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Motion

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MOTION

Physics.

Motion is a general property of matter. There is no rest in the absolute sense. An object at rest with reference to the earth's surface is in rapid motion with reference to the earth's axis of rotation, just as a person may be at rest in a Pullman car and at the same time be in rapid motion with reference to the ground. All divisions of matter,—masses, molecules, atoms, protons, and electrons are moving relatively all of the time.

Motion may be classified under three heads:—translatory, rotary, and vibratory. Translatory motion is illustrated by an automobile traveling down a road. By means of such a motion, we travel to distant parts of the earth's surface. Translatory motion may take place in a straight or a curved path depending upon the variations of its directions while in progress. Rotary motion is referred to an axis and is practically illustrated in the revolving parts of machinery. Vibratory motion is illustrated in the motion of the pendulum of a clock and in the pistons of steam engines and of gasoline motors. It is also roughly illustrated in the swaying of the branches of a tree or of growing stalks of grain when actuated by the force of the wind. Vibratory motion is also called periodic motion since it continuously repeats itself in a definite interval of time. In a broad sense rotary motion is also vibratory motion. It is evident that vibratory motion is basic in mechanic arts as well as in the phenomena of nature.

Of course the most important property of any kind of motion is speed or velocity. When a person sees an automobile dashing down the street, it is speed that attracts his attention. When the speed of a moving object is maintained without variation through successive hours, minutes, or seconds, it is said to possess uniform motion.

When, however, the speed of an object varies continuously, it is said to possess variable or accelerated motion.

Translatory motion is commonly studied in physical science under two heads,—uniform and variable motion. Generally, the man in the street estimates all translatory motion in terms of uniform motion. If a train travels 300 miles in 10 hours, he says it moves at the rate of 30 miles per hour. In reality that is only the average speed as it may never have possessed such a speed in an exact sense for more than a few moments during all its journey. Perfectly uniform motions are practically impossible in a gravitational field of force such as the earth possesses.

The high school student, like everyone else, readily grasps the idea of uniform motion since it illustrates the common way in which most of the motions of his experience are gauged. Consequently when he comes to a scientific consideration of accelerated motion, he has great difficulty. It comes to him more as an abstraction than as a concrete phenomenon, therefore it is best in taking up the simplest form of accelerated motion which happens to be uniformly accelerated motion in a straight line to introduce the subject with common every day illustrations.

Uniformly accelerated motions in an approximate practical sense are quite common in our daily environment. When an automobile starts to gather speed, it takes on uniformly accelerated motion, since the speed increases gradually up to a certain value desired by the driver. When the "gas" is turned off from the engine of the automobile, the speed of the car diminishes gradually even though the brakes are not applied. In the case of the retarded motion the speed diminishes and the acceleration is said to be negative. In the first illustration in which speed is gained, the acceleration is positive. It is evident that what we mean by acceleration is the change of speed or velocity per hour, per minute, or per second depending upon which unit of time we prefer. In the discussions of motion in physics, it is usual, in accordance with the C. G. S. system of units, to take the mean solar second as the unit of time. In a later article, the writer will discuss the significance of the C. G. S. system in physical measurement. ....

In the current texts on physics acceleration is expressed in terms of feet per second per second or in terms of centimeters per second per second. This doubling of the time in the expressions for accelerations is very abstract to the beginning student. That the acceleration of a freely falling body under the action of gravity is 32.2 feet per second per second might be more clearly presented to him by saying, that the per second velocity of a falling body increases 32.2 feet per second. This would mean that the per minute change of the per second velocity of a falling body is 60 x 32.2 feet or 1932 feet. In the same way, if the acceleration of a starting automobile is two feet per second per second, it would mean that its per second velocity is changing at the rate of two feet per second. This would equal a change of 120 feet per minute in its **per second** velocity and also it would mean a change of 7200 feet per minute in its per minute velocity. It is only by such illustrations that this puzzling expression can be made concrete,—perhaps even then its subtlety will be great to the average student. It is probably due to this subtlety of accelerated motion that some physics teachers are arguing for the elimination of the subject of falling bodies from the high school course in physics.

