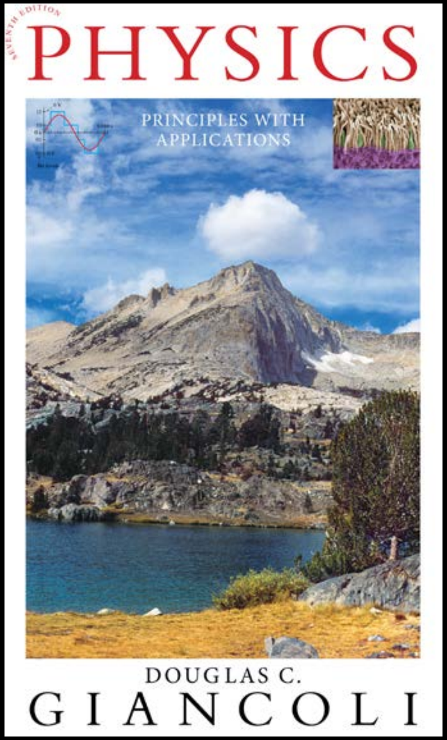
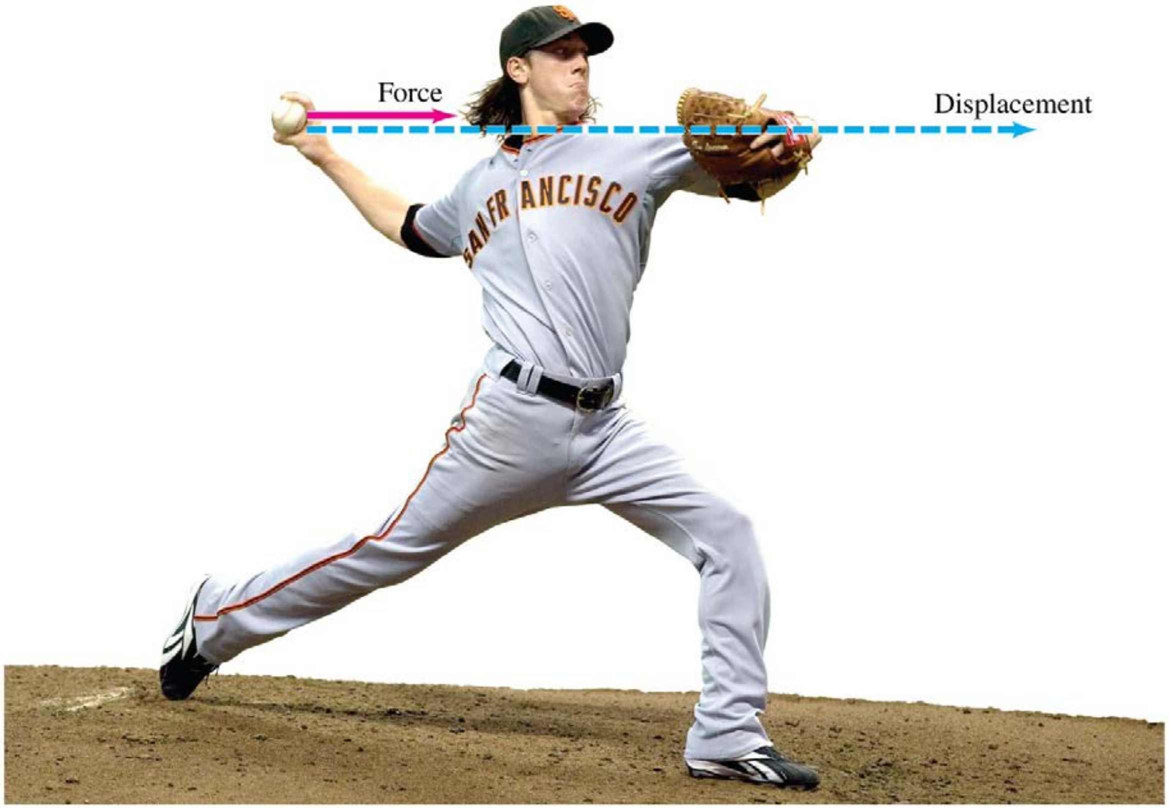


Lecture PowerPoints

Chapter 6
Physics: Principles with Applications, 7th edition
Giancoli

Chapter 6

Work and Energy



Contents of Chapter 6

- Work Done by a Constant Force
- Work Done by a Varying Force
- Kinetic Energy, and the Work-Energy Principle
- Potential Energy
- Conservative and Nonconservative Forces
- Mechanical Energy and Its Conservation
- Problem Solving Using Conservation of Mechanical Energy

