veterinary supervision of the university flocks and herds.

THE department of mining engineering of the University of Illinois has just issued its first circular of information. The course of study required for the degree of B.S. in mining engineering covers the usual period of four years. The technical studies relating to mining are begun in the sophomore year, mining principles in the first semester and earth and rock excavation in the second semester. In the junior year the study of mining methods, mine surveying and mine ventilation is pursued. In the senior year more time is devoted to the subjects relating particularly to mining. They are mechanical engineering of collieries, mine administration and organization, mining law, mining laboratory and economics of coal. Professor H. H. Stock, head of the department has been appointed a member of the Mine Commission by Governor Deneen. A Mine Explosion and Rescue Station has been established at the university under the direction of Mr. R. Y. Williams.

IT has been decided by Balliol College to offer next year an exhibition of £80 a year, tenable for two years, for the competition among students recommended by trade unions operating in Newcastle.

FOR the recently constituted degree of bachelor of science in agriculture at the University of Manchester, special courses have been prepared. The practical work will be carried on at the college of agriculture and horticulture at Holmes Chapel under the supervision of the principal, Mr. T. J. Young, who has been appointed a lecturer in the department of agriculture in the university.

THE professorship of natural history at the College of the City of New York has been filled by the promotion of Dr. Ivin Sickels, assistant professor, who since the death of Professor Stratford has directed the affairs of the department. Professor C.-E. A. Winslow, of the Massachusetts Institute of Technology, has accepted an appointment as associate professor of biology in the College of the City of New York and has been made curator of public health in the American Museum of Natural History. Professor Winslow is lecturing at the University of Chicago, on leave of absence from the institute during January, February and March, returns to Technology for the rest of the spring term and goes to New York in September.

DR. JOSEPH EVANS, of Philadelphia, has been appointed professor of clinical medicine and medical adviser to the students of the University of Wisconsin.

MR. HAROLD K. BARROWS, of the U. S. Geological Survey, has been appointed to the position of associate professor of hydraulic engineering at the Massachusetts Institute of Technology, made vacant by the resignation of Professor William E. Mott.

DISCUSSION AND CORRESPONDENCE

THE TEACHING OF ELEMENTARY DYNAMICS IN THE HIGH SCHOOL

TO THE EDITOR OF SCIENCE: So the teachers of physics have at last recognized and confessed the fact that they do not know how to teach elementary dynamics (or kinetics) to high school students, and they think they have discovered the cause of their trouble, viz., the multiplicity of forms in which the "youngster" is taught the familiar formula

$$\text{force} = \text{mass} \times \text{acceleration},$$

one of these forms being

$$\text{force (poundals)} = \text{mass (pounds)} \times \text{accel. (ft. per sec. per sec.)}$$ [1]

Instead of drawing the obvious conclusion, "let us simplify the subject and get rid of some of the forms, especially the one with the 'poundal' in it," the physicists are actually talking of running away from the difficulty. A majority of a conference of physicists have signed a statement which proposes among other things "that colleges should require of the schools no quantitative treatment of kinetics, or the behavior of matter undergoing acceleration."

To this lame and impotent conclusion have the teachers of physics come after years of blindly following the modern text-books. The aim of these text-books seems to be not to make

[1] See Professor Edwin Hall's paper in SCIENCE, October 29.

the subject of dynamics clear and interesting to the student, but to muddle it as much as possible with "poundals," "gee pounds," dynes, etc., and with such statements as "force is the time-rate of acceleration," etc. When the student gets into college he has to forget much that he has been trying to learn before he can get the clear concepts of dynamics that are necessary to further progress in the subject.

I have taught elementary dynamics to some high school students who were floundering with the mysteries of the text-book, and have also taught it to college students who combined a parrot-like memory of the words of the book they had used with total inability to make intelligent use of first principles. It may be of interest to some readers to have a short syllabus of my method of beginning the subject. Here it is:

Matter.—A stone is suspended by an elastic cord from a nail driven into a projecting shelf. The stone is a piece of matter. Define matter. Quantity of matter, determined by measuring (bulk or volume), or by weighing (weight). Bulk is inconstant and inexact, varying with temperature, porosity, etc. Weight (determined by weighing on an even balance scale) is exact and constant. The weight of the stone is W *pounds.* The unit of weight is the pound. The standard pound is kept in London and copies are made of it.

