

96. The angle DAF in Fig. 40, made by the body in its forward course with the perpendicular at the point of contact, is called the Angle of Incidence.

The angle EAF, made by the body in its backward course with the same perpendicular, is called the Angle of Reflection.

The great law of reflected motion is as follows:—*The Angle of Reflection is always equal to the Angle of Incidence.*

CHAPTER V.

MECHANICS (CONTINUED).

GRAVITY.

97. TERRESTRIAL GRAVITY.—When a stone is let go, we all know that it does not fly up in the air or move sideways, but falls to the ground. This is owing, as already mentioned, to a universal property of matter. The stone and the earth mutually attract each other; but the earth, being vastly superior in size, draws the stone to itself, or in other words, causes it to fall.

The tendency of bodies, when unsupported, to approach the earth's surface, is called Terrestrial Gravity, or simply Gravity.

98. GRAVITATION.—Attraction is universal. It is not confined to things on and about the earth's surface, but extends throughout space, millions of miles, and is in fact the great agent by which the heavenly bodies are kept moving in their respective spheres. The earth as certainly attracts the planet Uranus, at the vast distance of 1,828,000,000 miles, as it does the falling stone.

Figure 40. 96. What is the Angle of Incidence? What is the Angle of Reflection? What is the great law of reflected motion?

97. When a stone is let go, what does it do? To what is this owing? What is meant by Terrestrial Gravity? 98. What is Gravitation? How far does gravitation

The attraction subsisting between the heavenly bodies is called Gravitation.

To Sir Isaac Newton the world owes the great discovery of the law of Universal Gravitation. Galileo had investigated the subject of terrestrial gravity (A. D. 1590), but he did not imagine that any similar force existed beyond the neighborhood of the earth. Kepler advanced a step nearer the truth, and spoke of gravitation as acting from planet to planet; still he did not conceive of its having any effect on the planetary motions. This discovery, one of the most important that modern science has achieved, was reserved for the mighty genius of Newton. Sitting in his orchard one day (A. D. 1666), he observed an apple fall from a bough. This simple circumstance awakened a train of thought. Gravity, he knew, was not confined to the immediate surface of the earth. It extended to the greatest heights with which man was acquainted; why might it not reach out into space? Why not affect the moon? Why not actually cause her to revolve around the earth? To test these speculations, Newton at once undertook a series of laborious calculations, which proved that the attraction of gravitation is universal; that it determines the orbits and velocities of the planets, causes the inequalities observed in their motions, produces tides, and has given its present shape to the earth.

99. Three facts have been established respecting gravitation:—

1. Gravitation acts instantaneously. Were a new body created in space 1,000 miles from the earth, its attraction would be felt at the sun just as soon as at the earth, though the one would be 95,000,000 miles off, and the other only 1,000.

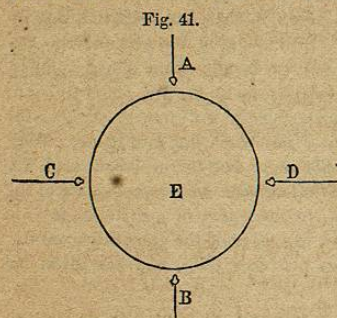
2. Gravitation is not lessened by the interposition of any substance. The densest bodies offer no obstacle to its free action. Were a body placed on the other side of the moon, it would be attracted by the earth just as much as if the moon were not between them.

3. Gravitation is entirely independent of the nature of matter. All substances that contain equal amounts of matter attract and are attracted by any given body with equal

extend? Give an example. By whom was the law of Universal Gravitation discovered? What advance had been made towards it by Galileo? What, by Kepler? Give an account of the circumstances and reasoning that led Newton to this discovery. What was proved by his calculations? 99. What is the first fact that has been established respecting gravitation? Give an example. What is the second fact? Give an example. What is the third fact? What evidence is there of this? 100. What

force. The action of the sun is found to be the same on all the heavenly bodies.

100. DIRECTION OF GRAVITY.—If a piece of lead suspended by a string be left free to move, it will point towards the earth. This is the case in all parts of the globe. Now, as the earth is round, it follows that at two opposite points of its surface, the plummet, or plumb-line (as this



suspended lead is called), will point in opposite directions. This will be seen from the relative positions of A and B, C and D, in Fig. 41. The lead, therefore, has no tendency to fall in any particular direction as such, but takes all directions according to the part of the earth's surface which it is near. The

universal law is, that *it must point towards the centre of the earth.*

It is not because any peculiar attractive power resides in the centre that a falling body tends towards that point; but because, in a sphere, this is the result of the attraction of all the particles. The particles on one side attract the falling body as much as those on the other; and consequently it seeks a point between them.

