ANALYSIS OF MOTION AND FORCE.

MOTION AND FORCE.

1. Definitions.
2. Communication of Motion.
3. Resistances to Motion.
4. First Law of Motion.
    - (1.) Inertia.
    - (2.) Momentum
5. Second Law of Motion.
6. Third Law of Motion.
7. Composition of Motions.
8. Composition of Forces.
9. Triangle of Forces.
10. Polygon of Forces.
11. Resolution of Forces
12. Motion in a Curve.
13. Circular Motion.
14. Reflected Motion.
15. Energy.
16. Kinetic and Potential Energy
17. Conservation of Energy.

MOTION AND FORCE.

1. Motion is change of place. All motion, as well as rest, with which we are acquainted, is relative.—*Examples:* When we ride in the cars, we judge of our motion by the objects around us.—A man on a steamer may be in motion with regard to the shore, but at rest with reference to the objects on the deck of the vessel. *Force* is that which produces or tends to produce or to destroy motion. *Velocity* is the rate at which a body moves. It is expressed by the number of units of space through which the body moves in a unit of time.—*Example:* Ten miles an hour, or fifteen feet a second.

2. The Communication of Motion is not instantaneous.* If I press with all my might against a rock weighing a ton, I fail to move it, press I ever so long. The force is not sufficient to overcome the friction between the rock and the ground. If, however, we could conceive the rock poised in empty space, the least touch would at once move it with a velocity proportional to $\frac{\text{pressure}}{\text{mass}}$. If I strike one

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* A stone thrown against a pane of glass shatters it; but a bullet fired through it will make only a round hole. The bullet is gone before the motion has time to be given perceptibly to the surrounding particles.—A fraction of time is required for a ball to receive the force of the exploding powder and to get under full headway.

end of a rail a mile long, the tremor will take a definite time to reach the other end. If, on the other hand, a powerful engine suddenly pulls at one end of the rail, so as to draw it over a considerable distance in a second, we can imagine that the other end will move after an almost infinitely short time; but if the engine drag the rail continuously, both ends will have the same velocity, and the whole rail will move together.

3. The Resistances to Motion are friction and the resistance of air and water. (1.) Friction is the resistance caused by the surface over which a body moves. It is of great value in common life. Without it, nails, screws, and strings would be useless; engines could not draw the cars; we could hold nothing in our hands; and we should every-where walk as on glassy ice. (2.) The resistance which a body meets in passing through air or water is caused largely by the particles displaced.

Laws of Motion.—There are three laws of motion, which were first distinctly formulated by Sir Isaac Newton.

4. First Law of Motion.—*A body set in motion will move forever in a straight line, unless acted on by some external force.* Obviously, no experiment will directly prove this law. There is a curious illustration, however, in the swinging of a pendulum under the receiver of an air-pump. The better the exhaustion, the longer will the pendulum vibrate. In the best vacuum we can produce, it will swing for

thirty or forty hours. It is supposed that if all resistances to motion were removed, the pendulum would never stop.

Inertia.—The law just stated is often called the *law of inertia.* Matter has no inherent power of producing change upon itself. If a body be already in motion, force has to be expended in stopping it. If it be at rest, force is required to start it in motion. In either case we "overcome its inertia." The danger in jumping from a car in rapid motion lies in the fact that the body has the speed of the train, while the forward motion of the feet is checked by contact with the ground. It is necessary to jump as nearly as possible in the direction in which the train is moving, and be ready to run the instant the feet touch the ground. Those who do so can then gradually overcome the inertia of the body, and after a few yards can turn as they please.

Momentum.—To measure any force we must know first what quantity of matter is moved, and also what velocity it receives. The quantity of matter in a body is called its *mass.* It is not the same as weight, but is proportional to this (see p. 57), so that we speak of pounds of mass as well as pounds of weight. The product of mass by velocity is called *momentum.** Thus if a mass of five pounds move

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* A heavy body may be moving very slowly and yet have an immense momentum.—*Examples:* An iceberg, with a scarcely perceptible motion, will crush the strongest ship as if it were an egg-shell.—Soldiers have thought to stop a spent cannon-ball by putting a foot against it, but have found its momentum sufficient to break a leg.

On the other hand, a light body moving with a high velocity may have with a velocity of twenty feet per second, it has one hundred units of momentum.