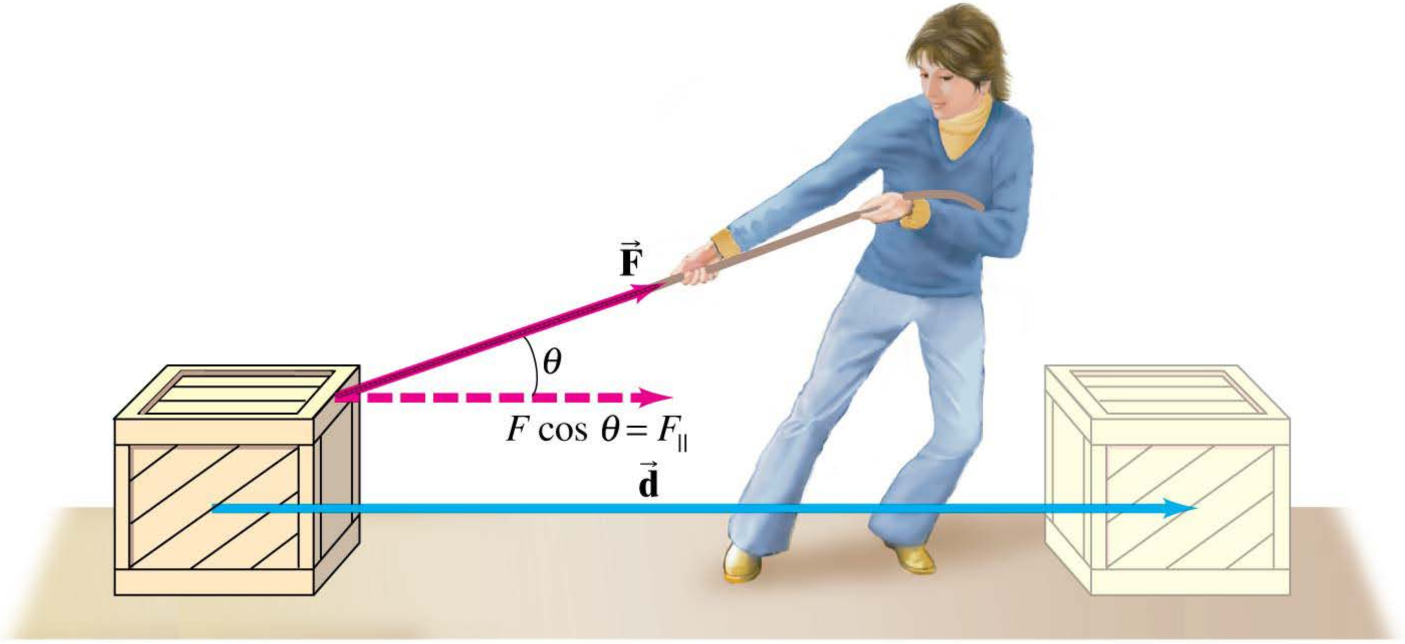
Contents of Chapter 6

- Other Forms of Energy and Energy Transformations; the Law of Conservation of Energy
- Energy Conservation with Dissipative Forces: Solving Problems
- Power

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:

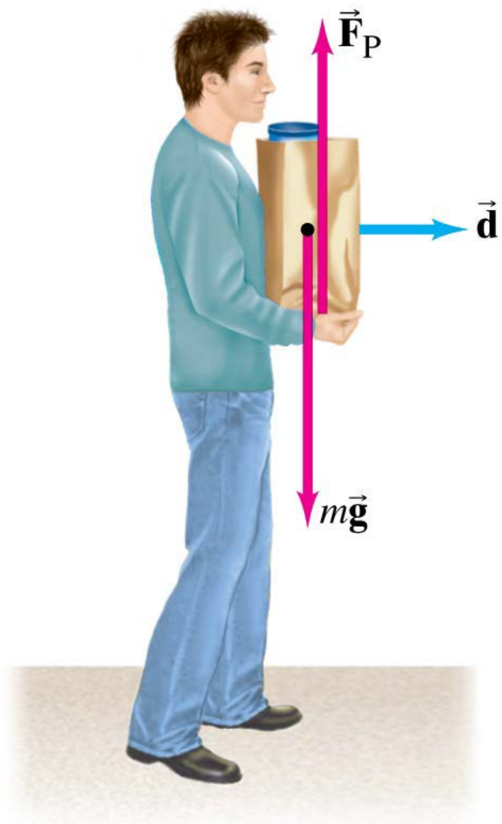
$$W = Fd\cos\theta \quad (6\text{-}1)$$



6-1 Work Done by a Constant Force

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

$$1 \text{ J} = 1 \text{ N} \bullet \text{m}$$



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.

