-wheels, &c.

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The action of the wind againſt buildings, and againſt the ſails of wind-mills and the ſails of ſhips.

The above principles applied to the ſailing of ſhips.

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Peculiar attractions.

1*ſt*, The attraction of the magnet for iron and for other magnets.

Two points in the magnet which attract more ſtrongly than any other parts of the magnet.

A magnet communicates its powers to a piece of iron without having its own power in the leaſt diminiſhed. Hence artificial magnets.

On the directive quality of the magnet, and the peculiarities of this quality. Poles of the magnet.

On the peculiarities relating to the action of magnets on one another.

Iron and ſteel made magnetical without the intervention of a natural magnet.

The various uſes of the magnet—Of the ma-

riners

riners compaſs; practical remarks on its conſtruction; directions relative to its uſe and management.

Various opinions about the nature of magnetiſm enumerated and examined—All of them hypothetical and inſufficient for explaining the phenomena.

2d, The attraction of amber, and of other ſubſtances peculiarly circumſtanced, for a variety of other ſubſtances.

Electricity—General phenomena exhibited.

Proofs of the exiſtence of the electrical matter—The mode of its paſſing from one body to another

Of what is called poſitive and negative electricity.

Of the ſimilarity between electricity and thunder.

The phenomena of thunder and lightning deſcribed and explained. Thunder proved to be identical with electricity.

The phenomena of the aurora borealis conſidered. Of the connection mutually exiſting be-

tween

tween the aurora borealis, electricity, and magnetiſm.

Practical directions for obviating the effects often produced by lightning.

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Conclusion, containing general remarks on the conſtitution of the world, the wiſdom diſplayed in its formation, and in the contrivances for its preſervation.

FINIS.

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