5. Second Law of Motion.—*A force acting upon a body in motion or at rest, produces the same effect whether it acts alone or with other forces.*—*Examples:* All bodies upon the earth are in constant motion with it, yet we act with the same ease that we should were the earth at rest.*—We throw a stone

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an enormous momentum.—*Examples:* The air in a hurricane will tear up trees by the roots and level buildings to the ground.—Sand driven from a tube by steam is used for drilling and in stone-cutting, engraving, etc.

"In a rude age, before the invention of means for overcoming friction, the weight of bodies formed the chief obstacle to setting them in motion. It was only after some progress had been made in the art of throwing missiles, and in the use of wheel-carriages and floating vessels, that men's minds became practically impressed with the idea of mass as distinguished from weight. Accordingly, while almost all the metaphysicians who discussed the qualities of matter, assigned a prominent place to weight among the primary qualities, few or none of them perceived that the sole unalterable property of matter is its *mass*. At the revival of science this property was expressed by the phrase 'The inertia of matter'; but while the men of science understood by this term the tendency of the body to persevere in its state of motion (or rest), and considered it a measurable quantity, those philosophers who were unacquainted with science understood inertia in its literal sense as a quality—mere want of activity or laziness I therefore recommend to the student that he should impress his mind with the idea of mass by a few experiments, such as setting in motion a grindstone or a well-balanced wheel, and then endeavoring to stop it, twirling a long pole, etc., till he comes to associate a set of acts and sensations with the scientific doctrines of dynamics, and he will never afterward be in any danger of loose ideas on these subjects."—MAXWELL's "Theory of Heat," p. 85

* A ball thrown up into the air with a force that would cause it to rise fifty feet, will ascend to that height whatever horizontal wind may be blowing.—While riding on a car, we throw a stone at some object at rest The stone, having the motion of the train, strikes just as far ahead of the object as it would have gone had it remained on the train In order to hit the mark, we should have aimed a little back of it.—The circus-rider wishes, while his horse is at full speed, to jump through a hoop suspended before him. He simply springs directly upward. Going forward by the momentum which he had acquired before he leaped from the horse, he passes through the hoop and alights upon the saddle again.—A person

directly at an object and hit it, yet, within the second, the mark has gone forward many feet.*—If a cannon-ball be thrown horizontally, it will fall as fast and strike the earth as soon as if dropped to the ground from the muzzle of the gun. In Fig. 5, *D* is an arm driven by a wooden spring, *E*, and turning on a hinge at *C*. At *D* is a hollow containing a bullet, so placed that when the arm is sprung, the ball will be thrown in the line *FK*. At *F* is a similar ball, supported by a thin slat, *G*, and so arranged that the same blow which throws the ball, *D*, will let the ball, *F*, fall in the line *FH*. The two balls will strike the floor at the same instant.

FIG. 5.

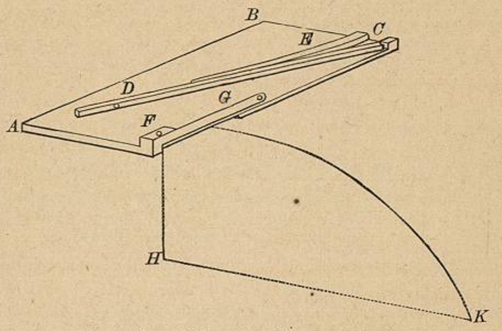

Illustration of the Second Law of Motion.

6. Third Law of Motion.—*Action is equal to reaction, and in the contrary direction.*—*Examples:* A bird in flying beats the air downward, but the air

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riding in a coach drops a cent to the floor. It apparently strikes where it would if the coach were at rest.

* The earth moves in its orbit around the sun at the rate of about eighteen miles per second. (See "Fourteen Weeks in Astronomy," p. 106.)

reacts and supports the bird.—The powder in a gun explodes with equal force in every direction, driving the gun backward and the ball forward, with the same momentum. Their velocities vary with their weights; the heavier the gun, the less will the recoil be noticed.—When we spring from a boat, unless we are cautious, the reaction will drive it from the shore.—When we jump from the ground, we tend to push the earth from us, while it reacts and pushes us from it; we separate from each other with equal momentum, and our velocity is as much greater than that of the earth as we are lighter.—We walk therefore by reason of the reaction of the ground on which we tread.