No two plummets suspended in different places have exactly the same direction, for the lines in which they hang would meet at the centre of the earth. At short distances, however, the difference of direction is so slight as to be imperceptible, and the plummets seem to point the same way.

101. It follows that *up* and *down* are relative and not absolute terms. What is *up* to a person in New York, is down to a ship a few miles south-west of Australia. If a person in a standing position at New York were to be carried in a straight line through the earth to its centre, and on in the same direction to the opposite side of the earth, he would come out in the Indian Ocean south-west of Australia, but would find himself on his head instead of his feet. His head, which at New York pointed up, would now point down.

is a piece of lead suspended by a string called? How does the plummet always point? On what does the absolute position of the plummet depend? Why does a falling body tend towards the *centre* of the earth? What is said of the difference of direction in plummets suspended in different places? 101. What is said of the terms *up* and *down*? Exemplify this. What is the real meaning of *up* and *down*? Why

Down, therefore, simply means towards the centre of the earth, and *up* away from the centre.

This explains what the unreflecting are sometimes puzzled to account for, —why persons and things on the side of the earth opposite to them do not fall off. Regarding themselves as on the *upper* side, they can not see what keeps those on the *under* side from being precipitated into space. But really there is no *under* side. All things are alike drawn towards the centre; all are kept on the earth's surface by the same force of gravity.

102. LAWS FOR THE FORCE OF GRAVITY.—The force of gravity (and the term is here used in its widest sense, including gravitation) depends on two things,—1. Amount of matter; 2. Distance,—according to the following laws:

1. *The force of gravity increases as the amount of matter increases.*
2. *The force of gravity decreases as the square of the distance increases.*

103. According to the first law, if the sun contained twice as much matter as it now does, it would attract the earth with twice its present force; if it contained three times as much matter, with three times its present force; &c. Observe, we say *if it contained twice as much matter*, not *if it were twice as large*; for it might be twice its present size, and yet so rare as to contain less matter and attract less strongly than it now does. If there were two heavenly bodies, the one of iron and the other of cork, the latter, though twice as large as the former, would have less attraction because it would contain less matter.

As already remarked, the earth is so much larger than the bodies near its surface that it is not perceptibly affected by their attraction. Even if a ball 500 feet in diameter were placed in the atmosphere 500 feet from the earth's surface, the earth, being 580 million million times greater than the ball, would draw the latter to itself, while it would advance to meet it, less than one ninety-six-thousand-millionth of an inch—a distance so small that it can not be appreciated.

The sun is 800 times greater than all the planets put together. It is on account of this enormous amount of matter that its attraction is felt by the most remote bodies of the solar system at a distance of many millions of miles.

do not objects on the *under* side of the earth fall off? 102. On what does the force of gravity depend? Repeat the two laws of gravity. 103. Explain the first law. Why is not the earth perceptibly affected by the attraction of bodies near its surface? Give an example. Why is the attraction of the sun so great? What would be its effect

A man carried to the surface of the sun would be so strongly attracted by its immense mass that he would be literally crushed by his own weight.

104. According to the second law, if the sun were twice as far from the earth as it now is, it would attract the latter with but $\frac{1}{4}$ of its present force; if three times as far, with $\frac{1}{9}$; if four times as far, with $\frac{1}{16}$, &c. So, if two equal masses were situated respectively 5,000 miles and 10,000 miles from the earth's centre, the nearer would be attracted not twice, but 4 times, as strongly as the more distant.

105. All bodies on the earth's surface, however small, attract each other with greater or less force according to their masses and distance. This attraction, in most cases, is absorbed in the far greater attraction of the earth, and consequently can not be perceived. In the case of mountains, however, it is so strong as to have a sensible effect on plummets suspended at their base. Instead of pointing directly towards the centre of the earth, a plumb-line in such a position is found to incline slightly towards the mountain.

106. **WEIGHT.**—When a body is supported or prevented from following the impulse of gravity, it presses on that which supports it, more or less strongly according to the force with which it is attracted. This downward pressure is called its **Weight**.

