PHYSICS

OF THE

HOUSEHOLD

BY

CARLETON JOHN LYNDE, Ph.D.

PROFESSOR OF PHYSICS IN MACDONALD
COLLEGE, CANADA

New York
THE MACMILLAN COMPANY
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PREFACE

This is an elementary textbook of physics, written for students of household science. It covers the ground usually covered by elementary textbooks, but differs from many of them in two ways: first, the illustrative examples and applications are taken largely from the home; second, the common system of weights and measures is used, in addition to the metric system.

The writer believes that we teach physics to young students for these reasons: first, that they may obtain knowledge of the physical world about them; and second, that they may gain, through this knowledge, the power to control the forces of nature for their own benefit, and for the benefit of others. In other words, we wish them to acquire knowledge which they will use in everyday life.

The reason for using illustrations taken from household appliances known to the student is obvious. It is good pedagogy to lead from the known to the unknown, and to illustrate the unknown by means of the known. This is the method followed in this book.

The use of the common system of weights and measures is, in the writer's opinion, justified by the desirability of having the students acquire their knowledge in terms of the weights and measures which they *must* use should they ever apply the knowledge in everyday life. Furthermore, the writer, although a strong advocate of the metric system, believes that it is pedagogically unsound to try to teach elementary physics by means of the metric system exclusively. It is an attempt to teach an unknown subject by means of an unknown system of weights and measures and leads to confusion and lack of power on the part of the student. Long experience leads the writer to believe that the correct method is to introduce the subject by means of the common system, later to teach the metric system and point out its advantages, and then to use the two systems side by side. This is the method followed in this book.

The writer wishes to thank the Macmillan Company for permission to use illustrations from other textbooks published by them. He has used illustrations from: "An Elementary Course of Physics" by Aldous; "A Classbook of Physics" by Gregory and Hadley; "Elementary General Science" by Simmons and Jones; "Elements of Physics" by Andrews and Howland; "Lessons in Elementary Physics" by Balfour Stewart; "Science of Common Life" by Simmons and Stenhouse; "College Physics" by Reed and Guthe; "A Textbook of Physics" by Spinney; "Elementary Lessons in Electricity and Magnetism" by Sylvanus P. Thompson; "Heat, Light, and Sound" by D. E. Jones; "Elements of Physics" by Crew and Jones. In addition, the writer wishes to thank the Stover Mfg. Co., of Freeport, Ill., for figure 13, the Andrews Heating Co., of Minneapolis, Minn., for figure 45, Messrs. Fay and Bowen of Geneva, N.Y., for figure 158, and Messrs. Sturgis & Walton, of New York, for permission to use illustrations from the writer's book, "Home Waterworks."

In conclusion the writer wishes to thank Dr. H. C. Sherman, of Columbia University, for many valuable suggestions, and Mr. A. Norman Shaw, of Macdonald College, for assistance with the proofreading and for excellent suggestions.

C. J. L.

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PHYSICS OF THE HOUSEHOLD

CHAPTER I

MECHANICS. SOLIDS

MECHANICAL APPLIANCES IN THE HOME

IN the first two chapters we shall study some of the household mechanical appliances which are related to the lever, wheel and axle, screw, and pulley.

LEVERS

A simple lever is represented in Fig. 1. A yardstick is suspended from a string and balanced, then a weight of 2 lb., 8 in. from the turning point, is balanced by a weight of 1 lb., 16 in. from the turning point on the other side.

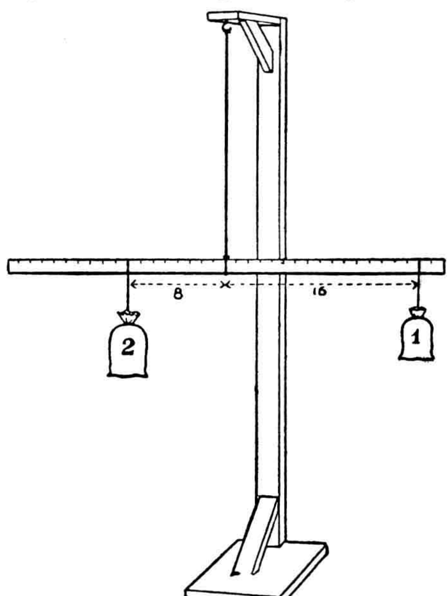

FIG. 1.—A simple lever.

