Commerce, and the other industrial and technical investigations and experiments which have been carried on by the Forest Service in the last two years, were discussed at a conference of Forest Service officials at Madison, Wis., on April 14 to 17. The Forest Service Laboratory, the Washington Office of Industrial Investigations, and each of the seven National Forest Districts were represented at the conference by specialists. Among the subjects discussed were: Cooperation of the Forest Service with industries, lumber distribution in the United States, utilization of low-grade lumber and mill waste, adaptation of manufacturing and grading to specific classes of consumers, unification and standardization of lumber grades, study and development of general markets for National Forest timber, mill scale studies, including technical methods, tallying, etc.; lumber depreciation and the collection and compilation of lumber price data.

UNIVERSITY AND EDUCATIONAL NEWS

Appropriations for two new buildings to meet the needs of the University of Ohio and for additional tracts of farm land west of the Olentangy have been voted through the finance committee of the lower branch of the legislature. These extensions would involve an expenditure of $340,000. A domestic-science building to cost $150,000 and a shop building for manual training to cost $120,000 are provided. Ninety acres of land would be purchased west of the Olentangy River at a probable cost of $70,000.

The department of geology of Oberlin College is to move soon from the old building to a modern home in the science quadrangle. The museum has recently added much valuable data, including a collection of paleozoic fossils carefully worked over, identified and labeled; a collection of gold and silver, lead, bismuth and other ores from Utah and Idaho; a considerable number of topographic coast survey and other maps, and a large collection of wall pictures.

Professor C.-E. A. Winslow has been appointed to the newly established Anna M. L. Lauder professorship of public health at the Yale Medical School. He will give up his connection with the New York State Department of Health and the Teachers' College to take up this work next fall, but will continue to act as curator of public health at the American Museum of Natural History.

Professor James F. Norris, head of the chemistry department and of the department of general science of Simmons College, Boston, has accepted the position of professor of chemistry and director of the chemistry laboratories of Vanderbilt University, Nashville, Tenn.

At the Massachusetts Institute of Technology Associate Professor Henry G. Pearson is advanced to the grade of professor of English and he will be placed in charge of the department on the retirement of Professor Arlo Bates at the end of the present academic year. The following assistant professors are advanced to the grade of associate professor in their respective departments: Dr. Robert F. Bigelow, zoology and parasitology; W. Felton Brown, freehand drawing; Harold A. Everett, naval architecture and H. R. Kurrelmeyer, German. Instructor Henry B. Phillips is advanced to assistant professor of mathematics, and assistant instructors K. C. Robinson and John E. Bird are advanced to the grade of instructor in mechanical drawing. Miss Ruth M. Thomas, research assistant in organic chemistry, is advanced to research associate in the same department. The title of Professor A. E. Kennelly is changed from chairman to director of the research division of the department of electrical engineering.

Mr. W. L. Mollison has been elected master of Clare College, Cambridge, in succession to the late Dr. E. Atkinson. He was second wrangler in the mathematical tripos of 1876, and was elected a fellow of Clare in that year.

DISCUSSION AND CORRESPONDENCE

THE PRESENTATION OF THE FUNDAMENTAL CONCEPTIONS OF MECHANICS

The recent discussion in Science of the fundamental equation in mechanics has suggested that perhaps some readers might be interested in a method of approach to the accurate physical conceptions of force and mass which I have been using recently with apparent success, and which differs, I believe, from that found in any text-book. I have come to believe that except for the very unusual student the disciplinary value of a dogmatic, mathematical presentation of mechanics is small, and that it is better to arouse and maintain interest by progressing from matters of every-day experience by as easy steps as possible, following largely the development of ideas which history has shown to be the natural one.

For the sake of brevity, I shall have to give the steps merely in outline. In fairness, then, the reader should remember that the work is supposed to extend over a period of several weeks, giving ample opportunity for the illustration of the various conclusions by numerous examples and problems, only a few of which can be suggested here.

Physics is largely a study of forces, and of the motions and strains due to forces. We will begin, then, with a study of common forces.

A. Force

1. *Introduction.*—Common experience. Muscular sensations. *Common effects of muscular exertion:*

(1) Gravitational force overcome—weight raised;
(2) Elastic force overcome—spring compressed or stretched;
(3) Frictional force overcome—sled dragged;
(4) Speed changed—ball thrown or caught;
(5) Direction of speed changed—stone whirled in circle.

To study these it is necessary to be able to compare or measure forces.