Fig. 6.

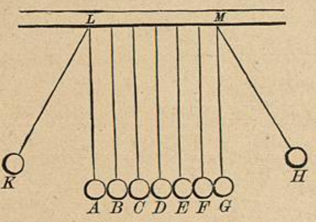

Illustration of the Third Law of Motion.

The apparatus shown in Fig. 6 consists of ivory balls hung so as to vibrate readily.* If a ball be let fall from one side, it will strike the second ball, which will react with an equal force, and stop the motion of the first, but transmit the motion to the third; this will act in the same manner, and so on through the series, each acting and reacting until the last ball is reached; this will react and then bound off, rising as high as the first ball fell (except the loss caused by resistances to motion). If two

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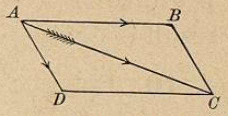
* The same experiments can be performed by means of glass marbles or billiard balls placed in a groove. Better still, attach strings to glass marbles by means of mucilage and bits of paper and suspend them from a simple wooden frame.

balls be raised, two will fly off at the opposite end; if two be let fall from one side and one from the other, they will respond alternately.

7. Composition of Motions.—Let a ball at *A* (Fig. 7) be acted on by a force which would drive it in a given time to *B*, and also at the same instant by another which would drive it to *D* in the same time; the ball will move in the direction *AC*.—*Examples:* A person wishes to row a boat across a swift current which would carry him down stream. He therefore steers toward a point above that which he wishes to reach, and so goes directly across.—A bird, beating the air with both its wings, flies in a direction different from that which would be given by either one.

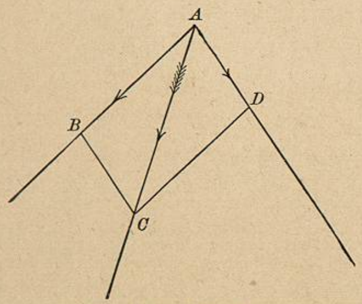
Fig. 7.



Composition of Motions.

8. Composition of Forces.—When a body is thus acted on by two forces, we draw lines representing their directions, and mark off *AD* and *AB*, whose lengths represent their comparative magnitudes. We next complete the parallelogram and draw the diagonal *AC*, which denotes the *resultant* of these forces, and gives the direction in which the body will move.

Fig. 8.



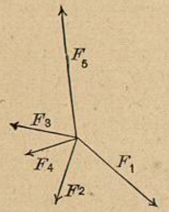
Composition of Two Forces.

If more than two forces act, we find the resultant of two, then of that resultant and a third force, and so on.

9. Triangle of Forces.—In Fig. 8 the resultant, AC, could have been obtained more easily by drawing AB to represent the magnitude and direction of one force, and then similarly BC for the other force. Connecting the initial point, A, of the first line with the terminal point, C, of the second line, we have AC for the magnitude and direction of the resultant, which completes a triangle.

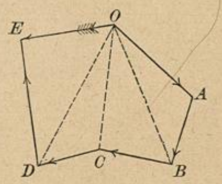
10. Polygon of Forces.—Let F_1, F_2, F_3, F_4, and F_5 (Fig. 9), represent five forces acting on the same point at the same time. To find their resultant, we draw (Fig. 10) OA, AB, BC, CD, and DE, equal and parallel respectively to F_1, F_2, F_3, F_4, and F_5. Then, joining the first point with the last, we have OE to represent the magnitude and direction of their combined resultant. For OB is the resultant for OA and AB; OC for OB and BC; OD for OC and CD; and OE for OD and DE. This method is applicable to the representation of any number of forces.

FIG. 9.



Five Forces acting at the same Point.

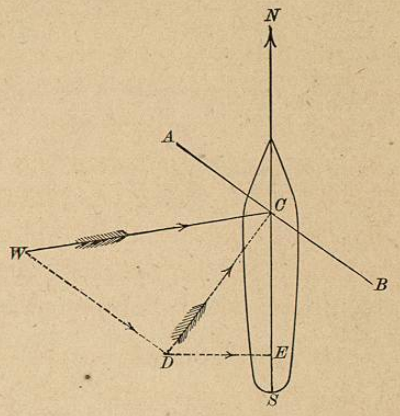
FIG. 10.