Force.—The cord is stretched when the stone is hung on it. Measure the stretch per foot of length. Why is the cord stretched by the stone? Attraction of the earth's gravitation. But the cord may be stretched by pulling it between the two hands horizontally. Also the cord with the stone or weight hung from it will return to its unstretched length if the stone be pushed upwards by the hand through a distance equal to the stretch. The pull of the earth upon the stone (gravitation), the opposite pull of the elastic cord on the stone, the pull of the hands, the push upwards by the hand, each is called by the name *force.* Force is defined as a pull or a push, something that causes or tends to cause either motion, or a change in the velocity or direction of motion. As the weight of a body (quantity of matter) is stated in pounds, so the amount of a force is also stated in pounds, a pound of force being defined as equal to the force with which the earth's gravitation attracts a one-pound weight. Force is generally represented by F. The force of the earth's gravitation acting on the stone whose weight is W pounds, is also W pounds, or $F = W$.[2] Force may be measured or weighed by a spring balance graduated in pounds, or by counterpoising it with weighted levers (illustration, the lever safety valve), or in other ways. This force varies somewhat with the latitude of the place, being about $1/1000$ part greater at London than at Philadelphia, but in ordinary and elementary problems relating to force, this difference is neglected. In advanced studies it will be considered.

We have thus far considered two different things, matter and force and the method of determining the quantity of each; W and F.

Space, Time.—Now let the cord be suddenly detached from the stone. The stone falls to the ground. It traverses a certain distance, which we call space, S, measured in feet, during a certain time, T, in seconds. We now have all four of the elements, or concepts, of dynamics, matter, force, space, time, represented by W, F, S, T. The whole science of dynamics is built on these four elements, and it may be defined as the relations existing between them when force acts on matter through space and in time.

Velocity, etc., of Falling Bodies.—The simplest case of the relation of these elements is that of a falling body, when the force acting in pounds is numerically equal to the pounds weight, or quantity of matter W. By experiment it has been found that when a body falls freely in air

for seconds $T =$	1	2	3	4	5
it will fall in each of the several seconds 16.1 ft. $\times$	1	3	5	7	9
And the total fall at the end of each second is $S = 16.1$ ft. $\times$	1	4	9	16	25

[2] The term "weight" is correctly used both as a measure of a quantity of matter and as a measure of the force with which that quantity would be attracted by the earth at London.

The velocity at the end of each second is $V = 32.2$ ft. per second $\times$	1	2	3	4	5
The increase of velocity per second is 32.2 ft. per second $\times$	1	1	1	1	1

Velocity, V, is here defined as the rate of motion. It is the space traversed divided by the time, $S \div T$, if the velocity is uniform. If it is not uniform, but increases at a constant rate, as in falling bodies, then the average velocity during any time, T, is $S \div T$. If the velocity is 0 at the beginning of any time T and V at the end of the time, then $V = 2S \div T$. The relation of time, space and velocity when the velocity is uniformly increasing may be illustrated by a right-angled triangle in which the bases are T and V and the area S.

$$S = \tfrac{1}{2}VT, \quad V = 2S \div T \qquad (1)$$

Expressing algebraically the results given in the above table we find

Total fall, $S = 16.1 \times T^2$, or if

$$g = 32.2, \; S = \tfrac{1}{2}gT^2 \qquad (2)$$

Velocity at the end of the time T,

$$V = 32.2 \times T = gT \qquad (3)$$

Velocity at the end of the fall S,

$$V = \sqrt{2 \times 32.2 \times S} = \sqrt{2gS} \qquad (4)$$

The last equation is commonly written $V = \sqrt{2gH}$, in which H = height of fall.

Acceleration.—A, $= V \div T$ = rate of increase of velocity, = 32.2 ft. per second in each second in the case of falling bodies at London. This quantity, 32.2 ft. per second per second, is commonly represented by g, and it is called the acceleration due to the earth's gravitation, or more briefly, the acceleration due to gravity.

Force causing Acceleration.—In the case of a falling body, a force which equals the weight W acts on the weight and causes it to move with an acceleration $A = 32.2$ ft. per sec. per sec. Suppose the weight is not a falling body, but a weight supported on frictionless rollers on a level plane, or a body floating in still water, and a constant force is applied to it horizontally, say by a cord the tension in which is kept constant and measured by a spring balance. What then will be the acceleration? The force is the cause of acceleration, and the acceleration is the effect of force. In general an effect is proportional to its cause. If the force applied to the weight is one tenth of the force of gravity, then the acceleration is one tenth that which would be caused by gravity, or 0.1 g or 3.22 ft. per sec. per sec.