Weight is simply the measure of a body's gravity, and is proportioned to the amount of matter contained. A ball of iron is heavier than a ball of cork of equal size, because it contains more matter.

Weight being nothing more than the measure of the force with which bodies are drawn towards the earth, it follows that, if the earth contained twice as much matter as it now does, they would have twice their present weight; if it contained three times as much matter, three times their present weight, &c.

107. *Weight above and below the Earth's Surface.*—Since the weight of a body is the measure of its gravity, and since gravity decreases as the square of the distance from the earth's centre increases, it follows that bodies be-

on a man carried to its surface? 104. Illustrate the second law with an example. 105. Why is not attraction exhibited between small bodies on the earth's surface? How is a plummet suspended near the base of a mountain affected? 106. What is Weight? To what is weight proportioned? If the earth contained twice as much matter as it now does, how would the weight of objects on its surface compare with

come lighter in the same proportion as they are taken up from the earth's surface. A mass of iron which at the earth's surface weighs a thousand pounds, taken up to a height of 4,000 miles, would weigh only 250 of such pounds, or one-fourth as much as before.

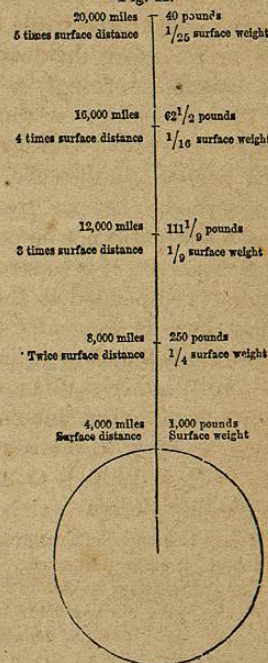
The reason of this is clear. The earth being about 8,000 miles through, from its centre to its surface is 4,000 miles; and from its centre to a point 4,000 miles above its surface, is 8,000 miles. 4,000 is to 8,000 as 1 to 2; but the weight at the surface would not be to the weight 4,000 miles above the surface as 2 to 1, but as the squares of these numbers, 4 to 1. Hence, if it would weigh 1,000 pounds at the surface, it would weigh only $\frac{1}{4}$ as much, 4,000 miles above the surface. For the same reason, it would weigh $\frac{1}{9}$ of 1,000 pounds at a distance of 8,000 miles from the surface; $\frac{1}{16}$, at a distance of 12,000 miles; $\frac{1}{25}$, at a distance of 16,000 miles, &c. These results are exhibited in Fig. 42.

At small elevations, the weight which an object loses amounts to but little. Four miles above the earth's surface, a body weighing 1,000 pounds would become only two pounds lighter. Raised to a height of 240,000 miles, the distance of the moon from the earth, its weight would be reduced to less than five ounces.

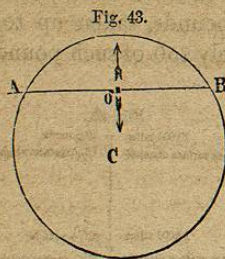
108. If we could go from the surface of the earth to the centre, we should find a given object weigh less and less as we advanced. The moment we descended beneath the surface, we would leave particles of matter behind us, and the attraction of these would act in a direction exactly opposite to gravity.

their present weight? 107. What is said of the weight of bodies taken up from the earth's surface? What would 1,000 pounds of iron weigh, 4,000 miles above the earth's surface? Show the reason of this. What is said of the loss of weight at small elevations? Four miles above the surface, how much would a body weighing 1,000 pounds lose? What would be its weight, 240,000 miles from the earth? 108. If we

Fig. 42.



Thus, in Fig. 43, let C represent the centre of the earth, and O any object beneath the surface. All the particles below the line A B attract O downward,



ward, but all above that line attract it upward, and thus diminish its weight.

At the centre of the earth (see Fig. 44) no object would weigh any thing. There would be as many particles above the line DE as below it; and O, being equally attracted on all sides, would have no weight.

109. All bodies carried below the earth's surface would, therefore, become lighter as they approached the centre. Their weight at any given number of miles below the surface may be found as follows:—

For 1 mile below, take $\frac{3993}{4000}$ of the surface weight.

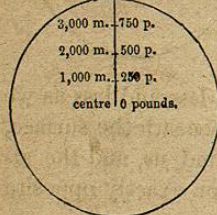
For 2 miles, take $\frac{3983}{4000}$ of the surface weight.

