FIRST BOOK

OF

Natural Philosophy and Astronomy.

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OF

NATURAL PHILOSOPHY

AND

ASTRONOMY.

BY

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PREFACE.

The present little volume treats of the elements of Natural Science, and is designed to meet the wants of young persons, who do not intend to pursue a complete course of academical study.

The catechetical form has been adopted, as better adapted to class recitation, in the case of young pupils, than the ordinary didactic form, and as admitting of greater condensation. It has, also, the important advantage of permitting a more rigid adherence to a logical method in the treatment of topics, and thus securing greater distinctness of conception, and consecutiveness of thought, on the part of the pupil.

The mental culture to be derived from the exercise of framing answers to the questions put by the teacher, can be truly realized only by the more advanced student. The young beginner is seldom capable of making his answers sufficiently precise, nor will he readily acquire by practice alone the habit of accurate statement.

As in a book intended for the young no opportunity should be neglected of addressing the mind through the eye, the principles stated are copiously illustrated by pictorial representations.

Especial pains are taken that clear conceptions should be obtained of the fundamental principles of the different branches of Natural Science. With the view of accomplishing this object more effectually, the method is pursued of ascending from particulars to generals. Practical applications of principles are added wherever they could be introduced to advantage.

INTRODUCTION.

As a fitting introduction to the pleasant task that is before us, we will take a general survey of the ground to be passed over. On glancing hastily over it we might conjecture that the order of things in the realm of inanimate Nature was fixed and invariable; but on a nearer view we perceive that all things, inanimate as well as animate, are subject to change. We soon discover, too, that change follows change in a certain established succession, and that a beautiful order and harmony everywhere prevail. We recognize the operation of natural causes as invariably producing certain effects, and so rise from the conception of that which is changeable and transient to that which is unalterable and everlasting. Looking farther, we discern the secret workings of the primary cause of this universal activity of change. We call it *Force*, and seem to see in it the subtile chain by which the universe is bound to the throne of the Creator. Our first great object, then, will be to inspect the characteristic forms which this primary principle of change assumes, or the so-called forces of nature, and examine into the effects they produce. While engaged in this interesting study we shall learn how these natural agents are made serviceable to man, and brought to labor obediently to his requirements.

After taking this comprehensive survey, we will descend to a lower point of view, and inquire into the various means by which external Nature produces impressions on our senses. When "the Spirit of God moved upon the face of the waters," and Force began to execute its divine commission, to evoke order out of chaos, *Light* burst into existence, the first of all created things, proclaiming the ultimate design of creation. The Divine Power which created the universe has sustained it and will sustain it through all time, and the all-bounteous light, fulfilling its destiny, now gladdens the earth and its teeming world of life as with the smile of His beneficence. It will be a pleasant task to follow the flashing light in its movements, study its deportment under different circumstances, and divine, if possible, by what subtile handicraft a beauteous drapery of many-colored light is daily fashioned and spread over the earth. It will be interesting, too, to scan the wonderful contrivances which the ingenuity of man has devised to increase his power of vision—the microscope, which discloses to view a new world of thronging life existing unheeded everywhere around us, and the telescope, which reveals the existence of innumerable shining worlds peopling the depths of immensity.

In the same connection the philosophy of sound will occupy our attention. We shall seek to understand its nature, the manner in which it is produced and conveyed to the ear, and the various ways in which it is modified in its character and affected in its propagation. The magical charm that dwells in the "concord of sweet sounds" will yield up its secret to our scrutiny.

Changing again our point of view, and seeking for the physical actions which bodies may have on each other, a new avenue opens out before us, conducting into a region not yet fully explored, but which has already rewarded research with many wonderful curiosities and valuable treasures. It is found that, besides light, and its ordinary attendant, Heat, other active principles, called Electricity and Magnetism, are intimately associated with the particles of bodies. In these ethereal principles, ever mysteriously at work in the most hidden recesses of nature, and coming forth at the call of science, are recognized but new forms of force, clothed with almost spiritual bodies.

Thus far our contemplations are mostly confined to the face of the earth. Looking away from the earth we see bending over us the blue dome of the sky, and admire its wondrous fretwork of stars. Observing attentively, it is perceived that the vaulted sky, with its luminous tracery, is not motionless and firmly established upon the broad pavement of the earth, but is in reality an ever-shifting panorama of celestial lights, gliding noiselessly over us. If we were to believe with the sages of the olden time, we might suppose a succession of crystalline spheres, freighted with stars, to be rolling around, and almost hear the music of their ceaseless revolution. But this may not be in the present day; a Copernicus has lived in a previous age, at the wave of whose hand all the complicated celestial apparatus of man's creation has passed away "like the baseless fabric of a vision." We now look through the filmy blue veil of the atmosphere into the immeasurable depths of space, and wonder unceasingly at the glories which fill immensity. The imaginary foundations of the earth are broken up, and it comes forth arrayed in a garment of light, to take its place among the rolling stars that circle around the sun. The system of the world has expanded into proportions that transcend our highest powers of conception ; but its strange complexity has dissolved into a divine simplicity. In its unrestrained flight through the fields of space, the mind seems almost to grasp the infinite, in extent and duration. Time past and time future swell into proportions before inconceivable. The vast cycles of change going on in the heavens seem, as it has been sublimely said, like the recurring beats of the pendulum of eternity. And so, too, by sounding the depths of space, from star to star, with the ethereal light for a sounding line, we almost measure off the infinity of distance. How greatly it tends also to enlarge our ideas of the past duration of the universe, to know that the light which comes from yon star, struggling into view in the field of the telescope, is wearied with the flight of tens of thousands of years.

If it should be imagined that the earth, if a shining star, bears about it no indications of a past existence, immeasurable by the flight of years, the geologist will tell us that the records of such an existence are found inscribed by the hand of time, or rather the finger of God, upon tables of stone buried beneath its surface. Passing over their upturned edges, he unfolds these tablets one after another, and reads the history of the earth as there traced in unfading characters. There is found, too, in the very structure and constitution of the rocky framework of the earth undoubted traces of a primeval age, when the mountains, and even the whole earth, were melted with fervent heat, and the flames played with their forked tongues over the wide regions that are now glowing with beauty and teeming with a bounteous life. This fiery conflict was in fact the process by which the materials for the things of life that were to spring up from the earth were prepared. Countless ages passed away, the flickering flames died out, and the earth lost its vesture of fire. Another succession of ages rolled by, and the uplifted mountains began to show their tops above a waste of waters, and dot its wide expanse with islands. These rose and sank, and one wave of revolution after another swept over the face of the earth, until at last the continents stood firm, and the sea was shut up within its bounds. Successive worlds of animal and vegetable life came and passed away, keeping pace with the changes that occurred in the material world, until man appeared as the "lord of creation" and the consummation of the Divine plan.

These teachings of the book of Nature in regard to the great antiquity of the earth and the material universe, are now well understood to be in harmony with the Mosaic account of creation. The volume of Creation and the Bible, two books of revelation from the same Divine Author, can not but confirm and illustrate each other when rightly understood.

Should it be supposed by the reader that such studies, however interesting or ennobling they may be, can have but little practical utility, we would remind him of the time-honored maxim, that "Science is the handmaid of Art." In fact, Science has responded to the demands of Art, and attended upon its progress in all the past. As new discoveries in science have been made, new industrial arts have sprung up. The most insignificant scientific truths have thus proved to be treasures of incalculable value to mankind. Nor have those truths which seemed to be too exalted ever to wear the homely garb of working-day life, failed to do good service in behalf of the material interests of mankind. The shining orbs that move so far above us, are lights in the firmament "for signs and for seasons, and for days and for years;" and white-winged commerce bears its treasures across the sea under the guidance of the remote stars. Science has given to the iron-horse his breath of fire and sinews of strength—disarmed the lightning of its terrors, and compelled it to wait upon man as his swift-winged messenger. Science has taught the sun-beam to daguerreotype the "human face divine." Science invents machinery, contrives articles of convenience and luxury, and in a thousand ways cheers and adorns the pathway of our daily life.

FIRST BOOK

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NATURAL PHILOSOPHY AND ASTRONOMY.

CHAPTER I.

MECHANICAL PROPERTIES OF BODIES.

1. Is a piece of wood, or a pebble, or an iron bar, all solid matter?

It is part matter and part empty space.

2. Is there as much matter in a piece of wood as in an iron bar of the same size?

There is less matter and more empty space in the wood than in the iron.

3. How is this fact generally expressed?

It is said that iron is *denser*, or more compact, than wood.

4. What are the empty spaces in the interior of bodies called?

Pores. The pores are visible in many substances; for example, in sponge, cork, and some kinds of wood.

5. Are the pores in the interior of bodies entirely devoid of matter of any kind?

The larger visible pores contain air; and the more minute pores, in even the densest substances, contain a very subtile ether, which also fills all space.

6. Can a body of matter be divided into smaller and smaller parts without any apparent limit?

It can.

7. What are the two ways in which matter can be divided and subdivided?

Mechanically, that is, by pounding, grinding, etc.; and by *solution.*

8. Give an example of the minute subdivision of matter by solution.

A grain of blue vitriol, smaller than the smallest pea, will give a blue tinge to half a gallon of water containing 20 drops of spirits of hartshorn. In this half gallon there are 250,000 drops.

9. Are there any last particles that can not be divided any further?

Chemistry informs us that there are

10. What are these indivisible particles called?

Atoms. Every body of matter is made up of indivisible atoms.

11. Are these atoms so close together as to be in actual contact?

They are not, they always stand apart from each other.

12. What holds them together?

Each particle pulls the others toward it, or attracts them, just as a magnet attracts a piece of iron that is brought near it.

13. What is this attraction between atoms called?

The attraction of *cohesion*, or simply *cohesion*.

14. Why do not the atoms rush together, and all bodies become perfectly solid?

Because the heat collected between or around the atoms exerts a repulsion, and keeps them a certain distance apart.

15. How do we know that heat has this effect?

If the heat be increased the particles are forced farther apart, and if it be diminished they draw nearer together.

16. What have you to say of the forces of attraction and repulsion exerted between the atoms of bodies?

That their energy is enormously great.

17. Illustrate the astonishing energy of the attraction between atoms.

The strongest iron wire, of one quarter of an inch in thickness, could not be broken by the united strength of five horses.

18. Illustrate the repulsion exerted between atoms from the effect of heat.

The explosive force of gunpowder projects heavy cannon balls to great distances, and rends the hardest rocks into fragments.

19. Have substances different mechanical properties?

They have; for example, iron is *hard*, and chalk is *soft;* glass is *brittle*, and gold is *malleable*.

20. Are there any other metals that can be hammered out into leaves, or rolled into sheets, besides gold?

Silver, lead, aluminum, tin, copper, zinc, platinum, and iron are all malleable.

21. What is meant when it is said that a certain metal, or other substance, is DUCTILE?

That it can be drawn out into a wire or thread.

22. What metals are ductile?

Platinum, silver, iron, copper, and gold. Zinc, tin, and lead are also ductile in an inferior degree.

23. What may be said of melted glass?

That it is very ductile. It can be drawn out, or spun into fine threads.

24. Why does a piece of India rubber when stretched fly back if left to itself?

Because the particles, when displaced, tend to recover their original positions.

25. Do we observe the same tendency under other circumstances?

We do; for example, when we squeeze an India rubber ball in our hand, or bend a piece of whalebone.

26. What is said of such a substance?

That it is *elastic*.

27. Mention other highly elastic substances.

Glass, ivory, steel, air, and all gases.

28. In how many different states does matter exist?

In three states—*solid*, *liquid*, and *gaseous*. A stone is solid, water is liquid, and air is gaseous.

29. How may a substance be made to pass from one of these states into another?

By increasing or diminishing the amount of heat which it contains. Water is converted into vapor by heat, and into ice by cold.

30. Suppose two polished plates of glass or metal are laid one on the other, and slightly pressed?

It will be found if we undertake to separate them, that they stick together.

31. What is the force that holds the plates together called?

Attraction of adhesion, or simply *adhesion*.

32. What is the reason that if two panes of common window glass are placed on each other they do not adhere?

Because they are not even and smooth enough to come into close contact.

33. Mention one or two familiar facts that are to be explained by adhesion.

The marks made in writing with chalk or a lead pencil; the sticking of dust to the walls and furniture of rooms.

34. Does adhesion manifest itself between liquids and solids, as well as between solids?

It does; if I dip my finger into water it becomes wet, because a film of water adheres to it.

35. Mention other illustrations of adhesion between liquids and solids.

Writing with ink, painting, varnishing, smearing rubbing surfaces in machinery with oil.

36. Does attraction manifest itself between bodies at a distance, as well as between those which are in close contact?

It does; the earth attracts all bodies, and causes them, if unsupported, to fall toward its surface.

CHAPTER II.

MECHANICS OF SOLIDS.

INERTIA OF MATTER—PRODUCTION OF MOTION.

37. Do we ever see a chair in a room or a stone on level ground set itself in motion of its own accord?

We do not.

38. To start such a body, what must be done?

It must be pushed, or pulled, or struck, with a certain *force*.

39. If a stone or a ball be rolled on the ground, it goes only a certain distance and then stops—does it stop itself of its own accord?

It does not; it encounters a resisting force which gradually checks its motion and finally stops it.

40. What is this resisting force called?

Friction; it arises from the roughness of the ground.

41. Can you mention any facts which go to show that there is such a force in operation in the case supposed?

If a boy undertakes to draw a hand sled on the bare ground, he must pull quite hard, but on the smooth snow he can draw it very easily.

42. Suppose a round stone be rolled on smooth ice?

It would go much farther than on the rough ground; the smoother the ice is the farther it will go.

43. We sometimes see a moving body, as a rolling ball, suddenly move off in a new direction—does it change the direction of its motion by its own inherent power?

It does not; it is made to take a new direction by striking against some obstacle, or by receiving a blow from one side.

44. In view of what has now been stated, what may we conclude?

That matter is perfectly passive or *inert.*

45. By what are all the motions and changes of motion that we observe produced?

By the action of external forces upon bodies.

46. How is the VELOCITY, or rate of motion, of a moving body measured?

By the space which the body passes over in a second, or any other interval of time.

47. If there were no friction, or other resistance in operation, would the continued exertion of a force be necessary to keep up the motion?

It would not; a body once set in motion would move on forever with the same velocity, and in the same direction.

48. Can we realize this supposition of a motion free from all resistances?

We can not; in every case of motion on the earth there is, of necessity, some resistance in play.

49. To keep up the motion of a body unchanged, what, then, is necessary?

That a force should be continually exerted just sufficient to overcome the resistance.

50. Illustrate.

When a horse draws a loaded wagon at a uniform pace, of some three miles an hour, his muscular effort continually overcomes the friction.

51. Give another illustration of the same principle.

When a train of cars proceeds at an unvarying speed, of say 25 miles per hour, the power of the locomotive neutralizes all the resistances, and so keeps up the velocity acquired at the outset.

52. Is any particular amount of force required to overcome the inertia of a body and set the body in motion?

The smallest force would produce some motion, no matter how large the body might be, if it were not opposed by a resistance.

53. How has this truth been strikingly illustrated?

It has been said that the kick of a fly moves the earth.

54. Give another illustration.

If there were no friction to be counteracted, a small boy could set a train of cars in motion.

55. Is there any exception to the general truth that bodies of matter do not move of their own accord?

There is; a man, or any animal, can move or stop moving at pleasure.

56. Do external forces take effect upon men and animals, as well as upon ordinary bodies of inert matter?

They do; if the support upon which we stand gives way we fall to the ground, just as a body of inert matter would.

57. Every one knows that if a horse, when going fast, suddenly stops, his rider is thrown forward—what is the reason of this?

It is owing to the inertia of matter; the rider merely retains the motion he had in common with the horse.

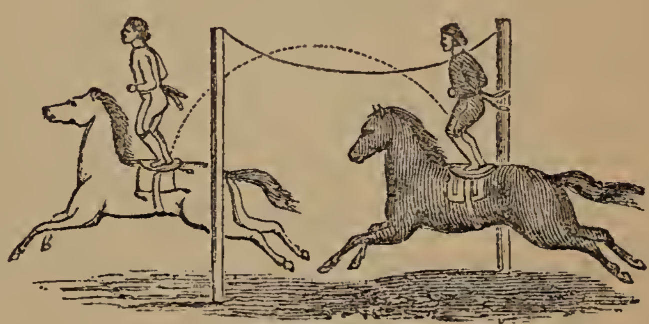
58. How do you explain the fact that, when a man jumps from a carriage in rapid motion, he falls forward as soon as his feet strike the ground?

In the same way; he is going forward just as fast when he reaches the ground as when he left the carriage.

59. When a circus rider, standing on a galloping horse, wishes to leap over a rope, what does he do?

He merely jumps up, and allows the motion which he has to carry him past it..

Fig. 1.



EFFECTS OF FORCES UNDER DIFFERENT CIRCUMSTANCES.

60. When a force acts by PULLING, as when a horse draws a wagon, what is it called?

A *force of traction.*

61. When a force acts by PUSHING from behind or from above, what is it termed?

A *force of pressure.*

62. Will the same blow from a club communicate as great a velocity to a large ball as to a small one?

It will not; if the large ball contains twice as much matter as the small one, it will go only one half as fast.

63. The velocity imparted to any body perfectly free to move, by a given amount of force, depends, then, upon what?

Upon the quantity of matter in the body. If the mass be great, the velocity is proportionally small.

64. That the same velocity may be imparted to a large mass as a small one, what is necessary?

The force applied must be greater in the same proportion that the mass is larger.

65. How can the effect of a force on a body be counteracted, so that no motion will ensue?

By applying a force of equal intensity in the opposite direction.

66. Illustrate by an example.

If two men of equal strength pull at opposite ends of the same rope, it will not move.

67. Suppose two blows of equal force are given to the same ball, at the same moment, in opposite directions?

The ball will remain at rest, just as if it had not been struck at all.

68. When a body moves forward constantly at the same rate, as when a horse trots for two hours with the same speed, what kind of motion is it said to have?

A *uniform motion.*

69. When a body goes faster and faster every instant, as a falling stone does, what is its motion called?

Accelerated motion.

70. When a stone is thrown upward, it moves slower and slower every instant—what motion is it said to have?

Retarded motion.

GRAVITY, AND OTHER FORCES.

71. When either end of a magnet is brought near a small nail lying on a table, what happens?

Fig. 2.

The nail is drawn into contact with the magnet, and is there held by a considerable force.

72. What is this force called?

The attraction of the magnet.

73. What is the reason that if a stone or other body be raised from the ground, and then left to itself, it falls with an accelerated motion?

Because the earth continually attracts it, just as a magnet attracts a nail.

74. What is this force of attraction called?

Gravity, or the *Attraction of Gravitation.*

75. What is the entire force which draws the body down called?

The *weight* of the body.

76. What is meant when it is said that a body is HEAVY?

That it has weight.

77. How may a heavy body be prevented from falling?

By placing it on some solid support, or suspending it from some fixed point above.

78. Illustrate by an example.

A book put on a table is supported and can not fall.

A lamp suspended by a rod or chain from the ceiling of a church, is thereby prevented from falling.

79. With what force does the book press upon the table, and the lamp pull downward upon the chain?

With its own weight.

80. Are all bodies equally heavy?

They are not; their weight is in proportion to the quantity of matter they contain.

81. Have two different substances the same weight when of the same bulk?

They have not. A piece of iron is denser, or contains more matter, than a piece of wood of the same size, and it is also heavier.

82. How is the fact that one substance is, from its essential nature, heavier than another often expressed?

It is said that its *specific gravity* is greater.

83. What amount of force must we exert upward to lift a heavy body from the ground?

A force a little greater that the weight of the body.

84. When a grocer puts a quantity of sugar in his scales, and says that it weighs one pound, what is meant?

That the weight, or downward pressure of the sugar, is the same as that of the pound weight which balances it in the other scale.

85. Is the quantity of matter also the same in each scale?

It is.

86. Give an example of the operation of another force similar to gravity.

The elastic force of a steel spring gradually uncoiling drives the wheels of a watch.

87. Are all forces of the same essential nature with gravity?

Some forces act by a sudden impulse, and produce their whole effect in an instant, or in a very short interval of time.

88. Give an instance of motion produced by such an impulsive force.

The explosive force of gunpowder impels a ball with great velocity out of a gun.

89. Why should a heavy iron ball shot from a cannon strike with such destructive force against any solid obstacle that it meets?

All the force that was expended in projecting it from the cannon is suddenly exerted against the immovable obstacle.

90. What is the force which a moving body exerts, or is capable of exerting, against an immovable obstacle called?

The *momentum* of the body.

MOMENTUM OF A MOVING BODY.

91. What does the momentum of a moving body depend upon?

Its mass and its velocity.

92. Which has the greatest momentum, a cannon ball or a musket ball fired with the same velocity?

A cannon ball; it will strike a wall with greater force because its mass is greater.

93. Why are very heavy cannon balls used to batter down the walls of a besieged fortress?

Because of the great momentum with which they strike.

94. Light comes to us from the sun with the astonishing velocity of 191,000 miles per second; if we suppose it to consist of particles a thousand times smaller than the smallest shot, with what force would a particle of light strike?

With a force equal to the momentum of a half ounce ball fired with the velocity of 2,000 feet per second.

95. What is this an instance of?

A very great momentum, resulting from the enormous velocity of a very small particle of matter.

96. What is the reason that when two trains of railroad cars, on the same track, meet under full speed, the effects of the collision are so destructive?

The masses in motion are very great, and they also rush together with great velocity.

97. Give one or two familiar examples of important effects produced by momentum.

A nail is easily driven by a hammer. Red hot iron is wrought into any shape by a blacksmith with his sledge-hammer.

98. What is a PILE?

A long stick of timber, sharpened at one end, that it may more easily be driven into the ground.

99. How are piles driven far into the ground?

By the momentum of a heavy mass of iron let fall upon the top.

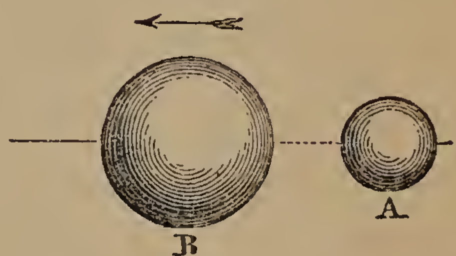
100. Are the useful applications of momentum confined to solid bodies in motion?

They are not. The force of running water is used to drive mill-wheels. The wind impels ships across the sea; and on land turns the wind-mill.

ACTION AND REACTION.

101. Suppose the two bodies, A and B, represented in Fig. 3, are both moving in the direction indicated by the arrow, and that A overtakes B and comes into collision with it, what will be the result?

Fig. 3.



A will lose a portion of its momentum, and B will gain an equal amount.

102. How is this generally expressed?

It is said that A acts on B, and B reacts on A; and that the action and reaction are equal and directly opposed to each other.

103. Is it universally true that whatever force one body exerts upon another, the second body exerts on the first in the opposite direction?

It is; action and reaction are always equal and directly opposed.

104. Illustrate this important principle by a simple example.

A book lying on a table presses on it by its weight, and is supported by the equal reaction of the table.

105. Mention another familiar illustration.

If we clap our hands, each hand receives the same blow.

106. Suppose a man pulls at one end of a rope that is attached to a post?

The post pulls at the other end just as hard as he does.

107. A magnet attracts a piece of iron that is brought near it—according to the principle of action and reaction, what is also true?

That the iron attracts the magnet with an equal force.

108. Does the same principle hold good in the case of the attraction which the earth exerts upon bodies at its surface?

It does; all bodies react upon the earth with a force equal to the earth's attraction.

109. Does the earth, then, move to meet a falling stone?

It does; but, owing to its enormous mass, its motion is exceedingly slow in comparison with that of the stone.

110. Has the principle of the equality of action and reaction any thing to do with the voluntary motions of men and animals?

It has; the immediate cause of all such motions is the reaction of something against which the muscular force of the animal is exerted.

111. Illustrate.

When we walk, it is the reaction of the earth to the force we exert that enables us to move.

112. How does a bird fly?

It strikes the air with its wings, and the reaction of the air bears it forward.

113. How does a fish swim?

By the reaction of the water to the pressure which it exerts against it with its fins and tail.

114. Is the principle the same in every other case of motion in which the original source of power is within the moving body?

It is; for example, a steamboat is propelled by the reaction of the water to the pressure of the revolving paddles.

115. If a large ship comes into collision with a small vessel at sea, do they receive the same or a different shock?

The same.

EFFECTS OF COLLISION ON THE MOTION OF BODIES.

116. When two balls, moving on the same line, as in Fig. 3, page 25, come into collision, what are the circumstances of their motion after the collision?

If they are inelastic they keep on together; but if they are elastic, like India rubber or ivory, they separate, and take different velocities.

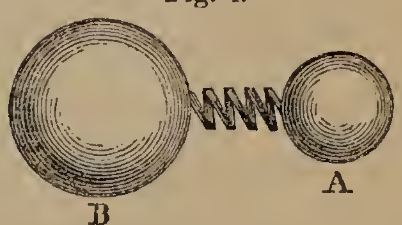
117. Why do elastic balls separate after collision?

Because they are both compressed by the shock, and then recover their form with a certain force, which urges them asunder.

118. How may this effect be illustrated?

The result is the same as if there were a steel spring between the two bodies, that was compressed by the shock, and then recovered itself.

Fig. 4.



119. If an elastic ivory ball should come against another of the same size at rest, what would be the effect of the collision?

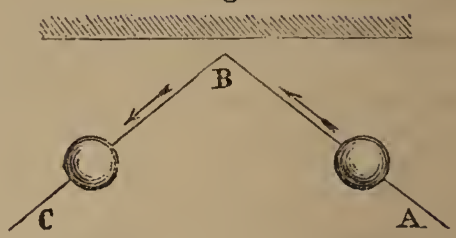
The moving ball would stop, and its motion would be taken up by the other.

120. Does a blow from a club, given to an India rubber ball, send it off any faster because the ball is elastic?

It does; nearly twice as fast.

121. If an elastic ball be thrown obliquely against an immovable wall, as shown in Fig. 5, in what direction will it glance off?

Fig. 5.



If it be thrown in a direction A B, it will bound off in another direction, B C, equally oblique to the wall.

122. If an India rubber ball were perfectly elastic, how high would it rebound if dropped on the floor?

To the height from which it fell.

RELATIVE MOTION.

123. What is relative motion?

The motion of one body with respect to another which is also in motion.

124. Give an example.

A man walking on the deck of a ship that is under sail is in motion relative to the bow or stern of the ship, and the whole ship at the same time moves forward and carries him along.

125. Suppose he were to run toward the stern at the same rate that the ship goes forward?

He would keep continually over the same point on the surface of the water. While he would be in motion relatively to the ship, he would be at rest in relation to the water.

126. If, as a steamboat was leaving her wharf, a person standing at the stern should throw an apple directly backward with the same velocity that the boat is going forward, how would the apple appear to move to a person on shore?

It would be seen to drop directly down into the water.

127. If two trains of cars, on the same railroad, were proceeding in opposite directions, at the respective rates of 20 miles and 30 miles per hour, with what velocity would they approach?

Fifty miles per hour.

128. If they were proceeding in the same direction, what would their relative velocity be?

Ten miles per hour. They would approach at this rate if the faster of the two trains were behind the other.

COMPOUND MOTION.

129. Can the same body have two different motions at the same time?

It can; some examples have just been given.

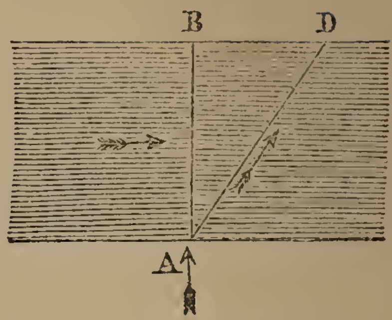
130. What is the actual motion of a body that has at the same time two or more different motions called?

Compound motion.

131. Give an example of compound motion.

The case of a boat rowed across a river at the same time that it is carried down stream by the current.

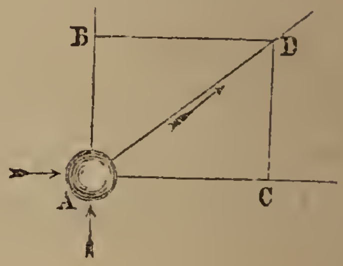
Fig. 6.



132. If the boat should be rowed steadily across the river, in the direction A B, and should be carried down by a uniform current a distance B D, what line would it actually follow?

The straight line A D.

Fig. 7.



133. Suppose two persons were to kick the same foot ball at the same instant, the one toward B and the other toward C, what direction would it take?

A direction A D, intermediate between the directions in which the two blows were given.

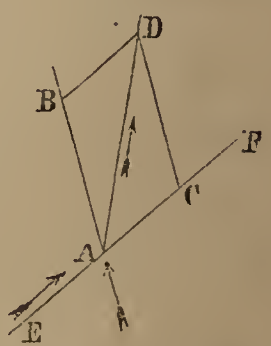
134. Would either impulse change the velocity in the direction of the other?

It would not.

135. If one impulse would have sent it to B in a second, and the other to C, where would it be from the joint action of the two at the end of a second?

It would be at D.

Fig. 8.



136. If a boy, while in the act of running along the line E F, should throw a ball from A toward B, would the ball go directly to B?

It would not; it would continue to go forward as fast as the boy does; and so, having two motions, would pursue an intermediate line of direction, as A D.

137. Where must another boy, who wishes to catch the ball, stand?

Somewhere on the line A D; and thus in advance of the line of direction in which it was thrown from A.

138. Suppose a man, riding in a wagon, tosses an apple directly upward, will it come down into his hands again?

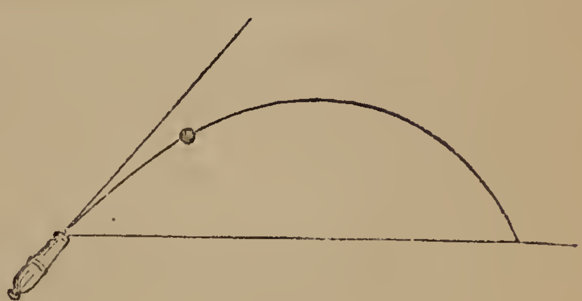
It will; because it moves along horizontally as fast as the man does.

MOTION IN A CURVED LINE.

139. Does a ball fired from a gun pursue a straight line through the air?

It follows a curved line, as shown in Fig. 9.

Fig. 9.



140. Why does it not proceed in the direction in which it was fired?

Because its weight continually draws it downward into a new direction.

141. How far could a cannon ball be fired if it were not retarded by the resistance of the air?

More than 30 miles.

142. What is the greatest distance that a cannon ball has actually been projected?

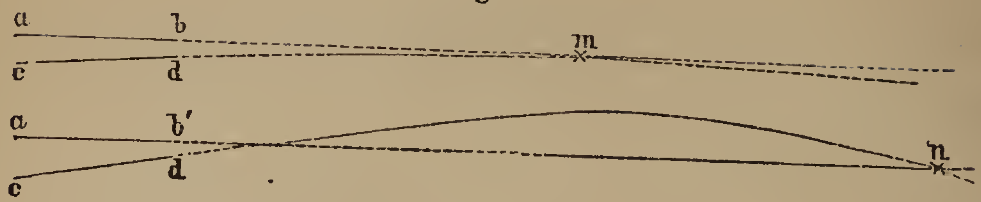
Only about three and a half miles; so great is the effect of the resistance of the air.

143. If a bullet pursues a curved line through the air, how is it that a marksman, in firing a rifle, aims at the mark he wishes to hit?

The line of fire is somewhat inclined to the line of aim, and intersects it.

144. Illustrate by Fig. 10.

Fig. 10.



a b is the line of aim, and *c d* is the line in which the bullet leaves the gun. The bullet follows the curved line, and is on the line of aim at the distant point *m*, or *n*.

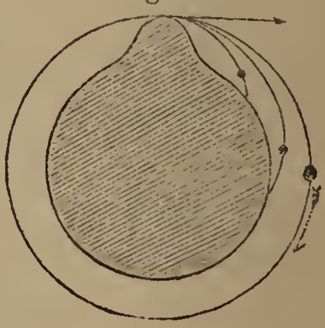
145. To what height could a cannon ball be fired vertically upward, if it were not for the resistance of the air?

Sixteen miles.

146. With what velocity and force would it return to the earth?

With the same that it leaves the gun.

Fig. 11.



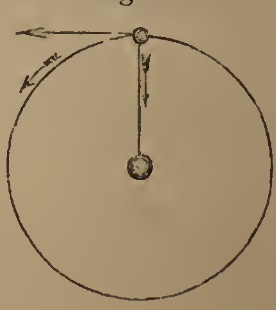
147. With what velocity should a cannon ball be projected horizontally from the top of a mountain, to go entirely around the earth, supposing that it did not encounter the resistance of the air?

About five miles per second.

148. Mention other instances of motion in a curved line.

The drops of water in a fountain rise and fall in beautiful curves. Brooks and rivers often flow through verdant valleys in graceful serpentine lines.

Fig. 12.



149. What kind of motion has the moon in space?

The moon moves in a vast circle around the earth.

150. What force is it that continually draws the moon out of its direction of motion into a circle?

The attraction of the earth.

151. How much less is this force at the distance of the moon than at the earth's surface?

About 3,600 times less.

CENTRIFUGAL FORCE.

Fig. 13.

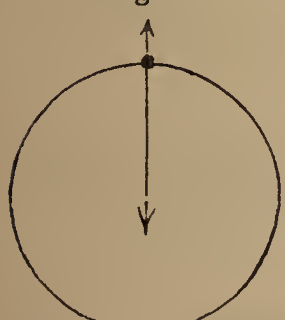
152. When a stone is whirled round in a sling held in the hand, it is perceived that it pulls outward upon the hand; what is this force, that acts along the string from the centre outward, called?

The *Centrifugal Force.*

153. What name is given to the force which draws the stone inward and keeps it in the circle?

Centripetal Force.

Fig. 14.



154. How are these two forces related to each other?

They are of equal intensity, and pull in opposite directions at the two ends of the string.

155. Explain more particularly.

The centripetal force pulls inward at the inner end, and the centrifugal force pulls outward at the outer end.

156. What keeps the cord stretched?

These two forces pulling at its two ends; just as a rope is stretched by two men pulling at the ends.

157. Suppose the stone should be whirled more rapidly, what would be the consequence?

The opposing centripetal and centrifugal forces would be increased, and the string might break.

158. If the string should be suddenly released from the hand, or should break, what would be the result?

Fig. 15.

The stone would fly off in a tangent, as Fig. 15 shows.

159. How does that appear?

As soon as the string gives way, there is no longer any force operating to change its direction, and it continues on, by virtue of its inertia, in the direction in which it is moving at that instant.

160. Does the centrifugal force have any effect after the string gives way?

It does not; it instantly ceases to act.

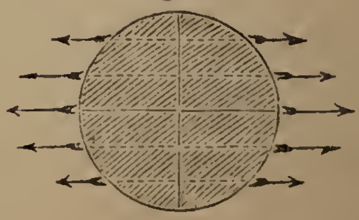
161. Are the same two forces in operation in other cases of circular motion, as in the revolution of the moon around the earth, and of the earth around the sun?

They are; the centripetal force in these cases is the attraction of the central body around which the revolution is performed.

162. Suppose a round body turns about an axis, like a top?

All its parts will be animated by a centrifugal force pulling directly outward from the axis, as represented in Fig. 16.

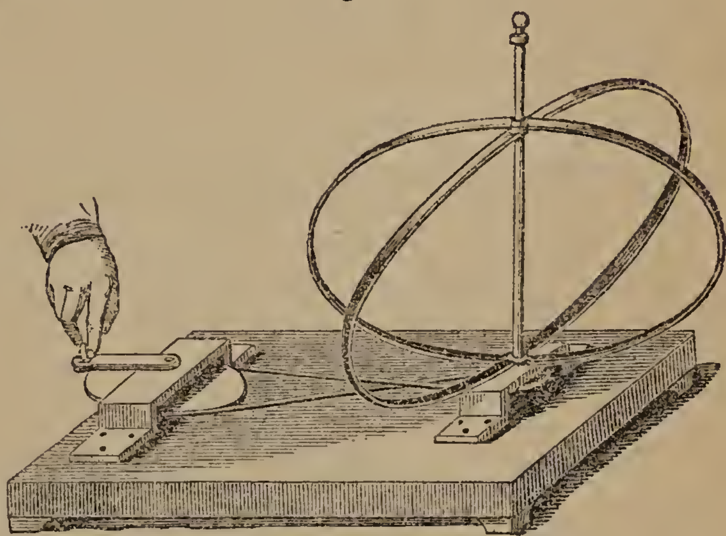
Fig. 16.



