

Analysis of a course of lectures on natural and experimental philosophy : viz. 1. Properties of matter, 2. Mechanics, 3. Chemistry, 4 and 5. Pneumatics, 6. Hydrostatics, 7. Electricity, 8. Electricity [sic], 9. Optics, 10. Use of the globes, &c.;, 11 and 12. Astronomy / by A. Walker.

Contributors

Walker, A. 1730 or 1731-1821.
Long, William, 1747-1818
Royal College of Surgeons of England

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A N A L Y S I S
O F
A C O U R S E O F L E C T U R E S
O N
N A T U R A L A N D E X P E R I M E N T A L
P H I L O S O P H Y,

V I Z.

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| 1. PROPERTIES OF MAT-
TER, | 7. ELECTRICITY, |
| 2. MECHANICS, | 8. ELECTRICITY, |
| 3. CHEMISTRY, | 9. OPTICS, |
| 4 and 5. PNEUMATICS, | 10. USE of the GLOBES,
&c. |
| 6. HYDROSTATICS, | 11 and 12. ASTRONOMY. |

E I G H T H E D I T I O N .

B Y A . W A L K E R ,

M E M B E R O F T H E D U B L I N S O C I E T Y ; L E C T U R E R O N
P H I L O S O P H Y T O H I S R O Y A L H I G H N E S S T H E D U K E
O F G L O U C E S T E R ; E T O N , W E S T M I N S T E R , A N D
W I N C H E S T E R C O L L E G E S , & C .

S O L D B Y T H E A U T H O R ,
P R I C E T W O S H I L L I N G S .

P r i n t e d b y C . B U C K T O N , G r e a t P u l t e n e y - s t r e e t , G o l d e n - s q u a r e .

A D V E R T I S E M E N T.

AS many who attend this Course may not have made PHILOSOPHY a *previous study*, it may be supposed that many of its useful parts will escape the memory; 'tis therefore at the request of *those* I have drawn up this short Analysis, by a short look at which, any particular proposition or experiment will easily be recollected.

A N A L Y S I S
O F
A COURSE OF LECTURES
O N
NATURAL AND EXPERIMENTAL
P H I L O S O P H Y.

LECTURE I.

On the general Properties of Matter.

AN hundred and fifty years are scarce elapsed since the clouds of prejudice, which had long overspread the world, began to clear up, and men were convinced, by cultivating the sciences and attending to nature, that no *fanciful conjectures* could ever lead them to the true causes of those various phænomena that incessantly, and every where, meet the observer's eye; but that the narrow limits of the human understanding, confine the course of our researches to *one single path*—namely, that of *experiment*, or the *use of our senses*. Yet, in this short period, natural philosophy hath risen to an high pitch of improvement, and may with truth be said to have made much greater advances towards perfection since the experimental method was introduced, than in the many ages before.

Because many bodies are reducible to water, *this* element has been thought, by many able philosophers, to be the primary origin of all matter ; and that bodies differ only as they contain more or less *particles*, or *pores* differently disposed. We find, indeed, the decomposition of bodies finite, being unable to carry it beyond a certain limit ; if we attempt to go further, we are always stopt by substances in which we can produce *no change*, which are incapable of being resolved into others, and which stand as so many *firm barriers* obstructing our progress. To these substances we affix therefore, more properly, the name of principles, or first elements, and they are *earth, air, fire, and water.*

☞ Mr. Cavendish has lately discovered a method of generating *water* by inflaming a mixture of common and inflammable air in a close vessel.

The properties that are common to all these elements, are : 1st, *Divisibility, i. e.* the particles of each element are so small, that they escape the scrutiny of our best glasses. A candle will fill a sphere of four miles in diameter with particles of light in a second of time. Two ounces of *assa-fœtida*, nicely weighed, may lie exposed to the air, and have its particles carried off by it for a fortnight together, and yet it will not lose the thousand part of a grain of its original weight. Eight grains of gold will cover a wire completely 13,000 yards in length. A grain of copper dissolved in a jill of *aqua fortis*, will cover as much polished iron with a fine skin of copper as the *aqua fortis* will wet : Nay, Lewenhock discovered with his microscope more living animalculæ in the milt of one cod-fish, than there are men, women, and children, on the whole earth.

2dly, The matter of which these elements are formed is *impenetrably hard*. If we pound the most brittle substance to the most impalpable powder its original particles still remain unhurt. If water has no bed of air to fall upon, it will fall upon the glass in which it is inclosed

like a piece of iron and make a loud click ; a column of air falling on a plate of an air-pump will give a report as loud as a gun : Nay, elementary fire, subtil as it is, strikes the bones, in the electric shock, like a solid body ; and lightning penetrates the hardest substances.

3dly, Matter is *inert*, *i. e.* can neither move, nor stop, of itself. A ball on the whirling-table, neither begins to move when the table moves, nor stops when the motion of the table is stopped. Give a sudden push to a bowl of water, and the fluid will fly over the bowl in a contrary direction ; but if you turn swiftly round with the bowl in your hand, and stop suddenly, the water will fly over the bowl the way it was going. The *inertia* increases as the quantity of matter. A man lying with a large anvil on his breast, will not be hurt when a blacksmith strikes upon it with a large hammer, with all his strength ; but if he had an anvil only a pound weight upon his breast, the first stroke of the blacksmith would kill him. The *vis inertiae* of the large anvil makes its resistance equal to the stroke of the hammer, so that the anvil may be said to strike the hammer as forcibly as the hammer strikes it ; and hence the difficulty of putting large bodies in motion. These are but small instances of those three laws of nature which Sir Isaac Newton found universal, *viz.* *That matter is perfectly indifferent to either rest or motion.* 2dly, *That bodies move in proportion to the force that acts on them.* And 3dly, *That action and re-action are equal, and contrary.*

4thly, *Matter attracts, and is attracted ; i. e.* All parts of matter have a tendency toward each other. A plumb line on the side of a mountain is drawn out of its perpendicular by the attraction of the mountain. Two cork balls, swimming on water, run together with an accelerated motion, and stick together. Water rises above its level against the side of the bowl which holds it ; and also in capillary or small tubes : And hence the reason why water rises in sponge, sand, between glass planes, &c. for all these may be conceived as made up of capillary tubes. Two planes of lead, marble, glass, iron, &c.

thrust close together, stick so, that excessive force alone can separate them. 'Tis this *attraction of cohesion* that makes all bodies cohere, or maintain any distinct form; and as some parts of matter attract more forcibly than others, iron becomes heavier, and more compact, than wood; gold and platina have more particles in less room than any other metal; lead is different from stone, because its particles attract one another more forcibly; so that all that variety which we see in both mineral, animal, and vegetable substances, arises from the different combinations of the four elements, the different degree of attraction in the particles of each, and in the different disposition of the pores, or interstices, that are between the particles of which they are composed. For the particles of the heaviest and lightest bodies are all of the same weight, as may be proved by dropping a piece of gold, and a feather, down a tall glass that has no air in it to resist their passage. Fire can destroy this cohesive quality in bodies, for a time, but makes no alteration in the original particles of bodies. It will insinuate itself into gold, and separate its particles, so as to make it into a fluid. Water and air are kept in a state of fluidity by heat. Fire increases (perhaps causes) the repulsive qualities of all bodies. Metals swell with a small degree of heat, as may be proved by the pyrometer. All nature is kept in motion by it; even blocks and stones swell by the heat of the day, and contract by the cold of the night. It gives water so repulsive a quality, that it flies off in steam. Air is so swelled by it, that, to keep up its equilibrium, it is perpetually agitated by winds and storms. Fire is the only *essential fluid*, and the cause of fluidity in other bodies, by separating their parts. However, there seems to be a repulsive quality common through nature, independently of fire. 'Tis said, "where the sphere of attraction ends, repulsion begins." The north pole of a magnet, at one-tenth of an inch from a suspended needle, attracts it; but at five-tenths from it, it repels it. A glass tube rubbed with a dry hand, will alternately attract and repel feathers, leaf gold, and other light bodies. A small needle will lie on the surface of water by its repulsion; flies run over it without wetting their feet, and a drop of oil will be sus-

tained by its repulsion; without ever touching the surface of the water. The rays of light are said to be repelled from the surface of a looking-glass, &c. however I doubt the universality of this principle.

5thly, *Elective attraction*, or the tendency which *one* part of matter has to unite with some other *particular* part in preference to every other part of matter, forms the grand basis of Chemistry.—Thus, water rushes into union with spirit, but not with oil.—Acids have the strongest affinity to phlogiston and alkali.—Air attracts water with greater avidity than salt, so that fresh water is absorbed by it from the surface of a salt sea, &c. Of the elective kind of attraction also is that of magnetism, because it only attracts iron, steel, and itself; some hold magnetism and electricity as relations, because steel struck by lightning, or a strong shock of electricity, acquires polarity and magnetic attraction. One Magnus, a shepherd, first discovered this wonderful stone from its sticking to the iron in his sandals, and from him it had its name: Its attraction is at two opposite points, called its poles, and if the stone was broke into a thousand pieces, each piece would have its attracting poles: This attraction is strongest in contact, and diminishes by a proportion not yet found out; but that point of a stone which attracts one end of a touched needle will repel the other. Flavius Gio, of Naples, about 350 years ago, first discovered that a piece of steel rubbed on it, and then suspended, had the property of pointing north and south, and thence applied it to navigation. An hundred years after, it was found by Sebastion Cabot to have varied above 11 degrees east. It continued to vary towards the east at the rate of about one degree in seven years, till the needle formed an angle with the meridian of 30 degrees. It then returned towards the west at the same rate, so that about the year 1600 the line of *no variation* passed over England, the needle pointing then directly north and south. Since that time it has continued varying towards the west, and with us at this time the needle is 22 degrees 48 minutes west. It is probable it will continue to vary westward till it makes an angle with the meridian of 30 degrees, (as it did at

its eastern extremity) and then return westward, finishing its revolution in between 900 and 1000 years. A line of no variation at present passes southward near Madagascar, doubles the Cape of Good Hope, slopes across the Atlantic, touching Brazil, and serpentine passes through Canada, over the Western Lakes, and terminates at the north magnetical pole, situated about 30° from that of the earth, in the meridian of California. From thence the *line of no variation* proceeds over the earth's north pole, inclining easterly over Siberia, Tartary, China, the Ladrone Isles, and New Holland, and then arrives at the south magnetic pole, situated to the south-east of Van Deiman's Land, about lat. 56° south, and 180° west long. from London. These lines, as well as poles, move westward at present; and Captain Cook in his last voyage, came so near the south magnetic pole, that his compass needle turned half round in 24 hours sailing—and the dipping needle stood almost perpendicular. If a piece of steel of spring temper be balanced on a point horizontally, so soon as it has received magnetic virtue, it dips or inclines, so as to point in a chord to the north or south magnetic pole of the earth: But if equidistant from both, it continues horizontal, like a balanced bar moved from one end to the other of a long artificial magnet.

The theory of making *artificial magnets* is derived from an *effluvium* supposed to flow from one pole of the magnet to the other,—the existence of which is made very probable, by steel filings scattered over a plate of window glass, with a *bar magnet* under it, when the effluvium in its passage from one pole to the other influences the filings into many parallel and beautiful curves. Two pieces of steel, *spring temper*, made in shape of horse-shoes, and their ends put together; if then two *bar magnets* just separated, and of opposite poles, or an *horse-shoe* or *natural* magnet be rubbed over them all the same way, *polarity* and *attraction* will be communicated to the steel; but if the two pieces be put together, so that the two repelling ends are together, they attract strongly: And hence several bars thus united

form a very strong magnet.—If a piece of iron, as a *conductor*, be put between the two poles, the magnet will long retain its virtue, particularly if it hangs loose so as it can turn north and south.—Lay four small bars of steel touching one another in a line, lengthwise; slide one pole of a magnet from the right hand to the left over them several times, and they will be good magnets: But if then you slide the same pole over them from the left hand to the right, the magnetic virtue will be entirely taken from them. *Fire* and *rust* destroy the power of these magnets, and time will weaken them, if a conductor of iron or steel do not form a magnetic circuit for the effluvium to pass through. To recal the decreased virtue of a magnet, hang a large *sand-bag* to the iron adhering to it, and keep every day increasing the sand.—To give the virtue to a *knife*, draw it over either pole from hilt to point several times.

By fire, is understood a complex idea of something *red, shining, that excites the sensation of heat, and rarefies or expands all known bodies*. It is the most powerful agent in the decomposition of bodies. It is the only *essential fluid* in nature, and the cause of fluidity in other bodies, by separating their parts; hence, even air itself may become solid when deprived of the fire it contains, as bodies of the most difficult fusion become fluid when penetrated by a sufficient quantity of the particles of fire. *All* bodies become hot by the approach of ignited bodies, and by friction; but bodies that contain a sufficient quantity of phlogiston, *only*, are capable of inflammation. Phlogiston is not fire, but one of the principles of inflammability; *i. e.* when it is combined with various substances in due proportion, it renders them inflammable with air; Phlogiston may be separated from one body, and given to another; hence an inflammable body may be deprived of its inflammability, and a body naturally not inflammable, may be rendered so by combining it with a sufficient quantity of phlogiston. When expelled from bodies it is not annihilated—it only escapes from the burning body into air, which gives proof of

its having acquired it, and is then said to be *phlogisticated*; and hence no inflammation will take place but in the common air. Combustion ceases when the air surrounding the burning body is filled with phlogiston—hence a fire is put out by blowing phlogisticated air into it—but enlivened by a current of fresh air. All bodies contain more or less of this wonderful principle—for all bodies grow hot by violent friction; friction may be therefore said to be a kind of *fire-pump*, that draws latent fire from the adjoining bodies to the place where the friction is going on, and strongly indicates that phlogiston may lie in a concrete form in, and be a constituent part of all bodies; nay, *Birgman* says, 100 ounces of charcoal contains 99 ounces of phlogiston, and but one of earth; metals deprived of their phlogiston are heavier as a calcs than as a metal; inflammable air is eight or ten times lighter than common air, &c. So little do we know of fire, that any attempt at a theory of it must appear presumptuous and premature; we find however that *light*, *heat* and *electric fluid*, have so many qualities in common with *phlogiston*, that hereafter it may probably be found they are all but modifications of the same principle. Rubbing, or friction, in *all* bodies produce *heat* and *electricity*, and both these dilate bodies, help vegetation, germination, evaporation, motion of the blood, the growth of the fetus, and the hatching of eggs. Heat and electricity both reduce, and melt metals; and bodies that receive *heat* with difficulty receive *electricity* so, &c. May not the rays of the sun be diluted phlogiston? May not the velocity with which they proceed from the sun prevent their absorption by the air, in their passage through it? And as all bodies have more or less affinity to phlogiston, may not this diluted phlogiston be absorbed by various bodies, and lie in a concrete form in them till called forth from them by friction or combustion? Experiments that favour this hypothesis are, 1st. Rays collected in the focus of a burning glass, produce on opaque bodies the most intense heat that is producible by the art of man. 2d. Living vegetables imbibe phlogiston (as nutrition) from the air,

and part with it back again into the air in the act of combustion, boiling, or putrefaction; (for rotten wood, putrid fish, ignis fatui; indeed, all animal and vegetable substances are luminous while decomposing by putrefaction)—which is but parting with the *inflammable principle* that was a constituent part of these bodies while in health. 3d. Bodies in the act of *delivering* phlogiston to the air, or any other affinitive menstruum are *universally hot*;—hence the heat of a common fire, where phlogiston is transferring from the coals to the air; inflamed gunpowder, &c.—The *heat* of effervescent mixtures, such as diluted vitriolic acid, and iron filings:—Copper and diluted nitrous acid:—Iron filings, water, and sulphur:—Air carrying off phlogiston from the lungs in the act of respiration, and thereby producing animal heat: Pyrites and water producing the heat of the Bath waters, &c. which is but the water seizing the vitriolic acid, and thereby expelling the phlogiston of the acid into the air, for a mixture of vitriolic acid and water always produce an intense heat:—The production of fire by the escape of phlogiston from phosphorus, pyrophorus, &c. when exposed to the air is another instance:—and the astonishing flame arising from oil of turpentine when a mixture of vitriolic and nitrous acid is poured upon it, alarms, while it proves, that air is the natural menstruum of phlogiston, and that inflammation will not take place except in common air. 4th. A fire-brand exposed in dephlogisticated air blazes out with a vivid flame, while the air seizes its phlogiston. 5th. Metals calcine but partially in small quantities of confined air, that air is so soon saturated with phlogiston;—a current of air must pass over melting metals or they will not calcine:—Air so exposed becomes phlogisticated and diminished. 6th. Metals reduced to a calcs by calcination, or by a solution in acids, part with their phlogiston during the process; and a calcs exposed in inflammable air, and heated by the focus of a burning lens, imbibes or swallows up the inflammable air, and revives into a perfect metal!—This extraordinary fact shews, that metals may as it were be taken in pieces and put together again—for if the phlo-

giston that flies off from a calcining metal could be preserved, and the calcs of that metal be heated in it, the calcs would seize the phlogiston it had lost, and become the very same metal it was before the process. Hence we have reason to believe that inflammable air is the true *elementary phlogiston*, and that it is this gas in a concrete state in coals, candles, wood, metals, &c. that makes them inflammable. Phlogiston in an active state produces *heat*—approaching to a latent state, *cold*. Hence the evaporation of volatile spirits; the mixture of salt and snow—and snow and spirit of nitre, serve to concentrate or deaden the action of phlogiston,—and by these mixtures in cold weather and cold climates, quicksilver has been frozen into a solid metal.

