to verify his conjecture, his hand faltered with the excitement, and he was forced to ask a friend to complete the task. The truth was reached at last, and the grand law of gravitation discovered (1682).

The sun-dial was doubtless the earliest device for keeping time. The clepsydra was afterward employed. This consisted of a vessel containing water, which slowly escaped into a dish below, in which was a float that by its height indicated the lapse of time. King Alfred used candles of a uniform size, six of which lasted a day. The first clock erected in England, about 1288, was considered of so much importance that a high official was appointed to take charge of it. The clocks of the middle ages were extremely elaborate. They indicated the motions of the heavenly bodies; birds came out and sang songs, cocks crowed, and trumpeters blew their horns; chimes of bells were sounded, and processions of dignitaries and military officers, in fantastic dress, marched in front of the dial and gravely announced the time of day. Watches were made at Nuremberg in the fifteenth century. They were styled Nuremberg eggs. Many were as small as the watches of the present day, while others were as large as a dessert-plate. They had no minute or second hand, and required winding twice per day.

On Attraction, as well as on subsequent topics treated in this book, consult Guillemin's "Forces of Nature;" Atkinson's "Ganot's Physics"; Arnott's "Elements of Physics"; Snell's "Olmstead's Natural Philosophy"; Stewart's "Elementary Physics"; Silliman's "Physics"; Everett's "Text-book of Physics"; Young's "Lectures on Natural Philosophy"; "Appleton's Cyclopedia," articles on Clocks and Watches, Weights and Measures, Gravitation, Mechanics, etc.; Peck's "Ganot's Natural Philosophy"; Miller's "Chemical Physics," Chap. III., on Molecular Force; Weinhold's "Experimental Physics"; Pickering's "Elementary Physical Manipulation"; "Fourteen Weeks in Astronomy," sections on Galileo and Newton, pp. 29–34.

The current numbers of "Harper's Magazine," "The Century Magazine," "Scribner's Magazine," "Popular Science Monthly," "Boston Journal of Chemistry," "Scientific American," "Knowledge," and "Nature," contain the latest phases of science.

IV.

ELEMENTS OF MACHINES.

NATURE is a reservoir of power. Tremendous forces are all about us, but they are not adapted to our use. We need to remold the energy to fit our wants. A water-fall can not grind corn nor the wind draw water. Yet a machine will gather up these wasted forces, and turn a grist-mill or work a pump. A kettle of boiling water has little of promise; but husband its energy in the steam-engine, and it will weave cloth, forge an anchor, or bear our burdens along the iron track.

"The hero in the fairy tale had a servant who could eat granite rocks, another who could hear the grass grow, and a third who could run a hundred leagues in half an hour. So man in nature is surrounded by a gang of friendly giants who can accept harder stints than these. There is no porter like gravitation, who will bring down any weight you can not carry, and if he wants aid, knows how to get it from his fellow-laborers. Water sets his irresistible shoulder to your mill, or to your ship, or transports vast bowlders of rock, neatly packed in his iceberg, a thousand miles."

EMERSON.

ANALYSIS OF THE ELEMENTS OF MACHINES.

ELEMENTS OF MACHINES.

- —The Simple Machines.
- —The Law of Mechanics.
- 1. The Lever.
  - 1. Definition.
  - 2. Three Classes of Levers.
    - (1.) *First Class.*
    - (2.) *Second Class*
    - (3.) *Third Class.*
  - 3. Law of Equilibrium.
  - 4. Steelyard.
  - 5. Compound Lever.
- 2. The Wheel and Axle.
  - 1. Definition and Illustration.
  - 2. Law of Equilibrium.
  - 3. Wheel-work.
- 3. The Inclined Plane.
  - 1. Definition and Illustration.
  - 2. Law of Equilibrium.
- 4. The Screw.
  - 1. Definition and Illustration.
  - 2. Law of Equilibrium.
- 5. The Wedge.
  - 1. Definition and Illustration.
  - 2. Law of Equilibrium.
- 6. The Pulley.
  - 1. Definition and Illustration.
  - 2. Fixed and Movable Pulleys.
  - 3. Combinations of Pulleys.
  - 4. Law of Equilibrium.
- 7. Cumulative Contrivances.
- 8. Perpetual Motion.

ELEMENTS OF MACHINES.

