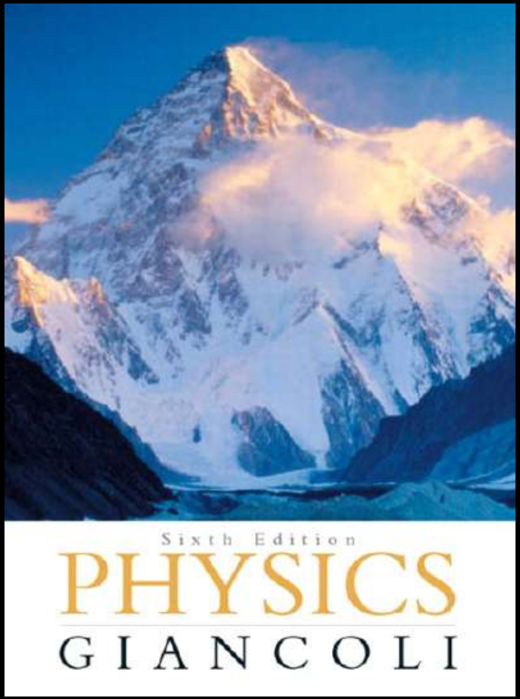


Lecture PowerPoints

Chapter 6

Physics: Principles with Applications, 6th edition

Giancoli

Chapter 6

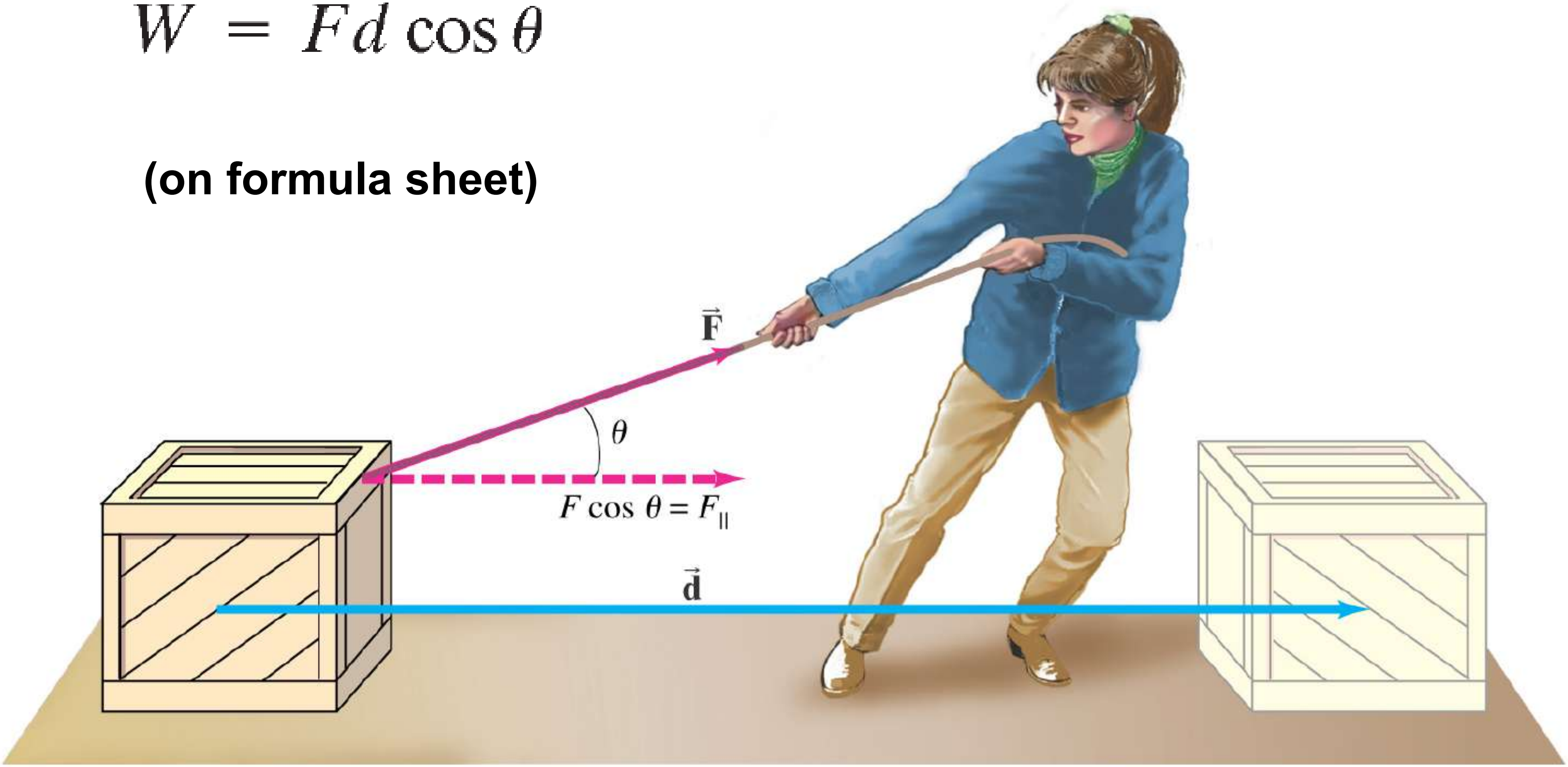
Work and Energy

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:

$$W = Fd\cos\theta$$

(on formula sheet)

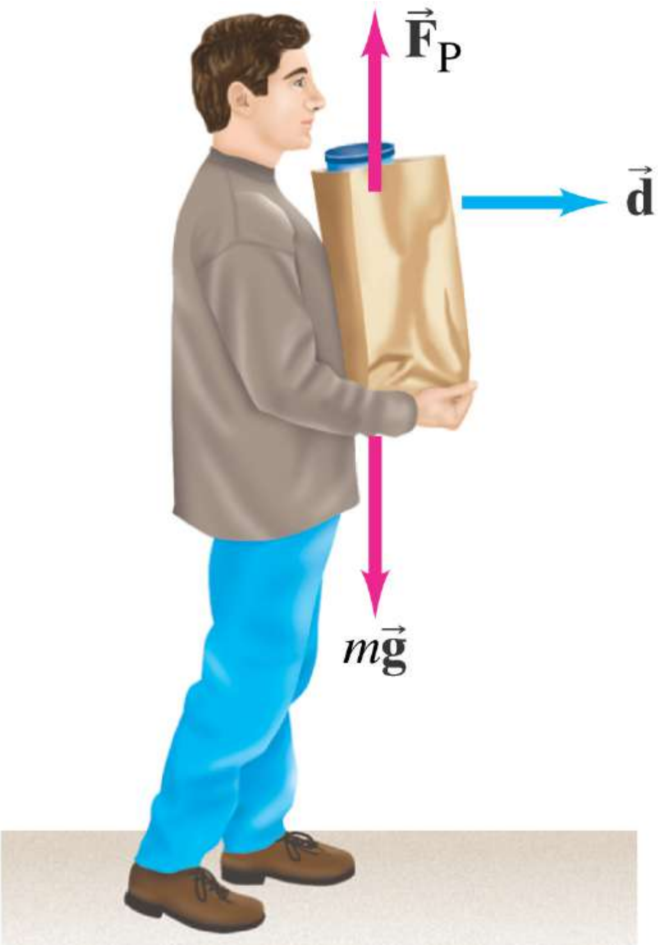


How much Work is done if you push against a wall?

