PARKER'S

First lesson

IN

NATURAL PHILOSOPHY.

博物楷梯

日本

海軍兵學寮

開版

N° 1

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CONTENTS.

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NATURAL PHILOSOPHY.

Lesson I.

OF MATTER.

1. What is Natural Philosophy?

Natural Philosophy treats of the properties of bodies, and the laws and operations of the material world.

2. What is Matter?

Matter is the general name of every thing which has length, breadth, and thickness.

3. What other words are used to express matter?

The words substance, body, or bodies, are but different names of the same thing, and all mean matter.

4. What is a body?

A body is any portion of matter.

5. How is matter supposed to be composed?

All matter is composed of very minute particles.

6. Are these particles held together in the same way in all bodies?

They are not.

7. In how many forms does matter exist?

Two—in a solid and fluid form.

8. When does matter exist in a solid form?

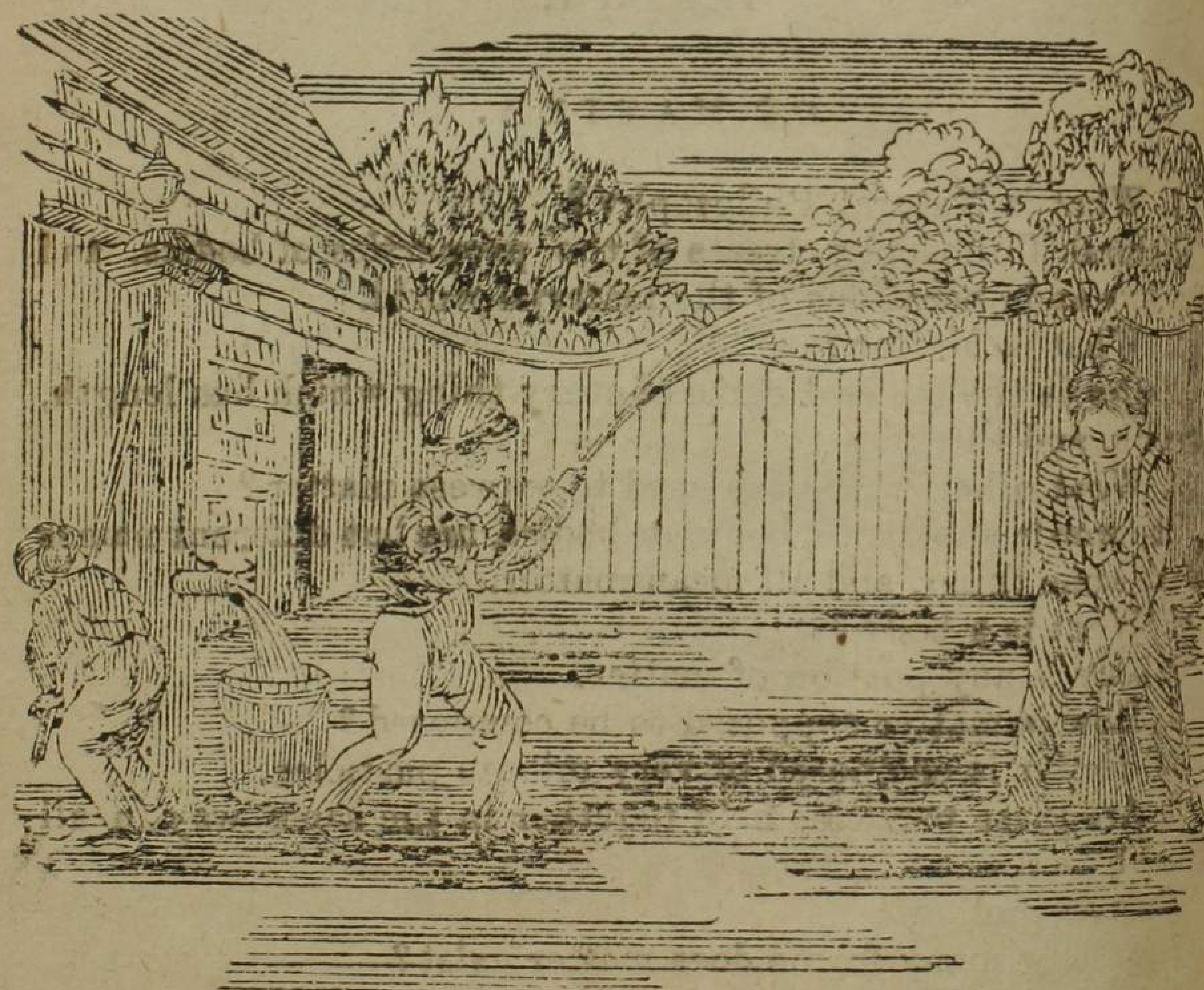
Matter exists in a solid form when the particles of which it is composed adhere together, so that one particle cannot be moved without moving the whole.

Give examples of matter existing in a solid form.

9. When does matter exist in a fluid form?

Matter exists in a fluid form when the particles do not adhere together, but move easily among themselves.

Give examples of matter in a fluid form.



JOHN WITH MATTER IN A FLUID FORM—CHARLES WITH A SOLID.

Lesson II.

ESSENTIAL PROPERTIES OF MATTER.

1. How many essential properties of matter are there, and what are they?

There are six essential properties belonging to all matter, namely: 1. Impenetrability, 2. Extension, 3. Figure, 4. Divisibility, 5. Indestructibility, and 6. Inertia.

2. Why are these called essential prorerties?

They are called essential properties, because no particle of matter can be deprived of them, or exist without them.

3. What is Impenetrability?

Impenetrability is the power of occupying a certain space, so that where one body is, another cannot be, without displacing it.

4. Does this power belong to fluids as well as solids?

It belongs to fluids as well as solid bodies. The reason why fluids appear less impenetrable than solid bodies, is, that the particles of which they are composed move easily among themselves.

5. What is Extension?

Extension is but another name for bulk, or size; and it is expressed by the terms length, breadth, width, height, depth, and thickness.

6. What is Figure?

Figure is the form or shape of a body. Two circles or two balls may be of the same shape or figure, while they differ in extension. The limits of extension constitute figure.

7. What is Divisibility?

Divisibility is susceptibility of being divided. To the divisibility of matter there is no known limit.

8. How may a single grain of gold be divided?

A single grain of gold may be hammered by a goldbeater until it will cover fifty square inches; each square inch may be divided into two hundred strips; and each strip into two hundred parts. One of these parts is only *one two-millionth* part of a grain of gold, and yet it may be seen with the naked eye.

9. Give another example of the divisibility of matter.

The particles which escape from odoriferous objects also afford instances of extreme divisibility.

10. What is Indestructibility?

By the Indestructibility of matter is meant that it cannot be destroyed.

11. May it be continually divided?

It may be forever divided, or altered in its form, color, and accidental properties, but it must still continue to exist in some form through all its changes of external appearance.

12. Give examples.

When water disappears, either by boiling over a fire, or evaporating by the heat of the sun, or, in other words, when *"it dries up,"* it rises slowly in the form of steam or vapor.

13. What becomes of the vapor or steam?

The vapor ascends in the air and constitutes clouds; these

clouds again fall to the earth in the shape of rain, snow, or hail, and form springs, fountains, rivers, &c.

14. Are the substances of which fuel is composed destroyed when it is burnt?

The simple substances of which fuel is composed are not destroyed when the fuel is burnt. Parts of them arise in smoke or vapor, and the remainder is reduced to ashes.

15. Does a body when burning undergo changes?

A body in burning undergoes remarkable changes; but the various parts into which it has been separated by combustion, continue in existence, and retain all the properties of bodies.

16. What is Inertia?

Inertia is the resistance which inactive matter makes to a change of state, whether of motion or rest. A body at rest cannot put itself in motion, nor can a body in motion stop itself.

Lesson III.

QUALITIES WHICH DISTINGUISH DIFFERENT KINDS OF MATTER.

1. What are the qualities which distinguish one kind of matter from another?

They are Porosity, Density, Rarity, Compressibility, Expansibility, Mobility, Elasticity, Malleability, Brittleness, Ductility, and Tenacity.

2. What are pores?

Pores are small spaces which separate the particles of matter from each other.

3. When is a body said to be dense?

A body in which the pores are small and few in number, is called a *dense* body.

4. When is a body said to be rare?

When the pores are large and numerous, the body is said to be *rare*.

5. What does Density imply?

Density implies the closeness and compactness of the particles of a body, and indicates the quantity of matter contained in it under a given bulk.

6. What does Rarity imply?

Rarity is the reverse of density, and implies extension of bulk, without increase of quantity of matter.

7. what is Compressibility?

Compressibility implies the reduction of the limits of extension. Of this all substances are susceptible if a sufficient force be applied.

8. What is Expansibility?

Expansibility is the reverse of compressibility, and implies the increase of the limits of extension.

9. What is Mobility?

Mobility implies susceptibility of motion.

10. What is Elasticity?

Elasticity is the property which causes a body to resume its shape after being compressed or expanded.

11. Give examples.

Thus, when a bow is bent, its elasticity causes it to resume its shape. India-rubber possesses this property in a remarkable degree, but the gases in a still greater.

12. What bodies are very elastic, and which are not?

The elasticity of ivory is very perfect, that is to say, it restores itself after compression with a force very nearly equal to that exerted in compressing it. Liquids, on the contrary, have scarcely any elasticity.

13. What is Malleability?

Malleability implies susceptibility of extension under the hammer, or the rolling-press.

14. Does this property belong to all metals?

This property belongs to some of the metals, such as gold, silver, iron, copper,&c., but not to all.

15. What metal is the most malleable?

Gold is the most malleable of all metals.

16. What is Brittleness? To what bodies does it belong?

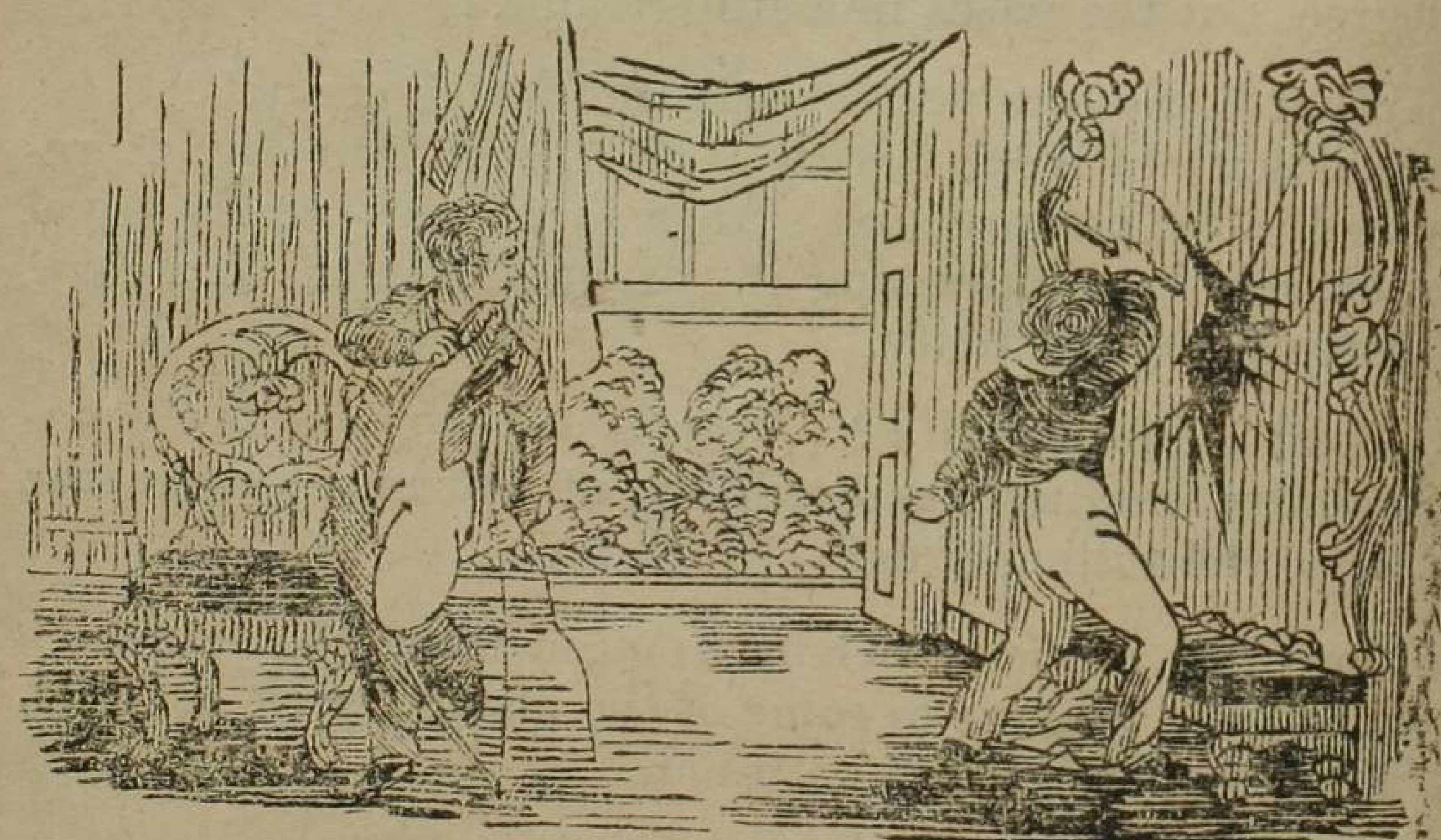
Brittleness is the reverse of malleability, and implies aptness to break into irregular fragments. This property belongs chiefly to hard bodies.

17. What is Ductility? Which is the most ductile metal?

Ductility is that property which renders a substance susceptible of being drawn into wire. Platina is the most ductile of all metals. It can be drawn into wire scarcely larger than a spider's web.

18. What is Tenacity? Which is the most tenacious metal?

Tenacity implies a great degree of adhesion among the particles of bodies. The tenacity of bodies constitutes their strength, or their capability of sustaining weight. Iron, on account of its fibrous structure, is very tenacious.



JOHN BENDING HIS BOW—ISAAC BREAKING THE GLASS.

Lesson IV.

ATTRACTION OF MATTER.

1. What is attraction?

Attraction is the tendency which particles of matter, or bodies have to approach each other.

2. How many kinds of attraction are there?

There are two kinds of attraction.

3. Name them.

The attraction of cohesion and the attraction of gravitation.

4. What is the attraction of cohesion?

The attraction of cohesion is that which unites the particles of a body.

5. What is the attraction of gravitation?

The attraction of gravitation is that which causes bodies at a distance to approach each other.

6. Give an example which will show the difference between the attraction of cohesion and the attraction of gravitation.

By the attraction of cohesion the particles which compose a stone are held together. By the attraction of gravitation the stone falls to the ground.

7. Explain further the difference between the attraction of cohesion and the attraction of gravitation.

The difference between the two kinds of attraction is this: the attraction of cohesion takes place in very minute particles, and at very small distances; the attraction of gravity acts on all bodies and at all distances. The attraction of cohesion takes place between the particles of the same body. The attraction of gravitation causes different bodies to approach each other.

8. What do you understand by gravity?

Gravity expresses the power with which one body attracts another.

9. If a stone be thrown into the air, what will become of it? And why?

If a stone be thrown into the air, it will soon fall to the earth. This is caused by the attraction of the earth.

10. What causes weight?

Weight is caused by the attraction of gravitation.

11. What do you mean when you say a body weighs an ounce, a pound, or a hundred pounds?

When we say that a body weighs an ounce, a pound, or a hundred pounds, we express, by these terms, the degree of attraction by which it is drawn towards the earth.

12. What then is weight?

Weight is the measure of the earth's attraction.

13. What bodies then will weigh the heaviest?

As this attraction depends upon the quantity of matter there is in a body, it follows that those bodies which contain the most matter will be most strongly attracted, and will consequently be the heaviest.

Lesson V.

OF MOTION AND VELOCITY.

1. What is motion?

Motion is a continued change of place.

2. Can a body put itself in motion, or stop itself?

On account of the inertia of matter, a body cannot put itself in motion, nor when it is in motion can it stop itself.

3. What is meant by the terms *force* and *resistance*?

The power which puts a body into motion is called a *force*; and the power which has a tendency to stop or impede motion is called *resistance*.

4. How does a body move when impelled by a single force?

The motion of a body impelled by a single force is always in a straight line, and in the same direction in which the force acts.

5. What is velocity?

The rapidity with which a body moves is called its velocity.

6. How is the velocity of a moving body determined?

The velocity of a moving body is determined by the time that it occupies in passing through a given space. The greater the space, and the shorter the time, the greater is the velocity. Thus, if one body move at the rate of six miles, and another twelve miles in the same time, the velocity of the latter is double that of the former.

7. How do you ascertain the space passed over by a moving body?

The space also may be ascertained by multiplying the velocity by the time. Thus, if the velocity be five miles an hour, and the time twenty hours, the space will be twenty multiplied by five, which is one hundred miles.

8. How many kinds of motion are there?

There are three terms applied to motion to express its kind; namely, uniform, accelerated, and retarded motion.

9. What is uniform motion?

Uniform motion is that of a body passing over equal spaces in equal times.

10. What is accelerated motion?

Accelerated motion is that in which the velocity continually increases as the body moves.

11. What is retarded motion?

Retarded motion is that in which the velocity decreases as the body moves.

12. How is uniform motion produced?

Uniform motion is produced by a force having acted on a body, and then ceasing to act.

A ball struck by a bat, or a stone thrown from the hand, is in theory an instance of uniform motion; and if both the attraction of gravity and the resistance of the air could be entirely removed, it would proceed onwards in a straight line, and with a uniform motion forever.

13. How is accelerated motion produced?

Accelerated motion is produced by the continued action of one or more forces.

14. Give an example.

When a stone falls from a height, the impulse which it receives from gravity would be sufficient to bring it to the ground with a uniform velocity. But the stone while falling at this rate is still acted upon by gravity with an additional force, which continues to impel it during the whole time of its descent.

15. How far will a body fall in the first second of time? How far in the second? Third, &c.?

In the first second it falls sixteen feet, three times that distance in the next, five times in the third, seven times in the fourth, and so on, regularly increasing its velocity according to the number of seconds consumed in falling.

16. How may the height of a building, or the depth of a well, be measured by gravity?

The height of a building, or the depth of a well, may be measured by observing the length of time which a stone takes in falling from the top to the bottom.

17. How is retarded motion produced?

Retarded motion is produced when a body in motion encounters a force operating in an opposite direction.

18. Give an example.

When a stone is thrown perpendicularly upwards, the force of gravity is continually operating in the opposite direction, and attracting it downwards to the earth. The stone moves upwards slower and slower, until the upward motion ceases, and the body returns with accelerated motion to the earth. It is found that a body thrown perpendicularly upwards, takes the same length of time in ascending that it takes in descending.

ATTRACTION OF GRAVITATION.

Lesson VI.

OF COMPOUND MOTION.

1. What is compound motion?

Compound motion is caused by the action of two or more forces upon a body at the same time.

2. Suppose a body is struck by two equal forces in opposite directions, what will be the result?

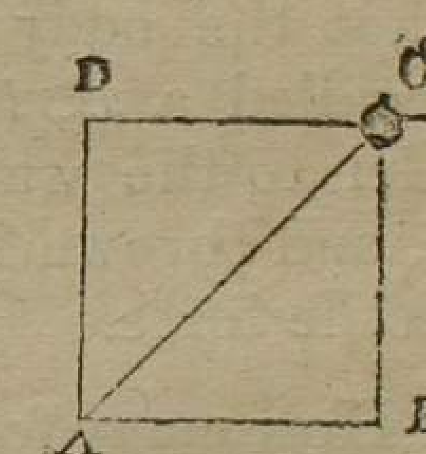
When a body is struck by two equal forces in opposite directions, it will remain at rest.

3. How will a body move, if struck by forces in different directions?

A body struck by two forces in different directions, will move in a line between them.

4. Explain this.

Let the figure represent a ball struck by two forces in the direction CB and CD. Suppose that the first force would send it from C to B in the same time that the second would send it from C to D. As it cannot obey both, it will go between them to A.



5. What time is occupied in passing from C to A?

The time occupied in its passage from C to A, is the same as would be required to pass over CB or CD, if the forces acted separately.

6. What is the line CA?

The line CA is called a diagonal.

7. What is rectilinear motion?
Rectilinear motion is motion in a straight line.
8. What is curvilinear motion?
Curvilinear motion is motion in a curved line.

9. What motion will be produced by the action of a single force?
A rectilinear motion.
10. How is curvilinear motion produced?
By the action of two or more forces.

11. What is a projectile?
A projectile is a body thrown into the air, as a rocket, a ball from a gun, or a stone from the hand.
12. If a body be thrown into the air, what is the force called which impels it?
It is called a projectile force.

13. What names are applied to projectile force?
When the body is thrown directly upwards or downwards it is called a *vertical* projectile force. When it is thrown parallel to the water-level, it is called a *horizontal* projectile force, and thrown in any other direction, it is called an *oblique* projectile force.

14. How many forces will act upon a body thrown horizontally?
A ball thrown in a horizontal direction is influenced by three forces.
15. What are they?
The first is the force of the projection; the second, the resistance of the air through which it passes; and the third, the force of gravity, which finally brings it to the ground.

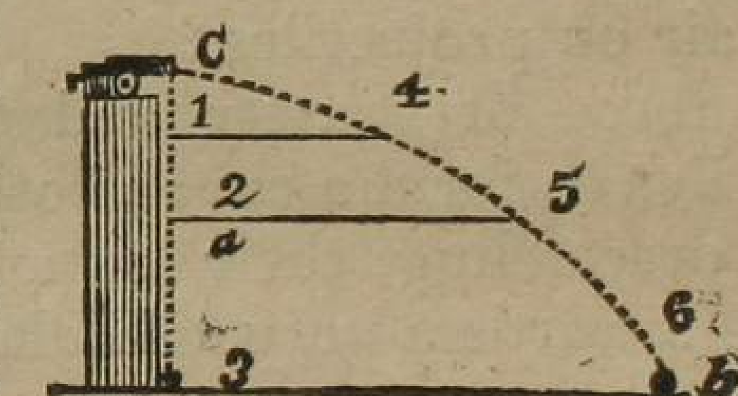
Lesson VII.

MOTIONS RESULTING FROM TWO FORCES.

1. What is resultant motion?
Resultant motion is the effect or result of two motions compounded into one.

2. Is the force of gravity affected by the projectile force?
The force of gravity is neither increased nor diminished by the force of projection.

3. Give an example illustrating this.
The figure represents a cannon, loaded with a ball, and placed on the top of a tower, at such a height as to require just three seconds for another ball to descend perpendicularly to the ground. Now suppose the cannon be fired in a horizontal direction, and at the same instant the other ball to be dropped towards the ground. They will both reach the horizontal line at the base of the tower at the same instant.



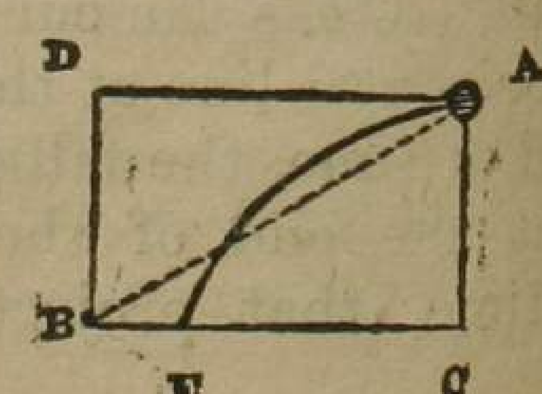
In this figure C *a* represents the perpendicular line of the falling ball. C *b* is the curvilinear path of the projected ball; 3 the horizontal line at the base of the tower. During the first second of time, the falling ball reaches 1, the next second 2, and at the end of the third second it strikes the ground. Meantime, that projected from the cannon, moves forward with such velocity, as to reach 4 at the same time that the falling ball reaches 1. But the projected ball falls downward exactly as fast as the other, since it meets the line 1 4, which is parallel to the horizon, at the same instant. During the next second the ball from the cannon reaches 5, while the other falls to 2, both having an equal descent. During the third second the projected ball will have spent nearly its whole force, and therefore its downward motion will be greater while the motion forward will be less than before. *Hence it appears that the horizontal motion does not interfere with the action of gravity, but that a projectile descends with the same rapidity while moving forward, that it would if it were acted on by gravity alone.* This is the necessary result of the action of two forces.

4. What effect have the force of gravity and the resistance of the air on projectiles?

The force of gravity and the resistance of the air cause projectiles to form a curve both in their ascent and descent; and in descending, their motion is gradually changed from an oblique towards a perpendicular direction.

5. Give an illustration of this.

In the figure, the force of projection would carry a ball from A to D, while gravity would bring it to C. If these two forces alone prevailed, the ball would proceed in the dotted line to B. But as the resistance of the air operates in direct opposition to the force



of projection, instead of reaching the ground at B, the ball will fall somewhere about E.

6. What is the curved line A B called, which a body would describe when acted on both by a projectile force and by the force of gravity?

It is called a parabola.

7. when a body is thrown obliquely, what curve will it then describe?

It will still describe a parabola similar to the curve represented in the figure.

8. What is a pendulum?

A pendulum consists of a weight or ball suspended by a rod, and made to swing backwards and forwards.

9. What are the motions of a pendulum calld?

The motions of a pendulum are called its vibrations.

10. By what are they caused?

They are caused by gravity.

11. What is the part of the circle called through which it moves?

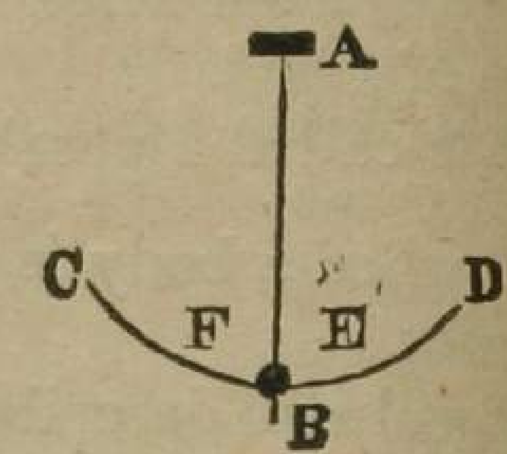
The part of a circle through which it moves is called its *arc*.

12. How do the times of vibrations compare, when the pendulums are of equal length?

The vibrations of pendulums of equal length, are very nearly equal, whether they move through a greater or less part of their arcs.

13. Explain the vibrations of the pendulum.

In the figure, A B represents a pendulum, D E F C the arc in which it vibrates. If the pendulum be raised to E it will return to F, if it be raised to C it will return to D in nearly the same length of time, because that in proportion as the *arc* is more extended, the steeper will be its beginnings and endings, and, therefore, the more rapidly will it fall.



14. On what does the time occupied in the vibration of a pendulum depend?

The time occupied in the vibration of a pendulum, depends upon its length. The longer the pendulum, the slower are its vibrations.

15. What is the length of a pendulum which vibrates sixty times in a minute?

The length of a pendulum which vibrates sixty times in a minute (or, in other words, which vibrates seconds) is about 39 inches.

16. How is a clock regulated?

A clock is regulated by lengthening or shortening the pendulum. By lengthening the pendulum, the clock is made to go slower; by shortening it, it will go faster.

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Lesson VIII.

MOMENTUM.

1. What is the momentum of a body?

The momentum of a body is its quantity of motion, or the force with which it would strike against another body. It is measured by multiplying its weight by its velocity.

2. Give an example of momentum.

If a body weighing six pounds move at the rate of two miles in a second of time, its momentum may be represented by six multiplied by two, which is twelve. Hence a small or a light body may be made to strike against another body with a greater force than a heavy one, simply by giving it sufficient velocity.

3. What are action and reaction?

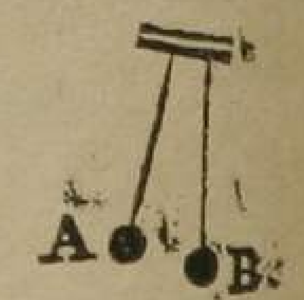
The *action* of a body is the effect which it produces upon other bodies *Reaction* is the effect which it receives from the body on which it acts. Thus, when a body in motion strikes against another body, it acts upon it, or produces action; but it also meets with resistance from the body which is struck, and this resistance is the reaction of the body.

4. Are action and reaction equal or unequal?

Action and reaction are always equal, but in opposite directions.

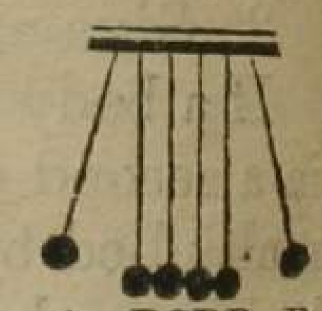
5. Give an example of this.

Let A and B represent balls of equal weight, &c., suspended by threads. If the ball A be drawn a little on one side and then let go, it will strike against the other ball B, and drive it off to a distance equal to that through which the first ball fell; but the motion of A will be stopped, because when it strikes B it receives in return a blow equal to that which it gave, but in a contrary direction, and its motion is thereby stopped, or rather, given to B.



6. Give another example.

Let A, B, C, D, E, and F represent six ivory balls, of equal weight, suspended by threads. If the ball A be drawn out of the perpendicular, and let fall against B, it will communicate its motion to B, and receive a re-action from it which will stop its own motion. But the ball B cannot move without moving C; it will therefore communicate the motion which it received from A to C, and receive from C a reaction which will stop its motion. In like manner the motion and reaction are received by each of the balls, D, E, F; but as there is no ball beyond F to act upon it, F will fly off.



Lesson IX.

CENTRE OF GRAVITY.

1. What is the centre of grvity of a body?

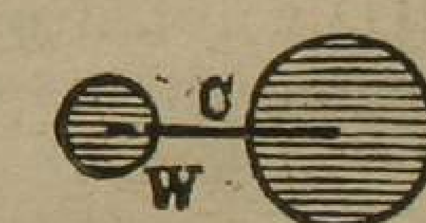
The centre of gravity of a body is a point about which all the parts balance each other.

2. If two equal bodies be fastened together by a bar, will they have a common centre of gravity, and where will it be?

Let W A W represent a bar with an equal weight fastened at each end: the centre of gravity is at A, the middle of the bar, and whatever supports this centre will support both the bodies and the bar.

3. If the weights are unequal, where will the centre of gravity be found?

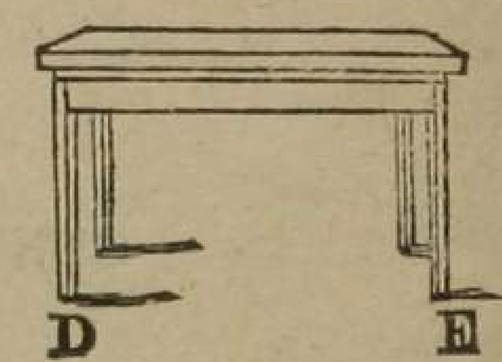
If the weights are unequal, as in the next figure, the centre of gravity will be at C, nearer to the larger body.