The Simple Machines are the elements to which all machinery can be reduced. The watch with its complex system of wheel-work, and the engine with its belts, cranks, and pistons, are only various modifications of some of the six elementary forms—the *lever*, the *wheel and axle*, the *inclined plane*, the *screw*, the *wedge*, and the *pulley*. These six may be still further reduced to two—the lever and the inclined plane.

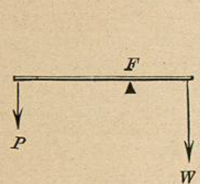
They are often termed the Mechanical Powers, but they do not produce work; they are only the means of applying it. Here again the doctrine of the Conservation of Energy holds good. The work done by the power is always equal to the resistance overcome in the weight.

The Law of Mechanics is, *the power multiplied by the distance through which it moves, is equal to the weight multiplied by the distance through which it moves.—Example:* 1 lb. of power moving through 10 feet = 10 lbs. of weight moving through one foot, or *vice versa.* In theory, the parts of a machine have no weight, move with no friction, and meet no resistance from the air. In practice, these influences must be considered.

1. The Lever is a bar turning on a pivot. The force used is termed the *power* (P), the object to be lifted the *weight* (W), the pivot on which the lever turns the *fulcrum* (F), and the parts of the lever each side of the fulcrum the *arms*.

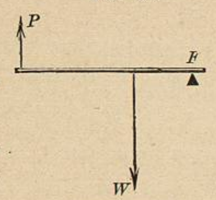
THREE CLASSES OF LEVERS.—In the three kinds, the fulcrum, weight, and power are each respectively be-

FIG. 37.



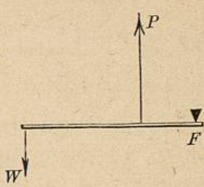
First Class.

FIG. 38.



Second Class.

FIG. 39.



Third Class.

tween the other two, as may be seen by comparing Figs. 37–39.

First Class.—We wish to lift a heavy stone. Accordingly we put one end of a handspike under it, and resting the bar on a block at F, bear down at P.—A pump-handle is a lever of the first class. The hand is the P, the water lifted the W, and the pivot the F.—A pair of scissors is a double lever of the same class. The cloth to be cut is the W, the hand the P, and the rivet the F.

FIG. 40.

Lifting a Stone.

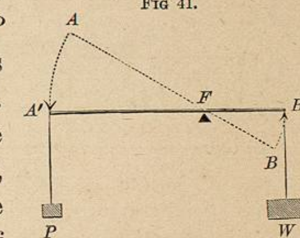
Second Class.—We may also raise the stone by resting one end of the lever on the ground, which acts as a fulcrum, and lifting up on the bar.—An oar is a lever of the second class. The hand is the

P, the boat the W, and the water the F. In this case the F is not immovable.

Third Class.—The treadle of a sewing-machine is a lever of the third class. The front end resting on the ground is the F, the foot is the P, and the force is transmitted by a rod to the W, the arm above.

LAW OF EQUILIBRIUM.—The product of P multiplied by the perpendicular distance between its line of action and F, is called the *moment* of P. In the lever, P balances W when the moments about the fulcrum are equal. In Fig. 41, assume AB to be the initial position of a lever, which is then turned into the position $A'B'$ by application of the power, P, which balances the weight W, its line of action being $A'P$, while that of W is $B'W$. The power moves through a distance equal to AA', while the weight moves through a distance equal to BB'. But these distances are proportional to $A'F$ and $B'F$. We may represent $A'F$ by Pd, the distance of the power's line of action from F; and $B'F$ by Wd, the distance of the weight's line of acton from F. Substituting these terms in the general expression of the law, we have,

FIG 41.