While a concrete understanding of all the properties of uniformly accelerated motion is difficult, there is no good reason why the general facts of the subject should not be readily grasped by the average high school student. The problems pertaining to velocity or speed of a falling object are, of course, the simplest. In considering such problems the student should understand to begin with that it is an experimental fact that a heavy object falling from a high point above the earth's surface, as for instance, from the roof of a tall skyscraper will have a speed of 32.2 feet at the end of the first second of its fall and 2 x 32.2 feet or 64.4 feet per second at the end of the second second and that its per second velocity would gradually increase by the same amount for each succeeding second. Contrariwise, he should be told also that when an object is shot vertically upward against gravity its per second velocity will lose 32.2 feet for each second of its rise until it comes to rest. For instance, if an object is projected upward with a speed of 64.4 feet per second, it will come to rest at the end of two seconds and begin to fall back to the earth's surface.

When the principle of speed or velocity of a falling body is once grasped by the student, it is not difficult to lead him to its application in a starting automobile or a starting train leaving a station. When a man steps on the accelerator of a car and gives the automobile an acceleration of two feet per second per second, its speed will be two feet per second at the end of the first second, four feet per second at the end of the second second, and so on for any number of seconds. Accordingly, the car would have a speed of 20 feet per second at the end of 10 seconds and a speed of 120 feet per second at the end of a minute. With each simple problem the student would likely discover for himself that the speed of any object possessing uniformly accelerated motion is always equal to the product of the acceleration times the number of intervals of time for which the motion is considered. After that an algebraic formula for velocity might follow.

Having proceeded thoroughly so far, it becomes easy to pass to a problem of velocity in which the moving object is given a speed or velocity to start with before the accelerated component enters. For instance, suppose one throws a brick straight down from a high window giving it an initial speed of 10 feet per second, what would its speed be at the end of three seconds? The final speed would be 106.6 feet per second. The force of gravity would give it a speed of 3 x 32.2 feet or 96.6 feet per second at the end of three seconds. Adding the 10 feet per second that was impressed on it by the initial throw makes a total of 106.6 feet per second. Keeping to simple arithmetical data, it is evident that one can create all sorts of problems pertaining to the speeds or velocities of uniformly accelerated moving objects whether actuated by the force of gravity or by a gasoline motor.

Problems pertaining to the distances traveled by an object in uniformly accelerated motion are also most easily approached from an arithmetical point of view. The student should first know that it is an experimental fact that a heavy object falling freely moves through a distance of 16.1 feet the first second; 3 x 16.1 feet the second second; and 5 x 16.1 feet the third second. The distance for each succeeding second is the product of 16.1 feet times the odd number taken in the order of the time elements. For example:—

1st second ....1 x 16.1 feet
2nd second ....3 x 16.1 feet
3rd second ....5 x 16.1 feet
4th second ....7 x 16.1 feet
5th second ....9 x 16.1 feet
6th second ....11 x 16.1 feet

Having grasped this experimental fact, it will be easy for him to solve simple problems like the following: How far will an object falling freely under the action of gravity move in three seconds? The solution is: 1×16.1 feet $+ 3 \times 16.1$ feet $+ 5 \times 16.1$ feet$=144.8$ feet. How far will the object fall in the third and fourth seconds only? Solution: 5×16.1 feet $+ 7 \times 16.1$ feet$=193.2$ feet. An object projected straight up in space will go as high as it would fall in the same time from a point of rest. How high will a cannon ball fired straight up into space rise in three seconds? Solution: 1×16.1 feet $+ 3 \times 16.1$ feet $+ 5 \times 16.1$ feet$=144.8$ feet.

Let us try a more difficult problem. How far will a stone move in three seconds when thrown straight downward from a point on high giving it a speed to begin with of 10 feet per second? Solution: The velocity alone would carry it 10 x 3 feet or 30 feet in three seconds. Its accelerated motion due to gravity would carry it during the same time 1×16.1 feet $+ 3 \times 16.1 + 5 \times 16.1$ feet or 144.8 feet. Accordingly, the total distance traversed would be the sum of 30 feet and 144.8 feet or 174.8 feet.