It will be noticed that when this lever is balanced, the weight on one side, multiplied by its distance from the turning point, is equal to the weight on the other side, multiplied by its distance from the turning point; that is, $2 \times 8 = 1 \times 16$. This is the law of the lever and is true in all cases; for example, 2 lb., 5 in. from the turning point, is balanced by 1 lb., 10 in. from the turning point, and $2 \times 5 = 1 \times 10$; also 3 lb., at 4 in., is balanced by 1 lb., at 12 in., and $3 \times 4 = 1 \times 12$; etc.

Definitions. — The turning point of any lever is called the *fulcrum* (see Fig. 2). The product obtained by multiplying a

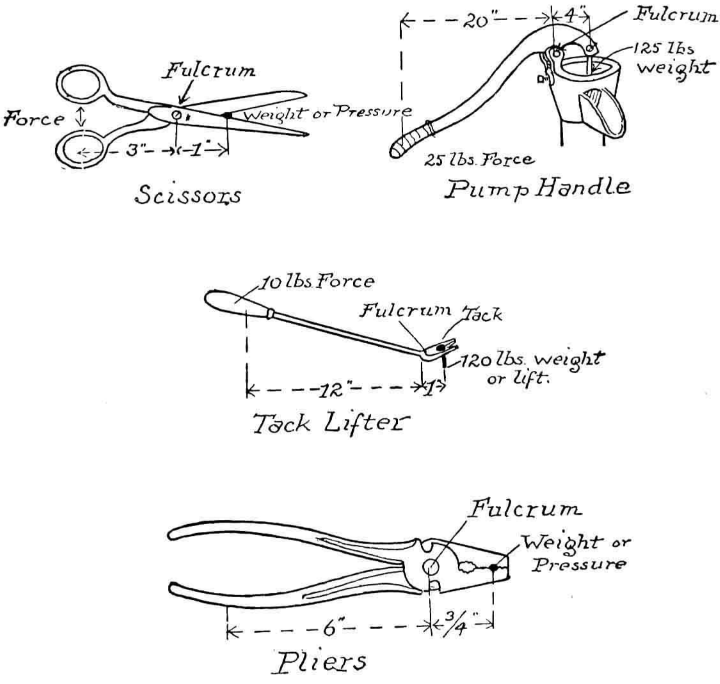

FIG. 2. — Household lever appliances showing position of fulcrum, force, and weight.

weight by its distance from the fulcrum is called the *moment* of the weight. The weight or force applied to any lever, by the hand or otherwise, is called simply the *force*. The distance from the force to the fulcrum is called the *force arm*. The weight, pressure, or lift exerted by a lever is called simply the *weight*.

The distance from the weight to the fulcrum is called the *weight arm.*

The lever law. — *Any lever is balanced when the moment on one side of the fulcrum is equal to the moment on the other.* This is the lever law. It can be stated also as follows: A lever is balanced when, weight × weight arm = force × force arm.

If there are a number of weights on each side of the fulcrum, the lever is balanced when the sum of the moments on one side is equal to the sum of the moments on the other.

Lever appliances. — A number of lever appliances are shown in Fig. 2, namely, the scissors, pump handle, tack lifter, and pliers. Since these appliances are levers, the lever law holds for them. The lever law is, when a lever is balanced, weight × weight arm = force × force arm. There are four quantities in this equation, and if we know any three of them, we can calculate the fourth.

In the case of the tack lifter shown above, it has been found by measurement that the weight arm is 1 in. long and the force arm 12 in. long. Let us calculate the weight or lift produced when we exert 10 lb. of force on the handle. We do this as follows:

$$\text{Weight} \times \text{weight arm} = \text{force} \times \text{force arm}$$
$$\text{Weight} \times 1 = 10 \times 12$$
$$\text{Weight} = 120 \text{ lb.}$$

That is, if we apply 10 lb. of force on the handle, the lift given to the tack is 120 lb.

In the case of the pump handle it has been found by measurement that the weight arm is 4 in., and the force arm 20 in. long. Let us calculate the weight or lift produced when we apply 25 lb. of force to the handle. As before:

$$\text{Weight} \times \text{weight arm} = \text{force} \times \text{force arm}$$
$$\text{Weight} \times 4 = 25 \times 20$$
$$\text{Weight} = 125 \text{ lb.}$$

That is, if we apply 25 lb. force to the handle, we produce a lift of 125 lb. on the pump rod.

In the case of the pliers it has been found by measurement that the weight arm is $\frac{3}{4}$ in. long and the force arm 6 in. long. Let us calculate the force necessary to produce 40 lb. weight or pressure.

$$\begin{aligned} \text{Weight} \times \text{weight arm} &= \text{force} \times \text{force arm} \\ 40 \times \tfrac{3}{4} &= \text{force} \times 6 \\ 30 &= \text{force} \times 6 \\ 5 &= \text{force} \end{aligned}$$

That is, an object in the jaws of the pliers is subjected to 40 lb. pressure when we exert 5 lb. force in drawing the handles together.