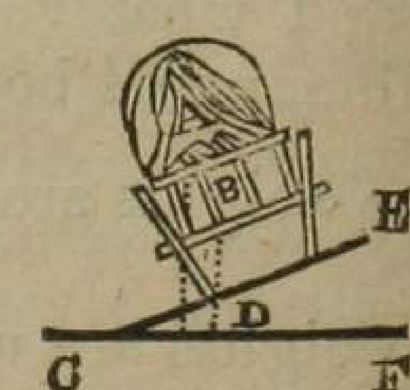
4. May the centre of gravity ever fall within the larger body?

The larger weight may exceed the less in such a degree that the centre of gravity will be *within* the larger body at C.

5. What is the line of direction of a body?
A line, drawn fröm the centre of gravity, perpendicular to the horizon, is called *the line of direction.*

6. What is the base of a dody?

The base of a body is its lowest side. The base of a body standing on wheels or legs, is represented by lines drawn from the lowest part of one wheel or leg, to the lowest part of the other wheel or leg. Thus, D E represents the base of the table.

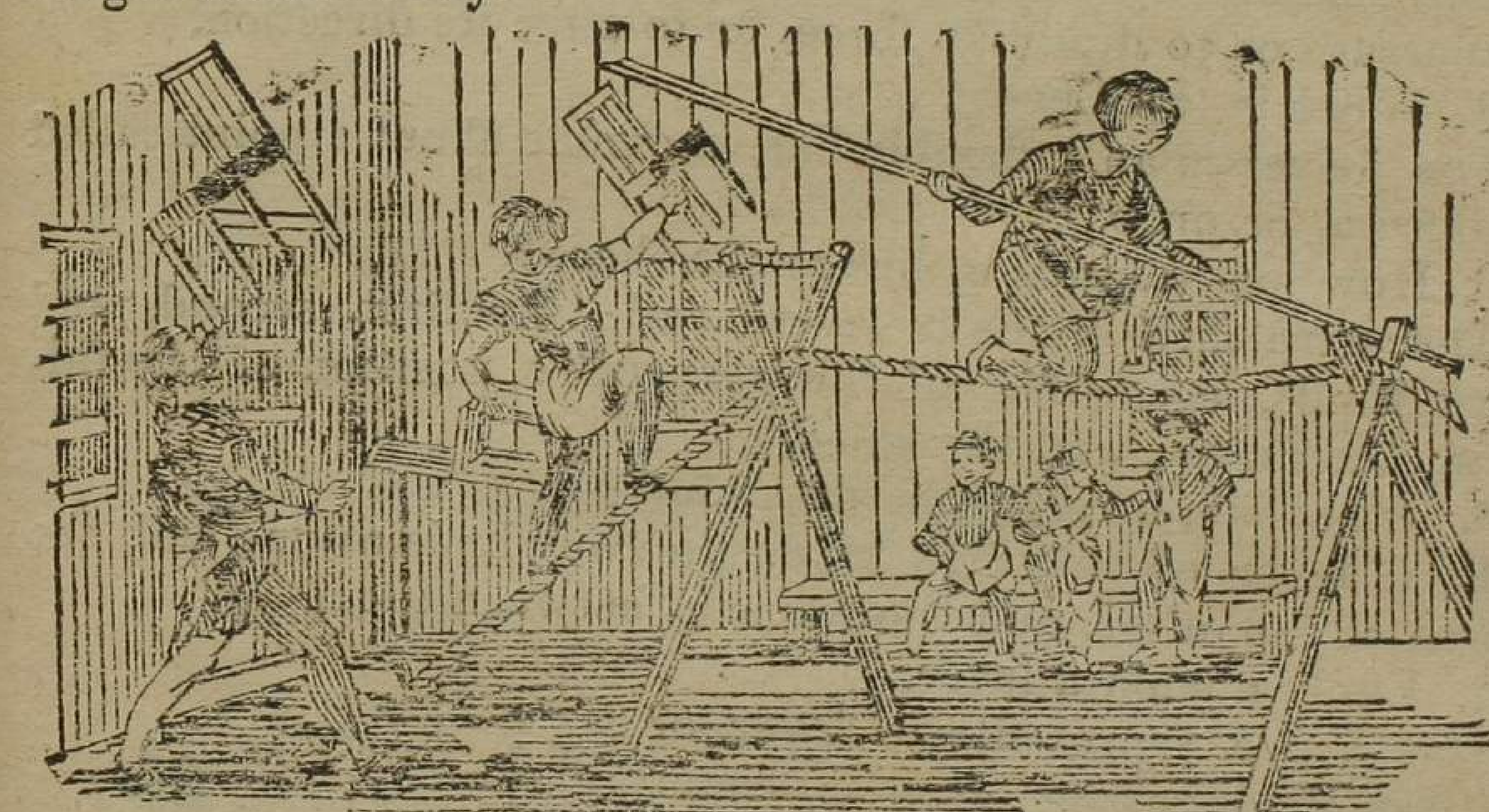
7. When will a body stand, and when will it fall?
When the line of direction falls within the base of any body, the body will stand; but when that line falls outside of the base, the body will fall or be overset.

8. Give an example of this.
Suppose a loaded wagon on the declivity of a hill. The line C F represents a horizontal line, D E the base of the wagon. If the wagon be loaded in such a manner that the centre of gravity be at B, the *line of direction* B D will fall within the base, and the wagon will stand. But if the load be altered so that the centre of gravity be raised to A, the *line of direction* A C will fall outside of the base, and the wagon will be overset.


9. When will a wagon or carriage be most firmly supported?
A wagon, or a carriage, will be most firmly supported when

the line of direction falls exactly between the wheels; and that is the case on a level road.

10. Where is the centre of gravity of the human body, and where the base?
The centre of gravity in the human body is between the hips, and the base is the feet. So long as we stand uprightly, the line of direction falls within this base. When we lean on one side, the centre of gravity loses its support, and we no longer stand firmly.



11. How do rope-dancers perform their feats of agility?
A rope-dancer performs his feats of agility, by dexterously supporting the centre of gravity. For this purpose he carries a heavy pole in his hands, which he shifts from side to side as he alters his position, in order to throw the weight to the side which is deficient; and thus, by changing the situation of the centre of gravity, he keeps the line of direction within the base, and he will not fall.

Lesson X.

OF THE LEVER.

1. What are the Mechanical Powers?

The Mechanical Powers are certain contrivances designed to increase or to diminish force, or to alter its direction.

2. What is the Lever?

The Lever is an inflexible bar, movable about a point called a fulcrum, or prop.

3. How many kinds of levers are there?

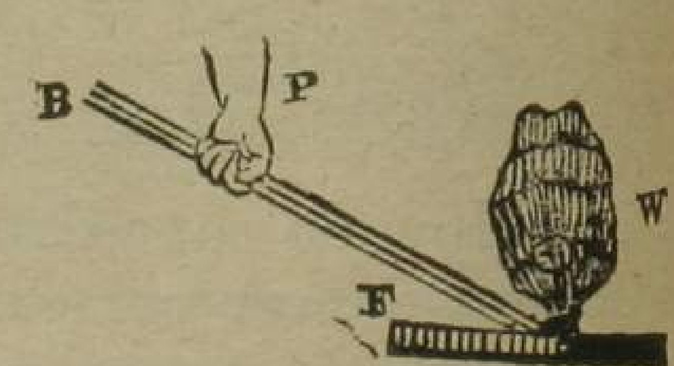
There are three kinds of levers, called the first, second, and third kinds, according to the respective position of the fulcrum, the power, and the weight.

4. What is a lever of the first kind?

In a lever of the first kind, the weight is at one end, the power at the other, and the fulcrum between them.

5. Explain such a lever.

The figure represents a lever of the first kind, resting on the fulcrum F, and movable upon it. W is the weight to be moved, and P is the power which moves it.

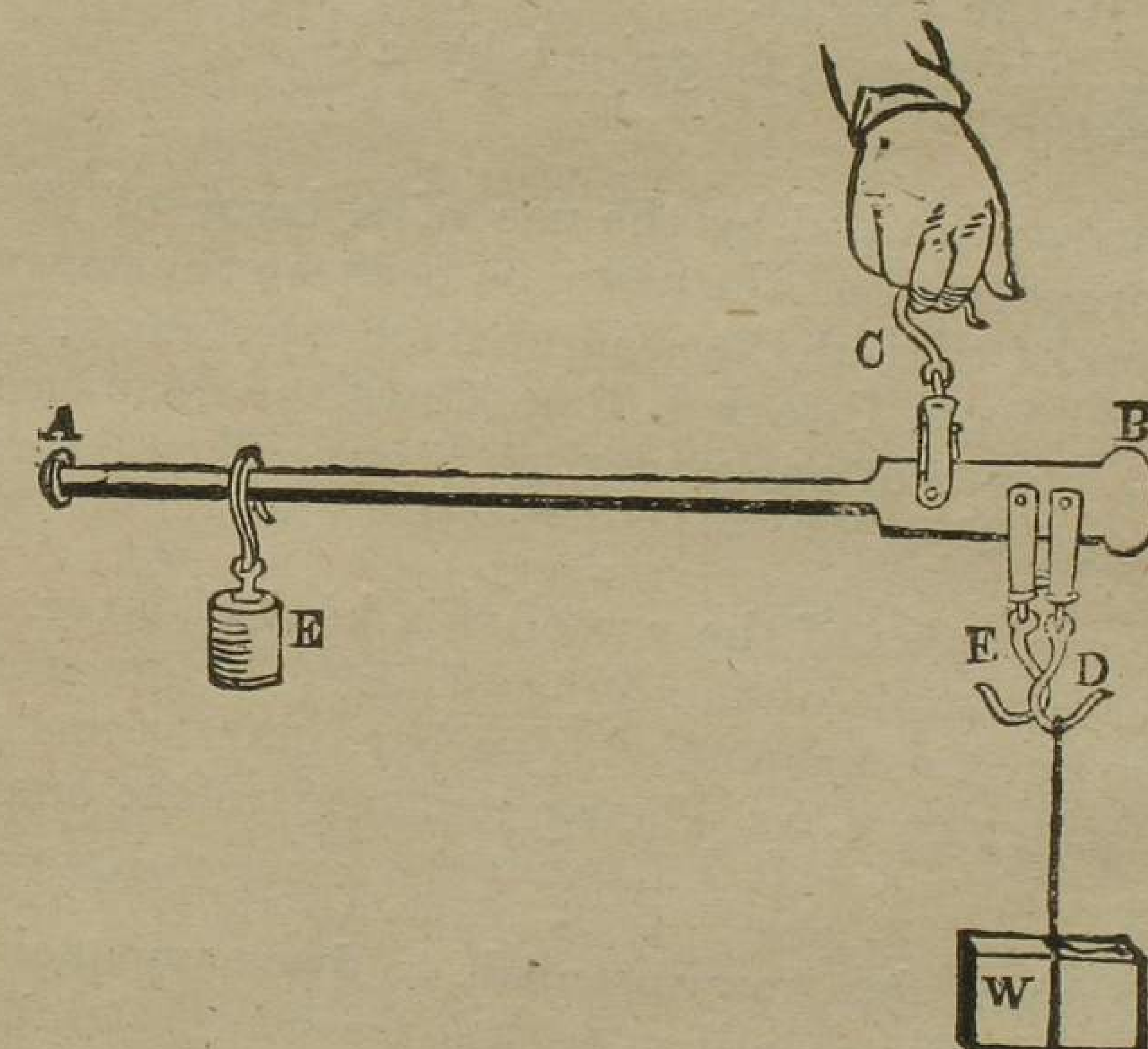


6. What advantage is gained by this lever?

The advantage gained by this lever is in proportion as the distance between the power and the fulcrum exceeds that of the weight from the fulcrum. Thus, if the distance between P and F be double that between W and F, a man, by the exertion of a force of 100 pounds with the lever, can move a weight of 200 pounds.

7. What is the common steelyard?

The common steelyard is an instrument for weighing articles, constructed on the principle of the lever of the first kind. It consists of a rod or bar, marked with notches to designate the pounds and ounces, and a weight which is movable along the notches. The bar is furnished with three hooks, *on the longest of which the article to be weighed is to be hung.*

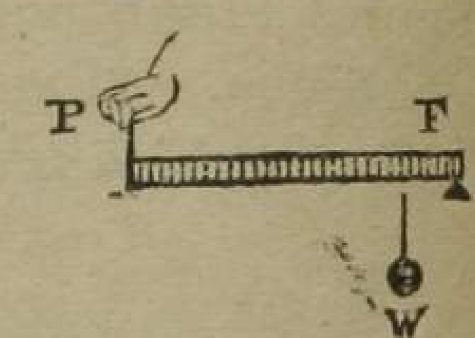


The other two hooks serve for the handle of the instrument when in use. The pivot of each of these two hooks serves for the fulcrum. When suspended by the hook C, it is manifest that a pound weight at E will balance as many pounds at W, as the distance between the pivot of D, and the pivot of C, is contained in the space between the pivot of C and the ring from which E is suspended.

8. What is a lever of the second kind?

In a lever of the second kind, the fulcrum is at one end, the power at the other, and the weight between them.

9. Explain a lever of the second kind.



The figure represents a lever of the second kind. F is the fulcrum, P the power, and W the weight.

10. What advantage is gained by a lever of this kind?

The advantage gained by the use of a lever of the second kind is in proportion as the distance between the power and the fulcrum exceeds that of the weight from the fulcrum. Thus, if the distance from P to F is four times the distance from W to F, then a power of one pound at P will balance a weight of four pounds at W.

11. Give examples of the use of this kind of lever.

1. On the principle of this kind of lever, two persons carrying a heavy burden, suspended on a bar, may be made to bear unequal portions of it, by placing it nearer to the one than the other.

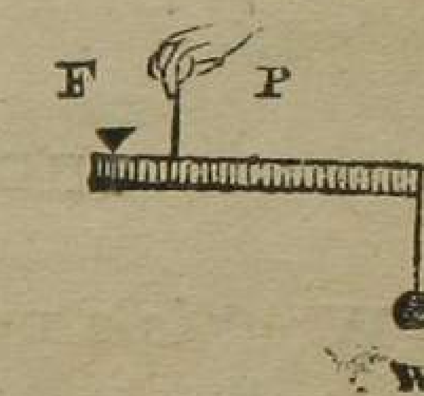
2. Two horses, also, may be made to draw unequal portions of a load, by dividing the bar (*called the whiffle-tree*) attached to the carriage in such a manner that the weaker horse may draw upon the longer end of it.

3. Oars, rudders of ships, doors turning on hinges, and cutting-knives, which are fixed at one end, are constructed upon the principle of levers of the second kind.

12. What is a lever of the third kind?

In a lever of the third kind, the fulcrum is at one end, the weight at the other, and the power is applied between them.

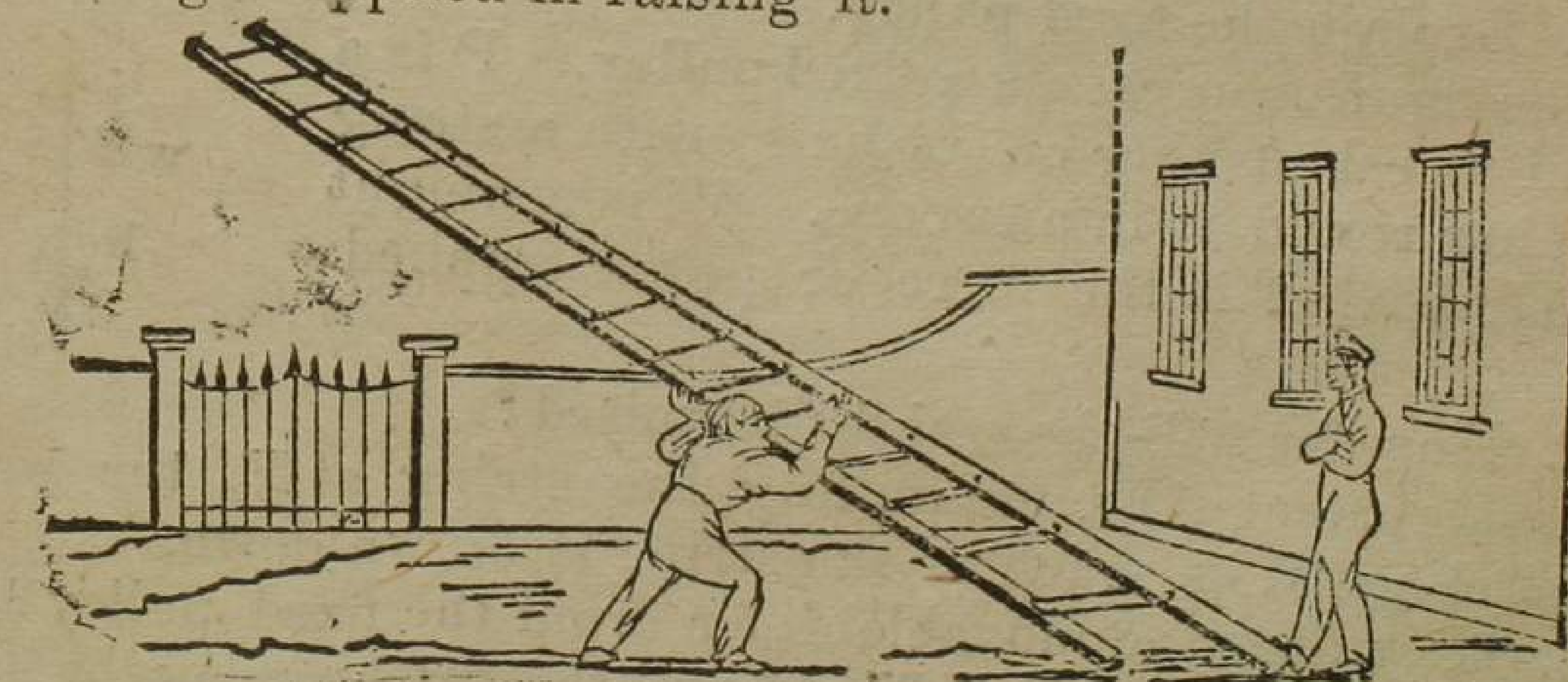
13. Explain this lever.



In the figure, F is the fulcrum, W the weight, and P the power between the fulcrum and the weight; and the power must exceed the weight in the same proportion that the distance between the weight W and the fulcrum F exceeds that between the power P and the fulcrum F.

14. Give an example of this kind of lever.

A ladder which is to be raised by the strength of a man's arms, represents a lever of this kind, where the fulcrum is that end which is fixed against the ground: the weight may be considered as at the top part of the ladder, and the power is the strength applied in raising it.



Lesson XI.

THE PULLEY—WHEEL AND AXLE.

1. What is a pulley?

The pulley is a small wheel turning on an axis, with a string or rope in a groove running around it.

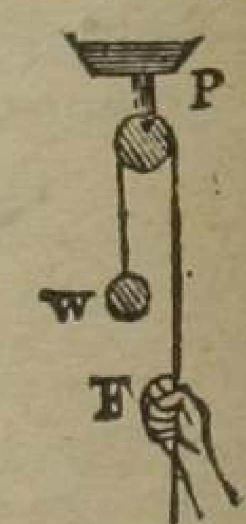
2. How many kinds of pulleys are there?

There are two kinds of pulley—the fixed and the movable.

3. What is a fixed pulley?

The fixed pulley is a pulley that has no other motion than a revolution on its axis, and it is used only for changing the direction of motion.

4. Explain the fixed pulley.



The figure represents a fixed pulley. P is a small wheel turning on its axis, with a string running round it in a groove. W is a weight to be raised, F is the force or power applied.

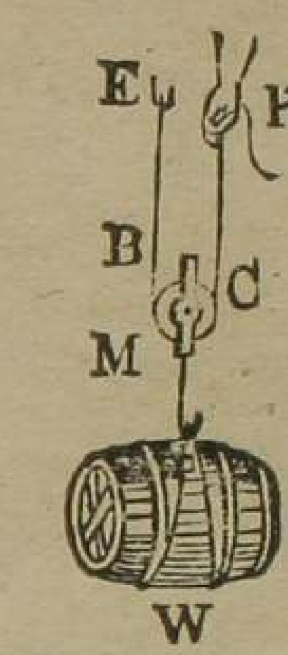
5. How far will the weight be raised?

It is evident that, by pulling the string at F, the weight must rise just as much as the string is drawn down.

6. How does the movable differ from the fixed pulley?

The movable pulley differs from the fixed pulley by being attached to the weight; it therefore rises and falls with the weight.

7. Explain the movable pulley.

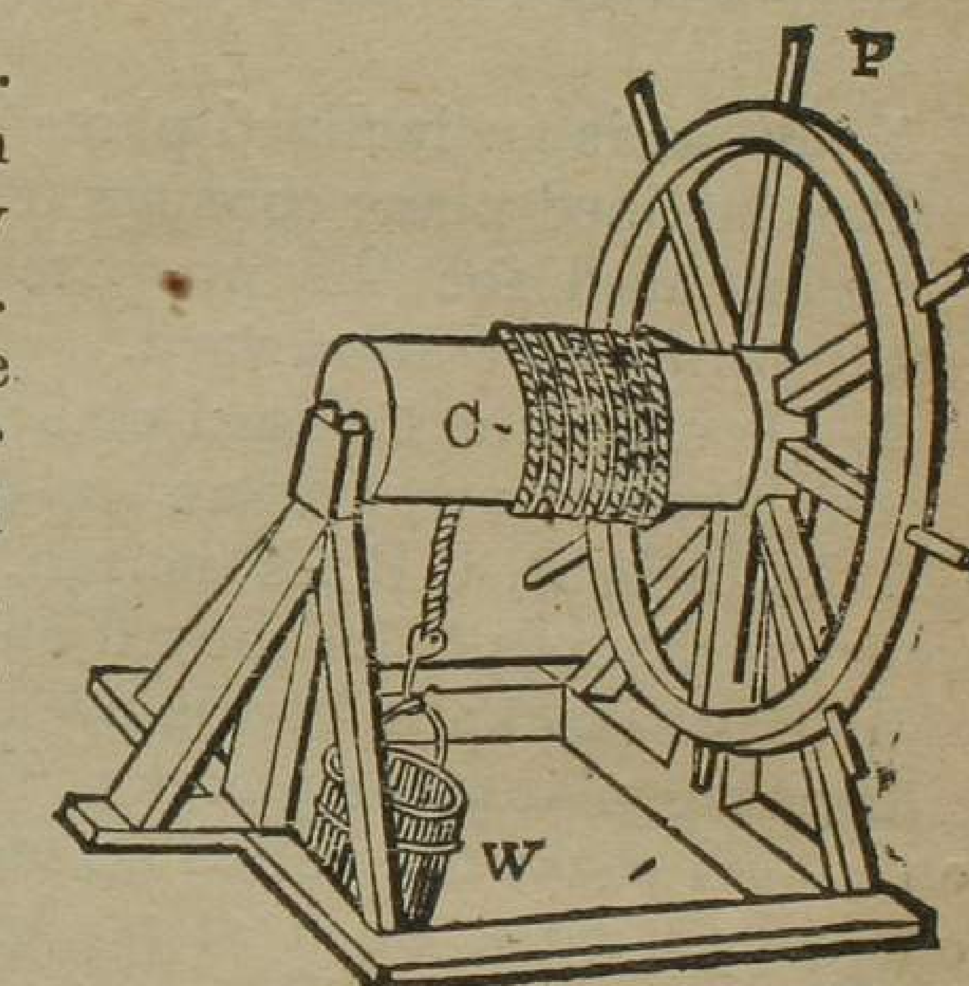


The figure represents a movable pulley, with the weight W attached to it by a hook below. One end of the rope is fastened at F; and as the power P draws the weight upwards, the pulley rises with the weight.

8. What is the wheel and axle?

The wheel and axle consists of two wheels of different sizes, revolving together around the same centre of motion.

9. Explain the wheel and axle.



The wheel and axle, though made in many forms, will easily be understood from the figure. In this figure, P represents the larger wheel, where the power is applied; C the smaller wheel or cylinder, which is the axle, and W the weight to be raised.

THE PULLEY.

Lesson XII.

THE INCLINED PLANE—THE WEDGE AND THE SCREW.

1. What is an inclined plane?

The inclined plane consists of a plain surface inclined to the horizon, used for the purpose of sliding or drawing things either upward or downward.

2. Describe the inclined plane.

The figure represents an inclined plane. C A its height, C B its length, and W a weight which is to be moved on it.

3. Give examples of the use of inclined planes.

Sloping planks or pieces of timber leading into a cellar, and on which casks are rolled up and down; a plank or board with one end elevated on a step, for the convenience of trundling wheelbarrows, or rolling barrels into a store, &c., are inclined planes.

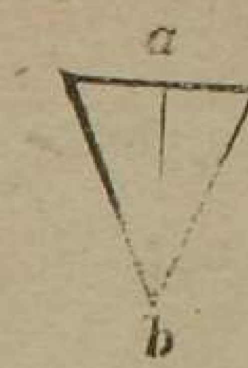
4. Are there any tools constructed on the principle of the inclined plane?

Chisels and other cutting instruments, which are sloped only on one side, are constructed on the principle of the inclined plane.

5. What is a wedge?

The wedge consists of two inclined planes united at their bases.

6. Describe the wedge.



The figure represents a wedge. The line *a b* represents the base of each of the inclined planes of which it is composed, and at which they are united.

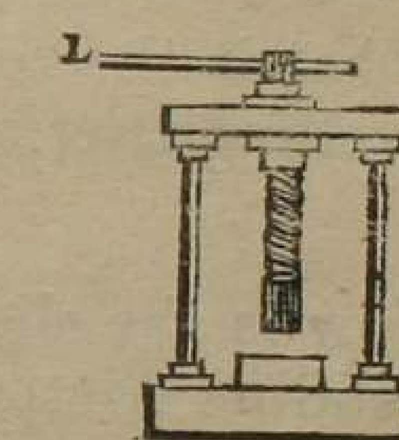
7. Is the wedge an important power?

The wedge is a very important mechanical power, being used to split rocks, timber, &c., which could not be effected by any other power.

8. What instruments are constructed on the principle of the wedge?

Axes, hatchets, knives, and all other cutting instruments chamfered, or sloped on both sides, are constructed on the principle of the wedge.

9. What is a screw?



The screw is a circular inclined plane, or an inclined plane wound around a cylinder. As a mechanical power it generally operates by pressure.

10. How is the screw worked?

It is worked by turning it around. This is sometimes done by a lever, or handle.

THE INCLINED PLANE.

THE WEDGE.

Lesson XIII.

OF FRICTION.

1. What is friction?
Friction is the resistance which bodies meet with in rubbing against each other.

2. How many kinds of friction are there?
There are two kinds of friction, the rolling and the sliding.

3. What is the rolling friction?
The rolling friction is caused by the rolling of a circular body.

4. How is the sliding friction produced?
The sliding friction is produced by the sliding or dragging of a flat surface.

5. Which friction is it most easy to overcome?
The sliding friction is overcome with more difficulty than the rolling.

6. Is friction considered in calculating the force of machines?
In calculating the power of a machine, an allowance must always be made for friction.

7. What allowance is made for friction?
It is usually computed that friction destroys one third of the power of a machine.

8. What causes friction?
Friction is caused by the unevenness of the surfaces which come into contact.

9. How may it be diminished?
It is diminished in proportion as the surfaces are smooth and well polished.

10. What substances are used to lessen friction?
Oil, grease, black-lead, and powdered soapstone, are each used to lessen friction, because they act as a polish by filling up the cavities of the rubbing surfaces, and thus making them slide more easily over each other.

11. By what means is the friction on roads overcome?
Wheels are used on vehicles to diminish the friction of the road.

12. Do large wheels or small most readily overcome obstacles on a road?
The larger the circumference of the wheel, the more readily it will overcome any obstacles, such as stones, or inequalities in the road.

13. Is there much friction between ice and smooth hard substances?
There is very little.

14. How may the friction be increased?
By throwing on sand or ashes, so as to prevent the surfaces from coming together.

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Lesson XIV.

HYDROSTATICS, OR FLUIDS AT REST.

1. Of what does Hydrostatics treat?

Hydrostatics treats of the nature, gravity, and pressure of fluids.

2. What is a fluid?

A fluid is a substance which yields to the slightest pressure, and the particles of which, having but a slight degree of cohesion, move easily among themselves.

3. Name some of the more common fluids?

Water is the most common of all fluids. Oil, liquors, cider, and beer, are also fluids.

4. What is the level of a fluid?

The level of a fluid is its upper surface when it is at rest; and this surface is always horizontal.

5. What is the equilibrium of a fluid?

The equilibrium of a fluid is its state when all the particles exactly balance each other, and are at rest.

6. Have fluids a tendency to preserve this state?

All fluids have a tendency to preserve their equilibrium; and hence the surface of every fluid will become horizontal, when left free.

7. What is a water-level?

A water-level is an instrument constructed on the principle of the equilibrium of fluids.

8. Explain the parts of it.

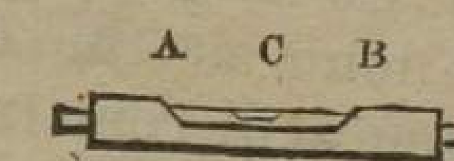
It consists of a glass tube, partly filled with water, and closed at both ends.

9. What is the use of it?

When the tube is not perfectly horizontal,—that is, if one end of the tube be lower than the other,—the water will run to the lower end. By this means the level of any line to which the instrument is applied may be ascertained.

10. Explain the water-level from the figure.

The figure represents a water-level. A B is a glass tube partly filled with water. C is a bubble of air occupying the space not filled by the water. When both ends of the tube are on a level, the air-bubble will remain in the centre of the tube; but if either end of the tube be depressed, the water will descend and the air-bubble will rise. The glass tube when used is generally set in a wooden or a brass box. It is an instrument much used by carpenters, masons, surveyors, &c.



11. How do solid bodies gravitate?

Solid bodies gravitate in masses, their parts being so connected as to form a whole, and their weight may be regarded as concentrated in a point called the centre of gravity.

12. How do fluids gravitate?

Each particle of a fluid may be considered as a separate mass, gravitating independently.

13. What is the consequence of this separate gravitation of the particles of a fluid?

The consequence of the separate gravitation of the particles of a fluid is, that a body of water, in falling, does less injury than a solid body of the same weight. But if the water be converted into ice, the particles losing their fluid form, and being united by cohesive attraction, gravitate unitedly in one mass, and fall with greater force.

14. How is the pressure of fluids exerted?

Fluids not only press downwards like solids, but also upwards, sidewise, and equally in every direction.

15. So long as the equal pressure is undisturbed, what follows?

So long as the equality of pressure is undisturbed, every particle will remain at rest.

16. What follows when the fluid is agitated?

If the fluid be disturbed by agitating it the equality of pressure will be disturbed, and the fluid will not rest until the equilibrium is restored.

17. How is the downward pressure of a fluid shown?

The downward pressure of fluids is shown by making an aperture in the bottom of a vessel of water. Every particle of the fluid above the aperture will run downwards through the opening.