For 100 miles, take $\frac{3900}{4000}$ of the surface weight.

For 1,000 miles, take $\frac{3000}{4000}$ of the surface weight, &c.

Fig. 43.

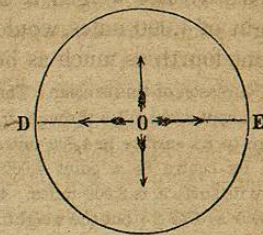
8,000 miles	$\frac{1}{4}$, 250 p.
7,000 miles	$\frac{16}{40}$, $326\frac{26}{40}$ p.
6,000 miles	$\frac{4}{9}$, $444\frac{4}{9}$ p.
5,000 miles	$\frac{16}{25}$, 640 p.
4,000 miles	1,000 pounds



ing 1,000 pounds at the earth's surface.

could go from the surface of the earth to the centre, what would we find respecting the weight of a given body? What is the reason of this decrease? Illustrate this with Fig. 43. What would all objects weigh at the centre? Show the reason of this with Fig. 44. 109. How may we find the weight of a given body one mile below the

Fig. 44.



110. *Law of Weight.*—From the above principles the following law of weight is deduced:—*All objects weigh the most at the surface of the earth: ascending from the surface, their weight diminishes as the square of their distance from the centre increases; descending towards the centre, their weight diminishes as their distance from the surface increases.*

Fig. 45 shows the operation of this law in the case of an object weigh-

111. *Weight at different Parts of the Earth's Surface.*—The weight of a body differs at different parts of the earth's surface. A mass of lead, for instance, that weighs 1,000 pounds at the poles, will weigh only 995 such pounds at the equator.

112. This is owing to two causes:—

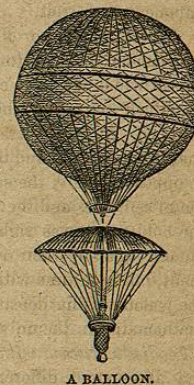
1. The equatorial diameter is about $26\frac{1}{2}$ miles longer than the polar diameter; and therefore an object at the equator is farther from the centre and less strongly attracted than at any other point.

2. The centrifugal force, as shown in § 79, is greatest at the equator, and therefore counterbalances more of the downward attraction there than at any other part of the surface, making the weight less. It has been computed, that, if the earth revolved 17 times as fast as it now does, the centrifugal force at the equator would counterbalance gravity entirely, and thus deprive all bodies of weight. If the earth's velocity were further increased, all things at the equator would be thrown off into space.

113. The general effect of gravity is to draw bodies towards the earth; but sometimes it causes them to rise. A balloon, for instance, mounts to the clouds. This is because it contains less matter than a mass of air of the same bulk, or, as we say briefly, it is lighter than air. Hence the air, acted on more strongly by gravity than the balloon, is drawn towards the earth under the latter, which is thus caused to rise.

For the same reason, smoke ascends. So, if a flask of oil be uncorked at the

Fig. 46.



A BALLOON.

earth's surface? Two miles? A hundred miles? A thousand miles? 110. Repeat the law of weight. 111. What is said of the weight of a body at different parts of the earth's surface? Give an example. 112. To what causes is this owing? What would be the result, if the earth revolved on its axis with seventeen times its present velocity? 113. Show how gravity sometimes causes a body to rise. Give some illustra-

bottom of a pail of water, the water will be drawn down below the oil, and force the latter to the top.

Falling Bodies.

114. VELOCITY OF FALLING BODIES.—If a feather and a cent be dropped from a height at the same time, the cent will reach the ground some seconds before the feather. This fact Aristotle and his successors explained by teaching that the velocity of falling bodies is proportioned to their weight; that a body of two pounds, for instance, would reach the ground in just half the time required by a body weighing one pound. Galileo was the first to correct this error (about A. D. 1590). He held that the velocity of falling bodies is independent of their weight, and that, if no other force than gravity acted on them, all objects dropped at the same time from the same height would reach the ground at the same instant.

So startling a proposition was at once condemned by the learned men of the day; but Galileo, convinced of the truth of his position, challenged his opponents to a trial.

