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**GET READY:** Go here and make sure you see the “Are you Ready” Sli.do Q  
Canvas -> Course Content -> Lecture (under Week 9 - Chapter 8)

# Physics 111 - Lecture 10

November 17, 2020

Do not draw in/on this box!

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## Reminders/Announcements

- Test 4 (Chapters 8 and 9) ends today at 9 PM

# Reminders/Announcements

## Homework (due Thurs 6 pm)

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

Week 7

Week 8

Week 9

Week 10

Week 11

Week 12

Week 13

## Test/Bonus Test (Thurs 6pm - Sat 6pm)

Test 0 **(not for marks)**

Test 1 (on Chapters 2 & 3)

Bonus Test 1

Test 2 (on Chapters 4 and 5)

N/A

Bonus Test 2

Test 3

Bonus Test 3

Test 4 (window moved to Sun Nov 15  
- Tues Nov 17 due to Fall mini-break)

Bonus Test 4

Test 5

Bonus Test 5

## Learning Log (Sat 6pm)

Learning Log 1

Learning Log 2

Learning Log 3

Learning Log 4

N/A

Learning Log 5

Learning Log 6

Learning Log 7

No Learning Log

Learning Log 8

Learning Log 9

Learning Log 10

# Chapter 9

# Important Concepts

# Why is energy important?

Energy is one of the most important concepts in science, engineering, and society. Some would say it is *the* most important. All life depends on energy, transformed from solar energy to chemical energy to us. Society depends on energy, from industry and transportation to heating and cooling our buildings. Using energy wisely and efficiently is a key concern of the 21st century.

# Energy Overview

- Everyone has some sense of what *energy* means.
  - Moving objects have energy.
  - Energy is the ability to make things happen.
  - Energy is associated with heat and with electricity.
  - We're constantly told to conserve energy.
  - Living organisms need energy.
  - Engineers harness energy to do useful things.
- Some scientists consider the *law of conservation of energy* to be the most important of all the laws of nature.

