1

Moving Stuff

Energy and Work

What You Need to Know

Energy is the capacity to make things change, and the process of making them change is called work. **Work** (*w*) is accomplished when a **force** (*f*) (a push or a pull on an object) causes an object to move, which is also the process of transferring energy. Thus, **energy** is the ability to do work.

The amount of work can be determined by multiplying the force by the distance (*d*) along which the force is applied. The equation for work is:

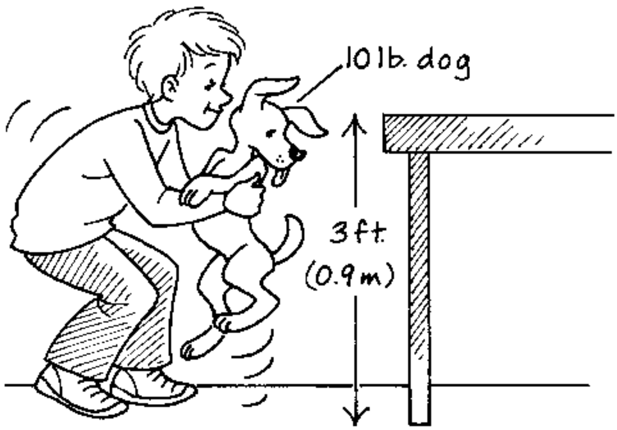
work = force × distance

$w = f \times d$

In the English system of measuring, a **pound** is a unit of force and a **foot** is a unit of distance. Therefore, the common unit for work in the English system of measuring is **foot-pounds (ft-lb)**. In the metric system, **newton (N)** is a force unit and **meter (m)** is a distance unit. The newton-meter work unit in the metric system is called a **joule (J)**. One joule is about 0.74 ft-lb.

Since energy and work are related, without any loss of energy, a given amount of energy can do an equal amount of work. So the work done in lifting an object is equal to the energy given to the object. If you want to lift an object, you must apply a force equal to the weight of the object. For example, to lift a 10-pound (45-N) dog onto a table that is 3 feet (0.9 m) high, you must apply a force equal to the weight of the dog as you raise the dog 3 feet (0.9 m). The work done in lifting the dog is:

English Measurements	**Metric Measurements**
$w = f \times d$	w = 45 N × 0.9 m
= 10 lb × 3 ft	= 40.5 Nm
= 30 ft-lb	= 40.5 J



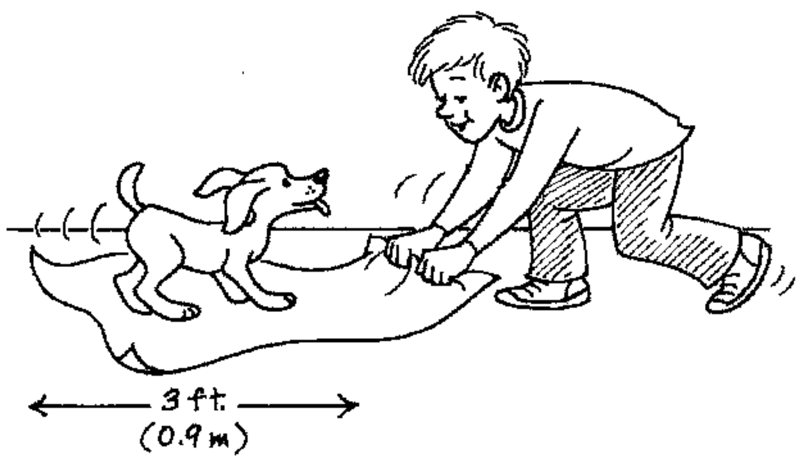
The work done in lifting the dog is 30 foot-pounds, which is the same as 40.5 joules of **kinetic energy (KE)** (the energy of moving objects). The energy of objects lifted above a surface is called **potential energy** (stored energy of an object due to its position or condition). Thus, while sitting on the table, the dog has 30 foot-pounds (40.5 J) of energy more than he had when sitting on the floor.

Let's suppose that instead of lifting the dog, you put the dog on a blanket and slide the blanket 3 feet (0.9 m) across the floor. The weight of the dog doesn't change, but you do not have to use as much force in pulling the dog to move him 3 feet (0.9 m) as you did in lifting him 3 feet (0.9 m). This is because to lift the dog, you have to overcome the pull of **gravity** (the force of attraction that exists between any two objects). Earth's gravity pulls objects near or on Earth toward Earth's center.