The leaning tower of Pisa [*pe'-zah*], Italy, was chosen as the scene of the experiment, and multitudes flocked to witness it. Two balls were produced, one of which weighed exactly twice as much as the other, and after being examined, to prevent the possibility of deception, at a given signal they were dropped. In breathless anxiety the crowd awaited the result, doubting not that it would confound the bold youth of six-and-twenty years, who had dared to oppose not only the sages of his own time, but also the established opinion of centuries and the great master Aristotle himself. To their amazement, the bold youth was right; the balls reached the earth at the same instant. Unable to credit their own senses, again and again they repeated the experiment, but each time with the same result. This triumph, though it awakened the jealousy of his defeated rivals, and cost Galileo his place as professor of mathematics in the university of Pisa, established the fact that *gravity causes all bodies to descend with equal rapidity, without reference to their weight, and that all apparent differences are caused by some other agency.*

115. RESISTANCE OF THE AIR.—The cause of the differ-

tions. 114. If a feather and a cent be dropped at the same time, which will reach the ground first? How did Aristotle explain this fact? What was Galileo's opinion on the subject? How was his theory received by the learned men of the day? Give an account of the trial that was made at Pisa. What fact was established by the experi-

ence of velocity in a falling feather and a falling cent is the Resistance of the Air.

This resistance is proportioned to the extent of surface which the falling body presents to the air. The surface, indeed, may be so extended that gravity can hardly overcome the air's resistance; thus, gold may be beaten into a leaf so thin that it will be exceedingly slow in its descent, floating for a time in the air.

116. That the resistance of the air causes the difference of velocity exhibited by falling bodies, may be proved in two ways:—

1. A piece of paper, a sheet of gold-leaf, or a feather, with its surface extended, floats slowly downward; roll it into a compact mass, and it will descend rapidly like a stone.

2. Remove the air from a high glass tube (see Fig. 47) by means of an instrument called the air-pump, to be described hereafter. Then, from an apparatus provided for the purpose, drop a feather and a cent simultaneously, and they will reach the bottom at precisely the same instant. Let in the air and drop them, and the feather will be several seconds longer than the cent in reaching the bottom.

Fig. 47.



117. *The Parachute.*—It is the resistance of the air that enables a person to descend in safety from a balloon at great heights above the earth's surface. A parachute, which spreads open like a large umbrella, is suspended beneath the balloon. Having taken his position in the basket-shaped car hanging beneath, the aerial voyager fearlessly detaches himself from the balloon; for, though he is borne downward by gravity, the force of his fall is so broken by the resistance which the air offers to the extended surface of the parachute that he incurs

Fig. 48.



A PARACHUTE.

ment? What was its result to Galileo? 115. What causes the difference of velocity in a falling feather and a falling cent? To what is the resistance of the air proportioned? How may the air's resistance almost be made to counterbalance gravity? Give an illustration. 116. Prove in two ways that the resistance of the air causes the difference of velocity in falling bodies. 117. How is a person enabled to descend safely

little danger. To ensure the safety of a common-sized man, a parachute must be at least 22 feet across. Fig. 48 represents a parachute; Fig. 46 shows it attached to a balloon.

118. **LAW OF FALLING BODIES.**—We have found that all bodies acted on solely by gravity fall to the earth with the same velocity. It is evidently an accelerated velocity; for gravity, which first causes the motion, continues acting. In other words, gravity gives a falling body a certain velocity in the first second of its descent; still forcing it downward, it increases that velocity in the following second; and so on till it reaches the earth.

To find the exact spaces passed over in successive seconds, and the velocity at any given point of the descent, was formerly exceedingly difficult, on account of the rapidity with which falling bodies move, and the want of conveniences for experimenting on them. Even the greatest perpendicular heights were inadequate to the purpose, as a falling body would reach their base in a few seconds. These difficulties are now removed by an ingenious apparatus, called, after its inventor, Atwood's Machine.

119. *Atwood's Machine.*—Atwood's Machine is represented in Fig. 49. It consists of a pillar, G, about six feet high, surmounted by a horizontal plate, JK; from which to the base of the stand extends a perpendicular graduated scale, CL, divided into feet, inches, and tenths of an inch. The plate JK supports a vertical wheel, D, the axis of which, that it may revolve as far as possible without friction, rests on four other wheels, *a, b, c, d* (*d*, being behind the rest, is not seen in the figure). A and B are equal weights, connected by a cord, which passes over the wheel D. F is a pendulum which vibrates once in a second; and I is a dial-plate and index (like the face and hand of a clock) for marking seconds.