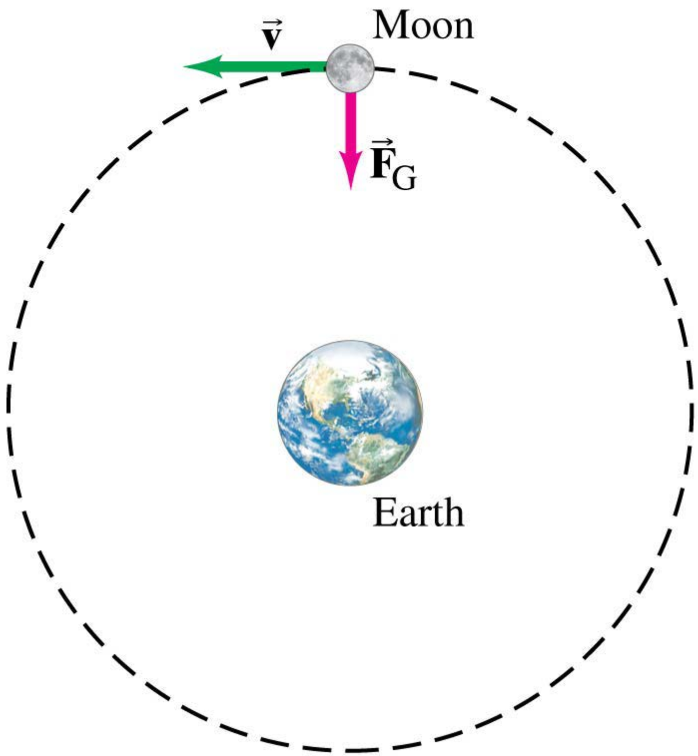
6-1 Work Done by a Constant Force

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.

6-1 Work Done by a Constant Force

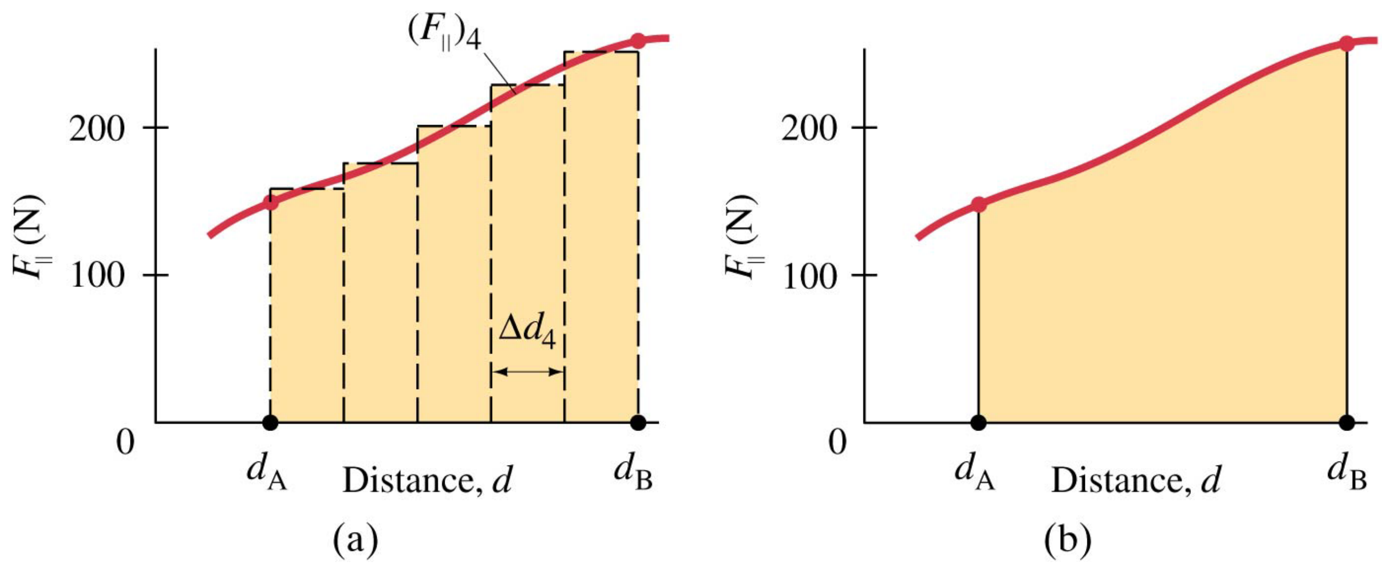
Work done by forces that oppose the direction of motion, such as friction, will be negative.