163. What parts of the rotating body will be urged outward by the greatest force?

Those which are most remote from the axis. This is indicated in the figure by the comparative size of the arrows.

Fig. 17.



164. How may the action of the centrifugal force, in the case of a rotating body, be illustrated experimentally?

By the apparatus represented in Fig. 17.

165. Of what does it consist?

It consists of two circular iron or brass hoops, so thin as to be flexible, and an arrangement for setting them in rapid rotation around the upright rod to which they are attached.

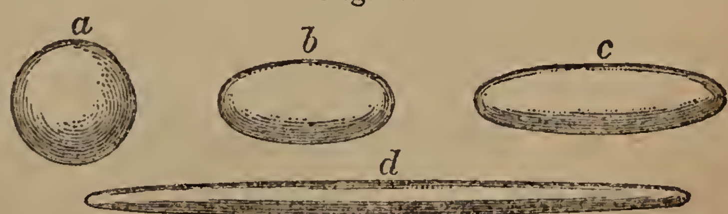
166. If they are made to turn rapidly, what will be the result?

They will be flattened at the top and bottom, and bulge out at the middle, as represented in the figure.

167. If a ball of moist clay, or other yielding material, should be set whirling about an axis, what would happen?

It would be more or less flattened, in a similar manner.

Fig. 18.



168. Might it be brought to the form of a flat disc, as shown at *d*, Fig. 18?

It might, if the material should be sufficiently tenacious, by making it turn rapidly.

169. How does the potter make use of the centrifugal force to aid him in his useful handicraft?

A piece of clay is placed on a rapidly moving flat wheel, and the clay flattens out in endeavoring to move from the centre; with the aid of his fingers and a little tool he, with great dexterity, turns cup after cup, and saucer after saucer.

170. How is our common window glass manufactured into sheets?

A mass of molten glass, on an iron rod, is made to turn rapidly round; it spreads out on the table into a thin round plate, from which afterwards are cut different sized panes.

171. It has been ascertained that the earth is somewhat flattened at its poles—what is the explanation of this curious fact?

The earth rotates about an axis, and it took that form under the influence of the centrifugal force, ages ago, when its entire mass was in a fluid state.

172. It is well known that large grindstones, turned rapidly by machinery, are occasionally broken into fragments that fly in every direction—what force is it that produces these violent effects?

The centrifugal force. This pulls outward with such energy as to overcome the cohesion between the particles of the stone, and the fragments fly off in a tangent.

173. Why can we not turn a sharp corner when running fast?

Because the effort we make is opposed by an energetic centrifugal force.

174. What is the reason that a train of cars, in passing rapidly around a curve on a railroad, is liable to be thrown off the track?

The centrifugal force in operation causes the flanges on the outside wheels to press against the outer rails.

175. Why do the circus rider and his horse lean toward the centre of the ring?

To counteract the effect of the centrifugal force. A skater, for the same reason, leans to the inside, when he is describing a curve on the ice.

CENTRE OF GRAVITY.

Fig. 19.

176. If a rod or cane be placed on the edge of a stationary body, by sliding it along we may find a point about which the weights of the two parts will balance each other; what is this point called?

The *centre of gravity* of the rod. Every body has its centre of gravity, or point about which, if supported, the body will balance itself in any position.

Fig. 20.

177. Why has the name centre of gravity been given to this point?

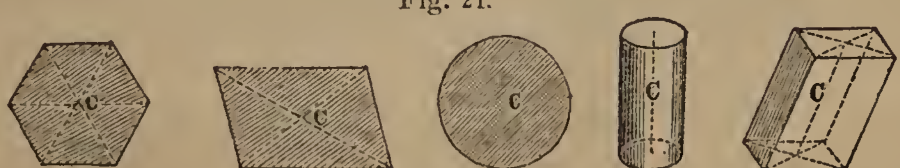
Because the entire weight of the body may be considered as collected and taking effect there.

178. Illustrate.

The body is drawn down by its weight, just as if a man were pulling downward with a certain force upon a cord attached to its centre of gravity.

179. In bodies of a regular form, as shown in Fig. 21, where is the centre of gravity situated?

Fig. 21.



At C, the centre of figure.

STABILITY OF HEAVY BODIES.

180. When is a heavy body said to be STABLE, or to have STABILITY?

When it is so supported that if disturbed from its position it will fall back again.

181. Give an example.

The *pendulum* of a clock, represented in Fig. 22; or a *plumb-line*, shown in Fig. 23.

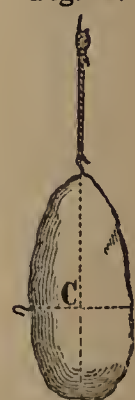
Fig. 22.

Fig. 23.

182. How is it with a body of any form suspended from a point directly over its centre of gravity (Fig. 24), or with bodies standing on their bases (Fig. 25)?

They are all stable.

Fig. 24.



183. When is a body said to be UNSTABLE?

When it is poised on a point or edge directly under its centre of gravity; so that if disturbed from its position it will upset. This is illustrated in Fig. 26.

Fig. 25.

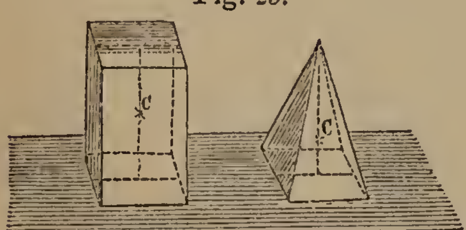
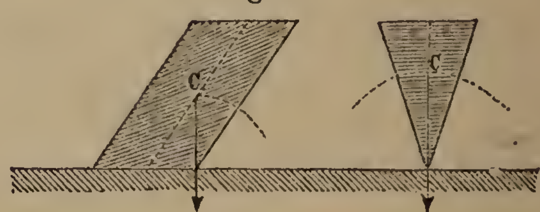


Fig. 26.



184. Give another example.

A pole standing on one end; if it be displaced, in the least, from that position, it will upset.

185. How may an upright pole be balanced on the finger, and kept from falling for some time?

By shifting the position of the finger from one side to the other, so as to counteract the tendency to fall.

186. What is the general rule with regard to the movements of a heavy body disturbed from its position of rest?

Its centre of gravity tends to the lowest possible position, and finally settles there.

187. Mention one or two illustrations of this tendency.

The oscillations, to and fro, of the pendulum of a clock. Or the similar movements of a swing.

188. In order that a body standing on the level ground may have stability, what is necessary?

That the centre of gravity should be directly over some point of the base of contact, as in Fig. 25 or Fig. 27.

Fig. 27.

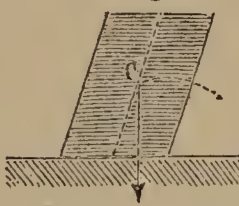
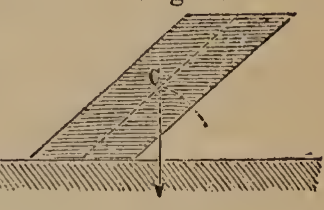


Fig. 28.



189. Suppose the centre of gravity overhangs the base, as shown in Fig. 28?

The body will upset.

190. Does the stability of a body depend on the breadth of its base?

It does; the broader the base the greater the stability.

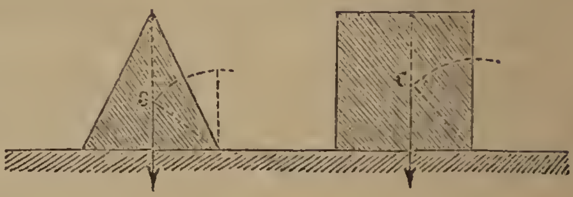
191. Mention a familiar case in which this principle is applied.

The legs of chairs are commonly spread out below the seat to give them greater firmness and security.

192. Mention other instances of the application of the same principle.

Candlesticks, table lamps, goblets, wine-glasses, and many other articles of household furniture, have stability given to them by a broad foundation.

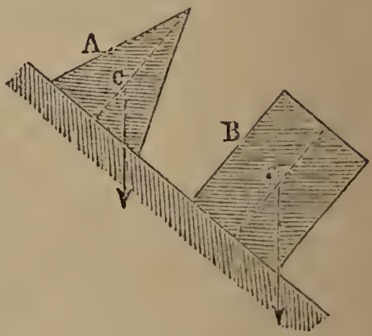
Fig. 29.



193. Is the stability of a body standing on a level surface the greater for the centre of gravity being low?

It is. It will require a greater displacement to overturn it, as shown in Fig. 29. It will also be less liable to upset if placed on a sloping surface.

Fig. 30.



194. Where is this shown?

In Fig. 30; the body B is on the point of overturning, but the body A, with a lower centre of gravity, stands firm.

195. Illustrate by a familiar fact.

A wagon loaded with stone is less liable to upset than one loaded with hay.

Fig. 31.

196. By what are ATTITUDES controlled?

By the necessity of preserving the centre of gravity.

197. Illustrate by an example.

If a man carries a load on his back, he stoops forward to keep the centre of gravity over his feet.

198. Suppose he bears a load in one hand or on one shoulder?

He leans to the other side, and if he carries it in his arms he leans backward, for the same purpose.

199. If he thrusts one leg out, what must he do?

He must throw his arms to the opposite side, or incline his body in that direction, to balance it.

200. How does the rope dancer perform his feats of agility?

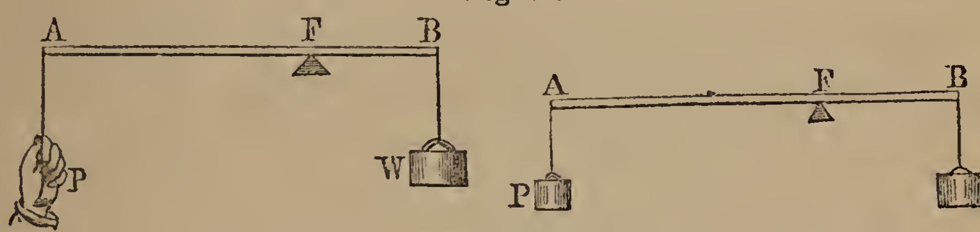
He balances himself with a heavy pole which he holds in his hands. He counteracts any tendency to fall on the one side, by thrusting the pole toward the other side.

THE LEVER.

201. What is a lever?

It is a bar of wood or metal movable around a fixed point called the *fulcrum*. In Fig. 32 A B represents a lever, movable about the fulcrum F.

Fig. 32.



202. For what general purpose is the lever used?

To raise a weight, or overcome a resistance greater than the power exerted; in other words, to gain power.

203. Illustrate by Fig. 32.

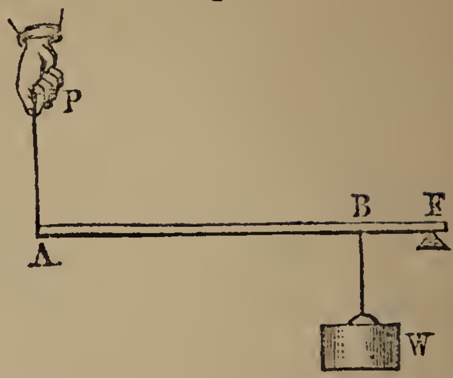
The power, P, applied at A, balances a greater weight, W, suspended at B, nearer the fulcrum.

204. Are the power and weight always applied on opposite sides of the fulcrum?

They are sometimes applied on the same side, as in Fig. 33.

205. To gain power, by the use of the lever, what is necessary?

Fig. 33.



That the power should act at a point farther from the fulcrum than the weight does; as in Figs. 32 and 33.

206. If the distance of the power from the fulcrum is twice as great as the distance of the weight, as in Fig. 32, how much greater is the weight than the power which balances it?

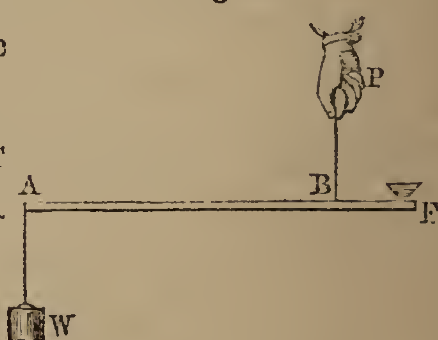
It is twice as great. If the distance of the power is three times that of the weight, the weight is three times the power, and so on.

207. What is the distance of the power or weight from the fulcrum called?

The *lever arm*, or *leverage* of the force. The power has a greater leverage than the weight in Figs. 32 and 33.

208. In the case of the lever represented in Fig. 34, which is the greater, the power, P, or the weight, W?

Fig. 34.



The power; because it acts nearer the fulcrum, or with a smaller leverage than the weight.

209. It seems, then, that with this lever we lose power instead of gaining it—can it be used to any advantage?

It can be advantageously used when it is desirable to obtain a more rapid motion.

210. Show that we may gain speed with it.

When this form of lever turns around its fulcrum, F, the point A, at which the resistance acts, moves faster than the point B, at which the power acts.

211. How does the loss of power compare with the gain of speed?

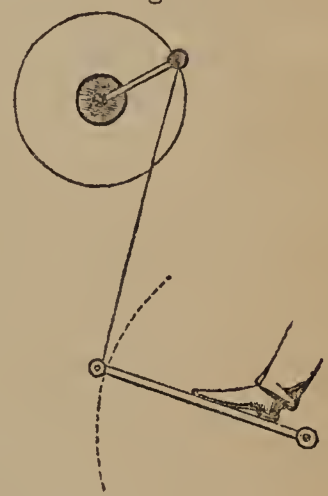
We lose power in the same proportion that we gain speed.

212. Can this be avoided in any mechanical contrivance?

It can not. There is often more power at command than is needed to overcome the resistance.

213. Give an example of the application of this kind of lever.

Fig. 35.



The treddle of a turning lathe, represented in Fig. 35. A small motion of the foot causes the spindle to turn rapidly.

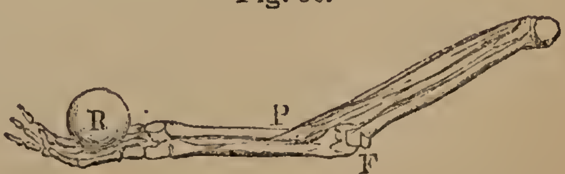
214 Explain the figure.

The treddle is a flat piece of board, movable about one end; the foot presses on the treddle near that end, and the pressure is transmitted by means of a rod from the other end to the spindle of the lathe.

215. Mention another, and the most interesting, application of this form of lever.

Our limbs, and the limbs of most animals, are levers of this description.

Fig. 36.



216. Explain, by the example of a man undertaking to raise a weight in his hand, by bending his arm at the elbow-joint, as represented in Fig. 36.

The elbow-joint is the fulcrum, and a strong muscle attached to the bone of the arm on the upper side, and just below the joint, is the power. In Fig. 36, F is the joint or fulcrum, and the muscle is at P.

217. What is the advantage of this arrangement?

A slight contraction of the muscle gives considerable motion to the limb.

218. In raising a heavy weight from the floor and holding it out at arm's length, the whole arm acts as a lever, with the fulcrum at the shoulder joint—how does the contractile force of the muscle at the shoulder joint compare with the weight raised?

To hold 50 pounds at arm's length requires an expenditure of muscular force at the shoulder equal to 2,450 pounds.

219. Has this feat ever been performed?

It has, by men of very great strength.

220. We gain power with the lever represented in Fig. 32; do we not lose velocity in the same proportion?

We do. In Fig. 32 the point B moves only half as fast as the point A, when the lever is in motion; and the weight is twice as great as the power.

221. How is it with other mechanical contrivances or machines?

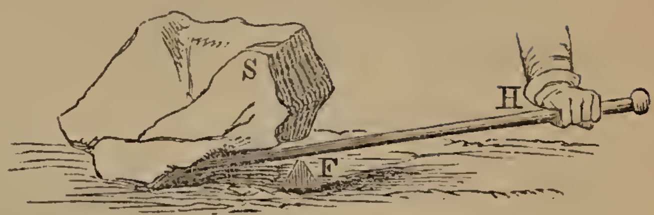
We can in no way gain power without losing speed in an equal proportion.

222. A man can easily lift a stone weighing 10 pounds to the height of 3 feet; suppose he should undertake, with the same muscular force, to raise a stone weighing 100 pounds to the same height, with the aid of a machine, how much longer would it take?

It would take ten times as long; and the force would have to be exerted through a distance of 30 feet.

23. Give an example of the application of the lever.

Fig. 37.



A pump handle; or a crow bar used to pry up a large stone, as in Fig. 37.

224. Mention other instances of the useful application of the same form of lever.

Fig. 38.

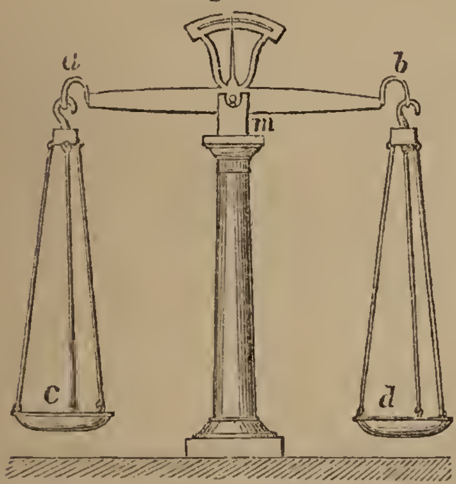
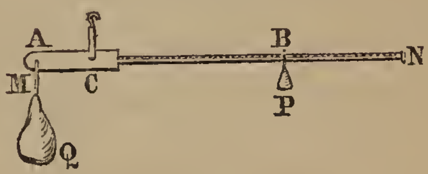


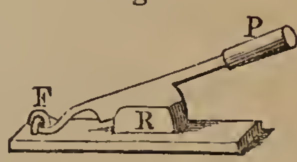
Fig. 39.



The *common balance*, for weighing bodies (Fig. 38); and the *steelyard*, used for the same purpose (Fig. 39).

225. Give an example of the form of lever shown in Fig. 33.

Fig. 40.



The chopping knife, represented in Fig. 40; the end fastened to the bench is the fulcrum, and in place of a weight to be raised there is the resistance of the substance to be cut.

Fig. 41.

226. Give an instance of the application of the bent lever.

A claw-hammer, used to draw a nail, is a *bent lever*.

227. On what principle does an oar act?

On the principle of the lever.

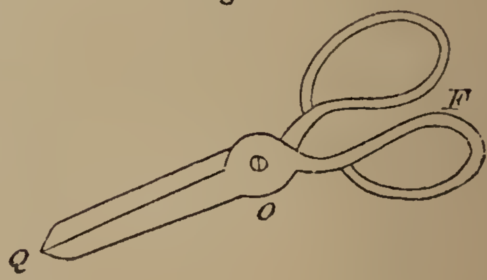
228. Where is the fulcrum?

Fig. 42.

The resistance of the water to the blade of the oar is the fulcrum; the boat is the weight or resistance, and the hand of the rower is the power.

229. Give a few examples of double levers; that is, of two levers turning about the same fulcrum.

Fig. 43.



Scissors, shears, nippers, and nut-crackers are double levers.

230. Where is the fulcrum

At the joint.

231. Mention two or three examples of double levers of the third kind, represented in Fig. 34.

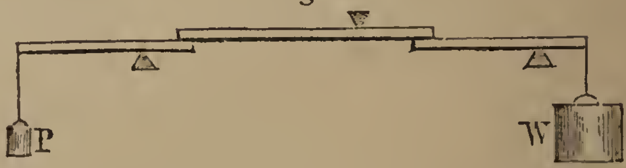
Tongs, sheep-shears, tweezers.

232. What advantage is gained by the use of them?

By a slight movement of the fingers the ends are brought together rapidly.

233. Can levers be combined, so as to overcome a greater resistance?

Fig. 44.



They can, as shown in Fig. 44; such a combination is called a *Compound Lever.*

234. Can you mention an instance of an important application of the compound lever?

The large platform scale is essentially a compound lever

235. Describe it.

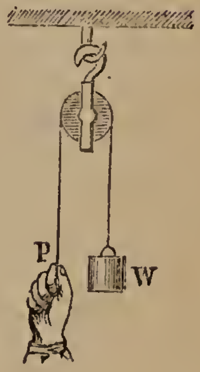
The platform rests on several levers which are connected with the side lever that supports the sliding weight; this weight, when brought to the proper notch of the lever, balances the load of hay, or coal, that rests on the platform.

THE PULLEY.

236. What is a PULLEY?

A small wheel movable about an axis, and turned by a rope that lies in a groove cut around its edge.

Fig. 45.



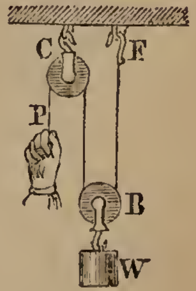
237. Fig. 45 represents a pulley with a fixed axis, and for that reason called a FIXED PULLEY—for what general purpose is it used?

A power, P, applied at one end of the rope supports, or gives motion to, a weight, W, suspended from the other end.

238. How does the power compare with the weight which it sustains?

It is just equal to it.

Fig. 46.



239. Describe the arrangement of pulleys shown in Fig. 46.

One end of the rope that hangs down from the fixed pulley is passed underneath another pulley, and then brought up and fastened to a fixed point, F.

240. Where is the weight suspended?

From the centre of the lower, or *Movable Pulley.*

241. When the end of the rope at which the power, P, acts is pulled down, what will take place?

The lower pulley will go up and take the weight with it.

242. How much greater is the weight than the power that supports it?

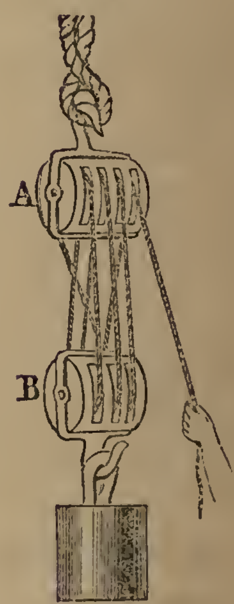
It is twice as great.

243. To raise the weight one foot, how far must the end of the rope be pulled down by the power?

Two feet.

244. What is the construction of the common tackle, so much used in raising heavy bodies to considerable heights?

Fig. 47.



It consists of several pulleys, placed side by side in two frames, or *blocks*—one fixed and the other movable. The same rope passes around all the pulleys.

245. Where does the power act?

At one end of this rope; and the other end is attached to the fixed block.

246. How much greater is the weight than the power which sustains it?

Four times, if there are two movable pulleys; six times, if there are three, and so on.

247. Are there any other mechanical contrivances, or MACHINES, by which power can be gained, besides the lever and pulley?

There are; those in most common use are known by the names—*Wheel and Axle*, *Inclined Plane*, *Wedge*, and *Screw*.

248. What are these machines, together with the lever and pulley, called?

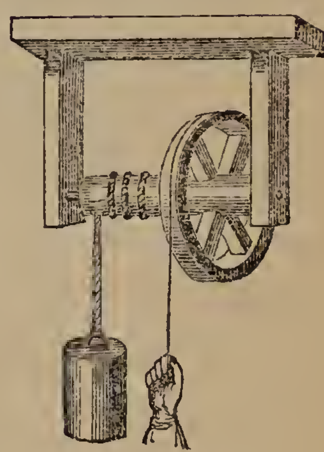
The *Mechanical Powers.*

THE WEEEL AND AXLE.

249. What does Fig. 48 represent?

A *Wheel* and *Axle.*

Fig. 48.



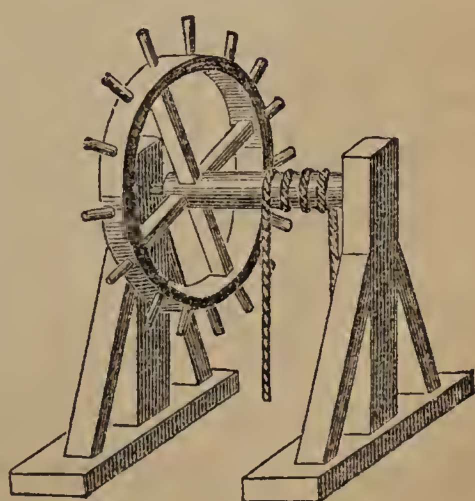
250. Where are the power and weight applied?

The power acts on the circumference of the wheel by means of a rope, and the weight is attached to a rope that passes off from the axle.

251. If the diameter of the wheel is ten times that of the axle, how great a weight will the power sustain?

A weight ten times as great as the power.

Fig. 49.



252. What do Figs. 49, 50, and 51 represent?

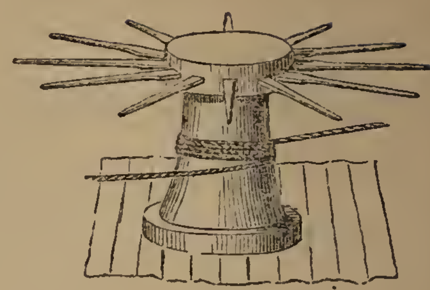
Various forms of the wheel and axle. Fig. 49 is the wheel used in steering vessels.

253. How is the power applied to it?

The hand grasps hold of wooden pins inserted in the rim of the wheel.

254. Explain Fig. 50.

Fig. 50.



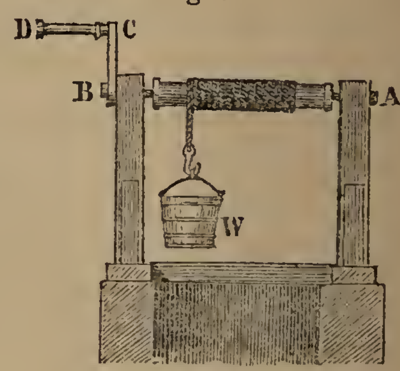
It represents the *capstan*, used on board ships, in lowering and raising the anchor, and on land in moving buildings.

255. What is the power by which the capstan is worked on ship board?

The combined strength of a number of sailors, applied to several handspikes inserted in the axle.

256. What does Fig. 51 represent?

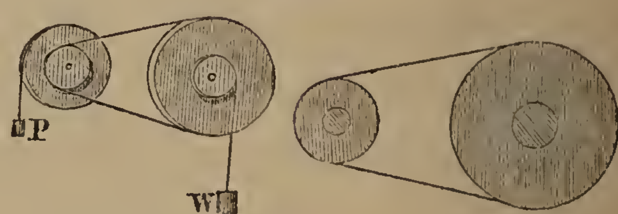
Fig. 51.



The common *windlass.* It is often used for drawing water from wells; the hand grasps the *winch*, B C D, at the handle, D.

257. How may the power and motion of one wheel be transferred to another?

Fig. 52.

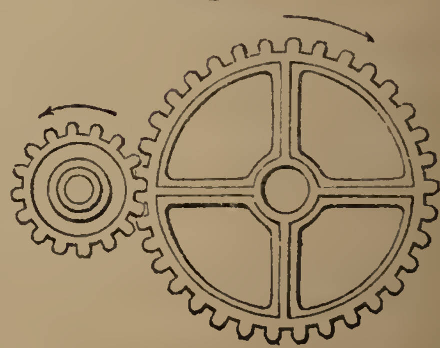


By an *endless band* passing round the two wheels, as shown in Fig. 52.

258. What is the more common method?

By means of projecting pieces, called *cogs* or *teeth*, set on the rims of the two wheels

Fig. 53.



259. Explain Fig. 53.

It represents two *toothed wheels*, of unequal size, engaging in each other.

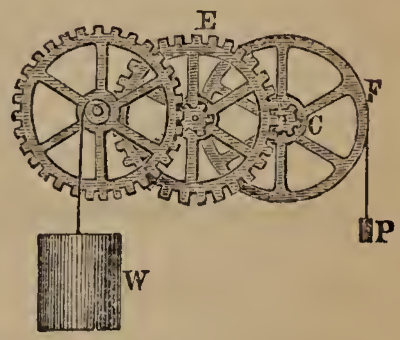
260. Which revolves the fastest?

If the larger wheel has five times as many teeth as the smaller one, the smaller one will make five turns while the other is making one.

261. What is a combination of wheels, such as is seen in Fig. 54, or in a watch, or in mills, called?

Wheelwork.

Fig. 54.



262. What can be obtained by means of wheelwork?

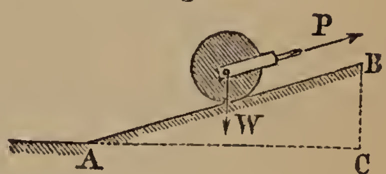
Any desired rate of motion, or any desired gain of power.

THE INCLINED PLANE.

263. What does Fig. 55 show?

A heavy body being raised by the *Inclined Plane*, A B.

Fig. 55.



264. Is any advantage gained by the use of the inclined plane?

The weight of the body is greater than the power necessary to draw it up the inclined plane; and many times greater if the slope is very gradual.

265. Mention a familiar case in which the inclined plane is usefully applied.

It is applied in rolling barrels of flour up a sloping plank into a wagon; also in lowering hogsheads of sugar, or molasses, by means of an inclined plank, into a cellar.

266. Mention other instances of the practical application of the inclined plane.

Inclined planes on rail roads; also the inclined ways down which a new ship is launched.

THE WEDGE.

267. What is a WEDGE?

A triangular block of wood, or iron.

Fig. 56.

268. For what is it used?

To split large blocks of wood, or stone, to separate bodies that are firmly pressed together, etc.

269. What is the power?

It is usually a blow from a beetle, applied to the head of the wedge.

270. Is a blow commonly more effective than a steady pressure?

It is; a moderate blow from a hammer will drive a nail, but a heavy weight placed on the head of the nail would scarcely force it in.

271. Where do the resistances act that are overcome by the blow given to the head of the wedge?

Against the two sides, and by pressure.

272. Mention an instance of a special application of the wedge.

Ships are sometimes raised in docks by driving wedges under their keels.

273. Give another instance.

The wedge is used with great effect in the *Wedge Press*, to extract oil from the seeds of certain vegetables.

274. On what principle do all cutting instruments, as chisels, knives, razors, saws, etc., act?

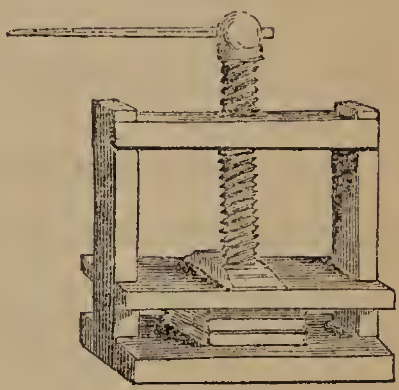
On the principle of the wedge.

THE SCREW.

275. What does Fig. 57 represent?

A *Screw*.

Fig. 57.



276. What is the projecting part that winds spirally around the upright cylinder called?

The *Thread* of the screw.

277. Where is the power applied?

Generally at the end of a long handspike, inserted in one end of the screw.

278. Where does the power take effect against the resistance?

At the other end of the screw.

279. What is the nut?

It is a hollow cylindrical piece within which the screw turns. It is firmly fastened to a frame, and has a spiral groove cut around its interior, into which the thread of the screw fits.

280. When the screw is turned around once, how far does the end advance?

Through a space equal to the distance between two contiguous threads.

281. Does the power at the end of the lever act through a much greater distance than the resistance at the end of the screw?

It does; and this shows that the screw must be a very powerful machine.

282. What else does it show?

That to obtain the greatest gain of power the threads of the screw must be close together, and the lever as long as possible.

283. Mention some of the more important applications of the screw.

The *Screw Press*, represented in Fig. 57. The screw is also used for elevating buildings, and raising ships in docks.

284. What are some of the purposes to which this powerful press is applied?

To express juices from fruits, and oil from seeds of vegetables.

285. For what other purposes is it used

To stamp coins, and to compress paper, cotton, and other soft and bulky materials, into a compact mass for more convenient transportation.

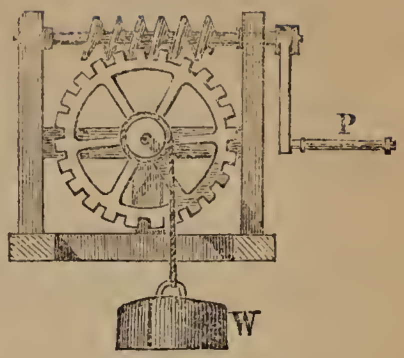
COMBINATIONS OF THE MECHANICAL POWERS.

286. What is the essential construction of the larger and more powerful machines in use?

The different mechanical powers are variously combined in their construction; machines of enormous power are thus obtained.

287. What does Fig. 58 represent?

Fig. 58.



A combination of the screw with the wheel and axle, called the *Endless Screw.*

288. How does it work?

By turning the winch the screw revolves, its threads press against the teeth of the wheel, and cause it to turn and draw up the weight, W.

289. How great a weight could a man raise with the endless screw, properly constructed?

A weight of several tons.

290. What other combinations are in common use?

Very powerful machines for raising heavy weights, as blocks of stone used in building, and large iron castings, are formed by combining the wheel and axle with pulleys.

291. In the working of all such powerful machines, does the weight rise very slowly?

It does; just in proportion to the power gained.

292. Is it possible, in the nature of things, to realize PERPETUAL MOTION; that is, to construct a machine which will run of itself for any length of time, raise weights, and do other work without the aid of any external force?

Perpetual motion is a mechanical impossibility. A machine is merely the means by which some mechanical agent does work, and can not possibly do any more work than the agent does in keeping it in motion.

293. Is there not, in fact, a certain amount of the moving power always wasted in the working of a machine?

There is; the friction and other incidental resistances generally consume a good deal of the working power.

294. In the machinery of mills and factories, is it the object to overcome great resistances?

It is not; but to obtain a variety of movements from the one motion of the point at which the propelling power acts.

THE PENDULUM.

295. What is a pendulum?

It is a heavy body suspended from a fixed point, and swinging to and fro, or *oscillating*, by its own weight.

296. How does the pendulum measure off time?

By its oscillations it divides time into equal parts.

297. Into what equal parts does the ordinary clock pendulum divide time?

Into seconds. It is said to beat seconds.

298. How many seconds are there in a day?

86,400.

299. By what is the wheelwork of a clock kept in motion?

Usually by a weight suspended by a cord that passes over one of the wheels.

300. Suppose the pendulum of a clock were to be removed, what would happen?

The clock would run down very rapidly.

301. What, then, is the office of the pendulum?

It checks the movement of the train of wheels, and causes the wheel with which it is immediately connected to revolve at a certain rate.

302. At what rate does that wheel revolve?

So as to make one complete turn in exactly one minute, or sixty seconds; the seconds hand is carried round by it.

303. What does Fig. 59 show?

Fig. 59.

The manner in which the pendulum is connected with the wheels.

304. What is this connection called?

Escapement.

305. What effect has the shortening of a pendulum upon its rate of motion?

It makes it oscillate faster.

306. What is the length of the seconds pendulum?

$39\frac{1}{10}$ inches, or about $3\frac{1}{4}$ feet.

307. What is the length of the pendulum of a mantel-clock, that beats half seconds?

One quarter of the length of the seconds pendulum.

308. How long must a pendulum be to make one oscillation in a minute?

More than two miles long.

309. What is the moving power of a watch?

A spiral steel spring, called the *main spring*, coiled up within a small drum. The inner end is firmly fastened, and the outer end is attached to the interior of the drum.

310. How does it move the wheels?

It gradually uncoils, carries the little drum around and all the wheels connected with it.

311. How is the drum connected with the first wheel?

By means of a chain that passes from the one to the other.

Fig. 60.

312. What regulates the motion of the wheels of a watch, in place of the pendulum?

An oscillating wheel, called the *balance wheel.* It is shown in Fig. 60.

313. What moves the balance wheel?

A delicate spiral spring, called the *hair spring.*

314. What makes it oscillate to and fro?

When the spring unwinds it winds up again, or passes to the other side of its natural position, and that brings it back.

CHAPTER III.

MECHANICS OF FLUIDS.

TRANSMISSION OF PRESSURE BY LIQUIDS.

315. WHAT is the characteristic property of a fluid?

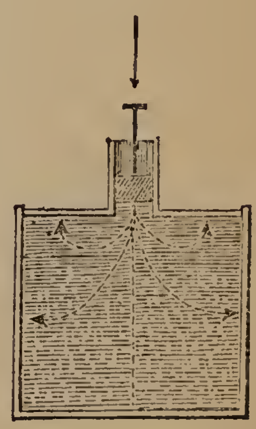
That its particles yield to the slightest force, and move freely among themselves.

