platinum, iron, and copper, but most of all in gold. A cubic inch of this metal may be beaten out till it covers 282,000 square inches, which makes the leaf only $\frac{1}{282000}$ of an inch thick. In other words, it would take 282,000 strips of such gold leaf, lying on each other, to make the thickness of an inch.

49. DUCTILITY.—Ductility is that property which renders a body capable of being drawn out into wire.

The malleable metals are for the most part ductile, but not always in the same degree. Thus gold exceeds all the other metals in ductility as well as in malleability; but tin, which can readily be beaten into very thin sheets, can not be drawn out into small wire.

Gold wire has been made so attenuated that fifty miles of it would weigh but an ounce. Platinum, which is nearly as ductile as gold, has been drawn into wire only $\frac{1}{30000}$ of an inch in diameter and invisible to the naked eye. Glass, when softened by fire, becomes exceedingly ductile, and may be spun out into flexible and elastic threads scarcely larger than the thread of the silk-worm.

CHAPTER III.

MECHANICS.

50. MECHANICS is that branch of Natural Philosophy which treats of forces and their application in machines.

51. FORCE AND RESISTANCE.—When we see a body begin to move, cease to move, or change its motion, since it can do neither of itself, we know that it has been acted on by some external agency, which we call a Force. The elasticity of a bow which sends an arrow through the air, is a force; the wind, which changes its direction, is a force; gravity, which brings it to the earth and helps to stop its motion, is a force.

examples. To what does malleability chiefly belong? Show the extreme malleability of gold. 49. What is Ductility? What substances are for the most part ductile? What is the most ductile substance known? What facts are stated, illustrating the ductility of gold, platinum, and glass?

50. What is Mechanics? 51. What is a Force? Give illustrations. What is the

That which opposes a force is called the Resistance. In the above example, the inertia of the arrow is the resistance.

Forces may act on bodies so as to produce either Motion or Rest.

Motion.

52. Motion is a change of place.

53. Motion is either Absolute or Relative.

Absolute Motion is a change of place with reference to a fixed point. Relative Motion is a change of place with reference to a point that is itself moving.

Two balls are rolled on the floor. The motion of each, as regards the point from which it was thrown, is absolute; their motion with reference to each other is relative.

54. REST.—Rest is the opposite of motion, and implies continuance in the same place.

Like motion, Rest is either Absolute or Relative. A man sitting on a steamer that is moving forward five feet in a second, is at rest *relatively* to the other objects on board. To be at rest *absolutely*, he must walk five feet every second towards the stern of the boat.

Strictly speaking, there is no such thing as absolute rest in any of the objects that surround us; for the earth moves round the sun at the rate of nearly 99,000 feet in a second, and carries with it every thing on its surface. Hills, trees, and houses, therefore, though they occupy the same place with respect to each other, are really travelling through space with immense rapidity. Yet as this is the case with ourselves, with the atmosphere, and all things about us, we regard an object as absolutely at rest if it has no other motion than this.

55. VELOCITY.—The Velocity of a body is the rate at which it moves.

This rate is determined by the space it passes over in a given time. The greater the space, the greater the velocity. Thus, if A walks two miles an hour, and B four, B's velocity is twice as great as A's.

Resistance? What may the action of forces on bodies produce? 52. What is Motion? 53. How is motion distinguished? What is Absolute Motion? What is Relative Motion? Illustrate these definitions. 54. What is Rest? Illustrate Absolute and Relative Rest. Show that there is really no such thing as absolute rest. 55. What is

56. The relation between the space passed over, the time employed, and the velocity, is such, that when two are given, we can find the third.

Rule 1.—To find the velocity of a body, divide the space passed over by the time.

Example. A locomotive goes 120 miles in 4 hours; what is its velocity?—Dividing 120 by 4, we get 30; *answer,* 30 miles an hour.

Rule 2.—To find the time, divide the space by the velocity.

Example. A locomotive goes 120 miles at the rate of 30 miles an hour; how long is it on the way?—Dividing 120 by 30, we get 4; *answer,* 4 hours.