Let W = weight, g = the acceleration that would be given by a force equal to W, A = the acceleration that would be given by any other force F, then

$$A : g :: F : W,$$

or the acceleration produced by any force F is to the acceleration due to gravity as the force F is to the weight of the body, or

$$A = gF/W. \qquad (5)$$

From this equation we see that the acceleration is proportional to the force, and inversely proportional to the weight. Illustrate this by Atwood's machine and by experiments on weights supported on rollers or floating in water. Writing A instead of g in the equations (2), (3) and (4), they become general and apply to all cases of uniformly accelerated motion, as well as to falling bodies.

Total space traversed in time T, $S = \tfrac{1}{2}AT^2$ (6)

Velocity at the end of the time T, $V = AT$ (7)

Velocity at the end of the space S,

$$V = \sqrt{2AS} \qquad (8)$$

Example (1), A boat in a canal weighs 20,000 pounds. If a boy pulls it with a string with a constant pull of 10 pounds, what velocity will the boat have acquired at the end of a minute, friction being neglected? Ans. 0.966 foot per second. (2) If an air gun has a bore 5 feet long and 1 square inch area, a bullet weighing one pound sliding frictionless in the bore, and propelled by compressed air supplied from a large reservoir at a constant pressure of 2,000 pounds per square inch behind the bullet, what will be the velocity of the bullet as it leaves the gun? Ans. 802.5 feet per second.

In the equation (5) $A = gF/W$, F and W are known and A is to be found, but if the acceleration is known, and also either one of the other two quantities, F or W, the third quantity may be found. Thus,

$$WA = gF, \text{ whence } W = gF/A \qquad (9)$$

and

$$F = W/g \times A. \qquad (10)$$

That is if a force produces a uniform acceleration A in a body whose weight is W, then the force in pounds is numerically equal to the weight in pounds divided by 32.2 and multiplied by the acceleration in feet per second per second.

Work, Energy, Effect of Force Acting through Space.—If a weight W is lifted against gravity through the height H, the product WH is called work, in foot-pounds. It is equal to the force exerted through distance, or $FS = WH = WS$. If the body falls through the space S, it acquires a velocity $\sqrt{2gS}$. If it is moved a distance S by a constant force F, other than the force of gravity, with an acceleration A, then the acquired velocity $V = \sqrt{2AS}$, from which $S = V^2/2A$. Taking this equation together with equation (10) $F = W/g \times A$, we find

$$FS = \tfrac{1}{2} W/g \times V^2. \qquad (11)$$

Work is defined as the sustained exertion of force through space, and its quantity, measured in foot-pounds, is the product of the force by the space, $F \times S$. If the force is exerted to lift a weight W through the height H, and the weight is stored at the top of the lift, it is evident that it is capable of being used to do work (illustrate). This capacity of a body at rest for doing work is called *potential energy.* If the body falls through the height H, it acquires a velocity $\sqrt{2gH}$, and it is capable of doing work by reason of that velocity, on any body which may offer resistance to its motion. This capacity is known as *kinetic energy,* or energy of motion, and its quantity is expressed by the second term of equation (11), viz., $\tfrac{1}{2}(W/g)V^2$ and is stated in foot-pounds. Let us collect together some of these equations for review:

(5) Acceleration in terms of weight and force,
$$A = Fg \div W,$$
(10) Force in terms of weight and acceleration,
$$F = W/g \times A,$$
(11) Energy in terms of weight and velocity,
$$FS = \tfrac{1}{2} W/g \times V^2.$$

If we replace the expression $W \div g$ by the letter M, the equations take a simpler form:

(5a) $$A = F \div M,$$

(10a) $$F = MA,$$

(11a) $$FS = \tfrac{1}{2} MV^2.$$

Mass.—It is convenient to call the quantity $M = W/g$ by a name, and the name "mass" has been given to it, although this name is perhaps unfortunate, since the word mass is also used in other senses. Thus it is commonly used to mean an indefinite quantity of matter, as a lump or portion. It is also used by many text-book writers in the sense in which we have used the word weight, for a definite quantity of matter stated in pounds, and these writers try to restrict the word weight to mean only the force with which the earth attracts matter. (Do not tell the student that "the engineer's unit of mass is 32.2 pounds." The engineer has no such unit. When he weighs a quantity of matter he records the result as a weight, and his unit is a pound.)