LECTURE II.

M E C H A N I C S.

THE *attraction of gravitation* is the weight of bodies, or that tendency which matter has towards the centre: By this power the earth is formed into a dense ball, and every thing that lives upon it held fast to its surface. A body left to the power of this agent falls about a rood in the first second of time; three roods in the second second; five in the third; seven in the fourth, &c. agreeable to the odd numbers, 1, 3, 5, 7, 9, 11, 13, &c. For the *vis inertiae* of the falling body, added to the power of gravity in every succeeding second, accelerates it, as the squares of the times. Thus,—at the end of the 4th second the body has fallen about 16 roods,—at the end of the 6th second it has descended 36 roods, &c. This is proved by a projected ball falling from an horizontal line one inch in the same time in which it falls 3, 5, 7, &c. inches in the succeeding times; and by the suspension of unequal weights over a pulley. Hence we find this power of gravity decreases as the squares of the distances increase, (*i. e.* a ball, which weighs 9 lb. on the earth's surface, would weigh only 1 lb. at three semi-diameters of the earth above it.) For it is found that the moon falls from a tangent to her orbit in this proportion; shewing that she is actuated by the same law that makes a pebble describe a curve when it is thrown from a sling. For that pebble, if it was projected with proper force, and had a vacuum to move through, as the moon has, would go round the earth for ever as she does.

Motion is rectilinear; i. e. all bodies put in motion by one force, endeavour to go off in a straight line. Hence,

if a coach in swift motion be turned suddenly, it oversets by endeavouring to go off straight: But if a body be impressed by *two* forces, in oblique directions, it will obey neither, but go the diagonal of the square. Hence a ball dropt from the mast head of a ship, under swift sail, falls on the deck as if the ship was at anchor: And a ball shot horizontally from a tall tower, obeys neither the powder nor its own weight, but comes to the ground in a curve formed of the two. We shall in due time see that the planets move by this wonderful law.

The momentum of a falling body is as the square root of its height. Ex, Hang a pound weight on one end of a scale-beam, and if at the other end you let fall a certain weight from the height of one foot, it will just lift, or cant the pound up: But if you let the same weight fall four feet, on one end of the scale-beam, it will cant up two pounds weight hung at the other. If it falls nine feet, it will lift up three pounds weight at the other, &c.

Fluids spout by the same law. A pipe of the same bore as another, but four times as far below the surface of the water in a cistern, discharges twice as much as the upper one; if it be sixteen times as far beneath the surface, it will discharge four times as much as the upper one, &c. For the velocity with which a fluid spouts, at any depth below the surface, is equal to that which a body let fall *that height* would acquire.

The *momentum*, or force, of a body, arises from its quantity of matter being multiplied into the velocity with which it moves: Thus, if a *battering ram* be 1000 lb. weight, and the velocity with which it strikes a wall be 20, then is its *momentum* 20,000: But a cannon ball shall do the same execution, if its quantity of matter be no more than 10 lb. provided it be thrown with a velocity equal to 2000, for $10 \times 2000 = 20,000$, so that the *momentum* of both are equal. This may easily be proved, by laying 2 lb. weight upon a *spring*; if it throws it one yard, it will throw 1 lb. two yards; and 8 lb. will be counter-

poised by 4lb. if it be hung on a balance at *twice* the distance from the fulcrum. Hence the force, or power, of any machine, whether simple or compound, is easily computed; for when two bodies are suspended upon any machine, so as to act against one another, if the perpendicular *ascent* of one body, be to the perpendicular *descent* of the other in the inverse ratio of their weights, they will balance one another; and therefore so much quicker as the power moves than the weight, so much is the advantage gained by the machine, and gives this mechanical axiom, "That what is gained in power, by any machine, is lost in time of working it. Sir *Isaac Newton's*.

All kinds of mechanical engines consist, more or less, of these *six powers*, viz. the *lever*, the *wheel and axle*, the *system of pulleys*, the *inclined plane*, the *wedge*, and the *screw*.

The *lever* is a bar of wood, or metal, turning upon a prop, or centre, (commonly called the *fulcrum*) and is used either to raise weights or overcome resistances. There are three kinds of levers, and in each of them, the velocity of each point is directly as its distance from the prop. When this *prop* is between the *weight* and the *power*, 'tis called a *lever of the first kind*: and so much as the power is further from the prop than the weight, (or its center of gravity) so much is the advantage gained by the power over the weight. *Iron crows, scissars, pincers, rudders of ships, &c.* are *levers of the first kind*. A *lever of the second kind*, is when the *weight*, or *resistance*, is between the *prop* and the *power*, as in doors turning on hinges, knives that turn on a centre at the point; oars, &c. A *lever of the third kind*, is when the *power* is applied between the *weight* and the *prop*, as in rearing a ladder against a wall; moving our legs and arms by the power of the muscles, &c. The *bended lever* differs in nothing from one of the *first kind*, but in form, it is like a hammer drawing a nail. In each of these levers, so much as the *power* moves farther, or shorter than the weight, so is

the advantage, or disadvantage, of each. The power of a *compound lever* is found by multiplying the power of each into one another.

In the *wheel and axle*, the advantage of the *wheel* over the *axle*, is as their diameters, *i. e.* if the *wheel* be four times as large as the *axle*, a man may lift four times as much by it, as by his own strength, allowing for friction. This *power* is the principal part of a common *crane*.

Upper pulleys that are fixed, only serve to change the direction of the power, and give no mechanical advantage thereto; but the under block of pulleys, moving with the weight, give an advantage proportionate to the number of ropes by which the weight is sustained; and which may be estimated also by so much as the power moves faster than the weight. A *running pulley* doubles whatever advantage was gained by the other parts of a machine before it was applied, always allowing for friction, which in pulleys is very great.

The *wedge* separates heavy, or cohering bodies, with a force proportioned, *as the thickness of its back is to the length*; *i. e.* if its back be one foot, and the length twelve feet; then may the momentum of the stroke which moves the wedge be one twelfth only of the weight, or cohering force, of the parts to be separated.

The *inclined plane* is half a wedge, and therefore its power is, *as its length is to its height*; *i. e.* I shall roll a cylinder up an inclined road of twenty yards in length, and but one yard perpendicular height, with one twentieth part of the force that would be necessary to lift it perpendicularly that yard.

The *screw* may be considered as an inclined plane wrapt round a cylinder; therefore as the power moves round the cylinder, while the weight rises, the power has an advantage over the weight, as the length of one thread round the cylinder, is to the distance of one thread from

another ; or as the velocity of the power is to the velocity of the weight.

In a *common jack* we have all these powers together, if to an arm of the fly the power be applied ; and so far as that power moves farther than the weight, so much is the advantage which the power has over the weight.

If machines could be made to move without *friction*, the least degree of power added to that which balances the weight would be sufficient to raise it: But as the smoothest bodies are full of pores, and little eminences, these will lock into one another in rubbing bodies, and greatly retard the motion of a machine. The friction in the *lever*, and in the *wheel* and *axle*, is very small: In *pulleys* it is very considerable: But in the *inclined plane*, the *wedge*, and the *screw*, it is very great. The allowance made for friction in machines consisting of several of the mechanic powers, is usually *one third* ; *i. e.* after calculating all the single powers as above, and multiplying these into one another, from the last product I deduct one third of it, and the remainder is the true momentum or force of the machine. Friction is of two kinds: The *rubbing friction*, and the *friction by contact* ; the rubbing of the locked wheel of a coach against the road may represent the *first* ; and the manner of its touching the road in its usual motion the *second*. When the *first* kind of friction can be reduced to the *second*, there is a manifest advantage given to the power of the machine, as is demonstrated by the experiments with the friction wheels. These wheels are hung so that their peripheries form an angle, in which the gudgeon of the heavy wheel turns. *Water wheels*, large *grinding stones*, and even *wheel carriages*, are hung in this way at a small expence ; but being apt to wear out very fast, they are better fitted to small weights moving with great velocity. And hence the friction balls in wheel carriages, cranes, &c. become soon uselefs. A *narrow* rubbing surface has much the advantage over a *broad* one, though they each sustain the same weight, because of fewer points and pores being in contact ;

hence the smaller the gudgeon or axle of a wheel the better, if it has but strength to support the weight. The friction in water that carries an under-shot mill, is much taken off by a sloping pedal; the velocity of the flat-boards of the wheel ought to be one-third of the velocity of the water; the number of staves in the trundle ought to be no even part of the number of cogs in the wheel that turns it; and the grinding stone should not make above 60 revolutions in a minute.

Besides the *mechanic powers*, and various instruments to explain *friction*, momentum, falling bodies, &c. the machines used to illustrate this lecture are, 1st. A moveable crane. 2d. A mill to saw marble. 3d. Ditto to saw timber. 4th. A common pile-driver. 5th. Voulou's pile-driver. 6th. The equitable moving wind-mill, that cloaths, uncloaths, and turns itself to the wind. 7th. Drill-ploughs. 8th. Ventilators. 9th. Wheel carriages. 10. Methods used in moving the great stone on which the statue of Peter the Great is erected in Petersburg. 11th. A compleat fortification. 12th. Boulton, Blakey, Smeaton's and the common fire or steam engines. 13th. Water engines of all denominations, viz. common pumps, forcing pumps, rope pumps, Archimedes's screw pump; bucket-engines, machines for draining, embanking, &c. &c. &c. These, and many more, from their size, cannot be removed from the Winter Lecture Room, now in George Street, Hanover Square.

LECTURE III.

PRINCIPLES of CHEMISTRY.

ALL bodies existing on the earth may be arranged under three heads, viz. the *animal*, *vegetable*, and *mineral* kingdoms. The first comprehends all bodies endowed with life and self-motion. The second, those which have life only, the power of growing, and propagating their species. The third, all bodies destitute of life and self-motion. Bodies are also considered as *simple* or *compound*.—Simple bodies are such as cannot be resolved into any thing more simple, such as pure earth, pure water, &c. Compound bodies consist of two or more of the primary elements, such as an *animal body*, for earthy particles and various fluids form its composition. That branch of philosophy which examines the properties of these bodies, by compounding or decomposing them, is called CHEMISTRY.—A branch so extensive and important, that the sustenance of life—the arts and sciences—various manufactories—nay, even trade and commerce depend upon a continual *composition* and *decomposition* of natural bodies.

SOLUTION is a property of *fluids*, whereby they imbibe (or incorporate themselves with) *solids*, by separating their parts.—The sea is a solution of salt in fresh water. Ink is a solution of vitriol and galls in water. Diluted nitrous acid dissolves copper; when the ebullition is over, the liquor will be a solution of copper. Diluted vitriolic acid in like manner gives a solution of iron. Quicksilver dissolves lead, tin, &c. Gold dissolved in aqua regia is a solution of gold, &c. and camphor in like manner is dissolved in spirit of wine, &c.—Solutions in water, spirits,

acids, air, &c. are transparent—but mixtures are muddy or opaque.

DISTILLATION is the application of heat to separate fluid and volatile parts from bodies; and to collect them in other vessels by means of cold. Heat expands all bodies, and puts their particles into a repulsive state; when this application becomes more powerful than the cohesion of the body, a decomposition takes place. Sea-water put in a retort, and exposed to the fire, the water soon rises in the character of steam—this steam passing through a cold pipe is condensed, and brought back again into water, but fresh, and the salts being less volatile, remain at the bottom of the retort. Liquors that have gone through a state of vinous fermentation, are disposed to part with spirit—and spirit rising in steam with less degree of heat than water, a separation of the two is easily effected in a still, by tempering the fire,—hence the steam of the spirit passing through a long spiral pipe (immersed in cold water) is condensed:—when the spirit is all come over, the water begins to rise in steam, and may be received in a separate vessel—the earthy and colouring particles of the wine will at last be found dry at the bottom of the still.

SUBLIMATION is but a distillation of dry substances. *Sulphur* exposed in a subliming vessel, is melted with a very gentle heat, and rises in steam, forming flocks of sulphur on the sides and top of the vessel, and is but the same sulphur that was melted. *Gum benzoin* melted within a tall receiver, with a sprig of rosemary in it, rises and forms an hoar-frost appearance on the leaves of the rosemary.—*Phosphorus* just covered with water, in a Florence flask exposed over a lamp, sublimes into the appearance of stars, and the aurora borealis. It rises with the steam of the water, and struggling to obtain the air, its menstruum, forms beautiful coruscations in the flask, particularly when separated from the lamp, and exposed in the dark.

PRECIPITATION is performed in fluid matters only—it is a disuniting of two or more ingredients by the addition of another, which by its greater affinity, unites with one of the ingredients, and separates the others from it, and by which they generally fall to the bottom of the liquor. Copper dissolved in diluted nitrous acid, is precipitated by iron—much of the dissolved copper becomes revived by the phlogiston of the iron, and forms a skin of copper on the iron; the rest falls to the bottom of the liquor precipitated, &c. &c.

SATURATION signifies the point at which the attractive and dissolving power of any menstruum stops, when filled with the matter it is to dissolve.—Solutions of salt or sugar in water; of sulphur in oil of turpentine; camphor in spirit of wine; silver in aqua fortis; water in air, &c. are transparent till fully saturated; if more be added, they sink, in their natural form, to the bottom undissolved, and the menstruum is said to be fully saturated. If water, spirits, oil, &c. be evaporated from the matter with which they are saturated, the matter assumes its natural form;—common salt will assume a cubical form; salt-petre the form of a prism, &c. &c. adhering to the bottom and sides of the containing vessels.

AFFINITY. This term is of great extent in chemistry, and signifies *the tendency which the constituent parts of bodies have to unite readily with some substances in preference to others.* Water and vinegar have affinity, because they are easily mixed together. Water and oil have no affinity because they will not mix, but shew a kind of repulsion to one another. If a mixture, A and B, have a third matter, C, added to them, to which A has a greater attraction or affinity than to B, then will A let go B, and join in union with C, and B is precipitated, Ex. 1st. Solution of sublimate mixt with oil of tartar. produces an orange coagulum; an acid (as the spirit of nitre) added, seizes the oil of tartar, (as an alkali, to which it has a strong affinity) the colour is discharged, and the liquor becomes pelucid. 2nd. A Solution of blue

vitriol mixt with spirit of sal-ammoniac, produces a blue-coloured alkaline liquor. The nitrous acid, added, seizes the sal-ammoniac as an alkali, discharges the colour, and the liquor becomes acid; if then an alkali be made predominant (as oil of tartar) the fine blue is again restored.

3d. Acid solutions are detected by syrup of violets, which turns them red: but the same syrup turns an alkaline solution green. Hence red or blue flowers steeped in acid water, impart their colouring particles to the water, which becomes red: oil of tartar added, turns it green.

4th. Salts instantaneously chrystalize when spirit of wine is added to their solution in water,—because spirit and water have a greater affinity to one another than salt and water.

5th. Inflammable air is not inflammable of itself, any more than fixt air is effervescent; but it is a constituent part of a compound, which being let loose, causes by its mixture with the empyreal part of the atmosphere the phænomenon of inflammation. Hence phosphorus (as a mine of phlogiston) when rubbed between the folds of brown paper to increase its surface and give it a little warmth, takes fire so soon as it becomes opened out to the air.

6th. Two thirds of nitrous acid and one third vitriolic acid mixed, and then poured on oil of turpentine, produces instant and tremendous inflammation!

7th. Ether dropt on water produces ice.

8th. Calcs's are revived, if while they are in fusion, inflammable air be blown upon them.

9th. Equal quantities of regulus of cobalt dissolved in diluted nitrous acid, and sea salt dissolved in water, make an ink that comes and goes with heat and moisture.

10th. Invisible writing, with a solution of sugar of lead, is rendered black by a solution of liver of sulphur, both in water. This phlogistic effect will take place through a thick book, or even a stone wall.

