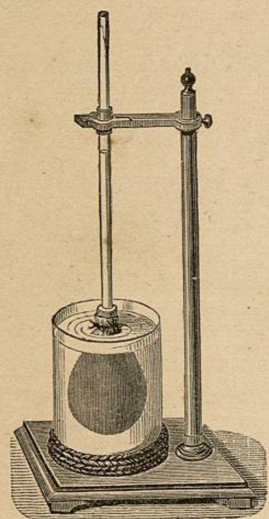
a curious manner, according to the nature of the liquid and the substance used. At the end of a glass tube (Fig. 24) fasten a bladder of alcohol. Fill the jar with water, and mark the height to which the alcohol ascends in the tube. The column will soon begin to rise slowly. On examination, we shall see that the alcohol is passing out through the pores of the bladder and mixing with the water, while the water is coming in more rapidly. The bladder is not porous in the sense of having sensible pores.

Fig. 24.



Osmose.

Diffusion of fluids, through the medium of a substance which attracts them unequally, is called osmose. It is applied by the chemist in methods of analysis where the separation of substances is based on their unequal diffusibility. Crystals in solution pass readily through animal membrane, like bladder, while substances that do not crystallize, like gum, gelatine, or white of egg, are stopped.

PRACTICAL QUESTIONS.

1. Why does cloth shrink when wet?
2. Why do sailors at a boat-race wet the sails?
3. Why is writing-paper sized?
4. Why does paint prevent wood from shrinking?

5. What is the shape of the surface of a glass-full of water? Of mercury?
6. Why can we not perfectly dry a towel by wringing?
7. Why will not water run through a fine sieve when the wires are greased?
8. Why will camphor dissolve in alcohol, and not in water?
9. Why will mercury rise in zinc tubes as water will in glass tubes?
10. Why will ink spilled on the edge of a book extend farther inside than if spilled on the side of the leaves?
11. If you should happen to spill some ink on the edge of your book, ought you to press the leaves together?
12. Why can you not mix water and oil?
13. What is the object of the spout on a pitcher? *Ans.* The water would run down the side of the pitcher by the force of adhesion, but the spout throws it into the hands of gravitation before adhesion can catch it.
14. Why will water wet your hand, while mercury will not?
15. Why is a pail or tub liable to fall to pieces if not filled with water or kept in a damp place?
16. Name instances where the attraction of adhesion is stronger than that of cohesion.
17. Why does the water in Fig. 18 stand higher inside of the tube than next the glass on the outside?
18. Why will clothes-lines tighten and sometimes break during a shower?
19. In casting large cannon, the gun is cooled by a stream of cold water. Why?
20. Why does paint adhere to wood? Chalk to the blackboard?
21. Why does a towel dry one's face after washing?
22. Why will a greased needle float on water?
23. Why is the point of a pen slit?
24. Why is a thin layer of glue stronger than a thick one?

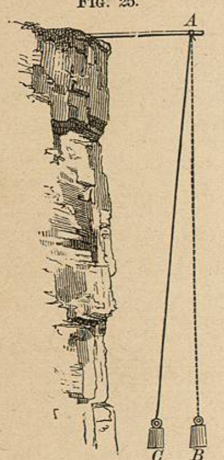
II. ATTRACTION OF GRAVITATION.

We have spoken of the attraction existing between the molecules of bodies at minute distances. We now notice an attraction which acts at all distances.

1. Law of Gravitation.—Hold a stone in the hand, and you feel a power constantly drawing it to the ground. We call this familiar phenomenon *weight.* It is really the attraction of the earth pulling the stone back to itself—an instance of a general law, one operation of an ever-active force. For *every particle of matter in the universe* attracts every other particle with a force proportional to the product of their masses, and increasing as the square of the distance decreases.*

Gravitation is the general term applied to the attraction that exists between all bodies in the universe. *Gravity* is the earth's attraction for terrestrial bodies; it tends to draw them toward the center of the earth.

FIG. 25.



Deflection of a Plumb-line by a mountain. (Exaggerated.)

2. Illustrations of Gravity.—A stone falls to the ground because the earth attracts it; but in turn the stone attracts the earth. Each moves to meet the other, but the stone passes through as much greater distance than the earth as its mass is less. The mass of the earth is so great that its motion is imperceptible.—A plumb-line hanging near a mountain is attracted from the vertical. In Fig. 25, AB represents the ordinary position of the line, while AC indicates the attractive power (greatly exaggerated) of the mountain.*

* The force of gravitation acts on every particle of matter, and hence it is not confined to our own world. By its action the heavenly bodies are bound to one another, and thus kept in their orbits. It may help us to conceive how the earth is supported, if we imagine the sun letting down a huge cable, and every star in the heavens a tiny thread, to hold our globe in its place, while it in turn sends back a cable to the sun and a thread to every one of the stars. So we are bound to them and they to us. Thus the worlds throughout space are linked together by these cords of mutual attraction, which, interweaving in every direction, make the universe a unit.

