Work

The work done on an object by a given force is the product of the amount of force that is accomplishing something and the displacement of the object. Mathematically, we can write this as:

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

W is the work done by the force

F is the force vector

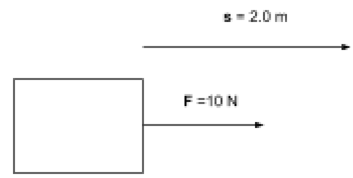
s is the displacement vector

• represents the dot product

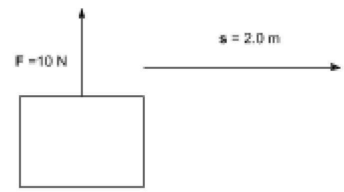
Units: newton-meters (Nm) or joules (J).

The **dot product** is the mathematical function that allows you to multiply only the parts of vectors that are along the same line. The result is a scalar quantity, so + or - values are not related to direction.

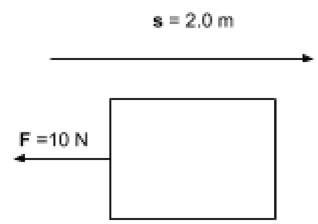
- If the force is applied in the direction of the displacement, the work done by the force is equal to the product of force and the displacement.
  W = (10 N)(2 m) = 20 J



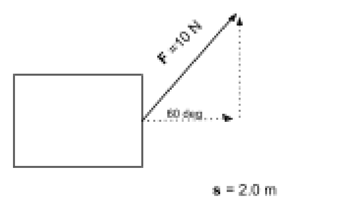
- If the force is perpendicular to the direction of the displacement, the work done is equal to 0 since the force is not accomplishing anything.
  W = 0 J



- If the force is applied directly against the displacement, the work done is negative.
  W=-(10 N)(2 m) = -20 J



- If the force is applied at an angle to the direction of motion, find the part of the force that is along the line of motion. Use this component to find the work done.
  W = (5 N)(2 m) = 10 J



All of these scenarios can be summarized by W = F s cos θ where θ is the angle between the force vector and the displacement vector.

1. A 2.0 kg block is pulled 5.0 m along a horizontal, frictionless surface by a horizontal force of 20.0 N.
   a. Calculate the work done on the block by the pull.
   b. Determine the work done on the block by the ground.
   c. Determine the work done on the block by the Earth.

2. Samuel (500 N) and Ateendra (450 N) are pushing in opposite directions on a block that is initially at rest on a horizontal surface. The block moves 2.0 meters as they push.
    a. Calculate the work done on the block by each force.
    b. Determine the total work done on the block.

3. Owen drags a 50 kg box up a frictionless ramp that is inclined at 10 degrees. His force along the ramp is 150 N. The length of the ramp is 8.0 meters.
    a. Calculate the amount of work he does on the box.
    b. Determine the amount of work done by the normal force on the box.
    c. Determine the amount of work done by the gravitational force on the box.
    d. Calculate the total work done on the box.

4. A pulley system is set up to lift a 240 kg slab with a force of 784 N.
    a. Sketch the pulley arrangement.
    b. Determine how much rope will have to be pulled by a person to lift the slab 10.0 meters. Justify your answer.

5. A given frictionless ramp allows someone to apply a force along the surface equal to ¼ the weight of an object and move the object at a constant speed..
    a. Calculate the angle of inclination of the ramp.
    b. Determine the height reached by a block if it moved 8 meters along the ramp.

Doing work on an object is a way to add (+ work) or remove (- work) energy from a system. One form this energy can take is **kinetic energy**. Kinetic Energy (E_K) is the energy related to the motion of the object. It is defined as $E_K = \frac{1}{2} m v^2$.

6. Calculate the kinetic energy for each of the following situations.
    a. Evan (m = 55 kg) is running with a speed of 8 m/s.
    b. A 1200 kg car traveling 15 m/s.
    c. The same 1200 kg car traveling 30 m/s.
    d. A 0.150 kg baseball is thrown with a velocity of 40 m/s at 30 degrees above the horizontal.

7. A baseball (m = 0.150 kg) is traveling 20 m/s when it hits a glove. The player moves his glove 25 cm as he slows the ball to rest.
    a. Calculate the work done by the glove on the ball.
    b. Calculate the average force of the glove on the ball.
    c. Determine what would happen to the force of the ball on the glove if the initial speed were doubled but the stopping distance stayed the same.