11th. Hembergs's pyrophorus requires one part sugar and three parts alum, to be melted, stirred, and dried on an iron shovel till it becomes a blackish coal; then bruise it into powder, and put it into a long-necked bottle, and the bottle into a crucible filled with dry sand; then place the crucible in a gradual fire, till the whole becomes red hot, and keep it so an hour, or till a weak sulphurous flame

has issued out of the bottle's neck a quarter of an hour; remove it by degrees, and cork up the bottle as soon as it will not burn it, or decant the pyrophorus into a dry bottle, well stopped from air. A little of this powder exposed to moist air on brown paper, instantly takes fire. 12th. Vitriolic acid contains more latent fire than water by one-third—therefore, when mixt, an equilibrium takes place, and the three parts are let loose in sensible heat. Hence iron pyrites lying in water produces heat, and becomes ink with an infusion of galls; rain water running over quarries of such pyrites above Bath, acquire the heat for which those waters are celebrated. 13th. Vegetables contain much nitre; the water therefore in which potatoes, spinage, &c. are boiled dissolves the nitre, and hence brown paper soaked in such water, becomes excellent *match* when cut in slips and dried. 14th. Silver dissolved in diluted nitrous acid, (or luna cornea) is precipitated by copper; for the acid has a greater affinity to copper than silver, therefore the silver precipitates, and form those beautiful ramifications called the arbor Diana.

ACIDS are both in a liquid and concrete form, have a sour taste, and they effervesce with alkalies. *Vitriolic acid* is fluid, transparent, colourless, and without smell; like water, but much heavier. It is got generally from sulphur, by distillation with water, to which it has great affinity.—*Nitrous acid* is of a brown colour, emits brown vapours, has a pungent smell, readily dissolves most metals, and is extracted by distillation from nitre or salt-petre, moistened with vitriolic acid: It attacks the phlogiston of metals, and has the greatest affinity to it. *Marine acid* is extracted from common salt, it is of a yellow colour, and smells like saffron.

ALKALIES, are saline bodies that combine readily with acids; in a concrete form they attract moisture from the air, and become fluid; they have an acrid burning taste; fuse with a moderate heat; dissolving earths with a strong heat; become glasses, &c. *Fixt mineral alkali* is obtained from sea salt; *fixt vegetable alkali* from

vegetables, both standing a great heat without dissipation. *Volatile alkali* is obtained from animal substances, by decomposition and putrefaction, and flies off with a *small* degree of heat; hartshorn drops are of this kind. Alkaline salts combined with oils form soap, &c.

SALTS are every thing with a sharp taste, and soluble in water. *Sea salt*, or *kitchen salt*, is a combination of marine acid and mineral alkali. *Luna cornea* is a salt formed by the union of silver and acid. *Verdigrise*, salts formed by the solution of copper in vinegar. *Ammoniacal salts*, are an acid saturated with volatile alkali. *Sugar*, an essential salt, containing vegetable acid combined with earth and oil. *Potash*, a fixt vegetable alkali extracted from the ashes of vegetables. *Nitrous salts* are found in old walls, or places impregnated with animal and vegetable juices—they are neutral, and produce nitrous acid and fixt vegetable alkali.

METALS. *Perfect metals*, or those that cannot be decomposed, are, gold, platina, and silver. *Imperfect metals*, are, copper, iron, tin, and lead, which in fire or strong menstruums lose their metalline properties become an earth, or calcs; but are revivable back to their original metals by phlogiston; hence imperfect metals are wholly composed of earthy matters and phlogiston. Pure metals are always found in their metallic form; but the imperfect metals in the form of calcs's or ores; these placed in a strong fire acquire from the combustibles phlogiston enough to become metals, and are then combustible themselves in a strong fire: Sparks produced by the stroke of flint and steel, are but particles of steel set on fire by the violence of the stroke. *Gold* is unalterable by art, is the heaviest of all known bodies, expands so, that a grain may be beat into a leaf of fifty square inches, and a gold wire one tenth of an inch in diameter, will suspend or support 500lb. weight without breaking. Reduced into fine powder, it is easily attacked by acids, but its metallic nature is in no respect altered. Gold dissolved by aqua regia, and then precipitated by volatile

alkali, and then washed and suffered to dry, explodes by a small degree of heat, with a quickness and violence far exceeding gunpowder. Ether poured on a solution of gold in aqua regia, and the mixture shook—the gold will leave the aqua regia and pass into the ether. Gold will continue months in a hot fire without losing any weight. *Platina*. This metal is found in small, angular, shining grains in the gold mines of South America; it is near as heavy as gold naturally, but deprived of the iron with which it is generally united it is heavier. It dissolves in aqua regia, but bids defiance to simple acids, or any fire, except that of a large burning glass. *Silver* is the third unalterable metal—it fuses in a small heat; is nearly as ductile as gold; a wire of it one tenth of an inch diameter will sustain 270lb. It assumes a black appearance when exposed to phlogistic vapours, for it is capable of over saturating itself with the inflammable principle. Nitrous acid dissolves silver more completely than any other acid. *Copper*, though an imperfect metal, comes near to silver in point of ductility. A wire, as above, supports 299lb. Moist air tarnishes, and even calcines it; this rust, or calx, is verdigrise. Acids, alkalies, saline matters, and oils, more or less dissolve copper, and the solution is of a green colour, and poisonous; hence culinary vessels of copper should be kept well tinned. A solution of copper in volatile alkali is blue when exposed to the air, but loses the colour when corked up; opened, it again becomes blue, &c.—So water impregnated with too little copper to be discovered, turns blue with a few drops of volatile alkali. Copper is mostly found combined with sulphur in mines; and is easily separated from other metals by sulphur. It requires a strong heat to melt it, emits pernicious fumes, and burns with a green or blue flame. It easily combines with other metallic substances—with zink it becomes *brass*—with tin, *bronze*, or *bell-metal*, &c. *Iron* is the most useful, the hardest, most elastic, and, except tin, the lightest of all metals. Such a wire as above, supports 450lb. As an ore, or a calx, it is not attracted by the magnet—but when phlogisticated by roasting in the fire, it is attracted. It is easily

deprived of phlogiston, by the calcs of other metals, water, moist air, acids, fire, &c. and becomes rust, or *crocus martis*. Iron, joined by substances that abound with phlogiston, in a strong fire, without the free access of air, becomes *steel*; and steel made red hot, and suddenly cooled in water or oil, becomes so hard tempered, and brittle that edge-tools, files, &c. are made of it. In the act of heating it changes colour, and hence many steel ornaments are made blue. Iron has great affinity with sulphur, and its fusion is so much facilitated by it that if iron in white heat, be rubbed with sulphur, it falls in liquid drops united with the sulphur; and if 60lb. of iron filings and sulphur, made into a paste with water, be buried a few inches under ground, it will swell, grow hot, emit vapours and flame, and shake the ground about it like an earth-quake. Iron may be alloyed with any metal except quicksilver and lead. *Tin* is the lightest, least elastic, or sonorous of any metal. A wire as above, supports 50lb. All acids dissolve and deprive it of its phlogiston. It melts with less heat than will make it red hot, and calcines into a grey powder called putty, (used in polishing metals, glass, &c.) It alloys with all metals, gives them brittleness; and its vapours impair the ductility of all metals. It amalgamates with quicksilver, and is then used to cover looking-glasses; compounded with lead it forms the solder of the plumbers.—*Lead* is still softer than tin; a wire as above only sustains 29lb. Acids of all sorts dissolve it—fumes of vinegar rusts it into *white-lead*. Calcs of lead is made into wafers; boiled in linseed oil, it becomes the *drying-oil* of the painters. Lead kept in a state of fusion, with a current of air passing over it, soon loses its phlogiston, and becomes calcined, and is then called *red-lead*: a stronger heat vitrifies this calx into *litharge*: and a still stronger heat, reduces it into *glass of lead*, which will run through the crucible like water through a sieve. This glass facilitates the calcination of imperfect metals, and is therefore used to purify the *perfect* metals. *Mercury*, or *quicksilver*, is like fluid silver opa-

que and very heavy. By great cold it can be made solid, and malleable as lead. It rises in vapours by a small degree of heat, and when these vapours are collected, they are found the very same quicksilver. Hence it is easily distilled, and by that means easily separated from lead, tin, &c. Acids and alkalies combine with mercury. Vapours of mercury and marine acid meeting, form chrystals like flattened needles, called *corrosive sublimate*. Mercury shook in vinegar, exhibits a curious phænomenon; and it is luminous when shook in vacuo. Quicksilver triturated with sulphur, forms *Ethiops mineral*; and this frequently sublimed, becomes cinnabar—or the vermilion of the painters. Cinnabar is also found a native in the mines, and may be considered as the ore of quicksilver.

E A R T H S.

Earths make up the solid part of our globe; they are so intermixed, that it is difficult to come at their components, which are, 1st. *Calcareous earths*, i. e. lime-stone, chalk, stalactites, or stone icicles, marbles, or any earths that effervesce with acids; that fall in white powder when burnt; that will not melt into glass by heat; but will melt when mixed with borax, or calcs's, and assist the fusion of lead, copper, and iron. *Siliceous earths*, or precious stones, as the diamond, ruby, topaz, opal, agate, cornelian, flint, jasper. Many of these strike fire with, and even scratch steel;—do not melt with the strongest fire; and do not effervesce with acids. *Argillaceous earths*, or clays that harden in the fire, and used to make porcelain; and clay marles, that moulder in water, and effervesce with acids, used as manure. *Micaceous earths* are composed of thin leaves, or lamina, with shining sur-

faces, and which divide into thinner leaves in the fire, and become brittle. *Asbestos earths*. These do not alter in the fire; are flexible and stringy, capable of being spun into threads, or wove into cloth. *Zeolites* are harder than calcareous stones; melt easily in the fire with swelling and ebullition; and dissolve with acids without effervescence,

LECTURE IV.

P N E U M A T I C S.

THE air is a thin fluid, which encompasses the globe of the earth on all sides, revolves along with it round its axis, and attends it on its annual journey round the sun. If a peach be supposed to represent the earth, the air will be aptly signified by the down growing on its surface.

This body of air, (together with the clouds and vapours that float in it) is called the atmosphere; and it reaches about forty-five miles above the ground before it degenerates into too thin an æther to refract the rays of light, or for any creature to breathe; this is known by measuring with a barometer the weight of the atmosphere in a low valley, and on a mountain, and may be familiarized by supposing a thousand fleeces of wool one piled above another, where the lowest will be greatly compressed or squeezed together, the next not so much, the next not so much as that, &c. till we come to the uppermost, which will lie in its natural loose state. The air, by being elastic, and partaking of the earth's attraction, is necessarily drawn into progressive state like this.

The air is so subtil that it pervades the pores of all bodies, and enters into the composition of most animal and vegetable substances; yet it is a body, because it excludes all other bodies from the place it possesses, if so confined that it cannot escape; hence the origin of the diver's bell, for if we sink a bell in water with the mouth open downwards, little water will make its way into it, and a person may descend and live at a considerable depth, if a vessel of the same kind be kept constantly

supplying him with fresh air, and that made noxious by his breathing be let out by a pipe reaching from the upper part of the bell above the surface of the water. For air taken into the lungs, returns phlogificated, having brought off the superabundant phlogiston of the blood, which makes a digression from the heart to receive purification from the air; and hence the blood returns thin, florid, and fit for circulation, while the expired air is ejected into the general mass phlogificated and unwholesome.

The air has all the properties by which a fluid is distinguished, it yields to the slightest impresson, its parts move easily among one another, and animals breathe and move through it without any difficulty. Yet it has three singularities which distinguish it from most fluids. 1. It can be compressed into a less space than it naturally possesses. 2. It can occupy a greater space than it naturally possesses. 3. It is of different density in every part upward.

As the air is a body, it must needs have *weight*; this is proved, 1. By its pressing the hand that covers the top of an exhausted receiver. 2. By immersing the stem of a bolt-head into a vessel of water, and covering both with a receiver, then exhausting the air out of both; on letting in the air on the surface of the water it forces it into the exhausted bolt-head. 3. A bottle that holds a wine quart being emptied of air, and weighed, is found to be about 17 grains lighter than when it is full of air; so that a quart of air on the earth's surface is 17 grains. 4. If a wet bladder be tied over the top of an open receiver, then set to dry, and after this the air exhausted from under it, the air's weight will then burst the bladder with a surprizing report. 5. On a moveable plate place a tall receiver, open its cock, and exhaust the air out of it, then shut the cock, and immerse the stem in which it is fixed into a vessel full of water; on opening the cock the air's pressure on the water will force it into the receiver in a beau-

tiful fountain. 6. If a hole be made in the bottom of a cup, and have a bit of dry hazel or willow branch fixed into it, and this be put into a hole on the top of a receiver; when quicksilver is poured into it, and the air exhausted, the quicksilver will be forced thro' the pores of the branch by the weight of the incumbent air, and will fall in a curious shower into the receiver. 7. If a tube of 32 inches long, and open only at one end, be filled with quicksilver, and then the open end immersed in a jar of quicksilver, *that* in the tube will sink to the height the quicksilver stands in the barometer; if this jar and tube be put under a tall receiver, and the air exhausted, the quicksilver will descend out of the tube into the jar; but upon admitting the air again into the receiver, its pressure will drive up the quicksilver into the tube, and support it therein as it stands in the barometer, which proves that the quicksilver in the barometer is kept up solely by the weight of the air. 8. If the air be exhausted out of two brass hemispheres of about 12 inches area, it will require a force equal to 180 pounds to separate them.

To prove that these effects are not produced by *suction*, and that there is *no such principle in nature*, 1. Place a small receiver at some distance from the hole in the pump-plate, and cover it with a large one *over* the hole; on exhausting the air the small one will remain loose, while the large one is made fast to the plate; but on letting in the air the big receiver will be released, and the small one pressed down. 2. If a pump be placed in water under a receiver, and the air exhausted, no water can be made to rise in the pump. 3. If two moveable plates be fixed upon a pump-plate, with communications between them that can be stopped by cocks, if the air is exhausted out of a receiver placed on one of them, and then a receiver placed on the other, and the communication opened, half the air in the last will by its spring make its way into the first receiver, and both shall be fixed on the plates.

Breathing is in some measure performed by the power of the intercostal muscles acting upon the ribs; they are disposed in form of a semicircular arch, and articulated with the vertebræ of the back behind, and connected with the sternum before, which are the two center on which they move: The diaphragma is a partition drawn across the body, dividing the thorax or chest from the abdomen or belly; it is a muscle, and by its disposition and structure capable of expansion, whereby it becomes concave downward, and of contraction, whereby it becomes flat; and by this motion alternately rarefying and condensing the air in the crevices of the thorax, and thereby destroying its equilibrium; to restore this the air will press into the lungs, and when the diaphragma contracts, will be forced out again; hence the action of breathing, as is represented by the lungs-bladder, whose inside has a communication with the external air, though it is inclosed in a thorax of glass with its bottom closed by a bladder, tied flaccid, representing the diaphragma.

The *elastic quality*, or *spring*, of the air is thus proved,

1. If an almost empty bladder be put under a receiver, and the air exhausted, the spring of the air in the bladder will then shew itself by swelling up the bladder, as if it was blown.
2. If a little of the shell be cut off from the small end of an egg, and the egg put under a receiver, on exhausting, the bubble of air in the big end of the egg will expand itself, and drive out the contents of the egg.
3. If a fish in water be put under a receiver, and the air exhausted, its air-bladder will swell the fish so as to make it specifically lighter than water, and of course the fish will be buoyed up to the surface.
4. If a cubic inch of dry wood in warm water be put under the receiver, and the air exhausted, large and innumerable bubbles of air will come out of the wood and make the water seem to boil; and in this manner may air be drawn visibly out of the hardest bodies.
5. A withered apple in an exhausted receiver will be plumped

up, and look quite fresh, by the spring of the air in the inside of it; and if a fresh one be pricked all over with a bodkin, and put in water under a receiver, on exhausting, it will appear as if it was roasting by a fire. 6. If a tall receiver be exhausted, and the neck of the vessel joined to its bottom be half full of water, the spring of the air on the surface of that water will force it out into the receiver in a beautiful fountain. 7. If a little air be tied up in a bladder, and put in a convenient vessel with great weights upon it, on exhausting the air, the spring of the air in the bladder will lift the weights, and shew that its spring is equally forcible with its pressure; therefore, though a middle-sized man sustains above 30,000lb. weight on his person, yet the equal spring of air within him makes him insensible of it.

Heat and cold, or, if you will, the presence or the absence of fire, are the usual causes of the air's rarefaction and condensation: If *air* be heated, it swells, so that the space it possessed before it was heated will contain fewer particles than it did in its cold state. *Wind* must be the necessary consequence of this; for by what means soever the equilibrium of the air is destroyed, its neighbouring parts will never be at rest till the balance is restored: Hence the reason why air rushes so violently into a glass-house; into a close room with a great fire in it; into warm towns, &c. When the sun's heat is increased by the reflection of sands, or the sides of rocky mountains, &c. the air will be rarefied, and by the rushing in of the colder neighbouring air will be forced up into the higher part of the atmosphere, as light smoke is up a chimney by the heavier air. If a large cloud keeps the sun's rays from the *air* under it, but rarefies *that* all round it, a wind will rush from beneath the cloud in all directions. Upon this principle also we account for the *trade winds* which constantly blow from the east towards the west about the equator; for as the sun passes over the earth in that direction, and rarefies the air as he goes, by heating the earth, and bottom of the sea (for transparent bodies receive no heat from solar rays) the colder

air will rush after him. This effect is also increased by the greater centrifugal motion, which the equatorial parts of the globe have more than those parts nearer the poles ; by which the globe slides as it were from under the air, causing an apparent motion in it the contrary way to that on which the earth turns on its axis—Hence also the *monsoons* ; the *day* and *night* breeze, on the islands in the West-Indies ; the wind from west to east on the coast of Guinea ; and the currents of Florida, Gibraltar, &c.