18. How is the lateral or side pressure of a fluid shown?

The lateral pressure is shown by making the aperture at the side of the vessel. The fluid will then escape through the aperture at the side.

19. How is the upward pressure shown?

The upward pressure is shown by taking a glass tube, open at both ends, inserting a cork in one end, (or stopping it with the finger,) and immersing the other in the water. The water will not rise in the tube. But the moment the cork is taken out, (or the finger removed,) the fluid will rise in the tube to a level with the surrounding water.

Lesson XV.

OF THE PRESSURE OF FLUIDS.

1. Where is the pressure of a fluid the greatest?

The pressure of a fluid is in proportion to the perpendicular distance from the surface. Hence, the deeper the fluid, the greater will be the pressure.

2. What experiment will illustrate the pressure of flnids?

A bladder filled with air, being immersed in water, will be contracted in size, on account of the pressure of the water in all directions: and the deeper it is immersed, the more it will be contracted.

3. What other experiment illustrates fluid pressure?

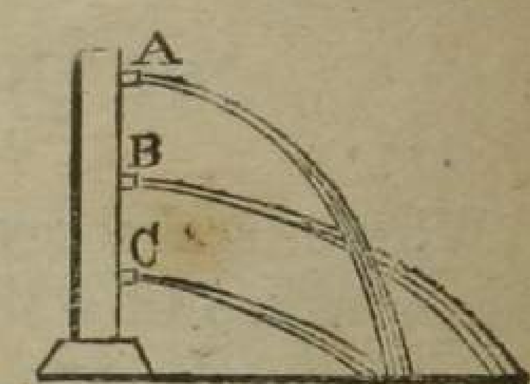
An empty bottle, being corked, and by means of a weight let down to a certain depth in the sea, will either be broken by the pressure, or the cork will be driven into it, and the bottle be filled with water. This will take place even if the cork be secured with wire and sealed. But a bottle filled with water, or any other liquid, may be let down to any depth without damage, because, in this case, the internal pressure is equal to the external.

4. If several orifices be made in the side of a vessel, from which will the fluid issue with the greatest force?

If orifices be made in the side of a vessel, the fluid will issue with the greatest force from the lowest orifice, and with the least force from the highest.

5. Explain the figure.

The figure represents a vessel of water, with orifices at the side at different distances from the surface. The different curves in the figure, described by the liquid in running out of the vessel, show the action of gravity, and the effects produced by the force of the pressure on the liquid at different depths. At A the pressure is the least, because there is less weight of fluid above. At B and C the fluid is driven outwards by the weight of that portion above, and the force will be strongest at C.



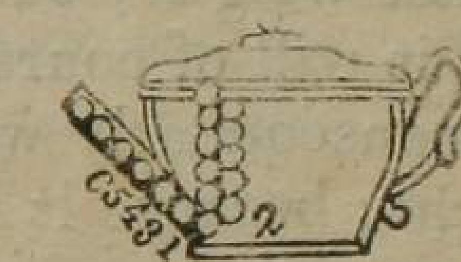
6. How can you show that fluids have an upward pressure?

When water is poured into a vessel with a spout, (like a tea-pot, for instance,) the water rises in the spout to a level with that in the body of the vessel. The particles of water at the bottom of the vessel are pressed upon by the particles above them, and to this pressure they will yield, if there is

any mode of making way for the particles above them. As they cannot descend through the bottom of the vessel, they will change their direction and rise in the spout.

7. Illustrate the upward pressure of a fluid by the figure.

The figure represents a tea-pot, and the columns of balls represent the particles of water magnified. From an inspection of the figure, it appears that the particle numbered 1, at the bottom, will be pressed laterally, by the particle numbered 2, and by this pressure forced into the spout, where meeting with the particle 3 it presses it upwards, and this pressure will be continued from 3 to 4, from 4 to 5, and so on till the water in the spout has risen to a level with that in the body of the vessel. If water be poured into the spout the water will rise in the same manner in the body of the vessel; from which it appears, that *the force of pressure depends entirely on the height, and not on the length or breadth of the column of fluid.*

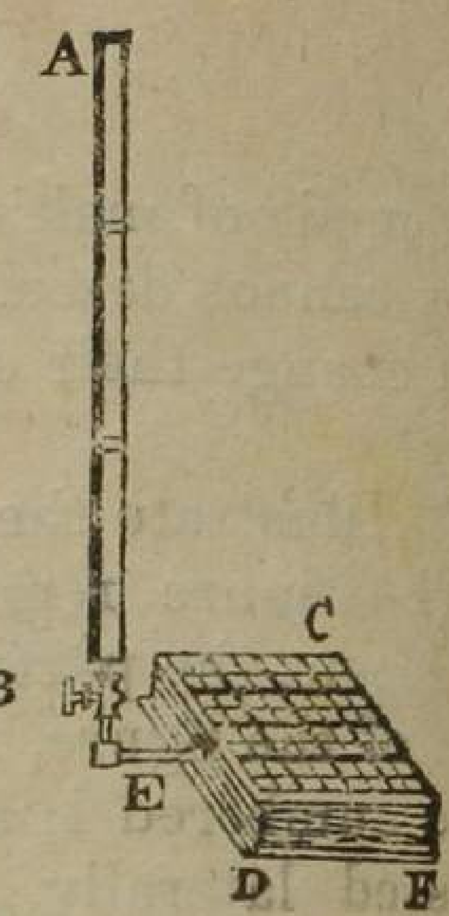


8. What do you understand by the hydrostatic paradox?

It is this: *That any quantity of fluid, however small, may be made to balance and support any other quantity, however large.*

9. Explain the hydrostatic paradox by means of the hydrostatic bellows.

The figure represents the hydrostatic bellows. A B is a long tube, *one inch square.* C D E F are the bellows, con-



sisting of two boards, *eight inches square*, connected by broad pieces of leather, or india-rubber cloth, in the manner of a pair of common bellows. One pound of water poured into the tube will raise 64 pounds on the bellows. If a smaller tube be used the same quantity of water will fill it higher, and consequently will raise a greater weight; but if a larger tube be used it will of course not fill it so high, and consequently will not raise so great a weight; because it is the *height not the quantity which causes the pressure.*

Lesson XVI.

OF SPECIFIC GRAVITY.

1. What is the specific gravity of a body?

It is the weight of the body compared with the weight of an equal bulk of rain water.

2. Give an example which will illustrate this.

If I take a quantity of water which will weigh exactly one pound, and then take the same size or bulk of any other substance, (as lead, for example,) and find that it weighs eleven and a half times as much, I conclude that lead is eleven and a half times heavier than water.

3. How much greater then is its specific gravity?

Eleven and a half times greater.

4. If a vessel be filled with water, and a body that will sink put into it, how much water will be displaced?

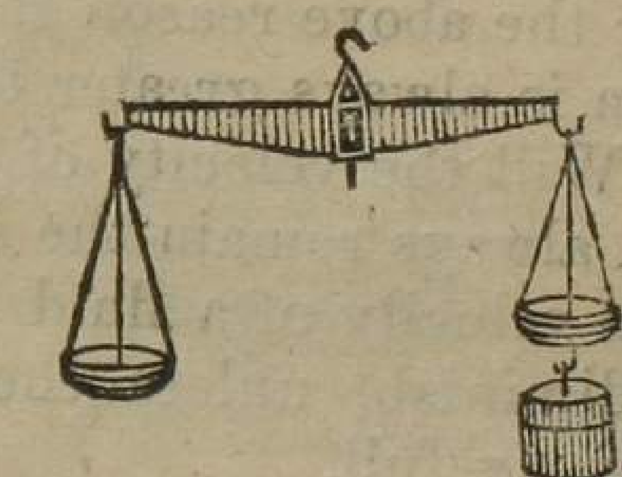
A quantity exactly equal to the bulk of the body.

5. How then may the specific gravity of bodies that will sink in water be ascertained?

The specific gravity of bodies that will sink in water is ascertained by weighing them first in water, and then out of the water, and dividing the weight out of the water by the loss of weight in water.

6. Explain the scales for determining the specific gravity of bodies.

The figure represents the scales for ascertaining the specific gravity of bodies. One scale is shorter than the other, and a hook is attached to the bottom of the scale, to which substances, whose specific gravity is sought, may be attached and sunk in water.



7. Explain how the specific gravity of a body may be determined by the scales.

Suppose a cubic inch of gold weighs 19 ounces when weighed out of the water, and but 18 ounces when weighed in water—the loss in water is one ounce. The weight out of water, 19 ounces, being divided by one (the loss in water) gives 19. The specific gravity of gold, then, would be 19, or, in other words, gold is nineteen times heavier than water.

Lesson XVII.

HYDRAULICS.

1. Of what does Hydraulics treat?

Hydraulics treats of the motion of fluids, particularly of water; and the construction of all kinds of instruments and machines for moving them.

2. What retards the motion of water in brooks and rivers?

Water, in its motion, is retarded by the friction of the bottom and sides of the channel through which it passes.

3. Where then will the velocity be the greatest?

For the above reason the velocity of the surface of a running stream is always greater than that of any other part.

4. Will the velocity of a fluid running from an orifice in a vessel always remain the same?

The velocity of a fluid running from an orifice in a vessel will diminish, unless the vessel from which it flows is kept constantly full.

5. Why is this?

This is a necessary consequence of the law, that pressure is proportioned to the height of the column above.

6 When a fluid spouts from several orifices in the side of a vessel, from which is it thrown to the greatest distance?

When a fluid spouts from several orifices in the side of a vessel, it is thrown to the greatest distance from the orifice nearest to the centre; because the streams from the lower

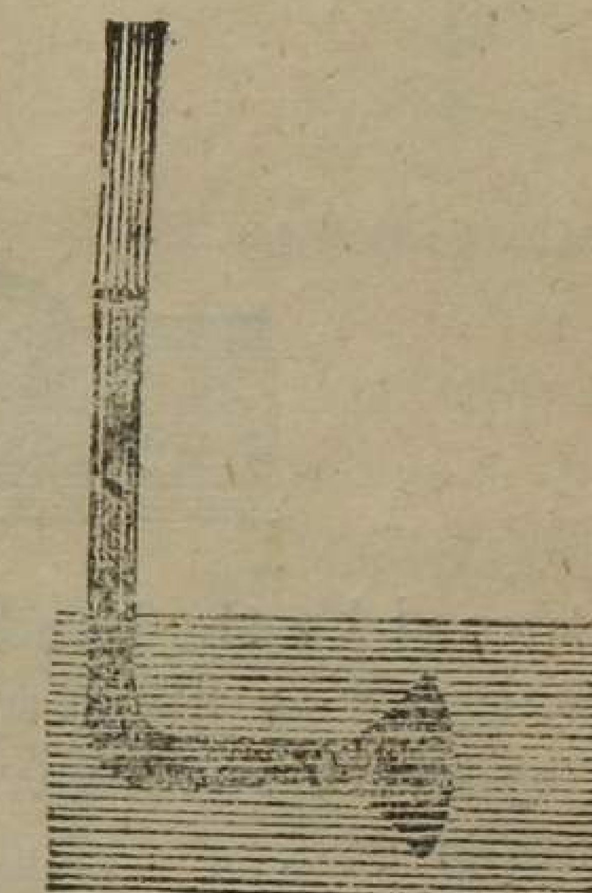
orifices will reach the ground before their projectile force is spent. But if the vessel be elevated, the fluid from the lowest orifice will be thrown to the greatest distance.

7. How can the velocity of a current of water be estimated?

The velocity of a current of water may be ascertained by immersing in it a bent tube, shaped like a tunnel at the end which is immersed.

8. Explain the instrument for ascertaining the velocity of a current.

The figure represents a tube shaped like a tunnel, with the larger end immersed in an opposite direction to the current. The rapidity of the current is estimated by the height to which the water is forced into the tube, above the surface of the current. By such an instrument the comparative velocity of different streams, or the same stream at different times, may be estimated.



9. What are waves, and how are they caused?

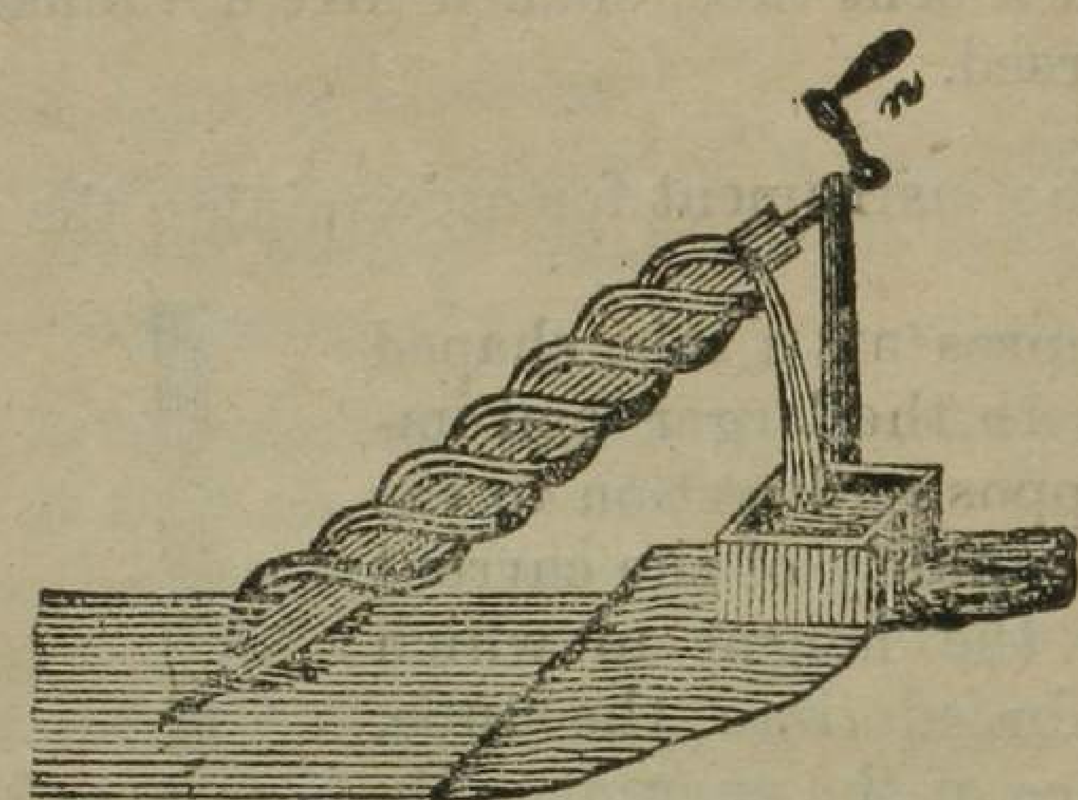
Waves are the elevations of the surface of water, and are caused by the friction of air and water.

10. What is the screw of Archimedes?

The screw of Archimedes is a machine said to have been invented by the philosopher Archimedes, for raising water and draining the lands of Egypt, about 200 years before the Christian era.

11. Explain the screw of Archimedes.

The figure represents the screw of Archimedes. A single tube, or two tubes, are wound in the form of a screw around a shaft or cylinder, supported by the prop and the pivot A,



and turned by the handle *n*. As the end of the tube dips into the water, it is filled with the fluid, which is forced up the tube by every successive revolution, until it is discharged at the upper end.

12. How are springs and rivulets formed?

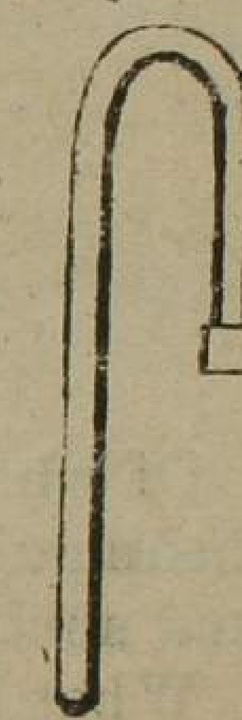
Springs and rivulets are formed by the water from rain, snow, &c., which penetrates the earth, and descends until it meets a substance which it cannot penetrate. A reservoir is then formed by the union of small streams under ground, and the water continues to accumulate until it finds an outlet.

13. What is a siphon?

The siphon is a tube bent in the form of the letter U one side being a little longer than the other.

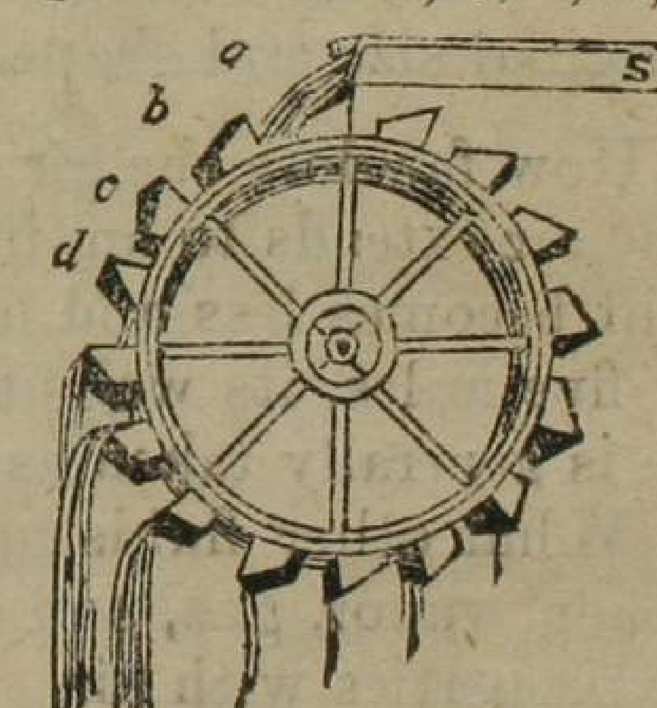
14. Explain the use of the siphon.

The figure represents a siphon. A siphon is used by filling it with water, or some other fluid, then stopping both ends, and in this state immersing the shorter leg or side into a vessel containing a liquid. The ends being then unstopped, the liquid will run through the siphon until the vessel is emptied. In performing this experiment, *the end of the siphon which is out of the water must always be below the surface of the water.*



15. Explain, by an example, how water is used as a mechanical power.

The figure represents a water-wheel. It consists of a wheel, turning on an axis, with compartments *a*, *b*, *c*, *d*, at the circumference, called buckets, which are successively filled with water from the stream S. The weight of the water in the buckets causes the wheel to turn, and the buckets being gradually inverted, are emptied as they descend. It will be seen, from an inspection of the figure, that the buckets in the descending side of the



wheel are always filled, or partly filled, while those in the opposite or ascending part are always empty until they are again presented to the stream. Water-wheels are of various kinds, and receive their names from the manner in which the water strikes them.

Lesson XVIII.

PNEUMATICS.

1. Of what does Pneumatics treat?
Pneumatics treats of the nature, properties, and effects of air and similar fluids.

2. What is the air?
The air is an elastic fluid which surrounds the earth.

3. What do you mean by the term elastic?
By elasticity is meant susceptibility of compression, and, after the removal of the compressing force, the restoration to its original size and shape.

4. How far does the air extend above the surface of the earth?
The air extends to an indefinite distance, but its density or weight becomes less and less. After reaching the distance of forty-five miles, its weight becomes very small, and that distance is generally taken as the height of the atmosphere.

5. What other fluids have similar properties with the air?
Steam, vapor, gas, and all fluids which are elastic, have the same properties with air.

6. How many principal properties has the air?
Air has two principal properties, viz. gravity and elasticity.

7. What is the weight of a column of air one inch square at the base, and reaching to the top of the atmosphere?
A column of air having a base an inch square, and reaching to the top of the atmosphere, weighs about fifteen pounds.

8. Is this pressure equally exerted in all directions?
This pressure, like the pressure of liquids, is exerted equally in all directions.

9. How does air become a mechanical agent?
Air becomes a mechanical agent by means of its weight, its elasticity, its inertia, and its fluidity.

10. What is a vacuum?
A vacuum is a space from which air and every other substance has been removed.

11. What is mercury or quicksilver?
Mercury is a liquid substance, like melted lead, and about fourteen times heavier than water.

12. Explain the Torricellian vacuum.
The Torricellian vacuum may be thus explained: a tube, closed at one end, and about 32 inches long, is filled with mercury. The open end is then covered with the finger so as to prevent the escape of the mercury, and the tube inverted and plunged into a vessel of mercury; the finger is then removed, and the mercury permitted to run out of the tube. It is found, however, that the mercury will remain in the tube to the height of about thirty inches, leaving a vacuum at the top of about two inches. This vacuum, called from the discoverer the Torricellian vacuum, is the most perfect that has been discovered.

13. What is a barometer?
The barometer is an instrument to measure the weight of the atmosphere.

14. Explain the barometer from the figure.

The barometer consists of a long glass tube, about thirty-three inches in length, closed at the upper end and filled with mercury. The tube is then inverted in a cup, or leather bag, of mercury, on which the pressure of the atmosphere is exerted. As the tube is closed at the top, it is evident that the mercury cannot descend in the tube without producing a vacuum at the upper end. The pressure of the atmosphere on the surface of the mercury in the basin, prevents the descent of the mercury in the tube; and the instrument, thus constructed, becomes an implement for ascertaining the weight of the atmosphere.

15. How does the weight of the air affect the height of the mercury in the tube?

As the air varies in weight or pressure, it must, of course, influence the mercury in the tube, which will rise or fall in exact proportion to the pressure. When the air is thin and light, the p essur is less, and the mercury will descend; and when the air is dense and heavy, the mercury will rise.

16. How is the rise and fall of the mercury shown?

At the side of the tube there is a scale, marked inches and tenths of an inch, to note the rise and fall of the mercury.

17. Will the pressure on the mercury in the bag continue the same in different pla es?

The pressure of the atmosphere on the mercury, in the bag or cup of a barometer, being exerted on the principle of the equilibrium of fluids, must vary according to the situation in which the barometer is placed. For this reason it will be the greatest in valleys or low situations, and least on the top of high mountains.

18. For what purpose is the barometer often used?

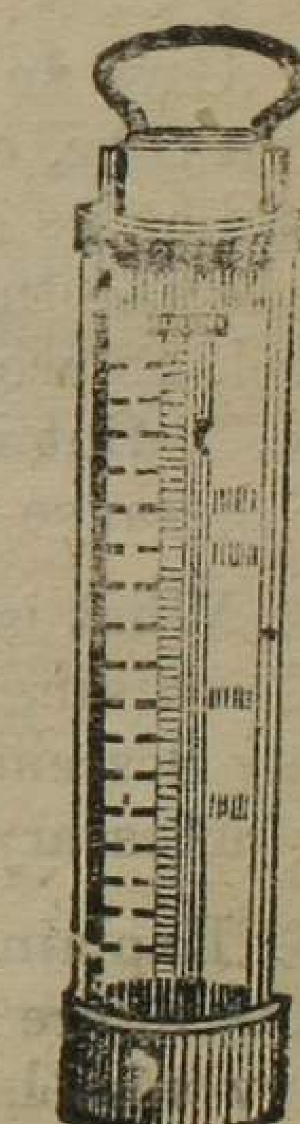
The barometer is often used to ascertain the height of mountains and other places above the level of the sea.

19. What is a thermometer?

The thermometer is an instrument used to indicate the temperature of the atmosphere.

20. Describe it.

In appearance the thermometer resembles a barometer, but it is constructed on a different principle, and for a different purpose. It consists of a very small tube, closed at the top, and terminated with a bulb, which is filled with m rcury. As heat expands and cold contracts most substances, it follows, that in warm weather the mercury must be expanded and will rise in the tube, and that in cold weather it will contract and sink. Hence the instrument becomes a correct measure for the heat and cold of the air. A scale is placed at the side of the tube, to mark the degree of heat or cold, as it is indicated by the rise and fall of the mercury in the tube.



Lesson XIX.

IMPENETRABILITY OF THE AIR.

1. What do you understand by the impenetrability of the air?
The impenetrability of the air is the power which the air has of occupying a certain space, so that no other body can occupy that space without displacing it.

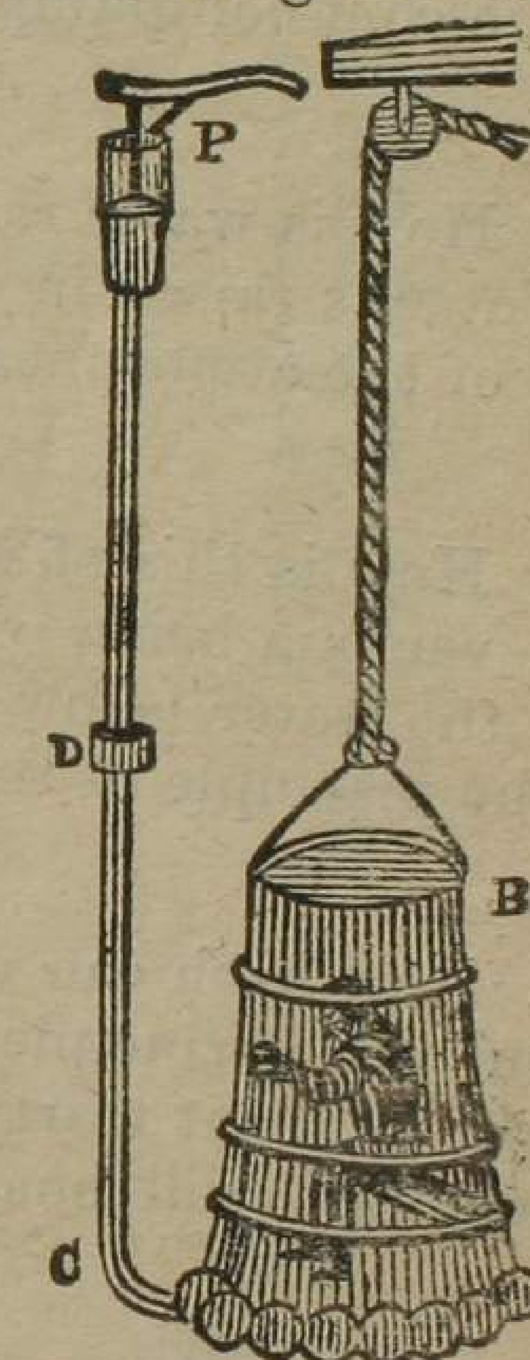
2. How is the impenetrability of air shown?
The impenetrability of air is shown by the fact that water will not ascend into an inverted vessel, unless the air is first permitted to escape.

3. Give an example which proves this.
If a tube, closed at one end, or an inverted tumbler, be inserted at its open end in a vessel of water, the water will not rise in the tube or tumbler, to a level with the water in the vessel, on account of the impenetrability of the air within the tube. But if the tube be open at both ends, the water will rise, because the air can escape through the upper end.

4. What is the diving-bell?
The diving-bell is a vessel so constructed, that a person may safely descend into the water to recover lost articles, or perform any necessary work under water.

5. Explain the manner of its construction.
The figure represents a diving bell. It consists of a large heavy vessel, formed like a bell, (but may be made of any other

shape,) with the mouth open. It descends into the water with its mouth downwards. The air within it having no outlet is compelled, by the order of specific gravities, to ascend in the bell, and thus (as water and air cannot occupy the same space at the same time) prevents the water from rising in the bell.



A person, therefore, may descend with safety in the bell to a great depth in the sea, and thus recover valuable articles that have been lost. A constant supply of fresh air is sent down, either by means of barrels, or by a forcing-pump. In the figure, B represents the bell with the diver in it. C is a bent metallic tube, attached to one side and reaching the air within; and P is the forcing-pump through which air is forced into the bell. The forcing-pump is attached to the tube by a joint at D. When the bell descends to a great depth, the pressure of the water condenses the air within the bell, and causes the water to ascend in the bell. This is forced out by constant accessions of fresh air, supplied as above mentioned. Great care must be taken that a constant supply of fresh air is sent down, otherwise the lives of those within the bell will be endangered. The heated and impure air is allowed to escape through a stop-cock in the upper part of the bell.

6. What is the common pump?
The common pump is an instrument used for raising water.

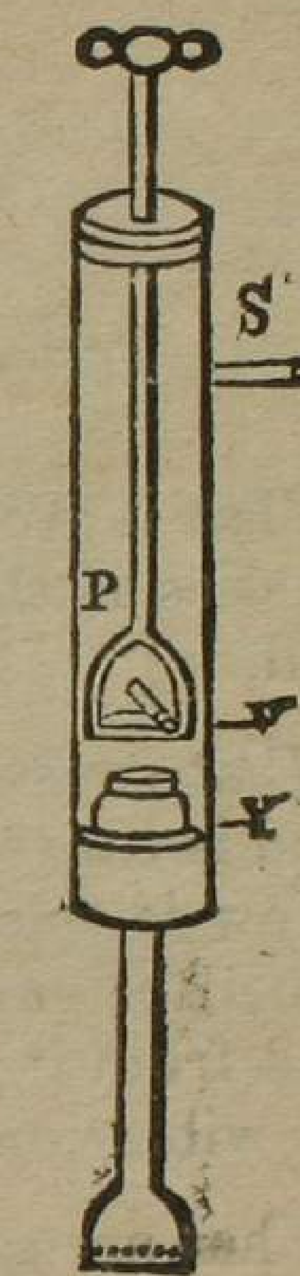
7. How is water raised by means of the common pump?
Water is raised in the common pump by means of the pressure of the atmosphere on the surface of the water.