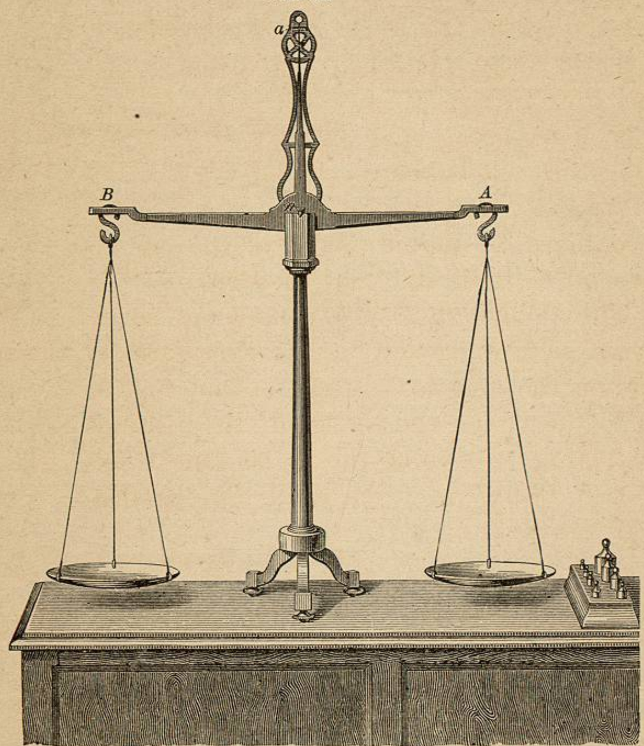


$$P \times Pd = W \times Wd \ (1) \qquad P : W :: Wd : Pd \ (2) \qquad P = \frac{W \times Wd}{Pd} \ (3)$$

In the first and second classes, as ordinarily used, we gain power and lose time; in the third class we lose power and gain time.

The Balance is a lever of the first class with equal arms. The bar, *AB* (Fig. 42), has a pair of scale pans suspended from its ends. At the middle

Fig. 42.



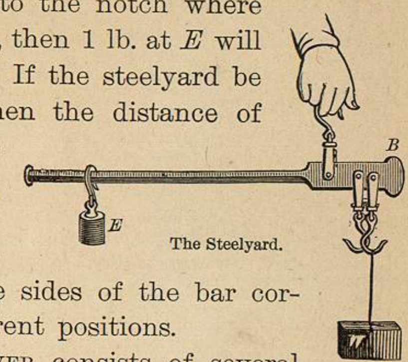
The Balance.

an axis, *n*, made of steel and provided with a knife edge, rests upon a hard surface, so that the friction may be the least possible; this is the fulcrum.

The Steelyard is a lever of the first class. The *P* is at *E*, the *F* at *C*, and the *W* at *D*. If the dis-

tance from the pivot of the hook *D* to the pivot of the hook *C* be one inch, and from the pivot of the hook *C* to the notch where *E* hangs be 12 inches, then 1 lb. at *E* will balance 12 lbs. at *W*. If the steelyard be reversed (Fig. 44), then the distance of the *F* from the *W* is only $\frac{1}{4}$ as great, and 1 lb. at *E* will balance 48 lbs. at *D*. Two sets of notches on opposite sides of the bar correspond to these different positions.

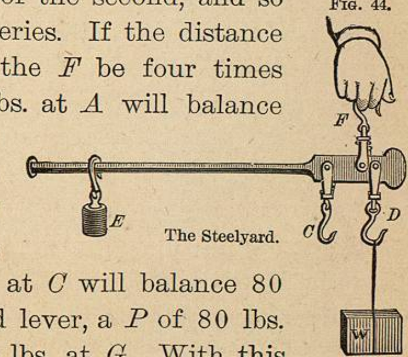
Fig. 43.



The Steelyard.

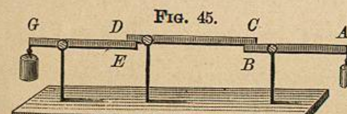
The Compound Lever consists of several levers so connected that the short arm of the first acts on the long arm of the second, and so on to the last of the series. If the distance of *A* (Fig. 45) from the *F* be four times that of *B*, a *P* of 5 lbs. at *A* will balance a *W* of 20 lbs. at *B*. If the arms of the second lever are of the same comparative length, a *P* of 20 lbs. at *C* will balance 80 lbs. at *E*. In the third lever, a *P* of 80 lbs. at *D* will balance 320 lbs. at *G*. With this system of three levers, 5 lbs. at *A* will accordingly balance 320 lbs. at *G*. To raise the *W* 1 ft., however, the *P* must move 64 ft. Thus what is gained in power is lost in time.

Fig. 44.



The Steelyard.

Fig. 45.

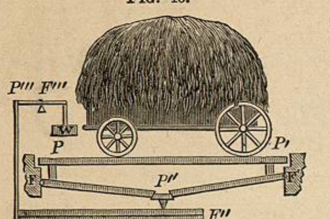


The Compound Lever.

There is no creation of force by the use of the levers; on the contrary, there is an appreciable loss because of friction.