Rule 3.—To find the space, multiply the velocity by the time.

Example. A locomotive goes 4 hours at the rate of 30 miles an hour; how far does it travel?—Multiplying 30 by 4, we get 120; *answer,* 120 miles.

57. *Table of Velocities.*—It may not be uninteresting to compare the average velocities of the following moving objects:—

	Miles per hour.		Miles per hour.
A man walking	3	A hurricane	80
A horse trotting	7	Sound	764
A slow river	3	A musket-ball, when first	
A rapid river	7	discharged	850
A fast sailing vessel	10	A rifle-ball	1,000
A fast steamboat	18	A 24-lb. cannon-ball	1,600
A railroad train	25	Earth in its orbit	68,040
A moderate wind	7	Light	691,200,000
A storm	50	Electric Fluid	1,036,800,000

58. KINDS OF MOTION.—There are three kinds of motion; Uniform, Accelerated, and Retarded.

59. Uniform Motion is that of a body which moves over equal spaces in equal times.

Uniform motion would be produced by a force acting once and then

ceasing to act, if the moving body were free from all other influences, for its inertia would keep it moving at the same rate. Gravity and the resistance of the air, however, constantly retard a moving body; and, therefore, to keep up a uniform motion, a force just sufficient to nullify these retarding agencies must continue acting. There are very few cases of uniform motion either in nature or art.

60. Accelerated Motion is that of a body whose velocity keeps increasing as it moves. It is produced by the continued action of a force.

A ball dropped from a height is a familiar instance of accelerated motion. The moment it is let go, the attraction of gravitation causes it to descend. Were this force and every other then suspended, the ball would fall to the earth with a uniform motion; but gravity, continuing to act, forces it along faster and faster, and thus imparts to it an accelerated motion.

A body is said to have a Uniformly Accelerated Motion, when its velocity keeps increasing at the same rate; when, for instance, it moves two feet in the first second, four in the next, eight in the third, &c.

61. Retarded Motion is that of a body whose velocity keeps diminishing as it moves. It is produced by the continued action of some resistance on a moving body.

A ball rolled over the ground, under the continued action of gravity and the resistance of the air, moves more and more slowly, till finally it comes to rest. This is an example of retarded motion.

A body is said to have a Uniformly Retarded Motion, when its velocity keeps diminishing at the same rate; when, for instance, it moves eight feet in the first second, four in the next, and two in the third.

Momentum.

62. The Momentum (plural, *momenta*) of a body is its quantity of motion.

A ten-pound ball, moving at the rate of 400 feet in a second, may be supposed to be divided into ten pieces, each weighing one pound. Each piece has a motion of 400 feet in a second; and the quantity of motion, or momen-

tum, of all ten, that is, of the whole ball, will be ten times 400, or 4,000. Hence the following rule :—

63. *Rule.*—To find the momentum of a moving body, multiply its velocity by its weight.

Example. What is the momentum of a ten-pound ball, moving at the rate of 400 feet in a second ?—Multiplying 400 by 10, we get 4,000 ; *answer,* 4,000.

64. When the momenta of different objects are to be compared, their weight and velocity must be expressed in units of the same denomination : if the weight of one is given in pounds, that of the other must be in pounds ; if the velocity of one is so many feet per second, that of the other must be expressed in feet per second. If different denominations are given, reduce them to the same denomination.

Thus : A weighs 50 pounds, and has a velocity of 7,200 miles an hour ; B weighs 100 pounds, and has a velocity of 4 miles a second. Which has the greater momentum ?

3,600 seconds make an hour ; and if A's velocity is 7,200 miles an hour, in a second it will be $\frac{1}{3600}$ of 7,200 miles, or 2 miles.

A's weight 50 multiplied by A's velocity 2 gives A's momentum 100.

B's weight 100 multiplied by B's velocity 4 gives B's momentum 400. Therefore B's momentum is 4 times as great as A's.

65. Two bodies of the same weight have momenta proportioned to their velocities. Thus, if two balls weighing 5 pounds each, move respectively at the rate of 20 and 10 miles an hour, then their momenta will be in the proportion of 20 to 10, or two to one.