Centripetal forces do no work, as they are always perpendicular to the direction of motion.

6-2 Work Done by a Varying Force

For a force that varies, the work can be approximated by dividing the distance up into small pieces, finding the work done during each, and adding them up. As the pieces become very narrow, the work done is the area under the force vs. distance curve.



6-3 Kinetic Energy and the Work-Energy Principle

Energy was traditionally defined as the ability to do work. We now know that not all forces are able to do work; however, we are dealing in these chapters with mechanical energy, which does follow this definition.

6-3 Kinetic Energy and the Work-Energy Principle

- If we write the acceleration in terms of the velocity and the distance, we find that the work done here is

$$W_{net} = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2 \qquad (6\text{-}2)$$

- We define the kinetic energy:

$$\boxed{KE = \tfrac{1}{2}mv^2.} \qquad (6\text{-}3)$$

6-3 Kinetic Energy and the Work-Energy Principle

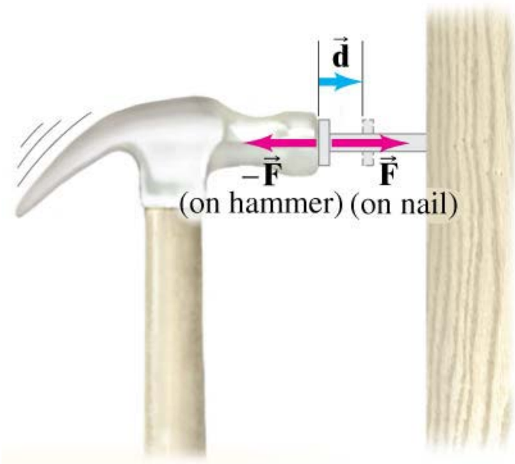
- This means that the work done is equal to the change in the kinetic energy:

$$W_{\text{net}} = \Delta \text{KE} = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2. \qquad (6\text{-}4)$$

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

6-3 Kinetic Energy and the Work-Energy Principle

Because work and kinetic energy can be equated, they must have the same units: kinetic energy is measured in joules.



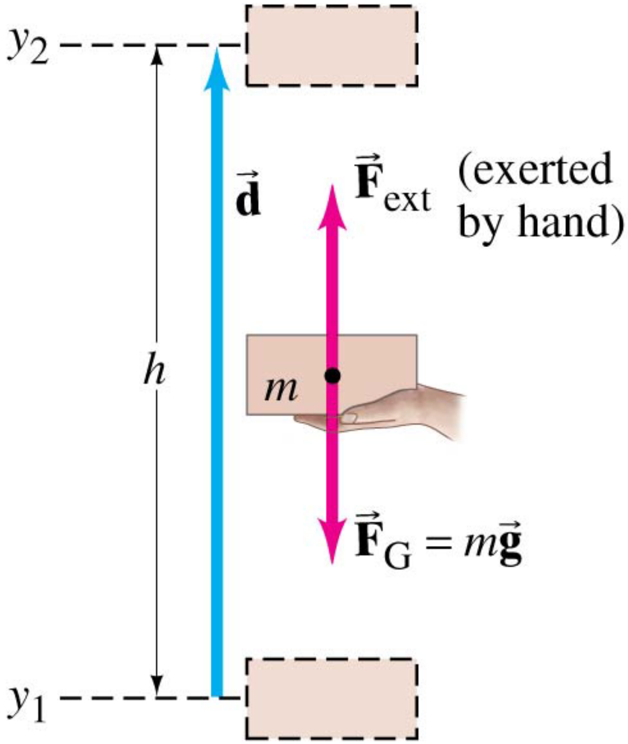
6-4 Potential Energy

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

6-4 Potential Energy



In raising a mass *m* to a height *h*, the work done by the external force is

$$W_{\text{ext}} = F_{\text{ext}}\, d \cos 0^\circ = mgh \tag{6-5a}$$
$$= mg(y_2 - y_1)$$