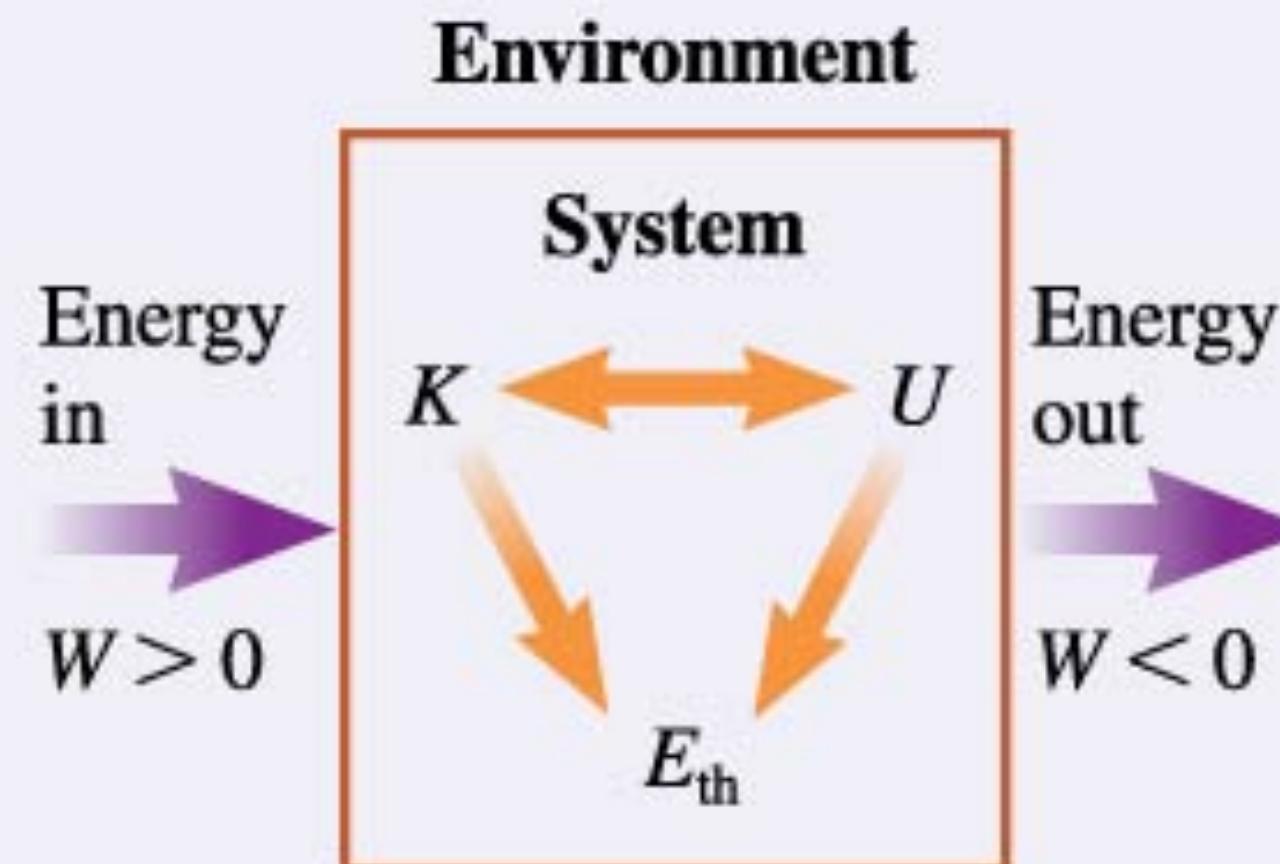
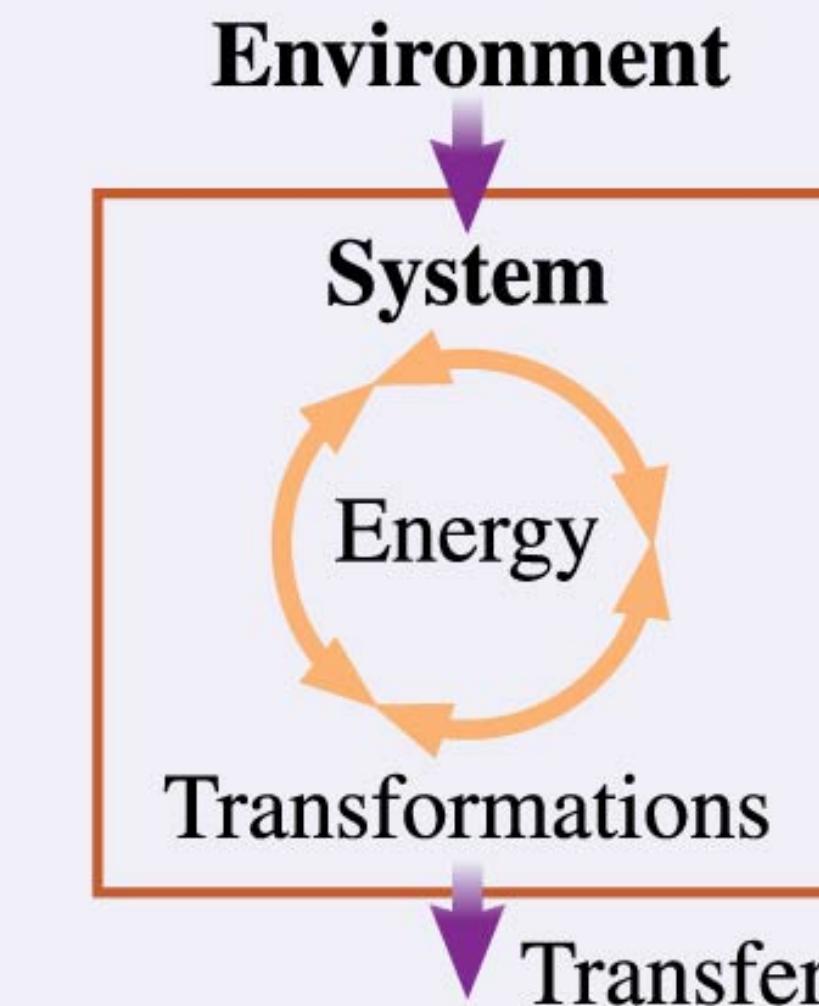
# How should we think about energy?

Chapters 9 and 10 will develop the **basic energy model**, a powerful set of ideas for using energy. A key distinction is between the **system**, which has energy, and the **environment**. Energy can be **transferred** between the system and the environment or **transformed** within the system.

« LOOKING BACK Section 7.1 Interacting objects

## Basic Energy Model

- Energy is a property of the system.
- Energy is *transformed* within the system without loss.
- Energy is *transferred* to and from the system by forces that do work  $W$ .
- $W > 0$  for energy added.
- $W < 0$  for energy removed.