Weight is a measure of the force of gravity on an object. When the dog is sitting on the floor, the dog's weight is the force pushing the blanket and the floor together. To move the dog across the floor, you have to overcome the friction between the blanket and the floor. **Friction** is the force that opposes the motion of objects whose surfaces are in contact with each other. The amount of friction between two surfaces depends on the force pushing the surfaces together and the roughness of the surfaces. Since the floor is horizontal, the weight of the dog is equal to the force pushing the blanket and the floor together. If the blanket and floor are slick, the frictional force is less than the weight of the dog. So the force needed to drag the dog across the floor might be only 2.5 pounds (11.25 N). Thus, the work done in moving the dog across the slick floor would be:

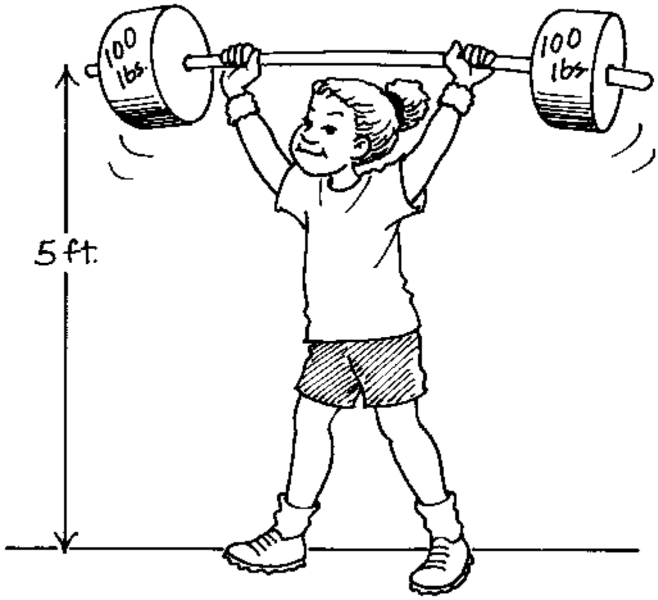
$$w = f \times d$$
$$= 2.5 \text{ lb } (11.25 \text{ N}) \times 3 \text{ ft } (0.9 \text{ m})$$
$$= 7.5 \text{ ft-lb } (10.13 \text{ J})$$

As before, the work done on the dog is equal to the energy given to the dog. But since the dog is not lifted, the energy given to the dog is not potential energy. Instead, it is kinetic energy. See chapters 3, 4, and 5 for more information about potential and kinetic energy.

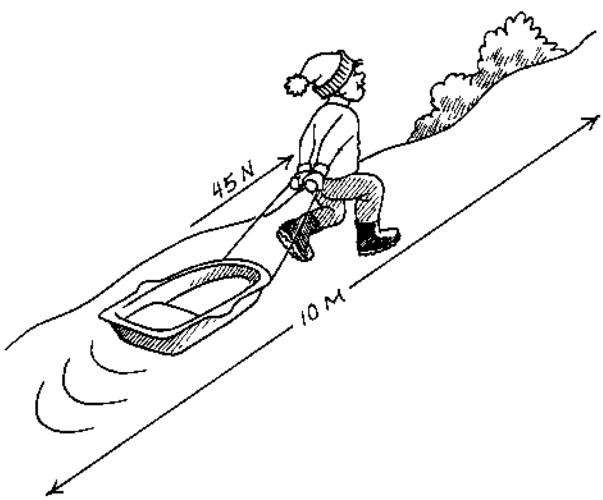


Exercises

1. How many foot-pounds of work would be done in lifting barbells weighing 200 pounds to a height of 5 feet?



2. How many joules of work are done if it takes 45 N of force to drag a sled 10 m uphill?



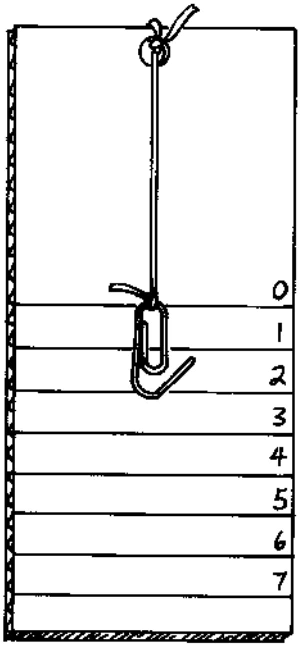
Activity: UPHILL

Purpose To compare the work done in moving an object by different methods.