Hay scales are constructed upon the principle of the compound lever. Considering the large mass on the platform as the power, its pressure is transmitted at the points P and P' (Fig. 46) to a pair of levers of the third class, whose fulcrums are at F and F'. Pressure is thus produced at P'' on another lever whose fulcrum is at F''. At the remote end of this in turn, pressure is transmitted by the upright bar to the end, P''', of a lever of the first class whose fulcrum is at F'''. The weight, W, can be adjusted at will until a balance is secured.

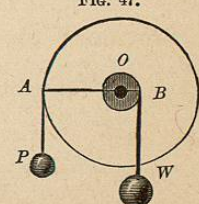
Fig. 46.



Hay Scales.

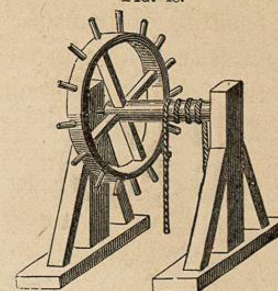
2. The Wheel and Axle is a kind of perpetual lever. As both arms work continuously, we are not obliged to prop up the W and re-adjust the lever. In the windlass used for drawing water from a well, the P is applied at the handle, the W is the bucket, and the F is the axis of the windlass. The long arm of the lever is the length of the handle, and the short arm is the semi-diameter of the axle. This is shown in a cross-section (Fig. 47) where the center, O, is the F, OA the long arm, and OB the short arm.—In Fig. 48, instead of turning a handle we take hold of pins inserted in the rim of the wheel.—Fig. 49 represents a capstan used on vessels for raising the anchor. The P is applied by handspikes inserted in the axle.—Fig. 50 shows a form of the capstan employed in moving buildings, in which a horse furnishes the power.

Fig. 47.



Wheel and Axle.

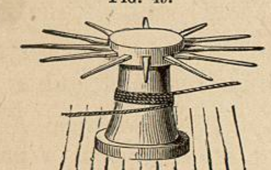
Fig. 48.



Wheel and Axle.

Law of Equilibrium.—By turning the handle or wheel around once, the rope will be wound around the axle and the W be lifted that distance. Applying the law of mechanics, $P \times$ the circumference of the wheel $= W \times$ circumference of the axle; or, as circles are proportional to their radii,

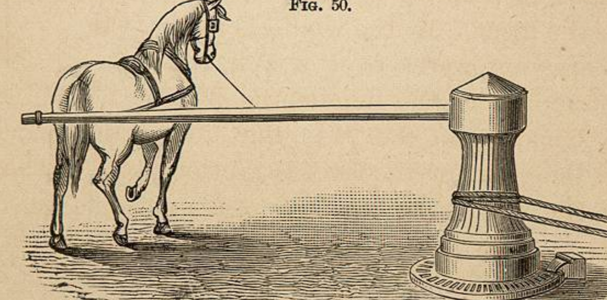
Fig. 49.



Capstan.

$$P : W :: \text{radius of the axle} : \text{radius of the wheel.} \quad . \; . \; . \; . \quad (4)$$

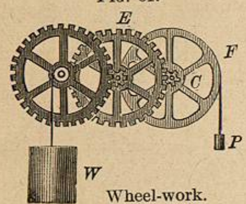
Fig. 50.



Capstan.

Wheel-work consists of a series of wheels and axles which act upon one another on the principle of the compound lever. The projections on the circumference of the wheel are termed *teeth*, on the axle *leaves*, and the axle itself is called a *pinion*. If the radius of the wheel *F* be 12 inches, and that of each pinion 2 inches, then a *P* of 1 lb. will apply a force of 6 lbs. to the second wheel *E*. If the radius of this be 12 inches, then the second wheel will apply a *P* of 36 lbs. to the third wheel, which, acting on its axle, will balance a *W* of 216 lbs. The *W* will pass through only $\frac{1}{216}$ the distance of the *P*. We thus gain power and lose speed. If we wish to reverse this we can apply the *P* to the axle, and so gain speed. This is the plan adopted in factories, where a water-wheel furnishes abundant power, and spindles or other machines are to be turned with great rapidity.

Fig. 51.

