Chapter 6
Work and Energy

6-1 Work Done by a Constant Force
The work done by a constant force is defined as the distance moved multiplied by the component of the force in the direction of displacement:

\[ W = Fd \cos \theta \]  \hspace{1cm} (6-1)

In the SI system, the units of work are joules:

\[ 1 \text{ J} = 1 \text{ N} \cdot \text{m} \]

As long as this person does not lift or lower the bag of groceries, he is doing no work on it. The force he exerts has no component in the direction of motion.
6-1 Work Done by a Constant Force

Solving work problems:
1. **Draw** a free-body diagram.
2. **Choose a coordinate system.**
3. **Apply Newton's laws** to determine any unknown forces.
4. **Find the work done by a specific force.**
5. **To find the net work,** either
   - find the net force and then find the work it does, or
   - find the work done by each force and **add**.

Think-Pair-Share

- **Question 3:** Can the normal force on an object ever do work? Explain.

Think-Pair-Share

- **Problem 3:** A 1300-N crate rests on the floor. How much work is required to move it at constant speed (a) 4.0 m along the floor against a friction force of 230 N, and (b) 4.0 m vertically?
Think-Pair-Share

• Problem 5: A 1300-N crate rests on the floor. How much work is required to move it at constant speed (a) 4.0 m along the floor against a friction force of 230 N, and (b) 4.0 m vertically?

Think-Pair-Share

• Problem 9: (a) Find the force required to give a helicopter of mass M an acceleration of 0.10g upward. (b) Find the work done by this force if the helicopter moves a distance h upward.

6-3 Kinetic Energy, and the Work-Energy Principle

• Energy is traditionally defined as the ability to do work.
• Not all forces are able to do work (Ex: centripetal force).
• We will deal mostly with mechanical energy, which does follow this definition.
  • kinetic energy
  • potential energy

We define the kinetic energy:

\[ KE = \frac{1}{2}mv^2 \]  

(6-3)
6-3 Kinetic Energy, and the Work-Energy Principle

This means that the work done is equal to the change in the kinetic energy:

\[ W_{net} = \Delta KE \]  

(6-4)

- If the net work is positive, the kinetic energy increases.
- If the net work is negative, the kinetic energy decreases.

Think-Pair-Share

- Problem 16: (a) If the kinetic energy of an arrow is doubled, by what factor has the speed increased? (b) If its speed is doubled, by what factor is its KE increased?

6-4 Potential Energy

An object can have potential energy by virtue of its surroundings.

Familiar examples of potential energy:

- A wound-up spring
- A stretched elastic band
- An object at some height above the ground
In raising a mass $m$ to a height $h$, the work done by the external force is

$$W_{\text{ext}} = F_{\text{ext}} d \cos 0^\circ = mgh$$

$$= mg(y_2 - y_1) \quad (6-5a)$$

We therefore define the gravitational potential energy:

$$PE_{\text{grav}} = mgy \quad (6-6)$$

This potential energy can become kinetic energy if the object is dropped.

Potential energy is a property of a system as a whole, not just of the object (because it depends on external forces).

If $PE_{\text{grav}} = mgy$, where do we measure $y$ from?

It turns out not to matter, as long as we are consistent about where we choose $y = 0$. Only changes in potential energy can be measured.

Think-Pair-Share

- Problem 27: A 7.0-kg monkey swings from one branch to another 1.2 m higher. What is the change in PE?

Potential energy can also be stored in a spring when it is compressed; the figure below shows potential energy yielding kinetic energy.
The force required to compress or stretch a spring is:

\[ F_S = -kx \]  \hspace{1cm} (6-8)

where \( k \) is called the spring constant, and needs to be measured for each spring.

The force increases as the spring is stretched or compressed further. We find that the potential energy of the compressed or stretched spring, measured from its equilibrium position, can be written:

\[ \text{elastic PE} = \frac{1}{2} kx^2 \]  \hspace{1cm} (6-9)

Think-Pair-Share

- Problem 29: A 1200-kg car rolling on a horizontal surface has a speed of 65 km/h when it strikes a horizontal coiled spring and is brought to rest in a distance of 2.2 m. What is the spring stiffness constant of the spring?