Polygon of Forces.

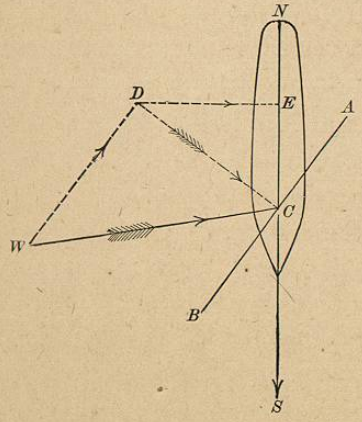
11. Resolution of Forces consists in finding what forces are equivalent to a given force under special conditions. A triangle is drawn, having the given force as one side.—*Example:* There is a wind, blowing nearly from the west (Fig. 11) against the sail, AB, of a vessel going northward. We may regard the wind-force, WC, as the resultant of two forces, WD and DC. The former, being parallel to the sail, is not effective; the latter is perpendicular to it, and tends to drive the vessel nearly north-east. Again, resolving DC, we find this equivalent to two forces, DE and EC. The former pushes the vessel sideways, but is largely counteracted by the resistance of the water against the broad side; EC is in the direction of the ship's course, and propels it north.

FIG. 11.



Resolution of Forces. Ship sailing northward.

FIG. 12.



Resolution of Forces. Ship sailing southward.

By shifting the rigging, one vessel may sail into the harbor while another is sailing out, both driven by the same wind. In Fig. 12, which represents a ship sailing southward, the lettering and explanation is the same as for Fig. 11, if we substitute "south" for "north."* If the ship were required to go westward, it would *tack* alternately *NW* and *SW*. In this way its resultant direction might be almost in the "teeth of the wind."

A canal-boat drawn by horses is acted upon by a force which tends to bring it to the bank. This force may be resolved into two, one pulling toward the tow-path, and the other directly ahead. The former is counteracted by the shape of the boat and the action of the rudder; the latter draws the boat forward.

12. Motion in a Curve.—Whenever two or more instantaneous forces act upon a body, the path is a straight line. When one is instantaneous and the other continuous, it is a curved line.—*Example:* When a body is thrown into the air, except in a vertical line, it is acted upon by the instantaneous force of projection and the continuous force of gravity, and so describes a line which curves toward the earth.

13. Circular Motion is produced when a moving body is drawn toward a center by a constant force.

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* In a similar manner we may resolve the three forces which act upon a kite—viz., the pull of the string, the force of the wind, and its own weight. In Fig. 11, let AB represent the face of the kite. We can resolve WC, the force of the wind, into WD and DC. We next resolve DC into DE and EC. We then have a force, EC, which overcomes the weight of the kite and tends to lift it upward. The string pulls in the direction CD, perpendicularly to the face. The kite obeys neither one of these forces alone, but both, and so ascends in a direction CA between the two. It is really drawn up an inclined plane by the joint force of the wind and the string.

Thus, when a sling is whirled, the stone is pulled toward the hand by the string, and as, according to the third law of motion, every action has its equal and opposite reaction, the hand is pulled toward the stone. If the string break, the stone will continue to move, according to the first law of motion, in a straight line in the direction of a tangent to the circle at that point. The tension of the string, acting inward, is called the *Centripetal* (*centrum*, the center, *petere*, to seek) force; and the reaction of the stone upon the string, acting outward, is termed the *Centrifugal* (*centrum*, the center, *fugere*, to flee) force.*