2. *Measurement of Force.*—It is simplest to use the first effect, for preliminary work. It is natural to assume, in agreement with common experience, that the effort or force required to lift a number of equal blocks of iron is proportional to the number of blocks, or, more generally, to the volume of iron lifted. For present purposes we will define the following as our units of force:

A kilogram weight (kg. wt.) is the force required to lift 128 c.c. of iron;

A pound weight (lb. wt.) is the force required to lift 3.55 cu. in. of iron.

We are now able to measure the forces required to produce the various effects mentioned above.

3. *Elastic Forces—Spring Balance.*—Stretch proportional to force. Hooke's Law. Calibration of spring balances for use where actual weights are inconvenient. Bending of a beam, stretching of a wire, twisting of a rod.

4. *Forces in Equilibrium.*—Two or more forces acting on a ring. Force table. Parallel forces acting on a beam. Non parallel forces acting on a derrick, etc. Definition of *vector, vector sum, moment of force, lever arm.*

Experimental laws:

(1) The vector sum of all forces acting must be zero.

(2) The algebraic sum of the moments of force about any axis must be zero.

Chemical balance.—Use to compare weights. Calibration of a set of brass and iron weights for use as standard forces.

5. *Frictional Forces.*—Friction is evidently equivalent to a resisting force equal and opposite to the force necessary to move the sled or other body uniformly along a horizontal plane. Study friction of wood on iron and wood on wood.

Experimental laws:

(1) Frictional force depends only slightly on the speed of relative motion. Kinetic and static friction.

(2) Frictional force is directly proportional to the force pressing the two surfaces together. $F=\mu P$. Define coefficient of friction.

(3) Frictional force is independent of the area of contact.

(4) Frictional force varies with the nature of the surfaces involved.

(5) A body started with a certain initial speed s_0, is brought to rest in a distance which is inversely proportional to the coefficient of friction. This suggests that on a perfectly smooth horizontal surface ($\mu=0$), a body would keep moving with constant speed.

Before we can determine the effect of a constant unbalanced force in changing the motion of a body, we must study some simple types of motion.

6. *Some Simple Types of Motion.*—(1) *Uniform motion* in a straight line with constant speed. Define velocity. $d = st$.

(2) *Constantly changing speed,* linear motion. Define acceleration of speed. Derive formulas: $s = at$; $d = \frac{1}{2}at^2$; etc.; and $s = s_0 + at$; $d = s_0 t + \frac{1}{2}at^2$; etc.

(3) *Parabolic motion,* combination of (1) and (2) at right angles. Formulas.

(4) *Uniform circular motion.* Constant speed but constantly changing velocity. Derive $a = s^2/r$. Distinguish *tangential* from *centripetal acceleration.*

7. *Type of Motion Due to a Constant Gravitational Force.*—(1) Atwood's machine, balanced forces; speed constant.

(2) Atwood's machine, small unbalanced force; $d \sim t^2$; positive acceleration.

(3) Atwood's machine, small retarding force; negative acceleration.

(4) Ball rolling down an inclined plane, or Fletcher's apparatus; $s \sim t$, $d \sim t^2$; acceleration constant.

(5) Water jet against blackboard, parabolic path; $d \sim t^2$.

(6) Ball rolling off table; measure g. Same for all bodies.

Conclusion: The motion produced is one with constant acceleration.

8. *Variation of Acceleration with the Force Acting on a Given Body.*—(1) Atwood's machine, various small unbalanced forces.

(2) Frictionless carriage on smooth horizontal plane.

Conclusion: The acceleration is directly proportional to the force.

9. *Measurement of Force Required to Give Centripetal Acceleration to a Given Body.*—(1) Swing 50 or 100 gm. on the end of a rubber band or spiral spring and determine the stretch during rotation at a fixed rate. Measure the gravitational force required to produce the same stretch. Compute the centripetal acceleration and show that the force required to produce it is to the weight of the body as the centripetal acceleration is to the acceleration of gravity.

(2) The centripetal force in the case of a mass rotating in a horizontal plane and free to slide along a rod may be measured directly by the weight required to produce the acceleration. Make the same computation as in (1).

Conclusion: The unbalanced force required to produce centripetal acceleration is equal to that required to give the same body an equal linear acceleration. Combining this with the conclusion of §8 we see that the acceleration produced by an unbalanced force acting on any given body is proportional to the force and is in the direction of the force, whether it is tangential or centripetal.