316. Water and the air are both fluids, but we call one a liquid and the other a gas—how does a gas differ from a liquid?

Its particles are wider asunder, and instead of being held together by a mutual attraction, repel each other, and are confined by an external pressure.

317. If a force of pressure be applied at an orifice in the cover of a vessel full of water, as shown in Fig. 61, what will be the effect?

Fig. 61.



The pressure will be transmitted through the entire mass of water confined in the vessel, and take effect, without diminution, against the bottom, sides, and top of the vessel.

318. Would the result be the same if the pressure were applied at an opening made in either side or in the bottom of the vessel?

It would.

319. If the hole be of the size of a square inch, and the pressure

ten pounds, what will the pressure be against each square inch of the containing vessel?

Ten pounds.

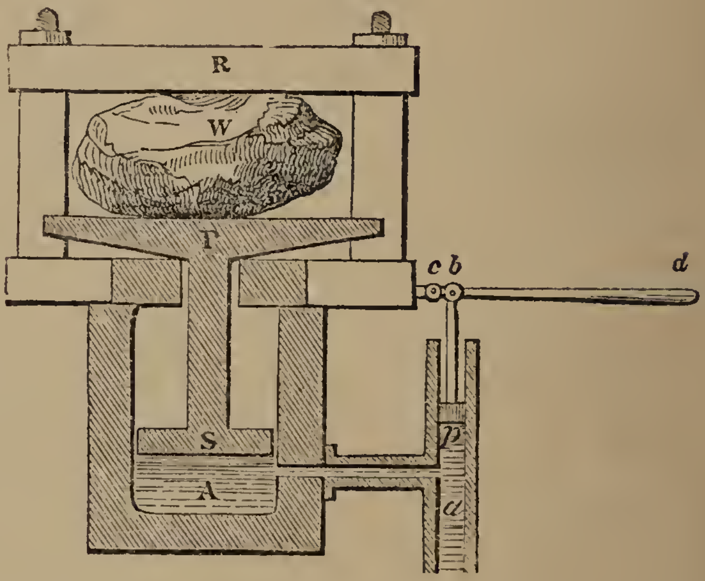
320. What is the important principle just stated called?

The principle of equal pressure.

321. In what powerful machine is this principle applied?

In *the Hydraulic Press*, represented in Fig. 62.

Fig. 62.



322. What is its construction?

It consists of two metallic cylindrical vessels, of very unequal size, communicating with each other by a small pipe; each vessel is provided with a water-tight piston.

323. How does it act?

A pressure is applied to the small piston, by forcing down the lever, *c d*, and this is transmitted and takes effect upward against the large piston.

324. Explain further.

The water that is forced into the large vessel is prevented from coming back by a valve set in the pipe.

325. How is its place supplied?

By more water flowing into the small vessel, from a reservoir near at hand, when its piston is raised again.

326. Suppose the small piston to be of the size of one square inch, and the large one of 1,000 square inches, a pressure of one pound upon the small piston will be attended with how great a pressure against the large piston?

1,000 pounds.

327. Suppose, now, the lever *c d* to increase the power 20 times, and that a man presses on the end of the lever with his whole weight (150 lbs.), how great a pressure would take effect at P?

3,000,000 lbs., or 1,339 tons.

328. To realize this enormous pressure, and raise the large piston one foot, through what space would the end of the lever have to be worked?

$3\frac{3}{4}$ miles.

329. How does the hydraulic press compare with other machines in power?

It is the most powerful of all machines.

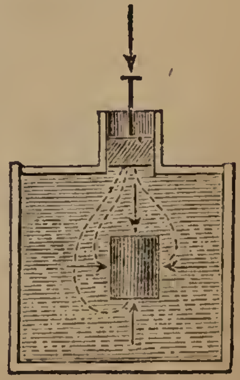
330. What are some of the purposes to which it has been applied?

To press paper, cloth, hay, etc., and to uproot trees.

331. Mention other applications.

To test the strength of ropes, chains, and building materials; also to raise ships in docks.

Fig. 63.



332. Does any pressure that may be applied to a confined mass of water, as shown in Fig. 63, take effect against the surface of any solid that is immersed in the water?

It does.

333. If no pressure were to be applied to water confined in a vessel, by means of a piston fitted to an

opening in the cover, as in Fig. 63, would there not still be a certain pressure in action at the opening?

The pressure of the atmosphere, 15 pounds to the square inch, would be exerted upon the exposed surface of the water.

334. Are fishes, in their liquid element, exposed to the pressure of the atmosphere?

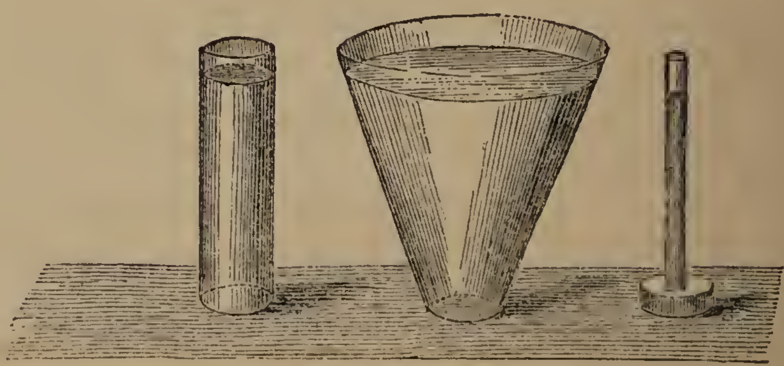
They are; the atmosphere presses on the level surface of every body of water, and its pressure is transmitted through the whole mass of the water.

335. Will a body of air confined in a close vessel transmit any external pressure that may be applied to it, after the same manner that water does?

It will; the only difference is that the air is compressed by an external pressure into a smaller space.

PRESSURE OF HEAVY FLUIDS.

Fig. 64.



336. In Fig. 64 are represented three open vessels, having bottoms of the same size, and filled with water to the same height—will the water press, by its own weight, with more force on the bottom of the large vessel than upon that of the small one?

It will not; the amount of pressure will be the same on the bottom of each of the three vessels, and will be equal to the weight of the column of water in the cylindrical vessel.

337. What is this remarkable principle called?

The *Hydrostatic Paradox.*

338. What is the height at which the water stands above the surface pressed, and upon which alone the pressure per square inch depends, called?

The *Head of Water.*

339. If the depth, or head of water, be increased, how will the pressure be affected?

If the depth becomes twice as great, the pressure will also be twice as great, and so on.

340. Does the pressure increase in the same manner in descending to different depths in the same vessel?

It does. In either of the three vessels in Fig. 64 the pressure on a square inch is only half as great at half the depth as at the bottom.

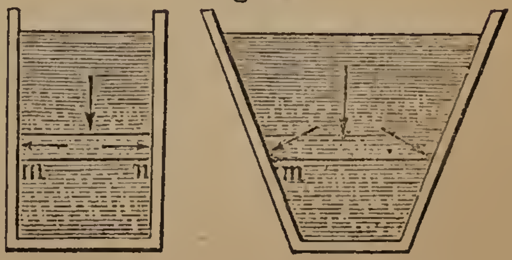
341. In deep reservoirs, lakes, rivers, etc., what is the pressure at the depth of 34 feet?

Very nearly 15 pounds on a square inch, and 2,125 pounds, or a little less than one ton, on a square foot.

342. For every additional 34 feet of depth, how much greater is the pressure?

Fifteen pounds on a square inch.

Fig. 65.

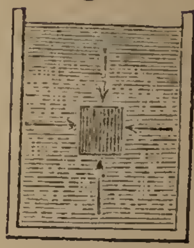


343. Does the downward pressure on any layer, as *m n*, Fig. 65, take effect LATERALLY throughout the layer, and against the sides of the vessel, as shown by the arrows?

It does; it is transmitted in

every direction through the layer, in accordance with the principle of equal pressure.

Fig. 66.



344. Suppose a body were immersed in water at a certain depth, would the pressure of the water take effect against its sides, as indicated by the arrows in Fig. 66?

It would; every square inch would experience a pressure increasing with the depth of immersion.

345. Suppose an empty bottle, tightly closed by a glass stopper, were let down into the sea, what would be the tendency of the pressures against all sides of it?

To crush it in.

346. Have bottles actually thus been crushed in?

The common square bottles have, at the depth of 60 feet or so.

347. When an iron pipe is used to convey water into a city from a large reservoir, what is the head of water upon which the pressure against the whole interior of the pipe depends?

The depth of the pipe below the level of the water in the reservoir.

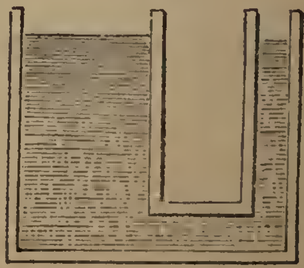
348. What would the pressure be if the head were 100 feet?

$43\frac{1}{3}$ pounds on each square inch.

349. Suppose a small orifice were made in the top of the pipe, how high would the water spout?

Nearly up to the level of the water in the reservoir.

Fig. 67.



350. If two vessels, containing the same liquid, communicate with each other, will the liquid stand at the same height in each?

It will; this is shown in Fig. 67.

351. Give an example of the operation of this principle.

Water is conveyed into cities by large iron pipes, and rises in small pipes in the houses to the level, or nearly so, of the water in the distant reservoir.

BUOYANT ACTION OF LIQUIDS ON IMMERSED SOLIDS.

352. What is the reason that when a stone, or any other body, held in the hand, is entirely immersed in water, it tends downward with less force than before, as if it had lost part of its weight?

The upward pressure of the water on the under part of the stone is greater than the downward pressure on the upper part.

353. The excess of pressure underneath will then tend to support the weight of the body—what is this called?

The *buoyant effort* of the liquid.

354. What is its amount?

It is equal to the weight of the liquid which the body displaces.

355. What will happen, then, if the liquid is denser and heavier than the body?

The body will rise to the surface, and *float* with a certain part above the surface.

356. Illustrate by an example.

A cork, if put under water, will rise and float with three quarters of its bulk out of water.

357. A cannon ball, which sinks so readily in water, will float on quicksilver—what is the explanation of this curious fact?

Quicksilver is more than 13 times heavier than water, and is heavier than iron.

358. Would a cannon ball have any less tendency to sink at the depth of a mile in the ocean than just below the surface?

It would not, unless the water is denser at that great depth. In point of fact its density is only about $\frac{1}{100}$th greater at that depth.

359. What weight will a floating body, as an empty cask, or a boat, bear up without sinking?

The excess of the weight of water that it can displace above its own weight.

360. Suppose a ship is loaded with a cargo weighing 800 tons, how much more water does she displace than when unloaded?

An amount weighing 800 tons. When unloaded, the quantity of water displaced will be equal in weight to the entire weight of the ship.

361. What is the explanation of the fact that iron boats are constructed which draw less water than similar boats built of wood?

The entire weight of the iron boat is less than that of the boat constructed of wood.

362. If an iceberg, of a regular form, is seen at sea floating with 50 feet out of water, what is its depth below the surface of the sea?

270 feet.

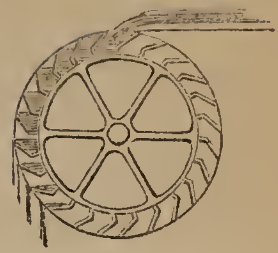
WATER WHEELS.

363. By what is the machinery of mills and factories often driven?

By water wheels; the most common forms are represented in Figs. 68, 69, and 70.

364. What is the wheel represented in Fig. 68 called?

Fig. 68.

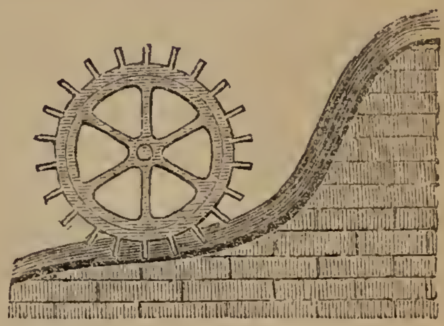


An *Overshot Wheel.* The water shoots over the top into the buckets that are set on the rim.

365. What is it that moves the wheel?

The weight of the water in the buckets. The buckets are full on one side of the wheel and empty on the other.

Fig. 69.

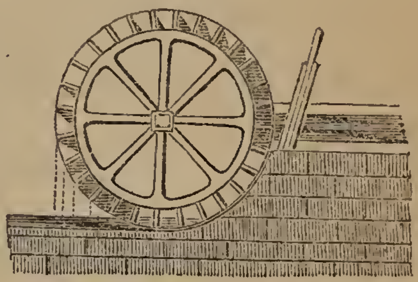


366. What is the wheel shown in Fig. 69 called?

An *Undershot Wheel.* The water shoots under the wheel, and strikes against the floats at the bottom.

367. Explain Fig. 70.

Fig. 70.



It represents a wheel intermediate between the other two, called the *Breast Wheel.*

368. Where does the water come on to the wheel?

Somewhere between the top and bottom, frequently about midway.

369. Which is the most efficient of these three wheels?

The overshot wheel.

370. Are there any other forms of water wheel in use?

There are also wheels that whirl around horizontally, called *Turbines.*

371. What may be said of these?

That they are the most efficient form of water wheels, and have lately come into extensive use.

PRESSURE OF THE AIR.

372. The body of air confined within a vessel, or room, presses outward against the walls of its inclosure—what is this outward pressure called?

The *Elastic Force*, or *Pressure of the Air.*

373. What have you to say of the condition of any limited portion of the external air?

It presses outward in the same manner.

374. What sustains and counteracts this outward pressure?

The equal inward pressure of the surrounding air.

Fig. 71.

375. If we apply the mouth to the upper end of a small glass tube, which has the lower end under water, and withdraw the air from it by suction, what will take place?

The water will rise in the tube and enter the mouth.

376. What causes it to rise after the air has been removed from the tube?

The pressure of the air upon the surface of the water outside of the tube.

377. What do the arrow, in the figure, and the dotted line leading from it, show?

The pressure of the air on the surface of the water, at a certain point, and how it is transmitted and forces the water up the tube.

378. It is often said, in such cases, that we draw the water up by suction—what do we really do?

We simply remove the air from the tube, and then the pressure of the outer air crowds the water into the empty space, or *vacuum*, formed within the tube.

379. Why does not the same pressure force the water up the tube before the air is withdrawn?

Because the elastic pressure of the air within the tube is equal to this transmitted pressure, and neutralizes it.

380. If I were to take a glass tube, 33 inches long, fill it with quicksilver, and close the open end with the finger, then invert the tube, dip the lower end in a vessel of quicksilver, and remove the finger, what would be the result?

Fig. 72.

The quicksilver would fall in the tube, until it stood about 30 inches above the level in the vessel.

381. What supports the column of quicksilver 30 inches high?

The pressure of the air on the surface of the quicksilver outside of the tube.

382. If the open end of the tube were of the size of a square inch, what would be the weight of the column of quicksilver supported by the atmospheric pressure?

Nearly 15 pounds.

383. What, then, is the pressure of the air in pounds on every square inch?

About 15 pounds; and 2,125 pounds, or nearly a ton on every square foot.

384. What is a BAROMETER?

It is simply the contrivance represented in Fig. 72, provided with a scale for reading off the height of the mercury in the tube.

385. What does it make known?

The amount of the pressure of the air at any time.

386. Does this pressure vary?

Somewhat from day to day, with variations of temperature, and changes in the weather.

387. If a barometer be taken to the top of a mountain, or carried up in a balloon, does the mercury continue to stand at the same height in the tube?

It does not; it falls more and more the higher the barometer is carried.

388. What does this show?

That the pressure of the atmosphere gradually decreases from the earth's surface upward.

389. What may we infer from this fact?

That the pressure of the air at any point is the weight of the entire column of air that rests on that point.

390. Can the height of a mountain be determined by observing how much the mercury in the barometer falls, when the barometer is carried from the bottom to the top of the mountain?

It can; near the level of the sea an ascent of 93 feet is attended with a fall of $\frac{1}{10}$th of an inch in the height of the barometer.

391. How high will the atmospheric pressure cause water to rise in a very long tube from which the air has been removed?

Thirty-four feet.

392. How may the pressure of the air on solids be readily shown experimentally?

By taking a tube, open at one end, into which a solid piston has been fitted air tight.

Fig. 73.

393. If a small orifice be made at the bottom of the tube, and the piston be pressed down to the bottom—on closing this orifice and undertaking to raise the piston, what will be observed?

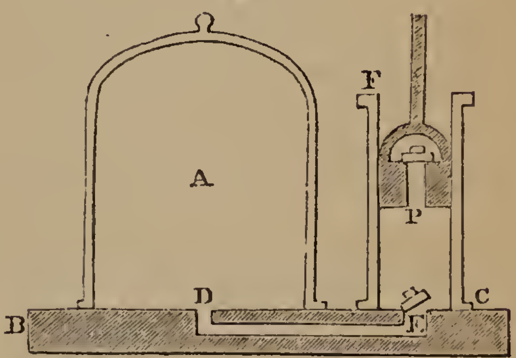
The piston will be held down with considerable force; as it rises, a vacuum will be formed below it, and so the pressure of the air on its upper side has to be overcome.

AIR PUMP.

394. What is an AIR PUMP?

It is a contrivance by means of which the air confined within a vessel can be removed from it, and a vacuum obtained.

Fig. 74.



395. Its essential parts are represented in Fig. 74—what are they?

An upright cylinder, C, into which a piston, P, is fitted air tight.

396. Is this piston solid?

It has an opening at its centre, covered by a *valve* that opens upward. There is another valve opening upward, fitted to an orifice at E, in the bottom of the pump.

397. Where does this orifice in the bottom of the pump lead?

It leads, by means of a small pipe, to the vessel A, from which the air is to be removed. This vessel is called the *Receiver*.

398. Suppose the piston is pressed down to the bottom of the pump, what happens when it is drawn up?

The pressure of the air in the pipe opens the lower valve, and air flows through the opening from the receiver, and fills the empty space which the piston leaves behind it.

399. What happens when the piston is forced down again?

All the air that is below it passes through the open valve in the piston, and mixes with the external air.

400. When the piston is raised again, what takes place?

More air flows out of the receiver; and, in this way, by repeatedly raising and depressing the piston, the air may be nearly all withdrawn from the receiver.

401. Whenever the piston is raised, the pressure of the air upon it has to be overcome—how is the power requisite for this obtained?

In some pumps by means of a long lever; but the more common expedient is to combine two pumps in such a manner that the pressures on the two pistons will balance each other.

402. What is Fig. 76 designed to represent?

A celebrated experiment performed by Otto Von Guerike, the inventor of the air pump.

Fig. 75.

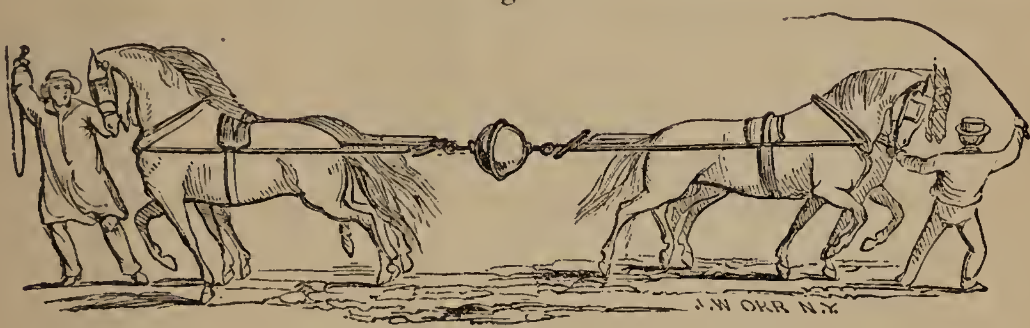
403. Describe it briefly.

Two hollow hemispheres of copper were nicely fitted to each other, and the space within them exhausted of air, through a cock by means of an air pump. These hemispheres are represented in Fig. 75.

404. What was then done?

It was then found that the hemispheres were held together so firmly by the pressure of the external air that several horses could not exert sufficient force to separate them.

Fig. 76.



PUMPS FOR RAISING WATER.

405. What does Fig. 77 represent?

The common *sucking pump*.

406. Describe it.

It consists of two tubes of unequal size, one on top of the other, and an air tight piston, P, that can be moved up and down in the upper tube, by applying a power to the piston rod. There are also two valves opening upward, one at E, and the other in the piston.

407. What is the use of the valves?

They allow the air or water to pass up through the opening over which they are placed, but prevent it from going down again.

408. When the piston is worked up and down, what is the effect?

The air is first pumped out; as it is removed, the water rises in the lower pipe, then into the body of the pump, and finally gets above the piston and is delivered at the spout.

Fig. 77.

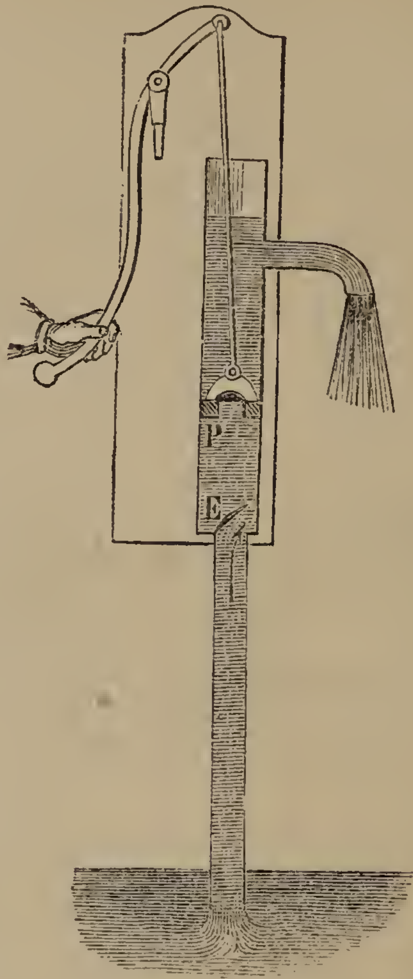
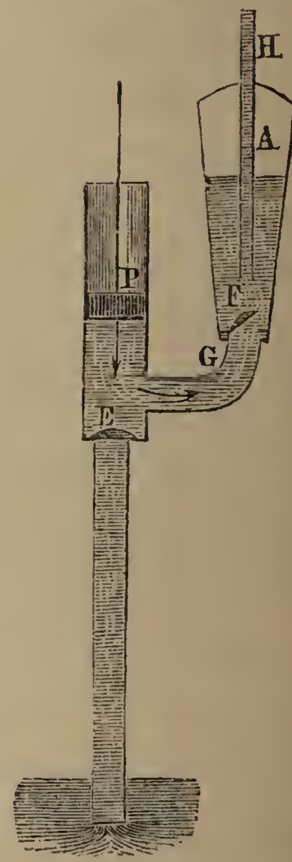


Fig. 78.



409. What causes the water to rise in the pump in proportion as the air in it is removed?

The pressure of the air outside of the pump, on the surface of the water in the well.

410. Explain Fig. 78.

It represents another form of pump called the *Forcing Pump*. The piston is solid, and the upper valve is at F.

411. How does it operate?

The air is pumped out, and the water rises to the piston, just as in the sucking pump.

412. What takes place after that?

Whenever the piston is forced down, the water below it is driven up the pipe G, and through the valve F.

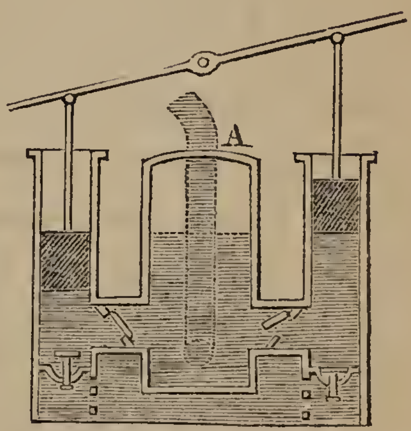
413. The water is represented as passing from this pipe into a closed vessel, A—what is this vessel called?

An *air vessel.*

414. For what purpose is it used?

The water that is forced into it crowds the air in it to the upper part, and this condensed air pressing on the surface of the water impels it up the ascending pipe, H, in a constant stream.

Fig. 79.



415. What kind of pump is used in the FIRE ENGINE?

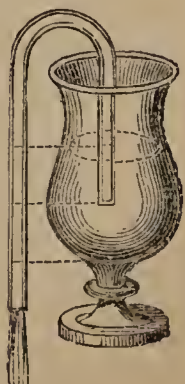
The forcing pump; the long handles which the firemen move up and down work two force pumps.

416. Into what do these two pumps force the water?

Into an air tight box, A. From this it is driven out through the pipe and hose in a constant stream.

THE SIPHON.

Fig. 80.



417. What is a SIPHON?

It is a bent tube, having its two branches of unequal length.

418. To what general purpose is it applied?

To draw water and other liquids from vessels.

419. How does it operate?

The shorter leg is plunged into the vessel of water, the mouth is then applied to the lower end, and the siphon filled with water by suction.

420. Will the water continue to run after the mouth is taken away?

It will.

421. The pressure of the air on the water in the vessel should fill the siphon with water as soon as the air is sucked out of it—but why should the water afterward flow steadily out at the lower end?

Because there is a pressure in all parts of the tube to keep it flowing in that direction.

422. Show that this is the case at the top of the siphon.

The pressure of the air acts upward at both ends of the siphon; and the pressure at each end is loaded with the weight of water in that leg.

423. What follows from that?

The pressure at the end of the short leg has the smallest load upon it, therefore the pressure transmitted from that end to the top of the siphon will be the greatest.

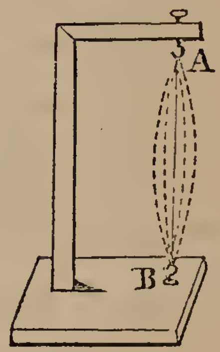
CHAPTER IV.

SOUND.

NATURE AND PRODUCTION OF SOUND.

424. WHAT kind of motion has a stretched cord when it is drawn to one side, and suddenly let go?

Fig. 81.



It vibrates to and fro, like a pendulum. This is represented in Fig. 81. The dotted lines show the extent of the vibrations.

425. How may the tension of the cord be increased?

By screwing up the upper hook.

426. What happens during each vibration of the cord?

The cord acts against the air with a certain force.

427. When the cord is tightly stretched and forced to one side, it vibrates with great rapidity—what is the result of this rapid vibration?

Sound is produced.

428. How is sound produced by a vibrating cord, or any other vibrating body?

The vibrations of the sounding body are communicated to the surrounding air; and spreading in all directions through the air, reach the ear.

429. What is the impression they make on the nerves within the ear called?

The *Sensation of Sound.*

430. What does the vibratory or trembling motion imparted to the air, and spreading out in all directions from the body, form?

A spherical *Wave of Sound.*

431. Do the particles rise and fall in a wave of sound, as in a wave of water?

They do not; they move forward and backward through a very short distance—that is, directly from and toward the sounding body.

432. Does a sounding body send out a regular succession of waves, corresponding to the successive vibrations?

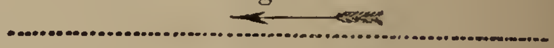
It does.

433. What does each wave convey to the ear?

The slight impulse with which the body acts against the air, and originates the wave.

434. If we consider only the trembling movement that is conveyed, or PROPAGATED, by a single line of particles reaching from the body to the ear—what have we?

Fig. 82.

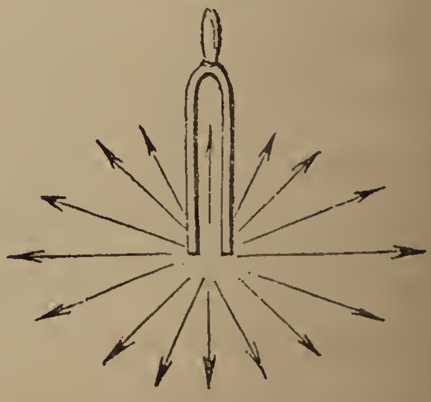


What is sometimes called a *Ray of Sound.*

435. Does a sounding body, for example, the tuning fork represented in Fig. 83, send out rays of sound in all directions?

It does; and they all proceed with the same velocity.

Fig. 83.



436. Do sounds differ in their character, or QUALITY?

They do. We distinguish between the crack of a whip, the report of a pistol, and the blow of a hammer; the sounds produced by the filing of a saw are harsh and grating to the ear, while the notes from a flute are soft and pleasing.

437. How is it that the ear thus distinguishes between sounds?

The vibrations of sounding bodies are all faithfully repeated in the ear, and all their peculiarities are impressed on the delicate nerves of the ear.

438. Mention a fact or two in illustration of the great delicacy of the human ear.

A practiced ear can distinguish between two sounds, the one having 80 vibrations in a second, and the other 81. It can also distinguish the different instruments of a band, when playing together the same note.

439. When a harp string is struck, or an empty glass tumbler tapped with the finger nail, why do we hear a MUSICAL SOUND?

Because the vibrations of the string, or glass, are repeated with perfect regularity.

440. When the impulses on the ear succeed each other at exactly equal intervals, the sound is then a pleasing one—does the ear take notice of the rapidity of the vibrations?

It does, with the greatest nicety. If one musical string vibrates more rapidly than another, it produces a sound of a higher *Pitch*.

441. If one string of a violin vibrates twice as fast as another, what is said of the two sounds produced?

That one is an *Octave* higher in pitch than the other.

442. What is the range of sensibility of the human ear to musical sounds?

The lowest, or most grave, musical note of which the ear is sensible, is produced by 8 vibrations in a second;

and the highest, or most acute, note, by 24,000 vibrations in a second.

443. Compare the highest and lowest notes of an ordinary piano forte.

The lowest is produced by 27½ vibrations in a second, and the highest by 3,520.

444. If a glass tumbler be made to ring with a musical sound, by tapping it with the finger nail, what is the reason that the sound ceases if the finger be placed on the rim?

The pressure of the finger stops the vibrations.

445. If water be poured into the tumbler, and it then be tapped, why does it give a note of a lower pitch?

Because it vibrates less rapidly than before. The pitch of a musical sound depends on the rapidity of vibration.

446. What does the loudness of a sound depend upon?

The force with which the sounding body acts against the air, and so upon the ear also, in each vibration.

447. Illustrate by an example.

If a violin player wishes to produce a loud note he draws his bow violently across the string; the string is thus made to vibrate through a greater distance, and act upon the air with more force.

448. Give another illustration.

A large bell gives out a louder sound than a small one; for two reasons—because the extent of the vibrations is greater, and the mass in vibration is larger.

PROPAGATION OF SOUND IN THE AIR.

449. Mention some facts which go to show that sound is not conveyed, instantaneously, from the sounding body to the ear.

We do not hear the blows of a hammer, at a distance, at the same instant that we see them struck. The report of a gun is always heard later than the flash is seen. A flash of lightning from a distant thunder cloud is seen several seconds before the thunder clap arrives.

450. What is the velocity of sound through the air?

1124 feet per second.

451. Why does the loudness of a sound diminish as it is propagated through the air, from the sounding body?

Because the original impulse communicated to the air is spread over a greater space.

452. Does the intensity of sound also vary with the state of the weather?

It does. Sounds are louder when they come with the wind, and in a cold than in a warm day; also in a humid than a dry state of the air, but they are obstructed by falling rain or snow.

453. Mention one or two striking facts in illustration of the great distance at which sounds may be heard over water and ice.

It is related in the account of the Third Polar Expedition of Captain Parry that a conversation was once held across the harbor of Port Bowen, a mile and a quarter wide. What is still more remarkable, the human voice has been heard across the Straits of Gibraltar, a distance of ten miles.

454. What is the greatest distance at which any sound has been heard?

The cannonade of a sea-fight between the English and Dutch, in 1672, was heard across England in Wales, a distance of over 200 miles. The explosions of volcanoes among the Andes, in South America, are said to have been heard at a much greater distance than this.

455. How can we ascertain the distance of an approaching thunder cloud?

By noting the number of seconds in the interval between a flash of lightning and the thunder clap that follows it, and allowing 1,124 feet for every second.

456. Hotels and large dwelling houses are frequently provided with SPEAKING TUBES, leading from one story to another. What is the reason that the lowest whisper at one end of the tube is distinctly heard at the other end?

The sound is confined to the tube, and does not spread and become weakened, as in the open air.

457. How far has a low whisper been heard through a pipe?

More than half a mile; through a continuous line of empty water pipes laid in the streets of Paris.

458. Why can we hear more distinctly along the outside wall of a house than at a distance from it?

Because the sound is prevented from spreading on the side on which the wall is.

459. Why do we hear better at night than in the day time?

Because the air is generally stiller and of more uniform density, and in the quiet of the night our ears are more sensitive to the impressions of sound.

ECHOS.

460. What happens when a sound strikes against an obstacle, as the side of a house, or the wall of a room, or a rocky cliff?

It rebounds, or glances off, like an elastic ball, and is heard at a certain distance, in the direction in which it proceeds, as an *Echo.*

461. Illustrate by an example.

A person looking into a very deep well hears every word that he speaks repeated to him from the water at the bottom of the well.

462. Mention another illustration.

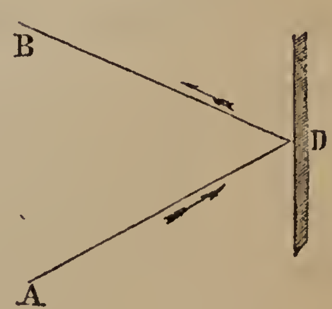
If I should stand at some distance from the wall of a house and clap my hands, I would hear the same sound again as an echo from the house.

463. How far must you be from the wall in a perpendicular direction to hear a distinct echo?

More than 62 feet.

464. If you were to stand at A, Fig. 84, and clap your hands, another person standing at B may hear an echo—how is the sound reflected to him?

Fig. 84.



As the figure shows; it strikes obliquely against the wall, and glances off with the same obliquity.

465. Does it ever happen that a loud sound is followed by more than one echo?

In particular localities echos are returned in succession from a number of surrounding objects. For example, at West Point, on the Hudson, the report of the morning and of the evening gun is prolonged by repeated echos from the surrounding highlands.

466. Mention another example.

There is a locality near the foot of Mount Washington, on the west side, where to the blast of a single horn a full band seems to reply from the adjacent heights.

467. Give another example.

On the Wengern Alp, in Switzerland, the prolonged note of the Alpine horn is caught up by the mountain heights and dies away into the softest melody in the upper sky.

468. What may be said of spacious rooms with vaulted ceilings, or surmounted by lofty domes?

They return every sound in a multiplicity of echos.

469. Illustrate by an example.

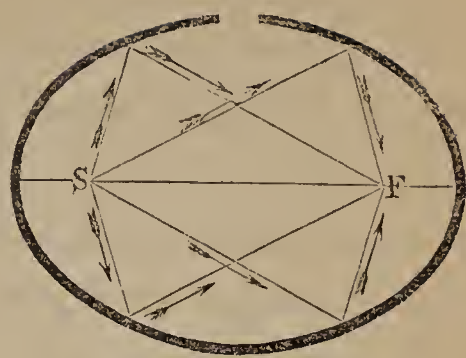
In the Rotunda of the Capitol at Washington, the hearing of conversation is much confused by the innumerable echos of every sound, received from the walls and the dome overhead.

470. What curious fact is observed in such spacious inclosures with curved walls or ceilings?

The sound produced at one point is often concentrated at another distant point, so that the faintest whisper can be heard from one to the other, although inaudible between the two. Such a room is called a *Whispering Gallery*.

471. Illustrate by Fig. 85, which represents a room of an oval shape.

Fig. 85.



All the rays of sound proceeding from a certain point, S, after striking against the curved wall are collected into a focus at F.

472. Give an example of a WHISPERING GALLERY.

At the base of the dome in St. Paul's Church, London, the feeblest sound is conveyed from one side to the other of the dome, a distance of more than 130 feet, but is not heard at any intermediate point.

473. When we speak in a room, why do we not always hear distinct echos from the walls and ceiling?

Because, unless the room is large, the interval of time between the sound of the voice and the return of the echo is too short; the two are heard as one sound.

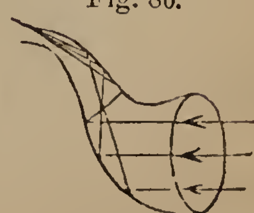
474. Why do we hear so much better in a room than in the open air?