The following examples are among those usually

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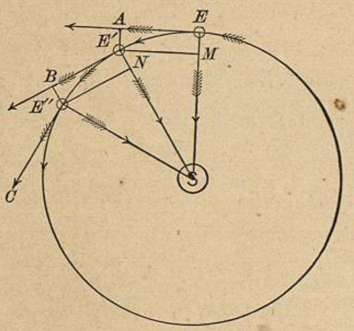
* It should be noticed that in circular motion there is but one true force concerned. It acts, however, upon a body in motion. The so-called centrifugal force has nothing to do with the production of the motion, being merely the resistance which the body offers by its inertia to the operation of the centripetal force, and ceases the instant that force is discontinued. It does not act at right angles to the centripetal force, as is often stated, but in direct opposition. A body never flies off from the center impelled by the centrifugal force, since that can never exceed the centripetal (action = reaction), and moreover the path of such a body is in the direction of a tangent, and not the radius of a circle. Thus, when water is thrown off a grindstone in rapid rotation, the tendency of the water to continue to move on in the direction of the straight line in which it is going at each instant (in other words, the inertia of the water) overcomes its adhesion to the stone, and it flies off in obedience to the first law of motion. So, also, when a grindstone, driven at a high speed, breaks, and the fragments are thrown with great velocity, we are not to suppose that the centrifugal force impels them through the air. That force existed only while the stone was entire. It was opposed to the force of cohesion, and in the moment of its triumph ceased, and the fragments of the stone fly off in virtue of the velocity they possess at that instant. Again, the so-called centrifugal force is not a real force urging bodies upward at the equator. The earth's surface is merely falling away from a tangent, and a part of the force of gravity is spent in overcoming the inertia of bodies. The term centrifugal force has caused much confusion, and will perhaps be discarded.

given to illustrate the action of the center-fleeing force: Water flies from a grindstone on account of the centrifugal force produced in the rapid revolution, which overcomes the *adhesion.*—In factories, grindstones are sometimes revolved with such velocity that this force overcomes that of *cohesion*, and the ponderous stones fly into fragments.—A pail full of water may be whirled around so rapidly that none will spill out, because the centrifugal force overcomes that of *gravity.*—When a horse is running around a small circle, he bends inward to overcome the centrifugal force.

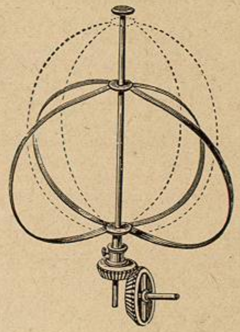
Fig. 13.



Circular Motion.

The heavenly bodies present the grandest example of circular motion. We may suppose the earth to have been moving originally in the direction *AE.* The attraction of the sun, however, drawing it in the direction *ES*, it passes along the line *EE′.* If the centripetal force were suddenly to cease, the earth would fly off into space along a tangent, as *EA.* The rapid revolution of the earth on its axis tends to throw off all bodies headlong. As this acts in opposition to gravity, it diminishes the weight of bodies at the equator, where it is greatest, being there equivalent to $\frac{1}{289}$ of the force of gravity. It also tends to drive the water on the earth from the poles toward the equator. Were the velocity of the earth's rotation to diminish, the water would flow back toward the poles, and tend to restore the earth to a spherical form.* This influence is well illustrated by the apparatus shown in Fig. 14. The hoop is made to slide upon its axis, and if revolved rapidly it will assume an oval form, bulging out more and more as the velocity is increased.†

Fig. 14.



14. Reflected Motion is produced by the reaction of a surface against which an elastic body is cast. If a perfectly elastic ball be thrown in the direction

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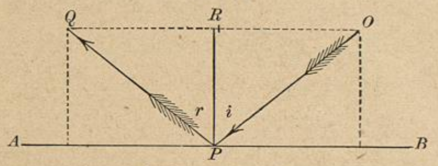
* Since the earth's polar diameter is nearly twenty-seven miles shorter than its equatorial diameter, we are not sure that this motion of its waters would make it perfectly spherical.

† This apparatus is accompanied by objects to illustrate the principle that all bodies tend to revolve about their shortest diameters. "Tie to the middle of a lead-pencil a piece of string about three feet long. Suspend so that the pencil will balance itself. Now twist the end of the string between the thumb and the first finger of the right hand, steadying and holding the string with the left hand. A circular motion will thus be communicated to the pencil, and it will revolve around the point on which it is suspended. Tie a piece of white string around the middle of the pencil, or its center of gravity, simply to show the position of that point. Now tie the first piece of string half-way between the end of the pencil and the center of gravity, and communicate the circular motion described above, and we shall observe that the pencil will still revolve around the center of gravity, the point marked by the white string being at rest. It can thus be shown that any thing, of whatever shape, will tend to revolve on its shortest diameter. If the end links of a small steel chain (such as is often attached to purses or parasols) be hooked together, the string tied to a link. and the circular motion given, it will be observed that the chain begins to take an elliptical form, which gradually approaches that of a circle, until at last it becomes a circle, when it revolves horizontally. This shows that even a ring revolves on its shortest axis."

