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ndamental advances in
theory of mass-energy

An Introductory Course IN COLLEGE PHYSICS

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Friction

53. Friction. What we have thus far said about machines has been based on the assumption that friction could be neglected. Generally, however, friction plays a very important part in the operation of a machine, sometimes detrimentally and sometimes to our great advantage. We may, therefore, profitably inquire what friction is and how it acts, what determines its magnitude, and how it affects what a machine can do.

By friction we mean **the resistance which opposes every effort to slide or roll one body over another.**

For example, suppose a block of wood weighing W pounds rests on a table (Fig. 4-4). The force perpendicular to the surfaces in contact is W pounds. By means of a spring balance acting parallel to the table, we find that it requires a force of F pounds to cause the block *to start from rest* and that it requires a smaller force of F' pounds to keep it moving slowly but steadily when once started.

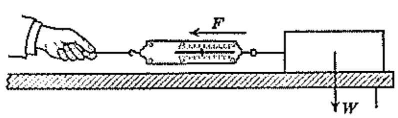

Fig. 4-4. Friction is resisting the force F.

Therefore we may say that **the starting friction, or static friction, is greater than the sliding friction.**

54. Friction often a help. Many machines, devices, and processes depend upon friction for their successful operation. Without friction, belts would not cling to their pulleys, automobile, streetcar, and railroad brakes would not work, and nails, screws, and matches would be useless. Even walking would be impossible, as anyone can see who has tried to run on a highly polished floor or on ice.

No railroad train or automobile could move without friction, because it is the friction, or *traction,* between the driving wheels and the rail or road that pushes them forward. It is to increase the traction that the surfaces of automobile tires are often made with knobs or irregular projections that bite into soft roads. On snowy days automobilists also use chains to increase traction, and locomotive drivers sprinkle sand on the tracks just in front of their wheels. Good traction is quite as important in stopping as in starting an automobile or a train. The automobile clutch, which connects the

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55. Factors affecting friction. The factors which determine the amount of friction in any particular case are so numerous and uncertain that only the most general principles can be stated positively. In general, friction depends (1) on the ***velocity,*** (2) on the ***load,*** and (3) on the nature and condition of the rubbing ***surfaces.*** If these rubbing surfaces are examined under a magnifying glass, they will be seen to be made up of hills and valleys (Fig. 4–5). In fact, it is these irregularities in the surfaces that rub which cause the friction. The tiny projections and depressions tend more or less to interlock when two surfaces are pressed together. The resistance to slipping produces heat and also wears away the surfaces when the resistance is overcome.

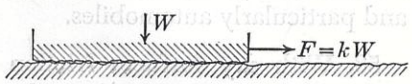

Fig. 4–5. Rough surfaces cause friction.

56. Effect of velocity on friction. It is commonly said that **friction does not depend much on velocity,** and this is approximately true. Nevertheless, *starting* friction is distinctly greater than *sliding* friction, as anyone can see who pulls a box or a heavy block of wood across a table top with a spring balance. This is why a locomotive can start a heavy train if the driving wheels are not allowed to slip; whereas, if they slip at all, they spin rapidly without accomplishing much. Furthermore, friction usually *decreases* somewhat with *increasing speed;* thus, the friction between the brake shoes and the wheels of railroad cars is only one-third to one-half as great at 60 miles per hour as at 20 miles per hour. This is why an engineer or a motorman lessens the pressure of his brakes as his train or car slows down. The same principle applies to automobile braking.

57. Effect of surfaces on friction: lubrication. On the other hand, **friction depends very much on the nature and condition of the rubbing surfaces.** Friction is less when the surfaces are smooth and hard. Thus, two well-finished metal surfaces may show only about half as much friction as two wooden surfaces under the same conditions, and the latter show only about half that of two unpolished stone surfaces.

Friction is also much diminished by proper **lubrication.** If soap or paraffin is rubbed on a drawer that sticks, it will be easier to move it. Two well-oiled metal surfaces may show only one-fourth or even only one-fifth as much friction as the same surfaces when dry. This is why it is so important to attend to the lubrication of all sorts of machines, not only the large machines in shops, but also sewing machines, bicycles, windmills, agricultural machinery, farm engines, and particularly automobiles.

58. With dry surfaces friction does not depend much on the area of contact. It takes about the same pull to drag a brick-shaped block across a table top when the block is standing on end as when it is lying on its side. This is because the force per unit area increases as the area decreases. On the other hand, **with well-lubricated surfaces friction is nearly proportional to the area of contact.**

59. Effect of load on friction: coefficient of friction. It is obvious that it requires much more force to push a loaded box along the floor than an empty one. In fact, the force needed to slide a given box over a certain floor is just about doubled when the total weight of the box and its contents is doubled, and tripled when the weight is tripled. In many cases the rubbing surfaces are not horizontal and the force pushing them together is not the weight; but here also the backward drag due to friction doubles or triples whenever one doubles or triples the perpendicular force with which the rubbing surfaces press against each other. In general, **the *force* needed to overcome friction is nearly proportional to the force pressing the surfaces perpendicularly together.** In other words, the fraction (force of friction divided by the perpendicular or normal force) is nearly constant for a given pair of surfaces no matter what the load. This fraction is called the ***coefficient of friction.***

$$\textbf{Coefficient of friction} = \frac{\text{force of friction}}{\text{normal force}}.$$

For example, suppose a block weighing 800 grams is dragged slowly along a horizontal board by a force of 300 grams. Then the coefficient of friction is $\frac{300}{800}$, or 0.375.

Often the coefficient of friction that applies to a given case is at least approximately known from engineering handbooks or previous