Because the sound is strengthened by the reverberation from the walls, ceiling, and floor.

475. What is the effect of curtains, carpets, and furniture in a public room?

They make it less easy to speak in, by deadening the echo and dispersing the sound. We may see this, by observing how much louder the voice sounds in an empty than in a furnished room.

Fig. 86.



476. How are deaf people enabled to hear?

By putting an *Ear Trumpet* to their ear.

477. How does this act to strengthen the sound?

It concentrates at the ear all the rays of sound that enter the large open mouth of the trumpet.

478. When a fireman wishes to throw his voice to a distance, what instrument does he use?

A *Speaking Trumpet.*

479. How does a speaking trumpet act to strengthen the sound?

Fig. 87.

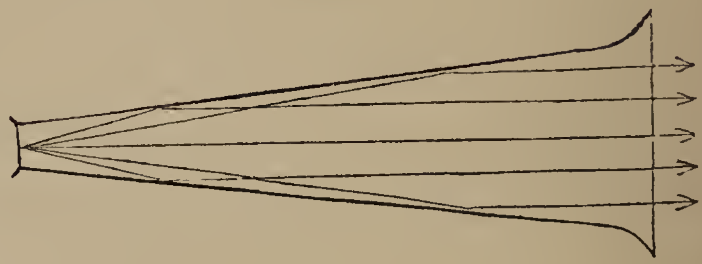


Fig. 87 shows that the rays of sound are reflected from the interior of the trumpet, and all proceed on in the same direction.

480. How far may a strong man's voice, sent through a trumpet 24 feet in length, be heard?

At a distance of three miles.

PROPAGATION OF SOUND IN LIQUIDS AND SOLIDS.

481. Is sound conveyed through liquids and solids, as well as through the air?

It is, and with greater velocity.

482. What is the velocity of sound in water?

4,708 feet per second, or about $4\frac{1}{4}$ times the velocity of sound in the air.

483. Can sounds be heard farther under water than in the air?

They can. Franklin, plunging his head under water, heard distinctly the blows of two stones struck together at the distance of half a mile.

484. How far has the sound of a bell, struck under water, been heard?

A distance of nine miles.

485. What is the velocity with which sound is transmitted by cast iron?

11,090 feet, or a little over two miles per second.

486. What is its velocity of propagation through solid substances in general?

From 7 to 17 times greater than through the air.

487. What general truth may be stated with regard to the conduction of sound by solids?

Sounds are conducted with greater distinctness by solids than by the air, or even by liquids.

488. Mention one or two facts that strikingly illustrate the facility with which sounds are conveyed by solids.

The scratching of a pin at one end of a long beam can be distinctly heard, if the ear be applied at the other end. The ticking of a watch can be heard as well by placing it between the teeth as by putting it at the ear.

489. Is the ground a good conductor of sound?

It is; by putting the ear to the ground we may ascertain the fact of the approach of a horse, wagon, or train of cars, before the sound reaches us through the air.

490. Do sounds pass from the air into a solid, the wall of a building, for instance, and then into the air again on the other side?

They do; but in doing so they experience a great diminution of intensity. We can hear in a perfectly tight room sounds from without, but they are much weakened.

MUSICAL INSTRUMENTS.

491. What are STRINGED INSTRUMENTS?

Musical instruments, in which the sounds result from the vibrations of stretched cords or wires. For example, the violin, guitar, piano, and Æolian harp are all stringed instruments.

492. What are the stretched cords employed in these instruments called?

Musical Strings. They are of different lengths and sizes, as in the piano; or of the same length but of different sizes, as in the violin.

493. Which strings give the notes of highest pitch?

The shorter and smaller strings; because they vibrate most rapidly. Every note has its particular length or size of string, and particular number of vibrations.

494. Has the force by which a musical string is stretched any thing to do with the pitch of the note that it gives?

If the tension of the string be increased, it will vibrate more rapidly, and give out a note of higher pitch.

495. What are WIND INSTRUMENTS?

Musical instruments in which the notes are produced by the vibrations of columns of air within the instrument; for example, the flute, the trumpet, and the organ.

496. From what do the deep base notes of the organ proceed?

From the long and large pipes; and the high notes from the short pipes.

THE VOICE.

497. How are the sounds of the voice produced?

The organs of voice form a wind instrument; the air contained in the mouth, throat, and upper part of the windpipe is set in vibration.

498. By what?

By a stream of air forced from the lungs through a narrow opening in the upper part of the windpipe.

499. How is this narrow orifice formed?

By the partial closing of a kind of membranous valve in the windpipe.

THE EAR.

500. What is the process of hearing?

The vibrations conveyed from the sounding body are collected by the outer visible ear, pass through the contracted opening into the ear-tube, and strike, at the bottom of the tube, on a stretched membrane, called the *Drum*, or *Tympanum*, of the ear.

501. Explain farther.

The vibrations imparted to the drum are propagated through another tube to a second membrane, and from this directly to the fluid of the internal ear, and to the delicate fibres of the nerves of hearing, spread out in the fluid. The nerves convey the impressions to the mind.

CHAPTER V.

LIGHT.

NATURE AND TRANSMISSION OF LIGHT.

502. WHAT is a LUMINOUS BODY?

A body that gives off light; the sun, for example, is said to be luminous.

503. How do we see a luminous body?

The light thrown off from it passes into our eyes and produces the sensation of sight.

504. What did the great English philosopher, Sir Isaac Newton, suppose light to be, in its essential nature?

He conceived that light consists of exceedingly minute particles given off from the sun and other luminous bodies. He supposed that the minute particles of light passing into the eye produce the sensation of sight, as the particles of fragrant matter passing from flowers to the nose, produce the sensation of smell.

505. What is the view now entertained by philosophers of the nature of light?

That it is analogous to sound; that there is a subtile ether filling all space, which is the medium of light, as air is the medium of sound.

506. Of what is light conceived to consist?

Of vibrations of this elastic ether, excited by the luminous body, and propagated in all directions through the ether; as sound consists of vibrations of the air, excited by the sounding body, and propagated through the air.

507. According to this view, how is the sensation of sight produced?

Luminous bodies send off waves of light, as sounding bodies send off waves of sound. These waves, striking upon the nerves of our eyes, produce the sensation of sight.

508. By what names are these two views concerning the nature of light distinguished?

The latter is called the *Wave Theory of Light*, the other, the *Newtonian Theory.*

509. Does light proceed in straight lines?

It does. We can not see through a small bent tube, such as is represented in Fig. 88.

Fig. 88.

510. Do all bodies give off light at all times?

They do not; some bodies, like the sun, are, in their nature, *self-luminous*, and others, like a house or a tree, are *non-luminous.*

511. How do non-luminous bodies become temporarily luminous?

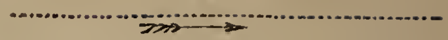
By receiving light from the sun, or some other self-luminous body. For example, a candle brought into a dark room renders the walls and furniture temporarily luminous, and therefore visible.

512. What is a ray of light?

It is a single line of light proceeding from a luminous point.

513. What does Fig. 89 represent?

Fig. 89.



The line of minute particles in a ray of light.

514. Do the particles in a ray of light move swiftly through space?

It was so supposed by Newton, but it is now known that they are stationary particles of ether, along which vibrations or trembling movements are conveyed in rapid succession.

515. Do rays of light proceed from every point of the sun, or other luminous object?

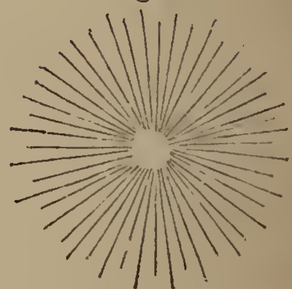
They do; and in every direction.

516. How is this truth generally expressed?

It is said that light *radiates* in every direction from every point of a luminous body.

517. Fig. 90 shows that individual rays of light emitted from a luminous point separate more widely the farther they proceed—how is this fact usually stated?

Fig. 90.



Such rays are said to *diverge*, and they are called *Diverging Rays*.

518. What consequence follows from the divergence of light?

That light decreases in intensity as it recedes from its source.

519. Illustrate by an example.

We receive less light from a candle the farther we are from it; because the same amount of light is spread over a greater space.

520. What does Fig. 91 represent?

Fig. 91.

A small pencil of diverging rays proceeding from a point in the flame of a candle to the eye. Every point in the flame sends to the eye such a pencil of rays.

521. What is the velocity of light?

191,000 miles per second.

522. At that rate, in how short a time would light pass entirely around the earth?

In one eighth of a second.

523. What is a TRANSPARENT substance or MEDIUM?

One through which light passes freely; glass, for example, is transparent.

524. What is an OPAQUE substance?

One that does not admit light to pass through it; a stone, for example, is opaque.

525. If a book is held before a candle in the evening, it intercepts the light that falls upon it, and its shadow is thrown upon the wall—why is the shadow on the wall larger than the book?

Because the rays of light that pass by its edges diverge from each other.

526. How far does the shadow cast by the book extend?

From the book to the wall, where it is intercepted.

527. What is the form of the shadow cast by a round body, the moon, for example, illuminated by the sun?

Fig. 92.

It tapers to a point, as shown in Fig. 92.

528. What becomes of the light that falls on an opaque substance?

A part is reflected back, the rest enters the substance, and is stopped, or *absorbed* by it.

ABSORPTION OF LIGHT.

529. Do glass, water, and other transparent media absorb any portion of the light that enters them?

Every transparent medium absorbs more or less light, according to its thickness.

530. How far does the light of the sun penetrate into the depths of the sea?

About 700 feet. At the bottom of the deep ocean there is utter darkness.

531. Does the atmosphere extinguish any portion of the light that comes from the sun and stars?

It does; even in its purest state it absorbs a large quantity of light, especially toward the horizon.

532. How do we know that the atmosphere has this effect?

It causes the stars to shine more dimly toward the horizon, and strips the sun of so much of his brightness at sunset that our eyes can bear the full light of his disc.

533. How much farther is it through the atmosphere in the direction of the horizon than perpendicularly upward?

It is 13 times farther.

534. What appearance have the stars seen through the thin air above the top of a lofty mountain?

They shine with a much brighter lustre than when viewed through the whole depth of the atmosphere.

REFLECTION OF LIGHT.

535. How are surrounding objects made visible to us by day?

Light falls upon them from the sun and sky, and is reflected to our eyes.

536. Is this light reflected in any particular direction?

It is reflected in all directions; it radiates from every point of the surface, as if that point were shining with its own light.

537. Suppose a ray of light falls upon the polished surface of a mirror, in what direction is it reflected?

Fig. 93.

Fig. 93 shows that it glances off, just as an India rubber ball does when thrown against a wall.

538. If the light falls perpendicularly on the surface of the mirror, in what direction does it leave it?

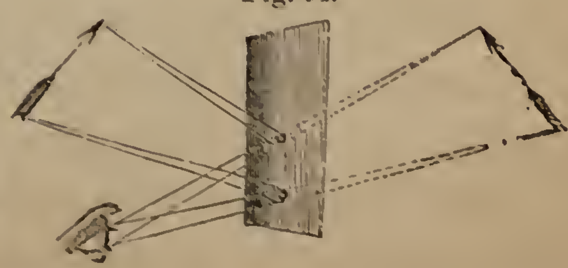
It returns in the same line, as a ball bounds back when thrown directly against a wall.

539. How is it that in looking into a common mirror or looking-glass, we see the images of objects that are in front of the mirror?

An object always appears to be in the direction in which the rays from it enter the eye, and the rays from the object which, after reflection, enter the eye, come from the mirror.

540. What does Fig. 94 show?

Fig. 94.



How rays radiating from any point of a luminous object, as an arrow, may fall upon a mirror, be reflected off to the eye, and enter it as if they came from a point behind the mirror.

541. What is seen, then, behind the mirror?

An image of the arrow; that is, what appears to be the arrow, but is not.

542. Where does the reflection take place in the case of the common looking-glass?

Chiefly at the smooth surface of the quicksilver that is spread over the back part of the glass.

543. Does not the front surface of the glass reflect light also?

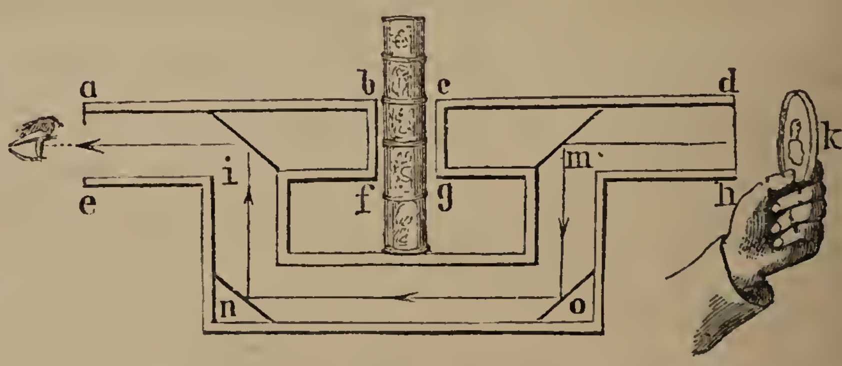
It does; in the evening the windows in our houses become so many mirrors, in which the objects within the room are reflected.

544. Why is this reflection not perceptible by day?

Because the impression of the reflected light on the eye is effaced by that of the strong light that comes from without.

545. What does Fig. 95 represent?

Fig. 95.



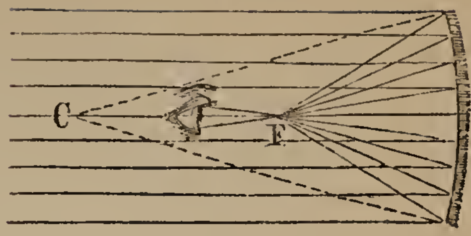
An amusing toy, called the *Magic Perspective.* A coin or any thing else held at *k*, can be seen by the eye at the other end, though a book be held between them at *b*.

546. How can that be?

The light from the coin follows the course shown by the arrows. It is reflected from mirrors at *m*, *o*, *n*, and *i*.

547. What does Fig. 96 represent?

Fig. 96.



The reflection from a *Concave Mirror*, of a beam of rays, supposed to come from a point of the sun's disc.

548. What is the course of the reflected rays?

They all converge to the focus, F.

549. What is such a collection of rays converging to a focus called?

A pencil of *Converging Rays.*

550. Suppose a white screen, of paper or cloth, were placed there to receive them, what would be seen at F?

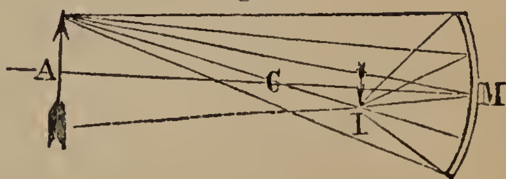
A bright point. This point can be seen also without a screen, by placing the eye in the position shown in the figure.

551. Suppose light were to fall on the concave mirror from all points of the sun's disc, what would be seen at F?

A small bright circle, which would be an image of the sun.

552. Explain Fig. 97.

Fig. 97.



The concave mirror, M, forms in the air, at I, an inverted image of the arrow, A. The course of the rays proceeding from a single point of the arrow, before and after reflection, is shown in the figure.

553. If the object were at I, near the mirror, where would its image be?

At A, and it would be larger than the object.

554. Is the image of an object that is in front of a concave mirror ever seen behind the mirror, as in a common looking-glass?

It has that position when the object is quite near the mirror, and it appears to be much larger than the object.

555. Of what material are concave mirrors usually made?

Of a metallic alloy of tin and copper, called *Speculum Metal*, that admits of a high polish, and does not tarnish readily. They are sometimes made of copper, steel, or silver; or of glass quicksilvered on the back.

556. When formed of speculum metal, what are they ordinarily called?

Specula.

557. Concave reflectors are used with great effect in light-houses—in what manner are they set up?

A number of mirrors are fastened on the outside of an iron circular rim, and a lamp is placed in the focus of each mirror.

Fig. 98.

558. Fig. 98 represents one of the mirrors thus arranged—for what purpose is it employed?

To throw the light of the lamp far out to sea. It does this by reflecting all the rays that fall upon it in nearly the same direction.

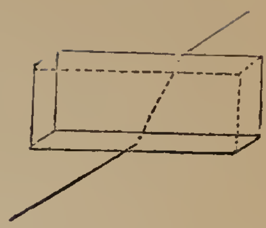
REFRACTION OF LIGHT.

559. What occurs when a ray of light passes from the air into a denser medium, as air or water?

It is bent, or *refracted*, so as to pursue a direction more nearly perpendicular to the surface.

560. Where is this effect represented to the eye?

Fig. 99.



In Fig. 99, where a ray of light is represented as entering and passing through a thick piece of glass.

561. Is it refracted again in passing out of the glass into the air?

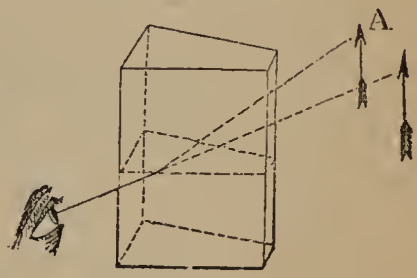
It is, but in the opposite direction, as the figure shows.

562. Does it recover its original direction on leaving the glass?

It does, if the thickness of the glass is everywhere the same, as in the case of common window glass.

563. What is the reason that, in looking through a pane of window glass, we sometimes see objects displaced from their true position?

Fig. 100.



Because the outer and inner surfaces of the glass, in such instances, are not even and truly parallel. Fig. 100 represents such a case, and shows the course pursued by a ray of light coming from an object at A.

564. What is the result?

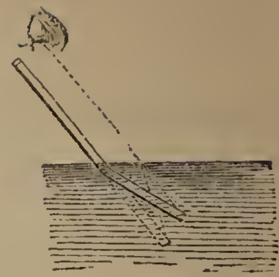
The object appears to be in the direction in which the light enters the eye, and is thus displaced toward the right.

565. What illusion is produced by the refraction of light in passing from water into air?

It causes objects immersed in water to appear to be higher than they really are.

566. What does Fig. 101 show?

Fig. 101.



That a stick partially immersed in water appears, from this cause, to be bent or broken at the surface.

567. Every one knows that a shallow stream never appears to be as deep as it really is—what is the reason?

The bottom is elevated by refraction.

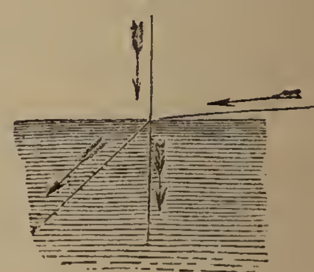
568. An interesting illustration of the refraction of light is represented in Fig. 102—what is it?

Fig. 102.

A coin, placed in a tea cup so as to be concealed from the eye, will rise into full view, if the cup be filled with water.

569. What is Fig. 103 designed to show?

Fig. 103.

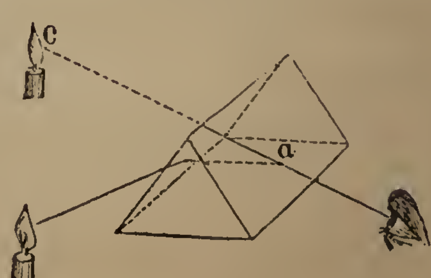


That a ray of light falling perpendicularly on a refracting surface, passes on without experiencing any change of direction; also that light is bent most out of its course when it enters the surface very obliquely.

570. Do all transparent substances effect the same change in the course of the light?

They do not; the refracting power of glass is greater than that of water, and the refracting power of the diamond is much greater than that of glass.

Fig. 104.



571. What does Fig. 104 represent?

A glass prism; the prism has three faces, and its ends are triangular.

572. What else is shown in the figure?

The direction in which a ray of light coming from a candle is bent on entering and leaving the prism.

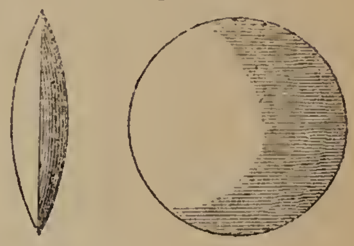
573. What effect has the prism, in the position shown in the figure, on the apparent direction of the object?

The object appears to be in the direction *a c*, and above its true position.

574. What is a common LENS, or BURNING GLASS?

It is a circular piece of glass, rounded on both sides, so as to be thicker at the middle than at the edges.

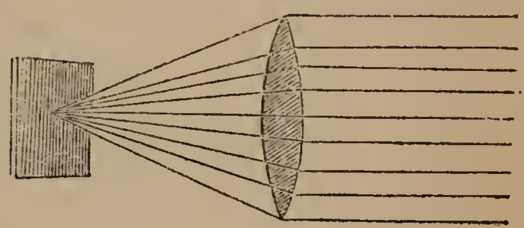
Fig. 105.



575. What is the ordinary effect of a lens upon the rays of light that pass through it?

It concentrates them at a focus, as shown in Fig. 106.

Fig. 106.



576. On what line is this focus situated?

On the line passing from the luminous point through the centre of the lens.

577. When the rays are parallel, or come from a distant point, what is the point of concentration called?

The *Focus of the Lens;* and the distance from the lens to the focus is called the *Focal Distance* or *Focal Length* of the lens.

578. What does Fig. 107 show?

In what manner images of objects are formed by a lens.

Fig. 107.

579. Explain how the image of the arrow is formed.

A pencil of rays proceeding from each point of the arrow falls on the lens, is concentrated into a focus, and thus forms an image of the point.

580. When the arrow is at A, remote from the lens, where is its image formed?

At I, a little outside of the focus of the lens; it is smaller than the arrow, and inverted.

581. If the arrow is at I, a little outside the focus, where is its image?

At A, remote from the lens; it is now much larger than the arrow.

MICROSCOPES.

582. What is a pocket microscope?

It is a small lens, with which minute objects may be magnified.

583. Suppose we wish to magnify the letters of a book, in what position must the microscope be held?

Between the eye and the open page of the book, and so near the page that the letters shall be in the focus of the lens.

584. How does a pocket microscope magnify objects?

It enables us to see them distinctly at a shorter distance than we can with the naked eye.

585. How can the letters of a book, or any small object, be magnified without the use of a lens?

By looking closely at them through a small hole pricked in a card with a needle.

586. When the magnified image of an object is formed in the air, as represented in Fig. 107, and the image is received on a white screen, what is the consequence?

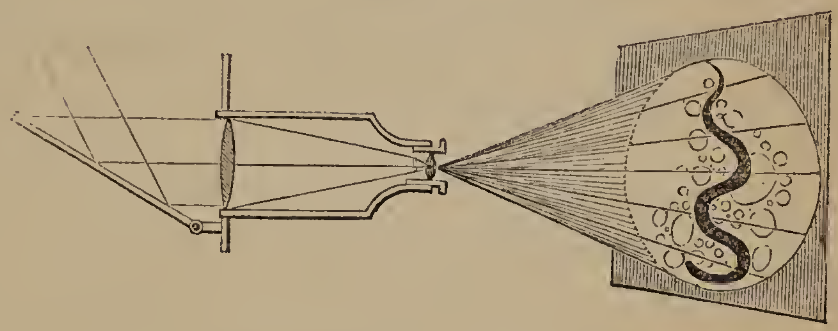
The light from the object is spread over a larger space, and the image appears indistinct.

587. How can it be rendered distinct?

By throwing a strong light upon the object, and darkening the room.

588. What two ways are there of accomplishing this?

Fig. 108.



One is by concentrating the light of the sun upon the object; when this is done, the magnifying lens becomes a *Solar Microscope.*

589. Where is the microscope placed?

In a tube, and one end of the tube is screwed into a hole in a window-shutter of a darkened room.

590. How is the light of the sun thrown upon the animalcule that is to be magnified?

A mirror on the outside of the window throws it upon a a large lens within the tube, and this concentrates it upon the object.

591. How is the magnified object seen?

It is received on a screen in the dark room, placed at the distance of 20 or 30 feet from the microscope, and is visible from all parts of the room.

592. How much does a good solar microscope magnify?

About 10 million times; that is, it would take 10 million animalcules to fill up the spot on the screen that is occupied by the image of one of them.

593. Mention some of the astonishing results that have been obtained with the solar microscope.

The most diminutive insects are magnified into creatures of large size. A drop of vinegar is seen thronged with eels, and a film of stagnant water becomes a large pool, in which a host of strange animals are darting about and preying on one another.

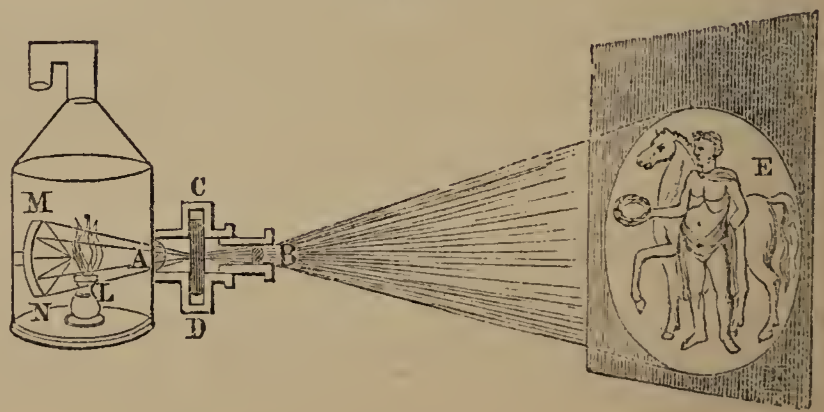
594. Mention other remarkable results.

The delicate and intricate structure of plants and flowers is distinctly seen, and the wonderful processes of crystallization, from the beginning to the close, go on before the eye.

595. What is the second method of illuminating objects that are to be magnified?

By concentrating on them the light of a lamp—this is the arrangement in the *Magic Lantern*.

Fig. 109.



596. What objects are put near the focus of the magnifying lens?

Small pictures, painted in transparent colors on glass.

597. Why is the apparatus represented in Fig. 109 called a magic lantern?

Because of the astonishing effects and wonderful illusions that may be produced by it.

598. What is the best and most convenient form of microscope for the careful examination of minute objects?

The *Compound Microscope.* The object is seen through two lenses placed at the ends of a tube about seven inches long.

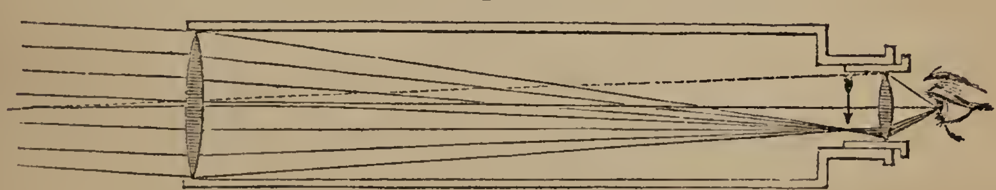
599. What is the magnifying power of COMPOUND microscopes?

They have been made to magnify 3,000 times, and to show lines marked on glass so close together that 80,000 of them would occupy only an inch.

TELESCOPES.

600. What is the construction of the common telescope for viewing the heavenly bodies?

Fig. 110.



It consists of two lenses placed at the opposite ends of a long tube.

601. What are these called?

The smaller one, into which the eye looks, is called the *eye-glass*, and the other the *object-glass.*

602. What is the diameter of the object-glass called?

The *aperture* of the telescope; the quantity of light coming from the object, that enters the telescope and passes on to the eye, depends upon the size of this lens.

603. How does a telescope enable us to see distant objects more distinctly?

The object-glass forms an image of the object at its focus within the tube, and the eye-glass magnifies that image, just as a pocket microscope magnifies the letters of a book.

604. How does the telescope enable the astronomer to see remote objects in the heavens, which are not visible to the naked eye?

The object-glass is much larger than the pupil of the eye, and condenses into a small space near the eye a much larger quantity of light than the naked eye would receive. This may be seen on referring to Fig. 110.

605. What is the power of a telescope to reveal remote invisible objects called?

Its *space-penetrating power.*

606. How is the magnifying power of a telescope ascertained?

By dividing the focal length of the object-glass by the focal length of the eye-glass. For example, if the former were 20 feet and the latter 1 inch (or $\frac{1}{12}$th of a foot), the magnifying power would be 12 times 20, or 240.

607. Long telescopes must then be more powerful than short ones —does not the real effectiveness and value of a telescope depend also upon the size of the object-glass?

It does; a telescope of large aperture furnishes more light, and thus admits of the use of a more powerful eye-glass. We have already seen that it is more effective for the discovery of remote invisible objects.

608. Is the same eye-glass used in the examination of all objects?

It is not; telescopes are furnished with several eye-glasses, to be used in looking at different bodies and in different states of the atmosphere.

609. Where is the largest and best refracting telescope in the world to be found?

At the Cambridge Observatory, near Boston; its object-glass is 15 inches across, and its focal length 22½ feet.

610. What is its highest magnifying power?

2,000; its lowest magnifying power is 180.

611. Does a common SPY-GLASS differ in any respect from a telescope for viewing the stars?

It has additional glasses inside of the tube to make objects, seen through it, appear erect.

612. How does a REFLECTING TELESCOPE differ from that which has just been described?

A large concave mirror takes the place of the object-glass; this mirror is at the bottom of a long hollow tube which rests on the ground.

613. Where does the observer stand?

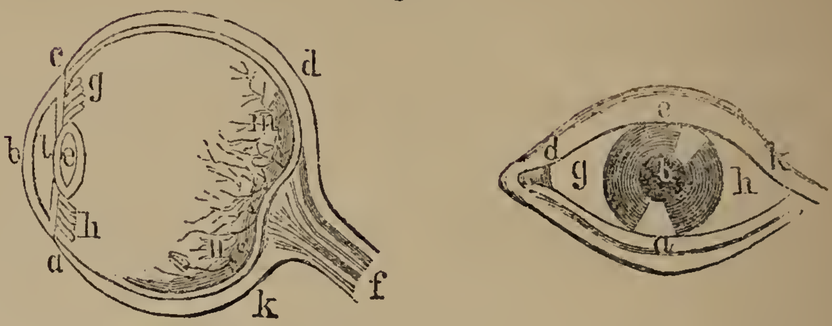
He stands with his back toward the object, at the elevated mouth of the tube; and looks through the eye-glass at the image thrown just before it by the concave mirror.

614. The largest reflecting telescope that has ever been made, was constructed by Lord Rosse, an Irish nobleman, and is of enormous size—give its dimensions.

The mirror is 6 feet across; the tube is 7 feet in diameter, and 52 feet long. The highest magnifying power of this monster telescope is about 9,000.

THE EYE.

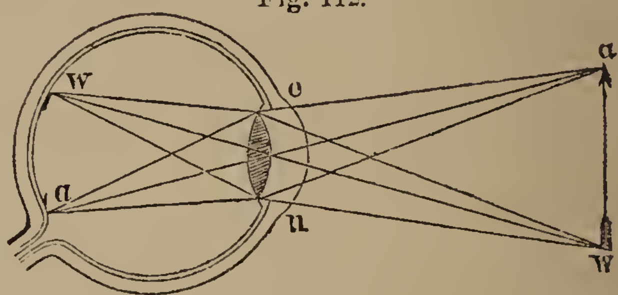
Fig. 111.



615. The essential parts of the eye are represented in Fig. 111—describe it.

The eye is a hollow ball composed of several membranes, and filled with a transparent liquid; within this is suspended a semi-liquid mass, of the shape of a lens, and called the *Crystalline Lens.* This is seen at *e.*

Fig. 112.



616. What is the action of the eye on a pencil of rays proceeding to it from any point of a luminous object?

The rays are all made to converge to a point on the back part of the eye, as shown in Fig. 112.

617. What is formed on the back part of the eye?

An inverted image or picture of the object.

618. What is spread over the back part of the eye to receive it?

The *Retina.* This is a fine net-work of fibres proceeding from the optic nerve that communicates with the brain; it is represented in Fig. 111.

619. What lies immediately in front of the crystalline lens?

An opaque screen with a hole in its centre, through which the light passes.

620. What is this screen called?

The *Iris;* the round opening at its centre is called the *Pupil* of the eye. The pupil is the aperture or window of the eye.

621. Is the pupil always of the same size?

It contracts when the light becomes strong, and dilates when it grows feeble;- so as always to allow the proper quantity of light to pass into the eye.

622. What produces this change?

The stimulus of the light upon the nerves of the iris either directly or by transmission from the retina.

623. Why do we see more distinctly, in the evening, after we have been out in the dark a little while, than we did at first?

Because the pupil dilates gradually. On the other hand, if we come from the dark into the presence of a strong light we are dazzled at first by it, because the pupil does not contract instantly.

DECOMPOSITION OF LIGHT.

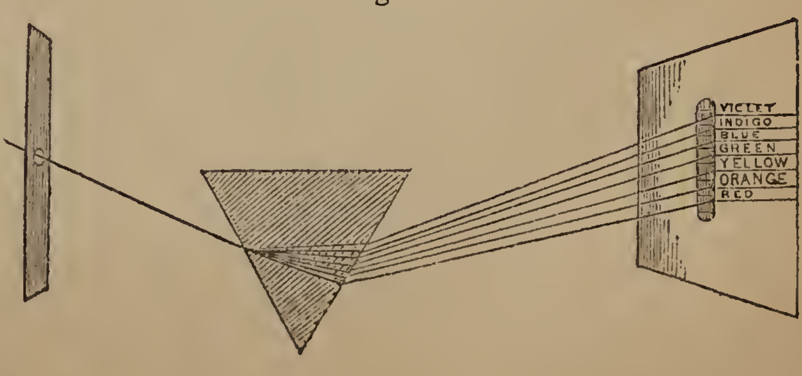
624. What does a ray of white light, from the sun or other source of light, consist of?

Several rays of different colors.

625. How may this be shown?

By admitting a ray of solar light through a very

Fig. 113.



small hole in a window shutter into a dark room, and allowing it to pass through a prism, as represented in Fig. 113.

626. What is observed on the white screen?

A beautiful display of brilliant colors, like a piece of a rainbow, called the *Solar Spectrum.*

627. How does the prism separate these colors and throw them on different parts of the screen?

It refracts some more than others.

628. Mention the seven colors of the spectrum, beginning with the color that is least refracted.

Red, orange, yellow, green, blue, indigo, and violet.

629. By whom was the decomposition of light with a prism first accomplished?

By Sir Isaac Newton.

630. Is it now believed that white light really consists of seven pure colors?

The present belief is that it is composed of but three simple colors, red, yellow, and blue.

631. Who has established this?

Sir David Brewster, of Scotland.

632. What has he shown to be true with regard to the other colors of the spectrum, viz., orange, green, indigo, and violet?

That they are but different combinations of the three simple colors; orange, for example, is chiefly a mixture of red and yellow, and green of yellow and blue.

633. How was the orange colored light of the spectrum separated into its elementary colors by Sir David Brewster?

By passing it through a piece of blue glass of a certain thickness. This extinguished the red light, and allowed the yellow to pass on to the eye.

634. It would seem, then, that all the red light does not go to one part of the spectrum, all the yellow to another part, and all the blue to another, as Newton supposed?

Some portion of each of these colors is found in all parts of the spectrum.

635. Why does one ray of light affect the eye with the sensation of red, another with the sensation of yellow, and a third with the sensation of blue?

The particles of ether vibrate more rapidly in a ray of yellow than in one of red light, and more rapidly in one of blue than in one of yellow light. These different rates of vibration produce different impressions on the retina.

636. To show the wonderful sensibility of the eye, mention the number of vibrations, per second, of each of the three simple colors?

In red light there are 458 trillions of vibrations in a second, in yellow light there are 535 trillions, and in blue light 622 trillions. The retina of the eye distinguishes between these numbers, so enormously great.

637. To what do the different colored rays correspond, among sounds?

To musical sounds of different pitch; thus blue may be said to be light of a higher pitch than yellow, and yellow to be light of a higher pitch than red.

638. Does the eye take the same delight in the variety and harmony of colors that the ear does in the variety and concord of musical sounds?

It does.

639. What colors, of the spectrum, harmonize with each other, or make an agreeable impression when seen together?

Red harmonizes with bluish green, orange with blue, yellow with indigo, green with reddish violet, and violet with yellowish green.