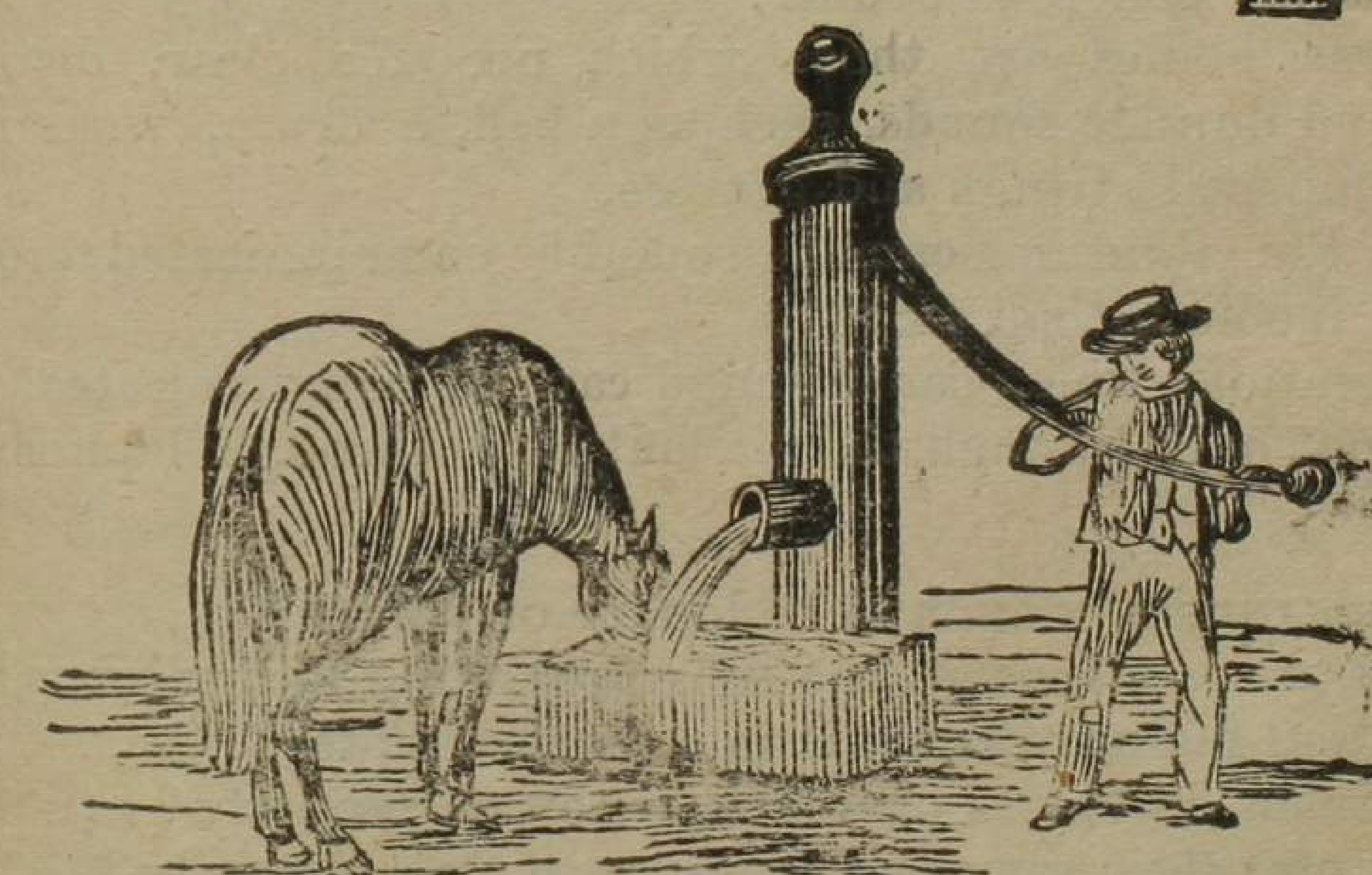
8. How is this effected?
A vacuum being produced by raising the piston or pump-box, the water below is forced up by the atmospheric pressure, on the principle of the equilibrium of fluids.

9. How high can water be raised by this principle?
On this principle the water can be raised only to the height of about thirty-three feet, because the pressure of the atmosphere will sustain a column of water of that height only.

10. Describe the common pump.
The figure represents the common pump, called the sucking-pump. The body consists of a large tube, or pipe, the lower end of which is to be immersed in the water which it is designed to raise. P is the piston, V a valve in the piston, which, opening upwards, admits the water to rise through it, but prevents its return. Y is a similar valve in the body of the pump, below the piston. When the pump is not in action, the valves are closed by their own weight; but when the

piston is raised it draws up the column of water which rested upon it, producing a vacuum between the piston and the lower valve Y. The water below, immediately rushes through the lower valve, and fills the vacuum. When the piston descends a second time, the water in the body of the pump passes through the valve V, and on the ascent of the piston is lifted up by the piston, and a vacuum is again formed below, which is immediately filled by the water rushing through the lower valve Y. In this manner the body of the pump is filled with water, until it reaches the spout S, where it runs out in an uninterrupted stream.





Lesson XX.

ACOUSTICS, OR THE LAWS OF SOUND.

1. What is Acoustics?

Acoustics is the science which treats of the nature and laws of sound.

2. What causes sound?

Sound is caused by a tremulous or vibratory motion of the air.

3. How is this proved?

If a bell be rung under an exhausted receiver, no sound can be heard from it; but when the air is admitted to surround the bell, the vibrations immediately produce sound.

4. What are sonorous bodies?

Sonorous bodies are those which produce clear, distinct, regular, and durable sounds, such as a bell, a drum, wind instruments, musical strings and glasses.

5. Can the vibrations causing sound be communicated through any other medium than air?

The vibrations which cause sound can be communicated to a distance not only through the air, but also through liquids and solid bodies.

6. What causes sounds to be louder or fainter?

Sounds are louder when the air surrounding the sonorous body is dense, and fainter when it is in a rarefied state.

7. To what do bodies owe their sonorous property?

Bodies owe their sonorous property to their elasticity.

8. What causes the sound produced by a musical string?

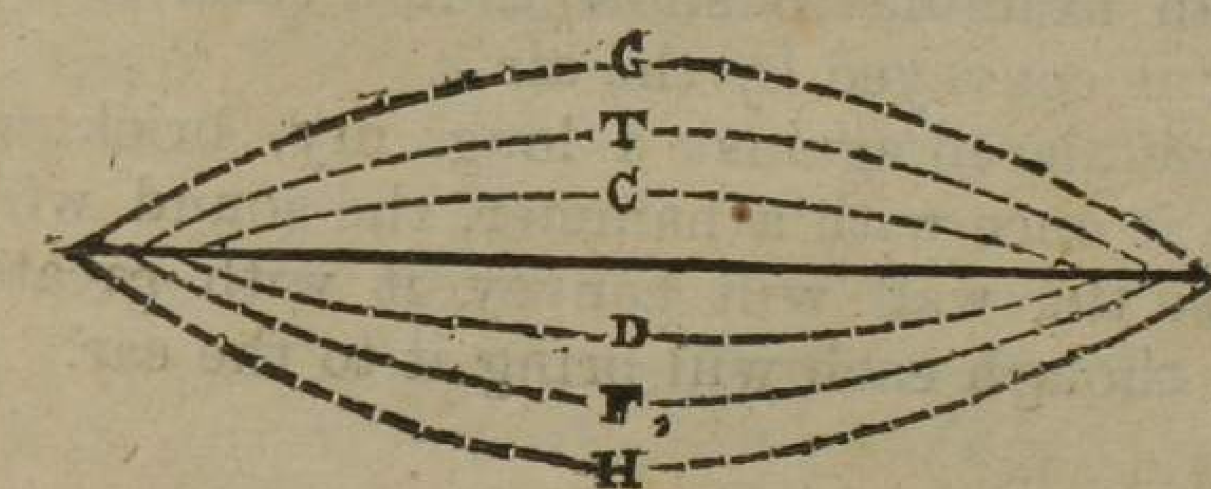
The sound produced by a musical string is caused by its vibrations.

9. Which strings in a musical instrument produce the low, and which the high tones?

Long strings vibrate with less rapidity than short ones, and for this reason the low tones in a musical instrument proceed from the long strings, and the high tones from the short ones.

10. Explain the vibrations of a musical string by the figure.

Let A B represent a musical string. If it be drawn up to G, its elasticity will not only carry it back again, but will give it a momentum which will carry it to H, from whence it will



successively return to T, F, C, D, &c., until the resistance of the air entirely destroys its motion.

11. How is the air affected by the vibrations of a sonorous body?

The vibrations of a sonorous body give a tremulous motion to the air around it, similar to the motion communicated to smooth water when a stone is thrown into it.

12. Through which is sound conveyed most rapidly, through solid bodies or the air?

Sound is communicated more rapidly and with greater power through solid bodies, than through the air, or fluids.

13. How much faster is it conducted by water than by air?
Sound is conducted by water about four times quicker than by air.

14. How much faster is it conducted by solids than by water?
It is conducted by solids about twice as rapidly as by water.

15. Give an example to show that a solid conducts sound better than air.
If a person lay his head on a long piece of timber, he can hear the scratching of a pin at the other end, while it could not be heard through the air.

16. Give an example to show that a solid conducts sound faster than it is conveyed by the air.
If the ear be placed against a long, dry, brick wall, and a person strike it once with a hammer, the sound will be heard *twice*, because the wall will convey it with greater rapidity than the air, though each will bring it to the ear.

Lesson XXI.

VELOCITY OF SOUND.

1. How fast does sound move through the air?
Sound, passing through the air, moves at the rate of 1142 feet in a second of time.

2. Does the loudness of sound make any difference in its velocity?
It does not. The softest whisper flies as fast as the loudest thunder.

3. Does the force or direction of the wind make any difference in the velocity?
The force or direction of the wind makes but slight difference in the velocity of sound.

4. What advantage results from the uniform velocity of sound?
This uniform velocity of sound enables us to determine the distance of an object from which it proceeds.

5. If the flash of a gun fired at sea be seen half a minute before the report is heard, what will be the distance?
If the flash of a gun, fired at sea, be seen a half of a minute before the report is heard, the vessel must be at the distance of six miles and a half.

6. How may the distance of a thunder-cloud be ascertained?
The distance of a thunder-cloud may be ascertained, by multiplying 1142 feet by the number of the seconds that intervene between the appearance of the lightning and the noise of the thunder.

7. What is an echo?

An echo is the sound produced by the vibrations of the air meeting a hard and regular surface, such as a wall, a rock, a mountain. The same sound is thus reflected back to the ear.

8. On what principle are speaking-trumpets constructed?

Speaking-trumpets are constructed on the principle of the reflection of sound.

9. How does it appear that they are constructed on this principle?

The voice, instead of being diffused in the open air, is confined within the trumpet; and the vibrations which spread and fall against the sides of the instrument are reflected, and fall in the direction of the vibrations, which proceed straight forward.

10. What are hearing-trumpets?

Hearing-trumpets are the trumpets used by deaf persons, and they are constructed on the same principle with the common trumpet; but as the voice enters the large end of the trumpet, instead of the small one, it is not so much confined, nor so much increased.

11. May sound be connected into a point or focus?

Sound, like light, after it has been reflected from several surfaces, may be collected into one point, as a focus, where it will be more audible than in any other part.

12. On what principle is a whispering-gallery constructed?

The famous whispering-gallery in the dome of St. Paul's church, in London, is constructed on this principle. Persons at very remote parts of the building can carry on a conversation in a soft whisper, which will be distinctly audible to one another, while others in the building cannot hear it; and the ticking of a watch may be heard from side to side.

13. How may sounds be conveyed to a greater distance than through the air?

Sounds may be conveyed to a much greater distance through continuous tubes than through the open air.

14. What are such tubes called, and where are they generally used?

The tubes used to convey sounds are called acoustic tubes. They are much used in public houses, stores, counting-rooms, &c., to convey communications from one room to another.

15. What general rule may be stated in regard to reflected sound?

As a general rule it may be stated, that *plane and smooth surfaces reflect sound without dispersing it; convex surfaces disperse it, and concave surfaces collect it.*

16. Does the moisture of the air affect the transmission of sound?

The air is a better conductor of sound when it is humid than when it is dry.

17. How does this appear?

A bell can be more distinctly heard just before a rain; and sound is heard better in the night than in the day, because the air is generally more damp in the night.

18. How far can sound be heard?

The distance to which sound may be heard depends upon various circumstances, on which no definite calculations can be predicated. Volcanoes, among the Andes, in South America, have been heard at the distance of three hundred miles; naval engagements have been heard two hundred; and even the watchword "*All's well,*" pronounced by the unassisted human voice, has been heard from Old to New Gibraltar, a distance of twelve miles.

19. How is the sound of the human voice produced?

The sound of the human voice is produced by the vibration of two delicate membranes, situated at the top of the windpipe, between which the air from the lungs passes.

20. How are the tones of the voice regulated?

The tones are varied from grave to acute, by opening or contracting the passage; and they are regulated by the muscles belonging to the throat, by the tongue, and by the cheeks.

21. May the voice be improved by cultivation?

The powers of the voice depend much upon cultivation; and although many persons can both speak and sing with ease, and with great power, without much attention to its culture, yet it is found that they who cultivate their voices by use, acquire a degree of flexibility and ease in its management, which in a great measure supplies the deficiency of nature.

22. What is ventriloquism?

Ventriloquism is the art of speaking in such a manner as to cause the voice to appear to proceed from a distance.

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Lesson XXII.

LAWS OF HEAT.

1. What is Hyronomics?

Pyronomics is the science which treats of the laws, the properties, and operations of heat.

2. What is the nature of heat?

The nature of heat is unknown; but it has been proved that the addition of heat to any substance produces no perceptible alteration in the weight of that substance. Hence it is inferred that heat is imponderable.

3. What bodies does heat pervade?

Heat pervades all bodies, insinuating itself, more or less, between their particles, and forcing them asunder.

4. How does heat affect the cohesion of the particles of bodies?

Heat and the attraction of cohesion constantly act in opposition to each other; hence, the more a body is heated, the more its particles will be separated.

5. In what can we see the effects of heat acting in opposition to cohesion?

The effect of heat in separating the particles of different kinds of substances, is seen in the melting of solids, such as metals, wax, butter, &c. The heat insinuates itself between the particles, and forces them asunder.

6. Does heat pass through all bodies equally well?

Heat passes through some bodies with more difficulty than through others; but there is no kind of matter which can completely arrest its progress.

7. What are the principal effects of heat upon bodies?
The principal effects of heat are three, namely :—
1st. Heat expands most substances.
2d. It converts them from a solid to a fluid state.
3d. It destroys their texture by combustion.

8. In what way does heat tend to diffuse itself?
Heat tends to diffuse itself equally through all substances.

9. How is this shown?
If a heated body be placed near a cold one, the temperature of the former will be lowered, while that of the latter will be raised.

10. How does it appear that one substance conducts heat better than another?
If the hand be successively applied to a woollen garment, a mahogany table, and a marble slab, all of which have stood for some time in the same room, the woollen garment will appear the warmest, and the marble slab the coldest of the three articles; but if a thermometer be applied to each, no difference in the temperature will be observed.

11. What is the reason of this?
The reason that the marble slab seems the coldest, is, that marble, being a good conductor of heat, receives the heat from the hand so readily, that the loss is instantly felt by the hand; while the woollen garment, being a bad conductor of heat, receives the heat from the hand so slowly that the loss is imperceptible.

12. What causes the difference in the warmth of substances used for clothing?
The different power of receiving and conducting heat, possessed by different substances, is the cause of the difference in the warmth of various substances used for clothing.

13. Why are woollen garments warm?
Woollen garments are warm, because they part slowly with the heat which they acquire from the body, and, consequently, they do not readily convey the warmth of the body to the air, but encase the body in a warm covering.

14. Why is a linen garment cool?
A linen garment is a cool one, because it parts with its heat readily, and as readily receives fresh heat from the body. It is, therefore, constantly receiving heat from the body and throwing it out into the air.

15. Why is ice in summer wrapped in woollen cloths?
To protect it from the heat of the air, which does not readily pass through woollen.

16. Do all bodies conduct heat with the same degree of facility?
Different bodies conduct heat with different degrees of facility.

17. What bodies are the best conductors of heat?
The metals are the best conductors, and among metals silver is the best conductor.

18. In what order do the metals stand with respect to their conducting power?
The metals stand in the following order, with respect to

their conducting power; namely, silver, gold, tin, copper, platina, steel, iron, and lead.

19. Is wood a good conductor of heat?

Wood conducts heat very imperfectly. For this reason wooden spoons and forks are preferred for ice. Indeed, so imperfect a conductor of heat is wood, that a stick of wood may be grasped by the hand while one end of the stick is a burning coal.

20. What other substances are bad conductors of heat?

Animal and vegetable substances, of a loose texture, such as fur, wool, cotton, &c., conduct heat very imperfectly; hence their efficacy in preserving the warmth of the body.

21. Why are the handles of metal tea-pots and coffee-pots commonly made of wood?

If they were made of metal, they would become too hot to be grasped by the hand, soon after the vessel is filled with hot water.

THE BLACKSMITH'S NEW APPRENTICE.

Lesson XXIII.

LAWS OF HEAT.

1. What surfaces reflect heat?

Heat is reflected from light and bright surfaces.

2. What surfaces absorb heat?

Black or dark-colored bodies absorb the heat that falls on them.

3. What follows from this law?

This is the reason why the bright brass andirons, or any other bright substances, placed near a hot fire, seldom become heated; while other dark substances, further removed from the fire, become too hot for the hand.

4. Will ice and snow melt most speedily under white or black cloth?

Snow or ice will melt under a piece of black cloth, when it will remain perfectly solid under a white one.

5. How is this principle applied in agriculture?

The farmers, in some of the mountainous parts of Europe, are accustomed to spread black earth, or soot, over the snow, in the spring, to hasten its melting, and enable them to commence ploughing early.

6. What takes place when bodies are violently compressed?

All bodies, when violently compressed or extended, become warm.

7. Give an example of this.

If a piece of india-rubber be quickly stretched and applied to the lip, a sensible degree of heat will be felt. An iron bar, on being hammered, becomes red-hot; and even water, when strongly compressed, gives out heat.

8. Into what classes are all substances, as affected by heat, divided?

All substances, as they are affected by heat, may be divided into combustible and incombustible bodies.

9. What substances are combustible?

Vegetable substances, charcoal, oils, most animal substances, as hair, wool, horn, fat, and all metallic bodies, are combustible.

10. What substances are incombustible?

Stones, glass, salts, &c., are incombustible.

11. What is the most obvious and direct effect of heat on a body?

The most obvious and direct effect of heat on a body, is to increase its extension in all directions.

12. What use is made of this law?

Coopers, wheelwrights, and other artificers, avail themselves of this property in fixing iron hoops on casks, and the tires or irons on wheels. The hoop or tire having been heated, expands, and being adapted in that state to the cask or the wheel, as the metal contracts in cooling, it clasps the parts very firmly together.

13. What effect has heat on the density of substances?

The density of all substances is augmented by cold, and diminished by heat.

14. Is there any exception to this?

There is a remarkable exception to this remark, in the case of water; which, instead of contracting, expands when freezing. This is the reason why pitchers, and other vessels, containing water and other similar fluids, are so often broken when the liquid freezes in them. For the same reason, ice floats instead of sinking in water; for as its density is diminished, its specific gravity is consequently diminished.

15. What takes place when heat is thrown on a bright or polished surface?

When heat is thrown upon a bright or polished surface it is reflected.

16. How does the angle of incidence compare with the angle of reflection, in relation to heat?

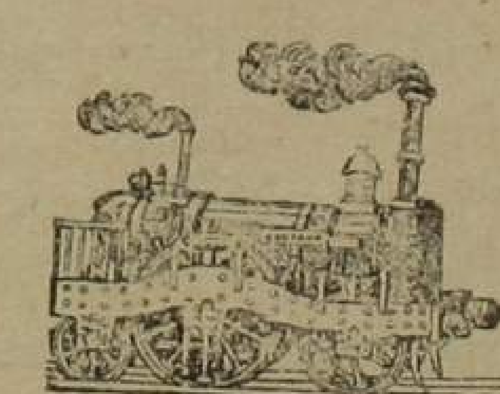
The angle of incidence will be equal to the angle of reflection.

17. What change does water undergo when a certain degree of heat is applied?

When a certain degree of heat is applied to water it converts it into steam or vapor.

18. What is the steam-engine?

The steam-engine is a machine moved by the expansive force of steam.



Lesson XXIV.

OPTICS.

1. Of what does Optics treat?

Optics is the science which treats of light, of colors, and of vision.

2. Into what classes does the science of optics divide all substances?

The science of optics divides all substances into the following classes: namely, luminous, transparent, and translucent; reflecting, refracting, and opaque.

3. What are luminous bodies? Give an example of a luminous body.

Luminous bodies are those which shine by their own light; such as the sun, the stars, a burning lamp, or a fire.

4. What are transparent bodies? Give an example of transparent bodies.

Transparent substances are those which allow light to pass through them freely, so that objects can be distinctly seen through them; as glass, water, air, &c.

5. What are translucent bodies? Give examples of translucent bodies.

Translucent bodies are those which permit a portion of light to pass through them, but render the object behind them indistinct; as horn, oiled paper, colored glass, &c.

6. What are reflecting substances? Give examples of reflecting bodies.

Reflecting substances are those which do not permit light to pass through them, but throw it off in a direction more or less oblique, according as it falls on the reflecting surface; as polished steel, looking-glasses, polished metal, &c.

7. What are refracting substances?

Refracting substances are those which turn the light from its course, in its passage through them.

8. What are opaque substances? Give examples of opaque substances.

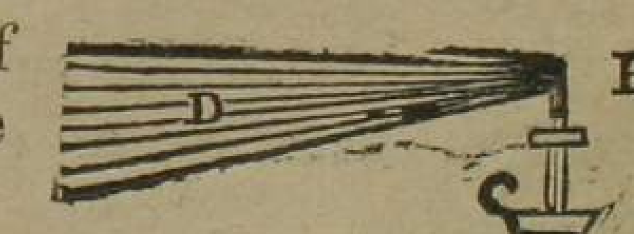
Opaque substances are those which permit no light to pass through them; as metals, wood, &c.

9. What is a ray of light?

A ray of light is a single line of light proceeding from a luminous body.

10. When are rays of light said to diverge?

Rays of light are said to diverge when they separate more widely, as they proceed from a luminous body. The figure represents the rays of light diverging as they proceed from the luminous body, from F to D.

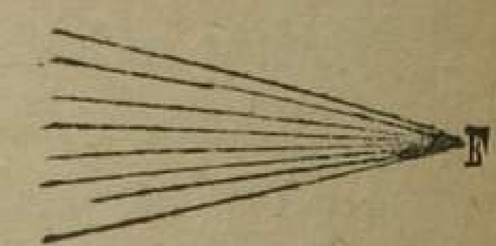


11. When are rays of light said to converge?

Rays of light are called converging when they approach each other.

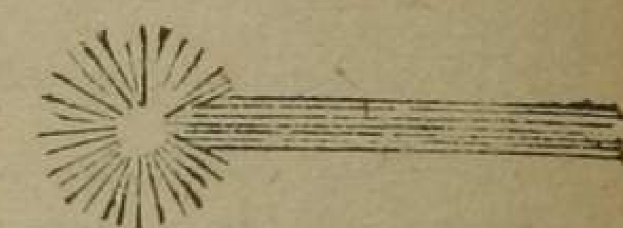
12. What is the point called towards which they converge?

The point at which converging rays meet is called the focus. The figure represents converging rays of light, of which the point F is the focus.



13. What is a beam of light?

A beam of light consists of many rays running in parallel lines. The figure represents a beam of light.



14. What is a pencil of rays?

A pencil of rays is a collection of diverging or converging rays.

15. What is a medium?

A medium is any substance, solid or fluid, through which light can pass; as water, glass, air, &c.

16. In what manner do rays of light issue from terrestrial bodies?

The rays of light which issue from terrestrial bodies, continually diverge, until they meet with a refracting substance.

17. In what kind of lines do the rays of light proceed from the sun?

The rays of the sun diverge so little, on account of the immense distance of that luminary, that they are considered parallel.

18. In what way is light projected forward from any luminous body?

Light, proceeding from a luminous body, is projected forward in straight lines in every possible direction.

19. How fast does light move?

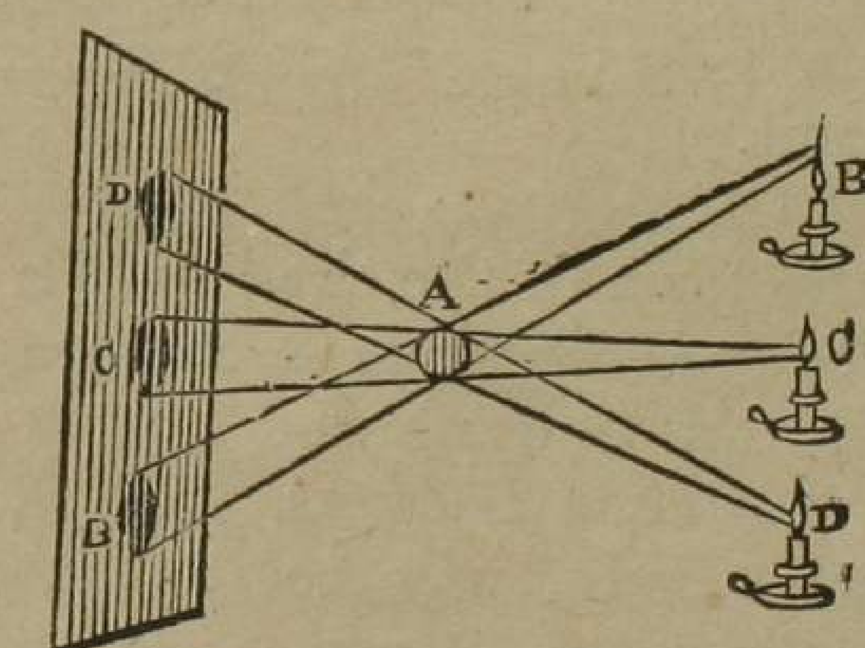
Light moves with a rapidity but little short of 200,000 miles in a second of time.

20. From what point of a luminous body does light radiate?

Every point of a luminous body is a centre, from which light radiates in every direction.

21. Do the rays of light cross each other?

Rays of light proceeding from different bodies, cross each other without interfering.



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Lesson XXV.

OF SHADOWS, AND REFLECTED LIGHT.

1. What is a shadow?

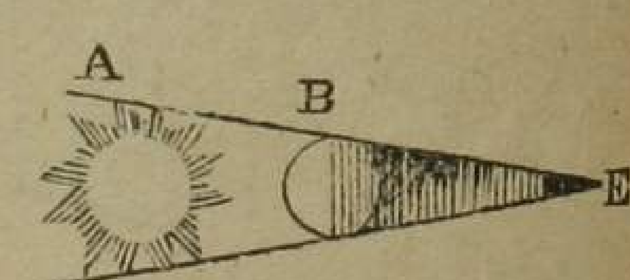
A shadow is the darkness produced by the intervention of an opaque body, which prevents the rays of light from reaching an object behind the opaque body.

2. What effect is produced on the shadow of an opaque body, when the luminous body is larger than the opaque one?

When a luminous body is larger than an opaque body, the shadow of the opaque body will gradually diminish in size till it terminates in a point.

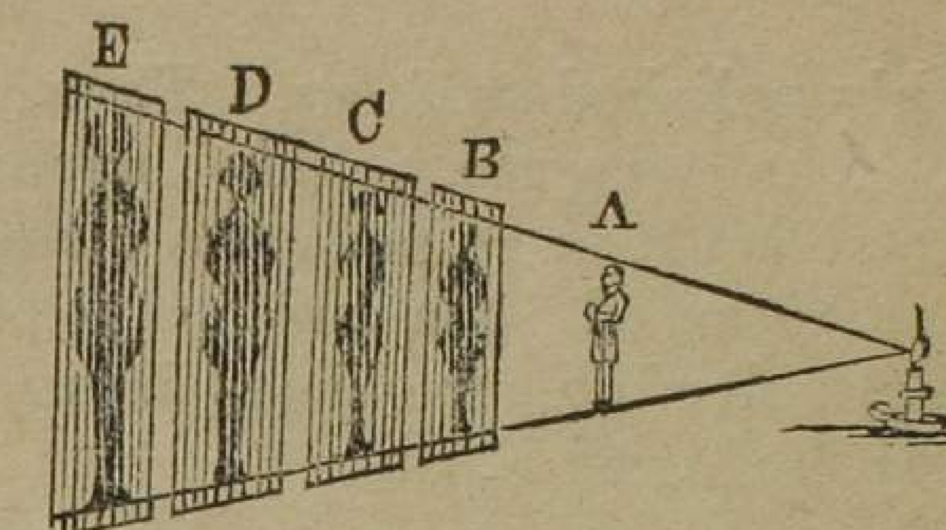
3. What will be the form of the shadow of a spherical body, when the luminous body is larger than the opaque body?

The form of the shadow of a spherical body, when the luminous body is larger than the opaque body, will be that of a cone. In the figure, A represents the sun, and B the moon. The sun, being much larger than the moon, causes it to cast a converging shadow, which terminates at E.



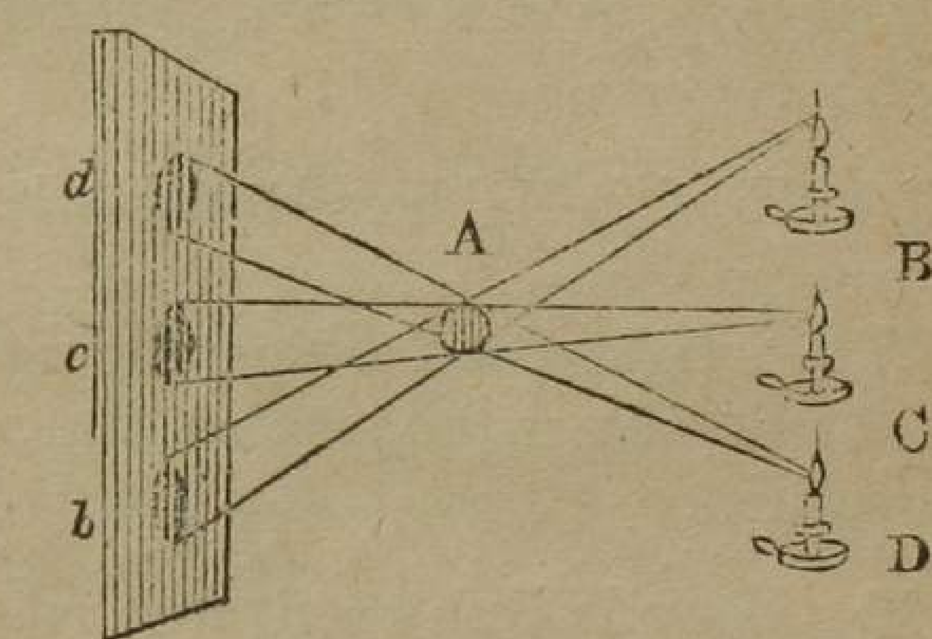
4. When the luminous body is the smaller, how will the shadow be affected?

When the luminous body is smaller than the opaque body, the shadow of the opaque body gradually increases in size with the distance, without limit. In the figure, the shadow of the object, A, increases in size at the different distances, B, C, D, E, or, in other words, it constantly diverges.



5. When several luminous bodies shine upon the same object, which of them will produce a shadow?

When several luminous bodies shine upon the same object, each one will produce a shadow. The figure represents a ball, A, illuminated by the three candles, B, C, and D. The light B produces the shadow *b*, the light C, the shadow *c*, and the light D, the shadow *d*; but as the light from each of the candles shines upon all the shadows, except its own, the shadows will be faint.



6. When is light said to be reflected?

Light is said to be reflected when it is thrown off from the body on which it falls.

7. From what bodies is it most reflected?

Light is reflected in the largest quantities from the most highly polished surfaces. Thus, although most substances reflect it in a degree, polished metals, looking-glasses or mirrors, &c., reflect it in so perfect a manner as to convey to our eyes, when situated in a proper position to receive them, perfect images of whatever objects shine on them, either by their own, or by borrowed light.

8. What is that part of the science called which treats of reflected light?

That part of the science of Optics which relates to reflected light, is called *Catoptrics*.

9. By what laws is reflected light governed?

The laws of reflected light are the same as those of reflected motion.

10. How is light reflected when it falls perpendicularly on an opaque body?

When light falls perpendicularly on an opaque body, it is reflected back in the same line, towards the point whence it proceeded,

11. How is light reflected when it falls obliquely?

When light falls obliquely, it will be reflected obliquely in the opposite direction; and in all cases the angle of incidence will be equal to the angle of reflection.