We therefore define the gravitational potential energy:

$$\boxed{\text{PE}_G = mgy.} \tag{6-6}$$

6-4 Potential Energy

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

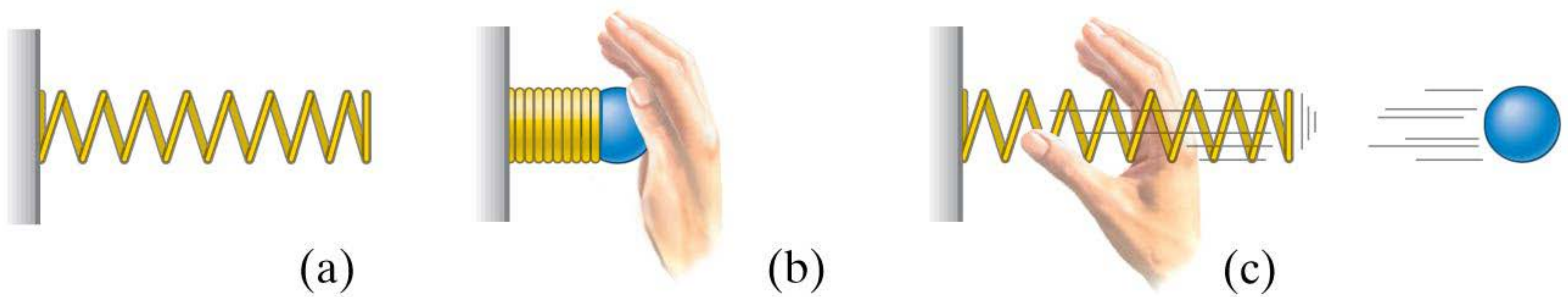
Potential energy is a property of a system as a whole, not just of the object (because it depends on external forces).

If $PE_G = mgy$, 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.

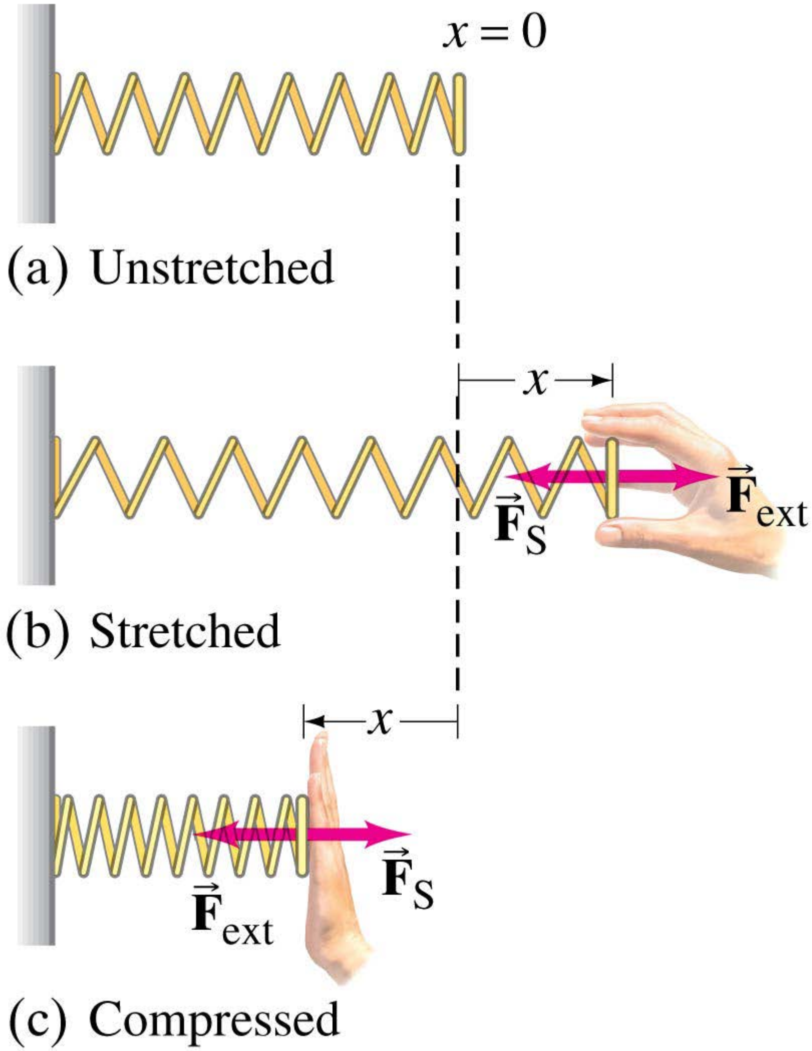
6-4 Potential Energy

Potential energy can also be stored in a spring when it is compressed; the figure below shows potential energy yielding kinetic energy.