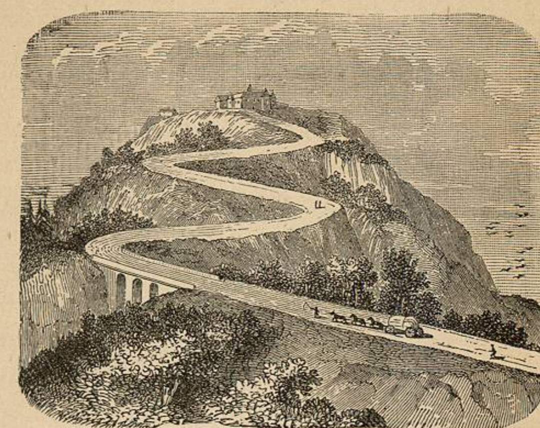


Wheel-work.

3. The Inclined Plane.—If we wish to lift a heavy cask into a wagon, we rest one end of a plank on the wagon-box and the other on the ground. We can then easily roll the cask up this inclined plane. When roads are to be made over steep hills, they are sometimes constructed around the hill, like the thread of a screw, or in a winding manner as shown in Fig. 52. There is a remarkable ascent of this kind on Mount Royal, Montreal.

Law of Equilibrium.—In Fig. 53 the *P* must descend vertically a distance equal to the length of the plane, *AC*, in order to move the *W* from *A* to *C* and thus elevate it through the vertical height *BC*. Ap-

Fig. 52.

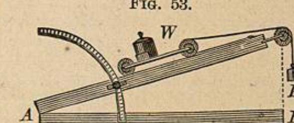

Inclined Plane.

plying the law of mechanics, *P* × length of inclined plane = *W* × height of inclined plane; hence,

P : *W* :: height of inclined plane : length of inclined plane.* (5)

If a road ascend 1 ft. in 100 ft., then a horse drawing up a wagon has to lift only $\frac{1}{100}$ of the load, besides overcoming the friction. A body sliding down a perfectly smooth inclined plane acquires the same velocity that it would in falling the same

Fig. 53.



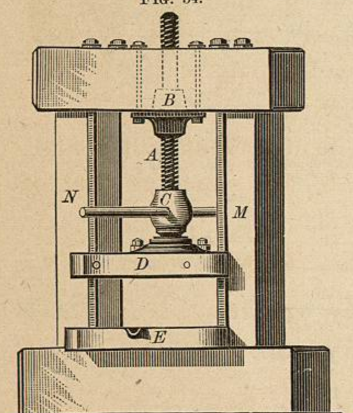
Inclined Plane.

* If we roll into a wagon a barrel of pork, weighing 200 lbs., up a plane 12 ft. long and 3 ft. high, we have 12 ft. : 3 ft. :: 200 lbs. : x = 50 lbs. We lift only 50 lbs., or $\frac{1}{4}$ of the barrel, but we move it through four times the space that would be necessary if we could elevate it directly into the wagon. We thus lose speed and gain power. The longer the inclined plane, the heavier the load we can lift, but the more time it will take to do it.

height perpendicularly. A train descending a grade of 1 ft. in 100 ft. tends to go down with a force equal to $\frac{1}{100}$ of its weight.*

4. The Screw consists of an inclined plane wound around a cylinder, the former being called the *thread*, and the latter the *body*. It works in a *nut* which is fitted with reverse threads to move on the thread of the screw. The nut may turn on the screw, or the screw in the nut. The P may be applied to either, by means of a wrench or lever. The screw is used in vises; in raising buildings; in copying letters, and in presses for squeezing the juice from apples, sugar-cane, etc.

Fig. 54.



Screw.

Law of Equilibrium.—When the P is applied at the end of a lever, attached to the head of the screw, it describes a circle of which the lever is the radius. The distance through which the P passes, is the circumference of this circle; and the height to which the W is elevated at each revolution of the screw, is the distance between two of the threads.

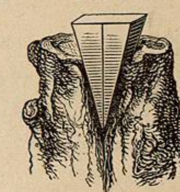
* Near Lake Lucerne is a forest of firs on the top of Mount Pilatus, an almost inaccessible Alpine summit. By means of a wooden trough, the log is conducted into the water below, a distance of eight miles, in but little more than as many minutes. The force with which it falls is so prodigious, that if it jumps out of the trough it is dashed to pieces.

Applying the law of mechanics, $P \times$ circumference of circle $= W \times$ interval between the threads; hence,

$$P : W :: \text{interval} : \text{circumference.} \quad \ldots\ldots (6)$$

The efficiency of the screw may be increased by lengthening the lever, or by diminishing the distance between the threads.