OP against the surface AB, it will rebound in the line PQ. The angle, i, between the direction OP and the perpendicular, PR, drawn at the point of incidence, is called the angle of incidence. The angle of reflection, r, is that between this perpendicular, PR, and the direction PQ. If OP represent the magnitude and direction of the incident force, it may be resolved into OR and RP. But the reaction, PR, is equal to the vertical portion, RP, of the incident force, while the horizontal portion is not checked. Hence $PQ = OP$, and the angle of incidence is equal to the angle of reflection.

FIG. 15.



Reflected Motion.

15. Energy is the power of doing work, *i. e.*, of overcoming any kind of resistance. It is in general a power put into a body by means of work, and which comes out of it when it does work.—*Examples:* A wound-up clock, a red-hot iron. The difference between energy and momentum is easily illustrated. When a bullet is fired from a rifle, the momenta of both are equal, but the energy of the former, *i. e.*, its power of doing work, as piercing a board, is far greater. Energy is proportional to the square of the velocity of the moving body. Thus, a cannon-ball given double speed will penetrate four times as far into a wall; and a stone thrown upward at the rate of ninety-six feet per second will rise nine times as far as with a velocity of thirty-two feet.

16. Two Forms of Energy.—Energy may be either active or latent. When a rock is tumbling down a mountain-side, it exhibits the force of gravity in full sway; but when the rock was lodged on the mountain-top, it possessed the same energy, which could be developed at any moment by loosening it from its place. These two forms are known as energy of motion and energy of position, or kinetic and potential energy.*

17. Conservation of Energy.—The sum of all the energy in the universe remains the same while its transformations are infinite. One kind of energy is changed into another; from an available form to one that is not controllable. A hammer falls by the force of gravity. In coming to rest when stopped, it does the work of crushing what it hits, and its motion as a mass is converted into one of molecules, revealing

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* The following may be taken as examples to show the difference between kinetic and potential energy. We wind a watch, and by a few moments of labor condense in the spring a potential energy, which is doled out for twenty-four hours in the kinetic energy of the moving wheels and hands. Lift a pendulum, and you thereby give the weight potential energy. Let it fall, and the potential changes gradually to kinetic. At the center of the arc the potential is gone and kinetic is possessed. Then the kinetic changes again to potential, which increases till the end of the arc is reached and the pendulum ceases to rise, when the energy is that of position, not of motion. Potential energy is like what is concealed, lying in wait and ready to burst forth on the instant. It is that of a loaded gun prepared for the arm of the marksman. It is that of a river trembling on the brink of a precipice, about to take the fearful leap. It is that of a weight wound up and held against the tug of gravity. It is that of the engine on the track with the steam hissing from every crevice. On the contrary, kinetic energy is that in actual operation. The bullet is speeding to the mark; the river is tumbling; the weight is falling; the engine is flying over the rails. It is that of heat radiating from our fires; electricity carrying our messages over the continent; and gravity drawing bodies headlong to the earth.

itself to our touch as heat. The sun is continually sending forth radiant energy, which has been stored up in it by the aggregation of matter during untold ages. Its kinetic energy is thus becoming dissipated into potential energy; but, even after it ceases to glow, the grand total, including all that was once kinetic, will remain unchanged.

PRACTICAL QUESTIONS.

1. A rifle-ball thrown against a board standing edgewise, will knock it down; the same bullet fired at the board will pass through it without disturbing its position. Why is this?

2. Why can a boy skate safely over a piece of thin ice, when, if he should pause, it would break under him directly?

3. Why can a cannon-ball be fired through a door standing ajar, without moving it on its hinges?

4. Why can we drive on the head of a hammer by simply striking the end of the handle?

5. Suppose you were on a train of cars moving at the rate of 30 miles per hour; with what velocity would you be thrown forward if the train were stopped instantly?

6. In what line does a stone fall from the mast-head of a vessel in motion?

7. If a ball be dropped from a high tower, it will strike the ground a little east of a vertical line. Why is this?

8. It is stated that a suit was once brought by the driver of a light wagon against the owner of a coach for damages caused by a collision. The complaint was "the latter was driving so fast that when the two carriages struck, the driver of the former was thrown forward over the dashboard." On trial he was nonsuited, because his own evidence showed him to be the one who was driving at the unusual speed. Explain.