12. By what light are opaque bodies seen?

Opaque objects are seen only by reflected light.

13. By what light are luminous bodies seen?

Luminous bodies are seen by the rays of light which they send directly to our eyes.

14. How are all objects seen?

All objects are seen by means of the rays of light emanating or reflected from them.

15. What then follows when no light falls on an opaque body?

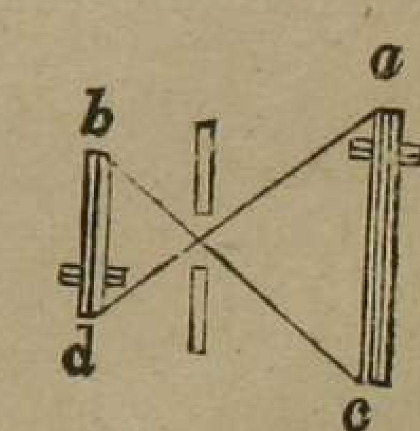
When no light falls upon an opaque body, it is invisible. This is the reason why none but luminous bodies can be seen in the dark. For the same reason, objects in the shade, or in a darkened room appear indistinct, while those which are exposed to a strong light can be clearly seen.

16. What kind of image is formed when rays of light, proceeding from an object, enter a small aperture?

When rays of light, proceeding from any object, enter a small aperture, they cross one another and form an inverted image of the object.

17. Illustrate this by the figure.

The figure represents the rays from an object *a c*, entering an aperture. The ray from *a* passes down through the aperture to *d*, and the ray from *c* passes up to *b*, and thus these rays, crossing at the aperture, form an inverted image on the wall. The room in which this experiment is made should be darkened, and no light permitted to enter excepting through the aperture.

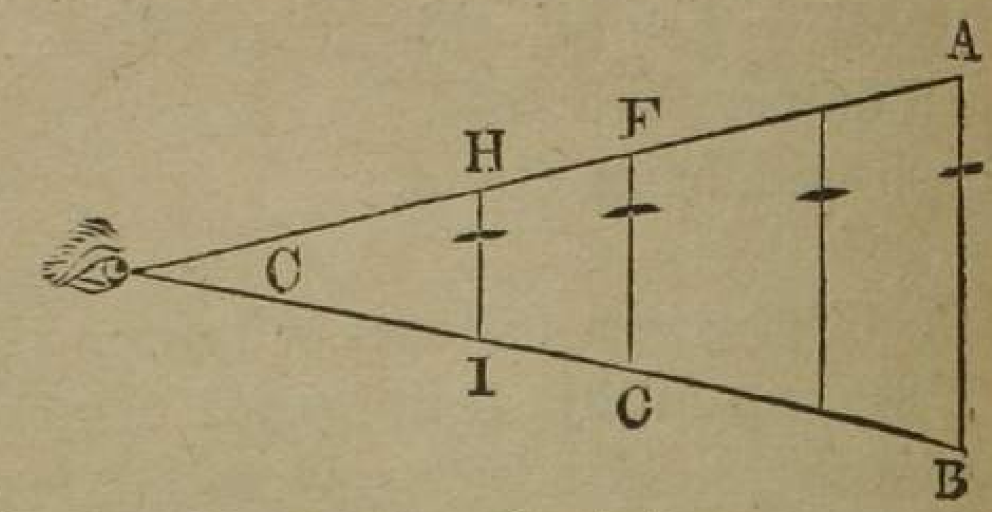


18. What is the angle of vision?

The angle of vision is the angle formed at the eye by two lines drawn from opposite parts of an object.

19. Explain the angle of vision from the figure.

The angle C represents the angle of vision. The line A C preceeding from one extremity of the object meets the line B C proceeding from the opposite extremity, and forms an angle C at the eye;—this is the angle of vision.

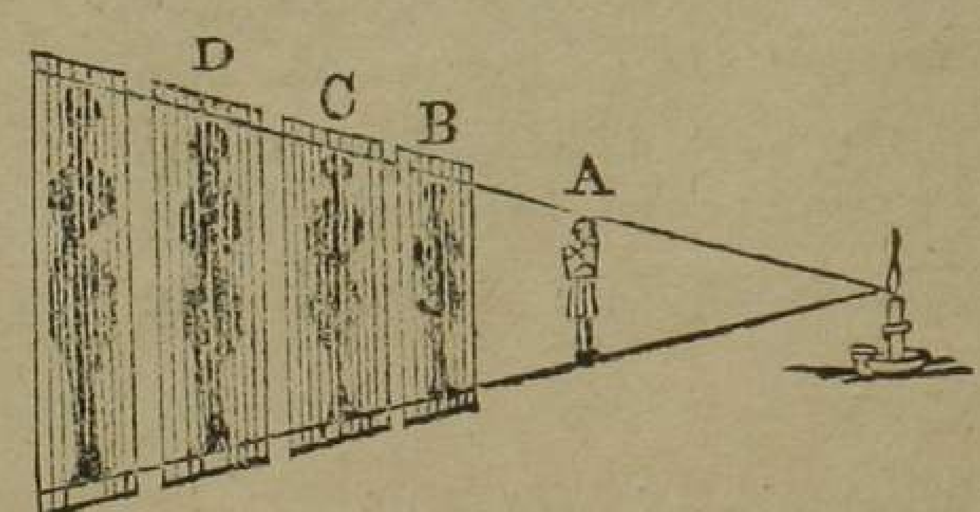


20. What is an angle?

An angle is the opening of two lines meeting in a point.

21. How is the magnitude of an angle measured?

The magnitude of an angle is measured by the width of the opening of the lines, and is not affected by the length of the lines. To measure an angle, a circle is drawn around the point where the lines meet; and the size of the angle depends on the part of the circle which will be included between the lines. The larger the part of the circle included between the lines, the larger will be the angle. Thus the figures at A, B, C, and D subtend the same visual angle.



Lesson XXVI.

OF MIRRORS.

1. What is a mirror?

A mirror is a smooth and polished surface, that forms images by the reflection of the rays of light.

2. How are mirrors made?

Mirrors (or looking-glasses) are made of glass, with the back covered with an amalgam, or mixture of mercury and tinfoil.

3. What reflects the rays of light?

It is the smooth and bright surface of the mercury that reflects the rays, the glass acting only as a transparent case, or covering, through which the rays find an easy passage.

4. Are any of the rays absorbed in their passage through the glass?

Some of the rays are absorbed in their passage through the glass, because the purest glass is not free from imperfections.

5. Of what materials are the best mirrors made?

The best mirrors are made of fine and highly-polished steel, so that they may not absorb the light.

6. How many kinds of mirrors are there?
There are three kinds of mirrors, namely, the plain, the concave, and the convex mirror.

7. What are plain mirrors?
Plain mirrors are those which have a flat surface, such as a common looking-glass: and they neither magnify nor diminish the image of objects reflected from them.

8. What is a convex mirror?
A convex mirror is a portion of the external surface of a sphere. Convex mirrors have therefore a convex surface.

9. What is a concave mirror?
A concave mirror is a portion of the inner surface of a hollow sphere. Concave mirrors have therefore a concave surface.

10. When you look into a plain glass, what do you see?
The reflected image of the object.

11. Where will that image appear to be?
As far behind the mirror as the object is in front of it.

12. If an object be reflected from a convex mirror, how will the image appear?
It will appear smaller than the object, and erect.

13. How will it appear when reflected from a concave mirror?
It will appear magnified, and will be either erect or inverted, according to the position of the eye.

14. If parallel rays are reflected from a plain mirror, how will they be after reflection?
If parallel rays are reflected from a plain mirror, they will be parallel after reflection.

15. If parallel rays are reflected from a convex mirror, how will they be after reflection?
If parallel rays are reflected from a convex mirror, they will diverge after reflection.

16. If parallel rays are reflected from a concave mirror, how will they be after reflection?
If parallel rays are reflected from a concave mirror, they will converge after reflection.

CONVEX MIRROR.

Lesson XXVII.

REFRACTION OF LIGHT.

1. What is Dioptrics?

That part of the science of Optics which treats of refracted light is called Dioptrics.

2. What is meant by the refraction of light?

By the refraction of light is meant its being turned or bent from its course.

3. When does refraction of light take place?

Refraction of light always takes place when it passes *obliquely* from one medium to another.

4. What is a medium in Optics?

By a medium, in Optics, is meant any substance through which light can pass.

5. Give some examples of media.

Air, glass, water, and other fluids, are media.

6. What is the first fundamental law of Dioptrics?

When light passes from one medium to another, in a direction perpendicular to the surface, it continues on in a straight line without altering its course.

7. What is the second fundamental law of Dioptrics?

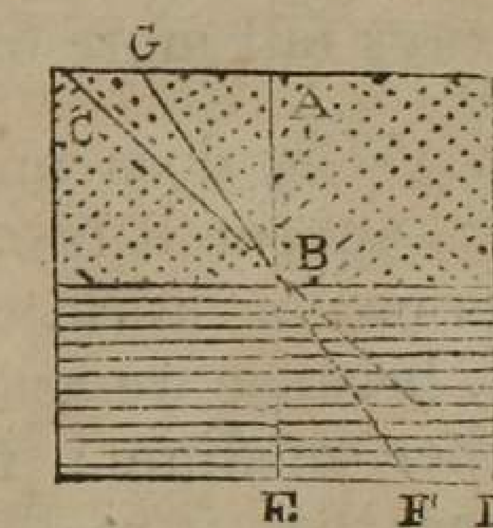
When light passes in an oblique direction, from a *rarer* to a *denser* medium, it will be turned from its course, and proceed through the denser medium *less* obliquely, and in a line nearer to a perpendicular to its surface.

8. What is the third fundamental law of Dioptrics?

When light passes from a denser to a rarer medium, it passes through the rarer medium in a more oblique direction, and in a line further from a perpendicular to the surface of the denser medium.

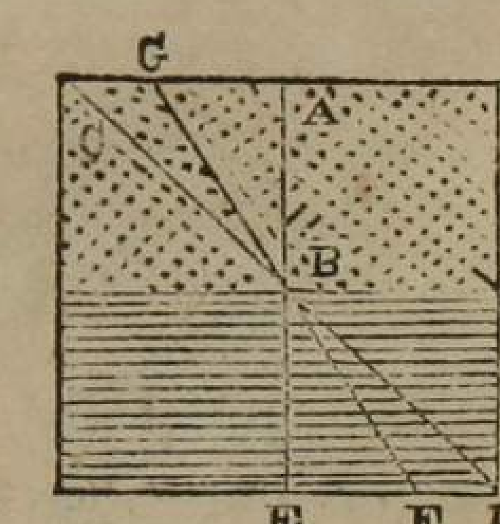
9. Explain the first law from the figure.

In the figure, the line A B represents a ray of light passing from air into water in a perpendicular direction. According to the first law, stated above, it will continue on in the same line through the denser medium to E. If the ray were to pass upward through the denser medium, the water, in the same perpendicular direction to the air, by the same law it would also continue on in the same straight line to A.



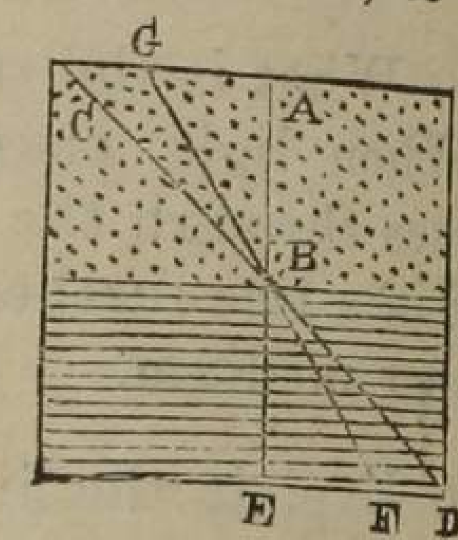
10. Explain the second law from the figure.

If a ray proceed from a rarer to a denser medium, in an oblique direction, as from C to B, when it enters the denser medium it will not continue on in the same straight line to D, but, by the second law, stated above, it will be refracted or bent out of its course, and proceed in a less oblique direction to F, which is nearer the perpendicular A B E than D is.



11. Explain the third law from the figure.

If a ray proceed from the denser medium, the water, to the rarer medium, the air, namely, from F to B, instead of pursuing its straight course to G, it will be refracted according to the third law above stated, and proceed in a more oblique direction to C, which is further from the perpendicular E B A than G is.

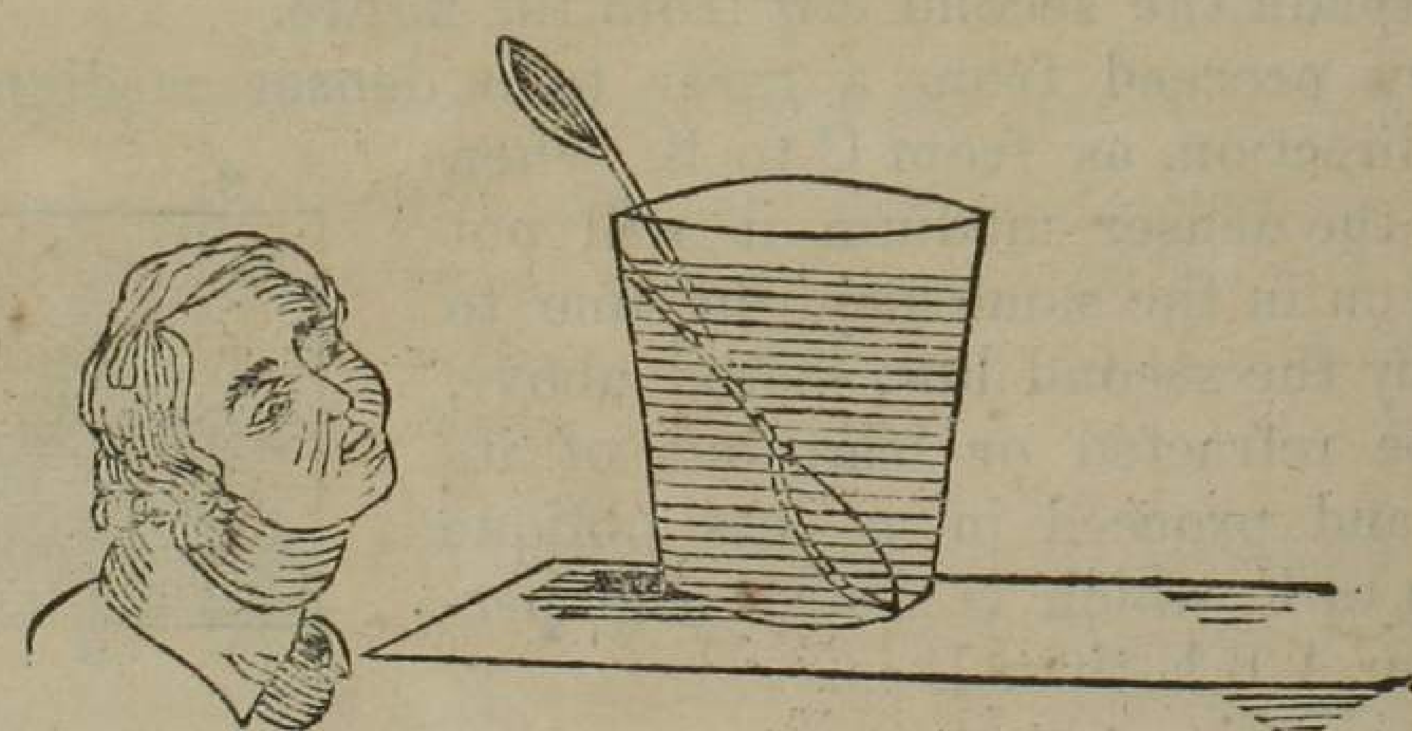


12. How does the refraction increase or diminish?

The refraction is more or less in all cases in proportion as the rays fall more or less obliquely on the refracting surface.

13. Why does an oar or stick, when partly immersed in water, appear bent?

An oar or stick, when partly immersed in water, appears bent, because we see one part in one medium, and the other in another medium: the part which is in the water appears higher than it really is, on account of the refraction of the denser medium.



14. Why does a body of water, when viewed obliquely, appear more shallow than it is?

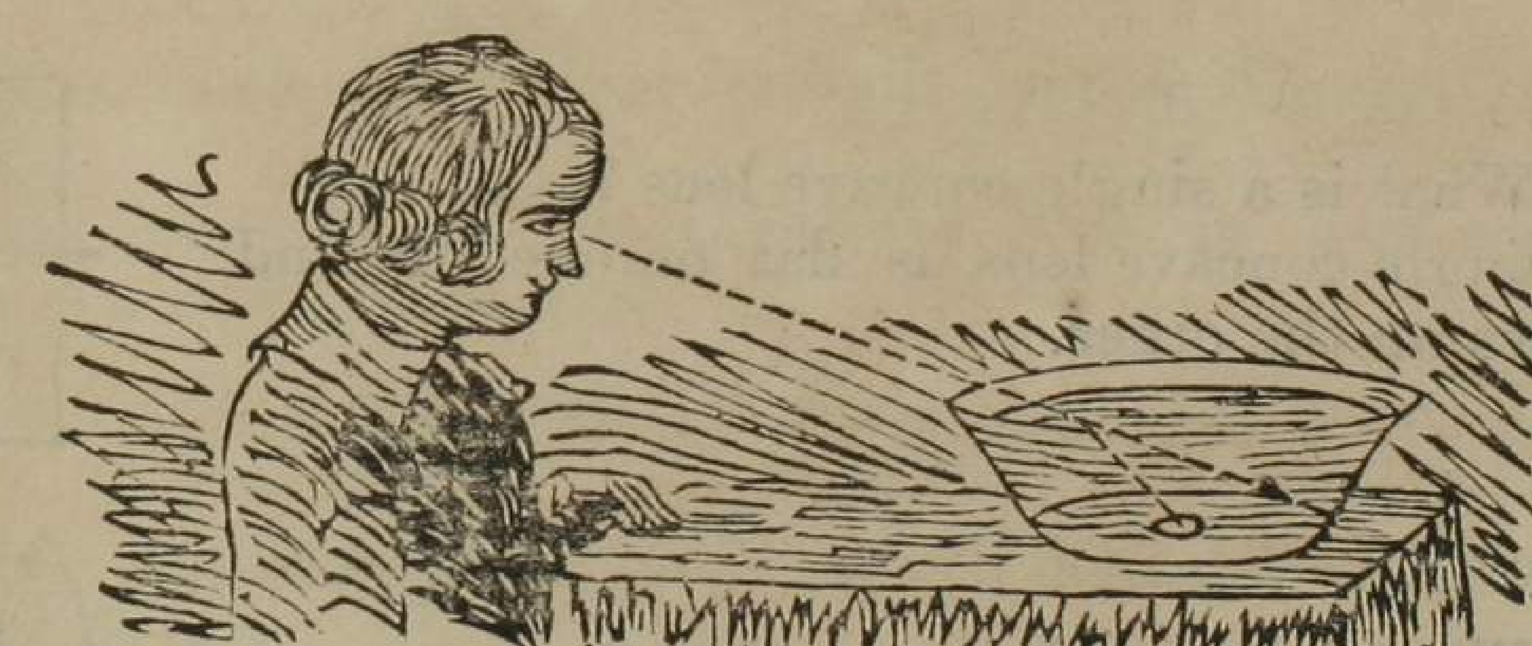
When we look *obliquely* upon a body of water it appears more shallow than it really is, because the bottom is apparently raised by the refraction.

15. In what direction can we look so as to cause no refraction?

When we look *perpendicularly* downwards, we are liable to no such deception, because there will be no refraction.

16. What experiment will show the refraction of light in passing from water into air?

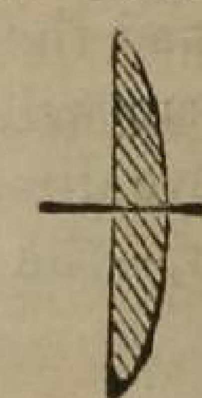
Let a piece of money be put into a cup or a bowl, and the cup and the eye be placed in such a position that the side of the cup will just hide the money from the sight; then keeping the eye directed to the same spot, let the cup be filled with water,—the money will become distinctly visible.



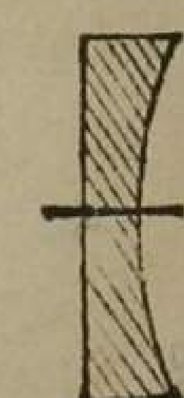
Lesson XXVIII.

OF LENSES.

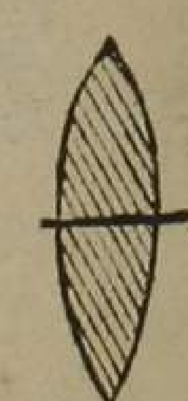
1. What is a lens?
A lens is a glass, which, owing to its peculiar form, causes the rays of light to converge to a focus, or disperses them according to the laws of refraction.



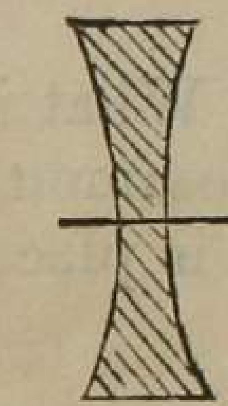
2. What is a single convex lens?
A single convex lens has one side flat and the other convex.



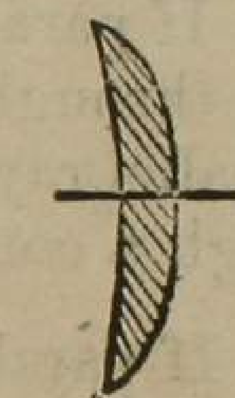
3. What is a single concave lens?
A single concave lens is flat on one side and concave on the other.



4. What is a double convex lens?
A double convex lens is convex on both sides.



5. What is a double concave lens?
A double concave lens is concave on both sides.



6. What is a meniscus?
A meniscus is convex on one side and concave on the other.

7. What is the axis of a lens?
The axis of a lens is a line passing through the centre perpendicularly.

8. What is the focus of a lens?
The focus of a lens is the point where the rays of light passing through it are collected.

9. What effect is produced by light passing through convex lenses?
Convex lenses collect the rays into a focus, and magnify objects at a certain distance.

10. What effect is produced by light passing through concave lenses?
Concave lenses disperse the rays, and diminish objects seen through them.

11. What is a burning-glass?
It is a convex lens, which collects the heat of the sun at the focus, opposite to the source of light.

12. What is a magnifying-glass?

A common magnifying-glass is a convex lens, in which the object is placed on one side, and the eye at the focus on the other.

13. If parallel rays proceed from a rarer into a denser medium, through a convex surface, what will take place?

Parallel rays proceeding out of a rarer into a denser medium, through a convex surface, are made to converge.

14. If parallel rays pass from a rarer into a denser medium, through a concave surface, what will take place?

Parallel rays passing out of a rarer into a denser medium, through a concave surface, will diverge.

THE SUN-GLASS.

Lesson XXIX.

OF THE EYE.

1. Of what is the eye composed?

The eye is composed of a number of coats, or coverings, within which are enclosed a lens, and certain humors, in the shape, and performing the office of convex lenses.

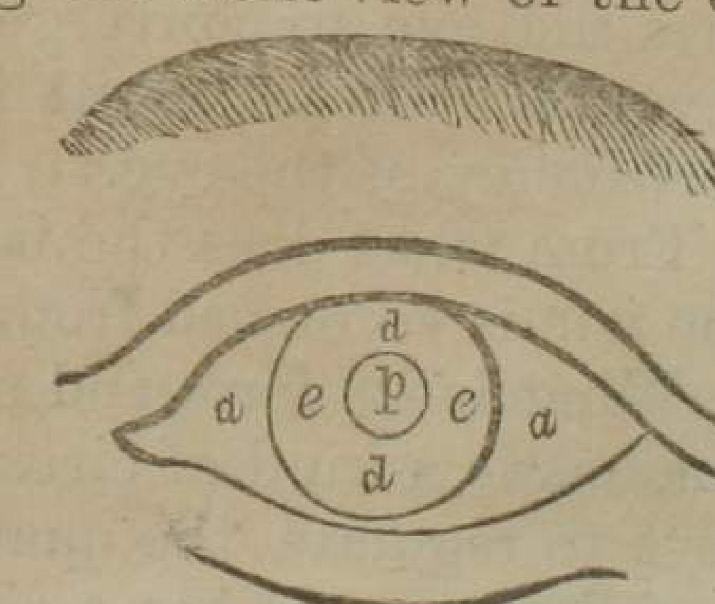
2. What are the different parts of the eye? First? Second? Third? Fourth? Fifth? Sixth? Seventh? Eighth? Ninth? Tenth?

The different parts of the eye, are:

1. The Cornea.
2. The Iris.
3. The Pupil.
4. The Aqueous Humor.
5. The Crystalline Lens.
6. The Vitreous Humor.
7. The Retina.
8. The Choroid.
9. The Sclerotica.
10. The Optic Nerve.

3. Explain the figure representing the front view of the eye.

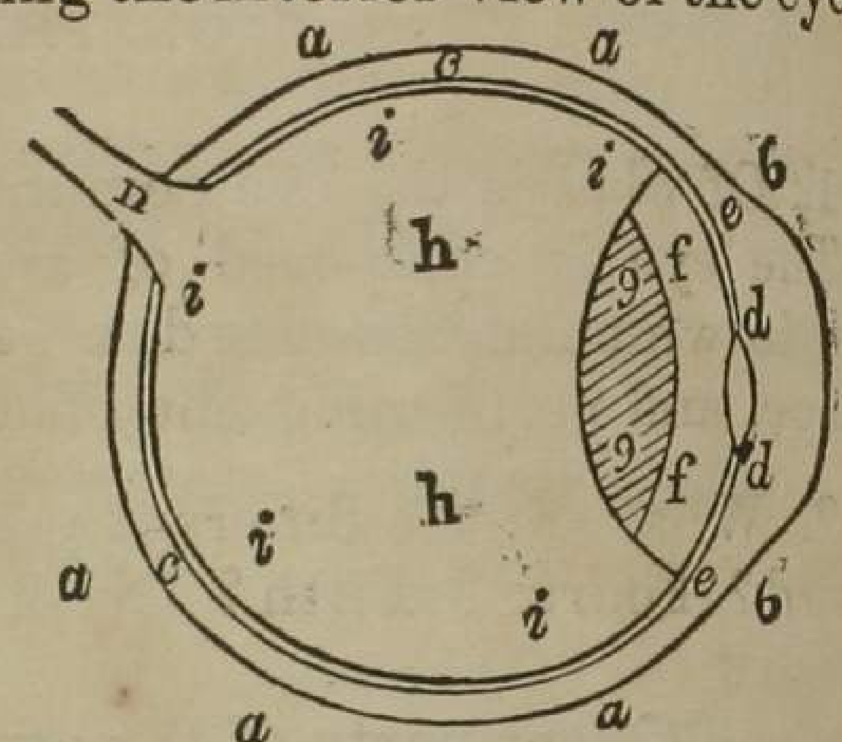
The figure represents a front view of the eye, in which *a a* represents the Cornea, or, as it is commonly called, the white of the eye; *e e* is the Iris, having a circular opening in the centre, called the pupil, *p*, which contracts in a



strong light, and expands in a faint light, and thus regulates the quantity which is admitted to the tender parts in the interior of the eye.

4. Explain the figure representing the interior view of the eye.

The figure represents a side view of the eye, laid open, in which *b b* represents the cornea, *e e* the iris, *d d* the pupil, *f f* the aqueous humor, *g g* the crystalline lens, *h h* the vitreous humor, *i i i i* the retina, *c c* the choroid, *a a a a* the sclerotica, and *n* the optic nerve.



5. What part of the eye does the cornea form?

The cornea forms the front portion of the eye. It is set in the sclerotica in the same manner as the crystal of a watch is set in the case.

6. What is the use of the cornea?

The principal office of the cornea is to cause the light which reaches the eye to converge to the axis. Part of the light, however, is reflected by its finely polished surface, and causes the brilliancy of the eye.

7. From what does the iris take its name?

The iris is so named from its being of different colors.

8. What is its form and use?

The iris is a kind of circular curtain, placed in the front of the eye to regulate the quantity of light passing to the back part of the eye. It has a circular opening in the centre, which

it involuntarily enlarges or diminishes to admit a due portion of light.

9. What is the pupil?

The pupil is merely the opening in the iris, through which the light passes to the lens behind.

10. What is its form in the human eye?

It is always circular in the human eye, but in quadrupeds it is of different shape.

11. What is the aqueous humor?

The aqueous humor is a fluid, as clear as the purest water.

12. What is its shape, and where is it situated?

In shape it resembles a meniscus, and, being situated between the cornea and the crystalline lens, it assists in collecting and transmitting the rays of light from external objects to that lens.

13. What is the crystalline lens?

The crystalline lens is a transparent body, in the form of a double convex lens, placed between the aqueous and vitreous humors.

14. What is its office?

Its office is not only to collect the rays to a focus, on the retina, but also to increase the intensity of the light which is directed to the back part of the eye.

15. What is the vitreous humor?

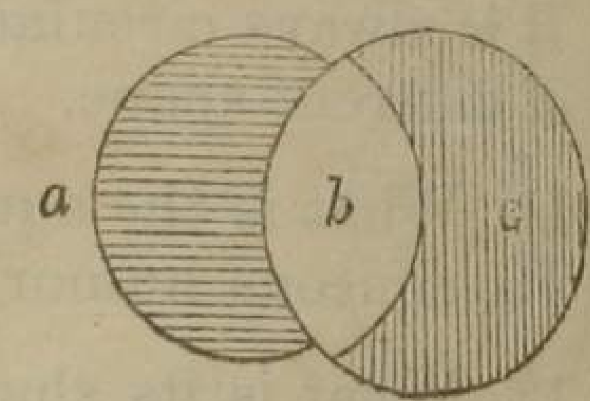
The vitreous humor (so called from its resemblance to melted glass) is a perfectly transparent mass, occupying the globe of the eye.

16. What is its shape?

Its shape is like a meniscus, the convexity of which greatly exceeds the concavity.

17. Explain the aqueous and vitreous humors from the figure.

In the figure the shape of the aqueous and vitreous humors and the crystalline lens is presented. *a* is the aqueous humor, which is a meniscus, *b* the crystalline lens, which is a double convex lens, and *c* the vitreous humor, which is, also, a meniscus, whose concavity has a smaller radius than its convexity.



18. What is the retina?

The retina is the seat of vision.

19. Where are the rays of light brought to a focus?

The rays of light being refracted in their passage by the other parts of the eye, are brought to a focus in the retina, where an inverted image of the object is represented.

20. What is the choroid?

The choroid is the inner coat or covering of the eye.

21. What is its use?

Its office is, apparently, to absorb the rays of light immediately after they have fallen on the retina. It is the opinion of some philosophers, that it is the choroid and not the retina, which conveys the sensation produced by rays of light to the brain.

22. What is the sclerotica?

The sclerotica is the outer coat of the eye.

23. From what does it derive its name?

It derives its name from its hardness.