3. Mass and Weight.—The quantity of matter in a body is its mass. The measure of the earth's attraction upon it is its weight. If m be the number of units of mass in a body, and g be the number of units of force expressing the earth's attraction, then its weight, w, is equal to m multiplied by g; or, $w = mg$, whence

$$m = \frac{w}{g}.$$

4. The Earth's Center of Gravity is that point within it where the attraction of all the particles on any one side is equal to the attraction of all those on the opposite side. As an attracting mass the whole earth may be regarded as if it were concentered at this point. Its position is probably very near the geometric center. When the earth's center is mentioned we generally mean its center of gravity.

5. The Center of Gravity of a Body is that point about which it may be balanced. A straight line from this point to the earth's center of gravity is called the line of direction. It is also called a vertical, or plumb-line. Gravity tends to cause the body to move along this line toward the center.†

* Maskelyne, in 1774, found the attraction of Mount Schehallien to deflect a plumb line 12″. By comparing this force with that of the earth, the specific gravity of the earth was estimated to be five times that of water. Later investigations make it 5.67.

† *Downward* means toward the earth's center; *upward* means the opposite. Any two bodies moving downward, one from America and the other from Europe, if unresisted, would meet at the earth's center if their fall were properly timed.

6. Laws of Weight.—I. *The weight of a body at the center of the earth is nothing;* for since the opposite attractions are mutually balanced there can be no tendency to motion in any direction.

II. *The weight of a body above the surface of the earth decreases as the square of the distance from the center of the earth increases.**

III. *The weight of a body varies on different portions of the surface of the earth.*† It will be least at the equator, because (1), on account of the bulging form of our globe a body is there farther from the earth's center; and (2), the centrifugal force is there strongest. It will be greatest at the poles, because (1), on account of the flattening of the earth a body at a pole is there nearer to the earth's center; (2), there is no centrifugal force at the poles.

7. Falling Bodies.—I. *Under the influence of the constant force of gravity alone all bodies fall with equal rapidity.*

* A body at the surface of the earth (4,000 miles from the center) weighs 100 lbs. What would be its weight 1,000 miles above the surface (5,000 miles from the center)? SOLUTION: (5,000 mi.)^2 : (4,000 mi.)^2 :: 100 lbs. : x = 64 lbs. Or, its weight would decrease in the ratio of $\frac{4000^2}{5000^2} = \frac{16}{25}$. Hence it would weigh $\frac{16}{25} \times 100$ lbs. = 64 lbs.—The weight of a body below the surface of the earth is commonly said to decrease directly as the distance from the center decreases. Thus, 1,000 miles below the surface, a body would lose $\frac{1}{4}$ its weight. In fact, however, the density of the earth increases so much toward the center, that "for $\frac{7}{10}$ of the distance the force of gravity actually becomes stronger than on the surface."

† In these statements concerning weight, a spring-balance is supposed to be employed. If it be graduated to indicate correctly at a medium latitude, it would show too little at the equator, and too much at the poles. In other words, a pound weighed with such a spring-balance at the equator would contain a greater mass of matter than one weighed at the poles by about $\frac{1}{192}$ part.

This is well illustrated by the "guinea and feather experiment." Let a coin and a feather be placed in a tube, and the air exhausted. Quickly invert the tube, and the two bodies will fall in nearly the same time. Let in the air again, and the feather will flutter down long after the coin has reached the bottom.* Hence we conclude that in a vacuum all bodies descend with equal velocity, and that the resistance of the air and the adhesion of the feather to the tube are the causes of the variation we see between the falling of light and of heavy bodies in it.

FIG. 26.

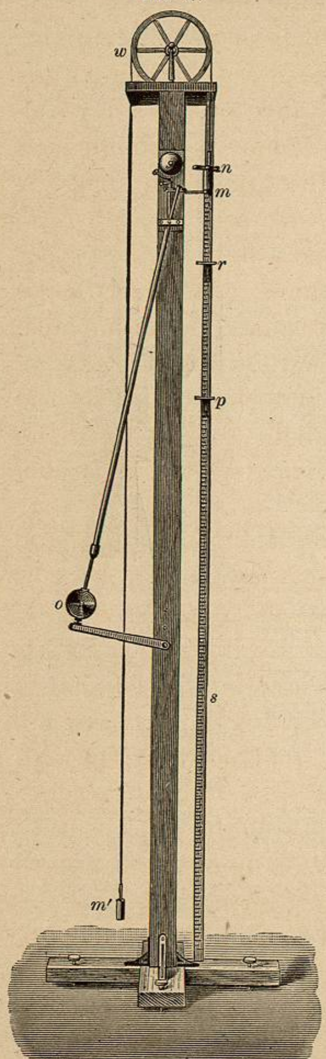
Guinea and Feather Experiment.