640. What is the explanation of the flashing brilliancy of the diamond?

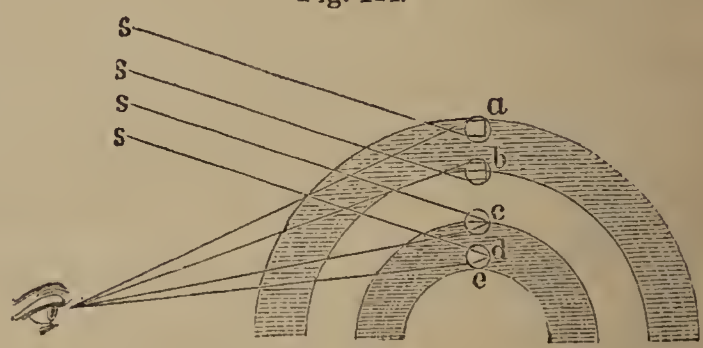
The diamond has a very high refracting power; as a consequence a strong light is reflected from the back part of the stone, and the light that enters one of the faces and passes out at another is widely dispersed into its elementary colors. For this purpose faces are cut on the original stone.

THE RAINBOW.

641. What is Fig. 114 designed to show?

The manner in which the rainbow is formed by the reflection of sun light from falling drops of rain.

Fig. 114.



642. Trace the course of the light.

It enters a drop, is reflected from the back part of it, comes out again at the front part, and passes on to the eye.

643. What is the cause of the colors of the rainbow?

The separation of the colored rays of which the sun's light is composed, as the light enters and leaves the drop.

644. What is the order of the colors in the rainbow?

The red is uppermost and the violet undermost.

645. We often see a second and fainter bow higher than the first—how is this formed?

By rays that enter the drops at the lower part, experience two reflections at the back part of the drops, pass out at the upper part, and proceed on to the eye, as represented in Fig. 114.

646. Why is this bow fainter than the other?

Because the light suffers two reflections, instead of one, and considerable light is lost in the act of reflection.

647. Do two different persons see the same rainbow?

They do not; they see the same colors, but these proceed from different drops.

648. When is the rainbow usually seen?

In the afternoon, when the sun shines at the same time that it is raining to the east of us. It is also sometimes seen in the west, on a showery morning.

649. Is it ever seen under any other circumstances?

We often see cataracts that send up clouds of spray spanned by its beautiful arch; and, in a bright day, its brilliant colors lend a new beauty and grace to fountains sparkling in the light of the sun.

COLORS OF BODIES.

650. Why is one object, as a wafer, red; another, as a lemon, yellow; another, green, etc.?

Because each reflects to the eye the light of its own color.

651. The color is not, then, any quality necessarily belonging to the substance?

It is not; for the colors of flowers, trees, and other objects, are only seen when light from the sun, or some other source, falls on them. Besides, the same substance has not always the same color.

652. Explain by an example.

Phosphorus, for example, is of a pale yellow color, but, if melted and cooled suddenly, it becomes perfectly black.

653. Give another example.

Charcoal is black and opaque, but the sparkling diamond, which is the same substance in another form, is as clear and transparent as glass.

654. What, then, is all the beautiful variety of colors in nature owing to?

To different arrangements of the particles of bodies. It is by this simple expedient that the beneficent Creator has so clothed the earth with beauty, and made it a delight to the eye.

655. Transparent gems, different varieties of glass, and many liquids are variously colored—to what do they owe their color?

Principally to colored light transmitted through them

They extinguish certain colors, and allow others to pass through to the eye.

656. Is the red light that comes from a red object, or the yellow light that comes from a yellow object, a pure unmixed color?

It is a mixture of that color with more or less of each of the other colors.

657. What simple proof have we of this?

It is observed that a colored object always appears of the color, whatever it may be, of the light that is thrown upon it.

658. We say that charcoal is black—is black a positive color?

Perfect blackness is the absence of all color and all light. An object is said to be black when it reflects a feeble light to us. Black is no more a color than silence is sound.

659. Why do certain objects, paper for instance, appear white?

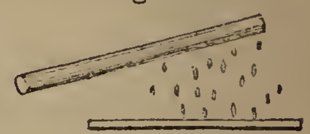
Because they reflect the different colors in about the proportion in which they are combined in white light.

CHAPTER VI.

ELECTRICITY.

EXCITATION AND CHARACTERISTIC EFFECTS OF ELECTRICITY.

Fig. 115.



660. If a thick glass tube be taken in the hand, rubbed briskly with a dry woolen cloth, or a silk handkerchief, and then brought near to light substances, as small pieces of paper, small balls of elder pith, etc., lying on a table, what will be observed?

The little pieces of paper, or pith balls, will fly into contact with the glass tube, and then dart off again. They will continue to fly up and down for some time.

661. How does the glass tube produce these effects?

It at first *attracts* these light bodies into contact with it, and then *repels* them away from it.

662. Will any other substance, besides glass, when held in the hand and rubbed, attract light bodies?

Sealing wax, and many other substances, when rubbed, will act on light bodies just as glass does.

663. What is this peculiar state into which the surface of the glass is brought, by rubbing, called?

The state of *Electrical Excitement;* the glass is said to be *electrically excited*, or *electrified.*

664. What is supposed to be the nature of this excitement?

The friction, from rubbing, is supposed to disengage on the surface an exceedingly thin and subtile fluid, which is called electricity.

665. Is friction the only mode of developing electricity?

The electric fluid may be disengaged by the simple pressure of one surface against another, also by heat, and chemical action. Every cause that produces any agitation among the particles of bodies, disturbs the electrical equilibrium, and sets free some of the electricity that is intimately associated with these particles.

666. Suppose an excited glass tube, or stick of sealing wax, were to be drawn through the hand, closed tightly upon it, what would be the result?

Its electrical excitement would be destroyed.

667. How is this explained?

The electric fluid passes off into the arm, and descends through the body into the floor; from thence it flows off into the ground.

668. Under this idea, what is the human body said to be?

A *good conductor* of electricity.

669. If the excited glass tube, or sealing wax, be touched, at one point only, with the knuckle, will the electric fluid be drawn off from all points of the surface?

It will not; only from the spot that is touched.

670. What may we infer from this?

That the electric fluid does not flow freely from one particle of glass, or sealing wax, to another.

671. What are such substances that obstruct the passage of electricity called?

Non-conductors of electricity. Some substances are better non-conductors, that is, offer more resistance to the flow of electricity than others.

672. Can a brass or iron rod be excited by holding it in the hand and rubbing it, as a glass tube can be?

It can not; but a metallic rod can be feebly excited, if it is provided with a non-conducting handle of glass by which it is held.

673. How are these facts explained?

The rod is a good conductor of electricity; if the hand touches it, the electricity flows off into the ground as fast as it is disengaged; when a glass handle is used, a non-conductor is interposed between the rod and the hand.

674. When, as in the case of a metallic rod held by a glass handle, an electrified conductor is supported by means of a non-conductor, so that the electricity can not flow off into the ground—in what state is it said to be?

It is said to be *insulated*.

675. What does Fig. 116 represent?

Fig. 116.

A piece of electrical apparatus, called the *Electric Pendulum*.

674. Of what does it consist?

Of a small pith ball, suspended by a silk thread, which serves to insulate it.

677. If an excited glass tube be brought near the pith ball, what will happen?

The ball will be attracted by the tube, will touch the glass, and after having touched it will immediately be repelled.

678. Suppose the attempt is made to bring the tube nearer to it?

If that be done, it will move farther off, showing that it is now repelled by the glass.

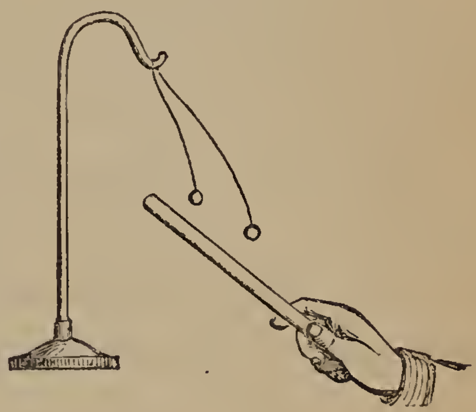
679. When the pith ball is in contact with the tube, being a good conductor, it becomes charged with electricity—what may we infer from the fact of the repulsion of the ball by the tube?

That an electrified body repels any other body that is in the same state of electrical excitement with itself.

680. How may we show that each of the two electrified bodies repels the other?

By taking two insulated pith balls, hanging side by side, and charging them both by bringing them into contact with an excited glass tube.

Fig. 117.



681. If this be done, what will be observed?

The balls will be seen to stand apart from each other, as the figure shows, and to be both of them repelled by the glass tube.

682. Suppose that I were to touch the two balls, and thereby draw off their electricity, what would be observed?

They would fall together, and now, being in their natural state, would be attracted by the glass.

THE TWO ELECTRICAL STATES.

683. We have just seen that a pith ball, charged with electricity from a glass tube, is repelled by the tube—if I were to bring near

the ball thus charged a stick of sealing wax, excited by rubbing it with woolen cloth, would it repel the ball, just as the glass does?

On the contrary, it would attract it.

684. What must we infer from this?

That there are two different states of electrical excitement; the one is produced by rubbing glass with woolen cloth, the other by rubbing sealing wax with the same.

685. How are they explained?

There are supposed to be two electric fluids in all bodies, instead of one, called respectively *Vitreous Electricity* and *Resinous Electricity*, or *Positive* and *Negative* electricities.

686. What is supposed to be the ordinary condition of these two fluids?

They are so combined in the natural state of bodies, that they have no sensible action on surrounding bodies.

687. What is the effect of friction?

It separates the positive and negative fluids, and causes one to collect on the body rubbed, and the other on the rubber.

688. Is the rubber, then, always in the opposite electrical state from the surface rubbed?

It is; if one gives signs of positive electricity, the other, if properly insulated, will give signs of negative electricity.

689. What other explanation of the two electrical states has been devised?

Franklin supposed that there is but one electric fluid in bodies, and that the *positive* excitement is an *excess* of fluid above the natural share, and the *negative* a *deficiency*.

690. What are the supposed relations of the two fluids to one another?

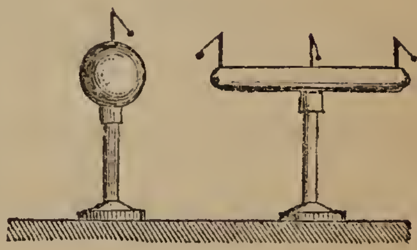
They mutually attract each other; but each exerts a repulsive action on another portion of the same fluid.

691. Can the two fluids be separated in any other way than by rubbing the surfaces of two bodies together?

They can also be separated in any body by bringing another electrified body near to it.

692. In Fig. 118 we have a large brass ball on a glass support, near a brass cylinder, insulated in the same manner—if the ball were charged with positive, or vitreous electricity, what effect would it have on the cylinder?

Fig. 118.



It would separate the two electricities in the cylinder, attract the negative to the nearer, and repel the positive to the farther end.

693. If the cylinder, when in this state, were to be touched by the hand, what would be the effect?

The positive electricity would flow off into the ground, but the negative would remain.

694. Why does not the negative electricity flow off like the other?

It is held fast by the attraction of the positive electricity on the ball. In this condition it is said to be *disguised.*

695. Suppose the ball were to be brought nearer and nearer to the cylinder, what would take place before they came into contact?

A vivid spark of light, attended with a snapping noise, would pass from the one to the other. This is called the *Electric Spark.*

696. Under what circumstances is it seen and heard?

Whenever a good conductor is brought very near to an electrified body; for example, if I were to touch an electrified body with my knuckle, I would receive a spark.

697. How is the electric spark supposed to be produced?

By the rushing of the two electric fluids together through the intervening air.

698. When do we see the electric spark exhibited on an enormous scale?

When a flash of lightning passes from a cloud to the earth. The slight snap of the ordinary spark is now the loud thunder.

CONDUCTORS AND NON-CONDUCTORS.

699. What substances are good conductors of electricity?

The metals, charcoal, the ground, water and most liquids, trees and animals, vapor, flame and smoke, and many other substances, are good conductors.

700. Do they all conduct electricity equally well?

They do not; the metals are much better conductors than water, or trees, or animals.

701. Are there any absolutely perfect conductors?

There are no perfect conductors, and no perfect non-conductors; and the same body, a glass rod for example, may conduct a large charge of electricity, and completely obstruct the flow of a small charge.

702. What substances belong to the class of non-conductors?

Gum-lac, gutta-percha, resin, wax, glass, hair, wool, dry paper, baked wood, India rubber, oils, etc.

703. Is the air a conductor or a non-conductor of electricity?

Dry air is a non-conductor, but moist air is a good conductor.

704. What important consequence follows from this?

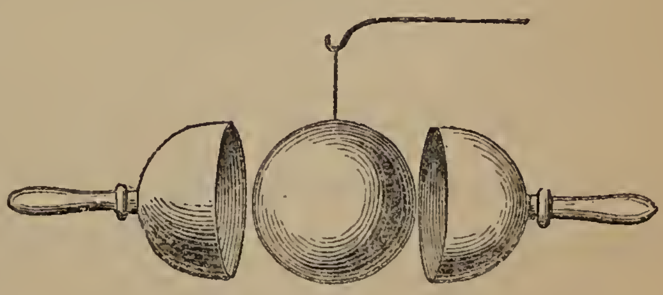
That electrical experiments do not succeed well when the air is humid; the disengaged electricity is rapidly conducted off by the moist air.

DISTRIBUTION OF ELECTRICITY OVER THE SURFACE OF INSULATED CONDUCTORS.

705. When an insulated conductor, like the large brass ball in Fig. 118, is electrified, does the electricity pervade the whole mass of the body?

It does not; it is confined entirely to the surface.

Fig. 119.



706. How may it be shown that electricity in such cases collects on the outer surface?

By covering an electrified ball with two covers provided with insulating handles, as represented in Fig. 119.

707. If this be done, what will be the result?

The electricity will flow from the ball into the covers; on removing these carefully, they will be found to be charged, but not a trace of electricity will be found remaining on the ball.

708. Does the electric fluid diffuse itself equally over the surface of insulated conductors?

It does, when the conductor is a round ball. On the surfaces of long bodies it accumulates at the ends. It is also more intense at the corners and edges of bodies than at other parts of their surface.

709. What is the state of the case when the surface tapers to a point?

The electricity collects in such large quantities at the point that it escapes and flows off quietly through the air to some other body, or diffuses itself in the atmosphere.

710. If a p inted metallic rod, or a needle, held in the hand, be brought within a few feet of a charged conductor, what will be the effect?

The electricity will be rapidly but silently drawn off; no spark will be seen.

711. Who first studied the effect of metallic points in discharging electrified bodies?

Franklin.

712. Did he make an important application of it?

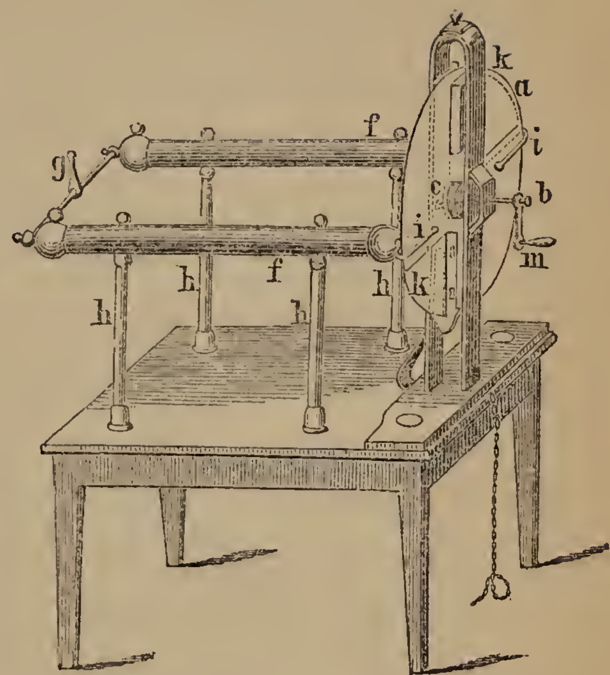
He did, in the construction of the LIGHTNING ROD. He made the rod pointed at the top, that it might in a thunder-storm draw off silently the electricity from the charged clouds over-head.

713. For any other purpose?

To direct any inevitable discharge to the rod, and thus convey it to the ground without injury to the house.

ELECTRICAL MACHINE.

Fig. 120.



714. What is an electrical machine?

A machine employed for developing electricity in large quantities. Fig. 120 represents one form of electrical machine.

715. Of what does it consist?

A circular plate of thick glass turned by a winch, two pairs of rubbers, an insulated conductor, called the PRIME CONDUCTOR, and a framed support.

716. What are the rubbers?

Each of the rubbers is a small cushion covered with leather, over which is spread a layer of an amalgam of zinc and quicksilver; this greatly augments the exciting effect of the rubber.

717. Where may the two pairs of rubbers be seen in the figure?

At the top and bottom of the plate; the rubbers in each pair are so arranged as to press against both surfaces of the plate.

718. Where is the prime conductor shown?

At *f*, *f*, and *g*; it is insulated by the glass supports, *h*.

719. How is the electricity that is excited by the friction of the amalgam on the surface of the glass plate, drawn off on to the prime conductor?

By means of metallic points that extend out toward the glass, on both sides; these are at *i* and *i*.

720. How may a body be charged with electricity from the prime conductor?

By extending a metallic rod, or chain, from it to the prime conductor.

721. Give some account of the most remarkable electrical machine ever made.

The largest and most famous electrical machine ever constructed, was made for the Teylerian Museum at Haarlem. When in full action, a zigzag flash would dart from the prime conductor, a distance of ten feet, to a neighboring conductor, and by bringing a metallic ball near to it, 300 sparks, forked like lightning, and two feet in length, could be obtained from it in a minute. Its attractive influence on light bodies extended to a distance of 40 feet.

LEYDEN JAR.

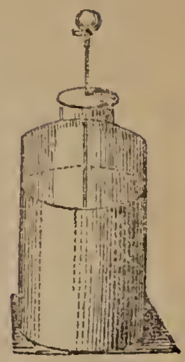
722. When there is occasion to accumulate a much larger quantity of electricity than can be obtained at once from the prime conductor of an electrical machine, what piece of electrical apparatus is employed?

The *Leyden Jar*.

723. What is its construction?

Fig. 121 represents a Leyden jar; it is a large glass

Fig. 121.



jar, coated, both on the inside and outside, to within a few inches of the top, with tin foil. The mouth is closed with a stopper of baked wood, and a brass rod, terminating in a knob, and connected with the inside coating, passes through the stopper.

724. Can electricity pass from the inside to the outside coating?

It can not.

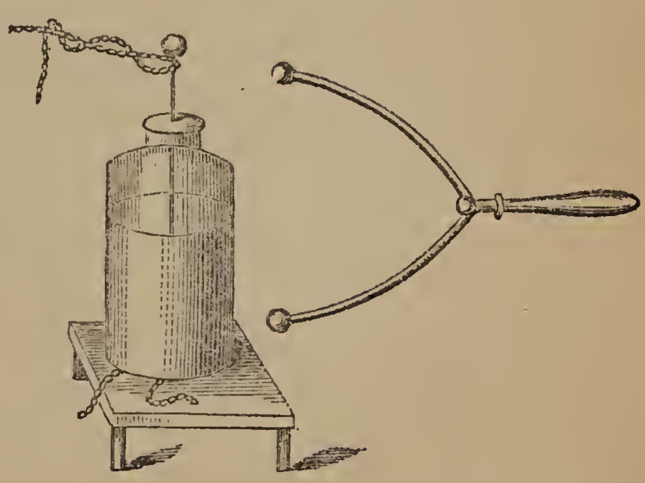
725. How is the jar charged?

The outside is connected with the ground by touching it with the hand or in some other way, and a metallic rod or chain is extended from the knob to the prime conductor of an electrical machine.

726. What does Fig. 122 represent?

A jar in the act of being charged.

Fig. 122.



727. On turning the electrical machine, what will take place?

The positive electricity will flow in a continuous stream from the prime conductor into the jar, until it becomes fully charged. Positive electricity will, at the same time, flow steadily from the outside coating into the ground.

728. Why should the electricity continue to flow into the jar for some time?

Because it is attracted by the negative electricity that is retained on the outside of the jar. The reaction of this negative electricity renders insensible a large quantity of positive electricity on the inside.

729. How is the jar discharged?

By bringing the outside and inside into conducting connection with each other; the two electricities rush together along this connection.

730. What is a common method of discharging the jar?

By means of the *Discharging Rod* represented in Fig. 122. It consists of two curved brass rods terminating in knobs, and having a common joint at the end of an insulating glass handle.

731. How is it used?

One of the knobs is first brought into contact with the outside coating, and then the other is made to touch the knob of the jar.

732. What takes place just as the two knobs are brought together?

The jar is discharged, with a loud report, and a vivid flash of light.

733. Suppose a person were to touch the outside of the jar with one hand, and the knob with the other?

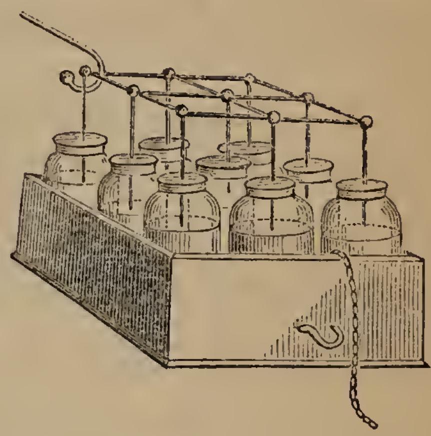
The discharge would take place through his arms and chest, and he would experience a sudden convulsive shock, called the *Electric Shock*.

734. Can several persons receive the electric shock at the same time?

They can, by taking hold of hands, and the person at one end of the line touching the outside of the jar, and the one at the other end touching the knob.

735. Explain Fig. 123.

Fig. 123.



It represents a combination of Leyden jars, called an *Electric Battery*.

736. What have you to say of the electric battery?

A much larger quantity of electricity can be accumulated with it, and much greater effects produced, than can be obtained with a single jar.

737. Illustrate by a remarkable example.

An electric battery of enormous size was constructed, to be used with the great Haarlem electrical machine; it consisted of 100 jars, each 13 inches in diameter, and 2 feet high. The discharge of this battery would rend the hardest wood to pieces, and would kill a dog instantly if passed through the head and spine.

VARIOUS EFFECTS OF ELECTRICITY.

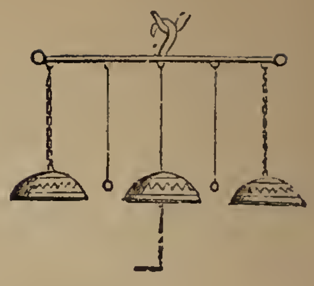
Attraction and Repulsion.

738. How may electrical attraction and repulsion be illustrated in an interesting manner?

By the apparatus called the *Electric Bells*, shown in Fig 124.

739. Describe it.

Fig. 124.



Three small bells are suspended from a brass rod, the two outer ones by brass chains, and the middle one by a silk thread; between the bells are hung, by silk threads, two metallic clappers.

740. How are the bells made to ring?

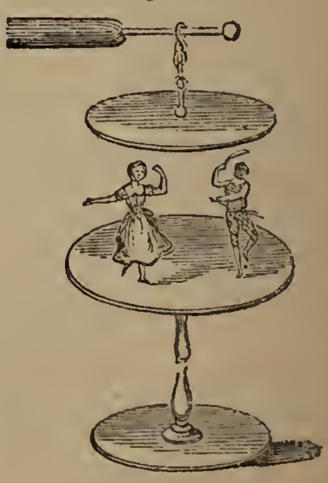
The middle bell is connected with the floor by a brass chain, and the rod from which they are all suspended is brought into connection with the prime conductor of the electrical machine.

741. What follows on turning the machine?

The electricity flows into the two outer bells; these attract the little clappers, which become charged as soon as they strike against them, and are then repelled off, strike against the middle bell. and become discharged.

742. What happens then?

Fig. 125.



The clappers are attracted again by the outer bells. In this way a constant ringing is kept up while the machine is turned. In a similar way little puppets, made of elder pith, may be made to dance by placing them between two metallic plates.

743. How must the plates be arranged?

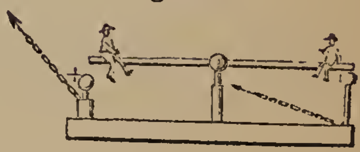
The lower plate must communicate with the ground, and the other with the prime conductor of an electrical machine in action.

744. What will be the action of the plates on the puppets placed between them?

The figures will be attracted by the upper plate, then repelled from it, then discharged by the lower plate, then attracted by the upper plate again, etc.

745. What is Fig. 126?

Fig. 126.



The *Electrical See-saw*, moved in a similar manner by electrical attraction and repulsion. The chains shown in the figure effect the necessary connections.

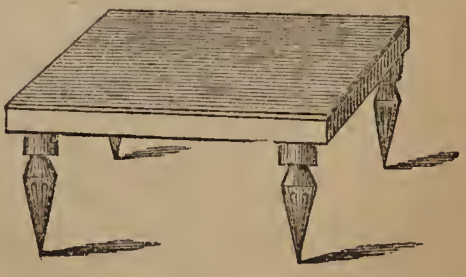
746. Explain Fig. 127.

Fig. 127.

It represents an amusing illustration of electrical repulsion. It is an artificial head covered with long hair; the stem is placed in the hole at the top of the prime conductor, and when the machine is turned, the hairs stand aloof in the ludicrous manner shown by the figure.

747. Can a person be silently and insensibly filled with electricity?

Fig. 128.



He can, by standing on an *Insulating Stool* with glass legs, and taking hold of a brass rod that rests on the prime conductor. In this condition his clothing will attract particles of dust, pieces of paper, and other light bodies; his hair will stand out, and sparks may be taken from his hands, his ears, his nose, or from any part of him.

748. Mention two or three instances of violent effects produced by the mutual repulsion of particles of bodies highly charged with electricity.

The charge of a large Leyden jar passed through water confined in a small glass tube and between two wires that nearly meet at the center, shatters the tube and scatters it into fragments. A quire of paper, placed between two metallic balls, may be perforated with the charge from a battery.

749. Mention other instances of similar effects produced by repulsion.

In a similar manner, brittle bodies, as pieces of loaf sugar, sealing wax, hard wood, stones, etc., may be broken and scattered into fragments.

750. How are all the violent effects of lightning, such as the shattering of trees, and stripping them of their bark, the destruction of articles of furniture in houses, etc., produced?

By the strong repulsion existing between the highly charged particles of the bodies that lie in the path of the lightning. This effect of repulsion may sometimes be greatly increased by the sudden conversion of the moisture in these bodies into steam.

Heating Effects of the Electric Discharge.

751. Can combustibles be set on fire by electricity in motion?

Ether and spirits of wine can be inflamed by the electric spark received from the prime conductor of an electrical machine.

752. Can solid combustibles be inflamed by the electric discharge?

Gunpowder will explode, and tow dipped in powdered resin will burst into flame, if the spark from a good-sized Leyden jar be passed through them.

753. Can metals be heated by the electric discharge, passed through them?

They may be melted, and even burned up, if they are used in the state of a fine wire to conduct the charge of a powerful battery.

754. In order that heat may be produced by electricity, what is necessary?

That a considerable quantity of electricity should be in motion, and meet with resistance at the point where the heat is to be produced?

755. What is the reason that lightning often sets fire to a building that it strikes?

Because of the resistance that the flash meets with from the combustibles through which it passes.

756. Will an ordinary lightning rod convey a flash of lightning to the ground without being materially heated?

It will; but the points of lightning rods have sometimes been melted, when struck by lightning.

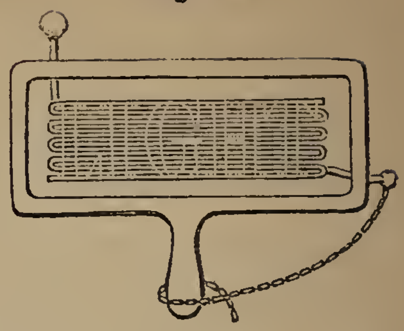
Electric Light.

757. Under what circumstances is light produced by the electric discharge?

Whenever the electric current passes through any space that is occupied by air; at every such point light is produced.

758. What does Fig. 129 represent?

Fig. 129.



A glass plate, with narrow strips of tin foil pasted on it, which have been cut across, here and there, with a knife, so as to form letters.

759. If the ring at the top be brought into communication with the electrical machine, and the chain on the right with the floor, on working the machine in a dark room, what will be observed?

The letters will flash out in the darkness as letters of light.

Fig. 130.

760. Is any luminous appearance connected with the flow of electricity from a pointed rod?

When positive electricity flows off from a pointed rod connected with a prime conductor, a brush of light is seen at the point, as represented in Fig. 130.

Fig. 131.

761. What is observed when negative electricity escapes from a metallic point, or the point is held in the hand and presented to the prime conductor?

It is seen to be illuminated by a minute but brilliant star.

762. Explain Fig. 131.

It represents a glass tube several feet long, having a pointed wire at the top and a brass ball at the bottom. If this tube be exhausted of air, by means of an air pump, a stream of electricity may be made to pass through it from one end to the other.

763. How may this be accomplished?

By connecting the lower end with the floor and the upper end with the prime conductor of an electrical machine.

764. What is the appearance of the light given out?

It plays in soft and flickering streams of varying colors, from one end of the tube to the other, and offers a strong resemblance to the fitful gleamings of the Aurora Borealis.

765. Is the light faint in proportion as there is less air left in the tube?

It is; when the vacuum is made as perfect as possible, there is still some air left in the tube; but for this there would be no light at all.

766. Is electric light given out only when the electric stream flows through the air.

It is also produced when the electric current flows through any gas or vapor, as the vapor of ether, and is of various colors.

ATMOSPHERIC ELECTRICITY.

767. How did Franklin establish that lightning and electricity are identically the same?

He drew the lightning down from the clouds, by means of a kite, and showed that it would produce the same effects as electricity.

768. Where did Franklin perform this remarkable experiment?

At Philadelphia, in the summer of 1752.

769. Was the experiment repeated elsewhere?

During the following summer M. de Romas, of France, raised a kite to the height of 550 feet, into the midst of a thunder-cloud, and obtained at the end of the wire coiled around the string, sheets of fire ten feet in length and an inch in thickness, accompanied with explosions louder than the report of a pistol.

770. What is the usual mode of collecting electricity from the atmosphere for the sake of observation and experiment?

By means of an insulated metallic rod terminating in a point directed upward. It is also sometimes collected by means of long insulated wires stretched on the tops of lofty poles.

771. What is the ordinary electric state of the atmosphere?

It is charged with more or less of positive electricity; the quantity increases from the surface of the earth upward.

772. What is the electric condition of thunder-clouds?

Sometimes positive and sometimes negative; and the same is true of the air in stormy weather.

773. Do thunder-clonds always discharge to the earth?

They do not, but generally from one to another.

774. When lightning strikes near to us, what is the character of the thunder?

It is a peculiar rattling, crackling noise, that continues for a short time.

775. Why is the sound prolonged?

Because it does not reach the ear from all points of the lightning's path at the same instant.

776. What is the original cause of thunder?

The sudden violent movement imparted to the air by the lightning in its passage.

777. What is the immediate cause of this movement?

The mutual repulsion of the particles electrified by the lightning.

778. What is the explanation of the heavy roll of thunder that often follows the first explosion after a short interval?

It is probably occasioned by reverberations of the original sound from the clouds.

779. What are some of the circumstances by which the sound that reaches the ear may be modified?

The zigzag or other form of the lightning's path, the number of simultaneous flashes, and the direction pursued by the flash.

CHAPTER VII.

MAGNETISM.

PROPERTIES OF MAGNETS.

780. WHAT is a loadstone?

A piece of iron ore found in the earth, which has the property of attracting iron.

Fig. 132.

781. Does the loadstone attract a piece of iron with the same force at whatever part of its surface the iron is presented?

The attraction is the strongest at two opposite points, called *Poles*. These are at N. and S. in Fig. 132.

782. In passing from the poles to the middle of the loadstone, how does the attraction vary?

It decreases rapidly, and near the middle vanishes altogether.

783. What is supposed to be the cause of this attraction?

A subtile fluid within the mass of the loadstone that has in some way been excited into action.

784. What is this fluid, or principle, whatever it may be, called?

Magnetism; and the loadstone is said to be a *Magnet.*

785. What is the general opinion of the philosophers of the present day as to the nature of the principle of magnetism?

It is believed that magnetism is electricity in a peculiar state of motion. This belief is founded upon the fact that the effects produced by magnetism may be obtained from currents of electricity circulating in wires.

Fig. 133.

786. What effect has a loadstone or magnet upon a piece of malleable iron brought into contact with one of its poles, as shown in Fig. 133?

It converts it at once into a magnet, as may be shown by applying a key to the other end.

787. Suppose, instead of malleable iron, a piece of hard steel be applied to either pole of a magnet?

The steel will also become a magnet, but the full effect will not be produced at once, and will be much less than on the iron.

788. How is it with cast iron?

Cast iron resists the magnetizing action of the magnet with about the same force that cast steel does.

789. What will happen if the piece of soft iron be withdrawn from the magnet?

It will return at once to its former condition.

790. Will the same be true of the piece of steel?

It will not, the steel will have become a permanent magnet, like the loadstone.

791. What is such a magnet called?

An *Artificial Magnet.* The loadstone is called a *Natural Magnet.*

792. Fig. 134 represents an artificial steel magnet—where are the two poles?

At the ends of the magnet.

Fig. 134

793. To magnetize a small steel bar completely, what must be done?

The bar must be rubbed several times, in the same direction, from end to end, against one of the poles of a strong magnet.

794. If a magnet be suspended at its middle, what position will it take?

It will point north and south. If it should be drawn out of this position, it would immediately return to it again.

795. What name is given to the pole at the north end?

It is called the *North pole* of the magnet, and the other the *South pole.*

796. How may the unequal distribution of magnetism over the bar be shown?

Fig. 135.

By rolling the bar in iron filings; the filings will adhere in the largest clusters at the ends and along the edges.

797. Does the attractive power exerted by the pole of a magnet take effect through paper, wood, stone, etc.?

It does, but diminishes rapidly as the distance from the pole increases.

798. Illustrate this by stating the result of a simple experiment.

If a sheet of paper be inserted between the pole of a magnet and a piece of iron, the attraction is much less than when there is an actual contact.

799. Is the power of a magnet weakened by use?

On the contrary, additions may be made from day to day to the weight that it first supports.

800. What inference may be drawn from the fact that the magnet does not lose its virtue?

That the piece of iron in contact with the pole does not draw its magnetism from the magnet, but contains the principle of magnetism within itself.

801. What may be inferred from the fact that the magnet is strengthened by use?

That the magnetism developed in the contiguous iron reacts on the magnet, and brings into action a new portion of its magnetism.

802. What is the sustaining power of good bar-magnets?

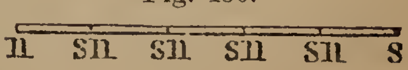
Bar-magnets are seldom found capable of supporting more than their own weight of iron.

803. Have small magnets greater proportional power than large ones?

They have; a small magnet set in a ring and worn by Sir Isaac Newton, is said to have lifted 250 times its own weight.

804. If a steel wire that has been magnetized is cut into small pieces, what is true of each piece?

Fig. 136.



Each piece is found to have a north pole at one end, and a south pole at the other end; as shown by the letters *n* and *s* in Fig. 136.

805. What is inferred from this?

That a magnet is made up of lines of particles all of which are little magnets, with the same poles turned the same way.

806. How is this explained?

There are supposed to be two magnetic fluids, as there are two electric fluids, and these are combined in each particle.

807. What may be said of this explanation?

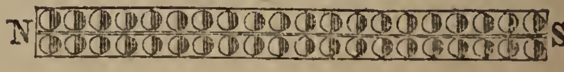
It is the simplest conception by which the facts can be represented, but is not believed to be a reality.

808. What are the two supposed fluids called?

Austral and *Boreal.*

809. What is supposed to take place when a bar of iron or steel is magnetized?

Fig. 137.



These fluids are separated in each of its particles by the action of the magnet; the austral fluid is made to occupy one half of each particle, and the boreal fluid the other half.

810. We have seen that each pole of a magnet attracts iron or steel—what is the nature of the action of two magnets on each other?

The north pole of each magnet attracts the south pole of the other, but repels the north pole; and the south pole of each magnet attracts the north and repels the south pole of the other.

811. We have seen that if either pole of a magnet be applied to the end of a small bar of iron, the bar will become a magnet—which pole will be developed on the end of the bar touched by the magnet?