6-1 Work Done by a Constant Force

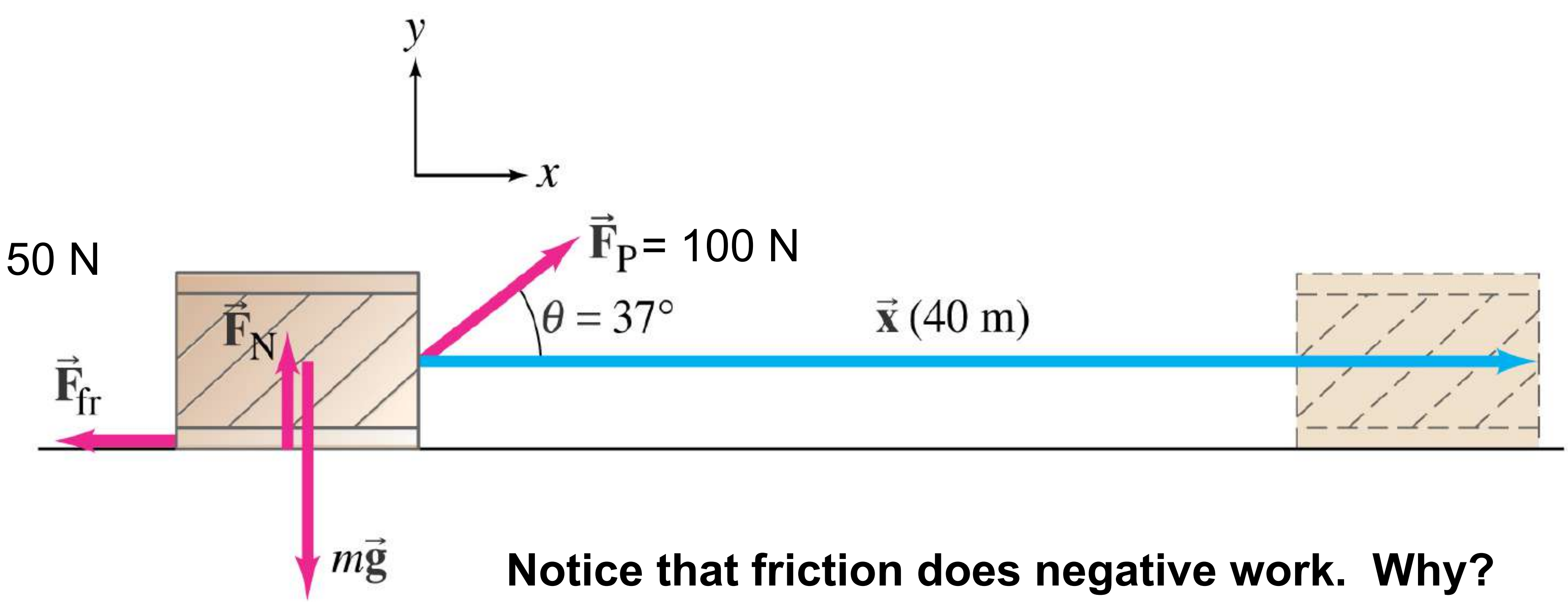
In the SI system, the units of work are **joules**:

$$1\,\text{J} = 1\,\text{N}\cdot\text{m}$$



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. What does work on the bag of groceries?

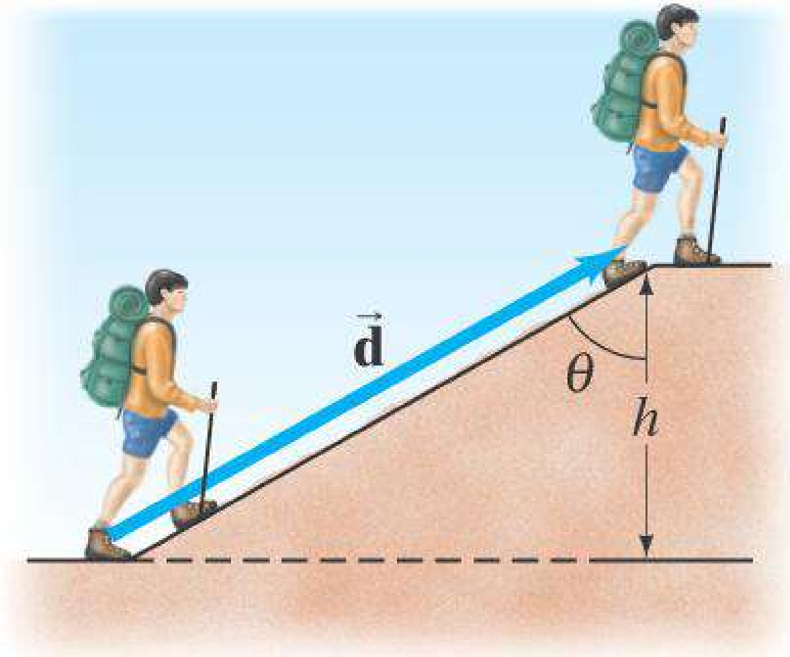
A 50-kg crate is pulled along a floor as shown below. Determine the work done by each force acting on the crate and the net work done on the crate.



Notice that friction does negative work. Why?

A box is dragged across the floor by an applied force which makes an angle with the horizontal. If the magnitude of the applied force is held constant but the angle is increased, the work done

- Remains the same
- Increases
- Decreases
- First increases, then decreases

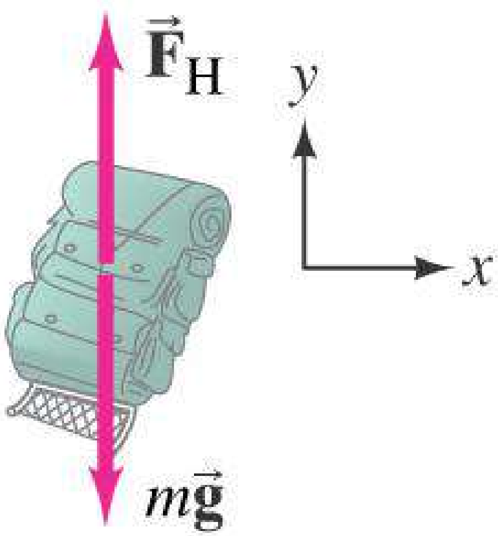


(a)

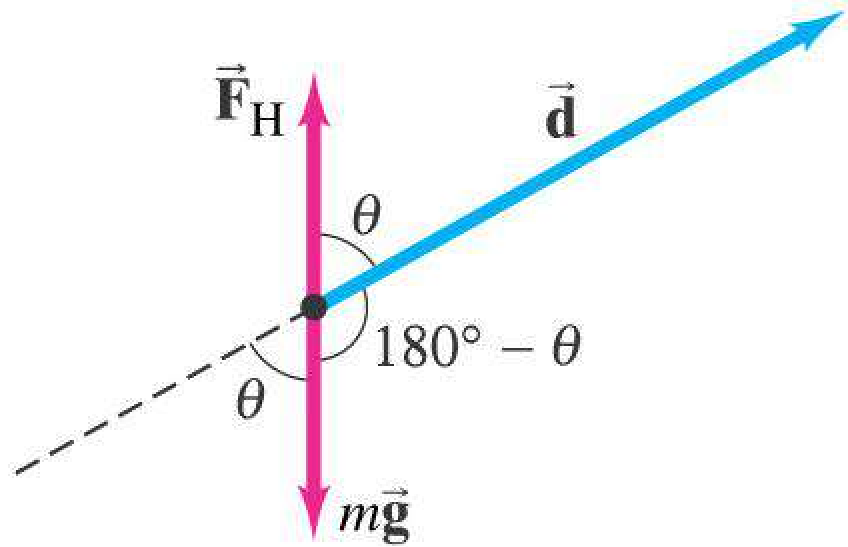
Determine the work the hiker does on the backpack, the work done by gravity on the backpack, and the net work done on the backpack. Does the angle of the incline matter?

Mass = 15.0 kg

h = 10.0 m



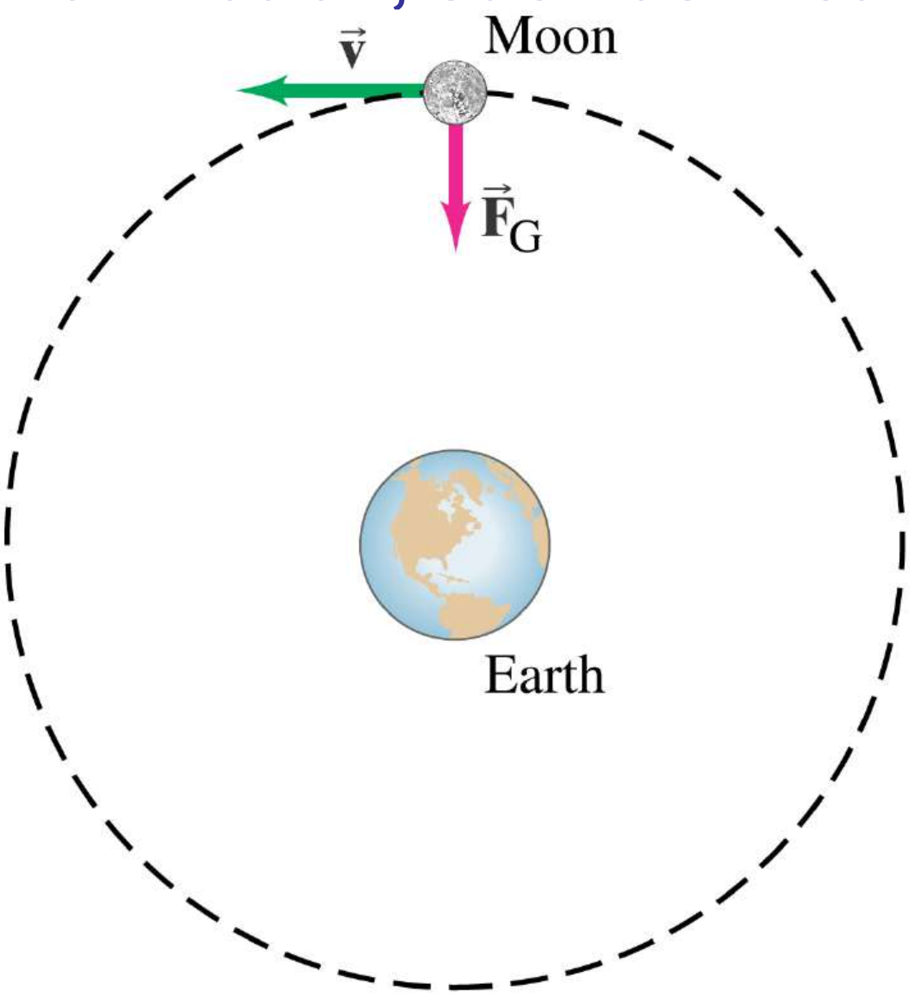
(b)