II. ATWOOD'S MACHINE.†—To deduce the laws of falling bodies we make use of Atwood's machine (Fig. 27). This consists of a very light grooved wheel, *w*,

* The same fact may be noticed in the case of a sheet of paper. When spread out, it merely flutters to the ground; but when rolled in a compact mass, it falls quickly. In this case we have not increased the force of attraction, but we have diminished the resistance of the air. "It is difficult for many pupils to understand how, under the influence of gravity alone, all bodies fall with equal rapidity. An illustration, which is usually effective, is that of a number of bodies of the same kind, say bricks, which will separately fall in the same space of time. The pupil will admit that, if all of them are connected together, inasmuch as nothing is thereby added to their weight, there is no reason why the mass of bricks should not fall in the time of a single one, notwithstanding it is a larger body."—WM. H. TAYLOR.

† If the teacher is not provided with Atwood's machine, or if the pupils

Fig. 27.



Atwood's Machine.

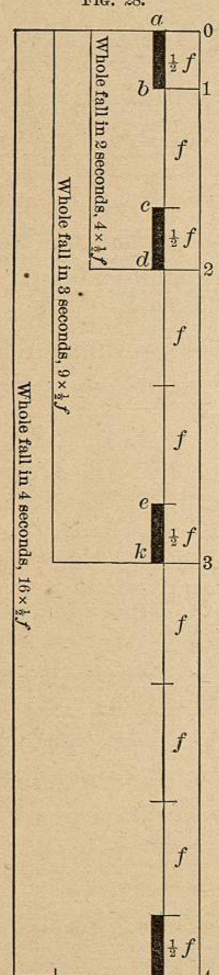
pivoted at the top of a firm vertical pillar, on one side of which is a graduated strip, *s*, divided into inches or centimeters. A silk thread, passing over the wheel, supports two equal masses, m and m'. The force of gravity on one of these just balances its force on the other. A small cross-bar, n, placed upon m, gives vertical motion, by the action of gravity on it, to the whole mass, which we may call M, made up of $(m + m' + n)$. Since the momentum of m, moving downward, is balanced by that of m', moving upward, the rate of motion of M is as much less than if it were falling freely as the mass of the cross-bar is less than

are unfamiliar with algebra, it may be found best to omit this discussion of Falling Bodies. The subject receives special attention in the present edition on account of the united request of many teachers. It has been reduced within the narrowest limit consistent with clearness.

the whole mass, M. An allowance has to be made for the mass of the wheel, which is put in circular motion at the same time. The cross-bar being thus made to fall slowly, the resistance of the air is decreased, and the distance that M moves through each second is easily measured on the graduated strip. A pendulum, *o*, marks the successive seconds, and is so arranged as to release the support of m at the proper moment, thus allowing M to move. Attached to the graduated strip are a movable ring, *r*, and a movable plate, *p*. If these be placed as shown in Fig. 27, m would pass through the ring and be stopped by the plate, while the cross-bar would be caught upon the ring, so that any further motion of m would be due to momentum alone.

Experiments with Atwood's Machine. — Suppose the size of the cross-bar to be so adjusted to that of m and m' that there is a fall of 5 cm. (see p. 7) during the first second, represented by the band, *ab*, in Fig. 28. Let the ring be now so placed that it shall stop the cross-bar at the end of the first second. The momentum of the mass will carry it through 10 cm. during the next second, so that m reaches the point *c*. This distance, *bc*, through which a body moves in a second, on account of momentum due to the action of a constant force upon it during the previous second, is called the *acceleration*. The removal of the cross-bar was in effect the same as removing the constant force of gravity. If we call the acceleration f, the distance the body moved during the first second was $\frac{1}{2}f$. Hence, *If a body be moved from a position of rest by a constant force, its distance during the first second is half the acceleration.*

Fig. 28.



Suppose the ring to be removed and the plate to be so adjusted as to stop the fall at the end of two seconds. The distance traversed will be found now to be 20 cm. (*ad*, Fig. 28). This is made up of 5 cm. ($\frac{1}{2}f$) due to gravity during the first second, 10 cm. (f) due to momentum thus acquired, and another 5 cm. ($\frac{1}{2}f$) due to the continued action of gravity during the next second.