Two bodies moving with the same velocity, have momenta proportioned to their weight. Thus, if two balls moving at the rate of 5 miles an hour, weigh 20 and 10 pounds respectively, then their momenta will be in the proportion of 20 to 10, or two to one.

66. Since momentum depends on velocity as well as weight, it is obvious that, by increasing its velocity sufficiently, a small body may be made to have a greater momentum than a large one. Thus, a bullet fired from a gun has a greater momentum than a stone many times larger thrown from the hand.

On the same principle, a very heavy body, though its motion may be hardly perceptible, may have an immense momentum : This is the case with icebergs, rendering them fatal to objects with which they come in collision.

an example. 63. Repeat the rule for finding a body's momentum. Give an example. 64. When the momenta of different objects are to be compared, what is essential ? Give an example. 65. When two bodies have the same weight, to what are their momenta proportioned ? Give an example. When two bodies have the same velocity, to what are their momenta proportioned ? Give an example. 66. How may a greater momentum be given to a small body than a large one ? Illustrate this. How do you account for the great momenta of icebergs, notwithstanding their slow mo-

Striking Force.

67. The Striking or Living Force of a moving body is the force with which it strikes a resisting substance.

Striking Force is sometimes confounded with momentum, but improperly, inasmuch as it is the product of the weight into *the square of the velocity.* Two moving bodies may have the same momentum, but differ greatly in their striking force.

Thus, the ball A, weighing 200 pounds and moving 2 miles a minute, has a momentum of 200 multiplied by 2, or 400. The ball B, weighing 20 pounds and moving 20 miles a minute, also has a momentum of 400 (20 multiplied by 20). How do they compare in striking force ? That of A is equal to its weight 200 multiplied by the square of its velocity, 4,—or 800. That of B is equal to its weight 20 multiplied by the square of its velocity 400,—or 8,000. Therefore, though the momenta of the two balls are equal, the striking force of B is 10 times as great as that of A ; if both were fired into a bank of moist clay, B would penetrate ten times as far as A.

68. As the velocity of a body increases, its striking force increases also, but in a higher degree.

If, for instance, a train of cars be moving 50 miles an hour, and another train of the same weight 10 miles an hour, the striking force of the former will not be to that of the latter as 50 to 10, but as the square of 50 is to the square of 10, or as 2500 is to 100. The former train would therefore do 25 times as much damage as the latter to any object with which it came in collision, or to itself in case of being thrown from the track. This result is borne out by facts.

69. *Rule.*—To find the striking force of a moving body, multiply its weight into the square of its velocity.

If the striking force of one body is to be compared with that of another, see that their weight and velocity are in units of the same denomination.

Example. The stone A, weighing 1 pound, is thrown at the rate of 20 ft.

tion ? 67. What is meant by the Striking or Living Force of a moving body ? What is the difference between a body's striking force and its momentum ? Exemplify this difference. 68. How does a body's striking force increase, compared with its velocity ? Give an example. How is this result borne out ? 69. Give the rule for finding the striking force of a moving body. When bodies are to be compared with respect to their striking force, how must their weight and velocity be expressed ? Solve the example under the rule.

a second. The stone B, weighing 3 pounds, is thrown at the rate of 2,400 ft. a minute. Which will penetrate further into a snow-bank?

20 times 20 is 400 = square of A's velocity.

400 × 1 (A's weight) = 400, A's striking force.

Reduce B's velocity to the same denomination as A's. If B move 2,400 feet in a minute, in a second it will move $\frac{1}{60}$ of 2,400 feet, or 40 feet.

40 times 40 is 1,600 = square of B's velocity.

1,600 × 3 (B's weight) = 4,800, B's striking force.

Ans.—A's striking force being 400, and B's 4,800, B will penetrate into the snow-bank 12 times as far as A.

EXAMPLES FOR PRACTICE.

1. (*See Rule* 1, § 56.) A fox-hound will run 30 miles in three hours. What is its velocity?