The basic idea in the above discussion is that every object starting from rest with uniformly accelerated motion will move a distance of only one-half its acceleration per second per second in the first second of its motion.

An automobile starting with an acceleration of two feet per second per second moves only one foot the first second. A train starting out of a station with an acceleration of six feet per second per second moves only three feet the first second. Also all other distances for the succeeding seconds are obtained by multiplying the three feet by the successive odd numbers taken in the order of the time elements. Practically all of the problems in uniformly accelerated motion found in our high school texts can be worked arithmetically in the manner illustrated above. Such solutions to the student. The algebraic for- demand a more detailed discussion and make the phenomenon of uniformly accelerated motion concrete mulas, $V=at$ and $S=\frac{1}{2}at^2$ should be brought in only after these fundamental concepts are clearly grasped by the student from a simple arithmetical point of view.

The writer will discuss in a following article the teaching of Newton's Laws of Motion emphasizing by concrete illustrations the great practical significance of these laws in our everyday environment. Newton's Laws of Motion and the phenomena of accelerated motion are

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decidedly abstract and are seldom mastered in even the most elementary sense by the average high school student. If the instructor proceeds in the right manner, they can be made concrete and very interesting to him.

Note:—Speed and velocity have been used interchangeably in the above article. There is a theoretical difference. The term velocity associates direction with the idea of speed.

All the problems on falling bodies given above can easily be duplicated by using 980 centimeters per second per second as the acceleration of gravity.

L. Begeman.

ASTRONOMY

General Science.

In the field of general science, astronomy offers projects for practical as well as very useful knowledge. One of the greatest values is its appeal to the intellect. Astronomy attempts to unravel the secrets of nature, not only on our planet, but also in the vastness of space around us that is within reach of man's powerful instruments. It acquaints man with what is going on around him as well as with what is happening in regions far removed from everyday experiences and personal contacts. Astronomy tries to make man feel "comfortable" and at "home" in his universe.

Without a knowledge of astronomy man would be without an accurate time piece. Land surveys would be impossible as there would be no means of finding true north and south. Map-making would be primitive and inaccurate, as even the shape of the earth would be debatable, and navigation would be relegated to the realm of uncertainty. One of the most recent fields to be invaded by astronomy, is that of meteorology. Weather and climate on the earth are largely dependent upon the heat which comes from the sun. A careful study of the sun reveals the fact that the amount of heat which comes from the sun varies from day to day, and from one year to another. It is quite possible that, if the law of variation of heat from the sun can be determined for given periods, long range weather forecasts will come within the realm of actuality. It would be impossible to measure the value of such forecasting to agriculture. It is thus evident that the modern world is greatly indebted to astronomy for its contribution to civilization.

It is with this thought in mind that the writer ventures a series of studies for general science work in the future Science Bulletins.

The first article will concern itself with a study of the stars. There are five different kinds of bodies in our solar system: the sun, planets, satellites, asteroids, comets and meteors.

What are stars and how can they be distinguished from planets? Stars are large incandescent bodies shining by means of their own light. While they have motion, their great distance from the earth makes them appear as fixed to the unaided eye. Our sun is a star but very small in comparison with many of the stars in our universe. Some of the larger stars which have been measured recently are Betelguese in Orion which is 230,000,000 miles in diameter; Antares of Scorpio, which is 350,000,000 miles, and Mira of Cetus, which has a diameter of 400,000,000 to 450,000,000 miles or 400 times the diameter of our sun. The size of a star is not determined by its brightness alone, but also by its distance from the earth. Astronomers have, for convenience, divided the stars into various magnitudes. The faintest star that can be seen with the naked eye is a sixth magnitude star. A first magnitude star is purely theoretical. It is the average of the first twenty brightest stars. Stars of intermediate brightness are called second, third, fourth and fifth magnitude stars. Some of the first magnitude stars are brighter than the average first magnitude stars and are known as zero magnitude stars or even negative magnitude stars. Astronomers have determined the ratio of one brightness to an-