Fig. 55.

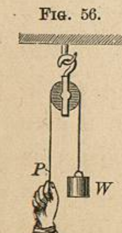

Wedge.

5. The Wedge consists generally of two inclined planes placed back to back. It is used for splitting wood and stone and lifting vessels in the dock. Leaning chimneys have been righted by wedges driven in on the lower side. Nails, needles, pins, knives, axes, etc., are made on the principle of the wedge.

The Law of Equilibrium is the same as that of inclined plane—viz.:*

$$P : W :: \text{thickness of wedge} : \text{length of wedge.} \quad \ldots (7)$$

Fig. 56.



Fixed Pulley.

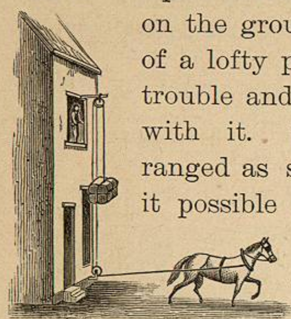
6. The Pulley consists of a wheel, within the grooved edge of which runs a cord.

A Fixed Pulley (Fig. 56) merely changes the direction of the force. There is no gain of power or speed, as the hand P must move down as much as the weight W rises, and both with the same

* In practice, however, this by no means accounts for the prodigious power of the wedge. Friction, in the other mechanical powers, diminishes their efficiency; in this it is essential, else the wedge would fly back and the effect be lost. In the others, the P is applied as a steady pressure; in this it is a sudden blow, and depends upon the kinetic energy expended in the stroke of the hammer.

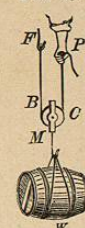
velocity. It is simply a lever of the first class with equal arms. By its use a man standing on the ground will hoist a flag to the top of a lofty pole, and thus avoid the trouble and danger of climbing up with it. Two fixed pulleys, arranged as shown in Fig. 57, make it possible to elevate a heavy load to the upper story of a building by horse-power.

Fig. 57.



Application of Fixed Pulleys.

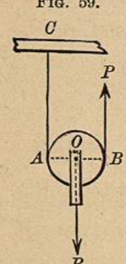
Fig. 58.



Movable Pulley.

A Movable Pulley is represented in Fig. 58. One half of the barrel is sustained by the hook while the hand lifts the other. As the P is one half the W, it must move through twice the space; in other words, by taking twice the time, we can lift twice as much. Thus power is gained and time lost.

Fig. 59.



Movable Pulley.

We may also explain the single movable pulley by Fig. 59. A represents the F, R the W acting in the line OR, and B the P acting in the line BP. This is a lever of the second class; and as $AO = \frac{1}{2}AB$, $P = \frac{1}{2}W$.

Fig. 60.

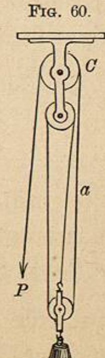
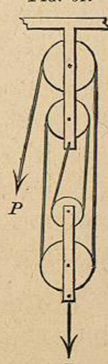


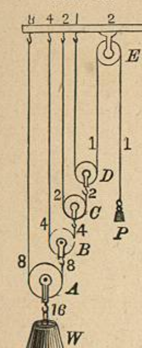
Fig. 61.



Systems of Pulleys.

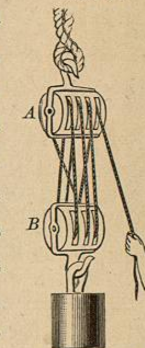
Combinations of Pulleys. — (1.) In Fig. 60, we have the W sustained by three cords, each of which is stretched by a tension equal to the P; hence, 1 lb. of power will balance 3 lbs. of weight. (2.) In Fig. 61, the P will sustain a W of 4 lbs. (3.) In Fig. 62, the cord marked 1 1 has a tension equal to P in each part; the one marked 2 2 has a tension equal to $2P$ in each part, and so on with the others. The total tension acting on W is 16; hence, $W = 16P$. In this system, D rises twice as fast as C, four times as fast as B, etc. Work must stop when D reaches E, which gives little sweep to A for lifting W. (4.) Fig. 63 represents the ordinary "tackle-block" used by mechanics.

Fig. 62.



System of Pulleys.

Fig. 63.



Tackle Block.