Giving the word mass to the quantity W/g, the above equations may be read thus:

(5a) Acceleration equals force divided by mass,
(10a) Force equals mass $\times$ acceleration,
(11a) Force into space $= \tfrac{1}{2}$ the product of the mass by the square of the velocity.

Momentum.—From equation (7) $A = V/T$; substituting this value of A in equation (10a) $F = MA$, we obtain $F = MV/T$, whence

$$FT = MV. \qquad (12)$$

This may be explained to mean that a force F acting constantly on a mass M ($= W/g$) which is free to move, will in the time, T, give it a velocity V. The quantity FT is sometimes called *impulse,* and the quantity MV *momentum,* and the equation is said to show the equality of impulse and momentum. (In some books momentum is called quantity of motion, but this is an error; it is merely the product of mass and velocity.)

The following equations should be memorized, as they are constantly needed in solving problems in mechanics:

$V = \sqrt{2gH}$, velocity of falling bodies,
$F = MA = MV/T$, force equals mass $\times$ acceleration,
$FS = \tfrac{1}{2} MV^2$, force into space equals energy,
$FT = MV$, force into time equals momentum.

By these four equations and their algebraic transformations, nearly all problems in dynamics (except those relating to impact) may be solved. The sign = is to be considered as meaning only "is numerically equivalent to," and never as meaning "is," as in the inaccurate statement "force is the time rate of momentum."

The main ideas in the above syllabus are:

1. That words should be used as far as possible in their most common meaning; thus, "weight," and not "mass," is the word that means, in ordinary language, the quantity of matter expressed in pounds.

2. That the English system of weights and measures is used until the subject has been carried as far as this syllabus extends. The metric system can now be used with the same equations, and the C.G.S. system with its "dimensions" postponed to the end of the course.

3. An attempt has been made to use no more technical terms and definitions than are absolutely necessary. The poundal and the gee-pound are ignored and the dyne and the erg postponed.

4. Force is treated as an entity, capable of being measured directly as matter and space are, and not as a mere mathematical function derived from length, mass and time.

5. The word "mass," which gives most difficulty to younger students, is postponed till near the end of the syllabus, and is then introduced merely as a convenient substitute for W/g. The word weight is explained to mean quantity of matter as determined by weighing it on an even balance scale (not on a spring balance). When W is so weighed, the London value of g is always used in finding $M = W/g$.

6. In teaching a class, after the preliminary study of the derivation of the equations is finished, I would put them on the blackboard and let them remain there for handy reference when solving problems. A great number of problems should be solved by the class.

I am aware that much of what I have written above will be considered rank heresy by many teachers of physics, but I submit that since in the past they have failed to teach dynamics in such a manner that the students can grasp the subject and use it in college, it is high time they changed their methods and try the method that was successfully used fifty years ago.

Wm. Kent

INFLUENCE OF OXYGEN ON THE VALUE OF COAL

To the Editor of Science: Dr. David White, in Bulletin No. 382 of the United States Geological Survey, under the title of "Oxygen in Coal," has presented some interesting and valuable matter. There are certain features, however, which may profitably have more exact examinations.

Dr. White shows that the presence of oxygen in coal has an effect equal to that of ash in reducing the heating power value of the fuel; it is, of course, true that it displaces an amount of combustible matter equal to that of ash. There is some question, however, as to what is implied by the statement. As far as the combustion process is concerned, oxygen is present as a gas and aside from displacing a corresponding weight of combustible matter in the coal, its only harmful influence is in carrying away a small amount of heat in its exit to the chimney; while the presence of ash, on the other hand, has a very harmful influence on the result produced in combustion, because ash makes clinker and otherwise obstructs the fire.

W. L. Abbott[1] has shown in a well-conducted series of experiments that the value of fuel, for the purpose of making steam, drops to zero when the ash content is equal to 40 per cent., as shown by the accompanying diagram. Therefore, it appears that ash is enormously more harmful than oxygen, because if the latter was present to the extent of 40 per cent. the loss of heat from this cause would not exceed 6 or 7 per cent.

While particular emphasis has been placed upon the presence of oxygen as an element by Dr. White, I would prefer considering the matter from the standpoint of the total inert volatile matter instead of simply that of oxygen

[1] *Journal of the Western Society of Engineers*, Vol. XI., p. 529.