Fig. 138

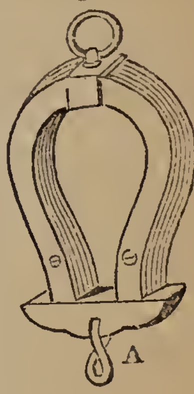
The pole of the opposite name; and if the bar is not too long, the pole of the same name will be developed at the other end; this is illustrated in Fig. 138.

812. What may be said then of the attraction between a magnet and a piece of iron brought into contact with it?

It is really an attraction between the opposite poles of two magnets.

813. What is a *Horse Shoe-Magnet?*

Fig. 139.



It is an artificial steel magnet bent into a shape resembling a horse shoe; the poles are at the two ends and are therefore by the side of each other. A piece of soft iron extends across from one pole to the other, and from this weights may be suspended by means of a hook.

814. What is this piece of iron called?

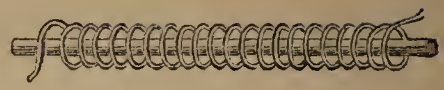
A *keeper*, or *armature*. It is so called because by means of it the full power of the magnet may be preserved for any length of time.

815. What may be said of the power of the horse shoe-magnet to support weights?

Its sustaining power is much more than double the natural attraction of either pole for a piece of iron.

816. Can a piece of iron or steel be magnetized in any other way than by touching it, or rubbing it with a magnet?

Fig. 140.



It can be more effectually magnetized by placing it within a coil of copper wire through which an electric current is made to pass; as shown in Fig. 140.

817. What is an *Electro-Magnet?*

Fig. 141.

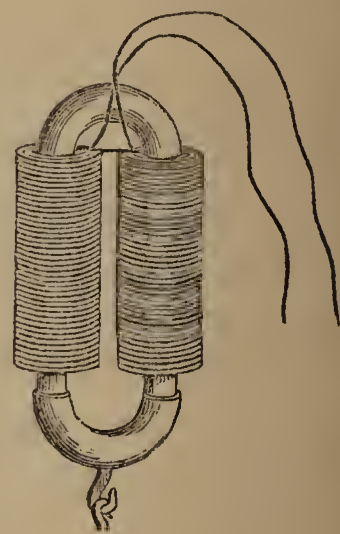


Fig. 141 represents an electro-magnet; it is a piece of soft iron, generally in the shape of a horse shoe, with a coil of copper wire wound around its ends. The iron is temporarily magnetized, by passing through the coil an electric current, from a galvanic battery.

818. How does the power of an electro-magnet compare with that of a permanent horse shoe-magnet?

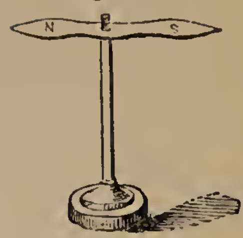
It is vastly greater; the largest horse shoe steel magnets support from 50 to 100 lbs.; but large electro-magnets may be made to sustain more than a ton. An electro-magnet has in fact been constructed capable of supporting 5,000 pounds weight.

TERRESTRIAL MAGNETISM.

819. What is a *Magnetic*, or *Compass Needle?*

It is a thin magnetized bar of steel, poised on a pivot about which it turns freely.

Fig. 142.



820. What important fact does it make known, by the position which it takes up and obstinately retains?

It points out, as if by instinct, in what direction North lies.

821. What is the most important application of the magnetic needle?

The *Mariner's Compass;* as a guide to the mariner in steering his course across the trackless ocean. By night and by day, in storms and in calms, the compass needle is ever true to the pole.

822. When was this *directive* property, as it is called, of the magnetic needle first discovered?

It was known to the Chinese a thousand years and more before the commencement of the Christian era.

823. When was the Mariner's Compass first used?

The Chinese appear to have steered vessels by the compass early in the Christian era, but it was not known in Europe until about the twelfth century.

824. Who was the first European navigator that is known to have sailed by the compass?

Vasco de Gama, in his first expedition into India.

825. Does the compass needle point due north at all parts of the earth?

It deviates, or *declines*, more or less from the true north at almost every place.

826. In which direction, to the east or to the west of north?

At some places to the east and at other places to the west of north.

827. On which side of north does the magnetic needle point in the United States?

In New England, New York, New Jersey, Pennsylvania, Maryland, Delaware, and the eastern part of Virginia, it points West of north.

828. In all other parts of the United States, even to the Pacific coast, how does it point?

To the East of north.

829. Suppose an imaginary line to be traced through a series of places at which the needle points due north, what is such a line called?

A Line of no Variation. A line of no variation is represented in Fig. 144, p. 148, proceeding from the magnetic pole and traversing the Western Continent.

830. As a ship sails across the Atlantic, from New York to Liverpool, how does the direction in which the needle points vary?

At setting sail it deviates about 7 degrees to the west of north, and afterward continually farther and farther, until, when the ship arrives at the port of Liverpool, it declines no less than 24 degrees to the west of due north.

831. How then does the mariner, when he is out to sea, know where the true north lies?

He has the means of ascertaining how far the needle declines from the due north, by making an astronomical observation.

832. In any other way?

Also, by consulting a chart on which are recorded the results of previous observations on the direction of the needle.

833. In what direction does the compass needle point in high northern latitudes?

At most localities very much to the west or east of north.

834. In what direction at Barrow's Straits and Melville Island?

What we call the north pole of the needle points toward the south.

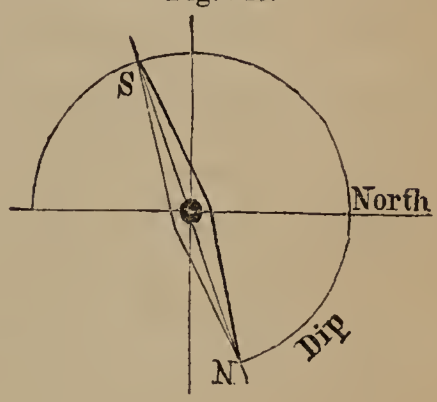
835. Are the same differences in the position taken up by the compass needle, observed in the Southern as in the Northern Hemisphere?

They are, and it is the same pole of the needle that points south in the two hemispheres.

836 If a magnetic needle be freely suspended by its centre of gravity, so that either end can move up or down, in what position will it settle?

In a position such as is represented in Fig. 143, in which the north end *dips* very much below a horizontal line.

Fig. 143.



837. What is the amount of the depression or *dip* of the north end of the needle in these latitudes?

About 73 degrees, or nearly three fourths of a right angle.

838. How is the ordinary compass needle brought into a horizontal position?

By making the south end heavier than the other.

839. In traveling north does the dip increase or decrease?

It increases; and in going south it decreases.

840. Is the dipping needle horizontal in any part of the earth?

It is horizontal in the vicinity of the equator; all along a certain line running round the earth, and lying partly to the north and partly to the south of the equator.

Fig. 144.

841. What is this line called?

The *Magnetic Equator.*

842. Are there any localities on the earth where the dipping needle points directly down?

There are four such points; two in the Northern and two in the Southern Hemisphere.

843. What are these points called?

The *Magnetic Poles* of the earth.

844. Where are they situated?

The strongest of the two north magnetic poles is on the continent of North America, and the other to the north of Siberia. The strongest south magnetic pole is on the Antarctic Continent, to the south of Australia.

845. In what latitude and longitude is the North American pole?

It is in longitude 97 degrees, and latitude 70 degrees.

846. Have the magnetic poles actually been reached by any of the Arctic and Antarctic voyagers?

The North American pole was reached by Commander Ross, of the English navy, on the 1st of June, 1831.

847. Is the intensity of the earth's magnetic force everywhere the same?

In the northern parts of this continent it is nearly twice as great as in the vicinity of the equator.

848. In what direction does this force act on the magnetic needle?

In the direction indicated by the dipping needle; that is, in these latitudes, very much inclined to the horizontal line.

849. How does the earth, as a whole, act on the magnetic needle?

As if it contained, within its mass, a great magnet, or rather two great magnets.

850. Where are the poles of these imaginary magnets situated?

At a great depth in the earth, and directly below the magnetic poles at the surface.

851. Is it believed that there are actually such magnets embedded in the earth?

It is not.

852. Is the real cause of the earth's magnetic action known with certainty?

It is not, but it is supposed to be due to the perpetual circulation of electric currents around the earth.

853. Is the magnetic action of the earth on the needle exerted from year to year, in exactly the same direction, and with the same intensity?

It is not; the compass-needle turns slowly either toward the west or toward the east, from one year to another.

854. In what direction is the north end of the needle slowly turning in New England and the Middle States?

Toward the west; it has been moving in that direction since about the year 1815. During the eighteenth century its motion was eastward.

855. What is the direction of the annual movement of the needle in Western Europe?

Toward the east; the slow movement in that direction began about the year 1815.

856. In London the compass-needle now points 22 degrees west of north—did it ever point due north there?

It did, about the year 1660.

857. Is this steady movement of the magnetic needle from year to year the only motion that it has?

It is not; it oscillates to and fro, very slightly, during each year, and also every day.

858. What other movements has it?

Irregular movements that occur at any hour, and can not, like the others, be foreseen.

859. What especial arrangements have been adopted for observing these movements?

Magnetic Observatories have been erected in all parts of the earth, and fitted up with long magnetic bars, delicately suspended, and all the appliances required for the nicest observations.

860. What are some of the remarkable results that have been obtained from the observations made in these observatories, upon the disturbances of the magnetic needle?

Most of the large irregular disturbances occur at about the same instant over the extent of a whole continent.

861. Illustrate by examples.

The needle begins to move at the same instant at

Philadelphia as at Toronto in Upper Canada; at the same instant at Paris as at St. Petersburg.

862. What other important result has been obtained?

It has been discovered that there are occasional periods of many hours' duration, in which remarkable disturbances occur. These are called *Magnetic Storms.*

863. To what are the regular and irregular movements of the magnetic needle for the most part traceable?

To some influence of the sun.

864. What remarkable evidence of the sun's disturbing action has recently been obtained?

It is found that the disturbances of the needle are uniformly the greatest and most frequent in those years in which the spots are largest and most numerous on the sun's surface.

865 What does this curious fact show?

That a magnetic needle, on the earth, trembles in sympathy with the commotions that occur on the sun's surface.

866. It is observed that the shooting beams. or *Streamers,* of the Aurora Borealis have a position corresponding to that of the dipping needle; does the needle appear to have any magnetic sympathy with the fitful changes and beautiful coruscations of an aurora?

An auroral display is generally attended with capricious movements of the magnetic needle. Sometimes the same aurora seems to affect all the magnetic needles both of the Western and Eastern continents.

DIA-MAGNETISM.

867. Are there any other substances, besides iron, that are attracted by a magnet?

There are—the two metals nickel and cobalt are quite strongly attracted; and many other substances are feebly attracted by a powerful magnet.

868. What remarkable discovery, in reference to the magnetic condition of substances, has recently been made by the celebrated English philosopher, Dr. Faraday?

He has discovered a large class of substances that are *repelled* by both poles of a powerful electro-magnet. These he calls *Dia-Magnetic* substances.

869. Mention some of them.

The metals bismuth, antimony, zinc, and tin, flint glass, India rubber, alcohol, water, and most vegetables are dia-magnetic. If brought near a powerful magnet they would be repelled from it.

870. What is the magnetic condition of our bodies?

The substance of our bodies is dia-magnetic; and Faraday observes that if a man were suspended over the poles of a sufficiently powerful electro-magnet, he would be repelled and lie crosswise to the line of the poles

871. In view of the recent magnetic discoveries made by Faraday and others, what important general conclusion do we arrive at?

That the principle of magnetism is not confined to a few substances; but is associated, in one or the other of its two forms, with all matter.

CHAPTER VIII.

THEORETICAL ASTRONOMY.

FIGURE OF THE EARTH.

872. WHAT is the form of the earth?

The earth is round, or globular, in its form, and isolated in space.

873. What evidence have we that the earth is round?

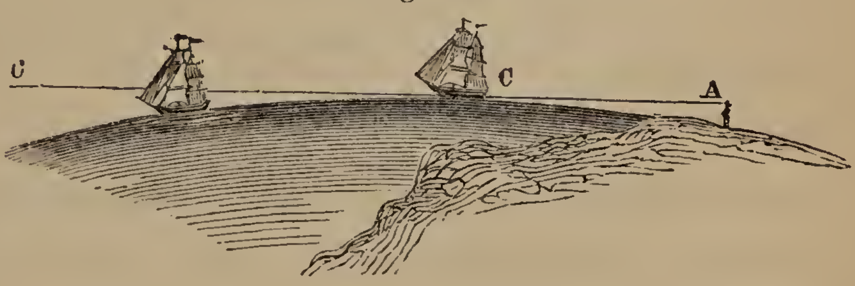
Navigators have sailed around it and returned to the port from which they set out.

874. Mention a familiar fact that proves the earth to be round.

If from a point on the coast we watch a ship that is putting out to sea, we first lose sight of the hull, then of the lower parts of the sails, and finally of the topsail.

875. How is this a proof of the roundness of the earth?

Fig. 145.



A person at A, in the figure, could not see any thing that is below the line C C, and as the ship sails on, the hull would first pass below this line, then the lower parts of the sails, and lastly the topsail.

876. This proves that the sea is round—is it known that the land is not much elevated above the general level of the sea?

It is; the highest mountains are five miles high, but they are very small in comparison with the vast size of the earth. They are like grains of sand on the surface of an ordinary terrestrial globe.

877. What is meant by the general level of the sea?

The surface of the sea supposed to be continued on under the land, so as to form a continuous round surface.

878. What is the size of the earth?

It is 4,000 miles from the surface of the earth to the center, and 8,000 miles through to the opposite side.

879. How long would it take a man to walk round the earth, if it was land all the way, and he walked 10 hours every day, at the rate of 3 miles per hour?

Two years, three months, and eight days.

880. In a level country, or at sea, we seem to be at the centre of a large circle that surrounds us, and beyond which we can not see —what is this circle that limits our vision called?

The *visible horizon.* What we see of the earth's surface lies within this circle.

881. Why does the visible part of the earth appear to be flat?

Because the earth is so large and we see so small a portion of it at a time.

882. As we travel over the earth, does the visible horizon change?

It does; it travels along with us.

883. What is the point directly overhead called?

The *zenith.*

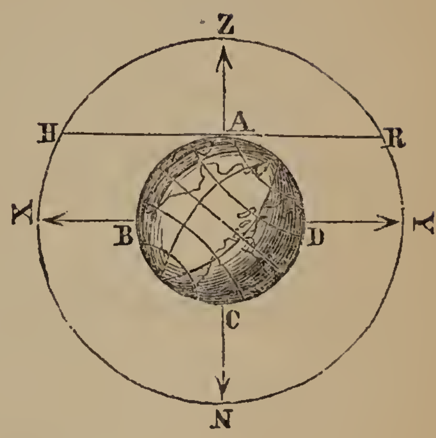
884. Does this move with us also?

It does.

885. Where is the zenith of a person standing at A (Fig. 146)?

At Z.

Fig. 146.



886. Where, of the station B?

At X.

887. Where, of the stations C and D?

At N and Y.

888. What is the relative situation of the zeniths of people living on opposite sides of the earth, and said to be *antipodes* to each other?

Their zeniths lie in opposite directions from the centre of the earth.

889. What is *up* and what is *down?*

At any station up is from the centre of the earth, and down is toward it.

890. Is down the same direction at two stations on opposite sides of the earth—A and C, for example?

It is not; the same direction that is down at A is up at C.

891. When bodies fall at the two opposite stations A and C, do they move in the same direction?

They move toward the centre of the earth at both places, and thus in opposite directions.

892. Why do bodies everywhere fall toward the earth's centre?

Because they are attracted by the earth.

893. What did the ancients, in their ignorance of these facts, imagine?

That the earth must be supported in some way from below, otherwise it would fall into the bottomless abyss.

THE SKY.

894. As we look away from the earth in clear weather, what do we see?

The *Sky.*

895. What appearance does the sky present?

It appears like a blue canopy spread over our heads, and resting on the earth at the horizon.

896. What is it in fact?

Fig. 147.

The earth's atmosphere, which is of a blue color when seen in the mass.

897. What evidence have we that the color of the air, when seen in large masses, is blue?

Distant mountains, seen through a large body of air, have a blue tint.

898. How is the appearance of solidity which the sky presents, to be explained?

It is an illusion. We actually look through the atmosphere into the depths of space, as through a filmy blue veil spread over the earth.

899. To what height does the atmosphere extend?

To the height of about 50 miles.

THE HEAVENS AND THE HEAVENLY BODIES.

900. What is the space outside of the earth and its atmosphere, and extending to an indefinite distance, called?

The *Heaven*, or *Heavens*.

901. What have you to say of it?

That there is a host of shining bodies dispersed through it, which are called *Heavenly Bodies*.

902. How are the heavenly bodies classified?

They are divided into the *Sun*, the *Moon*, and the *Stars*.

903. When the sun is above the horizon we say it is day, and when he is below the horizon we say it is night—what is the explanation of the constant succession of day and night?

The sun appears to move in a circle around the earth, and goes all the way round in a day and a night.

904. How does it move during the day?

It rises in the east, moves across the sky, and sets in the west.

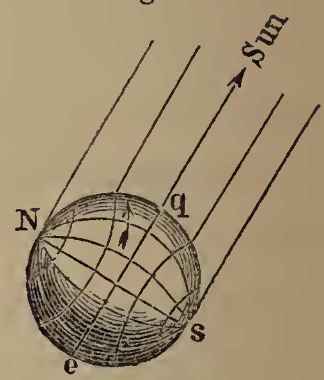
905. Is the sun really in motion, as it appears to be?

It is not; it is stationary in space.

906. What, then, is the true explanation of the succession of night and day?

The earth turns about an axis, like a spinning top, and completes a rotation in a day and a night. During the day, the side of the earth on which we are is turned toward the sun, and during the night it is turned away from him.

Fig. 148.



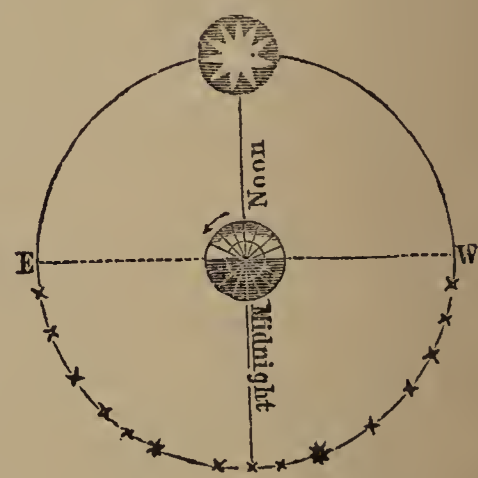
907. Explain Fig. 148.

N S is the earth's axis, N the north pole, S the south pole, and *eq* the equator. The arrow shows the direction of the earth's rotation.

908. In Fig. 149, in what direction is the observer on the earth supposed to be looking?

Toward the south, with the east on his left and the west on his right.

Fig. 149.



909. How may the explanation of the succession of day and night be illustrated experimentally?

By taking an apple to represent the earth, sticking a bit of paper or wafer on it, to show our position, and turning the apple round by the stem, while it is held before a candle.

910. Does the earth's rotation carry us along in the same direction that the sun appears to move?

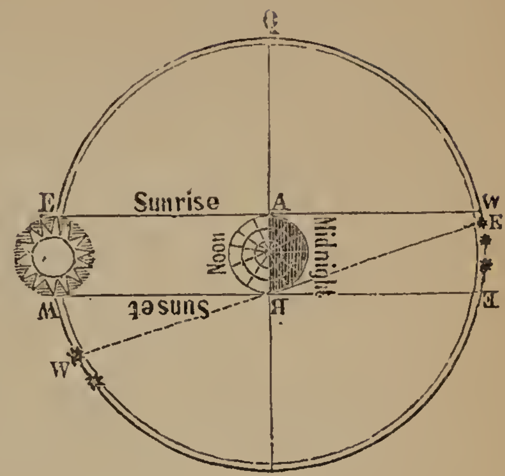
It does not, but in the opposite direction, or toward the east.

911. What have you to say of the apparent daily revolution of the sun around the earth?

It is a mere illusion, produced by the earth's rotation.

912. Show, by Fig. 150, that the rotation of the earth from west to east, would produce an apparent daily revolution of the sun in the opposite direction.

Fig. 150.



E A W represents the horizon at A; E is east and W is west. As the earth turns round, from west to east, the horizon is carried along with it, and goes down at E and rises at W.

913. What would happen, then, if the sun were at E?

The horizon would pass below it, and as we would be unconscious of the earth's motion, the sun would seem to us to come above the apparently stationary horizon, or rise.

914. How would it appear to move after that?

It would continue on toward the east, and arrive at Q at the hour of noon.

915. In twelve hours from sunrise how far will the earth's rotation have carried us?

Around to B, and the sun will be setting at W., on the left of the figure. We conceive the earth to have been stationary all the while, and the sun appears to us to have passed over, in the sky, from E to W, on the right.

916. If the earth turns round, what is the reason that we are unconscious of the fact?

Because we partake of its motion, and can neither see nor feel it move.

917. When is the moon seen?

It shines distinctly only at night, but it may sometimes be seen in the sky during the day.

918. Does it appear to rise in the east, move across the sky, and set in the west like the sun?

It does, and for the same reason.

919. When are the stars seen?

At night only. The stars are not seen by day because the air above us is illuminated by the sun, and the strong light reflected from it effaces the light of the stars.

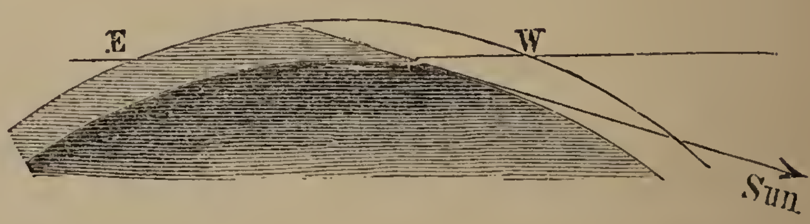
920. Why do not the stars shine out at once as soon as the sun has set, instead of coming out one by one?

Fig. 151.

Because the sun still continues to shine upon the upper air; just as his rays linger on the top of a lofty mountain for some time after he has set to the level country below.

921. Where is this fact made apparent to the eye?

Fig. 152.



In Fig. 152. The sun is below the western horizon. The portion of the atmosphere above the horizon, E W, that is not shaded, is still illuminated by the sun, and forms a veil of brightness through which the stars can not be seen.

922. What is the light called, that we thus continue to receive, by reflection from the atmosphere, for an hour or more after sunset?

Twilight.

923. What is the reason that it fades by slow degrees in the sky, until finally the stars shine out over the western horizon, and all traces of it have disappeared?

Because as the sun descends farther and farther below the horizon, the portion of the atmosphere that continues to receive light from him gradually becomes less and less.

924. Is there a gradual transition from night to day, before sunrise; or a morning as well as an evening twilight?

There is, and for a similar reason.

925. How are the stars affected by it?

They fade gradually, as the light increases in the sky, and disappear one after another according to their brightness.

926. Have the stars ever been seen during the day?

The brighter stars have been seen at the time of a total eclipse of the sun, when the sky has thus become dark during the day. They can also be seen, on any clear day, through a telescope.

927. Do the stars rise and set, and apparently move around the earth, like the sun and moon?

They do; the rotation of the earth makes all the heavenly bodies appear to move in this manner.

928. Illustrate by Fig. 150 (p. 159).

When the rotation of the earth bears us around beyond the position B, shown in the figure, the horizon will have a position such as is shown by the dotted line, and its continued motion will make the stars appear to rise at *e*, and set at *w*.

929. Do all the stars appear to rise and set every twenty-four hours?

The stars that are far to the north, remain constantly above the horizon, and do not rise and set.

930. How do they appear to move?

In circles around a fixed point in the northern heavens, called the *North Pole* of the heavens.

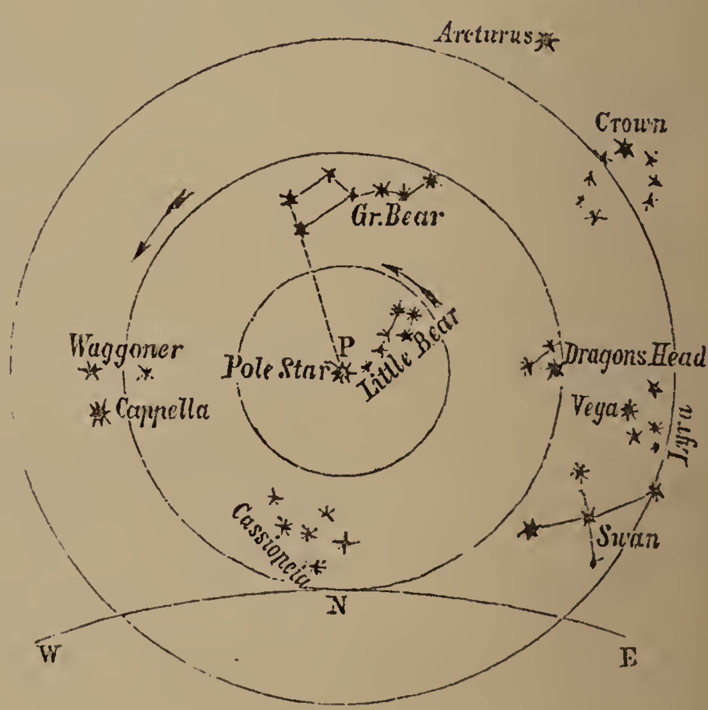
931. In what direction do they revolve around the pole?

In a direction contrary to the motion of the hands of a watch.

932. Explain Fig. 153.

It represents some of the stars of the northern heavens. P is the pole, and the stars move around this point in the direction shown by the arrows. W N E is the circle of the horizon.

Fig. 153.



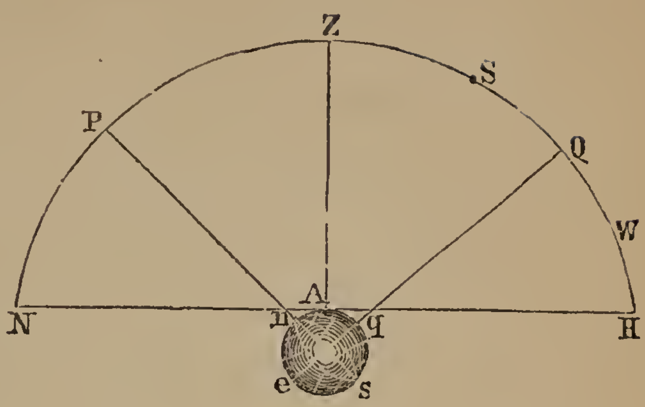
933. Is the place of the stationary pole in the heavens occupied by a star?

There is a bright star near the pole, and for this reason called the *Pole Star*.

934. What is the situation of the elevated pole in the heavens with respect to the north pole of the earth?

It is directly over it, as shown in Fig. 154, where *n* is the north pole of the earth, and P the pole of the heavens.

Fig. 154.



935. On what line, then, is the elevated pole of the heavens situated?

It lies on the earth's axis prolonged upward.

936. What general apparent movement of the sphere of the heavens is produced by the rotation of the earth?

In consequence of the earth's rotation about an axis, the whole heavens appear to rotate about the same line in the contrary direction.

937. How many degrees are there in the distance from the elevated pole down to the northern horizon; that is, from P to N, in Fig. 154?

The same number of degrees that there are in the latitude of the place.

938. What is the imaginary circle that passes through the pole and the zenith called?

The *Meridian* of the place. It is represented by N P Z Q, in Fig. 154.

939. Where does the equator in the heavens cross the meridian?

To the south of the zenith, a distance equal to the latitude of the place.

940. Illustrate by Fig. 154.

The equator crosses the meridian at Q, in the figure; and there are as many degrees from Z to Q as from A to *q* on the earth.

941. How are the stars classified?

There are two classes of stars, called, respectively, *Fixed Stars* and *Planets*.

942. What are fixed stars?

The greater number of stars preserve constantly the same positions in space, and are called fixed stars.

943. How have they been arranged by ancient and modern astronomers?

Into groups called *Constellations*.

944. What stars are represented in Fig. 153?

The principal stars of several of the northern constellations.

945. Mention the names of the constellations shown in the figure.

Great Bear, Little Bear, Cassiopeia, Swan, Lyra, Dragon's Head, Northern Crown, Wagoner.

946. What name is given to the two stars of the Great Bear farthest from the tail?

They are often called *Pointers*, because the line of these stars points to the pole star.

947. What are planets?

Stars which are not stationary in the heavens, but wander from one constellation to another.

948. How many planets are there?

There are seven principal planets, and forty-seven smaller and less noticeable ones, called *Asteroids*.

949. Mention the names of the principal planets.

Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune

950. Are they all visible to the naked eye?

All, with the exception of Uranus and Neptune.

951 Which are the brightest and most conspicuous?

Venus and Jupiter. These two planets are generally more brilliant than any of the fixed stars.

952. Describe Mars and Saturn.

Mars is a bright planet of a reddish color. Saturn shines with a pale dull light.

953. Do the planets wander on from one constellation to another, until they have made the circuit of the heavens?

They do; but they are occasionally seen stealing backward.

954. Do they actually revolve around the earth in space?

They do not; they all wheel in circles around the sun.

955. What heavenly body performs its circuit around the earth?

The moon. It passes entirely around the earth in $27\frac{1}{3}$ days.

956. In what direction does the moon move among the stars in the heavens?

From west to east.

957. Is the sun apparently stationary in the heavens?

It is not; it appears to revolve around the earth in the same direction that the moon does.

958. Does the sun actually revolve around the earth?

On the contrary, it is the earth that revolves around the sun.

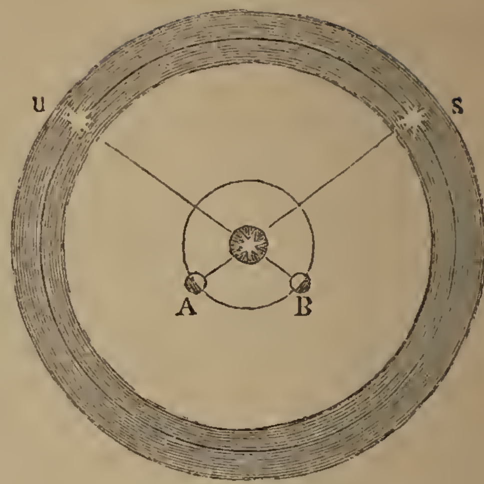
959. What makes the sun appear to go around the earth?

The revolution of the earth around the sun.

960. Explain by means of Fig. 155.

If the earth moves forward from A to B, the sun will appear to move from *s* to *u* in the heavens.

Fig. 155.



961. What effect has the sun's apparent motion upon the hours of rising and setting of the stars?

It causes them to rise and set earlier every day than on the preceding day.

962. Will the same constellations, then, be seen in the same quarter of the heavens, every evening in the year?

They will not. At opposite seasons of the year, the same constellations will have opposite positions; so that, with the exception of the northern constellations, which never set, the constellations visible at the same hour in the evening will generally be different.

963. What is the *Zodiac?*

It is a narrow belt of the starry heavens within which the sun and moon and most of the planets pursue their apparent circuits around the earth.

964. What does Fig. 156 represent?

The celestial girdle of the zodiac jeweled with stars.

965. How is it divided?

Into twelve equal portions, called the *Signs of the Zodiac.*

Fig. 156.

966. Mention the names of these signs.

Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.

967. On what day of the year does the sun enter the sign Aries?

On the 21st of March, the day of the vernal equinox.

968. What names have been given to the constellations that lie within the limits of the zodiac?

The same that have been given to the signs of the zodiac.

969. Do the constellations of the zodiac occupy the same place with the signs of the same names?

They did in very ancient times; but the signs have since moved backward in the heavens so far, that the sign Aries now nearly corresponds with the constellation Pisces.

THE SOLAR SYSTEM.

970. When we are traveling on a railroad, we notice that trees and other objects near by are constantly shifting their apparent relative positions. In the same way, as the earth proceeds on its course around the sun, our point of view in reference to the heavenly bodies is constantly changing; do the fixed stars appear to change their relative positions on this account?

They do not; the constellations constantly present the same appearance, from whatever position of the earth in its orbit they are viewed.

971. What may we infer from this remarkable fact?

That the whole extent of the earth's orbit is but a mere point in comparison to the vast expanse of space that separates it from the stars.

972. Of what heavenly bodies does the Solar System consist?

The solar system consists of the sun and the bodies that revolve around the sun.

973. What bodies revolve around the sun?

The earth, with the moon circulating around it, and the planets.

974. Are any of the planets attended by revolving bodies, as the earth is by the moon?

Jupiter, Saturn, Uranus, and Neptune have such attendants, or *Satellites*, as they are called.

975. Are there any other bodies belonging to the solar system?

There is another class of bodies that move around the sun, called *Comets*, or hairy stars, from their peculiar appearance. These are only seen occasionally.

976. Mention the principal planets (including the Earth) in the order of their distance from the sun.

Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

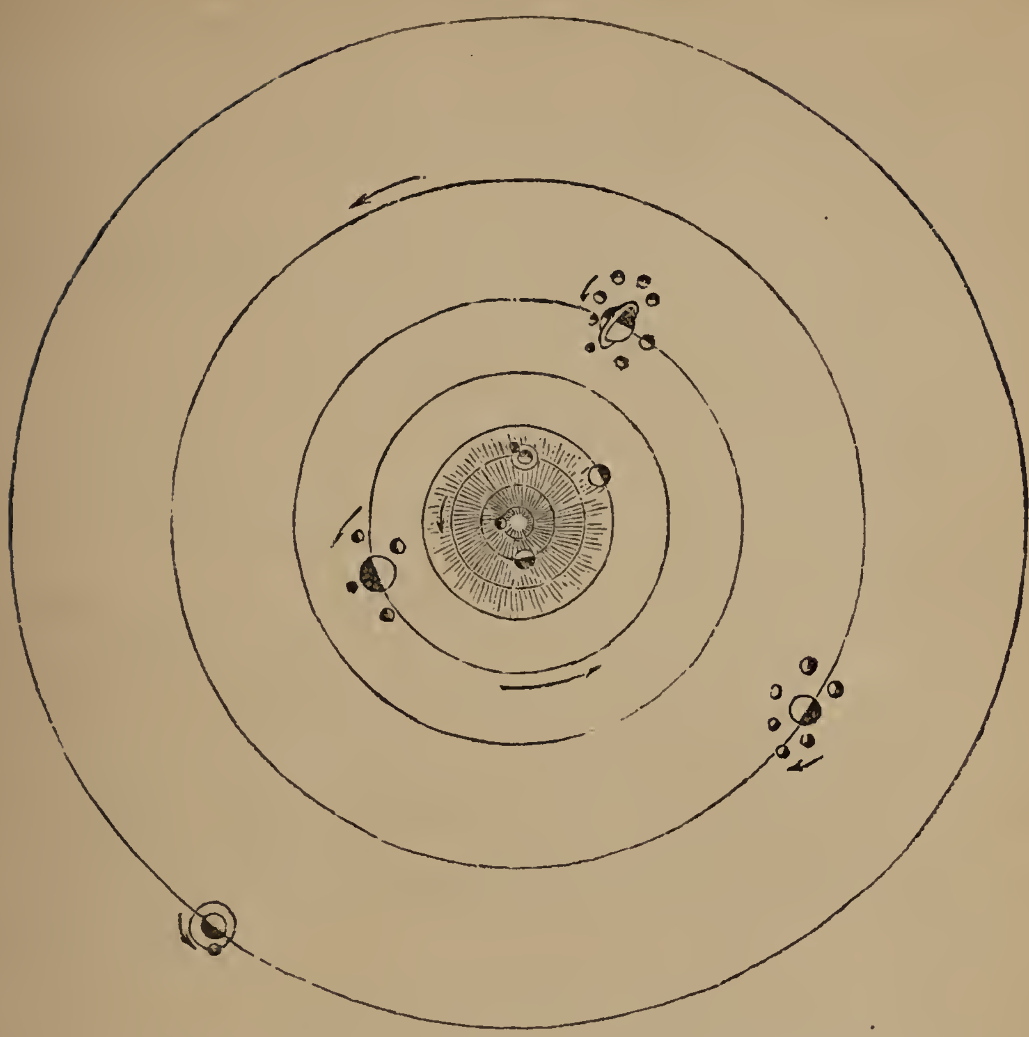
977. Between what two planets do the forty-seven asteroids revolve?