24. What is its use?

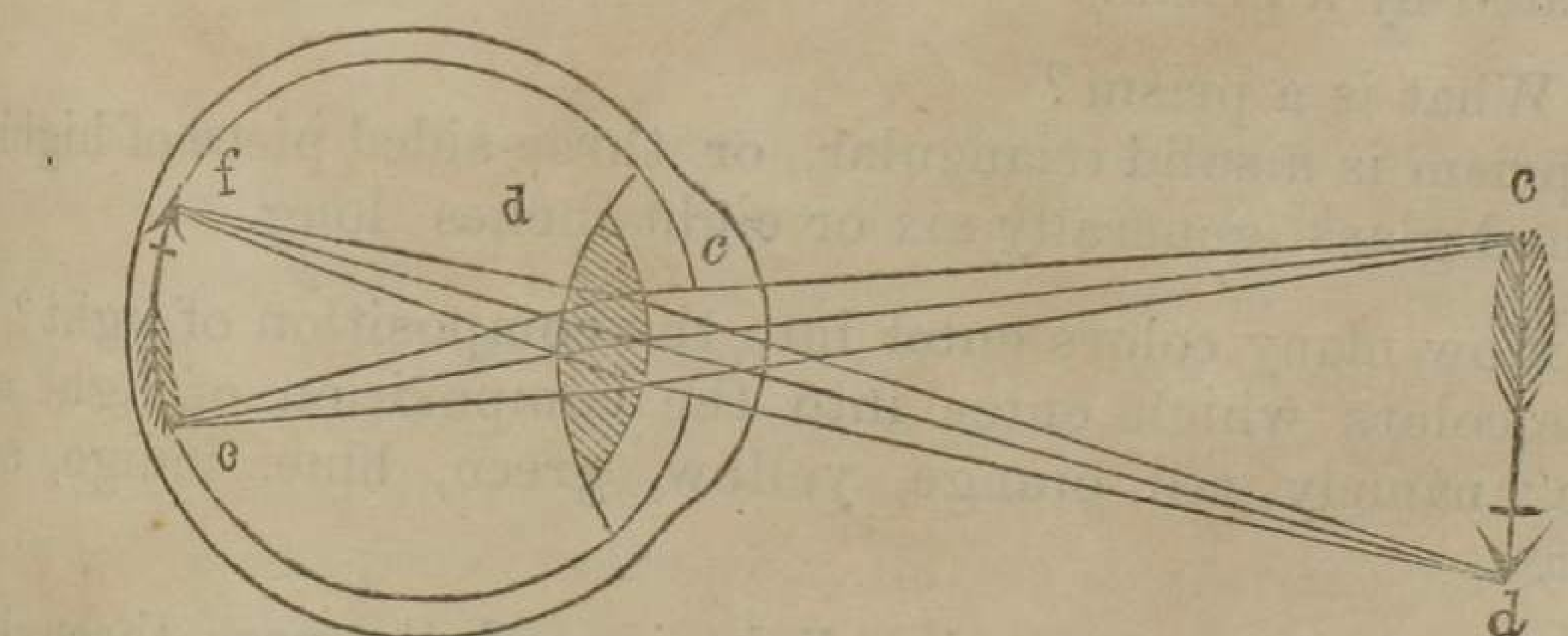
Its office is to preserve the globular figure of the eye, and defend its more delicate internal structure.

25. What is the optic nerve?

The optic nerve is the organ which carries the impressions made by the rays of light to the brain, and thus produces the sensation of sight.

26. How is the image formed on the retina?

The image is formed thus: The rays from the object *c d*,



diverging towards the eye, enter the cornea *c*, and cross one another in their passage through the crystalline lens *d*, by which they are made to converge on the retina, where they form the inverted image *f e*.

Lesson XXX.

CHROMATICS.

1. What is Chromatics?
That part of the science of Optics which relates to colors is called Chromatics.

2. What causes color?
Colors do not exist in the bodies themselves, but are caused by the peculiar manner in which the light is reflected from their surfaces.

3. Of what is light composed?
Light is composed of rays of different colors, which may be separated by a prism.

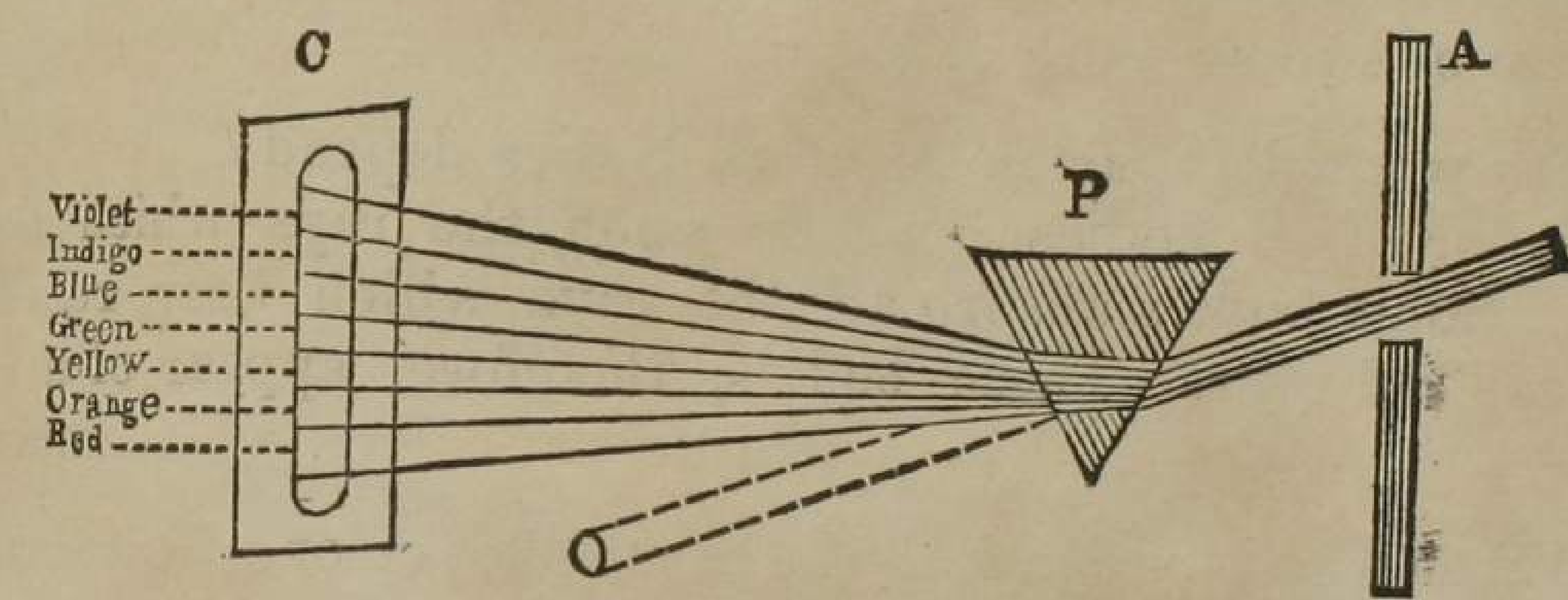
4. What is a prism?
A prism is a solid triangular, or three-sided piece of highly-polished glass, generally six or eight inches long.

5. How many colors enter into the composition of light?
The colors which enter into the composition of light are seven: namely, red, orange, yellow, green, blue, indigo, and violet.

6. What takes place when light is made to pass through a prism?
When light is made to pass through a prism, the different colored rays are separated, and form an image on a screen or

wall, in which the colors will be arranged in the order just mentioned.

7. Explain, from the figure, what takes place when light passes through a prism.
The figure represents rays of light passing from the aperture in a window-shutter, A B, through the prism P. Instead of continuing in a straight course to E, and there forming an



image, they will be refracted, in their passage through the prism, and form an image on the screen, C D. But as the different colored rays have different degrees of refrangibility, those which are refracted the least will fall upon the lowest part of the screen, and those which are refracted the most will fall upon the highest part. The red rays, therefore, suffering the smallest degree of refraction, fall on the lowest part of the screen, and the remaining colors are arranged in the order of their refraction.

8. If the colored rays which have been separated fall upon a convex lens, what will take place?
If the colored rays, which have been separated by a prism,

fall upon a convex lens, they will converge to a focus, and appear white.

9. Is white then a simple color?

It appears that white is not a simple color, but that it is produced by the union of several colors.

10. What are the colors of all bodies?

The colors of all bodies are either the simple colors, as refracted by the prism, or such compound colors as arise from a mixture of two or more of them.

11. On what does the color of all bodies depend?

The color of all bodies depends upon the rays which they reflect. Some bodies absorb all the rays which they receive except the red rays. These bodies, therefore, appear of a red color.

12. When a body reflects all the rays, what color will it have?

When a body reflects *all* the rays, it appears *white*.

13. What color will it have when it absorbs them all?

When it absorbs all the rays, it appears black.

14. What follows from the above laws?

It follows from the above laws, that white is a mixture of all the primitive colors, and black is the deprivation of all color.

15. Do light and color necessarily exist together?

They do. There can be no light without colors, and there can be no colors without light.

Lesson XXXI.

RAINBOW AND KALEIDESCOPE.

1. How is the rainbow produced?

The rainbow is produced by the refraction of the sun's rays in their passage through a shower of rain; each drop of which acts as a prism in separating the colored rays, as they pass through it.

2. How is this shown to be true?

This is proved by the following considerations. *First*, a rainbow is never seen except when rain is falling, and the sun shining at the same time; and that the sun and the bow are always in opposite parts of the heavens.

Secondly, that the same appearance may be produced artificially, by means of water thrown into the air, when the spectator is placed in a proper position, with his back to the sun, and,

Thirdly, that a similar bow is generally produced by the spray which arises from large cataracts, or waterfalls.

3. What is a multiplying-glass?

A multiplying-glass is a convex lens, one side of which is ground down into several flat surfaces.

4. How many times will an object viewed through a multiplying-glass be multiplied?

When an object is viewed through a multiplying-glass, it will be multiplied as many times as there are flat surfaces on the lens. Thus, if one lighted candle be viewed through a lens having twelve flat surfaces, twelve candles will be seen through the lens.

5. What is the principle of the multiplying-glass?

The principle of the multiplying-glass is the same with that of a convex or concave lens.

6. Of what does the kaleidescope consist?

The kaleidescope consists of two reflecting surfaces, or pieces of looking-glass, inclined to each other at an angle of 60 degrees, and placed between the eye and the objects intended to form the picture.

7. How is it constructed?

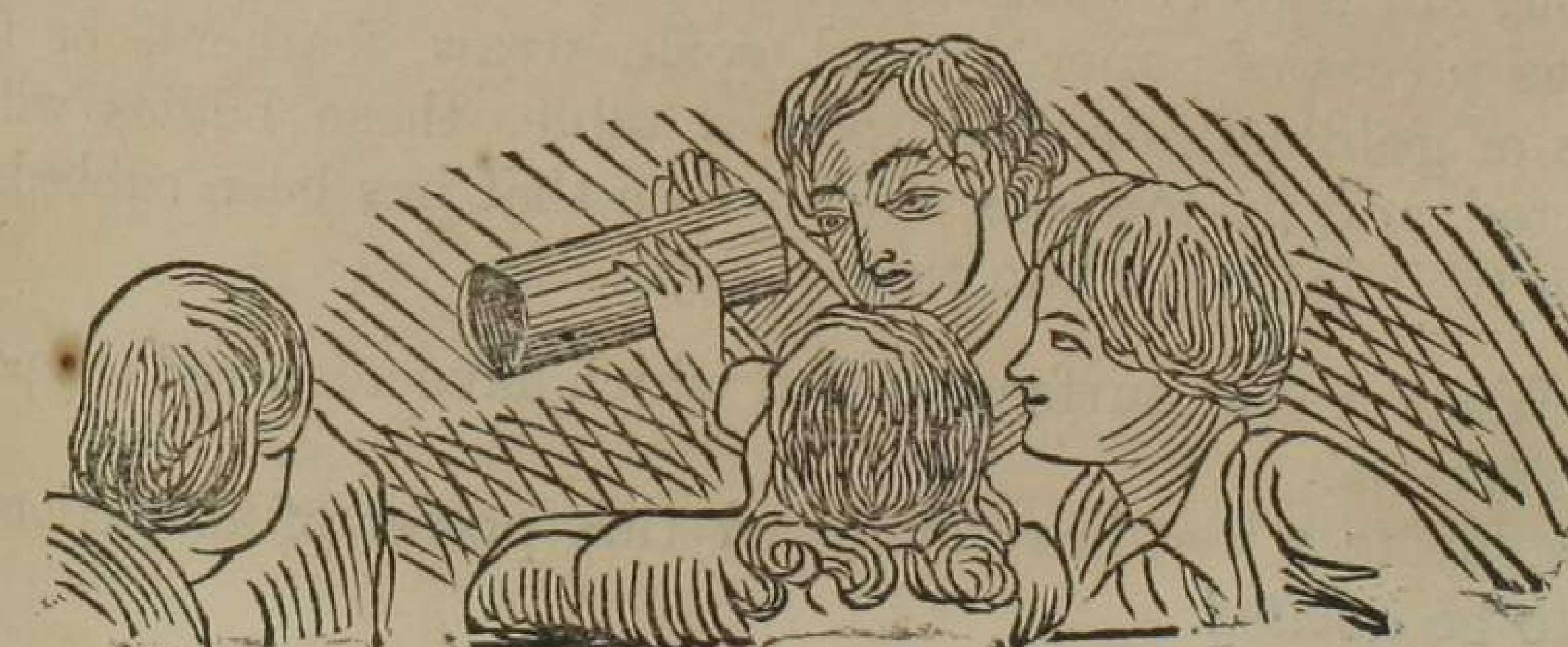
The two plates are enclosed in a tin or paper tube, and the objects, consisting of pieces of colored glass, beads, or other highly-colored fragments, are loosely confined between two circular pieces of common glass, the outer one of which is slightly ground, to make the light uniform.

8. What is seen in the kaleidescope?

On looking down the tube through a small aperture, and where the ends of the glass plates nearly meet, a beautiful figure will be seen, having six angles, the reflectors being inclined the sixth part of a circle. If inclined the twelfth part, or twentieth part of a circle, twelve or twenty angles will be seen.

9. What effect is produced by turning the tube?

By turning the tube so as to alter the position of the colored fragments within, these beautiful forms will be changed. In this manner an almost infinite variety of patterns may be produced.



Lesson XXXII.

ELECTRICITY.

1. What is Electricity ?

The word Electricity is a term used by philosophers to signify the operations of a very subtile and elastic fluid, which pervades the material world.

2. How can electricity be seen ?

Electricity can be seen only in its effects ; which are exhibited in the form of attraction and repulsion.

3. How may electricity be produced ?

If a piece of amber, sealing-wax, or smooth glass, perfectly clean and dry, be briskly rubbed with a dry woollen cloth, electricity will be produced on the surface.

4. How is it shown that electricity will be produced by friction ?

If the surfascs rubbed be held over small and light bodies, such as pieces of paper, thread, cork, straw, feathers, or fragments of goldleaf, strewed upon a table, these bodies will be attracted, and fly towards the surface that has been rubbed, and adhere to it for a certain time.

5. What are the surfaces called which have acquired the power of attraction ?

The surfaces that have acquired this power of attraction, are said to be *excited.*

6. What are the substances called which are capable of such excitement ?

The substances thus susceptible of being excited are called *electrics.*

7. What are those called which cannot be thus excited ?

Those which cannot be excited in a similar manner are called *non-electrics.*

8. Into what classes does the science of electricity divide all substances ?

The science of electricity, therefore, divides all substances into two kinds ; namely, *electrics*, or those substances which can be excited, and *non-electrics,* or those substances which cannot be excited.

9. May the electric fluid be communicated from one substance to another ?

The electric fluid is readily communicated from one substance to another.

10. Will all substances allow electricity to pass through them ?

Some substances will not allow it to pass through or over them, while others give it free passage.

11. What bodies are called conductors ?

Those substances through which it passes without obstruction are called *conductors.*

12. What bodies are called non-conductors ?

Those through which it cannot readily pass are called *non-conductors.*

13. What bodies are electrics and what non-electrics?

It is found, by experiment, that all *electrics* are *non-conductors*, and all *non-electrics* are good *conductors*, of electricity.

14. Name some of the substances which are electrics or non-conductors.

Atmospheric air, (when dry,) glass, diamond, feathers, wool, hair, &c.

15. Name some of the substances which are non-electrics or conductors.

All the metals, charcoal, living animals, vapor or steam.

16. When is a substance said to be insulated?

When a conductor is surrounded on all sides by non-conducting substances, it is said to be *insulated*.

17. Give an example of an insulated substance.

As glass is a non-conducting substance, any conducting substance surrounded with glass, or standing on a table or stool with glass legs, will be *insulated*.

18. Give a second example.

As the air is a non-conductor, when dry, a substance which rests on any non-conducting substance will be insulated, unless it communicate with the ground, the floor, a table, &c.

Lesson XXXIII.

METHODS OF EXCITING ELECTRICITY.

1. What is the simplest mode of exciting electricity?

The simplest mode of exciting electricity is by friction.

2. Explain how this may be done.

Thus, if a thick cylinder of sealing-wax, or sulphur, or a glass tube, be rubbed with a silk handkerchief, a piece of clean flannel, or the fur of a quadruped, the electric fluid will be excited.

3. How else may it be produced?

If a cat's back be gently rubbed from the tail to the head, sparks of electricity will be emitted: and if the experiment be made in a dark room, the sparks will be distinctly visible.

4. What is an electrical machine?

An electrical machine is a machine constructed for the purpose of accumulating or collecting electricity, and transferring it to other substances.

5. What is the electricity called which is excited in glass?

The electricity excited in glass is called the *vitreous* or *positive* electricity.

6. What is the electricity called which is obtained from sealing-wax?

The electricity obtained from sealing-wax, or other resinous substances, is called *resinous* or *negative* electricity.

7. Do the positive and negative electricities exist separately?

The positive and negative electricities always exist together.

8. What do you understand by a plate being charged?

If one side of a plate of glass be positively electrified the opposite side will become negatively electrified, and the plate is then said to be charged.

9. After a plate is thus charged, if the two surfaces be united by a conductor, what will take place?

When two surfaces oppositely electrified are united, their powers are destroyed; and if their union be made through the human body, it produces an affection of the nerves, called an electric shock.

10. What is the Leyden jar?

The Leyden jar is a glass vessel used for the purpose of accumulating the electric fluid, procured from excited surfaces.

11. Describe it from the figure.

The figure represents a Leyden jar. It is a glass jar, coated both on the inside and the outside with tinfoil, with a cork or wooden stopper through which a metallic rod passes, terminating upwards in a brass knob, and connected by means of a wire, at the other end, with the inside coating of the jar. The coating extends both on the inside and outside only to within two or three inches of the top of the jar. Thus prepard, when an excited surface is applied to the brass knob, or connected with it by any conducting surface, it parts with its electricity, the fluid enters the jar, and the jar is said to be charged. When the Leyden jar is charged, the fluid is contained in the inside

coating of the vial; and as this coating is insulated, the fluid will remain in the jar until a communication be made, by means of some conducting substance, between the inside and the outside of the jar. If then a person apply one hand or finger to the brass knob, and the other to the outside coating of the jar, a communication will be formed by means of the brass knob with the inside and outside of the jar, and the jar will be discharged.

12. Can a vial or jar be charged if it is insulated?

A vial or jar that is insulated cannot be charged.

13. What is an electrical battery?

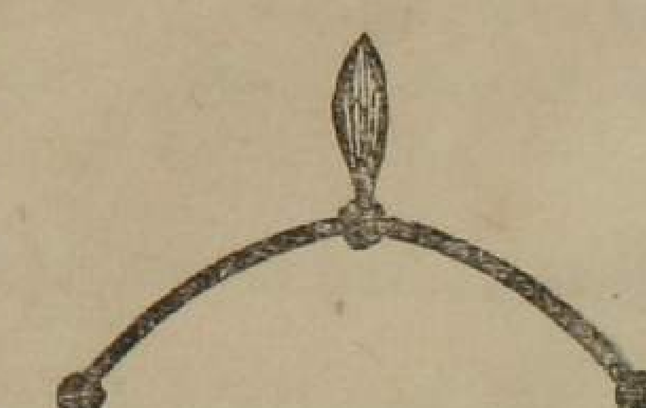
An electrical battery is composed of a number of Leyden jars connected together.

14. What is a jointed discharger?

The *jointed* discharger is an instrument used to discharge a jar, or battery.

15. Explain it from the figure.

The figure represents the jointed discharger. It consists of two rods, generally of brass, terminating at one end in brass balls, and connected together at the other end by a joint, like that of a pair of tongs, allowing them to be opened or closed. It is furnished with a glass handle, to secure the person who holds it from the effects of a shock. When opened, one of the balls is made to touch the outside coating of the jar, or the knob connected with the bottom of the battery, and the other is applied to the knob of the jar, or jars. A



communication being thus formed between the inside and the outside of the jar, a discharge of the fluid will be produced.

16. How do similar states of electricity act upon each other?

Similar states of electricity repel each other.

17. How do dissimilar states of electricity act upon each other?

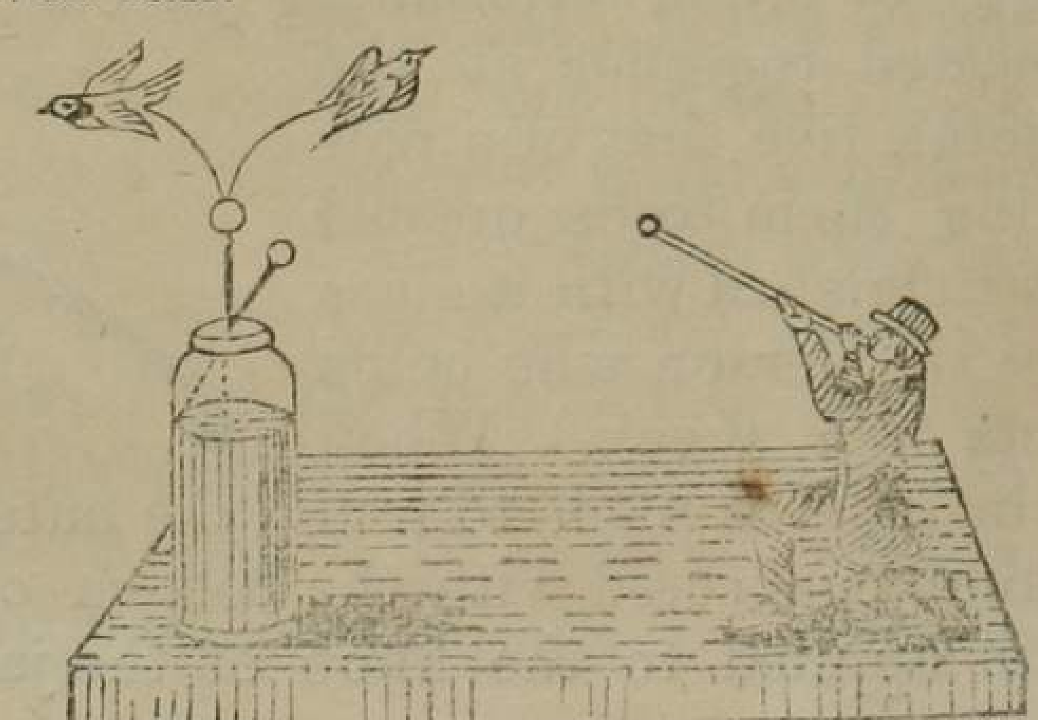
Dissimilar states of electricity attract each other.

18. Give an example of this.

If two pith-balls suspended by a silk thread, are both positively or both negatively electrified, they will repel each other; but if one be positively and the other negatively electrified, they will attract each other.

19. What is represented in the figure?

The figure represents the electrical sportsman. From the larger ball of a Leyden jar two birds, made of pith, are suspended by a linen thread, silk, or hair. When the jar is charged the birds will rise, as represented in the figure, on account of the repulsion of the fluid in the jar. If the jar be then placed on the tinfoil of the stand, and the smaller ball placed within a half-inch of the end of the gun, a discharge will be produced, and the birds will fall.



Lesson XXXIV.

EFFECTS OF ELECTRICITY.

1. What is lightning?

Lightning is the rapid motion of vast quantities of electric matter.

2. What is thunder?

Thunder is the noise produced by the rapid motion of lightning through the air.

3. What are lightning-rods?

Lightning-rods are iron rods pointed at the upper extremity, and attached to buildings to protect them against the effects of lightning.

4. Who first proposed the use of lightning-rods?

Lightning-rods were first proposed by Dr. Franklin, to whom is also ascribed the honor of the discovery that thunder and lightning are the effects of electricity.

5. How did Dr. Franklin discover that thunder and lightning are the effects of electricity?

He raised a kite, constructed of a silk handkerchief, adjusted to two light strips of cedar, with a pointed wire fixed to it; and fastening the end of the twine to a key, and the key, by means of a piece of silk lace, to a post, (the silk lace serving to insulate the whole apparatus,) on the approach of a thunder cloud, he was able to collect sparks from the key, to charge Leyden jars, and to set fire to spirits.

6. What did this experiment establish?

This experiment established the identity of lightning and electricity.

7. Was the experiment attended with danger?

The experiment was a dangerous one, as was proved in the case of Professor Richman, of St. Petersburgh, who fell a sacrifice to his zeal for electrical science, by a stroke of lightning from his apparatus.

8. What form of the lightning-rod is the best?

The square rods are better than round ones to conduct electricity silently to the ground, and thus to protect buildings against the effects of lightning.

9. In what different ways does the electric fluid sometimes pass in a thunder-storm?

In thunder-storms, the electric fluid sometimes passes from the clouds to the earth, and sometimes from the earth to the clouds; and sometimes from one cloud to the earth, and from the earth to another cloud.

10. Why is it not safe, in a thunder-storm, to take shelter under a tree?

It is not safe, during a thunder-storm, to take shelter under a tree, because the tree attracts the fluid, and the human body being a better conductor than the tree, the fluid will leave the tree and pass into the body.

11. What is the safest position during a thunder-storm?

The safest position that can be chosen during a thunder-storm, is a recumbent posture on a feather bed; and in all situations a recumbent is safer than an erect position.

12. When is there no danger to be apprehended from the lightning?

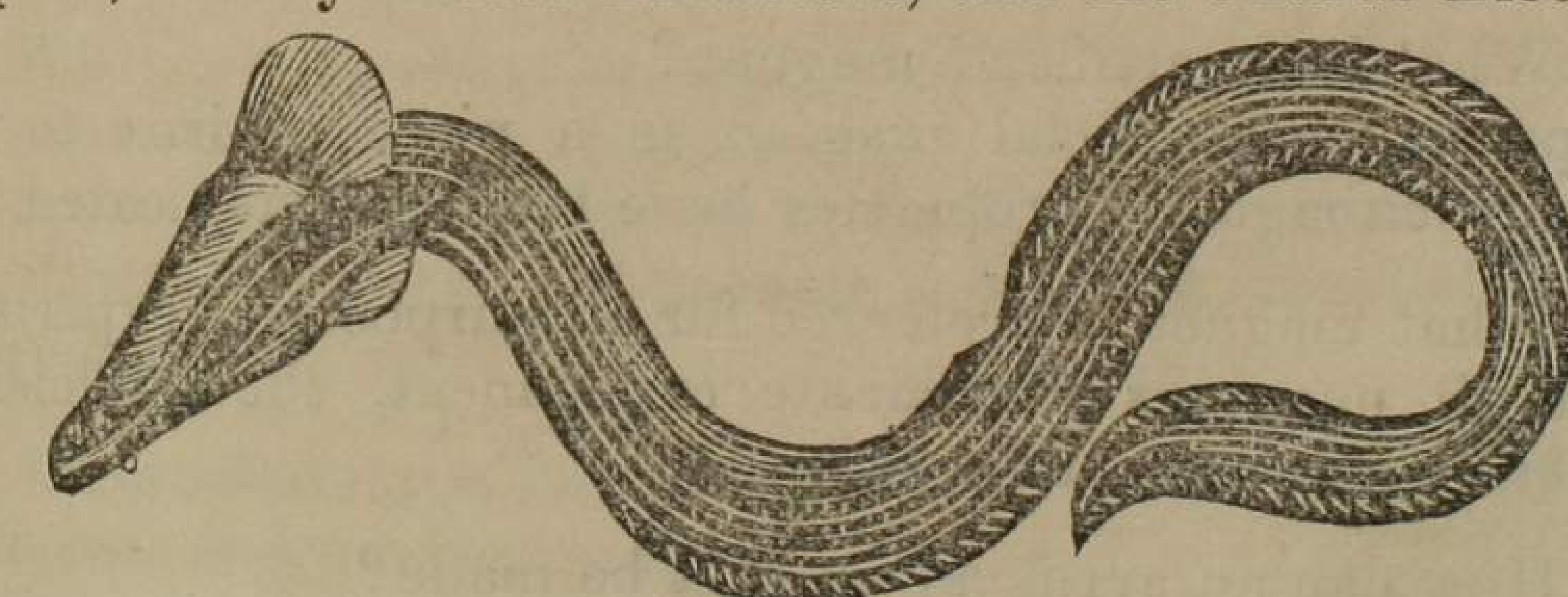
No danger is to be apprehended from lightning when the interval between the flash and the noise of the explosion is as much as three or four seconds. This space of time may be conveniently measured by the beatings of the pulse, if no time-piece be at hand.

13. Do any animals possess the power of giving shocks similar to those of the Leyden jar?

Among the most remarkable facts, connected with the science of Electricity, may be mentioned the power possessed by certain species of fishes, of giving shocks, similar to those produced by the Leyden jar.

14. What animals have this power?

There are three animals possessing this power; namely, the Torpedo, the Gymnotus Electricus, and the Silurus Electricus.



GYMNOTUS, OR ELECTRICAL EEL.

Lesson XXXV.

MAGNETISM AND ELECTRO-MAGNETISM.

1. Of what does Magnetism treat?

Magnetism treats of the properties and effects of the magnet, or loadstone.

2. How many kinds of magnets are there?

There are two kinds of magnets, namely, the native or natural magnet, and the artificial.

3. What is the native magnet?

The native magnet, or loadstone, is an ore of iron, found in iron mines.

4. What properties does it possess?

The native magnet has the property of attracting iron and other substances which contain it.

5. What is an artificial magnet?

A permanent artificial magnet is a piece of iron to which permanent magnetic properties have been communicated.

6. What magnet is preferred for all purposes of experiment?

For all purposes of accurate experiment, the artificial is to be preferred to the native magnet.

7. How can an artificial magnet be made?

If a straight bar of soft iron be held in a position nearly vertical, the lower end deviating to the north, and struck several smart blows with a hammer, it will be found to have acquired, by this process, all the properties of a magnet; or, in other words, it will become an artificial magnet.

8. How many properties has a magnet?

The properties of a magnet are four; namely,

1. Polarity.
2. Attraction of unmagnetic iron.
3. Attraction *and repulsion* of *magnetic* iron.
4. The power of communicating magnetism to other iron.

