W1

In physics, *physical work* is defined as the applied force multiplied by the distance over which it was applied. So if you're pushing a refrigerator 2.0 m across the floor, and you need to apply 900 N, you've done this much work:

N m = Joule = J

$$(900)\cdot(2.0) = 1800$$

So applying a force of 1.0 N over a distance of 1.0 m means that you've done 1 Joule of work. $1.0\ J = 1.0 \times 10^7$ ergs because ergs are dyne-centimeters, and there are 10^5 dynes per Newton and 10^2 centimeters in a meter. The FPS system of work uses the foot-pound as the unit for work.

But work isn't just the force applied multiplied by the distance traveled; it's also the force applied along the direction of travel. For example, look at the mass being pulled in Figure 7-1.

Figure 7-1: Dragging a mass.

The force applied along the direction of travel is what counts, so you want the component of F that is horizontal (assuming you're dragging the mass and not picking it up!). That horizontal component is $F \cos \theta$, so the work you do, W, is this:

$$W = F s \cos \theta$$

Here, F is the force applied, s is the displacement, and θ is the angle between them.

Suppose that you're pulling the mass in Figure 7-1 by applying 200 N and that the angle θ is 40.0°. How much work do you do dragging the mass over 50.0 m?

1. You're pulling a chest of drawers, applying a force of 60.0 N at an angle of 60.0°. How much work do you do pulling it over 10.0 m?

Solve It

2. You're dragging a sled on a rope at 30°, applying a force of 20 N. How much work do you do over 1.0 km?

Solve It

3. You're pushing a box of dishes across the kitchen floor, using 100.0 J to move it 10.0 m. If you apply the force at 60.0°, what is the force you used?

Solve It

4. You're pushing an out-of-gas car down the road, applying a force of 800.0 N. How much work have you done in moving the car 10.0 m?

Solve It

There's often more than one force involved when you're dragging a mass over a distance. Just think of the forces of friction and gravity.

For example, take a look at Figure 7-2, where a couch is being dragged up an incline. If you're applying force F, how much work is done as the couch is dragged up the incline?

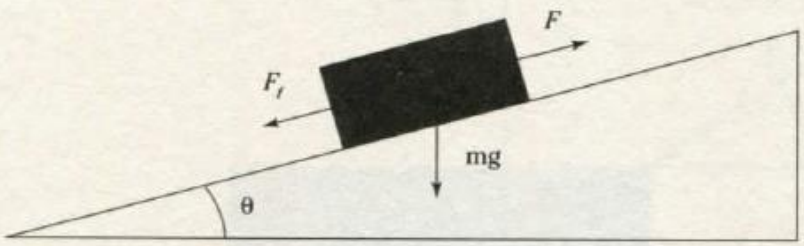


Figure 7-2: Dragging a mass up an incline.

Look at the forces involved in this scenario: There's the force you apply (your pull), the force due to friction that resists your pull, and the force due to gravity that also resists your pull. While all these forces do work on the couch as it's being pulled up the slope, the net work done on the couch is the product of the component of the *net* force multiplied by the distance traveled.

In other words, you may do 100 J of work on the couch; friction, which is opposing you, may do –50 J (the work is negative because the force here is opposite to the direction traveled); and the force of gravity may do –30 J. That means that a net work of 20 J was done on the couch by all the forces (100 – 50 – 30 = 20 J).

Suppose that the couch you're dragging in Figure 7-2 has a mass of 75.0 kg, and the angle of the ramp is 24.0°. If the coefficient of kinetic friction is 0.170 and you're pulling the couch 2.00 m with a force of 800.0 N, how much work is being done by the net force on the couch?

5. You're pulling a chest of drawers, applying a force of 600.0 N parallel to the slope. The angle of the slope is 40.0°. The chest has a mass of 40.0 kg, and there's a coefficient of kinetic friction of 0.12. How much net work do you do in pulling the chest of drawers 10.0 m up the inclined plane?

Solve It

6. You're applying a force of 800.0 N to yourself as you go up a ski slope on your new skis; this force is applied parallel to the slope. If the slope is 22.0°, the coefficient of kinetic friction is 0.050, and you have a mass of 80.0 kg, how much work do you do going up that slope 500.0 m? How much net work is done?

Solve It

When you have objects in motion, you have kinetic energy. When, for example, you slide an object on a frictionless surface, the work you do goes into the object's kinetic energy.

If you have an object with mass m moving at speed v, its kinetic energy is

$$KE = \frac{1}{2}mv^2$$

That's the energy of motion.

Say that you push a space ship, mass 1000.0kg, by applying a force of 1.00×10^4 N for 1.00 m. How fast does the space ship end up traveling?

7. You're applying 600.0 N of force to a car with a mass of 1000.0 kg. You're traveling a distance of 100.0 m on a frictionless, icy road. What is the car's final speed?

