retarded ; such is the motion of a train of cars when coming to rest, or that of a body thrown vertically upwards.

When the spaces passed over in equal times are continually increased or decreased by the same quantity, the motion is *uniformly accelerated*, or *uniformly retarded.* The motion of a body falling in a vacuum, is *uniformly accelerated;* that of a body shot vertically upwards in a vacuum, is *uniformly retarded.*

The velocity of a body having varied motion at any time, is the rate of the body's motion at that time. In varied motion the velocity is continually changing.

Forces, Powers, and Resistances.

19. If a body is at rest, any cause which tends to set it in motion, is called a *Force ;* if a body is in motion, any cause which tends to make it move faster, or slower, or to change its direction, is called a *Force.*

A Force, then, is any cause which tends to change the state of a body, with respect to rest or motion.

The attractions and repulsions between the molecules of bodies are forces; the muscular efforts of men or animals, employed in accomplishing any kind of work, are forces; the elastic efforts of gases and vapors are forces.

Forces which act to produce motion are called *Powers;* those which act to prevent or destroy motion are called *Resistances.* The effort of steam employed in moving a train of cars is a *power*, whilst friction and the inertia of the air, which tend to retard the motion, are *resistances.* Powers tend to accelerate motion, and are for that reason called *Accelerating Forces.* Resistances, on the contrary, tend to retard motion, and are for that reason called *Retarding Forces.*

Examples. Define uniformly accelerated and uniformly retarded motion. Examples. (**19.**) What is a Force? Examples. Define Powers and Resistances. Examples. By what other names may they be called?

Distinctive Characteristics of Forces.

20. In order that the effect of any force may be completely understood, three things must be known: its *point of application*, its *direction*, and its *intensity.*

The *point of application* of a force is the point where it exerts its action. Thus, in Fig. 6, which represents a child drawing a wagon, the force exerted by the child has its point of application at *A.*

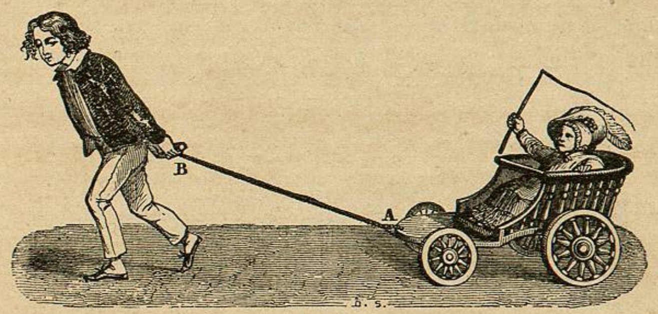


Fig. 6.

The *direction* of a force is the line along which it acts; thus, in Fig. 6, the line *AB* is the direction of the force exerted by the child.

The *intensity* of a force is the energy with which it acts; thus, in the same example as before, the intensity of the force exerted is the energy which the child exerts in overcoming the resistance of the wagon.

The intensity of a force is measured in pounds; thus, a force of fifty pounds is a force necessary to sustain a weight of fifty pounds. The intensity of a force may be represented by a distance which is usually laid off on the line of direc-

(**20**) What three elements determine a force? Define the point of application. The line of direction. The intensity. How is the intensity measured? How represented? Example.

tion of the force. Having assumed some unit of length, say one tenth of an inch, to represent one pound, this is set off as many times as the force contains pounds. In the example taken, if we suppose the force exerted to be seven pounds, and lay off from A to C seven tenths of an inch, then will AC represent the force both in direction and intensity.

Resultant and Component Forces.