(a) (b) (c)

6-4 Potential Energy



The force required to compress or stretch a spring is:

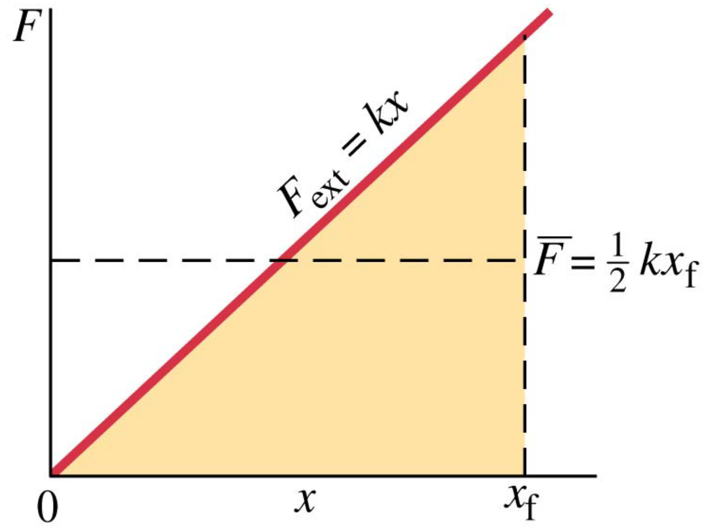
$$F_S = -kx \qquad (6\text{-}8)$$

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

6-4 Potential Energy

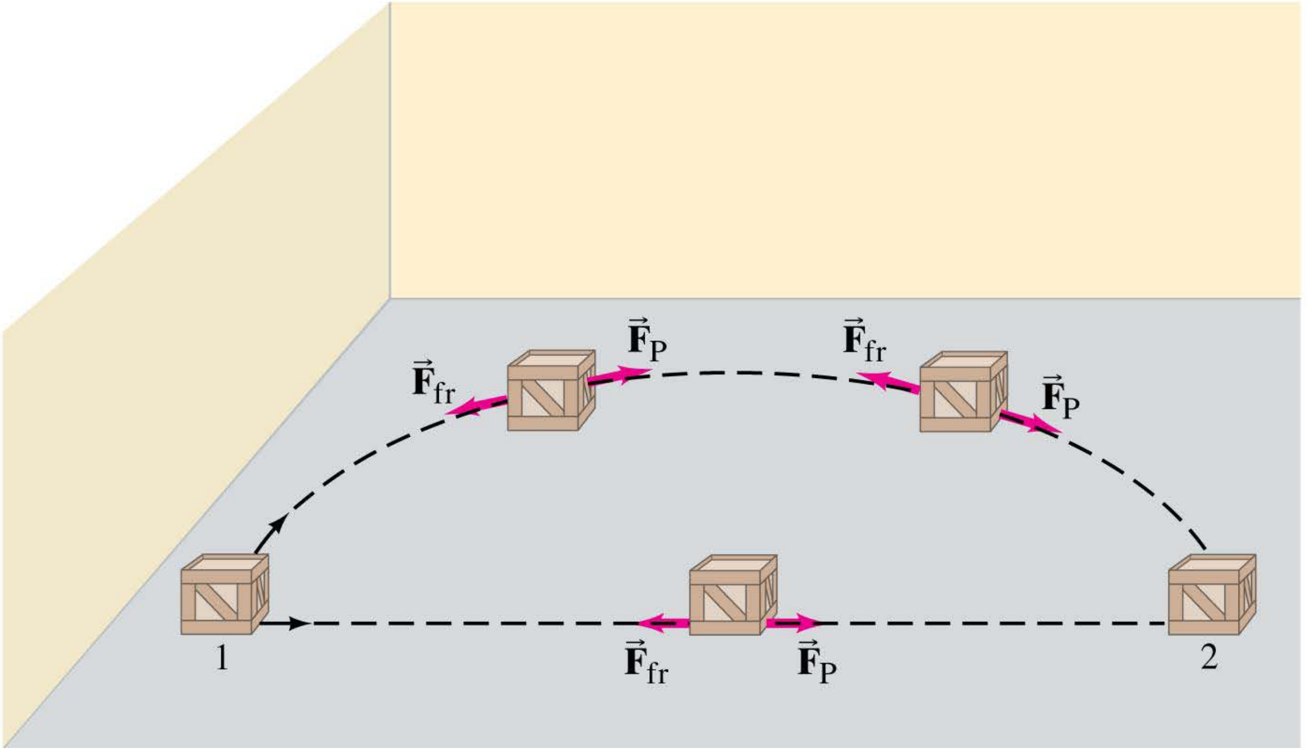
The force increases as the spring is stretched or compressed further. We find that the potential energy of the compressed or stretched spring, measured from its equilibrium position, can be written:

$$PE_{el} = \frac{1}{2}kx^2. \quad (6\text{-}9)$$



6-5 Conservative and Nonconservative Forces

If friction is present, the work done depends not only on the starting and ending points, but also on the path taken. Friction is called a nonconservative force.