(c)

6-1 Work Done by a Constant Force

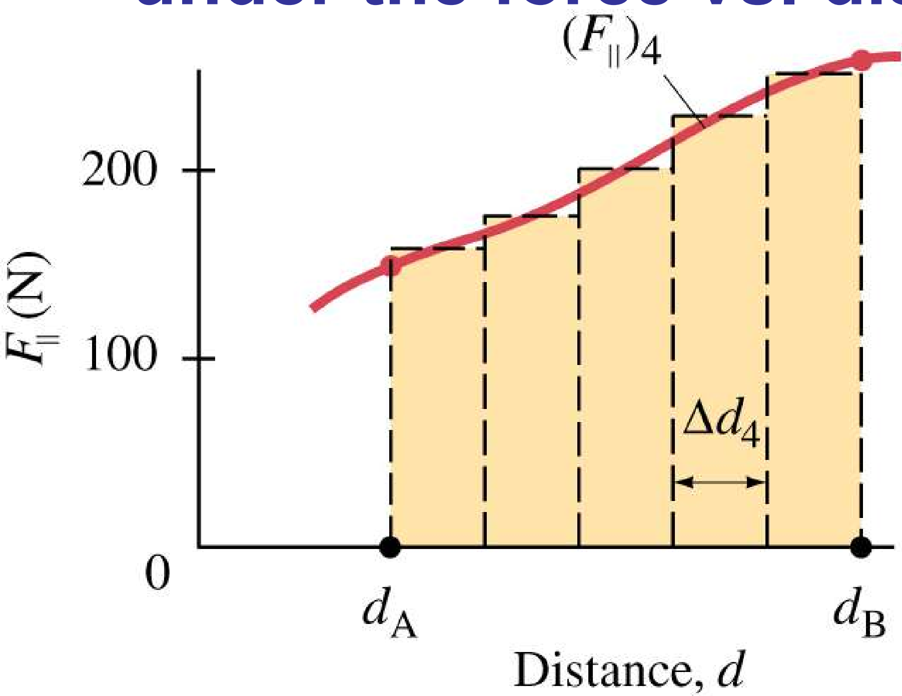
Work done by forces that **oppose** the direction of motion, such as friction, will be **negative**.

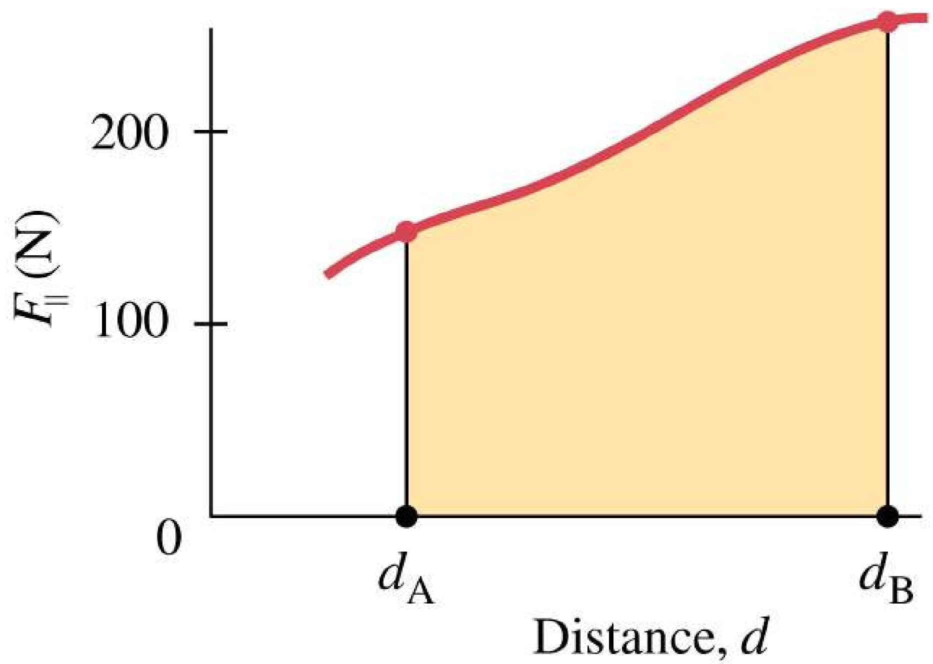


Centripetal forces do no work, as they are always **perpendicular** to the direction of motion. The Moon and artificial satellites can stay in orbit without burning fuel. However, eventually the satellite's orbit will deteriorate. Why?

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

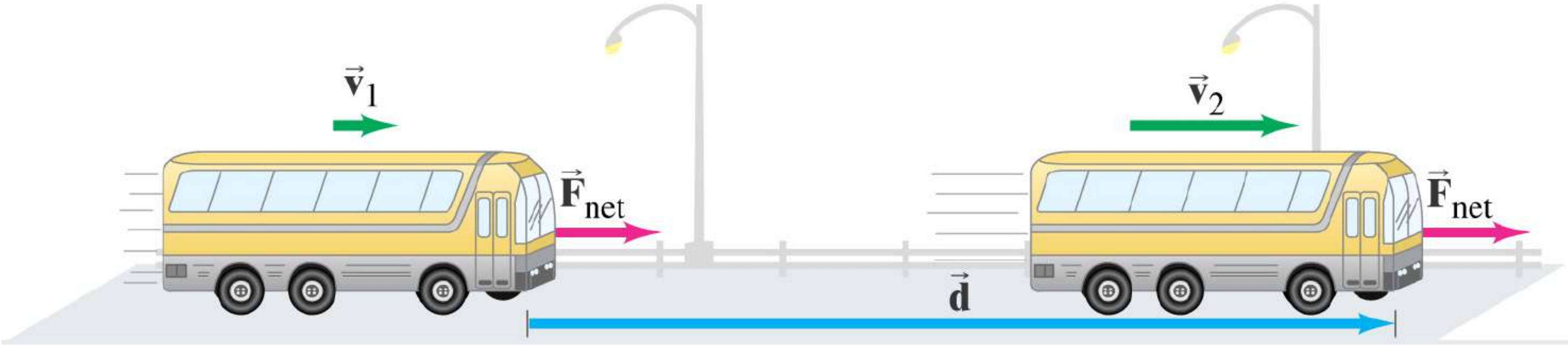
If we write the **acceleration** in terms of the **velocity** and the **distance**, we find that the work done here is

$$W_{net} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

We define the **kinetic energy:**

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

(on formula sheet)



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

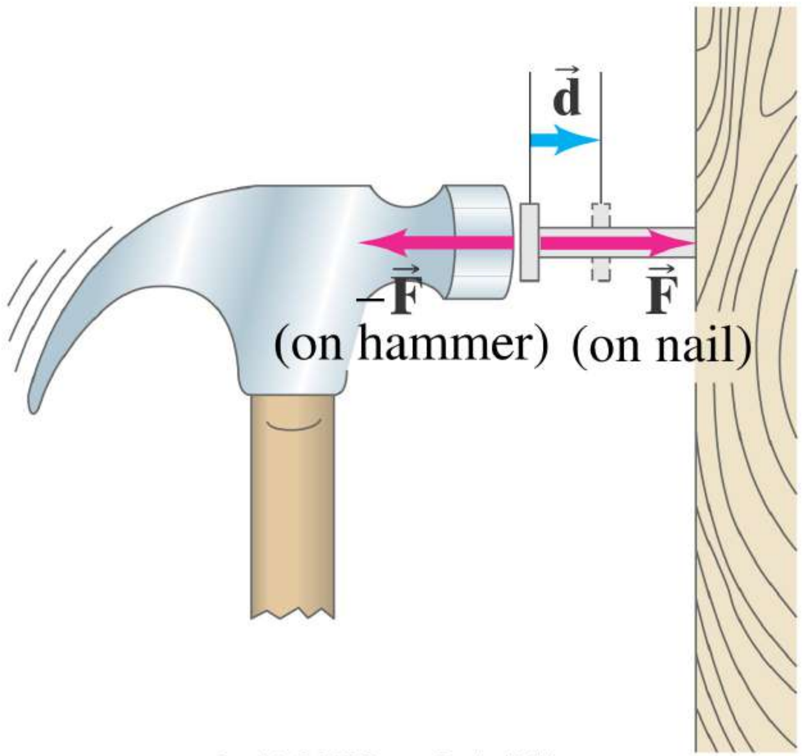
This means that the **work** done is equal to the **change** in the kinetic energy:

