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The Simple Machines

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know species, refusing only a few poisonous ones such as larkspur. The migratory locust may also equal or even exceed this record.

On the other hand, many different insects feed upon the same kind of plant, the oaks, for example harboring seven or eight hundred different species, while corn is attacked by at least two hundred kinds, twenty of which may be called pests. Poison ivy is unique in being almost free from insect attack, though even this plant is eaten by two or three kinds of larvae.

While practically every kind of animal is attacked by one or more insect pests, these parasitic forms are limited to only a few orders, the most savage of these being the Diptera represented by such common forms as the stable-fly and the mosquito. The order Hemiptera, the "bug group", also contains some serious pests such as the bedbug and the "cootie" or body louse. It is common knowledge that forms like butterflies and most ants and beetles never attack man. In fact, it may be said that most insects do not feed upon living animals.

Like many other great groups, the insects contain numerous species which prey upon their own kind or related species. The dragon flies, or as they are often called, snake-doctors, spend most of their lives catching mosquitoes and other small insects as prey. The robberflies, large, powerful insects, are notorious as killers of their insects relatives, as also, are many kinds of ground beetles. The larvae of several species of lady-bird beetles are persistent killers of plant-lice. Certain ichneumon flies parasitize and destroy the eggs and larvae of many species of insects, and several kinds of wasps provision their nests entirely with caterpillars or grasshoppers. What would happen to civilized man if the insects would cease their internecine strife and concentrate their destructive efforts solely upon him?

Even if the insects ceased fighting among themselves, man would still have many powerful allies in his struggle for supremacy. First among these should be named the birds. It is difficult to conceive the prodigous quantities of insects destroyed by birds. The birds of Nebraska alone, are credited with consuming more than a hundred thousand bushels of insects annually, and there is no reason why Iowa birds should not exceed this quantity. Such figures are not arrived at by mere guess. They are gained by patient watching of the food-habits of many kinds of nesting birds, and by examination of the crops of thousands of other specimens. Some birds are almost entirely insectivorous in food habit. Any one who has ever watched a turkey catching grasshoppers cannot fail to be impressed by the contribution of the birds to insect eradication.

The common garden toad is a great destroyer of insects; so also are most garter-snakes, and nearly half of the food of the common striped-ground squirrel or spermophile consists of common insect pests of farm crops. A casual examination of the dung around the burrow of the common skunk will quickly disclose the insectivorous habit of this creature; even foxes and raccoons feed upon them when other food is scarce.

Roy L. Abbott.

THE SIMPLE MACHINES

Physics

(Continued from October.)

With reference to a pulley system, the work equation is clearly discerned in its practical operation. In presenting the pulley, the writer uses a rectangular frame about two feet high and three feet wide. A number of hooks are screwed into the top cross piece of the frame. With such a device a number of different pulley combinations can be shown at one time.

Let us consider the problem in the case where we set up a pulley system containing two pulleys, one fixed and the other movable. Let us also assume that the fixed pulley fastened to the frame above has three sheaves while the movable one suspended below it has only two. In setting up the pulleys, a very smooth flexible cord should be used. The cord should be wound around the sheaves so that one of its ends is fastened to the top of the frame of the movable pulley. The other end is free for the application of the effort or force. A load of 100 gm. is attached to the lower movable pulley. If a pan with weights is attached to the loose end of the cord to draw up the load, the class will readily see that to raise the load 10 cm. the spring balance must move down a distance of 50 cm. Furthermore they will also note from the weights in the pan plus the weight of the pan itself that the force necessary to raise the load, where the motion is slow and uniform, is approximately 20 gm.

The work equation in the problem would be as follows:

$$20 \text{ gm.} \times 50 \text{ cm.} = 100 \text{ gm.} \times 10 \text{ cm.}$$

It will be noted in this equation that the ratio of the load, 100 gm. to the force applied, 20 gm., is exactly 5, which is just the number of strands supporting the load. This is the case in every pulley problem, so that we frequently find the pulley equation written as follows:

$$F \times n = R$$

In this equation n stands for the number of strands supporting the load R.

The following work equation holds good with reference to the screw:

$$F \times C = R \times p$$

In this C stands for the circumference of the circle in which the force acts and p stands for the pitch of the screw. The pitch of the screw is the distance between two of its consecutive threads. Apparatus firms sell small jack screws at a very small price. A short lever arm thrust into one of the holes bored through the top of the jack screw enables one to give a visual demonstration of the work equation as expressed above.

