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Newton's Laws of Motion

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mits, to correlate with the class work.

The writer desires to continue the collection of information concerning the winter birds of the state and will be very glad to receive reports. A list of all the birds reported upon in this study can be obtained by sending to the writer a stamped, addressed envelope. Below is given a list of books, bulletins and pictures which will be found useful in bird study.

Chapman—Handbook of Birds of Eastern North American—D. Appleton & Co., 29-35 West 32nd st., New York City.

Anderson—Birds of Iowa—Davenport Public Museum, Davenport, Iowa.

National Geographic Book of Birds—National Geographic Society, Washington, D. C.

Summer Birds of an Iowa Farm —Ex. Serv. Bul. 142—Extension Service, Iowa State College, Ames.

Some Common Birds Useful to the Farmer—Farmer's Bul. 630—U. S. Department of Agriculture, Washington.

Food of Some Well-Known Birds of Forest, Farm, and Garden—Farmer's Bul. 506—U. S. D. A.

How to Attract Birds—Farmer's Bul. 912—U. S. D. A.

Homes for Birds—Farmer's Bul. 1456—U. S. D. A.

Bird Migration—Bul. 185. U. S. D. A.

Primer of Bird Study (15 cents) —National Association of Audubon Societies, 1974 Broadway, N. Y.

Audubon Bird Cards—3 sets of 50 each (winter, spring, summer), $1 per set—National Association of Audubon Societies.

Birds of New York—Memoir No. 12—New York State Museum, Albany, N. Y.

O. R. Clark.

NEWTON'S LAWS OF MOTION

(Continued from February)

Newton's second law of motion states the relation between force and momentum. From this law we learn how to measure a force in terms of the momentum it creates in a unit of time or a second. The force acting on a mass free to move is proportional to the amount of momentum it creates in a second. In fact, it is numerically equal to the momentum per second when the proper units of measurement are applied to the problem.

In order to understand this, let us first define the term momentum. Momentum is measured by the product of the mass set in motion and the velocity it gains during the time the force acts, or

(1) Momentum$=$mv

Momentum is also measured by the product of the force acting on the mass and the time in seconds during which it acts, or

(2) Momentum$=$ft

These two equations (1) and (2) are strictly correct when the proper units are applied. By axiom (I) we derive from these two equations the following:

(3) ft$=$mv

The product ft is usually denoted as the "impulse" in mechanics, reserving the term momentum for the product mv. Dividing both sides of the question (3) by the time, t, we find that f, the force, is equal to mv divided by the time which brings us to the real meaning of the second law of motion; namely, that force is equal to the amount of momentum created by it in a second.

In the above discussion we have assumed the force to be acting on a mass free to move without friction. In such a case the motion is always uniformly accelerated in which we know that the change in velocity is equal to the acceleration per second per second multiplied by the time, or

$$V=at$$

Substituting this value for velocity in the equation (3) and then cancelling the time which appears on both sides of the equation, we finally come to this familiar equation of the physics texts, f$=$ma. This equation is another expression for the value of a force in terms of the mass and its acceleration per second per second.

When the mass in the above equation is measured in grams and the acceleration per second per second is measured in centimeters then magnitude of the force acting is expressed in dynes. Dynes$=$grams$\times$ acceleration in centimeters per sec-

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ond per second. When the mass is measured in pounds and the acceleration is expressed in feet per second per second then the force in pound weights is obtained by dividing the product by the acceleration of gravity or 32.2 feet per second per second. Hence force in terms of pound weights is equal to the product of the mass in pounds and the acceleration in feet per second per second divided by 32.2.

Having struggled through this maze of theoretical reasoning let us now get into the light by considering a few every day practical illustrations of Newton's second law of motion. We will start with a very simple one. Suppose I lift a stone weighing 50 lbs. off the ground how much force must I exert? Of course, it would be 50 lbs. if I could lift it very gradually without giving it any acceleration. However, that cannot be done until after I have started the stone to move upward. To start the upward motion of the stone requires an acceleration per second per second. Suppose now that this acceleration is at the rate of 10 feet per second per second. Then the total force I would have to apply to start the upward motion of the stone would be computed as follows. First there would be just 50 lbs. necessary to overcome its weight and second, there would be an additional force to give it the required start or acceleration of 50 × 10 ÷ by 32.2 or 15.5 lbs. Adding this inertial force to the weight of the stone gives us a total of 65.5 lbs. to raise the stone off the ground.