9. Suppose a train moving at the rate of 30 miles per hour: on the rear platform is a spring gun aimed parallel to the track and in a direction precisely opposite to the motion of the car. Let a ball be discharged with the exact speed of the train; where would it fall?

10. Suppose a steamer in rapid motion, and on its deck a man jumping. Can he jump farther by leaping the way the boat is moving than in the opposite direction?

11. Could a party play ball on the deck of an ocean steam-ship when steaming along at the rate of 20 miles per hour, without making allowance for the motion of the ship?

12. Since action is equal to reaction, why is it not so dangerous to receive the "kick" of a gun as the force of the bullet?

13. If you were to jump from a carriage in rapid motion, would you leap directly toward the spot on which you wished to alight?

14. If you wished to shoot a bird in swift flight, would you aim directly at it?

15. At what parts of the earth is the centrifugal force least?

16. What causes the mud to fly from the wheels of a carriage in rapid motion?

17. What proof have we that the earth was once a soft mass?

18. On a curve in a railroad, one track is always higher than the other. Why is this?

19. What is the principle of the sling?

20. The mouth of the Mississippi River is about 2⅓ miles farther from the center of the earth than its source. In this sense it may be said to "run up hill." What causes this apparent opposition to the attraction of gravity?

21. Is it action or reaction that breaks an egg, when I strike it against the table?

22. Was the man philosophical who said that it "was not the falling so far, but the stopping so quick, that hurt him"?

23. If one person runs against another, which receives the greater blow?

24. Would it vary the effect if the two persons were running in opposite directions? In the same direction?

25. Why can you not fire a rifle-ball around a hill?

26. Why is it that a heavy rifle "kicks" less than a light shot-gun?

27. A man on the deck of a large vessel draws a small boat toward him. Can you express the ratio of the ship's motion to that of the boat?

28. Suppose a string, fastened at one end, will just support a weight of 25 lbs. at the other. Unfasten it, and let two persons pull upon it in opposite directions. How much can each pull without breaking it?

29. Can a man standing on a platform-scale make himself lighter by lifting up on himself?

30. Why can not a man lift himself by pulling up on his boot-straps?

31. With what momentum would a steam-boat weighing 1,000 tons, and moving with a velocity of 10 ft. per second, strike against a sunken rock?

32. With what momentum would a train of cars weighing 100 tons, and running 10 miles per hour, strike against an obstacle?

33. What would be the comparative kinetic energy of two hammers, one driven with a velocity of 20 ft. per second and the other 10 ft.?

34. If a 100 horse-power engine can propel a steamer 5 miles per hour, will one of 200 horse-power double its speed?

35. Why are ships becalmed at sea often floated by strong currents into dangerous localities without the knowledge of the crew?

36. A man in a wagon holds a 50-lb. weight in his hand. Suddenly the wagon falls over a precipice. Will he, while dropping, bear the strain of the weight?

37. Why are we not sensible of the rapid motion of the earth?

38. A feather is dropped from a balloon which is immersed in and swept along by a swift current of air. Will the feather be blown away or will it appear to drop directly down?

39. Suppose a bomb-shell, flying through the air at the rate of 500 ft. per second, explodes into two parts of equal weight, driving one half forward in the same direction as before, but with double its former velocity. What would become of the other half?

40. Which would have the greater penetrating power, a 10-lb. cannon-ball with a velocity of 1,000 ft. per second, or a 100-lb. ball with a velocity of 100 ft. per second?

41. There is a story told of a man who erected a huge pair of bellows in the stern of his pleasure-boat, that he might always have a fair wind. On trial, the plan failed. In which direction should he have turned the bellows?

42. If a man and a boy were riding in a wagon, and, on coming to the foot of a hill, the man should take up the boy in his arms, would that help the horse?

43. If we whirl a pail of water swiftly around with our hands, why will the water tend to leave the center of the pail?

44. Why will the foam collect at the hollow in the center?

45. If two cannon-balls, one weighing 8 lbs. and the other 2 lbs., be fired with the same velocity, which will go the farther?

46. Resolve the force of the wind which turns a common windmill, and show how one part acts to push the wheel against its support, and one to turn it around.