$$W_{net} = \Delta KE \qquad (6\text{-}4)$$

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

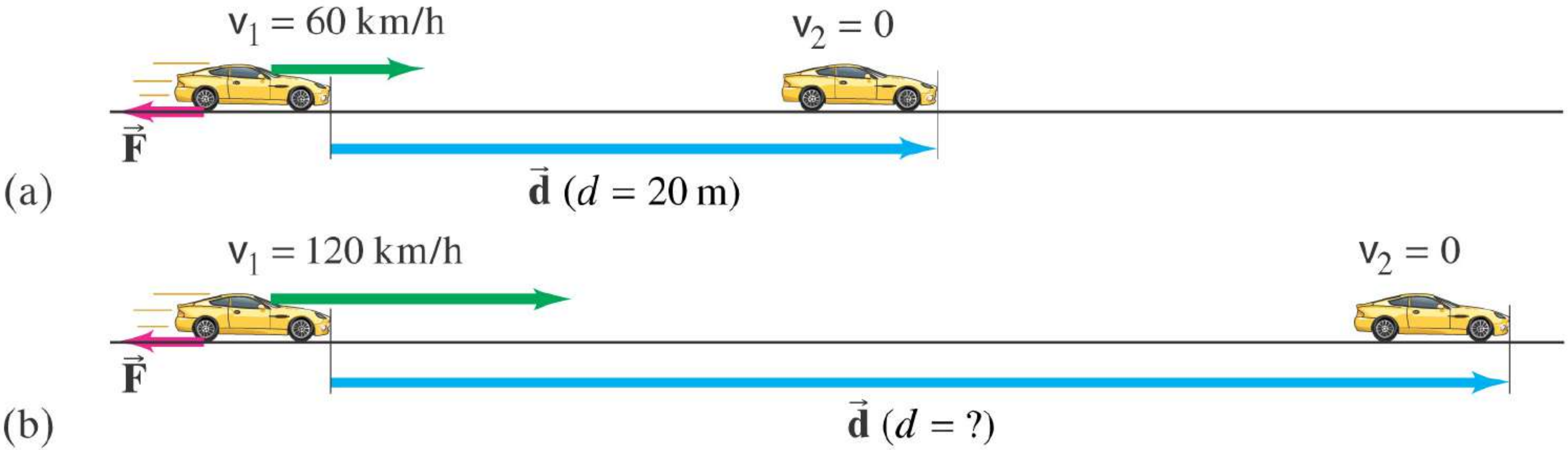
6-3 Kinetic Energy, and the Work-Energy Principle

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



How much net work is required to accelerate a 1000 kg car from 20 m/s to 30 m/s?

Can kinetic energy ever be negative?



If the car is going twice as fast, what is its stopping distance?

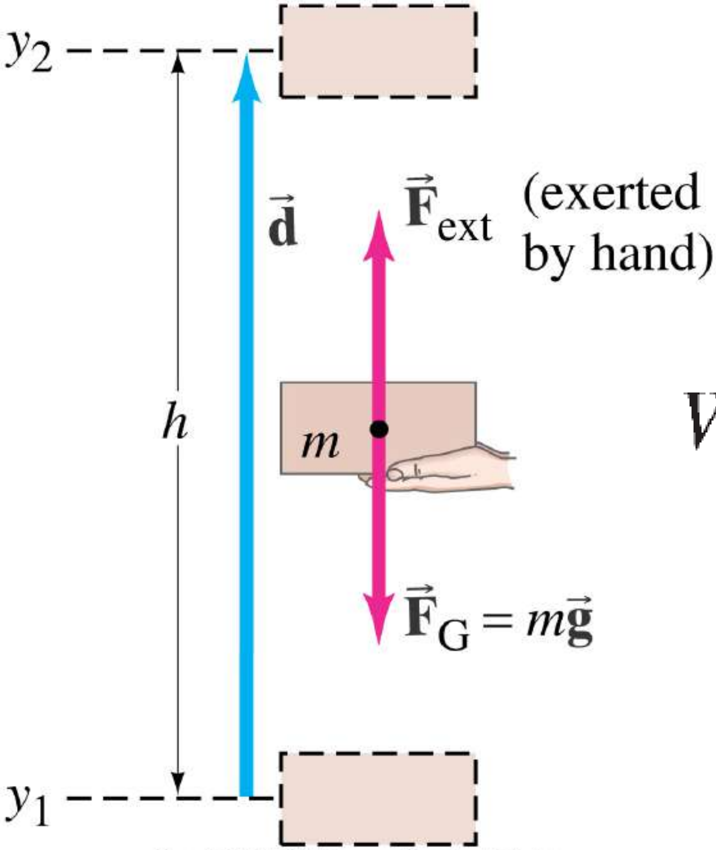
6-4 Potential Energy

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

$$W_{ext} = F_{ext}\, d \cos 0° = mgh$$
$$= mg(y_2 - y_1)$$

We therefore define the **gravitational** potential energy:

$$PE_{grav} = mgy$$

(on formula sheet but a little different)

6-4 Potential Energy

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

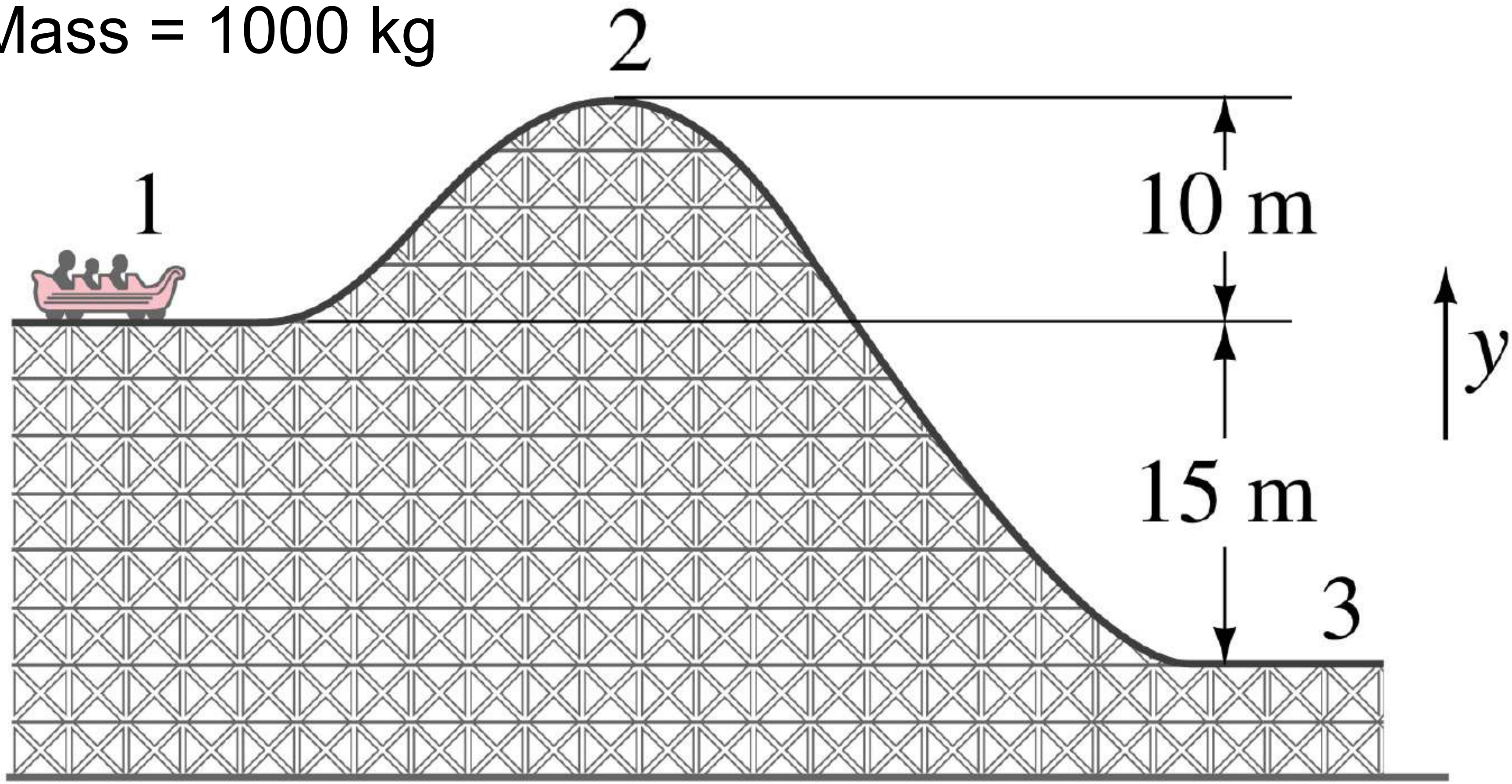
Potential energy is a property of a **system** as a whole, not just of the object (because it depends on external forces).