21. When a body is solicited by a single force, it is evident, if no obstacle intervene, that it will move in the direction of that force; but if it is solicited at the same time by

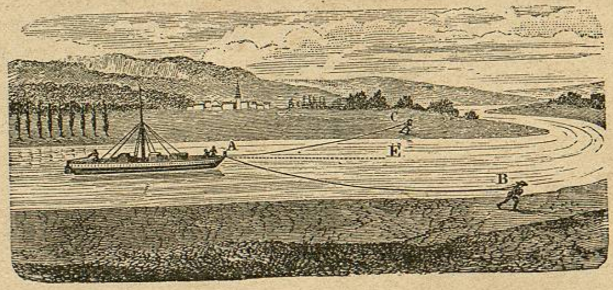


Fig. 7.

several forces acting in different directions, it will not, in general, move in the direction of any one of them. For example, if two men on opposite sides of a river tow a boat by means of a rope, as represented in Fig. 7, the boat will not move either in the direction AB, or AC, but it will move in some intermediate direction, as AE; that is, it will advance as though it were solicited by a single force directed from A towards E. This single force, which would produce the same effect as the two separate forces, is called

(**21.**) What is a Resultant of several forces?

their *Resultant*. The separate forces are called *Components* of the resultant.

In general the *resultant* of any number of forces is a single force whose effect is equivalent to that of the whole group. The individual forces of the group are called *Components*.

Parallelogram of Forces.

22. It is shown in Mechanics (Peck's Mechanics, Art. 27), that if AB and AD, Fig. 8, represent two forces acting at A, their resultant will be represented by AC. That is, *if two forces are represented in direction and intensity by the adjacent sides of a parallelogram, their resultant will be represented in direction and intensity by that diagonal which passes through their point of intersection.*

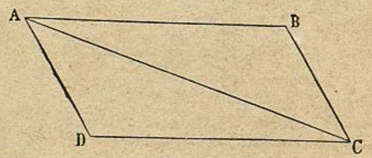
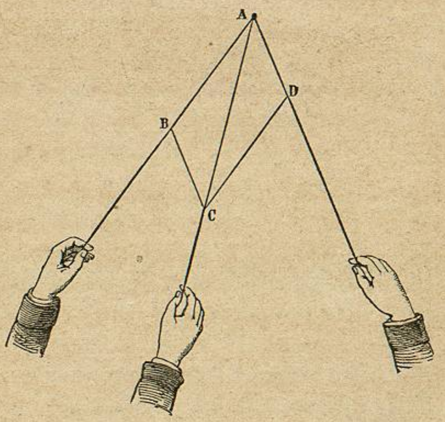


Fig. 8.

This principle is called the *Parallelogram of Forces.*

The operation of finding the resultant when the components are given is called *Composition of Forces;* the reverse operation is called *Resolution of Forces.*



When two forces are applied at the same point, as shown in Fig. 9, we lay off distances AB

What are Components? Illustrate. (**22.**) Enunciate the parallelogram of forces.

and AD to represent the forces, and having completed the parallelogram, we draw its diagonal AC; this will be their resultant. If the resultant AC is known, and the directions of its components are given, we draw through C the lines CD and CB parallel to their directions; then will the intercepted lines AD and AB be components of the force AC.

Practical Example of Composition of Forces.

23. A bird, in flying, strikes the air with both wings, and the latter offers a resistance which propels him forward.

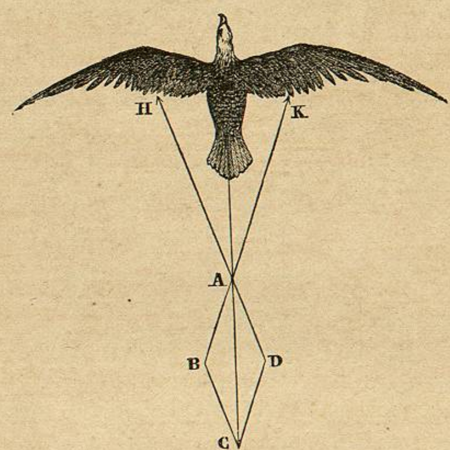


Fig. 10.

Let AK and AH, in Fig. 10, represent these resistances. Draw AB and AD equal to each other, and complete the parallelogram AC; draw also the diagonal AC. Then will AC represent the resultant of the two forces, and the bird will move exactly as though impelled by the single force CA.