Solve It

8. You're ice skating and traveling at 30.0 m/sec. If your mass is 65 kg, what is your kinetic energy?

Solve It

9. You're traveling in a car at 88 m/sec. If you have a mass of 80.0 kg and the car has a mass of 1200.0 kg, what is the total kinetic energy of you and the car combined?

Solve It

10. You're applying 6000.0 N of force to a hockey puck with a mass of 0.10 kg. It travels over a distance of 0.10 m on a frictionless ice rink. What is the puck's final speed?

Solve It

11. A 40.0 kg box of books is sliding down a 4.0 m ramp of 27°. If the coefficient of kinetic friction is 0.17, what is the box's speed at the bottom of the ramp?

Solve It

12. An 80.0 kg person trips and slides down a 20.0 m toboggan run of 27°. If the coefficient of kinetic friction is 0.10, what is the person's speed at the bottom of the run?

Solve It

13. A parked car with its wheels locked starts sliding down an icy street with an angle of 28°. If the kinetic coefficient of friction is 0.10, the street is 40.0 m to the bottom, and the car has a mass of 1000.0 kg, what is the car's speed at the bottom of the street?

Solve It

14. You're going down a 100.0 m ski jump at a angle of 40.0°. Your mass (including skis!) is 90.0 kg, and the coefficient of kinetic fri tion is 0.050. What is your speed at the bottom of the jump?

Solve It

Objects can have energy at rest simply by having a force act on them. For example, an object at the end of a stretched spring has energy because when you let the object go and it accelerates because of the spring, it can convert that stored energy into kinetic energy.

The energy that an object has by virtue of a force acting on it is called *potential energy.* For example, an object at height h in the gravitational field at the Earth's surface has this potential energy:

$$PE = m \cdot g \cdot h$$

For example, say that you have a basketball at height h. When it drops, its potential energy gets converted into kinetic energy. To figure out how fast the basketball (or any object) is going when it hits the ground, you use this equation:

$$PE = KE = mgh = \frac{1}{2}mv^2$$

During a basketball game, a 1.0 kg ball gets thrown vertically in the air. It's momentarily stationary at a height of 5.0 m and then falls back down. What is the ball's speed when it hits the floor?

When it comes to work in physics, you're sure to see problems involving *power,* which is the amount of work being done in a certain amount of time. Here's the equation for power, P:

$$P = \frac{W}{t}$$

W equals force times distance, so you could write the equation for power this way, assuming that the force was acting along the direction of travel:

$$P = \frac{W}{t} = \frac{F \cdot s}{t}$$

On the other hand, the object's speed, v, is just s / t (displacement over time), so the equation breaks down further to:

$$P = \frac{W}{t} = \frac{F \cdot s}{t} = F \cdot v$$

So power equals force times speed. You use this equation when you need to apply a force in order to keep something moving at constant speed.

You're riding a toboggan down an icy run to a frozen lake, and you accelerate the 80.0 kg combination of you and the toboggan from 1.0 m/sec to 2.0 m/sec in 2.0 sec. How much power does that require?

15. A 40 kg box of books falls off a shelf that's 4.0 m above the ground. How fast is the box traveling when it hits the ground?

Solve It

16. You jump out of an airplane at 2000 ft and fall 1000 ft before opening your parachute. What is your speed (neglecting air resistance) when you open your chute?

Solve It

17. The flagpole on top of a 300.0 m skyscraper falls off. How fast is it falling when it strikes the ground?

Solve It

18. If you're in an airplane at 30,000 ft, what is your potential energy if you have a mass of 70.0 kg?

Solve It

19. A 1000 kg car accelerates from 88 m/sec to 100 m/sec in 30 sec. How much power does that require?

Solve It

20. A 60.0 kg person is running and accelerates from 5.0 m/sec to 7.0 m/sec in 2.0 sec. How much power does that require?

Solve It

21. A 120 kg linebacker accelerates from 5.0 m/sec to 10.0 m/sec in 1.0 sec. How much power does that require?

Solve It

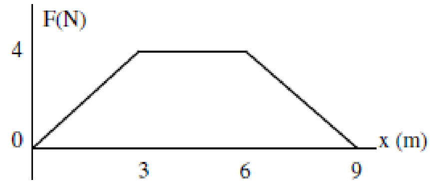
22. You're driving a snowmobile that accelerates from 10 m/sec to 20 m/sec over a time interval of 10.0 sec. If you and the snowmobile together have a mass of 500 kg, how much power is used?