B, having exactly the same weight as A, just counterbalances it. Now attach to A a small weight equal to one sixty-third of the combined weight of A and B. This slight addition causes A to descend; but as A descends, B of course ascends; and as neither A nor B, being counterbalanced

from a balloon at a great height? Describe the process. How large must a parachute be for a common-sized man? 118. With what sort of velocity must falling bodies descend? Why so? What made it difficult formerly to ascertain the velocity, &c., of falling bodies? What apparatus is now employed for this purpose? 119. Describe Atwood's Machine from the plate. Show its mode of operation. How does this ma-

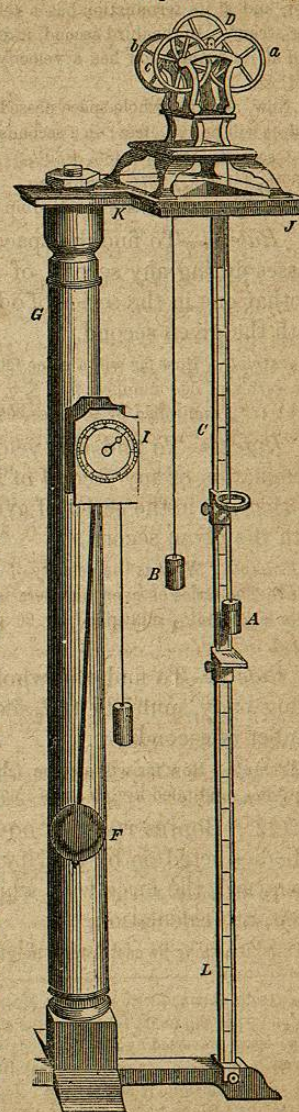
each by the other, has any gravity, the gravity of the small weight attached to A, which sets them in motion, must be divided into 64 equal parts. Hence A with the added weight is 64 times as long in descending as it would be if dropped freely in the air, and the experimenter thus has an opportunity of observing its velocity at different points, and ascertaining the relative distances passed over during the successive beats of the pendulum. The distances passed over in the first, the second, the third, and the fourth second, &c., bear the same relation to each other, as if the bodies were falling freely in space. The velocity, moreover, having been greatly diminished, the resistance of the air becomes so slight that it need not be taken into calculation.

120. It is found with Atwood's Machine, that, calling the distance traversed in the 1st second 1, that traversed in the 2d will be 3; that in the 3d, 5; that in the 4th, 7; and so on in the series of odd numbers. The velocity at the end of the 1st second will be a mean between 1 and 3, or 2; at the end of the 2d, it will be a mean between 3 and 5, or 4; at the end of the 3d, 6; at the end of the 4th, 8; and so on in the series of even numbers.

In 1 second a falling body descends $16\frac{1}{12}$ feet; therefore, according to the results obtained with Atwood's Machine, it has a velocity at the end of the 1st second of twice $16\frac{1}{12}$ feet, or $32\frac{1}{6}$

chine aid the experimenter? 120. What is found with Atwood's Machine, respecting the distances traversed in successive seconds? What is the relative velocity at the end of successive seconds? How far does a body fall in the first second? According

Fig. 49.



feet, per second. In the second second it descends 3 times $16\frac{1}{12}$ feet, or $48\frac{1}{4}$ feet, and at its termination has a velocity of 4 times $16\frac{1}{12}$ feet, or $64\frac{1}{3}$ feet, per second. In the third second, it descends 5 times $16\frac{1}{12}$ feet, or $80\frac{1}{2}$ feet, and at its termination has a velocity of 6 times $16\frac{1}{12}$, or $96\frac{1}{2}$ feet, per second, &c.

Now, as to the whole space passed through in any given time. In 1 second, it will be $16\frac{1}{12}$ feet; in 2 seconds, by addition ($16\frac{1}{12} + 48\frac{1}{4}$), $64\frac{1}{3}$ feet; in 3 seconds, ($16\frac{1}{12} + 48\frac{1}{4} + 80\frac{1}{2}$) $144\frac{3}{4}$ feet; in 4 seconds, ($16\frac{1}{12} + 48\frac{1}{4} + 80\frac{1}{2} + 112\frac{7}{12}$) $257\frac{1}{3}$, and so on.