If $PE_{grav} = mgy$, 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.

What is the PE at 2 and 3 relative to 1 (assume 1 is at y=0)? What is the change in PE when the car goes from 2 to 3? How would your answers be different if 3 is at y=0?

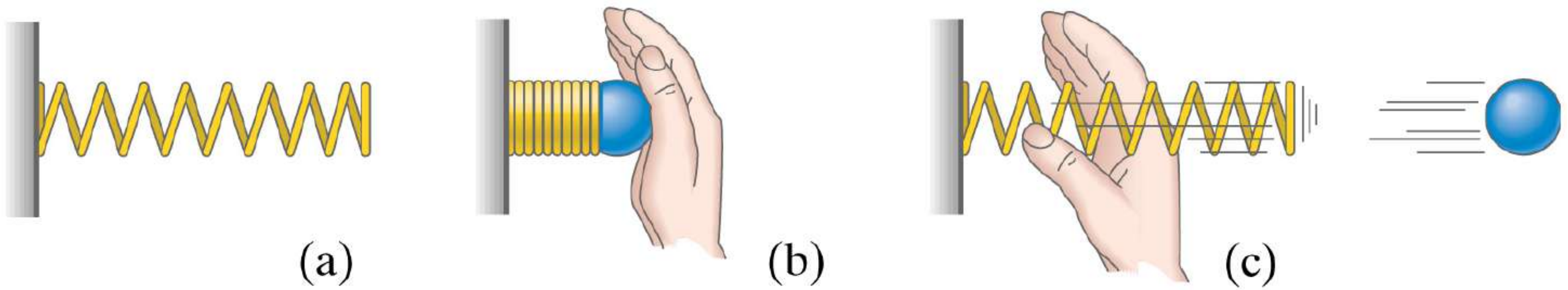
Mass = 1000 kg



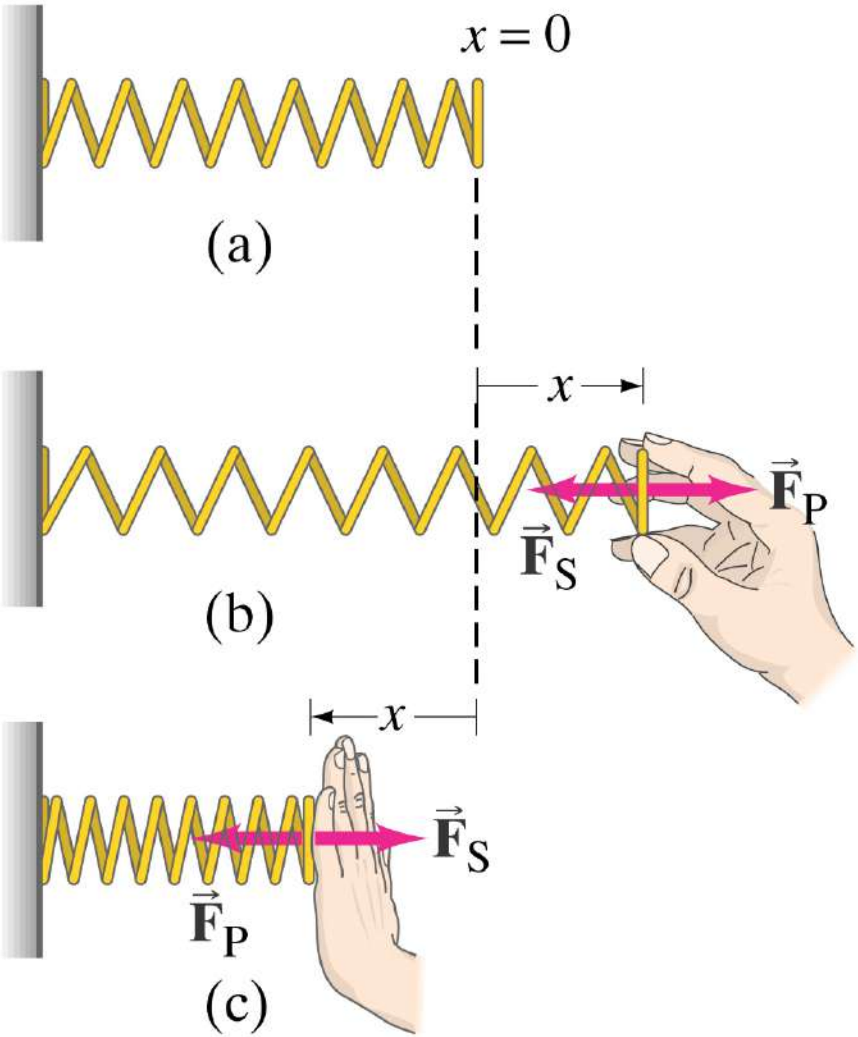
The change in the potential energy depends on the reference point.

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.



6-4 Potential Energy



The force required to **compress** or **stretch** a spring is:

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

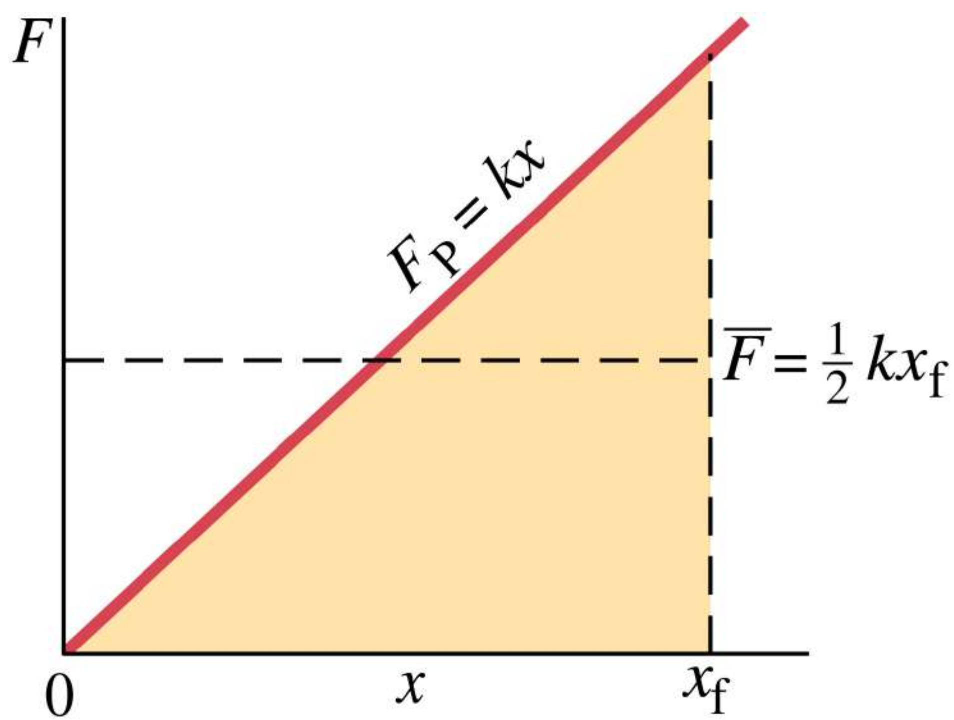
where *k* is called the **spring constant**, and needs to be measured for each spring.