Law of Equilibrium.—When a continuous rope is used, let n represent the number of separate parts of the cord which sustain the movable block. We then have

$$P = \frac{W}{n}. \quad \quad (8)$$

When the number of movable and of fixed pulleys is equal, in general, $W = P \times$ twice the number of movable pulleys.

7. Cumulative Contrivances. — A hammer, club, pile-driver, sling, fly-wheel, etc., are instruments for accumulating energy to be used at the proper moment. Thus we may press a hammer on the head of a nail with all our strength to no purpose; but swing the hammer the length of the arm, and the blow will bury the nail to the head. The strength of our muscles and the attraction of gravity during the fall both gather energy to be exerted at the instant of contact. A fly-wheel by its momentum equalizes an irregular force, or produces a sudden effect.*

8. Perpetual Motion.—It is impossible to make a machine capable of perpetual motion. No combination can produce energy; it can only direct that which is applied. In all machinery there is friction; this must ultimately exhaust the power and bring the motion to rest. The only question is, how long a time will be required for the leakage to drain the reservoir. Every year brings to light new seekers after perpetual motion. The mere fact that a man devotes himself to the solution of this impossible problem is now generally regarded as a proof that either his mental balance has been disturbed, or his knowledge of the laws of nature is too meager to entitle him to consideration.

PRACTICAL QUESTIONS.

1. Describe the rudder of a boat as a lever. A door. A door-latch. A lemon-squeezer. A pitchfork. A spade. A shovel. A sheep-shears. A poker. A pair of tongs. A balance. A pair of pincers. A wheelbarrow. A man pushing open a gate with his hand near the hinge. A sledge-hammer, when the arm is swung from the shoulder. A nut-cracker. The arm (see "Physiology," p. 48).

2. Show the change that occurs from the second to the third class of lever, when you take hold of a ladder at one end and raise it against a building.

3. Why is a pinch from the tongs near the hinge more severe than one near the end?

4. Two persons are carrying a weight of 250 lbs., hanging between them from a pole 10 ft. in length. Where should it be suspended so that one will lift only 50 lbs.?

5. In a lever of the first class, 6 ft. long, where should the *F* be placed so that a *P* of 1 lb. will balance a *W* of 23 lbs.?

6. What *P* would be required to lift a barrel of pork with a windlass whose axle is 1 ft. in diameter, and handle 3 ft. long?

7. What sized axle, with a wheel 6 ft. in diameter, would be required to balance a *W* of one ton by a *P* of 100 lbs.?

8. What number of movable pulleys would be required to lift a *W* of 200 lbs. by a *P* of 25 lbs.?

9. How many pounds could be lifted with a system of 4 movable pulleys by a *P* of 100 lbs.?

10. What *W* could be lifted with a single horse-power* acting on a system of pulleys shown in Fig. 62?

11. What distance should there be between the threads of a screw to enable a *P* of 25 lbs. acting on a handle 3 ft. long, to lift a ton?

12. How high would a *P* of 12 lbs., moving 16 ft. along an inclined plane, lift a *W* of 96 lbs.?

13. I wish to roll a barrel of flour into a wagon, the box of which is 4 ft. from the ground. I can lift but 24 lbs. How long a plank must I get?

14. What *W* can be lifted with a *P* of 100 lbs. acting on a screw having threads 1 in. apart, and a handle 4 ft. long?

15. What is the object of the balls often cast on the ends of the handle of the screw used in presses for copying letters?

16. In a steelyard 2 ft. long, the distance from the weight-hook to the fulcrum-hook is 2 in.; how heavy a body can be weighed with a pound weight?

17. Describe the change from the first to the third class of lever, in the different ways of using a pitchfork or a spade.

18. Why are not blacksmiths' tongs and fire-tongs constructed on the same principle?

19. In a lever of the third class, what *W* will a *P* of 50 lbs. balance, if one arm be 12 ft. and the other 3 ft. long?

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* We see the former illustrated in a sewing-machine, and the latter in a punch operated by a treadle. In the one case, the irregular action of the foot is turned into a uniform motion, and in the other it is concentrated in a heavy blow that will pierce a thick piece of metal.

* A *horse-power* is a force which is equivalent to 550 *foot-pounds*, *i.e.*, can raise against gravity 550 lbs. one foot in one second, or 33,000 lbs. one foot in one minute.

20. In a lever of the second class, what *W* will a *P* of 50 lbs. balance, with a lever 12 ft. long, and the *W* 3 ft. from the *F*?