121. These results are summed up in the following rules:—

Rule 1.—To find the space through which a falling body passes during any second of its descent, multiply $16\frac{1}{12}$ feet by that one in the series of odd numbers which corresponds with the given second.

Example. How far will a stone fall in the tenth second of its descent?—The series of odd numbers is 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, &c. The tenth is 19; $16\frac{1}{12}$ multiplied by 19 gives $305\frac{7}{12}$.—*Answer*, $305\frac{7}{12}$ feet.

Rule 2.—To find the velocity of a falling body at the termination of any second of its descent, multiply $16\frac{1}{12}$ feet by that one in the series of even numbers which corresponds with the given second.

Example. What is the velocity of a stone that has been falling ten seconds?—The series of even numbers is 2, 4, 6, 8, 10, 12, 14, 16, 18, 20. The tenth is 20; $16\frac{1}{12}$ multiplied by 20 gives $321\frac{2}{3}$.—*Answer*, $321\frac{2}{3}$ feet per second.

Rule 3.—To find the whole space passed through by a falling body, multiply $16\frac{1}{12}$ feet by the square of the given number of seconds.

Example. How far will a stone fall in 10 seconds?—Squaring 10 gives 100; $16\frac{1}{12}$ multiplied by 100 gives $1,608\frac{1}{3}$.—*Answer*, $1,608\frac{1}{3}$ feet.

122.—BODIES THROWN DOWNWARD.—These rules apply to bodies acted on by gravity alone. If a body is thrown downward, the force with which it is thrown must also be taken into calculation.

Thus, if a stone be cast from a height with a force that would propel it 50

to the results obtained with Atwood's Machine, how far will it fall in successive seconds, and what will be its velocity at the end of each? 121. Repeat Rule 1, for finding the space traversed by a falling body during any second of its descent. Apply this rule in the given example. Repeat Rule 2, for finding the velocity of a falling body. Apply this rule in an example. Repeat Rule 3, for finding the whole distance traversed by a falling body. Give an example. 122. To what bodies do these rules

feet in a second, then in the tenth second, instead of falling $305\frac{7}{12}$ feet, as in the example under Rule 1, it would fall 50 feet farther,—that is $355\frac{7}{12}$ feet. Its velocity at the end of the tenth second would likewise be obtained by adding 50 feet per second to the velocity obtained in the example under Rule 2: $321\frac{2}{3} + 50 = 371\frac{2}{3}$.—To obtain the whole space passed through, add to the result obtained by Rule 3, the distance traversed in consequence of the velocity originally imparted. A body thrown downward with a velocity of 50 feet per second, would, without any aid from gravity, pass through 500 feet in 10 seconds. Adding this to $1,608\frac{1}{3}$ feet, the distance through which gravity alone causes a body to fall in 10 seconds, we have $2,108\frac{1}{3}$ feet for the whole distance traversed in that time by a body thrown downward with a velocity of 50 feet per second.

123. In the above examples, no allowance is made for the resistance of the air. But even the bodies most favorably shaped for falling feel the effects of this resistance. Experiments in St. Paul's Cathedral, London, show that in $4\frac{1}{2}$ seconds a body falls 272 feet; whereas, according to the principles stated above, it should fall 325 feet. This difference, which amounts to nearly one-sixth of the whole distance, is owing principally to the resistance of the air.

124. As the velocity of a falling body increases $32\frac{1}{6}$ feet every second, it does not take long for it to acquire a tremendous speed; and, as the striking force is proportioned to the weight multiplied into the square of the velocity, it is clear that even a small body, falling any considerable distance, may become a very powerful agent. Hence the disastrous effects of hail-stones, which have been known to injure cattle and break through the roofs of houses, and which prove so destructive to the vineyards in parts of Southern Europe that the fields have to be protected from their visitations.

125. ASCENDING BODIES.—As a falling body increases in velocity $32\frac{1}{6}$ feet every second of its descent, so an ascending body, being acted on by the same force, loses a

apply? If a body is thrown from a height, what must enter into the calculation? If a stone were thrown down with a force that would propel it 50 feet in a second, how far would it fall in the tenth second? What would be its velocity at the end of the tenth second? What would be the whole distance traversed in ten seconds? 123. For what must allowance be made in applying these rules? How great a difference does the resistance of the air occasion? 124. How are the disastrous effects of hail-stones accounted for? 125. What is said of the velocity of an ascending body? How may