'Tis unnecessary to point out here how admirably these properties coincide with the general scheme of the creation.

LECTURE V.

P N E U M A T I C S.

THAT the air may be condensed or squeezed into less room than it naturally possesses is proved, 1. By putting a blown bladder in a receiver; if a forcing syringe be then applied to the receiver, and a quantity of air forced into it, the bladder will be shrivel'd up by the superior pressure of the condensed air. 2. If a copper ball be half filled with water, and a quantity of air forced into it as above, through a spouting pipe that reaches nearly to the bottom of the water, the spring of the condensed air on the surface of the water will exhibit an amazing fountain. 3. The most formidable instance of condensation is in the magazine, and walking-cane wind-guns; where the condensed air has a spring capable of discharging 20 or 30 balls with one charge, one after another, with the same force as if charged with gunpowder. Air so squeezed has a portion of its latent heat forced out, and the containing vessel becomes hot, like hammered iron.

By compounding charcoal and nitre, the principles of inflammation are united; charcoal affording phlogiston, nitre empyreal air, and sulphur sudden heat, by ignition. Hence flame displacing the air around it, causeth an explosion, which does not take place in vacuo.

Sound is caused by any thing that gives a smart stroke or a tremulous motion to the air; these waves striking upon the outward shell of the ear, are from thence conveyed up the auditory tube, and striking against the tympanum, or drum, are so increased, that in making their way up the labyrinth, it gives a shock to the auditory nerves, and, by their means, is conveyed to the soul the

idea of hearing, or sound. The artificial ear makes this very evident. And the clock striking in vacuo without being heard, is a proof of air being a conductor of sound. Musical strings, in tension, struck by a bow, a finger, the wind, &c. will divide themselves into imaginary frets, or bridges, viz. into halves, thirds, fourths, &c. a bridge, either real or imaginary, dividing a string into *two* equal lengths, each (*vibrating according to their weight*) will be an *octave* to the whole string, as half will vibrate twice as fast as the whole; and hence every second wave unites with the first of the whole string, and gives a pleasing sensation to the ear.—A string divided into *three equal parts*, each will vibrate three times while the whole string vibrates once; hence every third wave coming in contact produces a pleasing sensation, and the chord is called a *Twelfth*. Two-thirds of this string vibrates *three times* while the whole string vibrates *twice*, and gives that sweet chord called a *Fifth*. *Seven-ninths* of a string produce the major *Third*: and *three-fourths* the *Fourth*. Hence waves clashing against one another without contact, produce *dischords* in music, and serve as foils or reliefs to the counterpoint of according waves. Hence also the mechanical sympathy of musical instruments tuned in unison; one of which will sound when the other does, by the waves it produces. An harpsichord replies to every word spoken in the room where it stands, when its strings have no dampers upon them. Particular notes in an organ will shake the wainscot, set dogs a howling. Hence also the various sounds produced by the Eolian harp, when tuned unison, and exposed to a current of wind—the strings divide themselves into imaginary bridges, and produce *octaves, fifths, thirds, twelfths, fifteenths*, &c. The masterly performer on the violin assists this propensity, by touching lightly those aliquot parts of a string where nature would make this imaginary bridge, and hence are produced those notes called *harmonics*.

When the atmosphere is light, the noxious air pent up in the cavities of mines (communicating with the out-

ward air) will, by its effort to restore an equilibrium, swell into the mine, and hence the suffocating damp which is met with in mines when the barometer is low. This damp is made on the air pump by letting air into an exhausted receiver, through the flame of charcoal, sulphur, flame of a candle, &c. into which if an animal be put it suffers instant death. The fire-damp proceeds from the same cause, only that its particles are of the phlogistic or inflammable nature, as rising from the sulphurous, nitrous, or oleaginous strata in the mine: This, taking fire by the lights used by the workmen, will run like a train of gunpowder through the works; and as it is confined, the elasticity occasioned by the heat will cause such explosions as frequently blow up the mine. This damp is made on the pump, by letting the air into an exhausted receiver through the flame of the oil of turpentine or other inflammable matters; after which, if a lighted candle be put in the vapour it will take fire.

As the pores and cavities of all bodies are filled with air, an animal put under a receiver, and the air exhausted, will soon die; because as the air is drawn out of the lungs, *that* in the thorax will expand and swell the animal, shrivel up its lungs, and thereby stop the circulation of the blood.

Fixed air (*that wond'rous antiseptic*) arises from the effervescence of any acid and alkaline mixture, and easiest from chalk and diluted oil of vitriol.—Liquors fermenting discharge plenty of it, and it is found also in the common atmosphere. It is a constituent part of chalk, marble, limestone, and all calcareous earth. Water imbibes it, and thence acquires the sparkling appearance, acidulous taste, and medical qualities of *Pymont water*. Though noxious when breathed, it cures the sea scurvy, putrid intestines, inflamed, or putrid sores, &c. It is also said to be a compound of phlogiston, and dephlogisticated air.

Nitrous air is produced from the effervescence of copper filings and the nitrous acid.—It diminishes common air,

in proportion to its purity: and their mixture produces a brown effervescence.

Inflammable air, the pure and elementary phlogiston, is easiest procured from iron filings and diluted vitriolic acid; the acid seizes the earth of iron, and lets loose the fixt phlogiston, exhibiting it as elastic air. This gas is imbibed by any metallic calx, in a strong heat, and the calx becomes revived into its original metal. Lead in calcining loses its phlogiston—and becomes a calx called minium or red lead:—This phlogiston preserved, if the calx be placed in it, and the focus of a burning lens heat the calx, it instantly begins to imbibe the inflammable air, swallows it up, and soon becomes the individual lead it was before the process. This is taking a metal in pieces, and putting it together again; and intimates the inflammable principle to be the same in all bodies, viz. that inflammation in coals, candles, wood, &c. arises from letting loose concremented phlogiston from these substances into the air.—Inflammable air being eight or ten times lighter than common air, rises from bogs, and putrifying substances into the higher regions of the atmosphere, and lodging there, frequently receives inflammation from lightning or electricity, giving thunder its long progressive sound—Lightning the property of spreading over the whole hemisphere—and when by winds it is drawn into long streaks across the hemisphere, and receives from electricity inflammation at one end, the inflammation runs across the hemisphere, and we call the phenomenon falling stars, fiery dragons, meteors, Will-o'-th'-wisps, &c.—A soap bubble, filled with inflammable air, rises in the atmosphere like a cork in water, and is an air-balloon in miniature, rising from its specific levity, and was made by the Author twelve years before any balloon appeared in France. Inflammable air, when mixt with an equal quantity of common air, or a third of dephlogisticated air, explodes when confined in a gun, and inflamed by electricity, so as to discharge a ball with a force nearly equal to gunpowder.

Copper and spirit of salt produce an air (thro' quicksilver) that is very noxious,—quickly absorbed by water,—and a candle burns green in it. Water saturated with it is a strong spirit of salt, and dissolves iron with great rapidity.

Alkaline air is expelled by a candle from a gun-barrel filled with one-fourth pounded sal-ammoniac, and three-fourths quick lime mixed.

Common air imbibes *phlogiston*, which diminishes *that* air by precipitating the fixed air it naturally contains; and it becomes noxious in proportion to the diminution it is capable of suffering.—Hence phlogiston is the best test of air—unwholesome as it is more in it, and incapable of diminution; and wholesome as it has less phlogiston in it. For air imbibing this inflammable matter from the blood in its passage through the lungs, performs the office best when it has the least phlogiston in it. Hence candles go out in close rooms, and animals die in them; because air already saturated with phlogiston can contain no more.

Vitriolic acid air is produced by oil of vitriol just covered with olive oil in a vial, and discharged by a candle through quicksilver. Ice instantly melts in this air; and alkaline air put to it produces a white flaky precipitation.

Fluor acid air is forced by a candle from a vial containing pounded spar and oil of vitriol, through quicksilver into water. The phlogiston in the spar gives volatility to the vitriolic acid, so that, coming into contact with the water, they unite, and the stony matter of the spar precipitates in flakes, crusts, &c. a true silicious earth.

Dephlogisticated air, (called also *Vital air*; *Empyreal air*; and the *Oxygenous principle*) seems to be derived from earth and the nitrous acid, and bids fair to rob us of a received element. It is expelled from nitre

in a glass retort by a smart fire; also from red lead and spirit of nitre, out of a gun-barrel or a thin vial—or any earthy matter void of phlogiston, as pipe-clay, &c. In a given quantity of this remarkable air an animal will live near six times as long as in the same quantity of common air! A candle burns with an astonishing brightness in it, — a firebrand crackles in it — red hot iron melts in it— and inflammable air explodes prodigiously loud in it, &c. for dephlogisticated air is one of the ingredients of inflammability.

All substances, vegetable, animal, or mineral, mixt with nitrous acid, and exposed to a proper heat, give dephlogisticated air—if the substances be first deprived of phlogiston. But if the substances contain much phlogiston, (in those circumstances) they give *nitrous air*. If but a small quantity of phlogiston, *fixt air*; but if no phlogiston, the produce is *dephlogisticated air*.—So when a small quantity of phlogiston exists in the substance used, the *fixt* and *dephlogisticated airs* generally come over together.

From the smoke—putrid effluvia—calcination of metals—and breathing of animals, the air must be continually contaminated, and made unfit for human respiration. Providence has wisely made the vegetable kingdom the cure for this evil, for plants imbibe nourishment from putrid and phlogistic air at their leaves as may be seen by the superior vigour in plants growing near great cities — by their growing on walls without earth—and by a green plant put in noxious air, which imbibes nourishment, and cures the air at the same time. The air so purified in leaves and plants, leaves them, and becomes dephlogisticated, if the leaves and plants be exposed in water in a tall inverted glass, and exposed to the light.

Respiration is also a phlogistic process, affecting air in the very same manner as putrefaction, effervescence of iron filings and sulphur—calcination of metals, &c.

—diminishing its quantity and specific gravity, and rendering it unfit for respiration and inflammation—yet still capable of being restored by agitation in water, or a contact with vegetables. Air comes nearly in contact with the blood in its passage through the lungs, giving phlogiston to it when it wants, and taking phlogiston from it when it has too much. Too much phlogiston renders the blood black and thick—but the air having access to it, even thro' the vesicles of the lungs, renders it red again—and *dephlogisticated air still more perfectly* so, both in and out of the body—congealed as well as fluid, &c.

That *water* is present in *air*, is evident from seeing it precipitate in a cloud as a receiver is exhausting on the air-pump; from the *dew* on windows, or other cold bodies when water stands for some time in a hot room; from the wet hair of those who ascend the sides of mountains; and from its entering sponges and hygrometrical instruments when hung in air; from many more proofs 'tis evident that *air is a menstruum for water*. *Air*, lying on *water*, and rubbing perpetually against it, from this contact, and their natural attraction, the two fluids, mutually imbibe one another; (for air may be seen in water placed in an exhausted receiver.) That an *heavy* body can rise in a lighter one when its particles are separated, and its surface by that means encreased, is certain from *gold* being dissolved, and of course hanging in *aqua regia*,—*copper* in *aqua fortis*, &c. *Water* rises in *air* by the same law; and the ferment occasioned by all solutions may be seen in the air along the surface of wet ground, on a warm day, in that *quivering* which the rays of the sun suffer in passing through air and water not yet *intimately mixed*. *Heat assists all solutions*,—hence the quantity of clouds and rain where the sun is vertical:—The drying quality of the air in spring, and the rains and fogs in winter; for summer's warmth assists in filling the air with water, and the winter's cold condenses and brings it down in high latitudes; and as the higher regions of the air are cold, and thin, little assemblages of particles are dis-

erfed through the air and form *clouds*, about the height of the mountains:—The winds, and their own attraction, affift this junction—till they become big enough to precipitate in a *drop of rain*: If the drop is frozen in its defcent, it falls on the ground an *hail-stone*: If the *cloud* be frozen, then broken fragments of it defcend in *flakes of fnow*. *Fogs in an evening* are occafioned by the cold condensing the vapours new raifed from the ground before they are thus chemically united with the air.

LECTURE VI.

HYDROSTATICS.

THIS branch of philosophy treats of the *nature, gravity, pressure, and motion of fluids* in general, and of weighing solids in them. *Water*, like *air*, consists of *round and hard* particles, as is proved by putting salt in water without increasing its *bulk*, by the *round* pores of aquatic plants and the *Florentine experiment*, which forces water thro' the pores of a copper ball: Hence 'tis evident *there are vacuities in fluids*, and that no fluid can be pressed into a *less space* than it naturally possesses, except *air* and *steam*.

Fluids are said to be *perfect* or *imperfect*, as their parts slide with more or less ease over one another, therefore quicksilver is the most perfect of all fluids. Water being of the *imperfect* kind is seldom *pure*: It adheres to any substance it meets with, mixes with its particles, and thence becomes impregnated with whatever *strata* it runs over: If water has any thing alkaline in it, the *syrup of violets* turns it *green*; if any thing acid, the *syrup* turns it *red*; if it has run over *iron stone*, or *iron ore*, a solution of *galls* turns it *black*, and if allum, *oil of tartar* turns it *thick*, &c.—Hence water impregnated with lime-stone, and oufing slow amongst mosses, leaves, &c.—as the water evaporates, the stoney matter adheres to these substances, and assuming their shapes, gives that variety of whimsical petrefactions we meet with in Derbyshire,—the dropping well at Knaresborough, &c.

Water being *incompressible* will not be more *dense* at the *bottom* than the *top* of the sea; but will have the wonderful property of pressing, *upwards* and *sideways*, as forcibly as *downwards*, in proportion to its *perpendicular height*, with-

out any regard to its *quantity*; for as each particle is quite free to move towards that part on which the pressure is *least*; and hence no particle or quantity of a fluid can be at rest till it is *every way equally pressed*. A fluid may therefore be conceived as made up of *perpendicular columns of particles*, and as divided into *imaginary surfaces* each an inch or more from one another, the lowest pressed with the weight of *all* the rest, &c. hence the pipe fixed under the *most* surfaces will discharge the *most* water, &c.

To prove that fluids press in all manner of directions alike, take four *glass tubes*, open at both ends, but bent into all kinds of angles; if these be put in water nearly to their tops, the water will rise in them to its own level. Or take a vessel full of water, with a hole at the *bottom of its side*, of the same size as one in its *bottom*, and the two holes will be found to discharge the same quantity of the fluid in the same time.

That fluids press in proportion to their depth, without any regard to their quantity, is evident, 1. From a *bladder* tied flaccid over one end of an open *cylinder of glass*; if water be poured into it, the bladder will bulge *downwards*; but then if it be immersed in a vessel of water till the surface of the water within the cylinder be *even* with that in the vessel, the bladder will then be *flattish* as if it were not pressed at all, for indeed it is then pressed equally. If the cylinder be plunged *deeper*, the bladder will be pressed *upwards*, shewing that bodies swim merely by the force of the pillars of water under them endeavouring to rise to their level. 2. *Lead* is about $11\frac{1}{3}$ times heavier than its bulk of water; if therefore a piece be held tight to the mouth of a cylinder, (open at both ends) by a string within the cylinder, and let down into water above 11 times its thickness, the string may be let go, and the upward pressure of the water will hold the lead to the cylinder; but if the cylinder and the lead be raised till the lead is not $11\frac{1}{3}$ times its thickness below the surface of the water, it will then fall of and sink. 3. If a cube of 34 inches, open at one end, and filled with quick-

silver, have its open end immersed in a basin of quicksilver, hung so by strings that it may be *let down* into a deep vessel of water, according to the depth the vessel is *sunk*, the mercury will *rise a fourteenth part* in the tube, and demonstrate that quicksilver is fourteen times heavier than water.

4. If lead with a *flat upper side* be laid on the bottom of a vessel, and a piece of *flat wood* be held on while the vessel is filling with water; if no water can get in between the lead and the wood to form an *upward pressure*, the wood will be held on the lead by its own weight and that of the water above it.

5. If an *empty bottle*, just made so heavy as to sink in water, be corked, and suspended at one end of a balance, and, with its cork pulled out, be immersed in water and filled, it will require as *much weight* in the opposite scale to pull it up, as will weigh all the water in it, which shews that fluids weigh just as much in their *own element* as out of it.