By a similar calculation we find that in the case of the scissors shown above each pound of force used to pull the handles together produces 3 lb. pressure on the object between the blades.

Mastery. — These examples show how the lever law gives us greater mastery over lever appliances. We have greater mastery because we know *why* and *how much* the appliance helps us, also we know how the appliance can be altered to help us still more.

Let us consider these points for the case of the tack lifter. The reason *why* the tack lifter helps us is that it acts as a lever and changes the small force applied by the hand to a large lift exerted on the tack.

We find out *how much* it helps us *by dividing the force arm by the weight arm.* This gives us the *advantage* of the lever or how much it helps us. In this case it is $\frac{12}{1} = 12$. That is, each pound of force exerted by the hand is multiplied by 12, and produces 12 lb. lift on the tack.

We can see that there are two ways in which the tack lifter could be altered to help us still more; namely, by lengthening the force arm or by shortening the weight arm. For example, if the force arm were made twice as long, or 24 in., the advantage of the lever would be $\frac{24}{1} = 24$, or twice as great; that is, each pound of force would be turned into a lift of 24 lb. instead of 12 lb. Similarly, if the weight arm were made one half as long, or $\frac{1}{2}$ in., the force arm being the same, 12 in., the advantage would be twice as great, $\frac{12}{\frac{1}{2}} = 24$. That is, each pound of force would produce a lift of 24 lb. instead of 12 lb.

Three classes of levers. — Levers are divided into three classes according to the relative positions of the weight, fulcrum, and force.

Levers in which the fulcrum is between the weight and the force are known as levers of the *first class*. See (1), Fig. 3. The appliances which we studied above are levers of this class.

Levers in which the weight is between the fulcrum and the force are levers of the *second class*, and those in which the force is applied at some point between the fulcrum and the weight are levers of the *third class*.

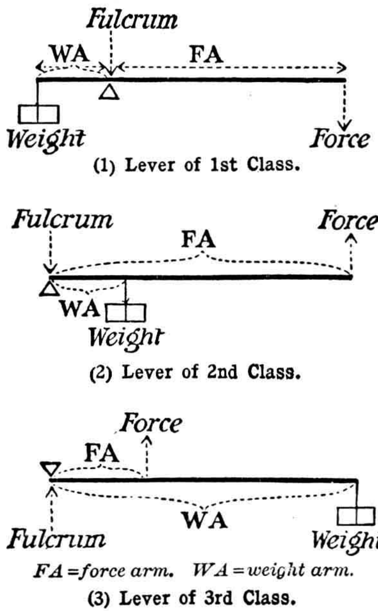

FIG. 3. — The three classes of levers.

Levers of the second class. — The appliances shown in Fig. 4 are levers of the second class, because the weight is between the fulcrum and the force.

The lever law applies to these levers, and if we find the weight arm and force arm of each by measurement, we can calculate the relation between the force and weight in each case.

In the case of the can opener, the weight arm is 1 in. long, and the force arm 6 in. long; therefore, 1 lb. of force produces a cutting pressure of 6 lb., 5 lb. of force a cutting pressure of 30 lb., etc. Similarly, 1 lb. of force exerted in drawing together the handles of the nut cracker, lemon squeezer, or fruit

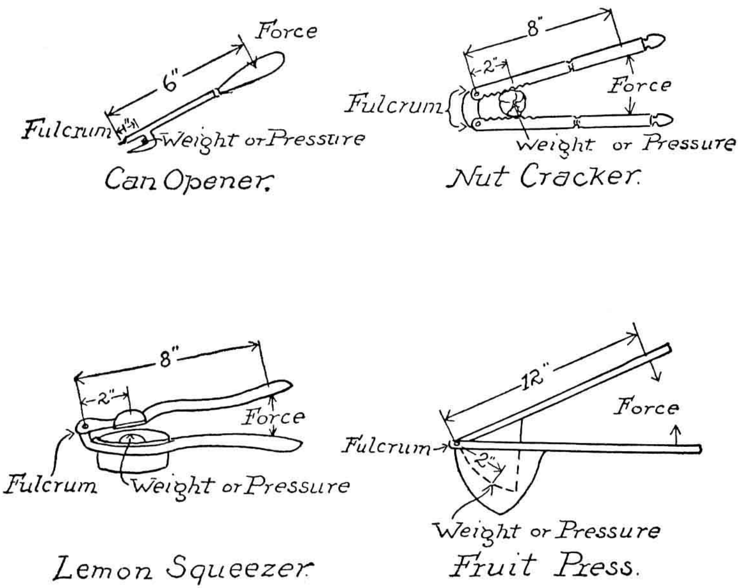

FIG. 4.—Levers of the second class.

press produces a weight or pressure of 4 lb., 4 lb., or 6 lb., respectively.