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:

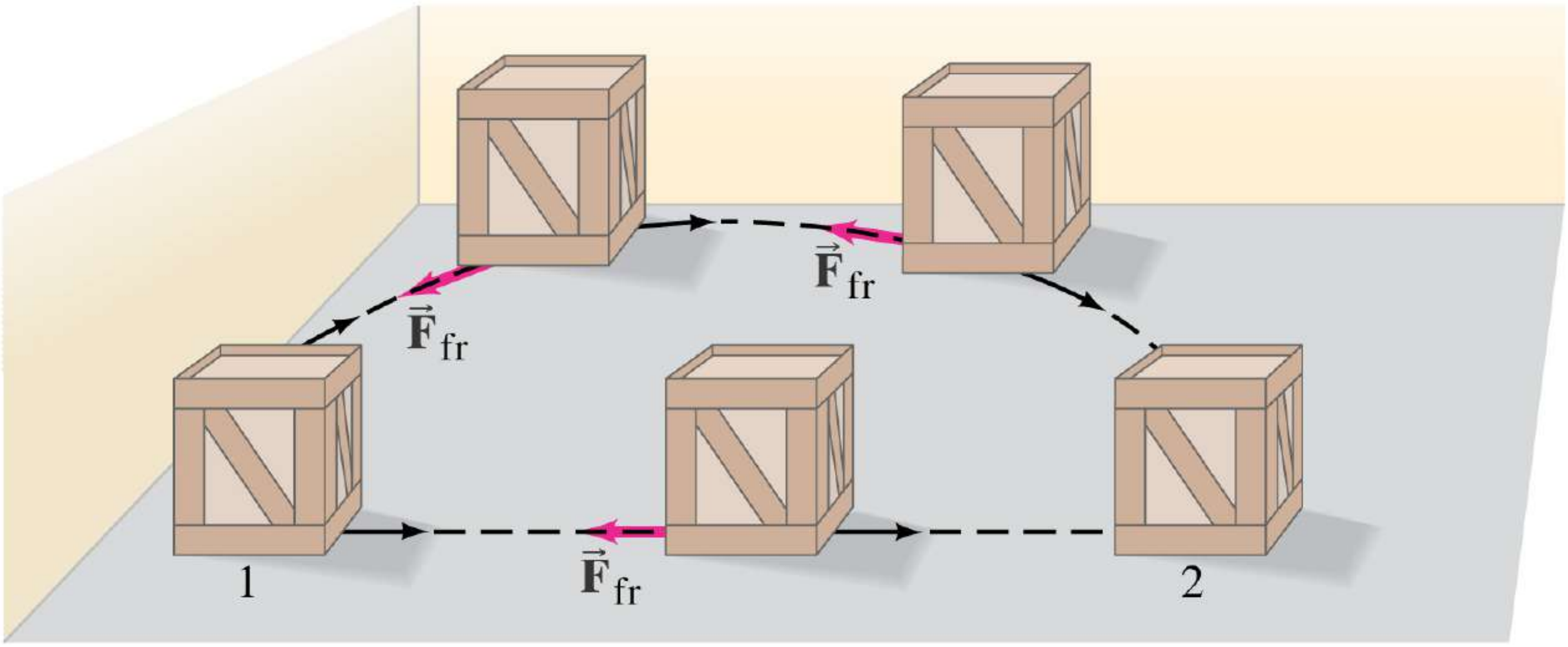
$$\text{elastic PE} = \frac{1}{2}kx^2$$

(on formula sheet)



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:

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

An object acted on by a constant force moves from point 1 to point 2 and back again. The work done by the force in this round trip is 60 J. Can you determine from this information if the force is conservative or nonconservative?

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.

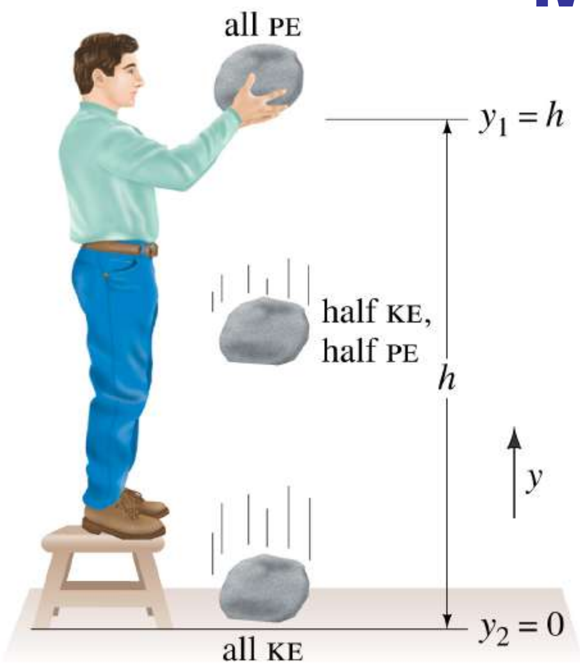
This allows us to define the **total mechanical energy**:

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

And its **conservation**:

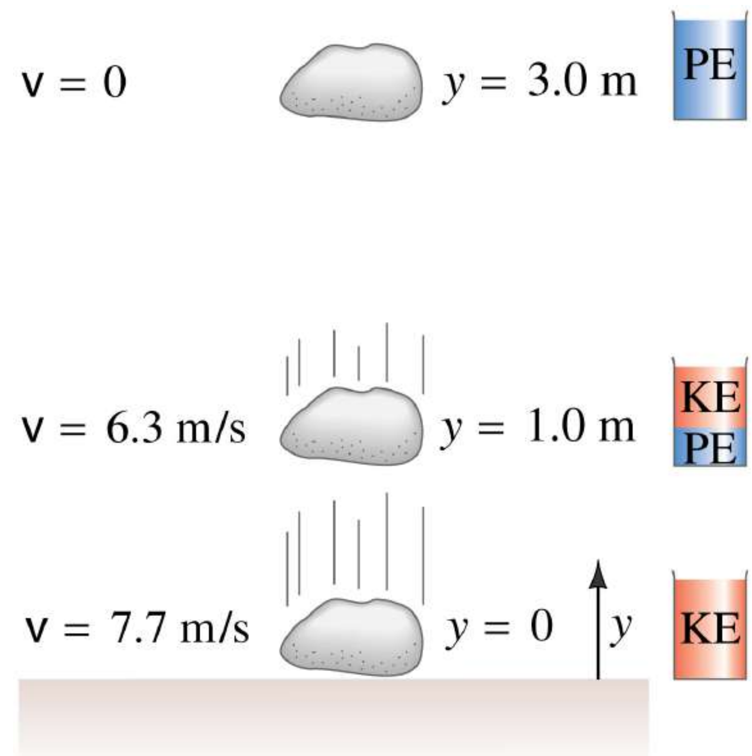
$$E_2 = E_1 = \text{constant} \qquad \text{(6-12b)}$$