According to the First Law of Motion (p. 22), any momentum once acquired will be retained. The velocity at the end of the first second was 10 cm. (f). The action of gravity during the next second will confer 10 *cm. more* of velocity, so that at the end of two seconds the final velocity is 20 cm. (*de*, or $2f$, Fig. 28). If the constant force had been greater than that of gravity, this increase of velocity in each successive second would have been greater. Hence,

The acceleration is the measure of a constant

force, and is equal to the increase of velocity which it causes in each successive second.

If the ring be removed, the body during the third second moves 5 cm. farther (*ek*, Fig. 28) than it would by momentum alone, or through 25 cm. In like manner we easily find that during the fourth second it moves 35 cm. In successive seconds, therefore, the spaces passed over are 5, 15, 25, and 35 cm. Adding these together, we see that the *whole* fall is at the end of one second, 5 cm.; two seconds, 20 cm.; three seconds, 45 cm.; four seconds, 80 cm.

Equations of Falling Bodies.—These results are combined in the accompanying table, where the acceleration, 10 cm., is represented by f.

Fig. 29.

t	1	2	3	4		
v	f	$f \times 2$	$f \times 3$	$f \times 4$	$v = ft$	(1)
s	$\frac{1}{2}f$	$\frac{1}{2}f \times 3$	$\frac{1}{2}f \times 5$	$\frac{1}{2}f \times 7$	$s = \frac{1}{2}f(2t-1)$	(2)
S	$\frac{1}{2}f$	$\frac{1}{2}f \times 4$	$\frac{1}{2}f \times 9$	$\frac{1}{2}f \times 16$	$S = \frac{1}{2}ft^2$	(3)

The horizontal line marked t gives the time in seconds; that marked v, the velocity at the end of each second; that marked s, the space traversed during each successive second; and that marked S, the whole space traversed from the beginning of fall to the end of each second. Taking any one of the vertical columns, such as the fourth, we see that

(1.) At the end of any given second, the velocity is equal to the acceleration multiplied by the number of the second; or, $v = ft$.

(2.) During any particular second, the space traversed is equal to half the acceleration multiplied by one less than double the number of the second; or, $s = \frac{1}{2}f(2t - 1)$.

(3.) The whole space traversed during a given number of seconds is equal to half the acceleration multiplied by the square of the time in seconds; or, $S = \frac{1}{2}ft^2$.

8. Bodies Falling Freely.—If a body falls freely, the acceleration is about 9.8 meters, or 32 feet.* If we represent this by g in the equations just deduced, we have

$$v = gt \quad \text{. . . . . (1)}$$

$$s = \tfrac{1}{2}g(2t - 1) \quad \text{. . . . . (2)}$$

$$S = \tfrac{1}{2}gt^2 \quad \text{. . . . . (3)†}$$

When a body is thrown upward, gravity causes it to lose 32 feet in velocity each second until it ceases to ascend. The velocity with which it begins to rise, and its time of rising, must be the same as the velocity with which it ends its fall, and the time of falling. The laws of falling bodies may hence be applied.

* For the latitude of New York, $g = 32.16$ more nearly, or 980.2 cm. This varies slightly with the latitude and elevation of a place; but for ordinary problems it will be sufficient to assume the values given in the text.

† An additional formula that is often useful may be obtained by eliminating t in combining equations (1) and (3). The result is $v = \sqrt{2gS}$. Since S represents height (h), it is often expressed $v^2 = 2gh$. (4).

9. Measurement of Kinetic Energy. (See p. 34.) —To lift a body through any height energy must be expended. The measure of this is the weight (w), multipled by the height (h), to which it is lifted. Using the initial letters of these words for symbols, we have

$$K = wh.$$

But from the equation, at the bottom of p. 64, we have $h = \frac{v^2}{2g}$. And from p. 57, $w = mg$. Substituting these values and reducing, we have

$$K = \tfrac{1}{2}mv^2.$$

10. Resistance of the Air to Moving Bodies.—A body in falling or otherwise moving through the air expends energy in overcoming the resistance of the air. From the formula just deduced we see that this is proportional to the mass of air moved and to the square of the velocity. The flight of a cannon-ball is never so great as it would be if shot through a vacuum. Practically it is not easy to calculate beforehand the amount of energy to be lost through resistances.

11. Equilibrium.—When a body is at rest the forces which act on every molecule in it are said to balance one another, or to be in equilibrium. The most important of these forces is gravity.

(1.) Three States of Equilibrium.—1st. A body is in *stable equilibrium* when the center of gravity is below the point of support, or when any movement tends to raise the center of gravity. In Fig. 30,