Figure 20
Lifting this trunk directly up requires more force than pushing it up the ramp, but the same amount of work is done in both cases.

Machines can alter the force and the distance moved

You have learned that mechanical energy is conserved in the absence of friction. This law holds for machines as well. A machine can increase (or decrease) the force acting on an object at the expense (or gain) of the distance moved, but the product of the two—the work done on the object—is constant.

For example, **Figure 20** shows two examples of a trunk being loaded onto a truck. **Figure 21** illustrates both examples schematically. In one example, the trunk is lifted directly onto the truck. In the other example, the trunk is pushed up an incline into the truck.

In the first example, a force ($\mathbf{F_1}$) of 360 N is required to lift the trunk, which moves through a distance (d_1) of 1.0 m. This requires 360 N•m of work (360 N × 1 m). In the second example, a lesser force ($\mathbf{F_2}$) of only 120 N would be needed (ignoring friction), but the trunk must be pushed a greater distance (d_2) of 3.0 m. This also requires 360 N•m of work (120 N × 3 m). As a result, the two methods require the same amount of energy.

Efficiency is a measure of how well a machine works

The simple machines we have considered so far are ideal, frictionless machines. Real machines, however, are not frictionless. They dissipate energy. When the parts of a machine move and contact other objects, some of the input energy is dissipated as sound or heat. The *efficiency* of a machine is the ratio of useful work output to work input. It is defined by the following equation:

$$eff = \frac{W_{out}}{W_{in}}$$

If a machine is frictionless, then mechanical energy is conserved. This means that the work done on the machine (input work) is equal to the work done by the machine (output work) because work is a measure of energy transfer. Thus, the mechanical efficiency of an ideal machine is 1, or 100 percent. This is the best efficiency a machine can have. Because all real machines have at least a little friction, the efficiency of real machines is always less than 1.

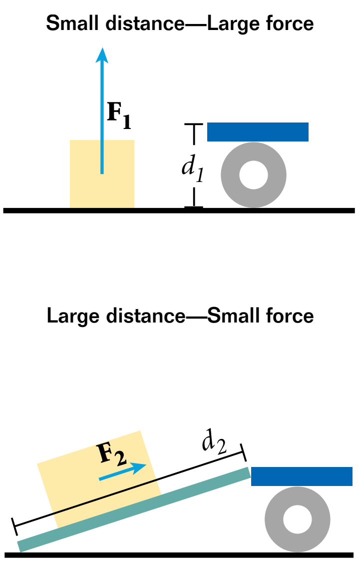

Figure 21
Simple machines can alter both the force needed to perform a task and the distance through which the force acts.