6-7 Problem Solving Using Conservation of Mechanical Energy



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

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

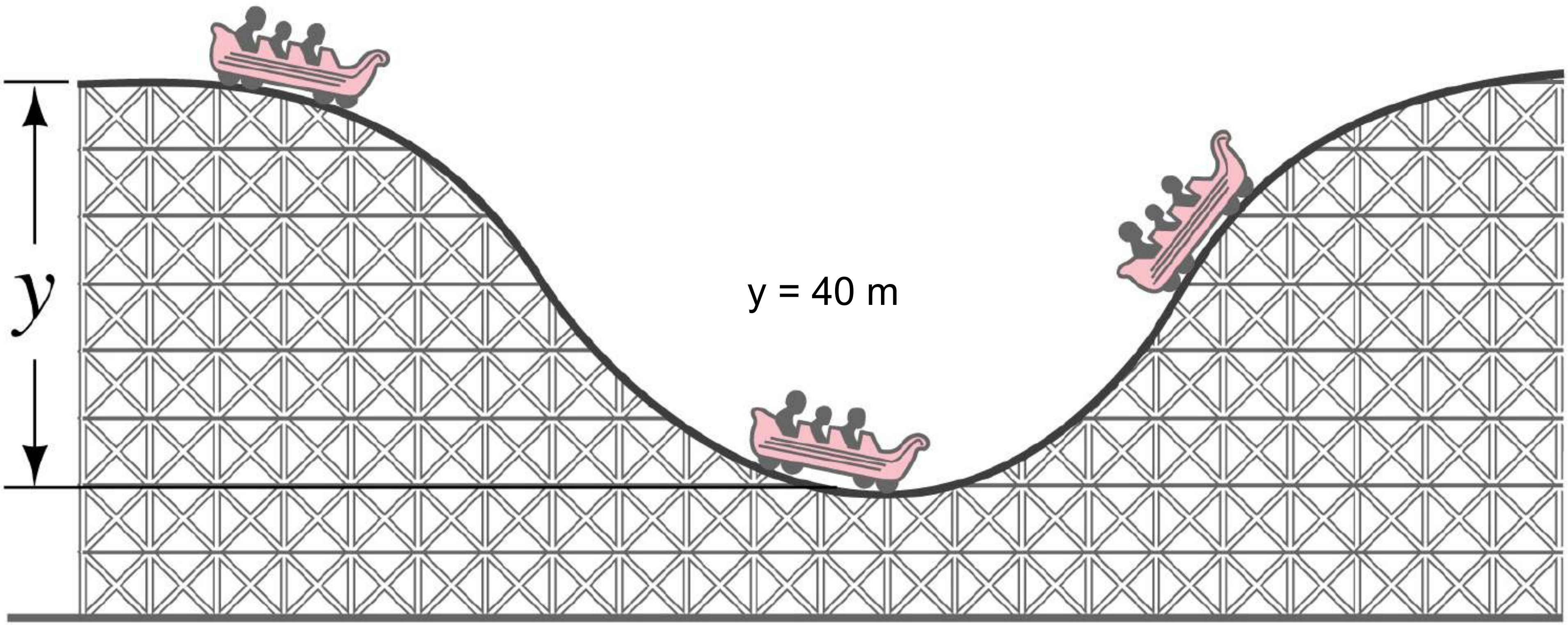


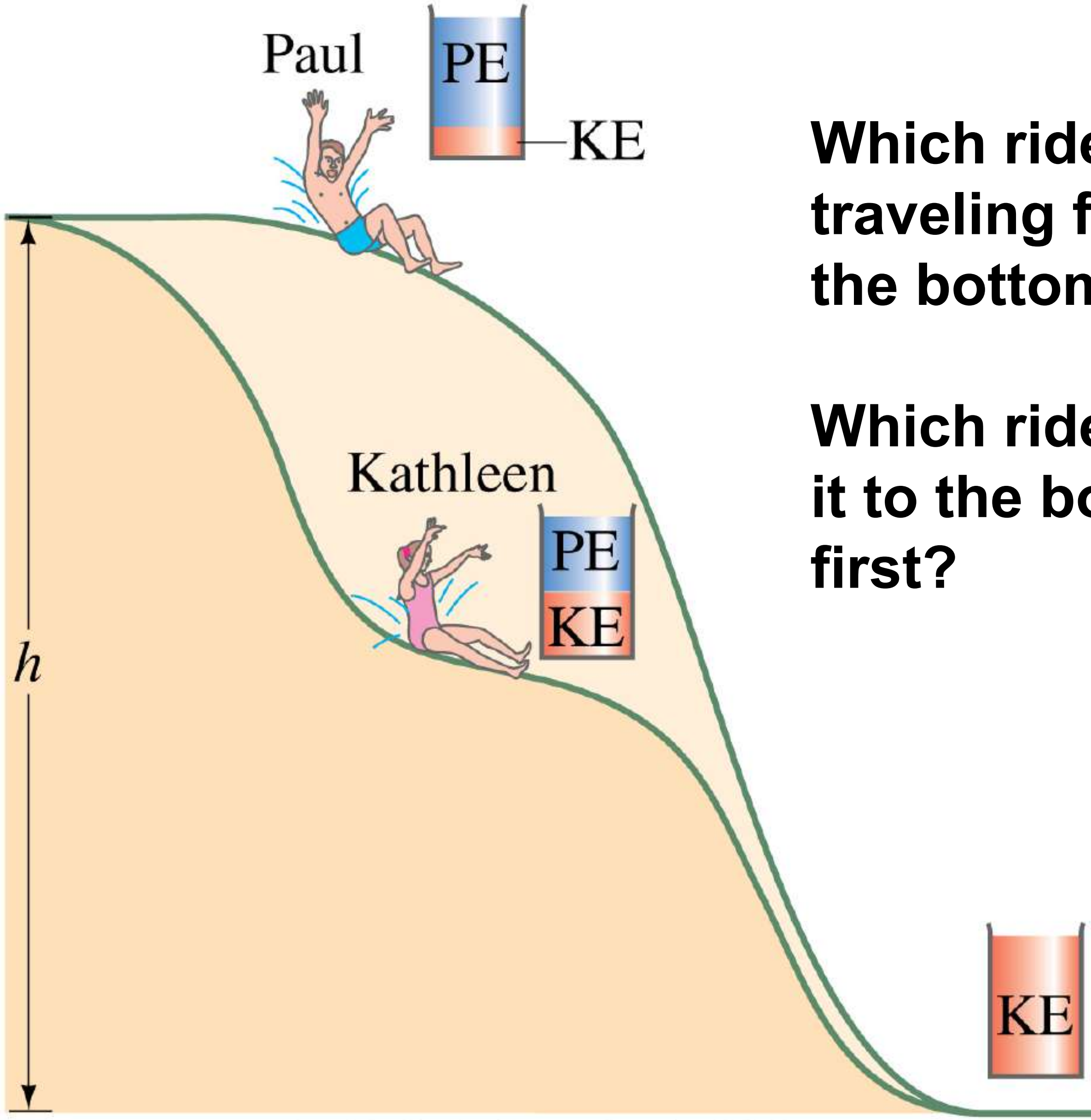
The **energy buckets** (right) show how the energy moves from all potential to all kinetic.

A rock falls from a height of 3.0 m. Calculate the rock's speed when it has fallen 2.0 m using conservation of energy.

A roller-coaster car moving without friction illustrates the conservation of mechanical energy.

What is the speed of the roller coaster at the bottom of the hill?
At what height will it have half this speed?





Which rider is traveling faster at the bottom?

Which rider makes it to the bottom first?

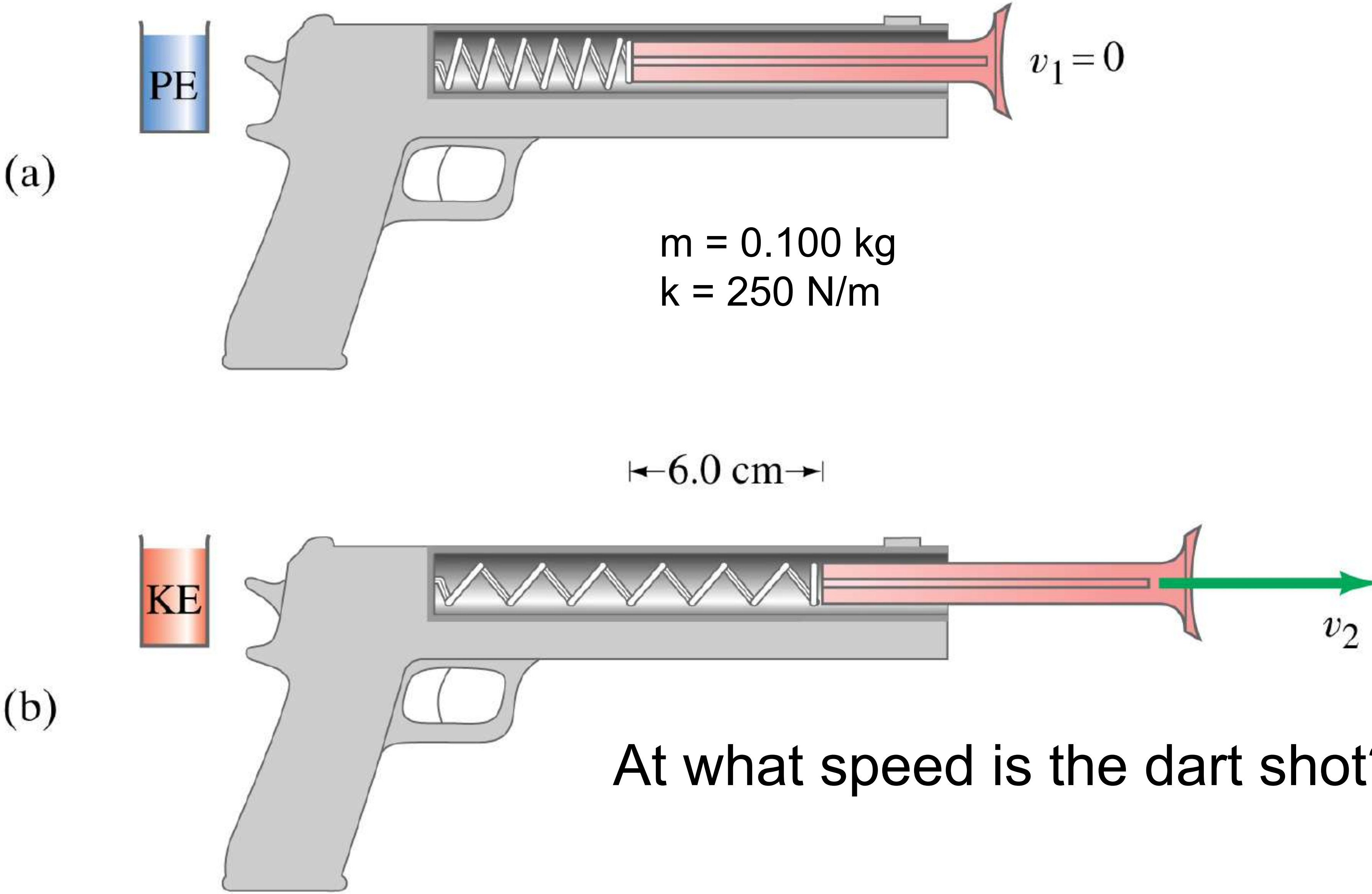
Two balls are released from the same height above the floor. Ball A falls freely through the air, whereas Ball B slides on a curved frictionless track to the floor. How do the speeds of the balls compare when they reach the floor? How do the times of fall compare?