Levers of the third class. — The appliances shown in Fig. 5 are levers of the third class, because in each case the force is applied at a point between the fulcrum and the weight.

The lever law applies to these levers, and by measuring the force arm and weight arm of each we can calculate the relation between the weight and force as above.

It will be noticed that in levers of the third class the force arm is shorter than the weight arm; therefore, the weight or pressure produced is always less than the force exerted.

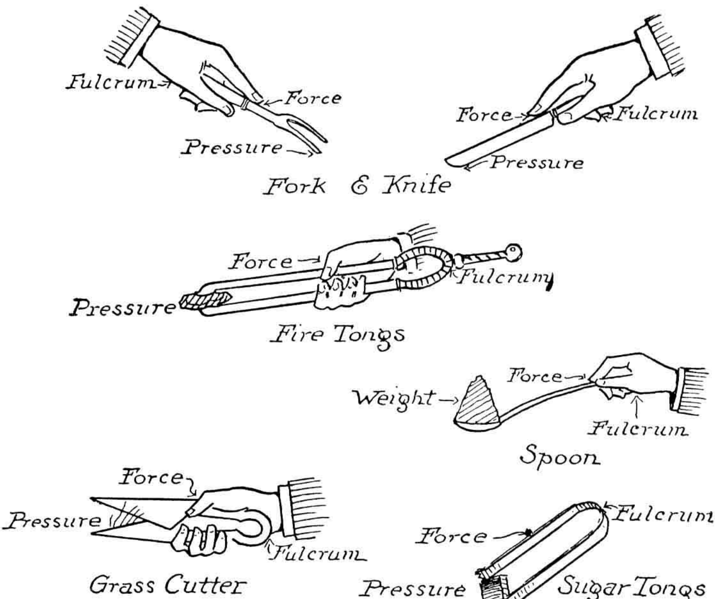

FIG. 5. — Levers of the third class.

WHEEL AND AXLE

The wheel and axle, Fig. 6, consists of a large and small wheel fastened together or fastened to the same axle. *It is in reality a lever;* for example, in Fig. 6, C is the fulcrum, P is the force, AC, the radius of the large wheel, is the force arm, Q is the weight, and CB, the radius of the small wheel, is the weight arm. If we find the force arm and weight arm by measurement, we can use the

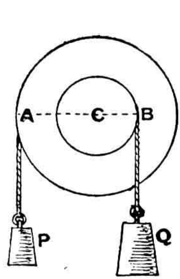

FIG. 6. — Wheel and axle.

lever law to find the relation between the force and weight as we did in the case of the levers.

Example. — If AC is 12 in. and CB is 6 in., a force P of 10 lb. will support a weight Q of 20 lb., because according to the lever law the wheel and axle balances when

$$\text{Weight} \times \text{weight arm} = \text{force} \times \text{force arm}$$
$$\text{Weight} \times 6 = 10 \times 12$$
$$\text{Weight} = \frac{10 \times 12}{6} = 20 \text{ lb.}$$

The windlass, Fig. 7, is one form of wheel and axle. It consists of a drum turned by a crank. The weight is attached to a rope wound on the drum and the force is applied to the crank handle. The radius of the drum is the weight arm, and the crank arm is the force arm.

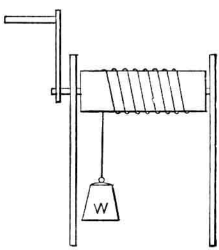

FIG. 7. — The windlass.

Wheel and axle appliances. — The appliances shown in Fig. 8 are wheel and axle appliances of the windlass type. The force arm of each is the length of the crank arm. The weight arm in the grate shaker, wringer, and ice-cream freezer is the radius of the grate, of the roll, and of the can, respectively. In the ice-cream freezer there are cogwheel gears at the top, but they are of the same size, and thus do not affect the relation between the force and the weight. In the case of the coffee mill, the weight arm is approximately the distance from the axle to the middle of the grinding surface. In the case of the bread mixer, the weight arm is approximately half the radius of the mixer.

If we measure the force arm and weight arm of any of these appliances, we can calculate the relation between the force and weight by means of the lever law.

Example 1. — The crank arm of a wringer is 9 in. long, the radius of the roll is 1 in. If 10 lb. force is applied to the