9. What is meant by polarity?

By the *polarity* of a magnet is meant the property of pointing, or turning to the north and south poles.

10. How are the ends of the magnet distinguished from each other?

The end which points to the north, is called the north pole of the magnet, and the other the south pole.

11. Where is the attractive power of a magnet the strongest?

The attractive power of a magnet is strongest at the poles.

12. When a magnet is so supported as to allow it to move freely, what position will it assume?

When a magnet is supported in such a manner as to move freely, it will spontaneously assume a position directed *nearly* north and south.

13. What advantage has the science of magnetism rendered to commerce and navigation?

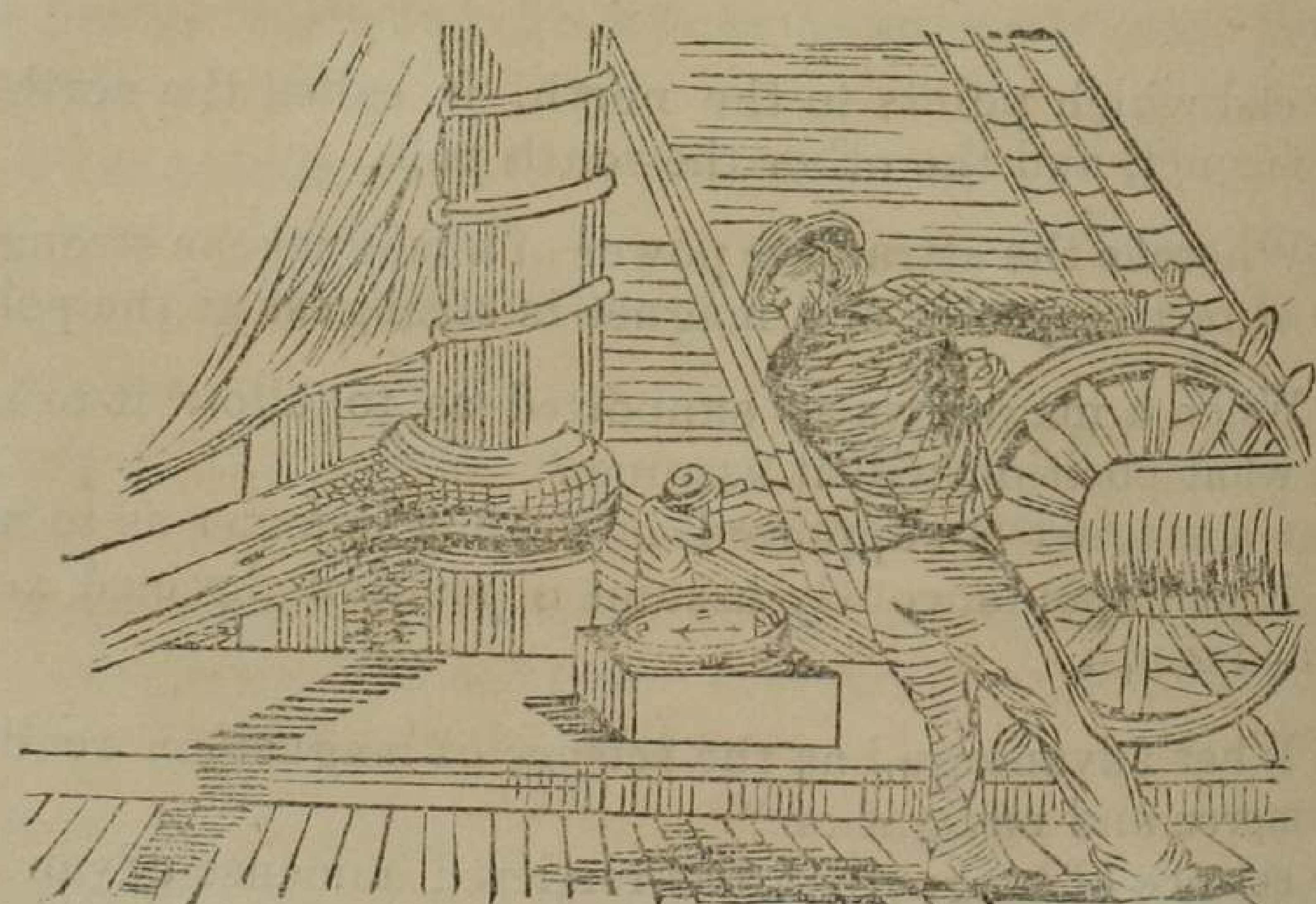
The science of magnetism has rendered immense advantages to commerce and navigation, by means of the mariner's compass.

14. Of what does the mariner's compass consist?

The mariner's compass consists of a magnetized bar of steel, called a *needle*, having at its centre a cap fitted to it, which is supported on a sharp-pointed pivot fixed in the base of the instrument. A circular plate, or card, the circumference of which is divided into degrees, is attached to the needle, and turns with it. On an inner circle of the card the thirty-two points of the mariner's compass are inscribed.

15. Where is the needle generally placed?

The needle is generally placed *under* the card of a mariner's compass, so that it is out of sight, but small needles, used on land, are placed above the card, not attached to it, and the card is permanently fixed to the box.



Lesson XXXVI.

ASTRONOMY—SOLAR SYSTEM.

1. Of what does Astronomy treat?

Astronomy treats of the heavenly bodies, such as the sun moon, stars, comets, planets, &c.

2. What is said of the earth?

The earth on which we live is a large globe or ball.

3. What is its diameter?

Its diameter is about eight thousand miles.

4. What is its circumference?

Its circumference is about twenty-five thousand miles.

5. How is the earth known to be round?

It is known to be round—*first*, because it casts a circular shadow, which is seen on the moon during an eclipse; *secondly*, because the upper parts of distant objects on its surface can be seen at the greatest distance; *thirdly*, it has been circumnavigated.

6. Where is the earth situated?

The earth is situated in the midst of the heavenly bodies, which we see around us at night, and forms one of the number of those bodies.

7. To what system does it belong?

The earth belongs to that system which has the sun for its centre.

8. What is this system called?

It is called the Solar System, because it is governed by the attraction of the sun.

9. Of what does the solar system consist?

The solar system consists of the sun, which is in the centre;

Of eight *primary* planets, named Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune;

Of four Asteroids, or smaller planets, namely, Ceres, Pallas, Juno, and Vesta;

Of eighteen secondary planets or moons, of which the Earth has one, Jupiter four, Saturn seven, and Uranus six; and

Of an unknown number of comets.

10. What are the stars supposed to be?

The stars, which we see in the night-time, are supposed to be suns, surrounded by systems of planets, too distant to be seen from the earth.

11. Do we see more stars by the aid of glasses than without?

Although the stars seem so numerous on a bright night, they appear much more so by the aid of glasses.

12. How may the planets be distinguished from the stars?

The planets may be distinguished from the stars by their *steady* light; while the stars appear to twinkle. The planets, likewise, seem to change their relative places in the heavens, while those luminous bodies which are called *fixed* stars appear to preserve the same relative position.

13. What are the sun, moon, planets, and fixed stars supposed to be?

The sun, the moon, the planets, and the fixed stars, which appear to us so small, are supposed to be large worlds, of various sizes, and at different but immense distances from us.

14. Why do they appear so small?

The reason that they appear to us so small is, that on account of their immense distances, they are seen under a small angle of vision.

15. Do the bodies of the solar system move?

The bodies of the solar system all revolve around the sun as a centre, in different times, at different distances, and with different velocities.

16. What are the paths in which the bodies move around the sun called?

The paths or courses in which the planets move around the sun are called their orbits.

17. What is a year on each planet?

A year is the time which each planet takes to make an entire revolution around the sun.

18. How long is the year on the planet Mercury?

The planet Mercury revolves around the sun in 87 of our days. Hence, a year on that planet is equal to 87 days.

19. How long is the year on the planet Venus?
The planet Venus revolves around the sun in 224 days. That is, therefore, the length of the year of that planet.

20. How long is the year on the earth?
Our earth revolves around the sun in about 365 days and 6 hours. Our year, therefore, is of that length.

21. Have the planets any other motion except that around the sun?
While the planets revolve around the sun, each also turns around upon its own axis, and thus presents each side successively to the sun.

22. What is the distance from the sun to Mercury?
About 36 millions of miles.

23. What is the distance from the sun to Venus?
About 68 millions of miles.

24. What is the distance from the sun to the earth?
About 95 millions of miles.

25. What is the diameter of the sun?
Eight hundred and seventy-seven thousand five hundred and forty-seven miles.

26. What is the diameter of the earth?
About eight thousand miles.

27. What is the diameter of the moon?
Two thousand one hundred and eighty miles.

28. What is the diameter of the planet Jupiter?
Eighty-six thousand two hundred and fifty-five miles.

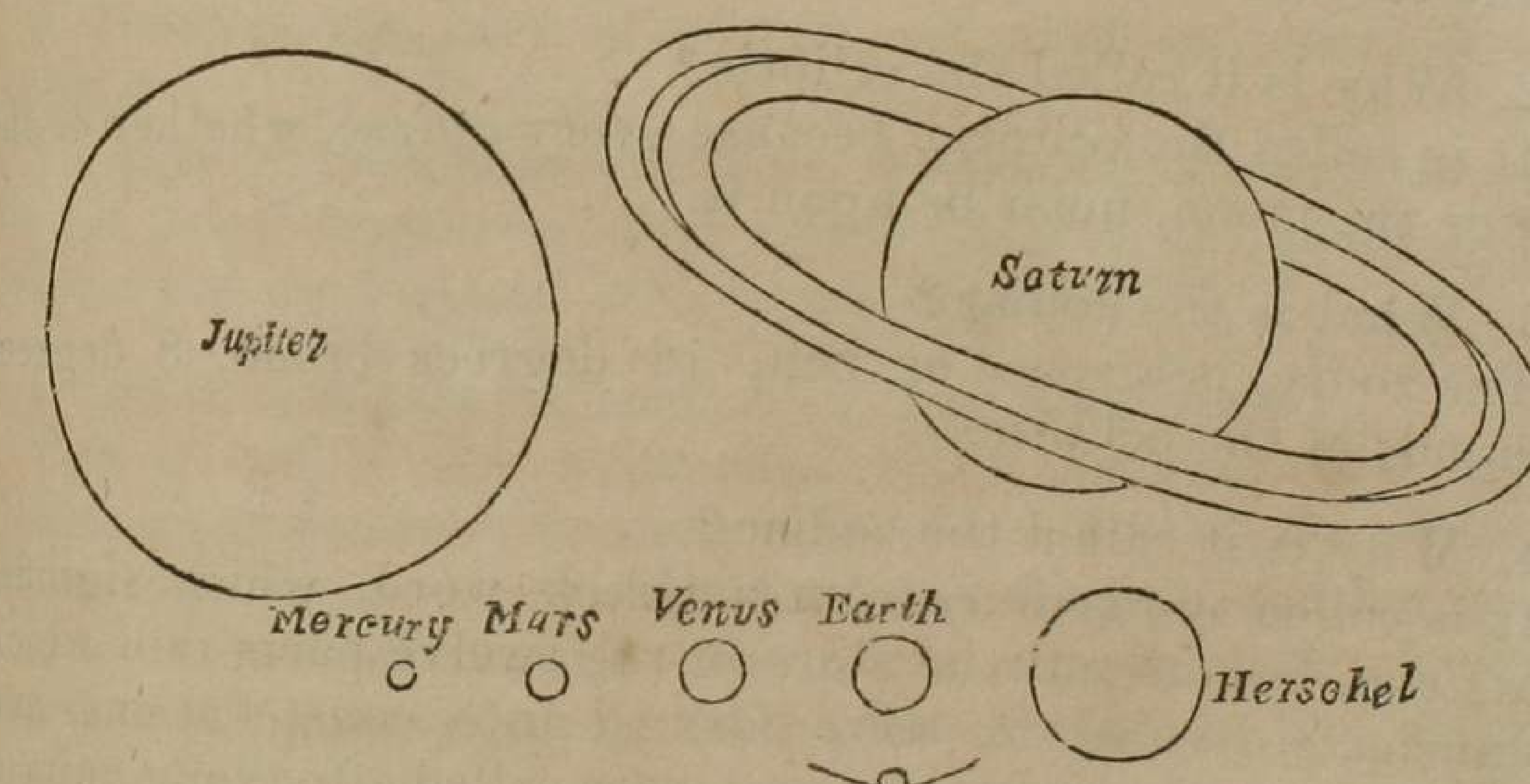
29. What is the diameter of Saturn?
Eighty-one thousand nine hundred and fifty-four miles.

30. What is the diameter of Herschel?
Thirty-four thousand three hundred and sixty-three miles.

31. What is the diameter of Venus?
Seven thousand six hundred and twenty-one miles.

32. What is the diameter of Mars?
Four thousand two hundred and twenty-two miles.

33. What does the following figure represent?
The following figure represents the comparative size of the planets.



Lesson XXXVII.

OF THE ECLIPTIC AND ZODIAC.

1. What is the ecliptic?
The ecliptic is the apparent path of the sun, or the real path of the earth.

2. Why is it called the ecliptic?
It is called the ecliptic, because every *eclipse*, whether of the sun or the moon, must be upon it.

3. What is the zodiac?
The zodiac is a space or belt, 16 degrees broad, 8 degrees each side of the ecliptic.

4. Why is it called the zodiac?
It is called the *zodiac*, from a Greek word, which signifies *an animal*, because all the stars in the twelve parts into which the ancients divided it, were formed into constellations, and most of the twelve constellations were called after some animal.

5. How is the zodiac divided?
The zodiac is divided into twelve signs, each sign containing thirty degrees of the great celestial circle

6. What are the names of the twelve constellations?
The names of these signs are sometimes given in Latin, and sometimes in English. They are as follows:

Latin.	English.	Latin.	English.
1 Aries,	The Ram.	7 Libra,	The Balance.
2 Taurus,	The Bull.	8 Scorpio,	The Scorpion.
3 Gemini,	The Twins.	9 Sagittarius,	The Archer.
4 Cancer,	The Crab.	10 Capricornus,	The Goat.
5 Leo,	The Lion.	11 Aquarius,	The Water-bearer.
6 Virgo,	The Virgin.	12 Pisces,	The Fishes.

7. What is the axis of a planet?
It is the diameter about which the planet turns or revolves.

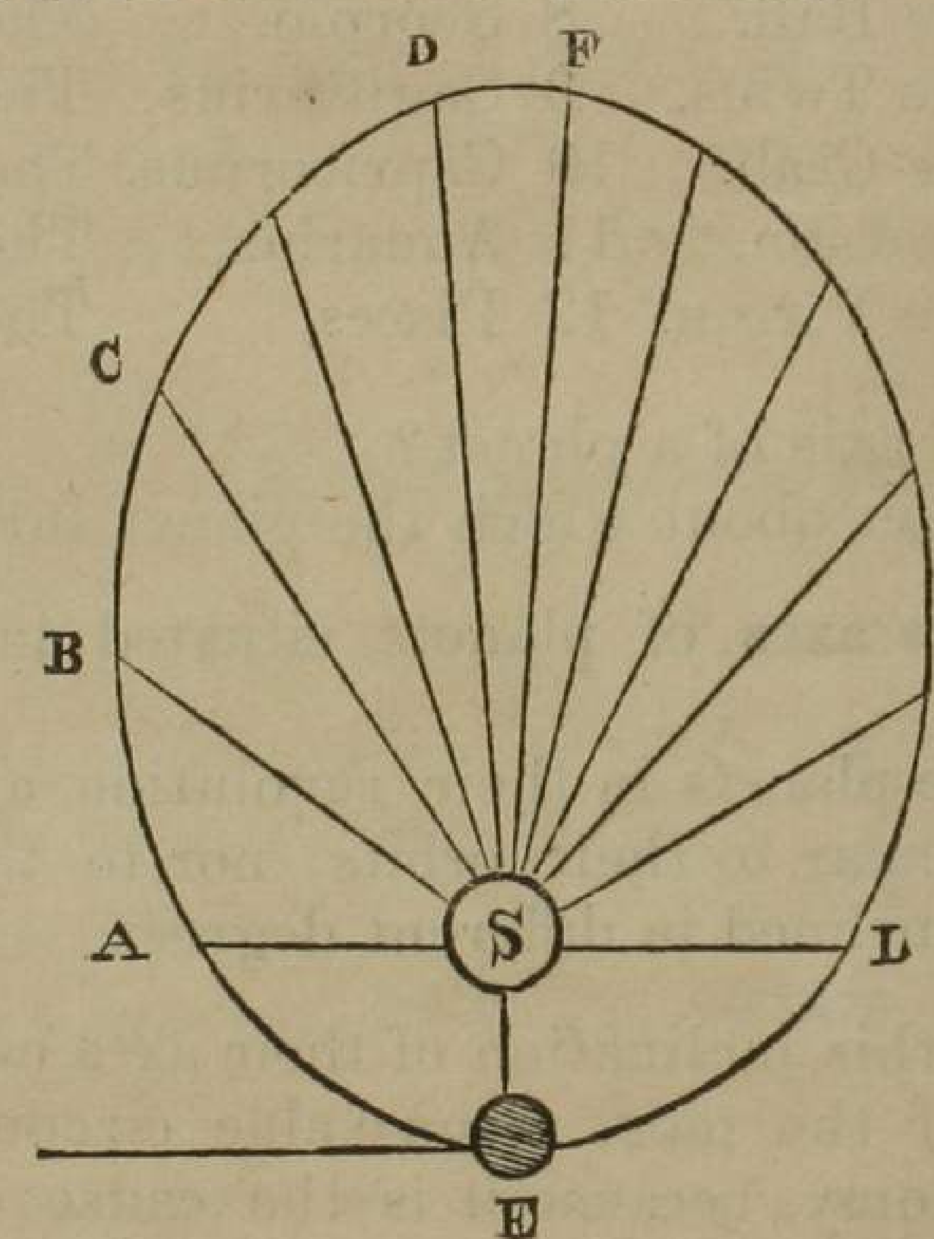
8. How are the axes of planets situated in regard to the ecliptic?
The axes of the planets in their revolution around the sun, are not perpendicular to their orbits, nor to the plane of the ecliptic, but are inclined in different degrees.

9. What does this inclination of their axes cause?
This is one of the most remarkable circumstances in the science of Astronomy, because it is the cause of the different seasons, spring, summer, autumn, and winter; and because it is also the cause of the difference in the length of the days and nights in the different parts of the world, and at the different seasons of the year.

10. Does the earth move around the sun in a circle?
The earth does not move around the sun in a circle, but in an oval called an ellipse.

11. Explain the manner in which the earth moves from the figure.

On the 23d of December the earth is at E, nearest the sun, and thence moves round through A, B, C, and reaches the opposite point, between D and F, on the 21st of June, when it returns again to E on the 23d of December.



12. How much nearer is the earth to the sun in the winter than in the summer?

The earth is about three millions of miles nearer to the sun in winter than in summer.

13. What follows from this fact?

That the heat of summer, therefore, cannot be caused by the near approach of the earth to the sun.

14. What other facts show that the parts of the earth nearest the sun are not the warmest?

Snow and ice never melt on the tops of high mountains; and they who have ascended in the atmosphere, in balloons, have found that the cold increases as they rise.

15. What follows from the inclination of the sun's axis, with respect to the sun's rays?

On account of the inclination of the earth's axis, the rays of the sun fall more or less obliquely on different parts of the earth's surface, at different seasons of the year.

16. When is the heat always the greatest?

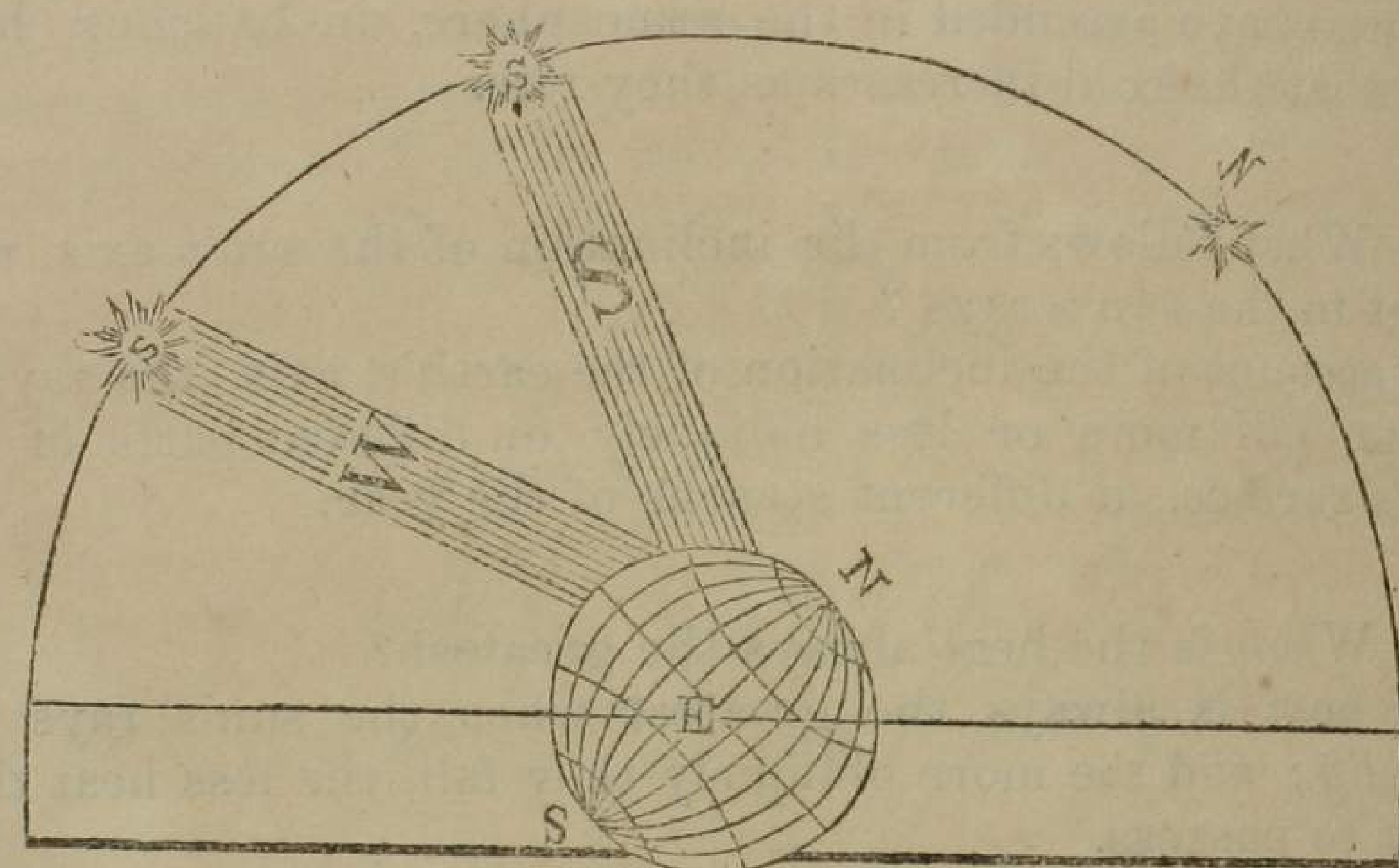
The heat is always the greatest when the sun's rays fall *vertically*; and the more obliquely they fall, the less heat they appear to possess.

17. What is the reason that the heat is greater in summer than in winter?

The reason why the days are hottest in summer, although the earth is farther from the sun at that time, is, because the rays are more nearly vertical.

18. Explain this from the figure.

The figure represents the manner in which the rays of the sun fall upon the earth in summer and in winter. The north pole of the earth, at all seasons, constantly points to the north star N; and when the earth is nearest to the sun, the rays from the sun fall as indicated by W, in the figure; and as their direction is very oblique, and they have a larger portion of the atmosphere to traverse, much of their power is lost.



Hence we have *cold* weather when the earth is nearest to the sun.

19. How are the signs of the zodiac, and the various bodies of the solar system, generally represented?

The signs of the zodiac and the various bodies of the solar system are generally represented in almanacs and astronomical works by the following characters:

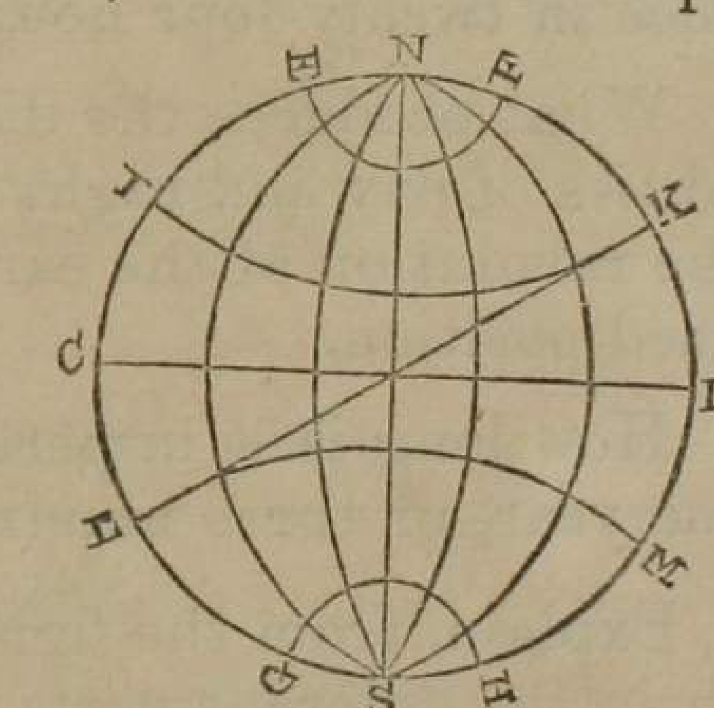
☉ The Sun.	⊕ The Earth.	⚳ Ceres.
☽ The Moon.	♂ Mars.	⚴ Pallas.
☿ Mercury.	⚶ Vesta.	♃ Jupiter.
♀ Venus.	⚵ Juno.	♄ Saturn.
	♅ Herschel.	

The follwoing characters represent the signs of the zodiac:

♈ Aries.	♌ Leo.	♐ Sagittarius.
♉ Taurus.	♍ Virgo.	♑ Capricornus.
♊ Gemini.	♎ Libra.	♒ Aquarius.
♋ Cancer.	♏ Scorpio.	♓ Pisces.

20. Explain the imaginary circles which are generally drawn upon the sphere.

The figure represents the earth. N S is the axis, or imaginary line, around which it daily turns; N is the north pole, S is the south pole. These poles, it will be seen, are the extremities of the axis N S. C D represents the equator, which is a circle around the earth, at an equal distance from each pole. The curved lines proceeding from N to S, are meridians. They are all circles surrounding the earth, and passing through the poles. These meridians may be multiplied at pleasure. The curved lines E F, I K, L M, and G H, represent parallels of latitude.



Lesson XXXVIII.

OF THE SEASONS.

1. What causes day and night?
The rotation of the earth about its axis.

2. How often does the earth perform a revolution about its axis?
Once in twenty-four hours.

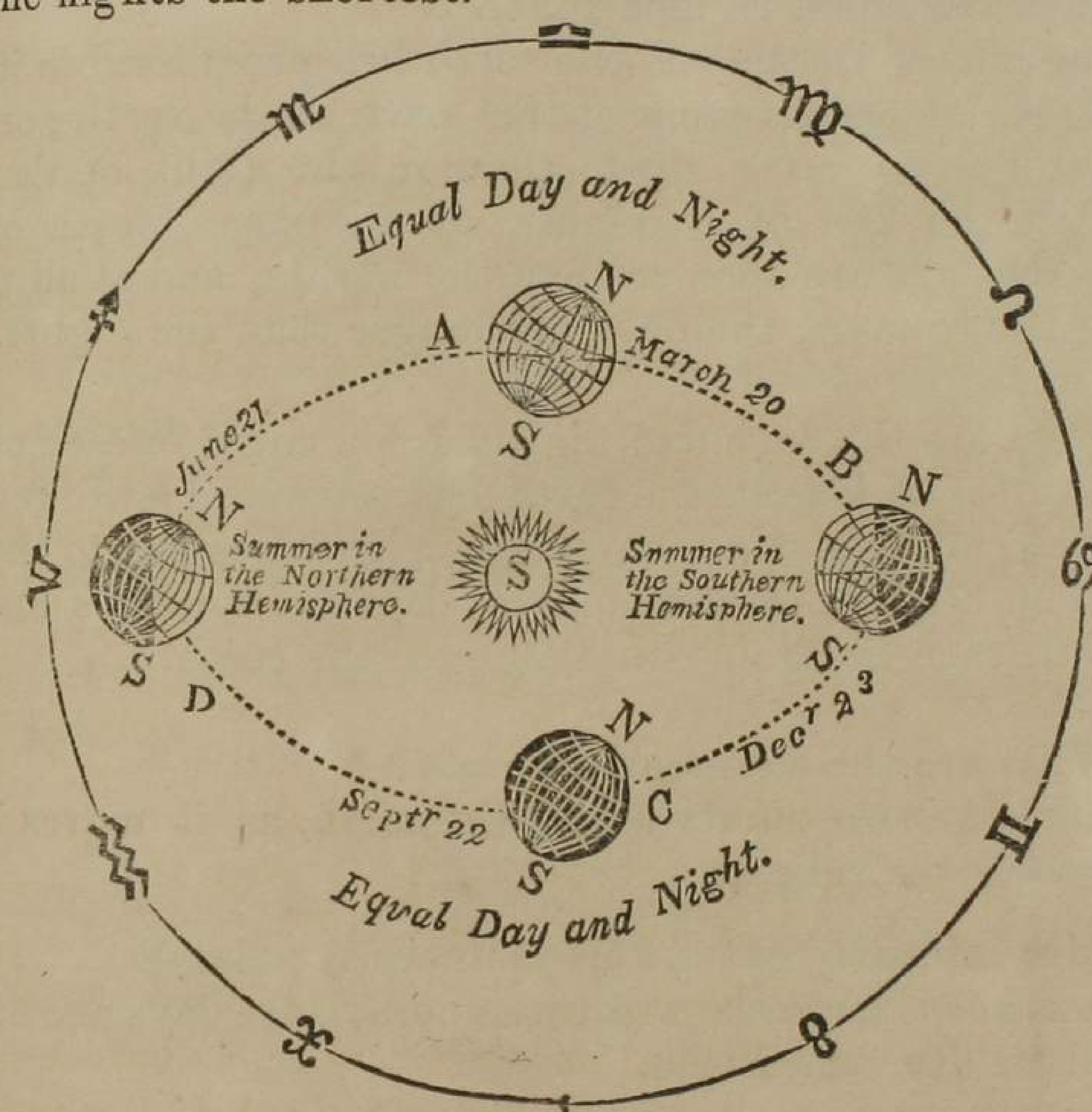
3. What produces the different seasons, and causes the inequalities of day and night?
The revolution of the earth in its orbit about the sun in an inclined position.

4. How long is it in performing this revolution?
One year, or three hundred and sixty-five days six hours.

5. Explain, from the figure, how the sun shines upon the earth in the different parts of its orbit.
The figure represents the manner in which the sun shines on the earth in different parts of its orbit. S represents the sun, and the dotted oval, or ellipse, A B C D, the orbit of the earth. The outer circle represents the zodiac, with the position of the twelve signs or constellations.