A little consideration will make it clear that this inertial component of force due to the starting acceleration might be larger than the weight of the object being lifted. Let us suppose, for instance, that a powerful motor operating a derrick should lift a mass of 2000 lbs. off the ground with an acceleration for a brief interval of time of 50 feet per second per second. This would mean an additional stress in the ropes of the derrick at the start of the lifting action equal to 2,000 lbs. times 50 divided by 32.2 or 2105 lbs. of force. This added to the weight of the mass makes a total of 5105 lbs. stress on the ropes of the derrick to raise the object off the ground. Engineers recognizing the validity of Newton's second law of motion fully realize the danger of quick action in the application of forces.

In the Sunday Chicago Tribune of January 5th, 1930, we find the following statement in an article on automobiles. "The Willys-Overland Company is presenting a new model which will accelerate in high gear from five to twenty-five miles per hour in eight seconds and will pick up from five miles an hour to fifty miles an hour in high gear in twenty-one seconds."

How much average force must the engine exert to change the speed of a car from five miles per hour to 50 miles per hour in 21 seconds? Newton's second law of motion enables us to readily solve this problem. Let us assume that the car weighs 3000 lbs. Furthermore we will neglect to begin with the force necessary to overcome the frictional resistance of the air and also that of the roadbed to the motion of the car. When the speed of a car changes from five miles per hour to 50 miles per hour in 21 seconds, there is a total change of 45 miles per hour in that time. Reducing this change of 45 miles per hour to feet per hour and dividing by 300 the number of seconds in an hour gives us a change of speed equal to 66 feet per second in 21 seconds. Dividing this 66 feet by the 21 seconds we get an acceleration of 3.1 feet per second per second. The total force then necessary to give a car weighing 3000 lbs. an acceleration of 3.1 feet per second per second would be 3000 × 3.1 divided by 32.2 or 280 lbs. approximately. This would be the average pull of the engine to change the speed from five miles to 50 miles per hour in 21 seconds in case there were no air resistance and no frictional resistance on the tires. Suppose that it would require 50 lbs.

of force additional to overcome these resistances then the total pull of the engine would be 330 lbs. The power it would have to supply to do this work in 21 seconds would equal 39 horse power. The last statement can easily be verified by calculating the distance the car would travel in 21 seconds under an acceleration of 3.1 feet per second per second by means of the forula for distance in uniformly accelerated motion. The distance multiplied by 330 lbs. and divided by the product of 21 seconds times 550 foot pounds per second, the value of a horse power per second, gives 39 horse power. It is evident from the foregoing discussion that Newton's second law of motion is of great practical importance to us in the science of mechanics.

Newton's third law of motion is the one that easily persists in the mind of the high school student, namely, "To every action there is always an equal and opposite reaction" or "action and reaction are equal." This of course applies to the application of physical forces. The student readily grasps the significance of the statements in a static sense, but seldom does he comprehend them completely in their kinetic aspects. It is easy to understand that when one stretches a rubber band that the band reacts equally to the muscular force applied; or when one presses down upon the surface of a table with muscular force, the table presses up against our hands with an equal force or reaction. This static conception of an applied force is simple. However, when we come to the matter of action of a force and its reaction in a case where motion or momentum of a mass is involved, the problem is not so easy.

In the kinetic phase of the third law of motion lies one of the greatest mechanical comcepts of physical science; namely, "the Doctrine of the Conservation of Momentum". Problems illustrative of this concept are found in every high school text. To illustrate, suppose that a freight car weighing 20 tons and moving with a speed of 15 feet per second on a level track collides with another stationary car weighing 30 tons. Suppose, also, that the two cars couple up and move on together. What would be the resulting speed of the coupled cars? The doctrine of conservation of momentum states that the momentum of the combined cars after collision will just equal the momentum of the single car before the collision. If this is true then 20 tons times the speed of the first car equals 50 tons times the speed of the two cars when coupled up. Dividing 20 × 15 by 50 we get a speed of six feet per second as the answer to the problem. Sometimes in problems of this kind both masses are in motion. Sometimes also the resulting velocities are directed in opposite directions. No matter how the problem of two colliding masses presents itself the doctrine of the conservation of momentum is always adequate for its solution.

L. Begeman.

MISLEADING TERMS

Geography.

"Tradition is the enemy of progress." Dr. Julius Klein, Assistant Secretary of Commerce, advises young people to adopt this as their slogan if they wish to make for themselves successful places in the business world. To train these embryo business men and women is the business of the public schools. Geography contributes to training for commerce more than any other science. Have geography teachers adopted the same slogan?

Geography is one of the oldest of the sciences and having gone through centuries of evolution, it has collected a great body of tradition, some of which cannot stand the glare of present day research. Tenaciously clinging to geography are many terms centuries old, which were poorly chosen in the first place. Some of these expressions were applied to small areas originally. Later they were widened to cover larger areas suspected to be similar but unexplored. As the earth has enlarged through centuries of exploration and discovery, as long period records have become available; the vocabulary, definitions, and principles of geography have undergone radical changes and refinements. There are, however,