6. If a small tube 30 inches long, open at both ends, and to one end (bent to a right angle) it has a *large bladder* tied; if then the bladder be put in a box, and a board be laid on it with 25 or 30lb. weight upon it, and water be poured into the tube, the bladder will raise the weights, though the bore of the tube should be so small as not to hold an ounce of water.

7. *The pressure of a fluid upon the bottoms of all vessels whatever, is proportional to their bases and perpendicular height, without any regard to the quantities they contain;* for if on a loose piston suspended on a balance, a column of water of a foot be weighed, it will be found to weigh as much as a column of water of the same height, though contained in a flanging vessel that holds ten times as much.

8. If a *small tube* be joined to a *very large one*, and the whole be bent in the bottom so as the two parts may be either *parallel*, or make *any angle*, water may be poured into *either tube*, and it will just rise as high in the *other*, even tho' one should contain ten thousand times as much as the other does: This also shews that fluids press in proportion to their perpendicular heights, without any regard to their quantities; that water in pipes will ascend to the *level of the spring* from whence it came; and that *jets or fountains*

would rise the *same height*, if not obstructed by *angular turnings*, and the *resistance of the air* into which they play.

Smoke does not rise into air because of its *positive levity*, but because it is *lighter* than the air where it is produced; hence if the small neck of a bolthead, full of water, be immersed in a glass of wine, the *lighter wine* will ascend up into the bolthead, and the *heavier water* descend into the glass. For the same reason, a body specifically (or bulk for bulk) *heavier* than water will sink in it; a body of the *same weight* will lie indifferently any where in it; and one specifically *lighter* will of course swim in it.

Smoke is forced up a chimney by the air in the room, pressing to the rarefied air *in* the chimney;—hence, the patent stoves, contracting the fire-place, obliges the air to rush *in* with great violence, and thereby it overcomes more effectually any wind that forces the smoke *down* the chimney.—Kitchen, or other open chimnies, are very liable to smoke with winds coming *over*, or blowing *against* a taller house, church, tree, &c.—because the smoke rising very slow and languidly by its specific lightness in the open air, or wide chimnies, is easily puffed down by the wind, if a ventilator or a feathered covering do not prevent it.

If a stick be counterpoised on a scale-beam by water, and after that immersed in a vessel full of water, it will cause so much of the water to flow over the brim as will be supplied by *that* in the opposite scale: Hence it is evident a *ship* displaces just so much water in the sea as is equal to its own weight and cargo: And hence also the *strength of wood* may be judged of; for if a piece of oak of a foot long be immersed in a narrow vessel of water, it will be found to sink about eight-tenths of its length: Beech about seven-tenths; Mahogany seven-tenths, &c.

A solid body, heavier than its bulk in water, will lose just so much of its weight when suspended in it, as its bulk of water weighs: But the weight lost by the solid is commu-

divided to the fluid. Hence if the weight of a body in air be divided by what it loses in a fluid, the quotient will shew how much heavier it is than its bulk of that fluid, or its *specific gravity*. By this trial, *pure gold* is found to be 19,637 times as heavy as its bulk of water: *Guinea gold* 17,793 times as heavy: *Quicksilver* 14 times: *Lead* 11,325 times: *Standard silver* 10,535: *Copper* 9: *Plate brass* 8: *Steel* 7,85: *Iron* 7,645: and *block-tin* 7,32. A cubic inch of brass loses $233\frac{1}{3}$ grains of its aerial weight in water: In proof spirits it loses 235 grains; therefore a cubic inch of water weighs $233\frac{1}{3}$; and a cubic inch proof spirits 235 grains: And the specific gravities of *pure spirits*, *proof spirits*, and *water* are as 840,923 and 1000. From hence may be conceived the great use of the hydrostatic balance.

A pipe fixed *four times* as deep below the surface of a fluid as another of the same diameter, will discharge *twice* as much in the same time; if *nine times* as deep, it will discharge *three times* as much, &c. agreeable to the square root of the depth: And the *velocity* with which a fluid spouts at any depth below the surface, is equal to that which a body let fall *that height* would acquire. Pipes also discharge a fluid (when placed at equal depths below the surface) agreeable to the squares of their diameters, *i. e.* a pipe *twice* the diameter of another will discharge *four times* as much of the fluid, in the same time; *thrice* the diameter, *nine times* as much; four times the diameter, *sixteen times* as much, &c.

The pressure of water against banks, the sides of containing vessels, &c. is in the proportion of falling bodies, *viz.* if the pressure against the first inch deep of the vessel be one pound, it will be three pounds pressure upon the inch below that; five pounds against the inch below that; seven pounds against the inch below, &c. so that pressure against banks, flood-gates, &c. is as the square of the depth, *i. e.* if the pressure be one pound against the uppermost inch, it will be four pounds against two inches deep; nine pounds against three inches deep;

sixteen pounds against four inches deep; twenty-five pounds against five inches deep, &c.

Fluids *press*, or *resist*, according to their *density*; and hence a boat will carry more on *salt* than *fresh* water. *The hydrometer* shews *this* very perfectly; it is buoyed up by *salt and water* mixed with *vinegar*, &c. but sinks in *wine*, *spirits*, &c. according to their lightness, and hence it is used for trying the lightness or strength of liquors.

A *syphon* acts agreeable to that *equal state* which nature affects through all her operations; it will not run unless the height of water in the *outer* leg be greater than that of the *inner* leg above the water in which it is immerfed; as the water falls therefore from the *outer* leg, it will make a continued *vacuum*, and of course the *pressure of the atmosphere* on the surface of the water will force it through the syphon in a *continued stream*, if kept free from that lodgment of air which frequently takes place on the top of the syphon. By the *Tantalus cup*, and *fountain at command*, the cause of *intermitting springs* is explained thus:

Clouds, being attracted by the mountains, give a continued supply to those reservoirs of water which are frequently found in the bowels of mountains, and which supply *springs* in general: But should the channel from one of these reservoirs be formed like a *syphon*, of course the spring which proceeds from it will *ebb* and *flow* like the sea, as those in Derbyshire, Berkshire, &c.

The action of the *common pump* depends on the *pressure of the atmosphere*: When the piston is drawn up, the column of air upon it is also lifted, and a vacuum is formed underneath it, the pressure of the atmosphere on the well will then force the water up the pump 33 feet, but not higher; which shews that a column of water of *that* height is equal to the weight of a column of air, of the same thickness, reaching from the earth's surface to the top

of the atmosphere. Therefore at any distance above the surface of the well less than 33 feet the piston will work, and water from thence may be lifted to any height whatever, if the pump be strong enough. In a *forcing pump*, the piston is a *solid plunger*; it raises the water above the sucking-valve as in the last, but when the plunger descends (as the water cannot return through the valve back again) it forces it into a larger air vessel which communicates with the body of the pump above the sucking-valve; and as by this force the air in the vessel becomes condensed, its re-action on the water causes it to flow through a small pipe in a continued stream. The engine for extinguishing fires consists of two such forcing pumps, with their air vessels.

The *lifting pump* can only be used in deep water, as its piston is worked by a rod going in at its bottom, and fastened to a frame coming up each side of the pump: This piston has a valve opening upward, and it works below the surface of the water in which the pump is immersed, and thence has no occasion for the air's pressure, or a sucking-valve. This pump is generally equipt with an air vessel as the last. On this principle engines are made for raising water above the level of rivers or springs, as at Marli; but if three pumps are worked in any engine by a triple crank, and all of them throw their water into one pipe, there is no occasion for an air vessel, because there will be always one or other of the pistons acting, so as to force the water out in a regular stream.

Archimedes' screw pump raises water by its endeavour to fall—'tis three or four hollow threads of a screw wound round a solid cylinder; it must rise out of the water sloping, so as the threads may all incline downwards; then, when 'tis turned round, water will rise in it, but to no great height.

The *upright cylindrical mill*, by Dr. Baker, is a tall tube of wood or metal, twenty feet high, and about five inches diameter; it stands on a point perpendicular, and has as to

its bottom two or more horizontal arms, or tubes, fixed, of about six feet long, communicating with the upright, tube, and perforated with holes, one in each arm and on the same side in each; through these holes the water which flows in at top spouts out, and by giving a push to the air, and preventing the water's pressure on that side the arm, forces the whole machine round, and carries a pair of stones at top, or pumps, or any thing else capable of being moved by a circular motion.

The *bucket engine*, for raising water by pumps out of mines, &c. is well calculated for situations where the stream that carries it has three yards of fall, and is too small to carry a wheel: The bucket hangs on one end of a beam like that of a fire engine; and at half the distance from thence to the fulcrum hangs the pump rods; on the other end of the beam hangs a counterpoise, rather heavier than the empty bucket, and a column of water on the piston; but when the bucket is filled by the stream, it is heavier and descends; the bucket hangs on centres a little on one side its centre of gravity, so that one side is heavier when empty, and the other when full, and being unlocked by its descent, its unequal poise turns and empties it, and then it ascends and opens a valve which again lets the stream into it, and makes it descend again. This motion works the pumps.

Two forcing pumps, for supplying houses with water, are also worked by an engine of similar principles, but with still greater simplicity: A beam inclining downwards to each end from the center on which it hangs, has a trough cut in it, from a division in the middle down to each end, where buckets are fixed for receiving the water that works it, and which flows into the trough, first on one side the division and then on the other, as the ends rise and fall: When one bucket descends, the valve in its bottom falls on the pin, which opens it, and lets out the water; mean while the stream is filling the other bucket, which, when full, descends in like manner, and each end works a forcing pump.

The *centrifugal machine* claims still greater merit as to its simplicity; its shape is like the letter T, 'tis hollow throughout, and its three ends are open: When the lowest end is immersed in water, and it is whirled round on that end, the air in the arms will be partly thrown out by the centrifugal force, and consequently the pressure of the atmosphere on the surface of the water into which it is immersed will force it up the tube and throw it out at the arms; hence a continued vacuum is made, and of course a continued stream thrown out. The perpendicular tube must not be above 33 feet high, for reasons already given. Two men will discharge near three times as much water with this machine, in the same time, as with any pump yet invented.

Several Models to shew how a Ship may pump herself.

The *fire* (or rather *steam*) *engine* is one of the noblest presents that art has made to the necessities of mankind! When the particles of *water* are separated by fire, they compose an *elastic vapour*, called *steam*; this vapour is capable of occupying 14,000 times the *space* it did in its state of *cold water*; 'tis of force sufficient to drive away the air, and it may be condensed, or brought back to water again by *cold*. Hence a long hollow *cylinder* of iron communicates with a huge and close *boiler*, half filled with water, by a neck which can be opened or shut by a sliding valve called a *regulator*: The *cylinder* is exactly filled by a *piston* made *air-tight*, that hangs on one end of a *beam* of timber about 20 feet long, and suspended on a centre like a scale-beam; at the other end of the beam hang the *rods* which work the *pumps* in the bottom of the *mine*, and throw up a part of the water into a *reservoir* on the top of the building: From this *reservoir* there comes a *pipe* under and through the bottom of the *cylinder*, that by opening the cock (called the *injection cock*) plays a *jet* of cold water into the *cylinder* to condense the steam; after which this water falls through a pipe (with a valve opening outward) and forms the *hot-well*: Another pipe also, with a valve outward, called the *sifted valve*, is fixed near the bottom of the cylinder,

and serves to let out the *air* or *steam* without letting it return. The *regulator* or *injection cock* are alternately opened and shut by a piece of timber hanging from the large beam; and a stream is let into the *boiler*, or stopped, by a floating *copper ball* in the boiler that regulates the height of the water. If now a *large fire* be put under the boiler, and the steam let into the cylinder by opening the regulator, it will drive out the air, and possess the space itself; but so soon as the *injection cock* is opened, a *jet* of *cold water* will play into the steam in the cylinder, and *condense* it into a *few drops*; hence a *vacuum* is formed in the cylinder, and the *pressure of the atmosphere* on the *piston* will force it down to the bottom of it; the steam then being let in again will counteract the air's pressure, and with the weight of the pump rods on the opposite end of the beam, bring up the piston to the *top* of the cylinder. This action is repeated *fourteen* or *sixteen* times in a minute, and works the pump in the mine. As the *friction* of this machine is very great, instead of reckoning 15 lb. pressure on every square inch on the piston, 8 lb. will be found nearer. If then the weight of a column of water, the depth of the mine, and the diameter of the pump be calculated, the necessary diameter of the cylinder will be easily found.

The *fire engine with the inverted piston* spares the expence of both a *beam and building*; the cylinder, with its open end downwards, stands over the pit or shaft of the mine, the boiler stands by its side, the *injection well* above it, and to its *piston* the *pump rods* are fastened. The *regulator* (of great simplicity) is the *injection cock* also. When the steam is let in at the top of the cylinder, and condensed by the injection water, the *upward* pressure of the atmosphere forces the piston from the bottom to the top of the cylinder, and the weight of the rods, and strength of the steam force it back again. This motion works the pumps.

The *cold water vacuum* will do this business with still less *machinery and expence*, where the water that works it has a fall of 40 feet. With the bottom of the cylinder there communicates a perpendicular wide pipe of 33 feet

long, having a regulator at its bottom, and another at its top. The piston and beam are the same as in the common *fire engine*. The water being let in at the bottom of the cylinder will fill both the cylinder and the pipe below it; if then the regulator at the bottom be opened, the water will descend out of the *cylinder*, but not out of the *pipe*, because it is *then* but a *counterpoise* for the *atmosphere*: Thus a *vacuum* is formed in the cylinder, and the piston will *descend* and shut the upper regulator; but when it reaches the bottom, it opens again, and as the cylinder fills, the piston rises. Thus action is given to the beam, and *water* applied in this way is perhaps a more *powerful agent* than it is in any other.—N. B. *For ought I know, these two engines are new, and unknown to the public.*

Watts' and Boulton's steam engine condenses the steam, without cooling the cylinder by a jet of cold water, and thereby saves fuel. The steam is produced in a boiler as usual—it passes into a double cylinder, and forces down the piston by its elasticity, for the rod of the cylinder works through a collar of leathers, and therefore the pressure of the atmosphere has nothing to do in this engine. When the piston is at the bottom of the cylinder, the steam-cock opens, and by the double cylinder, steam enters both above and below the piston, so that it rises in stagnate steam by the weight of the pump rods acting on the opposite end of the large beam. When the piston arrives at the top of the cylinder, a cock opens that communicates with a vacuum formed in a pond of cold water; this draws the steam from *under* the piston in a most perfect manner; and leaves the piston liable to the pressure of the steam *upon its top*: and as steam may be made of much stronger pressure than the atmosphere, this engine is proportionably more powerful than the common engine.

These, and many other hydraulic machines for various purposes, are too cumbrous to be removed from the stationary lecture-room.

LECTURE VII.

E L E C T R I C I T Y.