6-5 Conservative and Nonconservative Forces

TABLE 6–1 Conservative and Nonconservative Forces

Conservative Forces	Nonconservative Forces
Gravitational	Friction
Elastic	Air resistance
Electric	Tension in cord
	Motor or rocket propulsion
	Push or pull by a person

Potential energy can only be defined for conservative forces.

6-5 Conservative and Nonconservative Forces

Therefore, we distinguish between the work done by conservative forces and the work done by nonconservative forces.

We find that the work done by nonconservative forces is equal to the total change in kinetic and potential energies:

$$W_{\mathrm{NC}} = \Delta\mathrm{KE} + \Delta\mathrm{PE} \qquad (6\text{-}10)$$

6-6 Mechanical Energy and Its Conservation

If there are no nonconservative forces, the sum of the changes in the kinetic energy and in the potential energy is zero—the kinetic and potential energy changes are equal but opposite in sign.

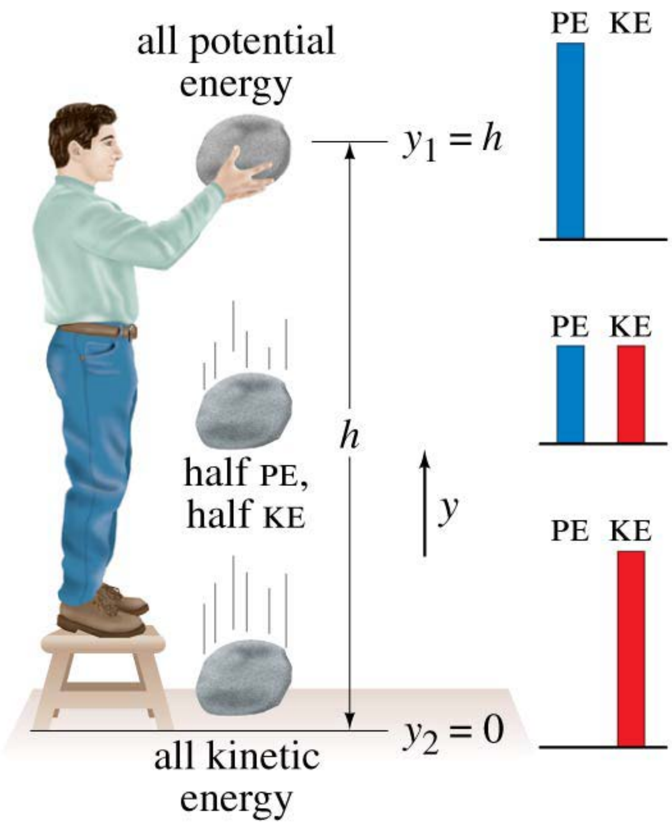
This allows us to define the total mechanical energy:

$$E = \text{KE} + \text{PE}$$

And its conservation:

$$\boxed{E_2 = E_1 = \text{constant.}} \qquad \text{(6-12b)}$$

6-7 Problem Solving Using Conservation of Mechanical Energy



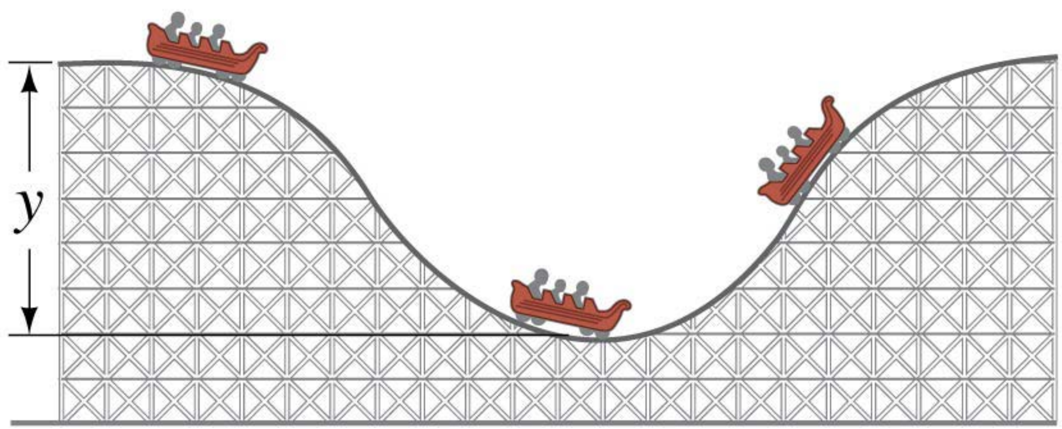
In the image on the left, the total mechanical energy is:

$$E = \mathrm{KE} + \mathrm{PE} = \tfrac{1}{2}\, mv^2 + mgy$$

The energy buckets on the right of the figure show how the energy moves from all potential to all kinetic.