21. In a lever of the first class, what *W* will a *P* of 50 lbs. balance, with a lever 12 ft. long, and the *F* 3 ft. from the *W*?

22. In a wheel and axle, the $P = 40$ lbs., the $W = 360$ lbs., and the diameter of the axle = 8 in. Required the circumference of the wheel.

23. Suppose, in a wheel and axle, the $P = 20$ lbs., the $W = 240$ lbs., and the diameter of the wheel = 4 ft. Required the circumference of the axle.

24. Required, in a wheel and axle, the diameter of the wheel, the diameter of the axle being 10 in., the *P* 100 lbs., and the *W* 1 ton.

25. Why is the rim of a fly-wheel made so heavy?

26. Describe the hammer, when used in drawing a nail, as a *bent lever*, *i.e.*, one in which the bar is not straight.

27. Describe the four levers shown in Fig. 46, when both the load of hay and the weight are considered, respectively, as the *W* and the *P*.

SUMMARY.

ALL machines can be resolved into a few elementary forms. Of these there are six, viz., the lever, the wheel and axle, the inclined plane, the screw, the wedge, and the pulley. Though called the mechanical powers, they are only instruments by which we can avail ourselves of the forces of nature. Molar energy or the motion of masses, as of air, water, steam, etc., is thus utilized, while the strength of a horse does the work of many men. A force of small intensity made to act through a considerable distance becomes one of great intensity acting through a small distance, and *vice versa*. By the use of the mechanical powers, the application of energy is made more convenient, but always some energy is absorbed in moving the machine and overcoming friction, and hence prevented from doing useful work. No machine can be a source of power, but, on the contrary, it thus involves a loss of power. The law of machines is, that the power multiplied by the distance through which it moves is equal to the weight multiplied by the distance through which it moves, plus the internal work involved in the motion of the machine. This law is equivalent to a statement that perpetual motion is impossible; for no known terrestrial source of energy is exhaustless.

The lever is a bar resting at some point on a prop as a center of motion. The crowbar, claw-hammer for drawing nails, pincers, windlass, and steelyard are examples of various classes of levers. The compound lever consists of several levers, so connected, that the short arm of one acts on the long arm of the next, as in the hay scales. In the bent lever, the power and weight act in lines that are not necessarily parallel, but still tend to produce rotation of the lever about its fulcrum, if the product of the power by the perpendicular distance from its line of action to the fulcrum be not equal to the weight multiplied by the distance from its line of action to the fulcrum. These two products are called the moments about the fulcrum. If the two moments are equal and opposite, the result is equilibrium.

To the lever may be reduced the wheel and axle, and the pulley. To the inclined plane may be reduced the wedge and the screw. The awl, vise, carpenter's plane, corkscrew, and stairs are common modifications of the inclined plane. The blade of a pocket-knife is a familiar example of the wedge, which itself is only a movable inclined plane. In the application of these last mechanical powers, friction becomes a most important and useful element; and it interferes so much with the operation of the simple machine alone, which should be devoid of friction in order to make exact calculation possible, that it is usually impossible to calculate the ratio between the power applied and the work accomplished through the medium of a wedge.

HISTORICAL SKETCH.

SIMPLE machines for moving large bodies are as old as history. The Babylonians knew the use of the lever, the pulley, and the roller. The Romans were acquainted with the lever, the wheel and axle, and the pulley (simple and compound). The Egyptians, it is thought, raised the immense stones used in building the Pyramids, by inclined planes made of earth which was afterward removed. Archimedes, in the third century B.C., discovered the law of equilibrium in the lever. * His investigations, however, were too far in advance of his time to be fully understood, and the teachings of Aristotle were long after accepted by scientific men. The law of mechanics, or of Virtual Velocities, as it is called, was discovered by Galileo.

* It is often said that Archimedes, in allusion to the tremendous power of the lever, asserted that, Give him a fulcrum and he could move the world. Had he been allowed such a chance, "the fulcrum being nine thousand leagues from the center of the earth, with a power of 200 lbs. the geometer would have required a lever 12 quadrillions of miles long and the power would have needed to move at the rate of a cannon-ball to lift the earth one inch in 27 trillions of years."

V

PRESSURE OF LIQUIDS AND GASES.

"THE waves that moan along the shore,
The winds that sigh in blowing,
Are sent to teach a mystic lore
Which men are wise in knowing."