Solve It

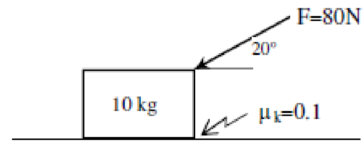
Please ignore air resistance, treat all surfaces as frictionless **unless otherwise specified or implied.**

Work and work-energy theorem:

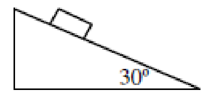
1. A 2kg crate rests on the floor. How much work is required to move it at constant speed
   a) 3m along the floor against a friction force of 4N, b) 3m along a frictionless air table, c) 3m vertically?
2. A 2-kg object is being pushed by a horizontal force F along a horizontal frictionless air-table. The object starts from rest at x = 0 and the force F acting on it changes according to the force F v.s. position x graph to the right.
   a) Find the work done by the force F on the object as the object moves from x=0 to x=9m.
   b) Find the speed of the object at x = 9 m.



3. The 10kg crate is being pushed 5m along a floor by an 80-N force. The μ_k between the floor and the crate is 0.1. Determine the work done on the crate by each of the following forces:
   a) the 80-N force, b) the gravity, c) the normal force, d) the friction, e) the net force.
   f) Find the change in the kinetic energy of the crate.



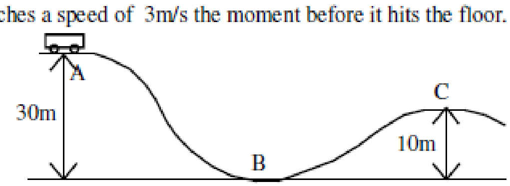
4. Starting from rest, a 4-kg block slides 10 m down a frictionless 30° incline. Determine the work done on the block by a) the force of gravity, b) the normal force, c) all of the forces (the net force) on the block.
   d) Find the kinetic energy of the block at the end of the 10m slide.



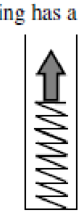
5. The 4-kg block is now pushed by a force parallel to the incline so that the block slides 10m up the 30° frictionless incline at constant speed. a) Find the magnitude of the pushing force. Determine the work done on the block by b) the pushing force, c) the force of gravity, d) the normal force, e) all of the forces (the net force) on the block. f) Find the change in the kinetic energy of the block.
6. If the speed of a particle is tripled, by what factor does its kinetic energy change?
7. How much work does it take to accelerate a 1000kg car from rest to 50m/s?
8. How much work does it take to stop a 1000kg car traveling at 50m/s?
9. A baseball (m=0.14 kg) traveling at 40m/s moves a fielder's glove backward 0.2m when the ball is caught. What was the average amount of force exerted by the ball on the glove?

Energy conservation: with and without friction & with and without spring:

10. Tarzan is running at top speed 8m/s and grabs a vine hanging vertically from a tall tree in the jungle. How high can he swing upward?
11. A projectile is fired at an upward angle of 60° with a speed of 100 m/s. It lands on a plateau 150 m higher. What is the projectile's speed the moment before it strikes the plateau?
12. A 0.01kg Styrofoam ball is released from rest 2 m above the floor. It reaches a speed of 3m/s the moment before it hits the floor. How much heat due to air resistance is generated during this process?
13. A roller coaster passes point A with a speed of 1.2 m/s.
    a) Assuming no friction, find the speed of the roller coaster at points B and C.
    b) If there is friction and the average friction equals to one-sixth of it's weight, with what speed will it reach point B? The distance traveled between A and B is 60 m.



14. The total length of a Hooke's law spring with a mass m = 0.2 kg hung under is 0.2 m. The total length of the same spring with a mass of 0.7kg hanging under is 0.25 m. a) Find the spring constant "k" of this spring.
    b) How much elastic potential energy is stored in the spring when the mass hung under is m = 0.7 kg?
15. What major energy change (e.g. U_g —> heat) is taking place when ...
    a) a rock is falling. b) a pendulum is swinging from its center position toward its endpoint.
    c) a parachutist is falling at a constant (terminal) speed. d) a pull-back car is accelerating across a level table.
16. If the potential energy stored in a spring is halved, by what factor has its stretched amount decreased?
17. A 1000kg car rolling on a horizontal surface has a speed of 30m/s when it strikes a horizontal coiled spring and is brought to rest in a distance of 2 m. What is the spring constant of the spring? Ignore friction.
18. A dart of 0.2-kg mass is loaded 0.05m into a vertically coiled spring (as shown on the right) and then is released. The spring has a stiffness constant k = 800 N/m and negligible mass.
    a) What is the block's speed the moment the spring restores to its relaxed length?
    b) What is the maximum height the block reaches (measured from its starting point)?



19. A 2-kg small block is dropped from rest at point A. The spring has a spring constant k = 500N/m.
    a) If the entire track is frictionless, find the maximum compression of the spring.
    If the entire track is frictionless except for the 1m between points B and C, where the coefficient of kinetic friction is 0.15, b) find the maximum compression of the spring, and
    c) find the final position of the block in terms of the distance from point B.