47. When an animal is jumping or falling, can any exertion made in mid-air change the motion of its center of gravity?

48. If one is riding rapidly, in which direction will he be thrown when the horse is suddenly stopped?

49. When standing in a boat, why, as its starts, are we thrown backward?

50. When carrying a cup of tea, if we move or stop quickly, why is the liquid liable to spill?

51. Why, when closely pursued, can we escape by dodging?

52. Why is a carriage or sleigh, when sharply turning a corner, liable to tip over?

53. Why, if you place a card on your finger and on top of it a cent, can you snap the card from under the cent, which will then drop on your finger?

54. Why is a "running jump" longer than a "standing jump"?

55. Why, after the sails of a vessel are furled, does it still continue to move? and why, after the sails are spread, does it require some time to get it under full headway?

56. Why can a tallow candle be fired through a board?

SUMMARY.

Matter, so far as we know it, is in constant change. Change of place is termed motion. Terrestrial motion is restricted by friction, by the air, and by water. Friction is caused by the roughness of the surface over which a body moves. It may be decreased by the use of grease to fill up the minute projections, or by changing the sliding into rolling friction. Air and water must be displaced by a moving body; the resistance they offer is measured by the kinetic energy expended in overcoming it, and is hence proportional to the square of its velocity. Motion takes place in accordance with three laws; viz.: A moving body left to itself tends to go forever in a straight line; a force has the same effect whether it acts alone or with other forces, and upon a body at rest or in motion; and action is equal and opposed to reaction. By means of the principles of the composition and resolution of forces, we can find the individual effect of a single force or the combined effect of several forces. Motion produced by two or more instantaneous forces is in a straight line; when one is continuous, the result is a curved line; and when the continuous force, directed toward a fixed point, acts upon a moving body, an ellipse is then described. A circle is one kind of ellipse. A croquet ball struck by two mallets at the same moment, illustrates the first kind of motion; the path of a bullet or rocket in the air exhibits the second; and the movement of a stone whirled in a sling or of a planet revolving about the sun, is an example of the third. When a rubber ball bounds back from a surface against which it is thrown, the angle of reflection equals the angle of incidence.

Energy, or the power of doing work, is a general term employed to represent the unification of all the forces of nature. The grand law of the Conservation of Energy teaches that the different forces are only forms of one all-pervading energy, and that they are mutually interchangeable, and indestructible as matter itself.—We can not account for its origin, we know not what will finally become of it. We only know its law of action, which we must finally refer to a Supreme Being.

HISTORICAL SKETCH.

Aristotle taught that all motion is naturally circular, and this view was held by his school. He divided the phenomena of motion into two classes—the natural and the violent. As an instance of the former, he gave the falling of a stone, which constantly increases in velocity; and of the latter, a stone thrown vertically up, which being against nature, continually goes slower. Newton, in his "Principia," published in 1687, propounded the laws of motion as now received. Other philosophers, notably Galileo, Hooke, and Huyghens, had anticipated much of his reasoning, yet so slowly were his opinions accepted that "at his death," says Voltaire, "he had not more than twenty followers outside of England."

The law of the Conservation of Energy, Faraday, the great English physicist, pronounced "the grandest ever presented for the contemplation of the human mind." It has been established within the present century; yet we now know that former scholars had inklings of the wonderful truth. It arose in connection with discoveries on the subject of Heat, and its history will be treated of hereafter.

Consult Stewart's "Conservation of Energy"; Youmans' "Correlation of the Physical Forces"; Faraday's "Lectures on the Physical Forces"; Everett's "Deschanel's Natural Philosophy"; Tait's "Recent Advances in Physical Science"; Maxwell's "Matter and Motion"; "Appleton's Cyclopedia," Art. Correlation of Forces; Tyndall's "Crystalline and Molecular Forces," in Manchester Science Lectures, '73-4; Crane's "Ball Paradox," in Popular Science Monthly, Vol. X., p. 725.

III.

ATTRACTION.

"The smallest dust which floats upon the wind
Bears this strong impress of the Eternal mind:
In mystery round it subtle forces roll,
And gravitation binds and guides the whole."

"Attraction, as gravitation, is the muscle and tendon of the universe, by which its mass is held together and its huge limbs are wielded. As cohesion and adhesion, it determines the multitude of physical features of its different parts. As chemical or interatomic action, it is the final source to which we trace all material changes."—Arnott.