Between Mars and Jupiter.

978. What does Fig. 157 show?

The circular paths or orbits of the principal planets, and also the revolution of the moon and the other satellites.

Fig. 157.



979. In what direction do the planets and satellites revolve?

In a direction contrary to the motion of the hands of a watch, as the arrows show.

980. Is there any exception to this general rule?

The satellites of Uranus furnish one exception. These all revolve in the same direction that the hands of a watch turn.

981. In what direction do the earth and planets turn about their axes?

In the same direction that they revolve around the sun.

982. Who first advocated the doctrine that the earth revolves around the sun in company with all the planets, and that the earth turns about an axis?

The celebrated astronomer Copernicus, who lived 300 years ago.

983. What force is it that constrains the earth and the planets to follow a circular path around the sun?

The attractive force of the sun.

984. How does this force operate?

It draws the planet incessantly out of the straight course it would otherwise pursue, into a circle.

985. What force maintains the moon in its orbit around the earth?

The attraction of the earth for the moon.

986. Who first discovered the existence of this force operating throughout the solar system, and binding all its parts together?

Sir Isaac Newton made this wonderful discovery in the year 1683.

987. What is this force called?

Universal Gravitation.

988. Where do the fixed stars lie in space?

They are dispersed in every direction around the solar system, but at such enormous distances from it, that the whole solar system dwindles into insignificance in comparison.

989. What is an *astronomical observatory?*

It is a building of a peculiar construction, fitted up with telescopes for observing the heavenly bodies, and with various instruments for ascertaining their directions, and following them in their motions.

990. To what other purposes are astronomical instruments applied?

The astronomer, also, from his observatory, sounds the depths of the starry heavens, measures the distance and size of the sun and of the planetary worlds that circle around him, and weighs them, as it were, in a celestial balance.

DIMENSIONS OF THE SOLAR SYSTEM.

991. Are the sun, moon, and planets all round bodies, like the earth?

They are, but of various sizes.

992. Are the moon and planets self-luminous bodies?

The moon and all the planets are opake, non-luminous bodies, and shine by reflecting the light they receive from the sun.

993. If a globe two feet in diameter be taken to represent the sun, how large a ball would represent the earth, on the same scale?

A ball the size of a pea, or less than one quarter of an inch in diameter.

994. How many feet would represent the distance of the earth from the sun?

Two hundred and fourteen feet?

995. How many inches the distance of the moon from the earth?

Six and a half inches.

996. What would be the distance of Mercury and Venus from the sun, on the same scale?

Mercury would be 82 feet distant, and Venus 155 feet.

997. How would the distances of Mars, Jupiter, Saturn, Uranus, and Neptune be represented?

The distance of Mars by 327 feet; of Jupiter by less than a quarter of a mile; of Saturn by less than half a mile; of Uranus by three-quarters of a mile; of Neptune by a mile and a quarter.

998. What does Fig. 158 represent?

The comparative distances of the planets from the sun.

999. Mention the periods of revolution of the principal planets.

Mercury completes a revolution around the sun in 3 months; Venus in $7\frac{1}{2}$ months; the Earth in $365\frac{1}{4}$ days, or one year; Mars in a little less than two years; Jupiter in about 12 years; Saturn in $29\frac{1}{2}$ years; Uranus in 84 years; and Neptune in $164\frac{1}{2}$ years.

1000. How many generations of men succeed each other on the earth while Neptune is accomplishing his annual circuit around the sun?

Five.

1001. Mention the planets in the order of their magnitude, beginning with the largest.

Jupiter, Saturn, Uranus, Neptune, the Earth, Venus, Mars, Mercury.

Fig. 158.

1002. If the sun be represented by a globe two feet in diameter, what familiar object would serve to show the comparative size of Jupiter?

A moderate-sized orange.

1003. How might the other planets be represented in their comparative magnitudes?

Saturn by a small orange; Uranus and Neptune by good-sized cherries; the Earth and Venus by peas; Mars by a rather large pin's head; and Mercury by a grain of mustard seed.

1004. Do the planets turn upon axes, like the earth?

The planets rotate, like the earth, in the same direction that they revolve around the sun.

1005. What is the direction of their motion of rotation, as seen by an observer looking down upon the north pole of the planet?

Contrary to the direction in which the hands of a watch turn.

1006. In what periods of time do they complete a rotation?

Mercury, Venus, and Mars, in about 24 hours. Jupiter and Saturn, in about 10 hours.

1007. How much less light and heat does Neptune receive from the sun than the Earth does?

Nine hundred times less.

1008. How does the sun's light on the surface of this remote planet compare with the light we receive from the full moon?

The sun gives as much light to Neptune as 330 full moons would shed upon the Earth.

1009. How much light and heat is bestowed upon Mercury?

Six and a half times as much as the Earth receives.

1010. Have we good reason to suppose that the planets are habitable globes like the earth, and are in fact inhabited by rational beings?

We have; they would seem to be fitted to be the abodes of living and rational beings by the same beneficent provisions by which life is maintained and gladdened on the earth.

1011. What are some of these provisions?

The sun shines for the planets, as for the earth; day and night succeed each other on their surfaces; and each revolving year the seasons come and go with all their genial variety, as upon the earth. Most if not all of the planets are provided with atmospheres, and many of them are attended by circling moons to give light to them by night.

CHAPTER IX.

DESCRIPTIVE ASTRONOMY.

THE SUN.

1012. WHAT is the part performed by the sun in the solar system?

The sun maintains the planets in their orbits by his powerful attraction, and dispenses to all of them the genial influences of light and heat.

1013. What is the size of the sun?

It is nearly a million and a half times larger than the earth. The diameter of the sun is 112 times greater than the diameter of the earth, or 888,000 miles.

1014. If the centre of the sun were placed at the centre of the earth, how far would its enormous bulk extend?

To nearly twice the distance of the moon.

1015. What do astronomers, on viewing the sun through a telescope, often discern on his disc?

Dark spots of various sizes and forms.

1016. What appearance do these spots generally present?

A black spot is seen surrounded by a dark border; sometimes the same border incloses a number of black spots.

Fig. 159.

1017. Are they seen usually as single detached spots?

They generally appear in clusters, composed of various numbers, from two to a hundred.

1018. Are spots seen on the sun's disc every year?

In some years they are very numerous; in others few, if any, are seen.

1019. What general rule may be stated about their appearanee?

They occur in greater numbers, and of a larger size, at regular intervals of ten or eleven years.

1020. What is the aetual size of the largest spots that have been observed?

Spots have been seen that were two or three times as large as the entire surface of the earth.

1021. What is the size of the smallest spot that can be discerned on the surface of the sun with a good telescope?

An area about 450 miles in length and breadth, or somewhat larger than the State of New York.

1022. Is the sun a world on fire?

It is not; it is a dark, solid body, like the earth, surrounded by a luminous atmosphere.

1023. From what are the light and heat of the sun supposed to proceed?

From self-luminous clouds in the sun's atmosphere, several thousand miles above the solid body of the sun.

1024. Do we ever see self-luminous clouds in the earth's atmosphere?

The auroral clouds that now and then, in the evening, light up our northern sky, are self-luminous, like the supposed solar clouds.

1025. What is the explanatiou of the sun's spots?

They are supposed to be the dark body of the sun, seen through rents made in its luminous envelope.

1026. Has the sun a motion of rotation about an axis, like the earth?

It has, and completes a rotation in 25½ days.

1027. How does the mass of the sun compare with the united mass of the planets?

The huge globe of the sun contains more than 700 times as much matter as all the planets united.

THE EARTH.

1028. What is the velocity of the earth in its annual circuit around the sun?

Nineteen miles per second.

1029. How much faster does the earth speed on its course than a cannon ball flies through the air?

Fifty times faster.

1030. What is the rate of rotation of a point on the earth's equator?

1,520 feet per second, or a little over 1,000 miles per hour.

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1031. What is the rate at which points on the earth's surface are carried toward the east, by the earth's rotation, at the latitude of 40°?

Not quite 800 miles per hour, and it is still less farther to the north.

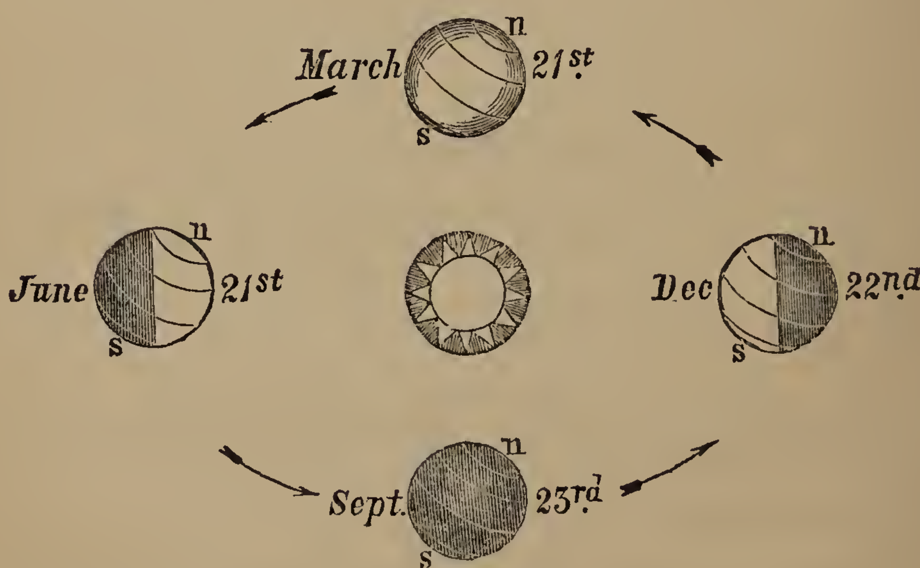
1032. We have seen that light would pass round the earth eight times in a second—in what length of time does a ray of light come from the sun to the earth?

In 8 minutes and 18 seconds. In this interval of time it passes over 95,000,000 of miles.

1033. What is the reason that the days are longer in the summer than in the winter, and that the nights are shorter?

Because in the summer the north pole of the earth is turned toward the sun, and in the winter is turned away from him. This is illustrated in Fig. 160.

Fig. 160.



1034. What does the figure show?

That in June the sun shines beyond the north pole, and upon more than half of the northern hemisphere; and that in December the light of the sun does not reach the north pole, and falls upon less than half of the northern hemisphere.

1035. How does the annual change in the length of the days result from these facts?

The figure shows that as the earth turns round, we remain, in the summer, longer in the light than in the dark; and that in the winter it is the reverse of this.

1036. When are the days the longest and the nights the shortest?

About the 21st of June.

1037. When are the days the shortest and the nights the longest?

About the 22d of December.

1038. Is the longest day of the same length all over the earth?

It increases in length from the equator to the pole.

1039. Are the days of unequal length at the equator?

At the equator the day is always 12 hours long, and the night is of the same length.

1040. What is the length of the longest day, as well as the longest night, at the polar circle?

Twenty-four hours.

1041. What is its length in latitude 74 degrees?

Three months.

1042. How many days and nights are there in the year, at the pole?

The year is there divided into one day and one night; each of six months' duration.

1043. How long does the twilight that precedes and follows the polar day of six months last?

About a month and a half.

1044. Do the remaining three months of the polar night form a period of complete darkness?

They do not; the moon is above the horizon during one half of this interval, and darkness is often dispelled from the polar sky by the Northern Lights.

1045. What is the apparent motion of the sun in the course of 24 hours, as seen from the pole?

His round orb skirts along the circle of the horizon, and accomplishes its entire circuit every 24 hours.

1046. At what periods in the year are the days and nights of equal length, at all parts of the earth?

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

1047. What are these periods called?

The Equinoxes.

1048. What is the position of the sun with respect to the poles of the earth on these days?

The sun shines directly down upon the equator, and illuminates both poles alike. The positions of the earth at the two equinoxes are shown in Fig. 160.

1049. What is the explanation of the annual change of seasons?

The change of seasons is another consequence of the varying position of the poles.

1050. How does that appear?

When the north pole of the earth is turned, in the summer months, toward the sun, not only are the days longer, but the sun shines down more directly upon the northern hemisphere.

1051. What is Fig. 161 designed to show?

Fig. 161.

That, at noon, a smaller number of solar rays fall upon any given space on the earth's surface in winter than in summer.

1052. What consequence follows from the two facts just mentioned?

The northern hemisphere receives, from these two causes combined, more heat from the sun in the summer than in the winter months.

1053. What is the simple provision by which the beneficent Creator has secured to us the pleasing succession of seasons, and the varying length of days and nights?

By inclining the earth's axis, so that it should not be perpendicular to the plane in which the earth moves around the sun.

1054. It has been said that the earth has a globular form—is the the figure of the earth that of an exact sphere?

The earth is not a perfect sphere; it is really somewhat flattened at its poles.

1055. To what extent is it flattened?

So that the poles are 13 miles nearer the centre of the earth than the equator is.

1056. Is the earth's orbit an exact circle?

Strictly speaking, it is slightly oval in its form.

1057. What consequence follows from this?

That the earth is a little nearer to the sun in our winter than in the summer.

1058. How much nearer is it on the 1st of January than on the 1st of July?

About $\frac{1}{30}$ nearer.

1059. Do the orbits of the planets and the orbit of the moon deviate in their form from true circles?

They have the same slightly oval form as the orbit of the earth.

1060. Who first discovered the elliptical form of the planetary orbits?

Kepler, a German astronomer, immortalized his name by this and other kindred discoveries, made early in the seventeenth century.

1061. What is the phenomenon known by the name of the *Tides?*

A rise and fall of the surface of the ocean twice in the course of a lunar day, or about 25 hours.

1062. What is the rise of the water called?

Flood Tide; and the fall is called *Ebb Tide.*

1063. What is the interval between one high tide and the next?

The average interval is $12\frac{1}{2}$ hours.

1064. What is the interval between high tide and low tide?

About six hours.

1065. How much later does high tide occur each day than on the preceding day?

About 50 minutes later, on the average.

1066. What is the cause of the tides?

The tides are produced by the attractive action of the sun and moon upon the waters of the ocean; chiefly by the attraction of the moon.

1067. What fact indicates that the attraction of the moon is the efficient cause by which the tides are produced?

It is observed that the time of high water depends upon the position of the moon, and at any given place is always about the same length of time after the moon's passage over the meridian.

1068. Does the moon draw up the waters of the sea by the direct exertion of its whole attractive force?

It does not; but by acting unequally on different portions of the sea.

1069. What is the direct result of this unequal action?

The waters under the moon are made lighter and those in the distance are made heavier.

1070. What happens in consequence?

The surface of the ocean falls where the waters are made heavier, and rises where they are made lighter.

1071. What fact shows that the sun has some effect in producing the tides?

The fact that the tides are highest about the times of new and full moon, and lowest at the first and last quarters.

1072. Why should this be the case if the sun acts in connection with the moon to raise the tides?

Because at new and full moon the two bodies would tend to produce the same effect, and at the first and last quarters would be opposed to each other.

1073. What are the tides that occur about new and full moon called?

Spring Tides; and those which occur at the first and last quarters of the moon are called *Neap Tides.*

1074. How much higher are the spring tides than the neap tides at New York?

Two feet.

1075. Why are there no tides on the large Western lakes?

Because those bodies of water are not so large that the moon acts unequally upon their different parts.

1076. How do the actual tides of the Atlantic and Pacific oceans compare with the tides that would be produced if the earth were covered entirely with water?

They are very different; the tides are very much modified by the continents.

1077. At what locality on the Atlantic coast of this continent do the highest tides occur?

At the head of the Bay of Fundy.

1078. How high does the spring tide rise in the Bay of Fundy?

To the height of 60 or 70 feet.

1079. What is the average height of the tides at Boston harbor?

Ten feet.

1080. What is it in the harbor of New York?

Four feet and one third.

1081. Do the day and night tides rise to the same height?

They do very nearly on the Atlantic coast of the

United States, but on the Pacific coast, as a general rule, there is one large and one small tide each day.

1082. What remarkable peculiarity do the tides in the Gulf of Mexico present?

On the northern shore of the Gulf of Mexico, from Florida to Texas, there is but one high and one low tide each day.

1083. What is the height of this single-day tide?

About one foot.

1084. In what direction does the great tidal wave of the Atlantic Ocean approach the eastern coast of the United States?

Nearly at right angles to the general direction of the coast. In like manner the tidal wave of the Pacific Ocean, as it approaches the western coast, is nearly parallel to its general direction.

THE MOON.

1085. How does the earth compare with the moon in size?

It would take 50 moons to make a world as large as the earth.

1086. How much smaller is the surface of the moon than the surface of the earth?

Thirteen times smaller.

1087. Does the moon turn upon an axis, like the earth?

It does; and at the same rate that it revolves around the earth.

1088. What is the consequence?

The same half of the moon is turned all the while toward the earth, and therefore we never see the other half.

1089. How can this be illustrated?

By taking an apple in the hand, and walking in a circle around a candle, and at the same time turning the apple, so as to keep the same side always toward the candle.

1090. How long is the solar day on the surface of the moon?

A day, on the moon's surface, contains $29\frac{1}{2}$ of our days.

1091. Has the moon an atmosphere?

It has not; at least it is known that its surface is as free from air as any vacuum we can obtain with an air pump.

1092. Are there any seas or other bodies of water on the moon's surface?

There are none on this side of the moon, and it is highly probable that there are none on the other side.

1093. From what may we draw this inference?

From the fact that the face of the moon is never covered with mists or clouds.

1094. Does the surface of the moon resemble the surface of the earth?

It is diversified by mountains, valleys, and plains, like the earth's surface, but is more rugged and mountainous.

1095. What are the large, dark spots that we see on the moon's disc?

The more level parts of the surface.

1096. What were these spots formerly supposed to be?

It was once supposed that the dark spots were seas, and they were named accordingly; but it is now known that they are covered with hills, and empty hollows, and therefore can not be bodies of water.

1097. What are the brighter portions of the moon's face?

The mountainous regions; these shine in the light of the sun with a silvery lustre.

1098. Do the mountains form distinct ranges on the moon, as on the earth?

There are long ranges of lunar mountains; but this is not the prevailing feature.

1099. What is the prevailing feature?

Circular mountain formations; that is, walls, or ranges of mountains, encircling a plain.

1100. Is the inclosed plain on a level with the general surface of the moon?

It is generally sunk much below it, forming vast caverns or craters.

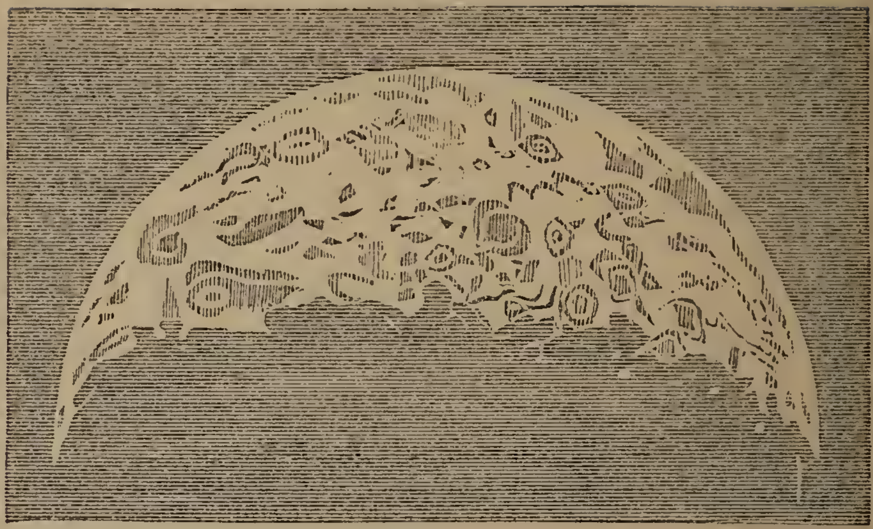
1101. What is the depth of these sunken plains?

In some instances they are three and a half miles deep.

1102. How have these remarkable facts with regard to the moon been ascertained?

Astronomers have made these discoveries by the aid of large telescopes, and other instruments.

Fig. 162.



1103. What does Fig. 162 represent?

The appearance of the crescent moon as seen through a telescope.

1104. What makes the lower edge so irregular?

The sun is just rising along this edge, and the moon's surface is very much broken up into mountains and depressions.

1105. What are the bright spots and lines on the dark part of the moon's face, near this edge?

They are the tops of mountains and mountain ranges, illuminated by the rising sun, while the valleys and plains below are still in darkness.

1106. What are the dark spots on the bright face?

The shadows of mountains, and deep craters into which the light of the sun does not penetrate.

1107. What is the greatest height of the lunar mountains?

Nearly five miles.

1108. Mention a curious fact with regard to certain mountains in the polar regions of the moon's surface.

At the poles of the moon there are mountains upon whose lofty summits the sun never sets. It may be truly said that eternal sunshine rests upon their heads.

1109. We sometimes see the moon as a crescent, sometimes as a half circle, and sometimes as a full circle—what are these different appearances which the moon presents called?

The moon's *Phases.*

1110. In what length of time does the moon pass through all its phases?

Its disc increases from a slender crescent to a full circle in about a fortnight, and then wanes to a small crescent again in another fortnight.

1111. What is the reason of these changes?

That half of the moon which is turned toward the sun is illuminated by the sun, while the other half is in the dark, and invisible.

1112. Explain further.

We see more of the luminous half in some positions than in others. When the moon is directly between us and the sun, we do not see any of it; when she is a little beyond that position, a small portion of the luminous face comes into view, and has the appearance of a narrow crescent.

1113. She now begins to fill her horns with light. As she revolves beyond this position, what happens?

We see more and more of the luminous face, and the disc gradually enlarges to a half circle, and afterward to a full circle.

1114. What does Fig. 163 show?

Various positions of the moon in the orbit she describes around the earth, and the corresponding phases. The sun is supposed to be on the left.

Fig. 163.

1115. When the moon is just between the earth and sun, what do we say?

That it is *New Moon.*

1116. When the moon is one quarter of the way round from this first position, and appears as a half circle, what do we say?

That it is the *First Quarter.*

1117. How is it when the moon is half way round, and its shining disc is a full circle?

We then say it is *Full Moon.*

1118. When it has performed three quarters of a revolution, and the disc has decreased to a half circle, what do we say?

We say it is the *Last Quarter.*

1119. What is a *Lunar Month?*

The interval of time in which the moon passes from New Moon around to New Moon again.

1120. How long is this interval?

Twenty-nine and a half days.

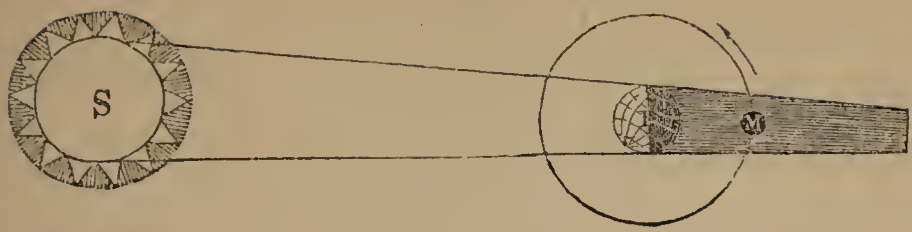
1121. Does it ever happen that the full moon is deprived for a time of the light of the sun?

This phenomenon is occasionally observed. The moon is then said to be *eclipsed.*

1122. How does the moon become eclipsed?

By passing into the shadow of the earth, as we see represented in Fig. 164.

Fig. 164.



1123. Is the moon entirely invisible while it is passing through the earth's shadow?

It is not; its disc is still seen shining with a dull reddish light.

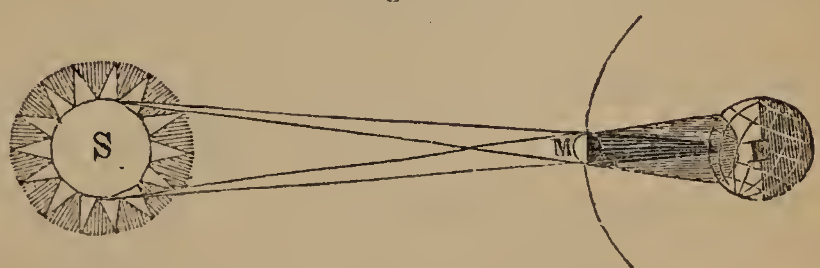
1124. What is the explanation of this curious fact?

The earth's atmosphere is supposed to act like a lens, and refract a certain portion of light into the interior of the shadow.

1125. Does the moon in circling around the earth, ever come directly between us and the sun, so as to conceal more or less of his disc?

This sometimes happens, and we then say, the sun is eclipsed.

Fig. 165.



1126. What can you say of Fig. 165?

That it shows the moon in such a position, casting its shadow on the earth. Where this shadow falls, the sun is eclipsed.

1127. What is the form of the moon's shadow?

It tapers toward a point.

1128. By what is it surrounded?

By a space that receives light from only a portion of the sun's disc; this is called the *Penumbra*.

1129. Is a part of the sun's disc, then, invisible at all places on the earth on which the penumbra falls?

It is, and the eclipse is said to be *Partial*. Where the shadow falls, the whole disc is obscured, or the eclipse is *Total*.

1130. What is the size of the moon's shadow as thrown on the earth?

It is never more than 130 miles broad.

1131. What is the breadth of the penumbral shadow?

It can not exceed 5,000 miles. The shadow is usually of an oval form, and its length may be greater than this.

1132. In what direction does this shadow move across the earth?

It moves, like the shadow of a flying cloud, over the face of the earth toward the east.

1133. How does it happen that an eclipse of the sun does not occur every new moon?

Because the moon generally passes the sun either on the north or south side of him.

1134. Why is not the moon eclipsed every full moon?

Because it usually passes to the north or to the south of the earth's shadow.

1135. Does not the moon move around the earth in the same level plane in which the earth moves around the sun?

Very nearly, but not exactly.

1136. When the moon comes between the sun and earth, is its shadow always long enough to reach as far as the earth?

It often falls short of the earth. In such instances there can not be a total eclipse, but there may be an

Annular eclipse; that is, the visible portion of the sun's disc may have the form of a ring.

1137. How long may an annular eclipse of the sun last at any one place?

Twelve and a half minutes.

1138. How long may a total eclipse of the sun last at one place?

Eight minutes.

1139. Is there any appearance of light in the sky at the place occupied by the sun, during a total eclipse?

There is. The dark body of the moon appears to be surrounded with a halo, or corona of light; and is fringed at certain parts with beautiful *rose-colored* flames.

1140. What inference may we draw from this fact?

We may infer that the bright surface of the sun is surrounded by a body of luminous matter that extends far into space, and is perhaps continually flowing away from the sun.

1141. When will the next total eclipse of the sun, visible in the United States, occur?

On August 7th, 1869. It will be total in North Carolina and Virginia.

1142. How many eclipses of the sun occur each year, visible from some part of the earth?

There are never less than two eclipses of the sun in any one year, and there may be as many as five.

1143. Are eclipses of the moon as frequently seen as eclipses of the sun?

They are not, when we take the whole earth into account; but from any one locality, lunar eclipses are to be seen much oftener than solar eclipses.

MERCURY.

1144. How large is the planet Mercury?

Sixteen times smaller than the earth.

1145. Why is it so seldom visible to the naked eye?

Because it is so near to the sun in the heavens.

1146. What has been ascertained in relation to its physical peculiarities?

That it is a solid body, surrounded by a dense cloudy atmosphere.

1147. Do we ordinarily see the body of the planet?

It is supposed not; thick clouds glowing in the light of the sun usually screen it from view.

VENUS.

1148. How does Venus compare with the earth in bulk?

It is a very little smaller than the earth.

1149. What have you to say of its appearance?

That it is the brightest and most beautiful of all the planets. It is, in certain positions, so luminous as to cast shadows at night, and to be seen in broad daylight.

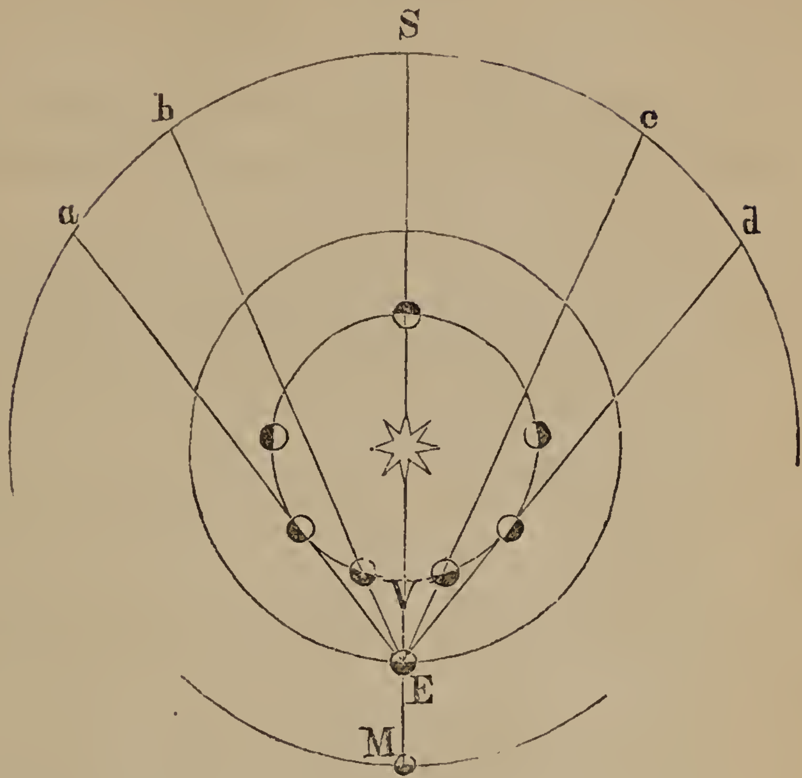
1150. What remarkable appearances does it present, when viewed at different times through a telescope?

The same variety of phases that the moon does.

1151. In what position is Venus when she appears as a crescent in the blue field of the telescope?

Between the sun and the earth; but to one side of the sun, as seen in the sky. Two such positions are shown near V, in Fig. 166. The corresponding apparent positions in the heavens are *b* and *c*; the sun appearing to be at S.

Fig. 166.



1152. What prediction was made by Copernicus, before the invention of the telescope, in reference to this planet?

It was boldly predicted by Copernicus that "should men ever see Venus better, they would discern her phases."

1153. By whom was this prediction verified?

By Galileo; directing the first telescope that had ever been pointed to the heavens, upon Venus, her spurious disc was gone, and a beautiful crescent hung trembling in its field of view.

1154. What other planet exhibits similar phases in the telescope?

Mercury; but the phases of this planet are less distinctly seen.

1155. Why is Venus called the *morning* and *evening star?*

Because it is either seen in the eastern sky in the early morning, or in the western sky early in the evening.

1156. What may we learn from Fig. 166?

That Venus may be seen, at different times, on either side of the sun in the heavens.

1157. How long does Venus continue to be an evening star?

She is an evening star for $9\frac{1}{2}$ months, and a morning star for the same length of time.

1158. In what part of the orbit does she appear as an evening star?

In that half of it which lies on the left or east side of the sun; and as a morning star in the other half.

1159. Is Venus, or Mercury, ever seen in the opposite quarter of the heavens from the sun?

It is apparent from Fig. 166 that these planets can never be on the opposite side of the earth from the sun.

1160. Is the same true of the other planets?

All the other planets revolve on the outside of the earth's orbit, and may be seen, at different times, at all angular distances from the sun in the heavens.

1161. Illustrate by the figure.

When the earth is at E, Mars might be at M, or in *opposition* to the sun, and would rise in the east about the time the sun was setting in the west.

1162. What is known of the physical peculiarities of Venus?

Venus is surrounded by a dense and cloudy atmosphere, like Mercury, and has lofty mountains on its surface.

MARS.

1163. What is the size of Mars?

Mars is seven times smaller than the earth.

Fig. 167.

1164. What is known with regard to the surface of this planet?

With the aid of telescopes, astronomers have frequently discerned spots of different shades on Mars, and have supposed they could see the outlines of continents and seas.

1165. Have the supposed continents and seas the same color?

The color of the continents is a dull red, and of the seas greenish.

1166. What is it that gives a red tint to the light of Mars?

The ruddy light reflected from the land.

1167. Are the outlines of continents and seas discernible on any of the other planets?

They are not.

JUPITER.

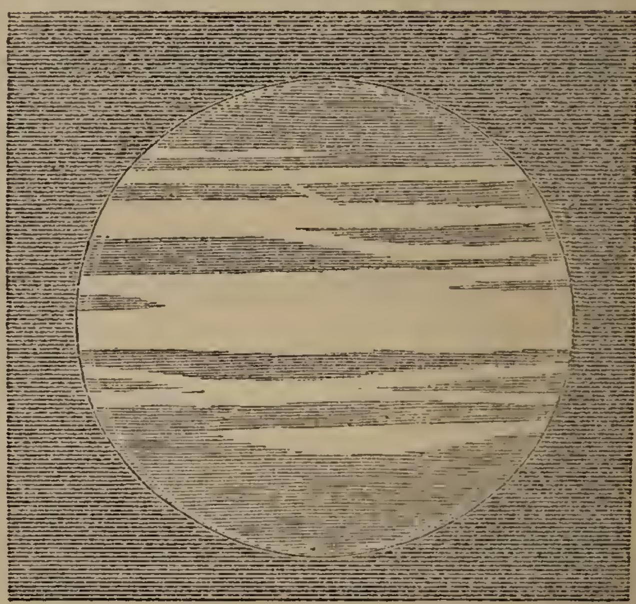
1168. It has been stated that Jupiter is the largest of the planets—how much larger is it than our earth?

It is more than 1,200 times the size of the earth.

1169. What is its diameter?

It is 11 times the diameter of the earth, or 87,000 miles.

Fig. 168.



1170. When Jupiter is examined with a good telescope, what are always observed on its disc?

Several dark streaks running parallel to his equator, called the *Belts* of Jupiter.

1171. Do the number, breadth, and situation of these belts remain always the same?

On the contrary, they are quite different at different times.

1172. What are these dark belts supposed to be?

The dark body of the planet seen through tracts of clear sky in a cloudy atmosphere.

1173. What is supposed to give them their common direction?

Prevailing winds, similar to the trade-winds on the earth, blowing nearly parallel to the equator.

1174. How many satellites has Jupiter?

Four; all of which can be seen in telescopes of the lowest power, and even in a common spy-glass.

1175. Do these satellites ever pass into Jupiter's shadow and become eclipsed?

The three satellites nearest to Jupiter are eclipsed every revolution. They are suddenly extinguished as they enter the shadow of the planet, and after a certain interval of time emerge from the shadow, and flash out again in a different place.

SATURN.

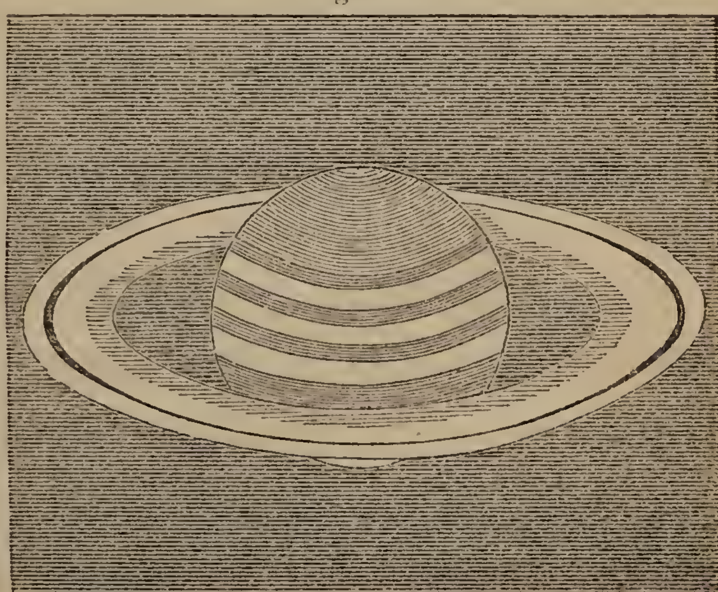
1176. How large is Saturn?

Saturn is nearly 1,000 times larger than the earth.

1177. Is its disc, like that of Jupiter, crossed by dark bands or belts?

Belts are sometimes observed on the surface of Saturn, but they are much less distinct than those of Jupiter.

Fig. 169.



1178. What is the great peculiarity of this planet?

It is surrounded by a luminous ring, entirely detached from the body of the planet.