How is the resultant found when the components are known? How are the components found? (**23.**) Explain the flight of a bird.

Practical Example of Resolution of Forces.

24. When a sail-boat is propelled by a breeze acting on the quarter in the direction *va* (Fig. 11), we may, by the rule in Art. 22, resolve the intensity of the wind into two components, one, *ca*, in the direction of the keel, and the

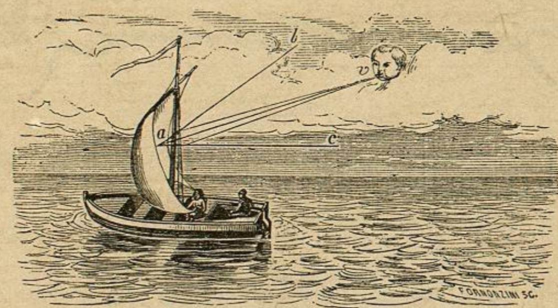


Fig. 11.

other, *ba*, at right angles to it. The first component alone is effective in giving a forward motion to the boat, whilst the second is partly destroyed by the resistance which the water offers to the keel, and partly employed in giving a lateral motion to the boat. This lateral motion is called *leeway.*

Resultant of Parallel Forces.

25. When two forces act in the same direction, as when two horses pull at the ends of a whiffle-tree to draw a wagon, *their resultant is equal to the sum of the forces.* When they act in a contrary direction, as in the case of a steamboat ascending a river, where the force of the engine acts to propel the boat forward, whilst the current acts to

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(**24**) Explain the sailing of a boat. (**25.**) What is the resultant of parallel forces when they act in the same direction? When they act in opposite directions? Examples.

retard its progress, *their resultant is equal to the difference of the forces.*

Equilibrium of Forces.

26. When several forces acting upon a body exactly balance each other, they are said to be *in equilibrium.*

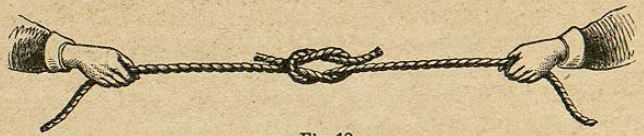

Fig. 12.

The simplest case of equilibrium is that of two equal forces acting against each other, as in the case where two men of equal strength pull at the two ends of a rope, as shown in Fig. 12.

In the same manner, if two buckets of equal weight are suspended in a well from the ends of a rope passing over a pulley, they will be in equilibrium.

When a body rests upon a table, there is an equilibrium between the weight of the body which urges it downwards, and the resistance of the table which prevents it from falling. If the weight becomes greater than the resistance, the table breaks and the body falls.

Centrifugal and Centripetal Forces.

27. The Centrifugal Force is the resistance which a body offers to a force which tends to deflect it from its course.

In consequence of its inertia, a body always tends to move in a straight line, and if we see it move in a curved line it is because some force is acting to turn it from its path. This deflecting force is called the *Centripetal Force*, and

(**26.**) When are forces in equilibrium? Illustrate by examples. (**27.**) What is the Centrifugal Force? Centripetal Force?

because action and reaction are always equal, *the centripetal and centrifugal forces are always opposed and equal to each other.* If a ball is whirled about the hand, being retained by a string, it has a continual tendency to fly off, which tendency is resisted by the strength of the string; the tendency to fly off is due to the centrifugal force, and the force which resists this tendency is the centripetal force.