2. At the battle of Brandywine, Gen. Greene's detachment marched 4 miles in 42 minutes, to relieve Gen. Sullivan. With what velocity did they move?

3. At the most flourishing period of its history, ancient Athens was 25 miles in circumference. With what velocity would an Athenian have had to move, in order to walk round the city in 5 hours?

4. A pigeon will fly 100 miles in 2 hours. What is its velocity?

5. P walks 2 miles in 30 minutes; Q walks 4 miles in 2 hours. Which has the greater velocity?

REMARK.—*When different denominations are used, they must be reduced to the same denomination, as shown in § 64.*

6. The current of a rapid river runs 1,200 feet in 2 minutes; a horse at a moderate trot passes over 30 feet in 3 seconds. Which moves with the greater velocity?

7. (*See Rule* 2, § 56.) Strabo tells us that ancient Nineveh was 47 miles in circumference; in what time could a person have walked around it, at the rate of 10 miles a day?

8. The bombardment of Ostend, on the coast of Holland, was heard in London, a distance of 70 miles. There are 5,280 feet in a mile, and sound travels at the rate of 1,120 feet in a second. How many seconds after a cannon was fired at Ostend, was the report heard in London?

9. From the base of the Pyramid of Cheops to its top is 704 feet; how long will it take a person to ascend it, walking at the rate of 4 feet per second?

10. A rifle-ball moves at the rate of 1,000 miles an hour. If it could maintain the same speed, how long would it be in crossing the Atlantic Ocean, which is 3,000 miles broad?

11. Light moves 192,000 miles in a second, electricity 288,000 miles in the same time. How long before we could see a flash of lightning in a cloud 2 miles off, and how long before the lightning could strike an object by our side?

12. In the year 1804, the French philosopher Gay Lussac ascended in a bal-

loon to the height of $4\frac{1}{2}$ miles. He came down at the rate of 660 feet in a minute; how long was he in making the descent?

13. (*See Rule* 3, § 56.) Some of the Alpine glaciers move 25 feet annually. How far would they move in 4 years?

14. The comet observed by Newton in 1680 moved 880,000 miles an hour. How far at this rate would it move in a day?

15. Which will pass over the greater space—a hurricane, moving at the rate of 80 miles an hour in 4 hours, or a locomotive, going 30 miles an hour, in 10 hours?

16. If the earth moves in its orbit 68,040 miles an hour, and is 365 days, 6 hours, in completing its revolution, how long is its orbit?

17. If a ray of light travels 691,200,000 miles in an hour, how far will it go in a day?

18. (*See Rules*, §§ 63, 69.) A 24-pound cannon-ball moves at the rate of 1,000 miles an hour. A battering-ram weighing 10,000 pounds moves at the rate of 10 miles an hour. How do their momenta compare?—*Ans. As 24 to 100; that is, the cannon-ball has a little less than one-fourth of the momentum of the battering-ram.*

How does the striking force of the above cannon-ball compare with that of the battering-ram; that is, what would be their comparative effect on the wall of a fortress?—*Ans. That of the ball would be 24 times as great as that of the battering-ram.*

19. An iceberg weighing 50,000 tons moves at the rate of 2 miles an hour. An avalanche of 10,000 tons of snow descends with a velocity of 10 miles an hour. How do their momenta compare?

How do they compare in striking force?

20. How does the momentum of a 32-pound ball with a velocity of 2,000 miles an hour, compare with that of a 16-pound ball with a velocity of 1,000 miles an hour?

Which would penetrate further into a bank of moist clay?

21. A locomotive weighing 20 tons moves with a velocity of 40 feet a second. Another locomotive weighing 25 tons moves at the rate of 4,800 feet in a minute. How do their velocities compare?

How do they compare in momentum?

If the one with the less striking force penetrate 10 feet into a snow-bank, how far will the other penetrate?

22. A stone weighing 15 ounces is thrown from the hand with a velocity of 1,320 feet in a minute. A rifle-ball weighing 3 ounces is discharged at the rate of 15 miles a minute. How do their velocities compare?

How do they compare in momentum?

How many times greater is the striking force of the rifle-ball than that of the stone?

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