10. *Nongravitational Forces, Magnetic, Electric, Frictional, etc.*—Can be balanced by gravitational forces; produce the same effect when unbalanced; can be measured in terms of the gravitational force which will balance them or which will give the same acceleration to the same body. From our experience with gravitational forces we generalize and assume that whenever a body is being accelerated it is being acted upon by an unbalanced force; and if the known forces acting on the body are insufficient to account for its acceleration, we immediately postulate the existence of another force and experiment to find out what physical properties of the body in question and of the other bodies concerned, determine the amount of the force.

We have studied the relative effect of various forces upon the *same body* and arrived at the important generalization that whether the acceleration produced be tangential or centripetal, it is proportional to the force and in the direction of the force. We will not study the effect of the same force on various bodies.

B. Inertia or Mass

11. *Introduction.*—The fact that force is necessary to change the velocity of any body implies a tendency to persist in uniform motion and to resist a change of motion. This property of bodies is called *inertia.* The easier it is to accelerate a body, the less its inertia, of

course. So it is natural to assume that the inertia of any body is proportional to the force (F) required to give it unit acceleration, or since acceleration is proportional to force and since the acceleration produced by unit force would be $1/F$, this is equivalent to assuming that inertia is inversely proportional to the acceleration produced by unit force.

12. *Inertia of Different Volumes of Iron.*—(1) Two carriages carrying two or three equal volumes of iron, accelerated toward each other by a stretched rubber band.

(2) Atwood's machine, same force, different volumes of iron.

Conclusion: Acceleration is inversely proportional to the volume of iron for the same force; therefore inertia is directly proportional to the volume of iron or to the amount of iron.

13. *Inertia of Equal Volumes of Various Substances.*—Assume that two bodies have the same inertia when the same force gives them the same acceleration. Using the same apparatus as in §12, we find that the ratio of the inertias or masses of any two bodies is equal to the ratio of their weights (at a given point on the earth).

14. *Units of Mass.*—Kilogram, gm., pound.

15. *Falling Bodies.*—Since the force acting is proportional to the mass of each body, the acceleration must be the same for all. This conclusion agrees with experiment.

C. *Fundamental Law of Mechanics*

16. *Summary:*

With same mass: $a_1 : a_2 = F_1 : F_2$.
With same force: $a_1 : a_2 = m_2 : m_1$.
With same acceleration: $m_1 : m_2 = F_1 : F_2$.
Combining these: $m_1 a_1 : m_2 a_2 = F_1 : F_2$.

17. *Fundamental Law.*—When any body is acted on by an unbalanced force, the acceleration produced is in the direction of the force, is proportional to the force and is inversely proportional to the inertia of the body acted upon.

18. *Gravitational Units of Force.*—Kg. wt., lb. wt. The units we have been using. If force is measured in kg. wt., mass in kg., and acceleration in cm. per sec. per sec. then

$$a = gF/m,$$

where g is the acceleration of gravity. The same equation holds for lbs. wt. and lbs. and ft. per sec. per sec. Variation of g with distance from center of earth. Units not absolute.

19. *Absolute Units of Force.*—Dyne, poundal. Independent of gravity. Simpler equation $F = ma$.

20. *Application to Various Special Cases.*—Atwood's machine, inclined plane, etc.

21. *Definition and Discussion of Momentum, Impulse, Work and Energy.*

I shall be very grateful for any suggestions in regard to the above outline, especially from those who are willing to concede that a departure from our present dogmatic method of presentation is advisable.

GORDON S. FULCHER
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April 1, 1915

GET THE UNITS RIGHT

PROFESSOR A. GRAY in a recent lecture on Kelvin's work in gyrostatics, says:

> It is always a good thing to get down to numbers and it is a most healthful mental discipline to be forced to *get the units right.*

The force of this remark is apparent in following the discussion in SCIENCE relative to the best expression of the fundamental equation in mechanics. Professor Kent criticizes Professors Huntington and Hoskins, objecting to the form of the equation $F = ma$. He rightly says:

> The equation is not true in the ordinary English system (foot-pound-second) until it is hybridized by valuing either F or m in some other unit than pounds (poundal or gee-pound) or a in gravitals (instead of feet) per second per second (1 gravital = 32.174 feet) or else the letter m is explained as not being quantity of matter in pounds but only the quotient or ratio W/g. Neither is it true in the metric kilogram-meter-second system. . . . It is of course true in the dyne-centimeter-gram-second system but this system is only used in higher physical theory and it should not be inflicted on young students.[1]

[1] SCIENCE, Vol. XLI., No. 1055, p. 424.