6-7 Problem Solving Using Conservation of Mechanical Energy

If there is no friction, the speed of a roller coaster will depend only on its height compared to its starting height.



6-7 Problem Solving Using Conservation of Mechanical Energy

For an elastic force, conservation of energy tells us:

$$\tfrac{1}{2}mv_1^2 + \tfrac{1}{2}kx_1^2 = \tfrac{1}{2}mv_2^2 + \tfrac{1}{2}kx_2^2 \qquad (6\text{-}14)$$

6-8 Other Forms of Energy and Energy Transformations; the Law of Conservation of Energy

Some other forms of energy:

- Electric energy, nuclear energy, thermal energy, chemical energy.

Work is done when energy is transferred from one object to another.

Accounting for all forms of energy, we find that the total energy neither increases nor decreases. Energy as a whole is conserved.

6-9 Energy Conservation with Dissipative Processes; Solving Problems

If there is a nonconservative force such as friction, where do the kinetic and potential energies go?

They become heat; the actual temperature rise of the materials involved can be calculated.

6-9 Energy Conservation with Dissipative Processes; Solving Problems

Problem solving:

1. Draw a picture.
2. Determine the system for which energy will be conserved.
3. Figure out what you are looking for, and decide on the initial and final positions.
4. Choose a logical reference frame.
5. Apply conservation of energy.
6. Solve.

6-10 Power

Power is the rate at which work is done—

$$\overline{P} = \text{average power} = \frac{\text{work}}{\text{time}} = \frac{\text{energy transformed}}{\text{time}} \qquad (6\text{-}17)$$

In the SI system, the units of power are watts:

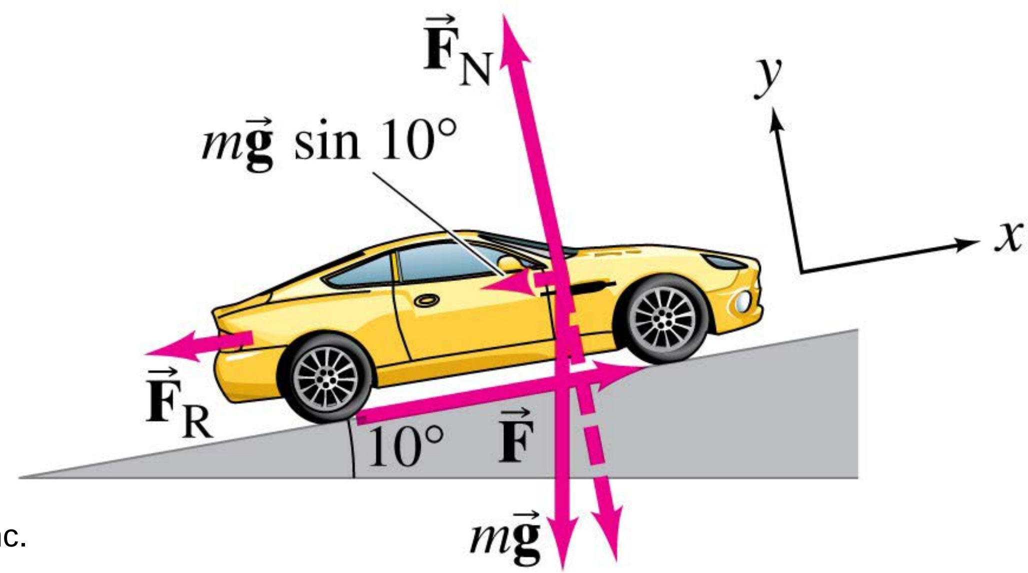
$$1\text{W} = 1 \text{ J/s}$$

The difference between walking and running up these stairs is power—the change in gravitational potential energy is the same.

6-10 Power

Power is also needed for acceleration and for moving against the force of gravity.

The average power can be written in terms of the force and the average velocity: $$\overline{P} = \frac{W}{t} = \frac{Fd}{t} = F\overline{v}. \qquad (6\text{-}18)$$



Summary of Chapter 6

- Work: $W = Fd \cos \theta$
- Kinetic energy is energy of motion: KE = ½ mv^2
- Potential energy is energy associated with forces that depend on the position or configuration of objects.
- The net work done on an object equals the change in its kinetic energy.
- If only conservative forces are acting, mechanical energy is conserved.
- Power is the rate at which work is done.