ELECTRICITY and *phlogiston*, having many properties alike, many think them only modifications of the same principle. Iron losing its phlogiston by vitriolic acid, loses by the same process its electricity; proved by insulating the process, when a wire communicating with the effervescing mixture, will betray signs of negative electricity. This most subtil fluid, seems more or less inherent in all matter—but some bodies conduct or transmit it, whilst others stop its progress from one body to another. Glass, hair, silk and gums are *non-conductors*, and called *electrics*: but metals, water, green wood, and most animal and vegetable substances are *conductors*, and are called *non-electrics*. 1. If a long tube of glass be rubbed with warm silk, an atmosphere of this fire will be formed all round it, and if a finger approach the tube, the fire will come visibly off the tube into the finger with a snap: The reason is, the friction collects the fire, from the earth (its grand reservoir) and the spark is the effort it makes to disperse itself again, and thereby restore its equilibrium. 2. If the same tube electrified, approaches, a *feather* hung by a silk thread it will *attract* the feather once, but if held to it again will repel it. The silk will not conduct the electric fire; the equilibrium is therefore effected between the tube and the feather on the first approach; on the second, the atmosphere of the tube pressing on that of the feather drives the feather from it, (for two bodies possessed of the same electricity universally repel one another;) but if the feather be suspended by a flaxen thread, the electrified

tube will always attract it, because the fire can make its escape up the thread, and thereby leave a continued inequality between them. A *large globe* or *cylinder* of glass, with a *basil-skin cushion* covered with an amalgama of quicksilver and tinfoil, or zink, or aurum mosaicum spread on black silk, saturated with mercurial ointment, to produce the friction; a *prime conductor* to take off the *electric atmosphere* from the glass, and deposit it in a *glass receiver* covered in and outside with tinfoil to within two inches of the top, and a *wheel* to put the cylinder in motion, is called the *electric machine*, or *fire pump*. An electric machine of great power is also made of oil'd or gum'd silk drawn between rubbers of cat's-skin with the fur on. When a machine is put in motion, it disturbs the equilibrium of the *electric fire* about it, and from thence the whole of its phenomena proceed, as may be proved by experiment. 1. If a person touch the electrified conductor, the fire will escape from it through the person into the ground with a flash and report. 2. If any number of persons take hands, and the first person holds a chain which communicates with the *outside* of the receiver, and the last person touches the communication with the *inside* when the phial is charged, the fire will restore itself through all the company at the same instant, giving each a severe shock at the wrists and elbows, in its passage back again to the *outside* of the phial. 3. If a person stands on a stool with *glass feet*, and holds a chain fastened to a conductor, on turning the machine, and touching him, sparks may be brought out of every part of his person and cloaths, and if he touch warm spirits or gunpowder with his finger, they will take fire; which shews that the electric fire is chiefly pumped from the earth, and cannot return to it again through glass. 4. If a ball be hung on the conductor, and a plate of *bran* or *leaf gold* be placed under it, on electrifying the ball, the bran will be alternately attracted to and repelled from it in a beautiful shower; here, the particles of the bran are carriers as it were of the electric fire from the ball to the plate: And if two

bells be hung on the conductor, one by a flaxen thread, and the other by a silk thread, (having from it a chain to the table) if a small *clapper* be hung between them on a silk thread, it will carry the fire from one to another and thereby ring both. 5. *Electrified feathers* spread out their threads radiantly; if a round body be held to them they *cling* to it and deposit their fire; but if a point be held near them they shrink at once; hence the reason why the wire conductors rising from the ground above the tops of houses, terminate in points to receive with more ease the *lightning* from the clouds, and thereby prevent its mischief. 6. If *wires* fixed like the spokes of a wheel be suspended on their center, with their points bent all the same way, and in the plane of the circle; on being electrified, the effluvia flowing from the points will strike so forcibly upon the air as to force the wheel round with great rapidity: Hence a simple and pleasing electric orrery is put in motion,—and various mills and other devices. 7. *Water and salt* (like the cylinder and cushion) will collect the electric fire when put in motion; for one is an *electric*, and the other a *non-electric* body; hence the *sea* itself becomes as it were an *huge electrical machine* when violently agitated by winds, collecting on its troubled surface the fire from beneath, and looking in the night as if it was all in flames. *Clouds* raised from a sea so circumstanced, must needs contain more of the electric fire than clouds raised from the land, or calm sea; if therefore two clouds meet, fraught with *unequal portions of this fire*, the cloud *more* electrified will deposit its abundance in the cloud *less* electrified, and with a flash of lightning restore the equilibrium; this fire driving to a distance the air that surrounds it—the stroke formed by the return of that air is *thunder*. Some think putrid fish, others animalcula, or an east wind, the cause of the luminous appearance of the sea. If a cloud attracted by a neighbouring mountain contains *more* electric fire than the mountain, the lightning will dart from the cloud to the mountain and vice versa; hence if an electric cloud comes too near a *tower, tree,*

horse, &c. and they are not wet, the fire will descend on them in an effort to restore the equipoise, and if greatly obstructed in its passage to the earth, will perhaps break them all to pieces; to stand under a tree or shed, is therefore dangerous in a thunder storm; and shews also the extreme utility of having a wire from the top of any tall building, down which the equilibrium will be restored without danger; and if the wire does not touch the ground, a finger at that time applied to the wire, will receive the *electric flash* much stronger than by a machine. A *kite* sent up into the thunder-cloud by a wire, having a key tied to its end, and held by a silk ribband, will extract the fire from the cloud; it will come down the wire, and stream off the key to the ground in a beautiful, but alarming torrent of fire.

'Tis thus, by weight and measure, the ALMIGHTY has appointed self-physic for the disorders of his works!

If a *capillary syphon* be made to decant water, it will fall from it in *small drops*, but if the water be electrified it flows from the syphon in a *swift stream*. Hence 'tis found that a person *positively electrified*, (*i. e.* having more electric fire thrown into him than his *natural quantity*, by standing on a cake of wax, or a glass-footed stool, and touching an electrified conductor) has his *pulse accelerated*. This acceleration has been found of great service in *obstructions, rheumatisms, palsies, &c.* and the *electrical shock* has been still more successful in removing *paralytic complaints, deafness, tooth-ach, numbness, &c.* Sparks drawn from chilblains, swellings, &c. have a great effect, and the aura from a wooden point has dispersed the cataract of the eye.

The electrical fluid always goes the nearest, and chuses the best conductors. A chain hung on a wall, and made part of the circuit from the *in* to the *outside* of the charged Leyden vial, is luminous when the vial is discharged,

and shews the road taken by the electrical fluid: but if a straight wire touch the two ends of the chain the chain will not be luminous, for the fluid will run invisibly thro' the wire, as being the *nearer* road. If the wire be then removed, and a stick put into its place, the chain again becomes luminous in the discharge, as the fluid will rather go a longer distance than pass thro' a bad conductor.

The electrical fluid poured on the inside coating of a Leyden vial, propels an equal quantity from the outside. 1. The outside coating of a vial being pieces of tinfoil not touching one another, the fire will be seen darting from one piece to another, till the charge is compleated: when discharged the fluid will return, and make the whole outside luminous. 2. A bottle, coated on both sides, having a cap cemented on its neck, with a valve, and from that cap a pointed wire going straight into the bottle: If this bottle be exhausted of its air, (but not to a vacuum) it will be found a good conductor; and when the cap is held to the prime conductor, flames like the Aurora borealis will issue from the point of the wire to the inside coating, and charge it;—but while an imperfect communication is made between the negative outside and the positive inside, the point receives the fluid, and exhibits only a star on its point:—Hence a *receiving* point always exhibits a *star* and a *delivering* point *flames* in an imperfect vacuum. Rarified air being so good a conductor, may not the sun's heat and the great centrifugal motion of the equatorial parts of the earth, make the air there so thin, as to become a conductor of that electric matter of which the earth is the known reservoir? and being thus thrown up into the upper regions of the atmosphere, may it not make its way towards the poles, where the small degree of centrifugal force is friendly to its reception? Aiming therefore at a point, may it not be so far concentrated and condensed, as to become visible, and make those radiant corruscations we call *streamers*? for electric matter streaming through highly rarefied air exhibits the very same appearance.

3. On the cover of a large Leyden jar, fix a smaller jar, so that the *outside* coating of the small jar may have a metallic communication with the *inside* coating of the larger;—the outside coating of the small jar becomes a conductor to the inside of the big one, when held to an excited prime conductor; if when charged, one knob of the discharging rod be applied to the negative side of the large jar, and the other applied to the knob communicating with the inside of the small jar, a flash will issue from the contact (being the natural electricity of the inside coating of the small jar) and by which the equilibrium of its two sides becomes destroyed. Electricity will then rise from the inside of the large jar upon the outside of the small one. This balance is again restored by forming a metallic communication between the *in*, and *outside* coatings of the small jar. By repeating these twenty or thirty times, the whole charge of the lower jar will be taken piecemeal out; and prove that what electricity is poured on one coating of a jar propels a like quantity from the other.

4. If a rod of wire, 18 inches long, having a light knob at each end, and suspended on an insulated point, be placed so between the knob of a charged jar and a metal pillar, that when one knob touches the pillar, the other may be six inches from that of the jar, then will the rod vibrate between the jar and the pillar, taking out the electricity so by little and little as to acquire ten minutes to compleat the discharge.

5. If a Leyden vial be charged on an insulated stool, having two pith balls hanging by fine threads projecting from its in and outside coatings, the balls communicating with the positive coating will separate; if then a finger touch the wire on which they hang, these balls will close, and those will open which communicate with the *negative* coating; touch that wire and the negative balls close, and the *positive* balls open, &c. for an amazing number of times! shewing, that though glass will not conduct electricity, the electric influence can operate through the thickness

of glass. 6. To superinduce electricity on a loose coating laid on plate-glass, touching the coating with the knob of a charged vial, then shake off the coating, and clap an insulated metal plate on the place, touching it at the time of contact, then lift up the plate, and it will give a spark to the knuckle; place it on the glass again, and touch and remove it as before, and it will give another spark, and continue to do so as long as the apparatus is kept clean and dry; making perpetual electricity, by which vials may be charged, inflammable air guns fired, &c.—N. B. The plate of glass must have a fixed coating on the opposite side to the loose one, and of the same size. This apparatus is called *Electrophorus*; and often instead of glass, a plate is made of sulphur, shell-lac, rosin, &c. To prove that the natural electricity of bodies may be disturbed by the near approach of excited electrics, let two projecting arms of insulated wood have slips of tinfoil glued on them from end to end, and pith balls hanging from one end of each; if the two arms be placed in a line, with the ball end of one touching the end without balls of the other, and an excited electric be held within an inch of the end without balls, then will all the four balls part;—at that instant, if one stand be separated from the other, the balls of one will be found in a negative and the other in a positive state, the balls farthest distant from the excited electric will be in the same state as the electric, and of course repelled by it; the nearest attracted, &c. Hence if any part of an electrical cloud comes near the earth, it will disturb the electricity in the earth, and drive it away; but if any other part of the cloud comes within the striking distance of any conductor to the earth,—the cloud will be discharged, and the disturbed electricity will return with a force that frequently proves fatal to animals in its way.

Electricity is applied to *inflamed eyes, tumours, &c.* by a chain coming from the prime conductor ending in a point

of hard wood; the point is held near the part by a glass handle, and an aura issues from it on the fore, that often performs a cure. 2. Paralytic and rheumatic patients are relieved by shocks sent through the side affected. 3. Obstructions are often cured in the female sex by positive electrification, *i. e.* by placing the patient on an insulated stool, communicating with the prime conductor, and keeping her electrified for half an hour together, occasionally drawing sparks from her.

LECTURE IX.

O P T I C S.

*Hail holy light! Offspring of heaven! First born!
Or of th' eternal coeternal beam;
May I express thee unblam'd?—*

MILTON.

THIS *modesty* of the poet becomes the dignity of so divine a subject.—*Light* is the blessing which gives poignancy to all others,—therefore the science of *optics*, which immediately treats of it, must reflect part of its lustre and importance. Plato defines light, “*a rare and subtil flame;*” and perhaps it is but diluted or very rare phlogiston, or flame in a state of great thinness or rarefaction. May it not be the inflammable principle perpetually let loose from the sun, and occasionally from other luminous bodies?—May not these phlogistic particles flowing from the sun, enter into the texture of other bodies, give them the power of inflammability, and become fixt in them, till let loose by the contact of bodies in actual inflammation?—Or finally, that the concreted rays of the sun in bodies having affinity with them, may give them the power of inflammability universally, and that colour in bodies may arise from a chemical rejection of the colour reflected to the eye, while all the rest are absorbed into the body? Some believe *light* to exist even in the *absence* of a luminous body, and that it is only a *luminous body* that puts it in motion. The most general, and probable opinion is, that it flows immediately from the luminous body in straight lines, in all manner of directions, and consists of *particles* so infinitely

small, as to exceed all human comprehension. A proof of this smallness is, that a *candle* will fill a sphere of four miles in diameter, without the least sensible loss of its substance: And if a *row of candles* stand parallel to a *black paper*, with a *pin-hole* in it, each candle (through that hole) will make a separate speck on the *paste-board* a little behind it. These particles by striking the *retina* of our eyes, excites in our minds the idea of light: And when they fall upon bodies, and are by them reflected to our eyes, they excite in us an idea of the colour and shape of these bodies.

In a room *perfectly dark*, if the hand (or any' thing) be put into light, and then taken into the dark room, it will be luminous some time, as if covered with phosphorus.—Calcined oyster shells taken out of the light into the dark room, exhibit the colours of the rainbow, &c. shewing that light striking upon bodies, excites their latent light, and makes it visible, as one candle is lighted from another. Or that light sticks to bodies plunged in it, as water does to the hand.

We cannot see through the bore of a bended pipe; which proves that light moves in straight lines in *every medium of uniform density*. But when they pass *obliquely*, out of one medium into another, which is either more *dense*, or more *rare*, they are *refracted*, or bent towards the denser medium, more or less, as they fall more or less obliquely on its surface. To prove which, put a *shilling* in the bottom of an empty vessel; stand so far from it that the vessel may hide the shilling; if water be then poured into it the shilling will again be seen. Hence we are deceived in the depth of water: A straight stick put into water will appear crooked; and hence the *sun's* rays being broken by passing thro' our atmosphere, we see him in the *horizon*, before he rises, and after he sets in it. When *rays* fall perpendicularly on any medium, they pass straight through without any refraction.

Glass is generally ground into eight different shapes for opticial purposes. 1. A *plane glass*, is a flat, and even on both sides, and of an uniform thickness; will refract the rays of light, but not collect them into one focus. 2. A *plano-convex*, is flat on one side, and a portion of a sphere on the other. When parallel rays fall directly upon it, they pass through it, and are so refracted, as to unite in a point called its focus, just so far behind it, as is equal to the diameter of the sphere of which it is a part. 3. A *double convex*, is convex on both sides: Parallel rays passing through it *converge* or meet in a focus, at half the distance they do through the *plano-convex*; and as the heat of all those rays are collected in that focal point, it will burn, melt or calcine all opaque bodies. 4. A *plano-concave* is flat on one side and concave on the other. 5. The *double concave* is hollow on both sides, and parallel rays passing through *diverge* or spread out agreeable to the laws of refraction. 6. A *meniscus-glass* is convex on one side, and concave on the other. 7. A *flated plano-convex*, or multiplying glass, has its convex side ground into several flat surfaces. And, 8. The *prism* has three flat sides, and viewed endwise appears like an equilateral triangle. The *prism* held obliquely to a ray of light in a dark room, will effect its smallest *particles* the *most*, and shew them to be a fine *violet colour*; it will assemble the next in size close to the first, and shew them to be of an *indigo colour*; the next *blue*; the next *green*; the next *yellow*; then *orange*; and at last the *red*, which consists of the largest particles, and therefore by the momentum of their motion, the least capable of being attracted out of their way. 'Tis wonderful that these colours occupy spaces on the screen on which they are thrown by the prism, exactly proportionate to the diatonic scale of the *seven notes of music*! If in the rays so divided a *double-convex lens* be put, it will bring them into one point that shall be perfectly white; which accounts for the *white appearance of light*. As *white* is therefore a composition of all colours, so *black* is a privation of them all, and properly *no colour*, and such a blank exists in the space above our atmosphere: In looking up therefore we see what is called the *blue sky*, a colour na-

turally resulting from the mixture of *black* and *white* through which we look; or perhaps blue is the natural colour of the atmosphere, so that distant mountains look blue, by being look'd at through a medium of that colour. All bodies appear of that colour whose rays they reflect most; as a body is red when it reflects the *red rays*, and absorbs the rest. Two, or more, colours that are quite transparent by themselves, become dark when put together. Thus, if *spirits of wine* be tinged *red*, and put in a square bottle, every object seen through it will be *red*; because it only suffers the red rays to pass through it, and stops the rest. If another bottle be tinged blue, all objects viewed through it will be blue for the same reason: But if the two bottles be held together, the object can no more be seen through them; for whatever rays pass through one bottle to the eye will be stopped by the other, &c. Rays of light suffer different degrees of refraction, by falling more or less obliquely on the *prism* or *convex lens*, &c. and are thereby separated as above; this happens to them in passing through *drops of falling rain*: For being *reflected* towards the eye from the sides of those drops which are farthest from the eye, and again *refracted* by passing out of these drops into the air, they come in refracted directions to the eye, and make all the colours to appear successively in the form of a fine arch in the heavens, which is called the *rainbow*: All drops passing through an ideal plane in the shower, refract a certain colour to the eye—passing through another a little lower they refract another, &c. so the bow appears permanent while the shower lasts.

Light is *reflected* by the *repellent* quality of bodies, and flies back from polished surfaces, like a ball thrown against an hard and smooth plane: If a stick stand perpendicularly on that plane, and the ball be thrown obliquely on the plane near its foot, it will rebound on the other side the stick, and form an angle with it, equal to that in which it was thrown; the first of these is called the *angle of incidence*, and the other the *angle of reflection*. If upon a *plane looking-glass* a ray falls from any object, if a perpendicular be erected there, and the eye go off such a

distance as to form the *same angle* on the other side of it, the object will be seen in a straight line behind the glass, —for it is an axiom in optics, *that we always see objects in that line of rays that come to the eye last*. Hence I see my whole person in a glass but *half* its length; for the rays from my feet striking upon the bottom of the mirror, will form the *angle of reflection* in my eye the same as if it was the *whole* length, &c. Hence also the effects of *diagonal mirrors, opera glasses, cameras, &c.* Parallel rays falling on a *concave mirror* will be reflected also agreeable to those *angles*, and meet in a point at half the distance of the mirror, from the centre of its concavity; if the rays proceed from an hot sun, his image will likewise be found in that point, and burn. The rays which proceed from any small *terrestrial object*, come *diverging* to the mirror, and therefore will not be *converged to a point* at half the distance of the mirror's surface from the centre of its concavity, but *nearer to that surface*; the image will be less than the *object*, but will be seen *inverted*, and hanging pendant in the air, quite distinct by an eye placed opposite the mirror. If the *object* be in the *centre of the mirror's concavity*, the *image* and *object* will be *together*, and of *equal bulk*: Therefore when the object is more remote than the centre of concavity, the *image* will be *less* than the *object*, and between the *object* and *mirror*: But when the object is *nearer* than the centre of concavity, the *image* will be *more remote*, and *bigger* than the object. The angles of *incidence* and *reflection* also account for the *small image* in a *convex mirror*.