6. When will the days be the longest in the northern hemisphere?
On the 21st of June, when the earth is at D, the north pole will be turned towards the sun, and the whole northern polar region is continually in the light of the sun. At this season of

the year the days will be the longest in the northern hemisphere, and the nights the shortest.



7. When will the days and nights be of equal length?
On the 23d of September, when the earth is at C, its axis is neither inclined *to* nor *from* the sun, but is sidewise; and, of course, while one half of the earth, from pole to pole, is enlightened, the other half is in darkness, as would be the case if its axis were perpendicular to the plane of its orbit; and it is this which causes the days and nights, of this season of the year, to be of equal length.

8. When will the nights be the longest and the days the shortest in the northern hemisphere?

On the 23d of December, the earth has progressed in its orbit to B, which causes more of that part of the earth north of the equator to be in the shade than in the light of the sun. Hence, on the 23d of December, at all places north of the equator, the days are shorter than the nights, and at all places south of the equator, the days are longer than the nights.

9. When are the days and nights again equal to each other?

On the 21st of March, the earth has advanced still further, and is at A, and has the same position with respect to the sun as it had on the 23d of September. Hence, the days and the nights will then be again equal all over the earth.

10. What are the equinoctial points?

They are the two points where the earth, as it moves in its orbit, crosses the ecliptic.

11. Why are they called the equinoctial points?

Because when the earth is at these points, the days and nights are equal all over the world.

12. At what times in the year is the earth in these positions?

On the 21st of March and the 23d of September.

13. How are these equinoctial points distinguished from each other?

The first is called the vernal or spring equinox, and the second the autumnal equinox.

14. What are the solstices?

They are the two points of the ecliptic where the sun appears farthest from the equator.

15. Why are they called the solstitial points?

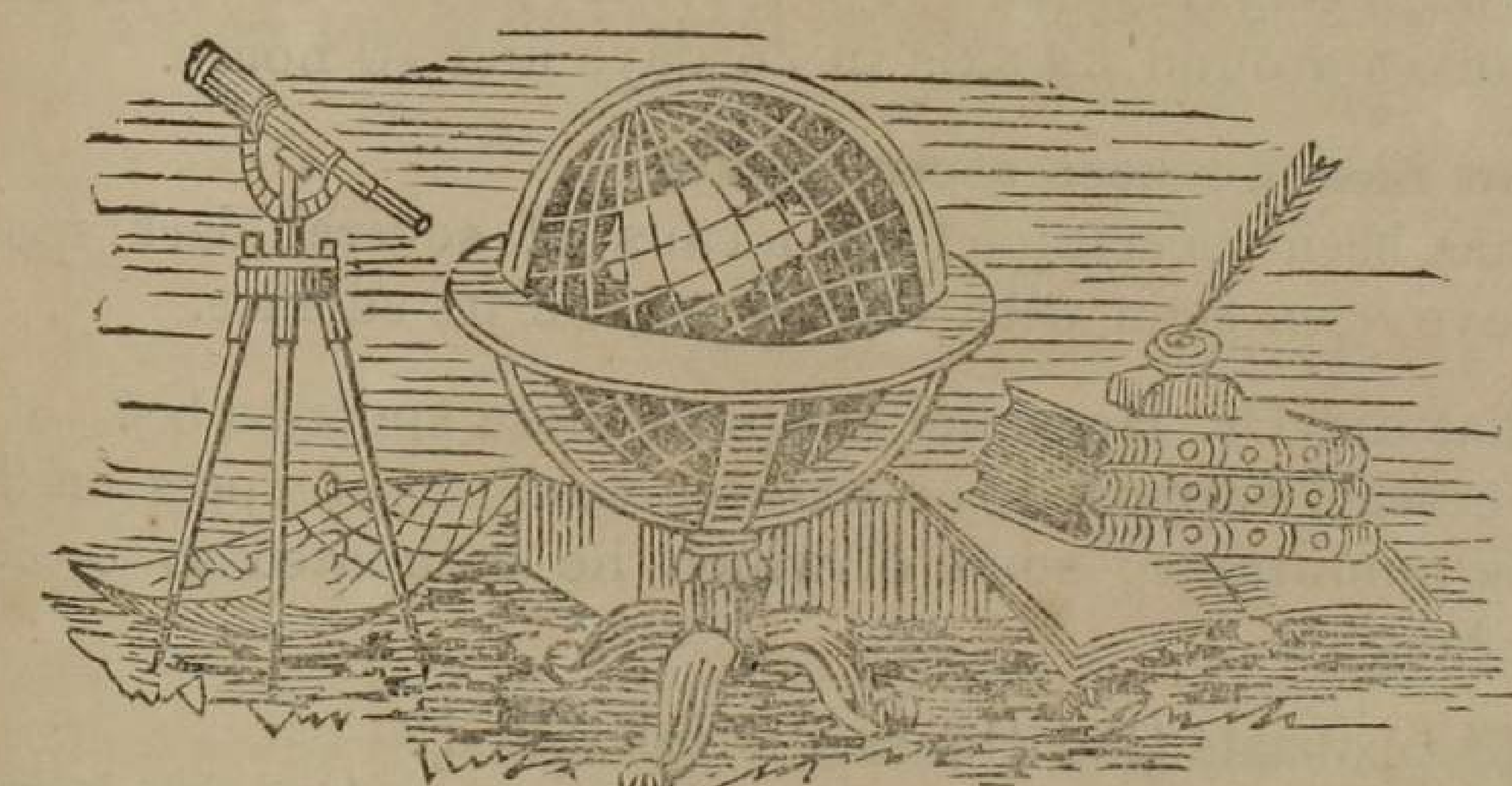
Because the sun, after receding from the equator, appears to stand at the same height in the heavens for several days in succession.

16. At what seasons of the year does the sun appear to occupy these positions?

On the 21st of June and the 23d of December.

17. How are these solstitial points distinguished from each other?

The first is called the summer solstice, and the second the winter solstice.



Lesson XXXIX.

OF THE SOLAR SYSTEM.

1. What is said of the sun?
The sun is a spherical body, situated near the centre of gravity of the system of planets of which our earth is one.

2. What is its diameter?
Its diameter is 877,547 English miles, which is equal to 100 diameters of the earth.

3. How long is it in performing its revolution about its axis?
It revolves around its axis in 25 days and 10 hours.

4. How has this been ascertained?
This has been ascertained by means of several dark spots, which have been seen with telescopes, on its surface.

5. What did Dr. Herschel suppose these spots to be?
Dr. Herschel supposed the greater number of spots on the sun to be mountains; some of which he estimated to be 300 miles in height.

6. Is it probable that the sun is inhabited?
It is probable that the sun, like all the other heavenly bodies, (excepting, perhaps, comets,) is inhabited by beings whose nature is adapted to their peculiar circumstances.

7. What planet is nearest the sun?
Mercury is the nearest planet to the sun, and is seldom seen.

8. Why is it seldom seen?
It is seldom seen because his vicinity to the sun occasions his being lost in the brilliancy of the sun's rays.

9. What is said of the heat of this planet?
The heat of this planet is so great, that water cannot exist there except in a state of vapor; and metals would be melted.

10. How much greater is the sun's heat in Mercury than on the earth?
The intenseness of the sun's heat, which is in the same proportion as its light, is seven times greater in Mercury than on the earth.

11. How can Mercury be recognised when seen?
Mercury, although in appearance only a small star, emits a bright white light, by which it may be recognised when seen.

12. At what time does it appear?
It appears a little before the sun rises, and again a little after sunset; but it is never to be seen longer than one hour and fifty minutes after sunset, nor longer than that time before the sun rises.

13. What planet is nearest the earth?
Venus, the second planet in order from the sun, is the nearest to the earth, and on that account appears to be the largest and most beautiful of all the planets.

14. When is Venus called the morning star?

During one part of the year Venus rises before the sun, and it is then called the morning star.

15. When is Venus called the evening star?

During part of the year it rises after the sun, and it is then called the evening star.

16. How much greater is the heat and light at Venus than at the earth?

The heat and light at Venus are nearly double what they are at the earth.

17. What is meant by the transit of these planets?

Both Mercury and Venus sometimes pass directly between the sun and the earth. This is called the transit of these planets.

18. What planet is next to Venus?

The earth is the next planet, in the solar system, to Venus.

19. What is the form of the earth?

It is nearly a perfect sphere.

20. How many moons has the earth?

It is attended by one moon.

21. What is the diameter of the moon?

The diameter of the moon is about two thousand miles.

22. What is the moon's distance from the earth?

The moon's mean distance from the earth is about 240,000 miles.

23. How often does the moon turn on its axis?

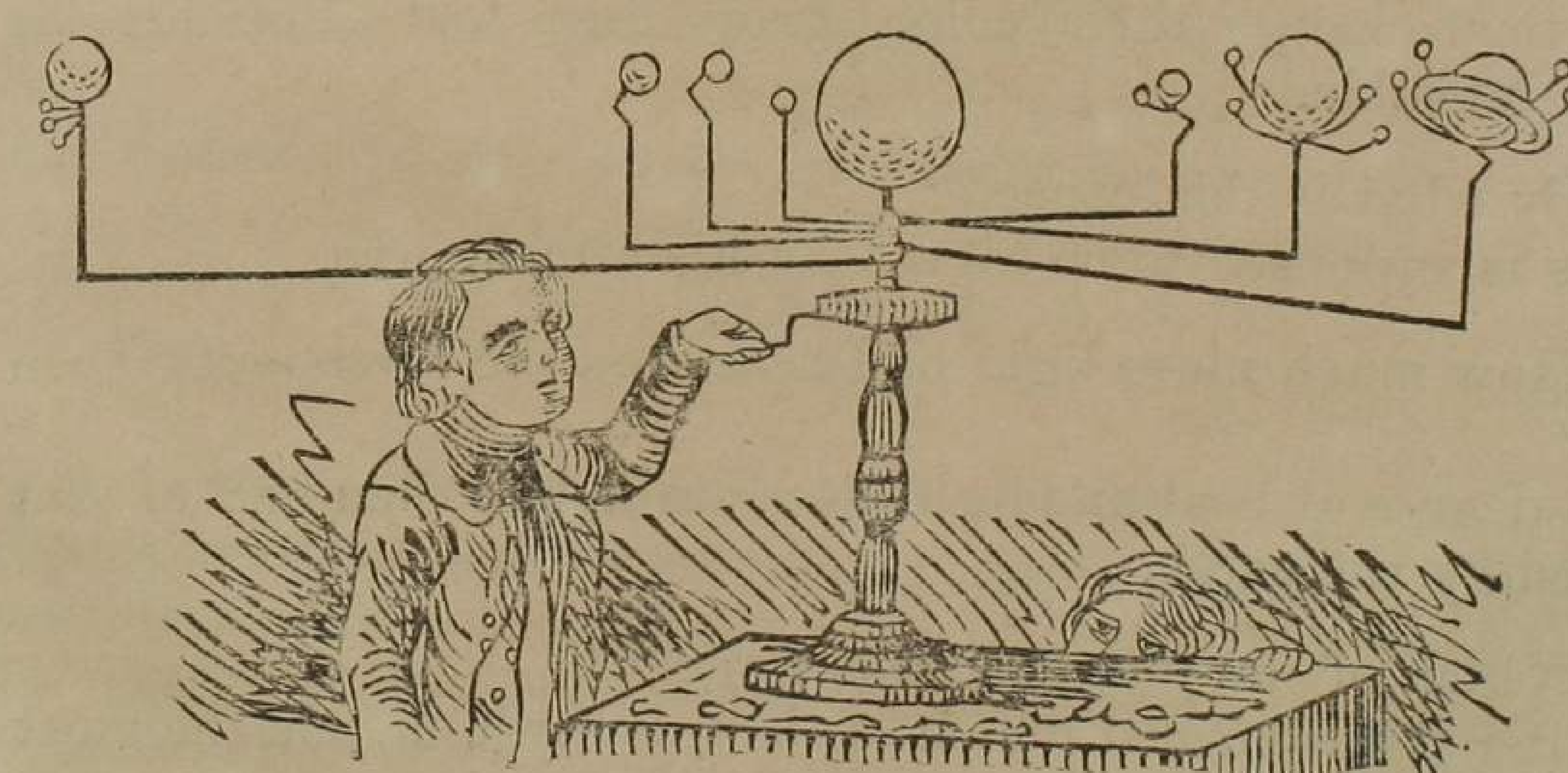
The moon turns on its axis in precisely the same time that it performs its revolution round the earth; namely, in twentynine days and a half.

24. What appearance would the earth, if viewed from the moon, present?

The earth, when viewed from the moon, exhibits precisely the same appearances that the moon does to us, but in opposite order. When the moon is full to us, the earth will be dark to the inhabitants of the moon; and when the moon is dark to us, the earth will be full to them.

25. Is all of the moon's surface seen from the earth?

As the moon, however, always presents nearly the same side to the earth, there is one-half of the moon which we never see, and from which the earth cannot be seen.



Lesson XL.

OF THE SOLAR SYSTEM.

1. What planet is next to the earth?
Next to the earth is the planet Mars.

2. What renders it conspicuous?
Mars is conspicuous for its fiery red appearance.

3. What is supposed to cause this appearance?
It is supposed to be caused by a very dense atmosphere.

4. When this planet passes between us and any of the fixed stars, what appearance do they exhibit?
When this planet passes between us and any of the fixed stars, they change their color, grow dim, and often become totally invisible.

5. By what is this caused?
This is supposed to be caused by his atmosphere.

6. How much more light and heat does the earth enjoy then Mars?
The degree of heat and light at Mars is less than half of that received by the earth.

7. Which of the planets is the largest?
Jupiter is the largest planet of the solar system, and the most brilliant, except Venus.

8. How much more heat and light does the earth enjoy than Jupiter?
The heat and light at Jupiter is about twenty-five times less than that at the earth.

9. How many moons has Jupiter?
This planet is attended by four moons, or satellites, the shadows of some of which are occasionally visible upon his surface.

10. What are the distances of these moons from the planet?
The distances of those satellites from the planet are two, four, six, and twelve hundred thousand miles, *nearly*.

11. In what time do they perform their revolutions about the planet?
The nearest revolves around the planet in less than two days; the next in less than four days; the third in less than eight days; and the fourth in *about* sixteen days.

12. How does the size of these moons compare with that of ours?
The nearest appears to them four times the size of our moon; the second about the same size; the third somewhat less; and the fourth about one-third the diameter of our moon.

13. How does Jupiter appear when viewed through a telescope?
When viewed through a telescope, several belts or bands are distinctly seen, sometimes extending across his disk, and sometimes interrupted and broken.

14. How does Saturn compare in size with the other planets?
Saturn is the second in size, and the last but one in distance from the sun.

15. How does its degree of heat and light compare with that of the earth?

The degree of heat and light at this planet is eighty times less than that at the earth.

16. How is Saturn distinguished from the other planets?

Saturn is distinguished from the other planets by being encompassed by two large luminous rings.

17. What is said of these rings?

They reflect the sun's light in the same manner as his moons. They are entirely detached from each other and from the body of the planet.

18. How many satellites has Saturn?

Saturn has seven satellites, or moons, revolving around him at different distances, and in various times, from less than one to eighty days.

19. How may Saturn be known?

Saturn may be known by his pale and steady light.

20. How does Uranus compare in size with the other planets?

Uranus, the third in size, is the most remote of all the old planets. It is scarcely visible to the naked eye.

21. How does the light and heat of Uranus compare with that of the earth?

The light and heat at Uranus are about 360 times less than that at the earth.

22. How many moons has Uranus?

Uranus is attended by six moons, or satellites, all of which were discovered by Dr. Herschel.

23. What is the next planet in order?

The planet Neptune is a recent discovery by Le Verrier. But little is yet known in regard to it.

24. Are there any other planets, not named, which belong to the solar system?

There are four small planets, called Asteroids.

25. What are their names?

They are called Vesta, Juno, Ceres, and Pallas.

26. In what part of the heavens are the orbits of these planets found?

Between the orbits of Mars and Jupiter.

27. Are there any other bodies, besides those which have been named, that are supposed to belong to the solar system?

The name comet is given to a numerous class of bodies, which occasionally visit and appear to belong to the solar system.

28. What appearance do these bodies exhibit?

They appear to consist of a small body resembling a star, attended with a lurid blaze, like flowing hair, called the tail of the comet.

Lesson XLI.

OF THE FIXED STARS.

1. What are the fixed stars?
The fixed stars are the small luminous bodies, which in a clear night are seen in the heavens above us.

2. Into how many magnitudes are the stars classed?
The stars are classed into six magnitudes: the largest are of the first magnitude, and the smallest that can be seen by the naked eye, are of the sixth.

3. What are telescopic stars?
Those stars which can be seen only by means of telescopes, are called telescopic stars.

4. Why cannot the distance of the fixed stars be determined?
The distance of the fixed stars cannot be determined, because we have no means of ascertaining the distance of any body which exceeds 200 thousand times that of the earth from the sun. As none of the stars comes within that limit, we cannot determine their real distance.

5. To what is the difference in their apparent magnitude supposed to be owing?
It is generally supposed that part, if not all, of the difference in their apparent magnitudes is owing to the difference in their distance.

6. What is the Galaxy, or Milky Way?
The Galaxy, or Milky Way, is a remarkably light broad zone, visible in the heavens, passing from northeast to southwest.

7. Of what is it supposed to consist?
It is supposed to consist of an immense number of stars, which, from their apparent nearness, cannot be distinguished from each other.

8. What did Dr. Herschel observe with his telescope?
Dr. Herschel saw, in the course of a quarter of an hour, the astonishing number of 116,000 stars pass through the field of his telescope, while it was directed to the Milky Way.

9. How did the ancients divide the stars?
The ancients, in reducing astronomy to a science, formed the stars into *clusters*, or *constellations*, to which they gave particular names.

10. What was the number of constellations among the ancients?
The number of constellations among the ancients was about fifty.

11. How many have the moderns added?
The moderns have added about fifty more.

12. What effect has the daily motion of the earth on the appearance of the fixed stars?
The daily rotation of the earth on its axis causes the whole

sphere of the fixed stars, &c., to appear to move round the earth every twenty-four hours from east to west.

13. What is the north pole star?

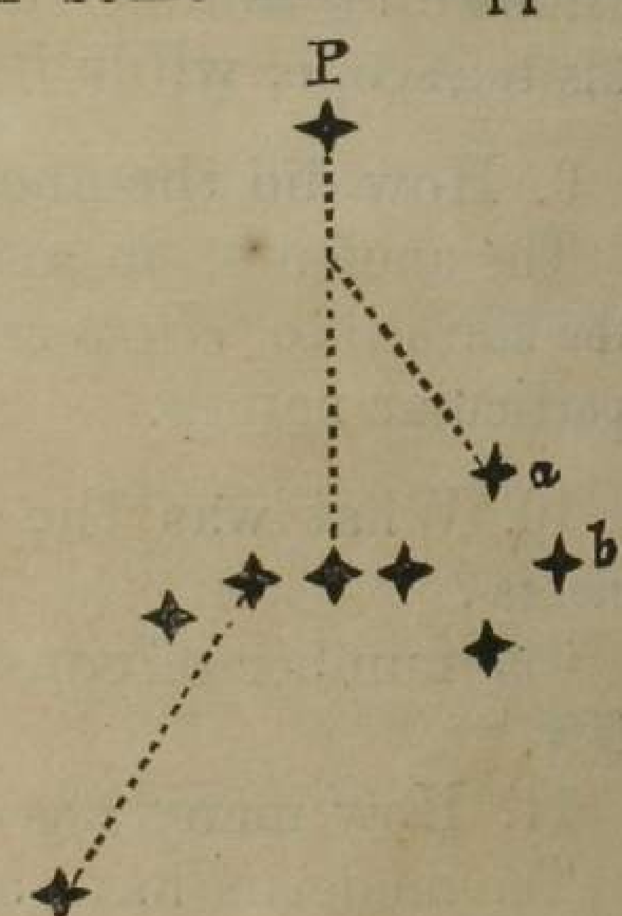
The north pole star is the star towards which the north pole always appears to point.

14. Is there a southern pole star?

To the inhabitants of the southern hemisphere, there is another, and a corresponding point in the heavens.

15. How can you distinguish the north pole star in the heavens?

The north pole star belongs to a constellation called the Little Bear. The pole star can be found by means of a constellation called the Great Bear, which some have supposed aptly to represent a plough; but it is more generally called a dipper. If a line be drawn through the stars *b* and *a*, and carried upwards, it will pass a little to the left, and nearly touch a star represented in the figure by P. This is the polar star, or the north pole star; and the stars *b* and *a*, which appear to point to it, are called the *pointers*, because they appear to point to the polar star.



16. How is the pole star distinguished?

The polar star shines with a steady and rather dead kind of light. It always appears in the same position; and the north

pole of the earth always points to it *at all seasons of the year*.

17. How do the other stars appear, with respect to the pole star?

The other stars seem to move round it as a centre. As this star is always in the north, the cardinal points may at any time be found by starlight.

Lesson XLII.

OF THE TIDES AND ECLIPSES.

1. What are the tides?
The tides are the regular rising and falling of the water of the ocean twice in about 25 hours.

2. What causes the tides?
The tides are occasioned by the attraction of the moon upon the matter of the earth; and they are also affected by that of the sun.

3. What is an eclipse?
An eclipse is a total or partial obscuration of one heavenly body by the intervention of another.

4. When does an eclipse of the sun take place?
An eclipse of the sun takes place when the moon, passing between the sun and the earth, intercepts his rays.

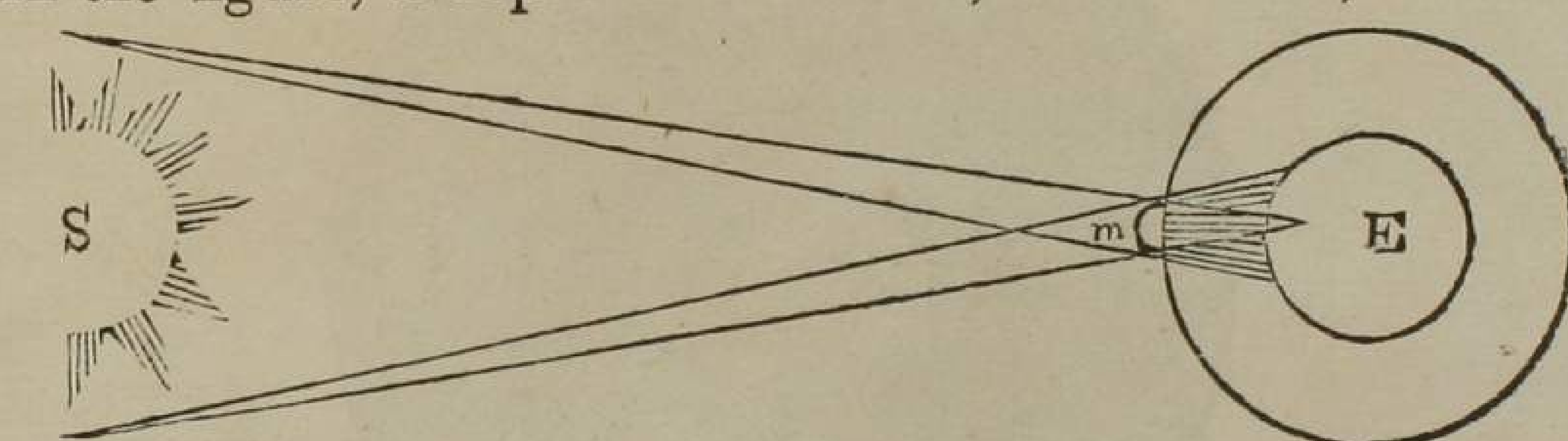
5. When does an eclipse of the moon take place?
An eclipse of the moon takes place when the earth, coming between the sun and the moon, deprives the moon of his light.

6. When, then, can an eclipse of the sun take place?
An eclipse of the sun can take place only when the moon changes.

7. When only can an eclipse of the moon take place?
An eclipse of the moon can take place only when the moon fulls.

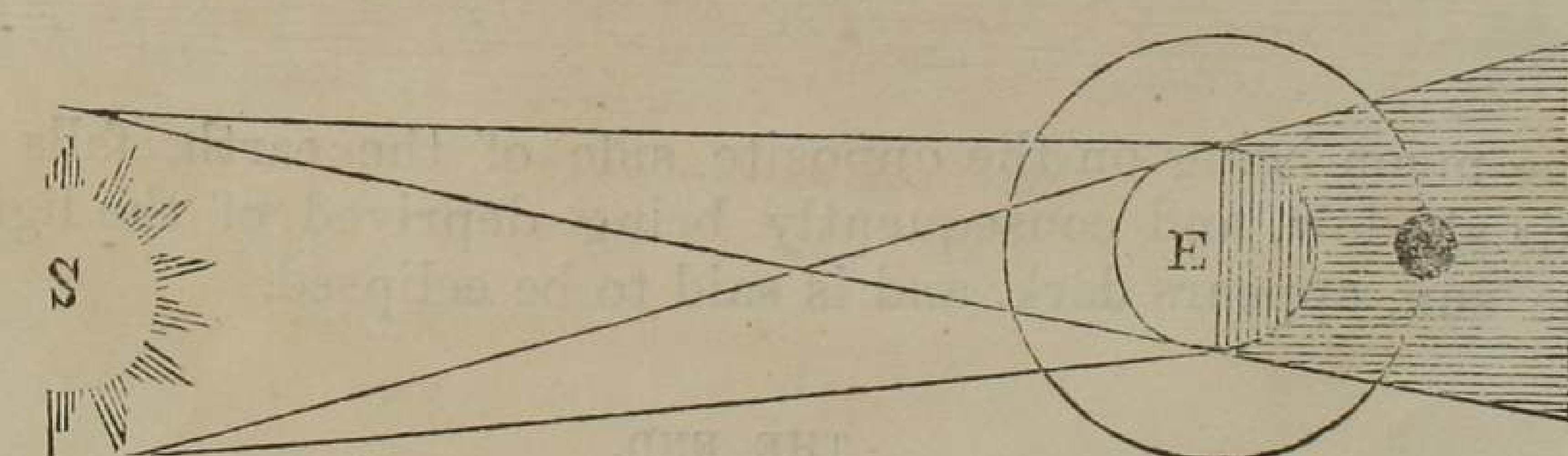
8. What is the reason that the sun, moon, and earth must have these positions at the time of eclipses?
Because, at the time of an eclipse, either of the sun or the moon, the *sun, earth, and moon must be in the same straight line.*

9. Explain how an eclipse of the sun takes place.
In the figure, S represents the sun, E the earth, and *m* the

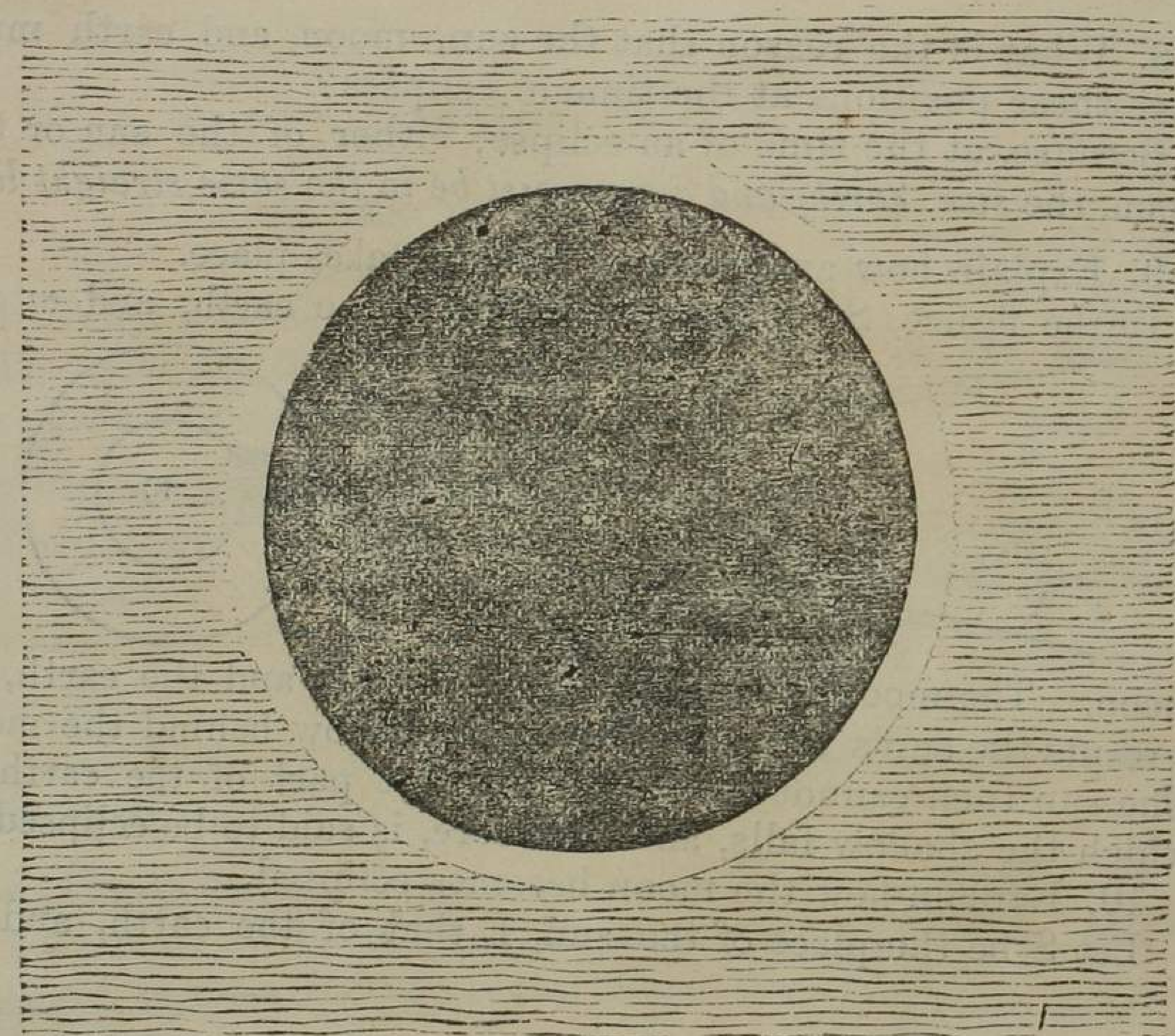


moon. The moon, passing between the sun and the earth, intercepts the sun's rays, and causes a shadow behind the moon. The sun then cannot be seen from that part of the earth on which the shadow falls, and therefore, is said to be eclipsed.

10. Explain how the moon becomes eclipsed.
Let S be the place of the sun, E that of the earth, and the



small dark body to the right, the moon. The earth intercepts the sun's rays, and produces a shadow behind it at the right.



The moon being on the opposite side of the earth, falls into this shadow, and consequently being deprived of the light of the sun, appears dark, and is said to be eclipsed.

THE END.