1179. What is the size of this ring?

The diameter of its outer edge is 176,000 miles. The entire distance around this edge is no less than 553,000 miles, or 22 times the circumference of the earth.

1180. How far is the inner edge of the ring from the body of the planet?

19,000 miles.

1181. What are the breadth, and thickness of the ring?

Its breadth is 29,000 miles; its thickness is not more than 250 miles.

1182. Is the ring single or double?

It is double. The space between them, as it appears in telescopes of high power, is shown in Fig. 169.

1183. How many satellites attend upon Saturn?

Eight.

URANUS AND NEPTUNE.

1184. How much larger is the planet Uranus than the Earth?

It is about 80 times larger.

1185. Has any knowledge been obtained of the peculiarities of its surface?

Not as yet; no spots have ever been seen on his disc.

1186. How many satellites has Uranus?

Their number is not known with certainty; there are certainly four, and probably eight.

1187. How far is Uranus from the sun?

1,824,000 miles, or 19 times the Earth's distance.

1188. How far is Neptune from the sun?

Thirty times farther than the Earth.

1189. How does Neptune compare with Uranus in size?

It is a little smaller; its diameter is about 31,000 miles, or 4,000 miles less than the diameter of Uranus.

1190. Have any satellites been discerned attending upon Neptune?

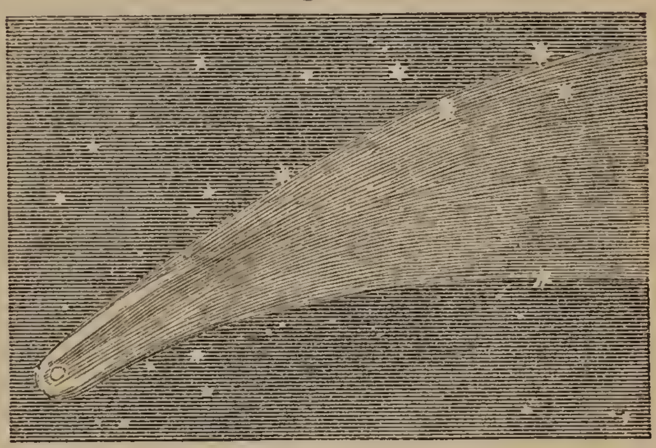
One has been seen. Prof. Bond, of the Cambridge Observatory, supposes that he has detected a second satellite, with his large telescope.

COMETS.

1191. What does Fig. 170 represent?

The usual appearance of a comet.

Fig. 170.



1192. What is the bright point on the left called?

The Nucleus; this and the luminous matter surrounding it, form the Head of the comet.

1193. What appears to proceed from the head in a direction opposite to the sun?

A stream or train of similar luminous matter.

1194. What is this called?

The Tail of the comet.

1195. Is it uniformly bright throughout its whole extent?

It decreases in brightness toward the end, and is less bright along the middle than at the borders.

9*

1196. What may we infer from the last mentioned fact?

That the tail is really hollow.

1197. Is the tail of a comet really curved, as shown in Fig. 170?

It is usually bent backward, as if it met with a resistance in passing through the ether of space. For example, the tail of the comet of 1744 was bent into nearly a quarter of a circle.

1198. Over how much of the sky does the tail of a comet extend?

The apparent length is very different for different comets; in some instances it has been enormously great.

1199. Two bright comets were seen in the years 1618 and 1769—how long were the tails of these comets?

They reached as far as the distance from the horizon to the zenith.

1200. Are all comets provided with the luminous appendage called a tail?

They are not; for example, the bright comet of 1682 had no tail.

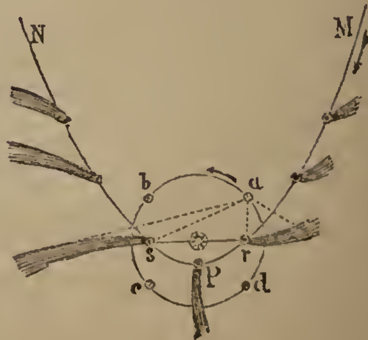
1201. Do comets move round the sun in circles?

Their paths through the fields of space differ very much from circles.

1202. What does Fig. 171 represent?

A portion of the orbit of a comet; the entire orbit is a long oval.

Fig. 171.



1203. What consequence follows from this form of a comet's orbit?

It follows that the comet alternately approaches and recedes from the sun.

In Fig. 171 the comet approaches the sun until it arrives at its *perihelion*, P, and then recedes from him.

1204. Do most comets, in moving away from the sun, withdraw to a very great distance from him?

The greater number of them pass far beyond the outermost limits of the solar system; and do not return until after the lapse of centuries.

1205. How near did the great comet of 1843 come to the sun?

Within 90,000 miles of his surface. This comet is now moving darkly away to its more distant goal, many thousand millions of miles from the sun.

1206. Are comets visible throughout an entire revolution?

They are visible during only a small part of their revolution, while they are in the vicinity of the sun.

1207. When will the comet of 1843 return to its *perihelion*, or nearest point to the sun, and display itself in our firmament again?

Some astronomers have predicted its return in 1865; others that it will not make its appearance until the year 2018.

1208. What was the velocity of this comet at the time of its nearest approach to the sun?

About 360 miles per second. It passed half way round the sun in about two hours.

1209. What have you to say in respect to the actual size of comets?

The nucleus is never more than a few thousand miles in diameter; but the cometic matter is disseminated, in the head and tail, over hundreds of thousands and even millions of miles.

1210. What was the greatest length of the tail of the great comet of 1843?

108,000,000 of miles.

1211. What is the nature and condition of the substance of comets?

We only know that it is far more rare and subtile than the thinnest film of vapor that ever makes its appearance in our sky.

1212. Is the tail of a comet permanently connected with the head?

Probably not. It is apparently made up of particles of nebulous matter flowing away very rapidly from the head.

1213. What force expels these particles and urges them to such enormous distances from the head of the comet?

A repulsive action exerted by the sun.

1214. How many of these remarkable bodies are there, connected with the solar system?

Their number is not known, but it is undoubtedly very large. There can not be less than several thousand comets revolving around the sun.

1215. Are the periods of revolution of all the comets that have been observed known and their times of return predicted?

The number of comets whose periods and times of return are known with certainty is comparatively small.

FIXED STARS.

1216. In a clear night the blue vault of the sky is studded with stars—how many of these stars can be seen at any one time at a given place?

Not more than 2,000.

1217. How many stars can be seen with the naked eye, in the whole heavens?

Not more than 7,000.

1218. Are the same constellations visible from all parts of the earth?

The constellations that lie around the south pole of the heavens never come above our horizon. At corresponding latitudes in the southern hemisphere of the earth, the same constellations never set.

1219. Which is the most conspicuous of these southern constellations?

The Southern Cross.

1220. How many stars are visible with the aid of telescopes?

Many millions.

1221. How much farther can a person see into space with the best telescope ever constructed than with the naked eye?

About 420 times farther.

1222. How are the fixed stars classified?

They are divided into stars of the *first magnitude*, stars of the *second magnitude*, etc., according to their apparent brightness.

1223. How many stars are assigned to the first magnitude?

From 20 to 24 only.

1224. Mention the names of some of the stars of the first magnitude which come above our horizon.

Sirius (or the dog-star), Arcturus, Regulus, Vega, Capella, Aldebaran.

1225. Which is the brightest star in the whole heavens?

Sirius. Vega is the brightest star in the northern heavens.

1226. How many stars are there of the second magnitude?

From 50 to 60.

1227. How many of the third magnitude?

200.

1228. How is it as we pass to the lower magnitudes?

The number increases rapidly.

1229. Is the difference in the brightness of the stars probably owing to a differenee of size or a difference of distance?

Chiefly, no doubt, to a difference of distance.

1230. Are the stars of our firmament dispersed in about equal numbers in every direction through space?

Fig. 172.

They are mostly disposed in a vast bed, of moderate thickness in comparison with its great extent.

1231. What is the position of the sun in this bed of stars?

The position of the sun is shown by the letter s.

1232. What consequence follows from the fact that the sun, with his attendant planets, is located in this thick bed of stars?

That the whole heavens appears to us to be encircled by a girdle of stars, so closely compacted together as to be separately invisible to the naked eye.

1233. What is this starry belt called?

The *Milky Way*.

1234. What is the estimated number of stars in the Milky Way?

Eight millions.

1235. How far from us is the nearest fixed star?

So inconceivably remote, that its light employs more than *three years* in journeying to us; although it darts from the sun to the earth in a little over eight minutes.

1236. How much farther removed are the most distant stars that faintly glimmer in the field of a telescope of medium power?

About 360 times farther. The light by which we now see them, started on its journey a thousand years ago.

1237. What is the nature and office of the stars?

They are doubtless the suns of other planetary systems, upon which they bestow the genial influences of their light and heat.

1238. What is our sun in the firmament of the inhabitants of those celestial worlds?

A fixed star.

1239. How would the sun, if seen from the distance of the nearest fixed star, appear?

No brighter than a star of the first magnitude does to us; it would not be so bright as Sirius.

1240. Do all the stars preserve their brightness unchanged from night to night and from year to year?

Some of them undergo regular variations of brightness; these are called *variable stars.*

1241. Do any of these stars continue to wane in lustre until they finally disappear, and then reappear again?

A few do; there is a variable star in the constellation of the Whale that dies out every 332 days, and remains in darkness for five months.

1242. Have new stars ever made their appearance in the heavens?

There are a few instances on record of stars that burst forth suddenly in great splendor, and after a time gradually died out again.

1243. What are *double stars*, *triple stars*, etc.?

Stars that appear single to the naked eye, but in telescopes seem to consist of two or more stars, very near together.

1244. Are there many such stars?

There are several thousand.

1245. Do the two individual stars that make up a double star retain the same relative position from year to year?

In numerous instances they are found to be revolving around each other.

1246. In what periods of time do they complete their vast circuits?

In periods varying from 30 to 600 years.

1247. Are all the fixed stars, so called, perfectly stationary in the heavens, from year to year?

They are not; great numbers of them are observed to be moving rapidly through space.

1248. Give an example of a star that is moving through space.

There is a star in the constellation of the Swan, called 61 Cygni, which is moving steadily forward in one direction, at the rate of 43 miles per second.

1249. Does this rapid movement produce any considerable change in the place of the star in the heavens, in the course of a year?

The change is so slight that it is only by very nice telescopic observation that it can be detected at all.

1250. How is this remarkable fact to be explained?

By considering the enormous distance of the stars. At the distance of the nearest star the whole solar system would occupy but a mere point on the face of the heavens.

1251. Is the sun stationary in space?

The sun, with his attendant system of planets, is moving through space at the rate of nearly five miles per second.

1252. *Clusters of stars* are seen in various parts of the heavens—mention one of the most conspicuous clusters.

The *Pleiades*.

Fig. 172

1253. Are there any clusters which can be seen in telescopes only?

A large number. For example, there is a beautiful cluster to be seen, with a good telescope, in the constellation Hercules.

1254. Are there not clusters visible as cloudy specks, in ordinary telescopes, that do not distinctly reveal their individual stars even in the largest telescopes?

There are many hundreds of such clusters scattered through space. In the field of view of the monster telescopes of the present day, these are but specks *of star-dust.*

1255. Are there not other clusters that are just discernible in the largest telescopes, as mere specks of light?

There are; the distance of some of these clusters is estimated to be no less than ten thousand times that of the nearest fixed star.

1256. When did the light that reveals their existence to us start on its journey?

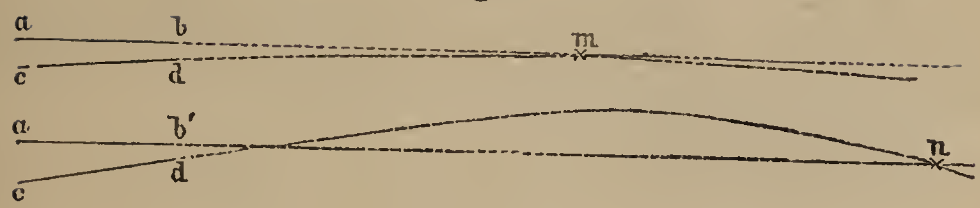
More than 30,000 years ago.

1257. Are clusters of stars, or *nebulæ*, all of one and the same form?

On the contrary, they occur of almost every variety of form.

ILLUSTRATIONS.

Fig. 10.



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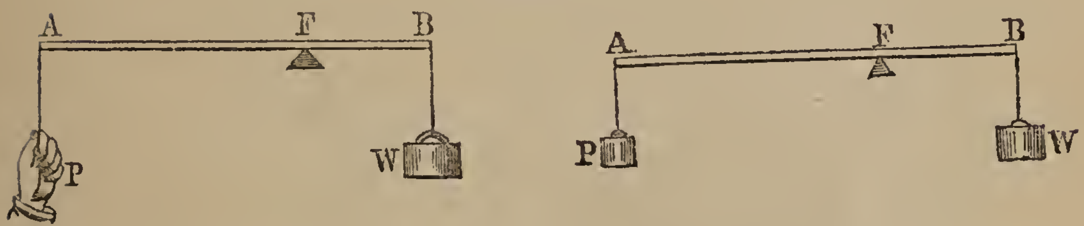
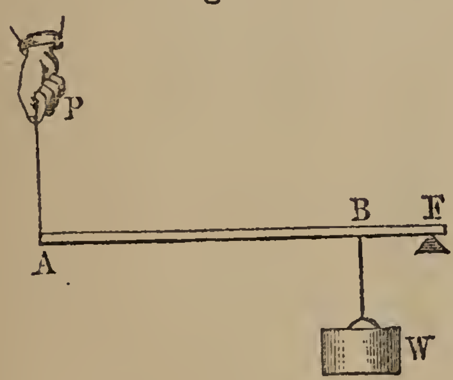


Fig. 33



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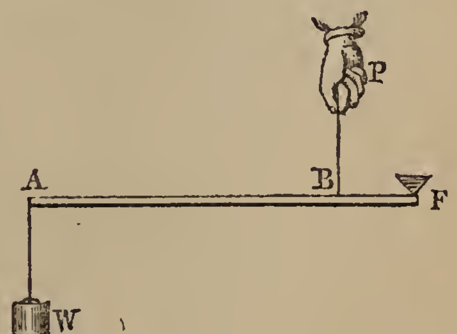

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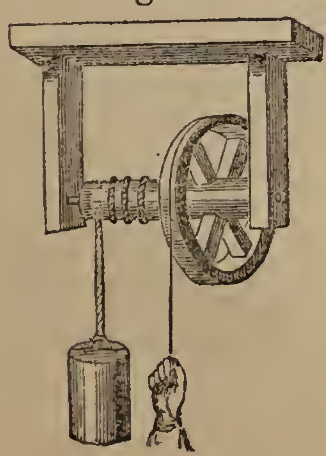

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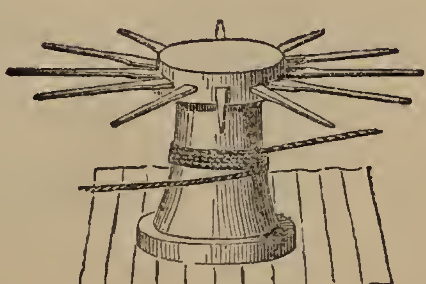

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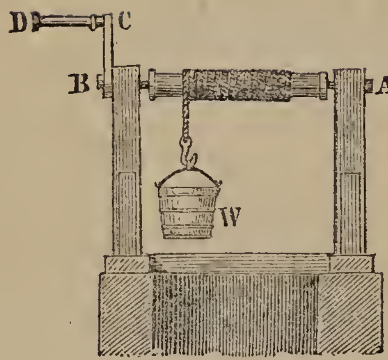

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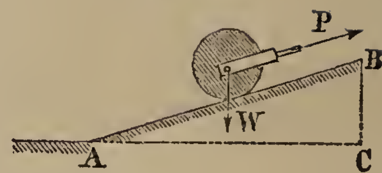

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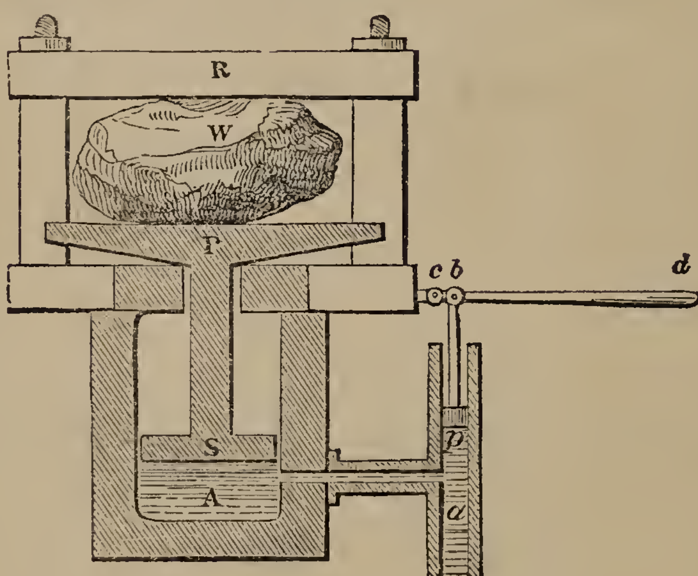

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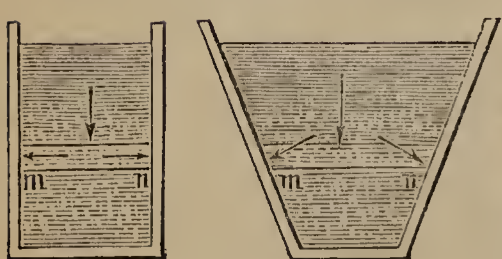

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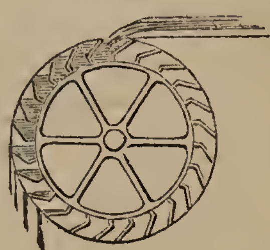

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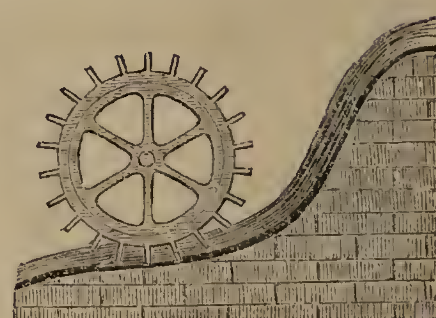

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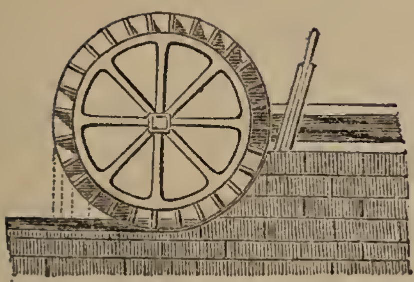

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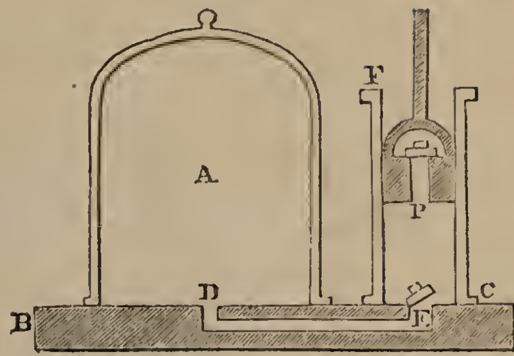

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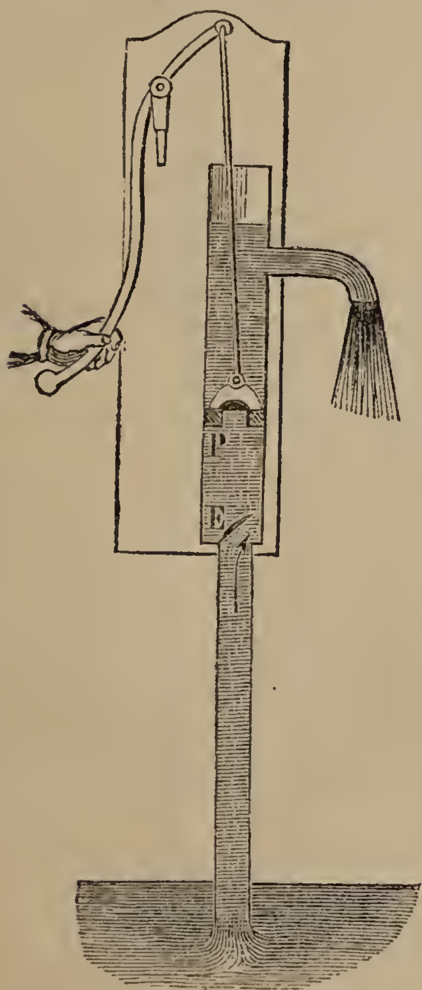

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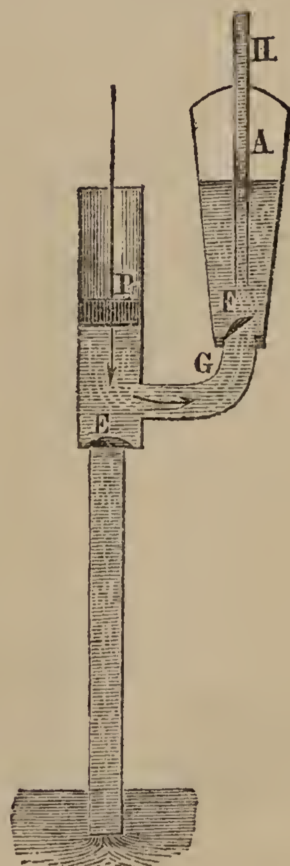

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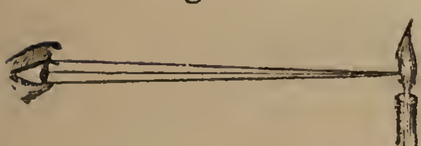

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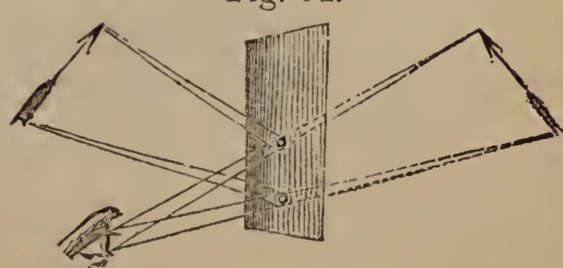

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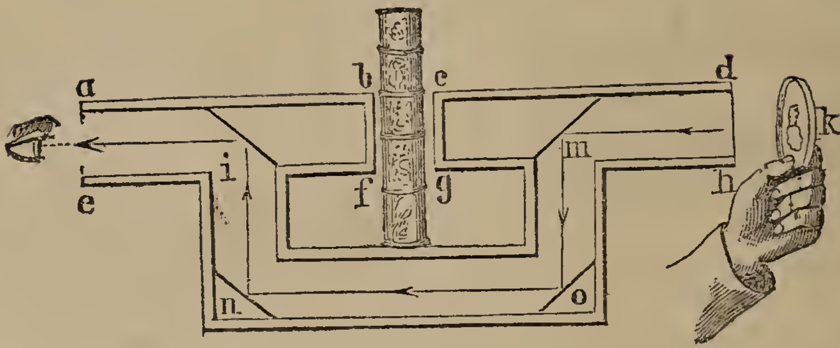

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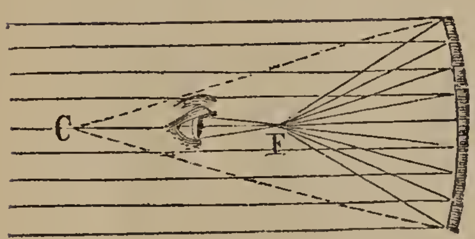

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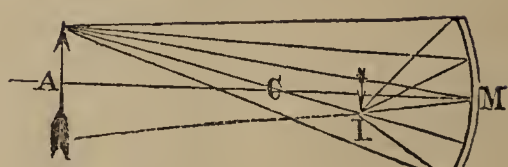

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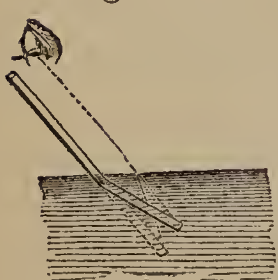

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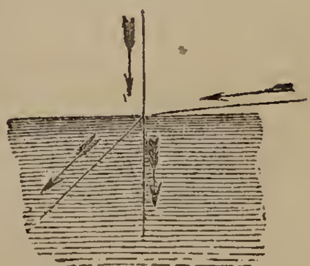

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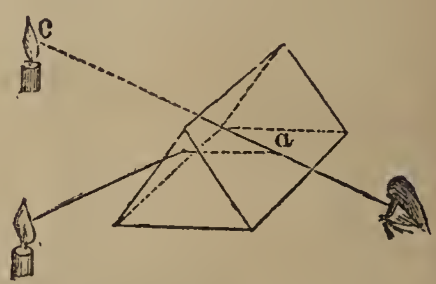
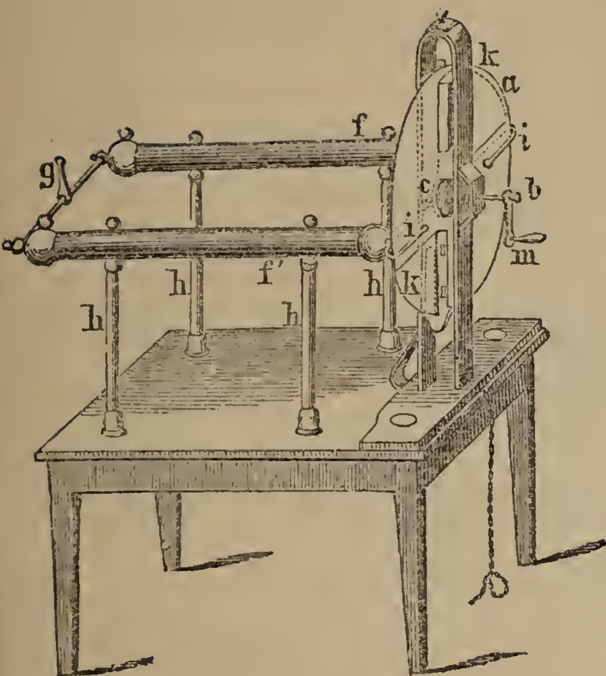


Fig. 107.

Fig. 120



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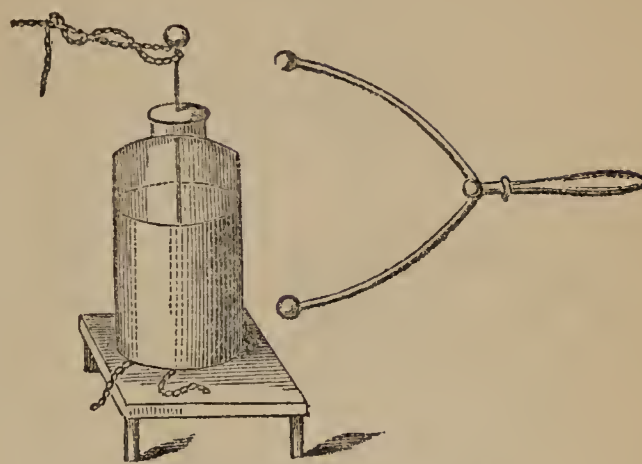

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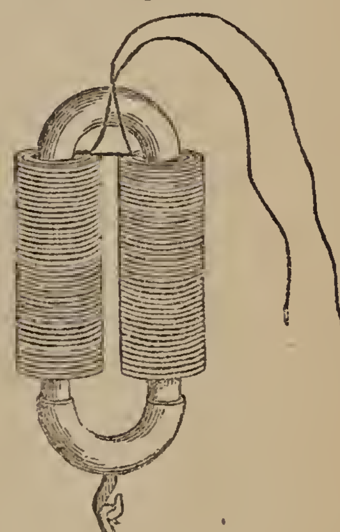
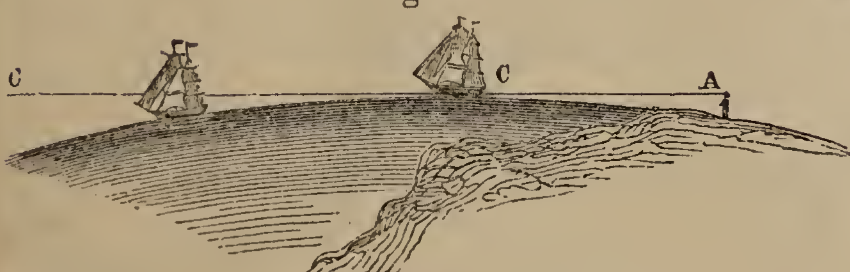


Fig. 126.

Fig. 131.

Fig. 145.



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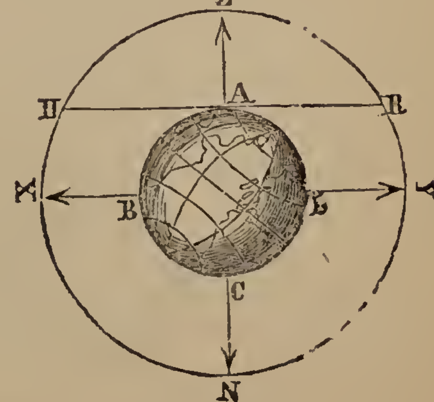

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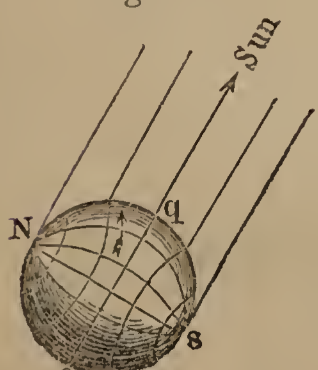

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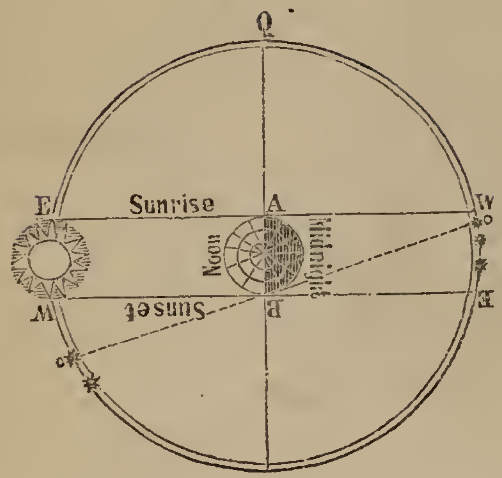

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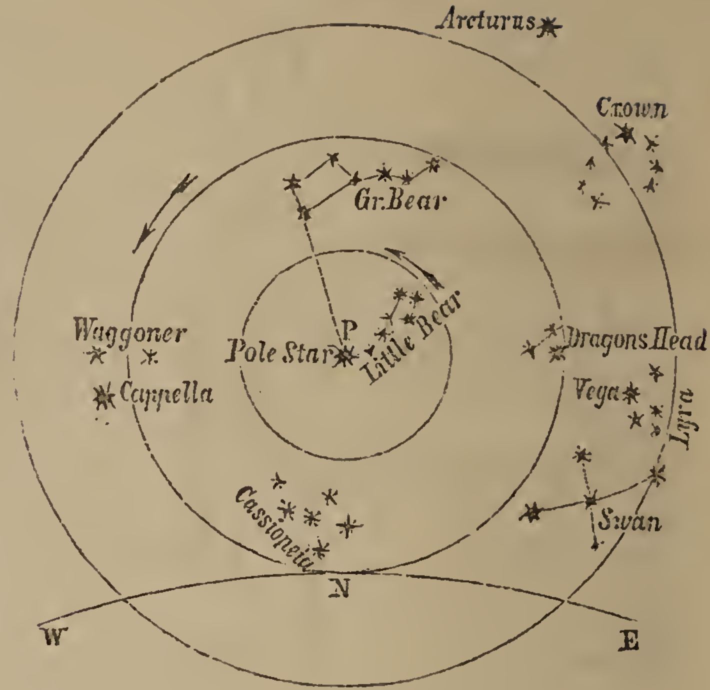

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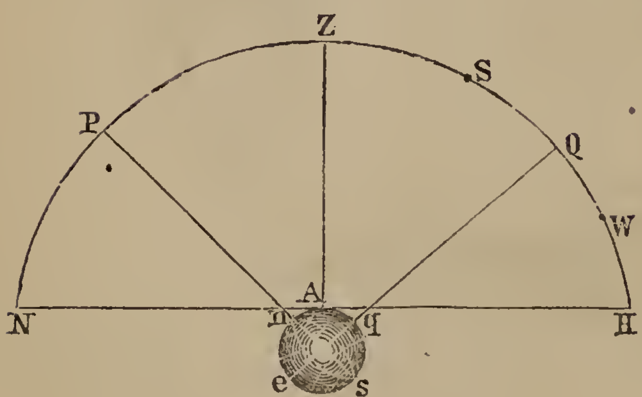

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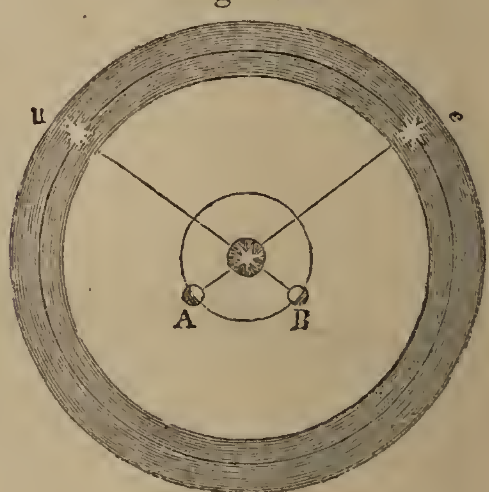

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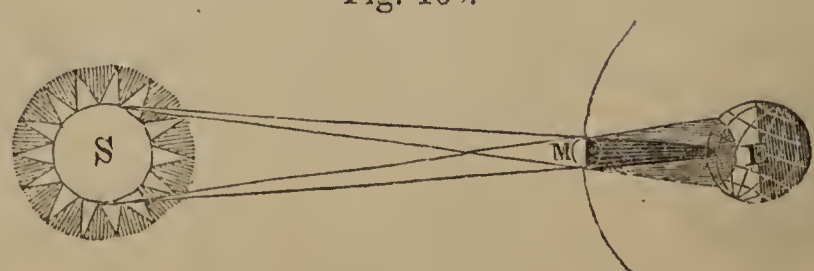

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Fig. 166.

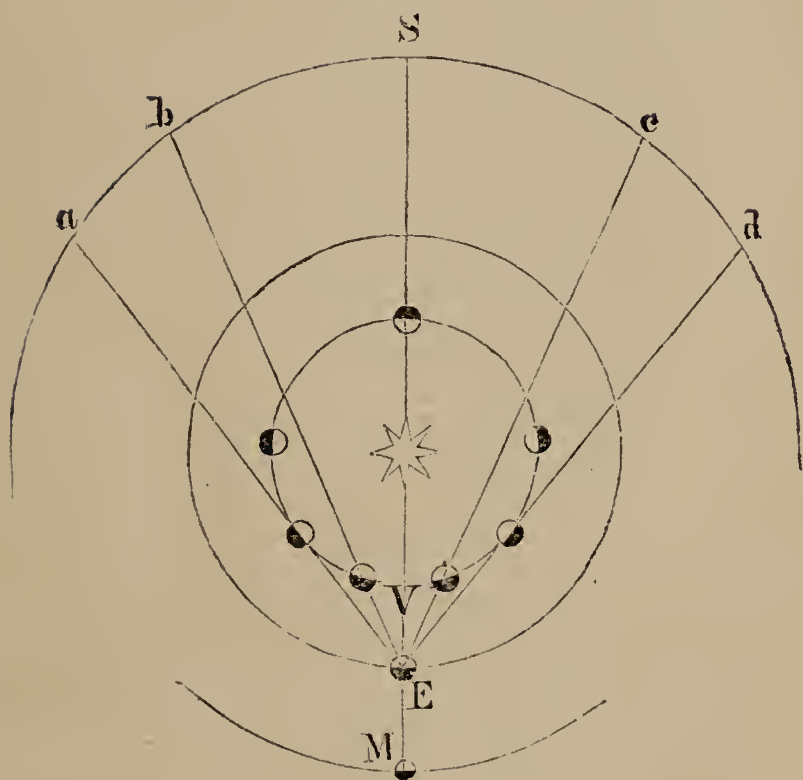

Fig. 171.