The *human eye* is lodged in a bed of fat, and secured in an hollow orb of bone;—'tis moved by *muscles* which act on its outside like *pullies*, and consists of *four coats*, and *three humours*. The coat, in which the *back part* of the eye is contained, is called the *sclerotica*; it is a *large portion of a globe*, very strong, and of a non-elastic nature; —that part which *completes the globe* on the *fore-part* of the eye, is the *cornea*; it bulges a little forward out of that shape, and is a fine transparent membrane. Next within the *sclerotica* is that called the *choroides*, which

serves as it were for a *soft lining* for the other; and within this, is spread a fine expansion of the optic nerve, like a net, called the *retina*, upon which are painted, as in a *camera obscura*, the images of all well enlightened objects. The *iris* is composed of two sets of muscular fibres, which dilate, or contract the *hole* in it, called the *pupil*, so as to adapt it to a strong or weak light. The *adnata*, or *conjunctiva*, is the white of the eye, a fine membrane that *folds under the eye-lid*, and joins to it. Under the *cornea* is a fine transparent fluid like water, and thence called the *aqueous humour*: It gives the protuberent figure to the cornea, and goes through the pupil. Behind this lies the *crystalline humour*, shaped like a double-convex glass, transparent as crystal, of the consistence of hard jelly, and which converges the rays that pass through it to a focus on the *retina*. It is inclosed in a fine transparent membrane, from which proceed radiant fibres called the *ligamentum ciliare*, all round its edge, and joined to the outward edge of the *iris*: These fibres, by a power of contracting and dilating, alter the convexity of the *crystalline humour*, and shift it a little *backward* or *forward* in the eye, to suit it to the different distances of objects (*an admirable provision.*) The *crystalline humour* is bedded on the *vitreous humour*, which fills the whole of the other part of the orb of the eye, and is transparent like glass; this is the largest of all in quantity, and is much of a consistence with the white of an egg. The *optic nerve* comes from the *brain*, through the *sclerotica* and *choroides*, on that side the eye next the nose; and is inclosed on the outside the eye by coats proceeding from the *pia* and *dura mater*, and of which the *sclerotica* and *choroides* are but a continuation. These are the parts of this wonderful organ.

Rays from any enlightened *object* stream upon the *retina*, and there paint it invertedly, as may be seen by cutting off the three coats from the back part of a fresh bullock's eye, and putting a piece of white paper over that part: If the eye is then held before any bright

object, an inverted picture of it will be painted on the paper. The *optic nerve* incloses a *blood-vessel*, which renders objects invisible that fall on it; how wisely therefore is it placed on one side of each eye! that the same parts of an image which fall on the optic nerve of *one* eye should not fall on the *other*! If three patches are placed at a foot distance from each other on a wall, if the *right* eye be covered, and the *left* looked fastly at the right-hand patch, the middle patch will disappear, because it falls on the artery in the optic nerve.

The nearer any object is to the eye, the larger is the angle under which it is seen; therefore an object looks twice larger at *one* than at *two* miles distance. Hence the use of *convex glasses*, which, by increasing *this* angle, make *minute objects* visible; and when the *humours* are grown so flat in decayed eyes, that the picture falls behind the retina, can bring the rays to converge so that the picture shall be brought back as it were to the *retina*. Hence also the reason that the *too round* eye requires the *double concave* glass, by its divergency, to remove the image from the vitreous humour forward to the retina.

The *single microscope* is only a small convex glass having the object placed in its focus; and the eye at the same distance on the other side. Its magnifying power is thus calculated: A good eye cannot see any object distinctly at less than six inches distance; if this be divided by the focal distance of the glass, the quotient will be how much the diameter of the object is multiplied.

The *double microscope* consists of an *object glass* and an *eye glass*, between which the image is formed and magnified, by having the object a little further from the object glass than its principle focus; this image, brought so near, is viewed by the eye through the eye glass. If each glass magnifies *six times* (as by the last calculation) then is the object magnified *thirty-six times* by both. This instrument is equipt with a mirror, which, by the *angle of incidence*

and *reflection*, throws up light on the *underside* the object; which object being placed in the focus of a *moveable lens*, has its *upper side* enlightened also.

The *solar microscope* is placed in a round hole in a shutter that only admits, into a dark room, a small cone of rays; that these rays may be sent straight through the tube, a plain mirror on the *outside* is so fixed, as to reflect them in; they then pass thro' a large convex lens; after which, they fall upon, and enlighten the object, which is placed in the focus of a *small magnifier*, through which they carry a large inverted image of the object to a white sheet, placed at any distance for its reception.

A *refracting telescope* may be made of *two convex glasses*, viz. an *object glass* and an *eye glass*, if the focus of the *eye glass* be in the same part of the tube where the image is formed by the *object glass*: but then the image will be inverted and therefore 'tis only suitable for celestial objects. The magnifying power of this telescope is as the focal distance of the *object glass* to the focal distance of the *eye glass*: Therefore if the *former* be divided by the *latter*, the quotient will express the magnifying power, and shew, that if the focal distance of *each were alike*, the magnifying power of the telescope would be nothing; and that this magnifying power will increase with its length, for the greater the focal distance of the *object glass*, the less may be the focus of the *eye glass*.

A *refracting telescope*, that will shew objects in their natural posture, must have *two equal convex glasses* added to the *eye glass*, and all three must stand at double their focal distances from one another. As these three do but as it were compose one *eye glass*, the magnifying power of this telescope may be calculated as the last.

Dollond's patent telescope is formed on the same principles, only its *object glass* is much larger, and is composed of two joining glasses of different densities, one a *plano-concave*, and the other a *double convex* that fits into

the other's concavity. These make the field of view larger, and, by taking off the coloured rays, the image becomes bright, and quite distinct: For as the rays which pass through the *edge* of a *convex glass* are more *unequally refracted* than those that pass nearer its *middle*, they don't meet in the same point, but form a circle of prismatic colours round the image: In *the common telescope* these are partly taken off by a *black plate* fixed in the tube, with an hole through its centre; but the *patent glass* does this much more effectually.

The *reflecting telescope* exceeds all others in its *magnifying power* and *portable size*; and its outward figure consists of a great and small tube, screwed into the end of one another. At the bottom of the great tube is placed the large concave mirror, with an hole through its middle. Parallel rays from celestial objects falling on this mirror, are reflected back by it, and form the *image* a little short of the *small concave mirror* which faces the hole in the large one. From this image the rays diverge to the small mirror, and are from thence reflected parallel, and inverted into the small tube, through the hole in the large mirror: here meeting with a convex lens, they are so refracted as to form the image in the *small tube*. The *image being now brought so near*, requires nothing but a single, or compound *eye glass* to send it duly magnified to the retina. Rays from any terrestrial object *will not come parallel* but converge a little; hence the image is formed nearer the great mirror, and therefore a screw is fixed to the small mirror, on the outside the tube, to adjust it to it; and also to the *greater or lesser convexity* of different eyes. Dr. Herschel's reflector is formed on the Newtonian plan, viz. its great mirror is not perforated, and therefore its image is received by a plane mirror placed diagonally within the tube, and which sends that image through the magnifying or microscopic part fixed perpendicularly in the tube. The excellence of this instrument consists in the parabolic *curvature* and *polish* of its great mirror, which forms the image of the object looked at *so perfect*, that a magnifying power of 6500 can be applied to it.

This instrument is carried to still a greater magnifying and distinct power by a mirror of near 5 feet diameter, and of 40 feet focal length, without any obstructing mirrors, so the light even from the moon is too strong for a naked eye to look at through it.

The *diagonal mirror*, for viewing prints, is a pleasing instrument. If a *plane mirror* be placed at an angle of 45 degrees above a print lying horizontal and inverted, it will turn the rays reflected from the print into an horizontal direction to the eye: If then a *large convex lens* be placed between the eye and the mirror, the picture will be prodigiously magnified; and if an assemblage of *shell-work* environ the view between the *print and the mirror*, the picture will have a beautiful frame to it.

The *camera obscura* is formed on the same principles. A *diagonal mirror* is set at the same angle against the landscape, and reflects it downward through a *convex lens* into a *dark box*, where it is painted on a *white paper* placed in the focus of the lens, and on which a hand put into the box may draw the landscape to the minutest exactness.

The *opera glass* is also formed of a small diagonal mirror, which sends the rays through a convex glass to the eye. Through this a gentleman may look at a distant lady in the company, and the lady know nothing of it.

The *magic lantern* is formed on the same principles as the *solar microscope*; a candle supplies the place of the sun; and having its rays tinged with the colours of *transparent figures painted on glass*, throws them through two convex lenses on a white wall in a dark room, prodigiously magnified. Argand's Lamp has improved this instrument very much, as well as the lucernal microscope, common illumination, the sea lights invented by the author, &c.

LECTURE X.

USE of the GLOBES.

WHEN a ship approaches us at sea, the first part of her we see is her *upper sails*, after that we see her *lower sails*, and then the *hull*:—'Tis evident she moves on a round surface or we should see the whole at a time. In sailing from capes we lose sight of them first at the *bottom*, then the *middle*, and at last the *top* disappears. These effects are in all parts of the world. Several persons have sailed round the earth. And all the bodies in the system are round. Hence we conclude that the *earth is a globe* also.

The earth's roundness is no more affected by the largest mountains, than the roundness of a common globe is by a few grains of dust thrown upon it; for they bear no greater proportion to its bulk. It is 7,970 miles in diameter: Near 100 millions of miles from the sun: Moves round him in 365 days 5 hours and 49 minutes, at the rate of 60,000 miles an hour; and turns round upon its axis every 24 hours, from west to east, which makes all the heavenly bodies seem to turn round the contrary way, or from east to west.

The particles of which the earth is composed would fly into confusion, if not held together in the form of a globe by the *power of gravitation*. 'Tis this power which gives *weight* to all bodies, or that tendency they have towards the center of the earth. Hence the general *top* of the earth becomes its whole surface, and the general *bottom* its center. The *Antipodes* are therefore as much

on the top as we. But as the parts of the earth are loose, the violent motion it has on its axis will in some degree overpower even the force of gravity, and accumulate more matter round the *Equator*, because the *centrifugal force* is greatest there; hence the true figure of the earth is an *oblate spheroid*, or like an orange, 35 miles more in diameter at the equator than at the poles. This was proved by an actual mensuration, and is explained by the whirling rings.

This oblate figure proves its *diurnal motion*; if it was at rest it would be necessarily a perfect sphere. We perceive not this motion, because the *air* in which we live, partaking of the general gravitation, is carried round along with the earth. When a ship turns round, if we look out at the cabin windows, we believe ourselves at rest, and the neighbouring country turning round us; —we are deceived in like manner in the motion of the earth.

Where there is no reflection from contiguous objects, a globe can but be *one half* enlightened by a luminous body; hence, if a globe turns round, there must be a succession of light and darkness, or day and night, to its inhabitants.

Had a globe no other motion, there could be no variety in its seasons or length of days. As gravity decreases according to the squares of the distances, it follows that if one body move in an oval round another as its centre of motion, the square of its periodical times will be as the cube of its distance from that body; this holds precisely with regard to the planets and their moons. The planets sometimes appear to *stand still*, sometimes to *go backwards*; this must always be the case where one body moves nearly in the same plane, and circular within the orbit of another moving body.—The eclipses of Jupiter's satellites appear later to us by 16 minutes at one time of our year than at another. 'Tis matter of observation, that all the planets revolve round the

fun. From all which we are certain that the earth goes round the fun, and not the fun round the earth.

We know the path our earth describes in the heavens, by observing *that* which the sun seems to describe in the opposite part of the heavens. We find one star without any apparent motion, situated 23 degrees and a half from the axis of this orbit, and which is occasioned by being nearly opposite to one of the poles of our earth, and thence called the polar star; hence we discover that sublime contrivance the inclined axis of the earth, which keeping always *parallel to itself*, occasions the different seasons, and different lengths of day and night; diffusing equally, over the face of both hemispheres, the blessings of the sun.

The axis so disposed will necessarily bring the northern and southern parts of the earth alternately to the sun, therefore when it is summer in the *north* it will be winter in the *south*, and vice versâ. So far on each side the equator as the sun at any time of the year shines vertically, is called the *torrid zone*, and it is bounded by two imaginary lines; *that* to the north is called the *tropic of cancer*, and *that* to the south, the *tropic of capricorn*. When the sun shines vertically over the first, he must shine 23 degrees and a half further than the north pole, and will not therefore set for many days together to the inhabitants of the *north frigid zone*—but it will be then total darkness (the same time) to those of the *southern frigid zone*; hence the poles *must* but have one day and one night in the year. These two zones (as they are called) are bounded by lines also, the north called the *artic*, the south the *antartic* circle. The intermediate spaces between the torrid and frigid zones are called the *temperate zones*.

In the northern hemisphere the *vernal equinox* (or equal day and night in the spring) is about the 20th of March; and the *autumnal equinox* is about the 23d of September; in the southern hemisphere the contrary:

At the equinoxes the sun shines over the equator ; at the *solstices* he shines 23 degrees and a half from the equator.

The *meridian* of any place is a semicircle passing through it, cutting the equator at right angles, and terminating in the poles. The earth's circumference is 360 degrees, each near 70 English miles, and as the earth turns round on its axis in 24 hours, each meridian revolves 15 degrees in an hour, for $24 \times 15 = 360$. Therefore every place to the *eastward* of another has its hours sooner, if *westward*, so much later.

The *longitude* of any place is the number of degrees between its meridian, and the meridian of any place, from whence the longitude is reckoned, and is deemed *east* or *west* according as it is situated. The eclipses of *Jupiter's satellites* afford a method of finding the longitude, thus : Suppose an eclipse of any *satellite* happens in London at six in the morning, and that it is seen at another place at four in the morning, the difference of time is two hours, which answers to 30 degrees west of London. These observations the motion of a ship hinders from being made at sea ; and hence may be perceived the extreme utility of a regular time-keeper.

The *latitude* of a place is so many degrees as it is from the equator ; if to the north, it is said to be in *north latitude* ; if to the south of the equator, in *south latitude* ; hence by the lines of latitude and longitude, the face of a globe is covered with *imaginary squares*, by which the situation of every spot on the face of the earth is as exactly ascertained as the parts of an estate are by its hedges and ditches.

The *rational horizon* of a place extends 90 degrees from the place on all sides. The *sensible horizon* is the boundary of the observer's sight on all sides.

The *ecliptic* is that circle in the heavens through which the earth makes its revolution round the sun; and it is distinguished by conspicuous assemblages of fixed stars, called signs or constellations, such as *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, &c. The *zodiac* extends to eight degrees on each side of the ecliptic, and with it round the heavens.

The four continents of the earth are, *Europe*, *Asia*, *Africa*, and *America*. The oceans are the *Northern*, the *Atlantic*, the *Ethiopic*, the *Indian*, the *Pacific*, and the *Southern Oceans*. The unknown parts of the earth contain 160,566,276 square miles; the inhabited parts 38,990,569, *i. e.* Europe 4,456,065; Asia 10,768,823; Africa 9,654,807; America 14,110,874. In all 199,556,845; which is the number of square miles on the whole surface of our globe.

When a round ball has the different countries, kingdoms, towns, and rivers delineated upon it agreeable to their situations, it is a representation of the earth. If an hollow spherical ball could have the fixed stars properly marked on its inside, with the sun, moon, and planets, it would be a representation of the heavens to an eye placed in its centre; but this being inconvenient, the fixed stars are placed on an opaque globe, and the sun and planets represented by patches placed on the ecliptic, because they are continually changing their places.

LECTURE XI.

On the MOON, &c.

THE *moon* is no planet, but only a satellite, or an attendant on the earth. The farther any planet is from the sun, the more occasion it has for such an help to its light; hence Mercury and Venus are without moons, as being near the sun; but Jupiter has four, and Saturn five, (now known to be seven) because of their distance from it.

The moon's face abounds with great *inequalities*, and hence she reflects a more chaste and agreeable light than if her surface was smooth. She always keeps the *same face* towards us (some say because the quality of that side of her is more adapted to catch the attraction of the earth than the other) and consequently must turn once round on her axis, while she goes once round the earth in her orbit. Her *periodical revolution*, or time of going round from one point of her orbit to the same point again, is 27 days 7 hours 43 minutes: But her *synodical revolution*, or time from change to change, is 29 days 12 hours 44 minutes;—this difference is caused by what the earth has advanced in the ecliptic during that time, which is 29 one-tenth degrees. (*Illustrated by the Orrery and Ferguson's paradox.*)

The moon's mean distance, found by her parallax, is 240,000 miles. Her diameter is 2180 miles,—and she moves about 2290 miles every hour.