Materials scissors
rubber band
paper clip
paper hole punch
4-by-10-inch (10-by-25-cm) piece of corrugated cardboard
metric ruler
pen
4 tablespoons (60 ml) dirt (sand or salt will work)
empty soda can with metal tab
24-inch (60-cm) piece of string
4 or more books

Procedure

1. Cut the rubber band to form one long piece.
2. Tie one end of the rubber band to the paper clip. Open one end of the paper clip to form a hook.
3. Using the paper hole punch, cut a hole in the center of the edge of the cardboard.
4. Tie the free end of the rubber band in the hole in the cardboard. The top of the paper clip should reach the center of the cardboard.
5. Use the ruler and pen to draw a line across the cardboard, making it even with the top of the paper clip. Label the line 0.
6. Then draw as many lines as possible 1 cm apart below the 0 line. You have made a scale.



7. Pour the dirt into the soda can.

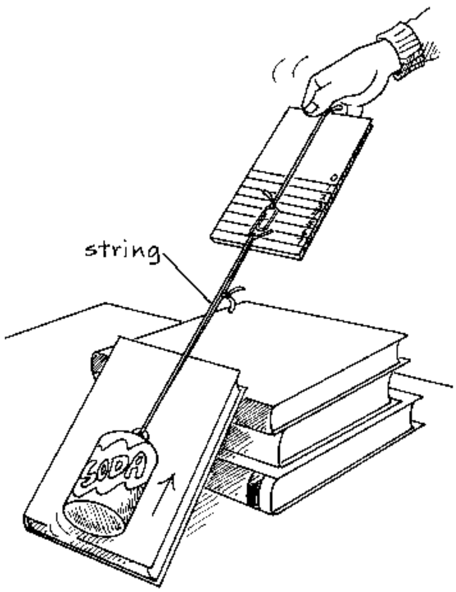
8. Thread the string through the hole in the tab of the soda can. Tie the ends of the string together to make a loop.

9. Place the string loop over the hook on the scale.

10. Stack all of the books except one. Lean the extra book against the stacked books to form a ramp as shown.

11. Stand the can next to the stack of books. Then lift the can straight up by pulling on the top of the cardboard until the bottom of the can is even with the top of the books. Note the scale line closest to the top of the paper clip hook.

12. Lay the can on the book ramp. With the scale still attached to the string, drag the can to the top of the ramp. Again note the scale line closest to the top of the paper clip hook as the can is being moved.



Results The rubber band stretches more when the can is lifted straight up than when it is pulled up the ramp. So the number on the scale when you pulled the can straight up was higher than the number when you were pulling the can up the ramp.

Why? Gravity pulls the can down. When you lift the can straight up, the rubber band scale indicates the full pull of gravity, which is the weight of the can. The work done in lifting the can to the height of the stacked books is the product of the weight of the can times the height of the books.

A **ramp** is a tilted surface used to move objects to a higher level. A ramp is called a **machine** because it is a device that helps you do work. When using a machine, you generally have to use less effort. For example, the decrease in the amount the can on the ramp stretched the rubber band indicates that the force needed to pull the can up the ramp is less than that needed to lift the can straight up. It takes less effort to drag the can up the ramp, but the can moved a longer distance. While it takes less effort to move an object up a ramp, the overall work done is more than the work in lifting the can because of friction between the can and the ramp. The effort force in moving the can up the ramp depends on the friction between the can and the ramp. A smooth ramp would require less effort than a rough one.

Solutions to Exercises

1. *Think!*

- Work is the product of force needed to move an object times the distance the object moves. The equation is $w = f \times d$.
- Foot-pounds (ft-lb) is the English unit for work if the force is measured in pounds and the distance in feet.
- The force needed to lift an object is equal to its weight. So the work done in lifting the barbells is w = 200 lb × 5 ft.

The work done in lifting the barbells is 1,000 ft-lb.

2. *Think!*

- Joules (J) is the metric unit of work if the force is measured in newtons (N) and the distance in meters (m).
- $w = f \times d$
- w = 45 N × 10 m

The work done in moving the sled is 450 J.