6-7 Problem Solving Using Conservation of Mechanical Energy

For an **elastic force**, conservation of energy tells us:

$$\frac{1}{2}mv_1^2 + \frac{1}{2}kx_1^2 = \frac{1}{2}mv_2^2 + \frac{1}{2}kx_2^2 \quad \textbf{(6-14)}$$

Dart Gun Problem



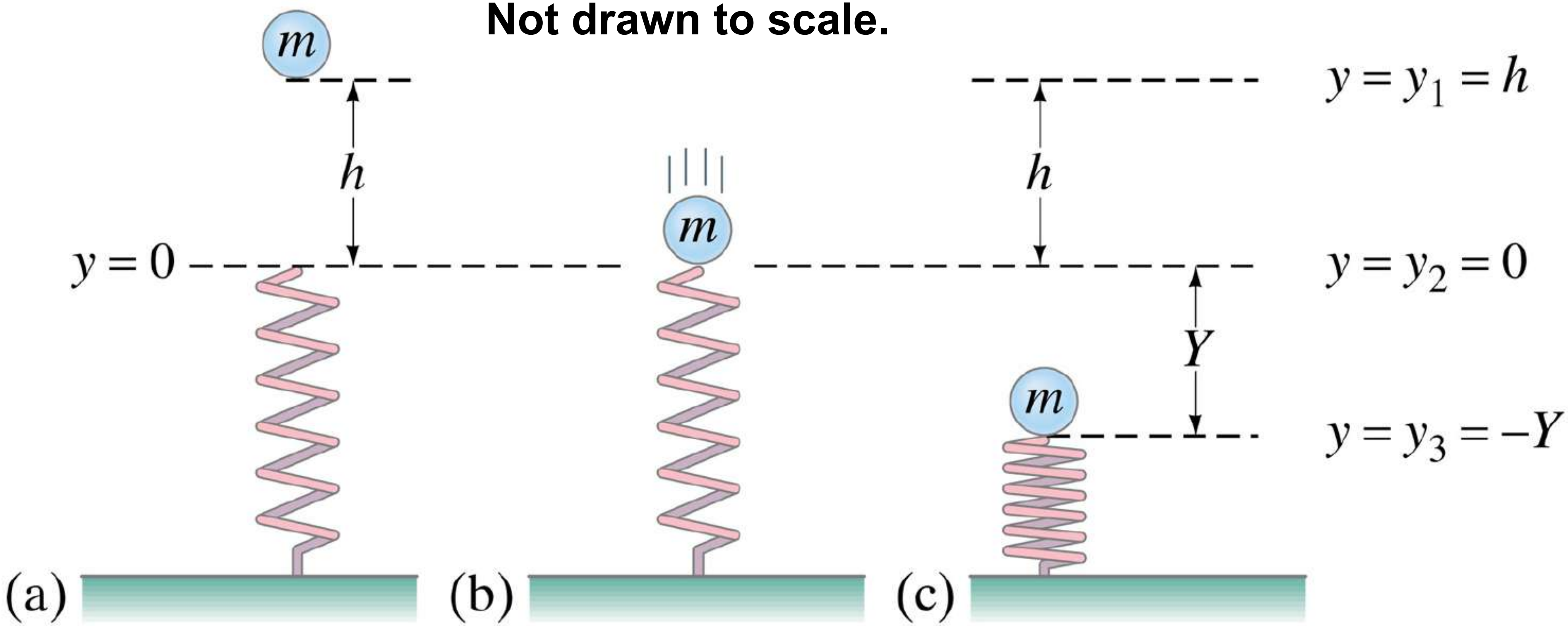
m = 0.100 kg
k = 250 N/m

At what speed is the dart shot?

Gravitational and Elastic Potential Energy

m = 2.60 kg h = 55.0 cm Y = 15.0 cm

Not drawn to scale.



Determine the spring constant.

6-8 Other Forms of Energy; Energy Transformations and the 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**.

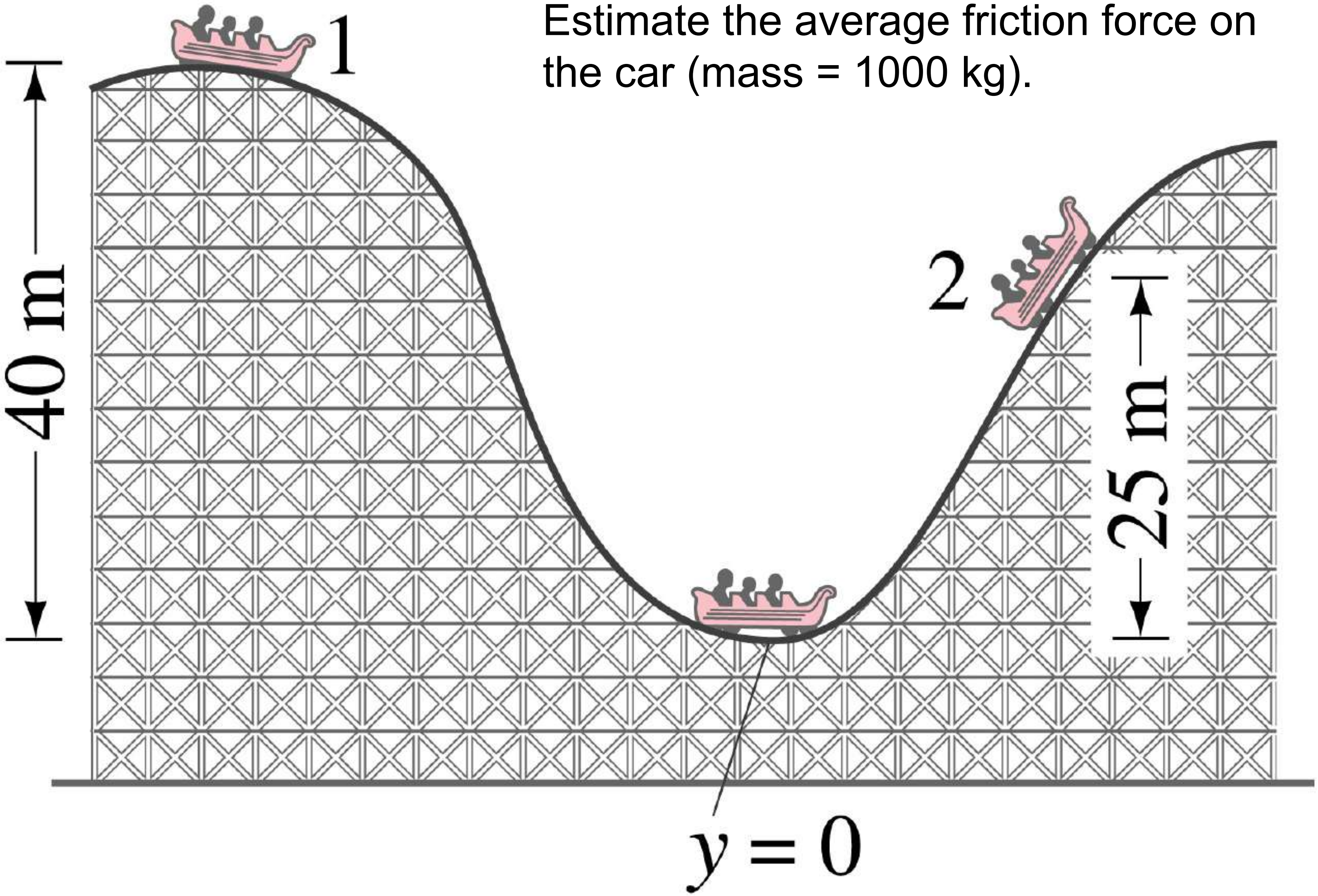
6-9 Energy Conservation with Dissipative Processes; Solving Problems

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.

Because of friction, a roller coaster car does not reach the original height on the second hill.

Estimate the average friction force on the car (mass = 1000 kg).



6-10 Power

Power is the **rate** at which **work** is done –

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

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. (One horsepower = 746 Watts)

A 60. kg person runs up a long flight of stairs in 4.0 s. The vertical height of the stairs is 4.5 m. How much power does the person generate (in watts and horsepower)? How much energy did this require?

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**:

$$\overline{P} = \frac{W}{t} = \frac{Fd}{t} = F\overline{v} \qquad (6\text{-}17)$$

Calculate the power required of a 1400 kg car under the following circumstances:

a) the car climbs a 10° hill at a steady 80 km/h

b) the car accelerates along a level road from 90 to 110 km/h in 6.0 s to pass another car.

(Assume the total of all of the friction forces is 700 N)