The curved path in which a body moves may be regarded as made up of short straight lines, and if at any instant the centripetal

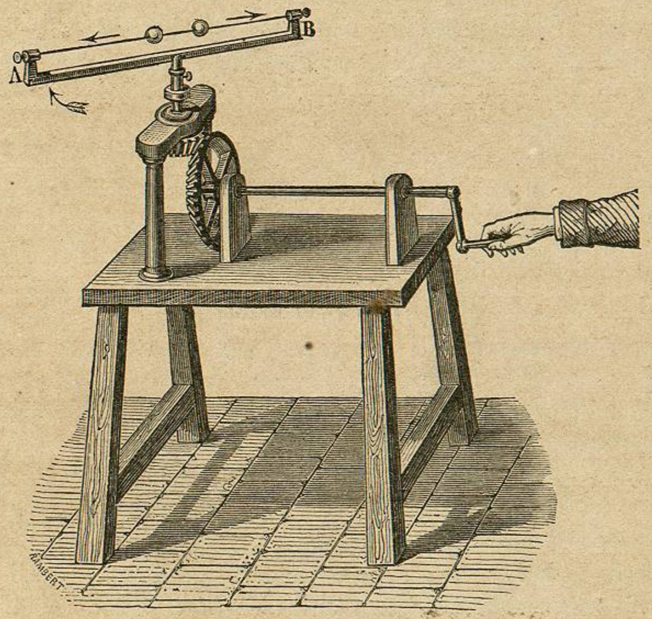

Fig. 13.

force were destroyed, the body would continue to move along that line on which it was situated; that is, its new path would be tangent to its old one.

The existence of the centrifugal force may be shown experiment-

Example. *How does a body move when the centripetal force is destroyed?*

ally by the apparatus represented in Fig. 13. It consists of a bar, *AB*, having its ends bent up so as to hold a wire which is stretched between them. On this wire two ivory balls are strung so as to slide along it, and the whole bar is made to turn about an axis at right angles to it by means of a crank and two bevelled wheels. When the bar is made to revolve about the axis, the balls, acted upon by the centrifugal force, are thrown against the ends of the bar with an energy which becomes greater as the motion of revolution becomes more rapid.

Some Effects of the Centrifugal Force.

28. When a train of cars turns round a curve in the road, the centrifugal force tends to throw the train off the track, a tendency which is resisted by raising the outer rail and by making the wheels conical.

It is in consequence of the centrifugal force, that the mud adhering to the tire of a carriage-wheel is thrown off in all directions.

In the circus, where horses are made to travel rapidly around in a curved path, the centrifugal force tends to overturn them outwards, which tendency is partly overcome by making the outside of the track higher than the inside, and partly by both horse and rider inclining inwards, so as to make the resultant of their weight and the centrifugal force perpendicular to the path.

When a sponge filled with water and held by a string is whirled rapidly around, the centrifugal force throws off the water and leaves the sponge dry. This principle has been used for drying clothes in the laundry.

A very remarkable effect of the centrifugal force is the flattening of our earth at the poles. The earth turns on its axis every twenty-four hours, which rotation gives rise to a centrifugal force at every point of its surface. At the

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Explain the experiment. (**28**) Give examples of the action of the centrifugal force. Cars on a curve. Mud from wheel. Circus. Sponge. Effect on the form of the earth.

equator the centrifugal force is greatest, because the velocity is there the greatest, and from the equator it grows feebler towards each pole, where it is zero. The centrifugal force at every point is perpendicular to the axis, and may be resolved into two components, one directed outwards from the centre, and the other perpendicular to this. The former component lessens the weight of bodies, and the latter acts to heap the particles up towards the equator. It has been found that the earth is a spheroid, flattened at the poles. The polar diameter is about twenty-six miles shorter than the equatorial diameter. Observations upon the heavenly bodies show that other planets are in like manner flattened at their poles.

The manner in which the centrifugal force acts to flatten a sphere, is shown experimentally by an apparatus, represented in Fig. 14. This apparatus consists of a vertical rod to which a motion of rotation may be imparted, as shown in Fig. 13. At the lower part of this rod four strips of brass are firmly fastened and bent into circles, as shown by the dotted lines; their upper ends are fastened to a ring which is free to slide up and down the rod. When the axis is made to revolve rapidly, the centrifugal force causes the ring to slide down the rod, the hoops become more curved, as shown in the figure, and the whole assumes the appearance of a flattened sphere.