In the discussion of simple machines there are three concepts that should be mastered by the student. These concepts are cultural in nature as well as practical. They are commonly denoted by the terms, efficiency, mechanical advantage, and conservation of energy. A work equation applied to a frictionless machine is a specific expression of the doctrine of the conservation of energy. In a practical machine where there is friction the work equation would have to be modified to express the doctrine of conservation of energy. In the case of a practical machine, the work put into a machine is used up in two ways. One part of it does useful work and the rest is wasted in the heat of friction or other forms of energy. In practice, input equals the useful output of a machine plus the energy wasted in the operation of the machine. When every thing is considered, the doctrine of conservation of energy also holds good in a practical machine. In the above discussion the term "input" means the total work applied to a machine and the term "output" means the work or service taken out of it.

The idea of efficiency arises from the fact that the useful output of a machine in practice never equals the total input of work or energy applied to a machine. If the input of a machine equals 100 foot pounds and its useful output is only 80 foot pounds then its efficiency is 80 per cent. Efficiency is evidently the ratio of the useful output to the total input expressed in per cent.

A good practical problem illustrating the idea of efficiency can easily be carried out by means of an inclined plane and a small metal wagon, such as is commonly used with problems on the inclined plane. The inclined plane commonly sold by apparatus houses carries a small pulley fastened to the top end of the incline. A smooth cord is attached to the wagon and then drawn over the pulley at the top of the incline. A pan for holding weight is fastened to the loose end of the cord, hanging down from the pulley. First weigh the pan. Then attach the pan and place weights into it until the wagon moves with slow, uniform motion up the incline for a given measured distance. When the wagon is empty, no useful work is done by the machine and the efficiency is zero. Now add a load of 50 gm. to the wagon which we will call the useful load. Then add weights to the pan until a slow uniform motion for the measured distance is obtained. Calculate the work done by the force applied,—that is obtain the product of the weight of the pan plus the weights it contains times the distance through which it is raised. Divide the latter product by the former to get the efficiency. It will probably not be a large per cent. Now increase the load successively five or six different times calculating the efficiency in each case. Finally plot the efficiencies against the useful work accomplished in each case. This problem will be found to be interesting to both student and teacher and will show how the efficiency of a machine can vary as the load is varied.

The third idea that the teacher should emphasize in the study of simple machines is that of mechanical advantage. This idea like that of efficiency is expressed concretely in terms of an arithmetical ratio but not in terms of per cent. It is denoted by the ratio of the resistance overcome in the machine to the force applied. If in an operating lever, for instance, 100 pounds of applied force overcomes a resistance of 500 pounds, the mechanical advantage is 5 or the ratio of 500 to 100. Whenever this ratio turns out to be a whole number as in the above problem, it indicates a machine to do heavy work at a slow speed. For a 100 pound force to overcome a force of 500 pounds in a machine, it would have to act through a distance of 5 feet for every foot that the resistance is overcome. Such an action would be an extremely slow process in a machine where the mechanical advantage runs into terms of hundreds of thousands as is frequently the case in a hydraulic machine.

Sometimes the ratio denoting the mechanical advantage of a machine turns out to be a fractional number. This is the case in the so-called third class lever where the force is applied between the fulcrum and the resistance. In an application of this kind, the resistance moves through a large distance while the applied force moves through a short distance. When the mechanical advantage is fractional, it indicates a speed machine in which force is sacrificed to gain speed and save time. Such machines as the sewing machine and the bicycle are speed machines.

Finally, it would be well as a matter of general information, to bring home to the student the various advantages that man derives in the use of machines. First, there is the economic advantage that saves labor. Natural forces, such as beasts of burden, steam, electricity, water power, are utilized by machines. Man directs and the forces of nature do the work. Second, a machine enables a force to be applied in a convenient direction. A man might raise bricks and mortar to the top of a building by standing on the top of the building and drawing up the material hand over hand by means of a rope. A more convenient way would be to fasten a pulley to the top of the building and then have some one standing on the ground below pull down on the rope to raise the material attached to the other end of the rope drawn over the pulley. Better still, he could fasten another pulley somewhere on the ground so that the rope could be drawn parallel to the ground by means of a horse. Finally, he could improve this still more by using pulleys of three sheaves above and two sheaves below fastened to the load. In this case the horse would have to walk five feet to raise the load one foot. However, the force required to pull up the load would be reduced accordingly. In the last case distance is substituted to save force. It illustrates the greatest advantage derived from a machine, the possible mutual substitution of the two work elements, force and distance.

Equation for the simple machines.

Lever .... $F \times l = R \times l'$

Wheel and axle .... $F \times r = R \times r'$

Inclined plane .... $F \times l = R \times h$

Pulley .... $F \times n = R$

Screw .... $F \times c = R \times p$.

A short drill in these equations will be found extremely profitable before taking up the numerical problems of the text.

Below is given the prices of simple machines as listed by apparatus houses:

Inclined plane with wagon $7.00

Wheel and axle 3.25

Jack screw 1.10

Lever holders .... .25

Pulley .... .50

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