The *moon* has no light of her own, but only reflects the beams of the sun, as a polished body does the light of a candle;—hence, as she is a globe, we must sometimes see *more* sometimes *less* of her enlightened side, *viz.* when she is between us and the sun, her dark side is towards us, and therefore she disappears; as she advances forward we see a small part of her enlightened side, and call it the *new moon*; because next evening she is got a few degrees farther to the east and we see *more* of her illumin'd side;—every evening we find her advanced till she rises in the east in opposition to the sun in the west, and ~~the~~ her whole enlightened face is towards us, and we say she is at the *full*; her decline is from the same reasons; and a ball over a gate enlightened by the sun conveys a clear idea of both. (*Illustrated by the Orrery.*)

The earth is a *moon* to the moon, waxing and waning as she does; it appears 13 times as large to the lunarians as the moon does to us, affording them both an useful and an amazing spectacle, for its continents and seas may be plainly perceived by them, as well as its rapid motion round its axis. (*Proved by the Orrery.*)

The planets as well as their satellites being *enlightened by the sun*, must cast *shadows* towards that part of the heavens opposite to the sun. Was the earth bigger than the sun, its shadow would spread and extend far beyond the orbit of Mars, and consequently *eclipse him*, for he is but 42 millions of miles from the earth, when they are in conjunction; but the earth's shadow never reaches him, therefore it must end in a *point* much short of that distance; another proof how much the sun is bigger than the earth: But the moon is eclipsed when she falls into the earth's shadow, which, for the reasons above, can never happen but when she is at the *full*, because that is the only time when she is opposite to him; but was she a *luminous body* she could not be darkened by the earth's shadow. (*Proved by a real sun and moon.*)

The sun is eclipsed when the moon passes directly between him and any part of the earth; this can only happen at the *change of the moon*. (*Proved in like manner.*)

Was the moon's orbit in the *plane* of the earth's path round the sun, she would be eclipsed every time she came to the *full*, and would eclipse the sun every time she came to the *change*; but one half of her orbit is on the *north side* of the ecliptic, and the other half on the *south side* of it, and must therefore cut the ecliptic in two opposite points, called the *moon's nodes*. The angle of this orbit with the ecliptic is 5 degrees and one third. (*Shewn on the Orrery.*)

When the moon is at full, above 12 degrees from either of these nodes, she passes clear of the earth's shadow, and cannot be eclipsed; and when she changes above 18 degrees from either of them, she passes either above or below the sun, and therefore cannot eclipse him: But if she be at full or change within those distances, then an eclipse happens, and if she be *in* the node, the eclipse is central. (*Explained by the Orrery.*)

If these nodes kept always in the *same* signs of the ecliptic, the sun and moon would always be eclipsed in the *same places* and at the *same time* every year:—but the eclipses *fall back* every year from the east to the west, in such a manner as to prove that the moon's orbit *moves backwards* 19 degrees one-third every year, so that in 18 years and 225 days there is a period or restitution of the *same eclipses*; and they then appear in the *same places* and the *same time* as before. (*Illustrated by the Orrery.*)

The earth and moon are chained to one another as it were by their *mutual attraction*, which, like the sun and planets, is in proportion to their quantities of matter. If an heavy and light ball be tied to the two ends of a string a yard long, and tossed up into the air, they will form to themselves a centre of gravity. On this centre of gravity the earth and moon revolve in *equilibrio*, and its distance from their centres is inversely as their quantities of mat-

ter, *viz.* 6000 miles from the earth's; consequently the centre of gravity forms the *real orbit*, and makes the earth 12000 miles nearer the sun at the time of *full moon*, than at the time of change. This is demonstrable by the sun's appearing so much larger at the full than at the change of the moon. (*Proved by the whirling tables.*)

The further any part of the earth is from this centre of gravity, the greater is its tendency to fly off in a tangent, — therefore the *side of the earth* which is turned away from the moon has a greater *centrifugal motion* than its *center* has: and this *centre* a greater than the *side* next the moon. At the earth's *centre*, the moon's attraction balances the centrifugal force, but must be *stronger* than the centrifugal force of the *side of the earth next her*, and *weaker* than the centrifugal force of the *side farthest from her*. As the moon's attraction is greater than the centrifugal force on that side of the earth next the moon, of course the *tide* will rise on that side: But as the centrifugal force on the opposite side is greater than the moon's attraction, the tide will also rise on that side; hence the reason of *two tides* in 25 hours. (*Proved by the tide table.*)

The sun agitates the water in proportion to the moon, as 3 to 10; therefore, when the sun and moon draw in the *same direction*, they cause a *spring tide*, and this happens at the change of the moon. If the earth had no moon, the sun would cause a *small tide* in its oceans, therefore at the full of the moon spring tides happen as well as at the change, for the sun's centrifugal tide being reinforced by the moon's attraction, and the moon's centrifugal tide by the sun's attraction, spring tides happen both at full and change of the moon; but at the quarters, when they attract in *contrary directions*, they destroy the effects of each other in a degree, and then we have *neap tides*. At the *equinoxes* the sun and moon being both on or near the equator, their attraction is more in a *line* than at most other seasons, hence the *prodigious tides* which generally follow these seasons, both in the air and sea. A planet

also falling in conjunction with the sun and moon, will increase the tides still more. (*Shewn by the tide tables.*)

The *air* being a fluid much lighter than water, is more affected by the moon's attraction. Hence at the full and change the barometer is most affected; and some say lunatics are more affected at those seasons.

To the inhabitants situated at a considerable distance from the equator, the *different parts* of the ecliptic rise at very *different angles* with the horizon. In northern latitudes, the signs *Pisces* and *Aries* rise with the *smallest angles*; *Virgo* and *Libra* with the *greatest*; therefore when the moon is in *Pisces* and *Aries* she must rise nearly at the *same hour* for six or seven days together. In *winter* the moon is in those signs about the time of her first quarter, but as she must then rise about *noon*, that rising is not taken notice of. In *spring* the moon is in them about her *change*, but as she then gives *no light*, her rising is also unnoticed. In *summer* she rises in *Pisces* and *Aries*, in her *third quarter*, about twelve o'clock at night, consequently the phænomenon is seldom *then* regarded; but in *autumn* those signs are opposite to the sun, and therefore the moon must be *full* in them, and, very usefully for the farmers, rises in their harvest immediately after sunset for several evenings together, and thence acquires the name of the *harvest moon*. (*Proved by the Orrery and Globe.*)

LECTURE XII.

A S T R O N O M Y.

THE planets are retained in their orbits by the *power of gravity*:—but as the sun is by far the largest body in our system, if no other power acted on them they would be *drawn down to the sun*. All bodies therefore that move in curves, as the planets do round the sun, must be acted upon by *two principles*; and motion being *rectilineal*, we suppose the Almighty gave each planet this kind of impulse at its creation, so that between one power *drawing to the centre*, and another *acting perpendicular to it*, the planets are impelled in elliptic orbits round the sun, as a pebble tied to a mill-stone, and thrown from the hand, would revolve round the mill-stone. An idea of this is given by a ball impelled singly in a square in two directions, one perpendicular to the other; when they both act they give the diagonal of the square, &c.

Our system must be conceived as within the concave sphere seeming to be formed by the *fixed stars*, and the *sun* as near the centre of it, an huge globe of fire, near a million of miles in diameter, and near 100 millions of miles from the earth, according to calculations made from the transits of Venus.—He turns round on his axis in 25 days and 8 hours, as may be seen by spots on his face; and was no doubt intended to give light, heat, and vegetation to the six primary and ten secondary planets which revolve round him.

All these planets move round the sun from *west by south, to east*, in orbits nearly circular, and almost in the same plane. The *comets* move in all manner of directions, in orbits which are very long ellipses, much inclined to one another, and to all the orbits of the planets. The tails of comets are only thin vapours; for if they were flame no star could be seen through them.

The time in which any planet goes round the sun is the *length of its year*, and the time on which it turns round on its axis, is the *length of its day and night* taken together, as represented on the Orrery.

The nearest planet to the sun is *Mercury*; he goes round him in 87 days 23 hours, is about 3000 English miles in diameter, and distant from the sun 42 millions of miles; he moves in his orbit about 100 thousand miles every hour; the length of his days and nights are unknown, being but 56 times the sun's apparent diameter from him; he sets and rises too near the sun for any observations to be made of his spots.

Venus goes round the sun in 224 days 17 hours, her diameter is near 7,900 miles, her distance from the sun is 79 millions of miles, her hourly motion in her orbit is 69 thousand miles, and she turns round on her axis in 24 days 8 hours of our time. By her axis inclining 75 degrees from a perpendicular to her orbit, (agreeable to the older astronomers), she has two summers and two winters at her equator.

Her orbit also deviates three one-half degrees from the plane of the ecliptic, so that she has two nodes, or places where she crosses the ecliptic, one in the 14th degree of Gemini, and the other in the 14th of Sagittarius. If the earth happens to be in those signs when *she* is, then we see her transit over the sun's face, a phænomenon which happened the 1st of April, 1761, and gave the astronomers

the opportunity of calculating the sun's parallax, *viz.* 7" 40" and of consequence his distance, as well as that of the planets.

The *earth* is the next planet in the order of the system.

Mars, still higher in the system, is 167 millions of miles distant from the sun, moves at the rate of 47,000 miles an hour, goes round the sun in 678 days, and turns round on his axis in 23 hours 39 minutes and 22 seconds, at a medium, according to Dr. Herschel's observations on a spot on the face of Mars; though he observes his motion not to be regular. He is about one-fifth as large as our earth; his *red appearance* is supposed to be occasioned by a gross thick atmosphere with which he is surrounded, and which is supposed to supply his want of a moon.

Jupiter, the largest of the planets, is 570 millions of miles distant from the sun, and above 400 millions from our orbit; he moves round the sun in about 12 years of our time, at the rate of 30,000 miles per hour; he is near 90,000 miles in diameter (*i. e.* near 1000 times as large as our earth) is accompanied by four moons, some bigger and some less than the earth, which revolve round him as our moon does round us; and the faint substances on his face, called his belts, are supposed to be parts of his atmosphere drawn into lines by his exceeding quick revolution on his axis, which is once in 9 hours 49 minutes.

Saturn, the second in magnitude, and hitherto considered the most distant of all the planets, is 949 millions of miles from the sun;—near 70,000 miles diameter; moves at the rate of 18,000 miles an hour,—but is too remote for his spots to be seen. He is equipt with *five moons*, (Dr. Herschel has seen two more) besides a *broad luminous ring* which also reflects the sun's light strongly

upon him. This planet is near 30 of our years in making his revolution round the sun.

The *Georgian Planet* (or rather the *Herschel*) so called by its ingenious and indefatigable discoverer Dr. Herschel; was first seen near one of the feet of Gemini; its year is calculated to be $82\frac{1}{2}$ of ours, its distance twice that of Saturn from the sun, and its size 100 times as large as our earth.

These calculations are the latest and most accurate that have been made; they are given in round numbers, to ease the memory, and are founded on *mathematical* as well as *ocular* certainty.

By an *attempt* at the same kind of calculation to 'find the distance of the *fixed stars*, 'twas found *that the whole diameter of the earth's orbit would not make a parallax or angle with the nearest of them!* Their distance therefore must be inconceivably great. Light diminishing as the squares of the distances increase, the sun's rays therefore cannot enlighten the fixed stars; and a telescope which magnifies 400 times does not sensibly magnify them; 'tis therefore highly probable they are *suns* like ours, shine by their own unborrowed lustre, were not intended for our service, but to give light, heat, &c. to systems of worlds of their own, formed probably for the same purposes as ours, though too remote for our eyes assisted by the best glasses to perceive. We find the worlds of our system covered with *continents, seas, hills, &c.* Who can doubt therefore but they are inhabited, as well as all the worlds of the other systems? How much too big is this idea for the human imagination! By the lately improved telescopes thirty thousand of these suns have been found more than the naked eye can perceive! Were our glasses still better, we should, no doubt, find more — 'tis not improbable there may be stars so distant that their light has not reached the earth since the creation. Many of those stars appear double, and coloured green, blue, red, violet, &c.

Let us on the wings of imagination then launch into the immensity of space, and behold *system* beyond *system*, *above us*, *below us*, to the *east*, the *west*, the *north*, the *south*! Let us go so far as to see our sun but a *star* among the rest, and our system itself as a point, and we shall but even then find ourselves on the *confines of creation*! How inadequate then must be the utmost stretch of human faculties, to a conception of that amazing *Deity* who made and governs the whole! Should not the narrow prejudices, the littleness of human pride soften into humility at this thought!

E X P L A N A T I O N

Of such uncommon Words as cannot, without affectation, be omitted in this COURSE.

*A*BSORB, to drink in.

Acid, sour.

Accelerated, hastened, hurried forward.

Accumulate, to heap up.

Adhesion, the sticking together.

Affinity, related to, having an affection for.

Alkali, fixed salt or substances effervescing with acids.

Analogy, likeness, proportion.

Apparatus, instruments for experiments.

Attraction, a drawing together.

Axis, an axle on which any thing turns.

C

Capillary, small as an hair.

Calcs, the earth or cinders of a metal.

Centrifugal, a direction given to a body different from that inclining to the centre.

Centripetal, tending towards the centre.

Cohesion, clinging or sticking together.

Collateral, lying side by side.

Compress, to squeeze together.

Concave, spherically hollow.

Condense, to bring the parts of matter close together.

Contact, touching each other.

Convex, swelling spherically outwards.

Converge, to draw towards a point.

ChrySTALLIZATION, salts shooting into their usual forms.

Cylinder, like a rolling stone.

D

Density, compactness, closeness.

Diagonal, the line running between opposite corners of a square.

Diverge, to spread out.

E

Ebullition, a bubbling like boiling water.

Elastic, having a spring.

Electrometer, an electrical gage.

Effervescence, a ferment or discharge of fixed air, waxing hot.

Ellipses, an oval line or surface.

F

Fibre, a small string.

Flaccid, lax, loose, or flabby.

Fulcrum, a prop or point of support.

Frigorific, chill, or causing cold.

G

Gravity, weight, or the tendency one body has to another.

H

Hemisphere, half a globe.

Hermetically sealed, tube closed with melted glass.

Hypothesis, a supposition.

I

Immerse, to dip or plunge in.

Impel, to drive onwards.

Incompressible, not to be squeezed into less compass.

Incidence,

- Incidence*, a falling or lighting on.
- Insulate*, to cut off, like an island.
- Interstices*, intervals, or intermediate spaces.
- L
- Lateral*, sideway.
- Longitudinal*, lengthwise.
- M.
- Medium*, a means of conveyance.
- Momentum*, the moving force of a body.
- N.
- Nomenclature*, a system of relative names given to chemical substances.
- O.
- Oblique*, crooked, inclining.
- Orbit*, the tract described by a planet round the sun.
- Oxygenous Principle*, dephlogisticated air.
- P.
- Particles*, exceeding small parts.
- Percussion*, striking, or the effects of a stroke.
- Perforate*, to bore through.
- Piston*, a moveable plug, just fitting a pipe.
- Phenomenon*, an appearance in nature.
- Phlogiston*, one of the principles of inflammability in bodies.
- Pores*, small interstices in bodies.
- Preponderate*, to descend, be heavier.
- Projectile*, a body in motion, cast or thrown.
- R.
- Rarefy*, to thin, to make dense matter weaker.
- Reflection*, rebounding back, returning.
- Reciprocal*, mutual, relative.
- S.
- Refract*, to incline, or break.
- Reservoir*, a cistern, or head for a reserve of water.
- Reverberate*, to beat back, to echo.
- Rotation*, returning about.
- S.
- Saturation*, absorption, drinking in, &c.
- Secrete*, to separate.
- Sensorium*, the seat of perception in the brain.
- Solution*, a solid dissolved in a fluid.
- Species*, sort or kind.
- Specific*, peculiar, bulk for bulk.
- Spiral*, like a rope coiled round.
- Subterraneous*, within the earth.
- Sublimation*, distillation of dry substances.
- Syphon*, a bent tube, or crane.
- System*, composing a general structure.
- T.
- Tangent* a straight line touching the circumference of a circle.
- Tangible*, capable of being felt or handled.
- Tenacity*, a clinging together.
- Tension*, a stretching out.
- Transit*, the passing of a planet before the face of another, or the sun.
- Tube*, a pipe.
- V.
- Vacuum*, a space devoid of air.
- Valve*, a trap door, letting a fluid come thro' but not return.
- Velocity*, the moving speed.
- Vertex*, the point at the top of any thing.
- Vibrate*, to swing as a pendulum.
- Undulating*, moving in waves.
- Volatile*, subject to evaporate or fly off.