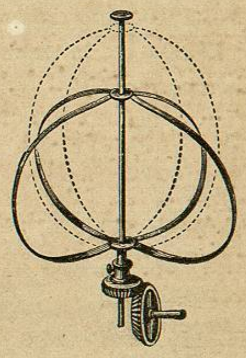

Fig. 14.

Machines.

29. A MACHINE is any contrivance that transmits the action of a force. A force which is used to move a machine is a *motor*.

Effect on the weight. *Explain the experiment.* (**29.**) What is a Machine? What is a Motor?

When we cut an apple with a knife, the hand is the *motor* and the knife is a *machine.*

A horse drawing a cart is a *motor*, and the cart which serves to utilize the force of the horse is a *machine.*

Water turning a water-wheel, wind turning a wind-mill, and steam driving a locomotive, are all motors.

Machines do not increase the energy of the motors, but by modifying their action they enable us to do work which we could not otherwise perform. For example, by the aid of a lever, about to be described, a man may raise a weight which he could not otherwise overcome.

The Lever.

30. A Lever is an inflexible bar free to turn about a fixed point, called the *Fulcrum*, and acted upon by two forces which tend to turn it in opposite directions. The force which acts as a motor, is called the *Power*, the other one is called the *Resistance.*

Levers are of three classes, according to the position of the fulcrum with respect to the power and resistance.

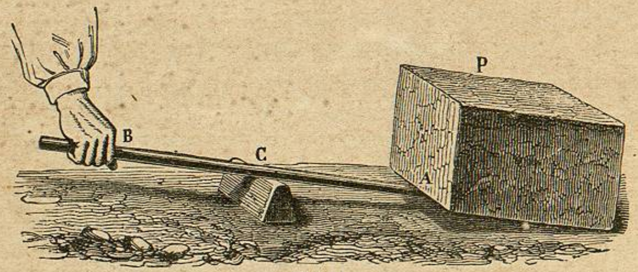

Fig. 15.

Lever of the first class.—In this class the fulcrum is between the power and the resistance. Such a lever is represented in Fig. 15. The hand is the power, the weight P is the resistance, and the fixed point C is the fulcrum.

Examples. *What is the advantage of Machines? Example.* (**30.**) What is a Lever? How many classes? Give examples of each class.

Lever of the second class.—In this class the fulcrum is beyond both the power and resistance, and nearest the resistance. Such a lever is shown in Fig. 16. The power is applied at B, the resistance at A, and the fulcrum is at C.

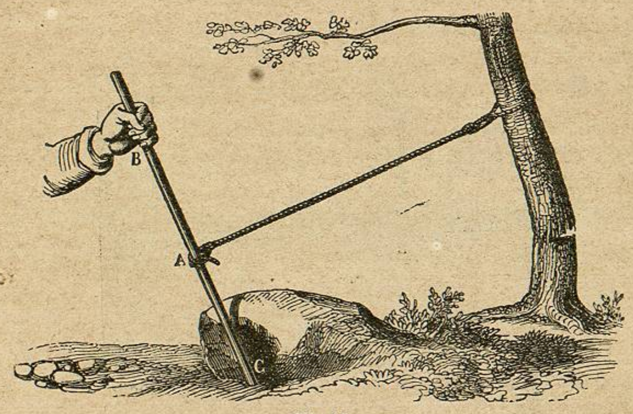

Fig. 16.

Lever of the third class.—In this class the fulcrum is beyond both the power and the resistance, and nearest the power, as shown in Fig. 17.

In every class of lever, the distances from the fulcrum, to the power and resistance, are called *Lever Arms.* In each of the figures in this article, CA is the lever arm of the power, and CB the lever arm of the resistance.

Conditions of Equilibrium of the Lever.

31. It is demonstrated in Mechanics (Art. 78), that the effect of a force produced by the aid of a lever increases as its lever arm increases, so that, if the lever arm be doubled or tripled, the effect of the force is always doubled or tripled.

What are the Lever Arms? (**31.**) What is the relation between the power and resistance?