# What are some important forms of energy?

Three important forms of energy:

- **Potential energy** is energy associated with an object's *position*.
- **Kinetic energy** is energy associated with an object's *motion*.
- **Thermal energy** is the energy of the random motion of *atoms* within an object.

Energy is measured in **joules**.

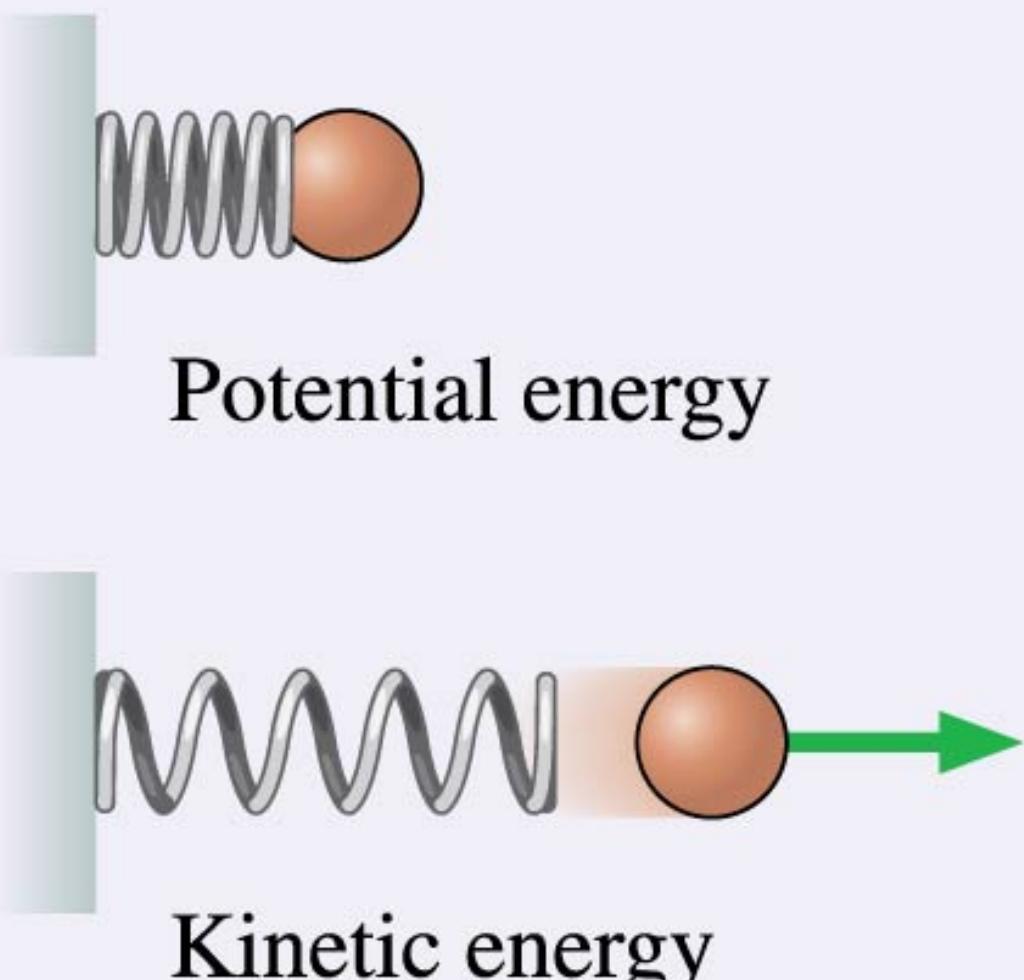
**Kinetic energy** is an energy of motion:  $K = \frac{1}{2}mv^2$

**Potential energy** is stored energy.

**Thermal energy** is the microscopic energy of moving atoms and stretched bonds.

**Dissipative forces**, such as friction and drag, transform **macroscopic** energy into thermal energy. For friction:

$$\Delta E_{\text{th}} = f_k \Delta s$$



# Kinetic Energy $K$

- Kinetic energy is the energy of motion.
- All moving objects have kinetic energy.
- The more massive an object or the faster it moves, the larger its kinetic energy.



# Potential Energy $U$

- Potential energy is stored energy associated with an object's position.
- The roller coaster's gravitational potential energy depends on its height above the ground.



# Thermal Energy $E_{\text{th}}$

- Thermal energy is the sum of the microscopic kinetic and potential energies of all the atoms and bonds that make up the object.
- An object has more thermal energy when hot than when cold.

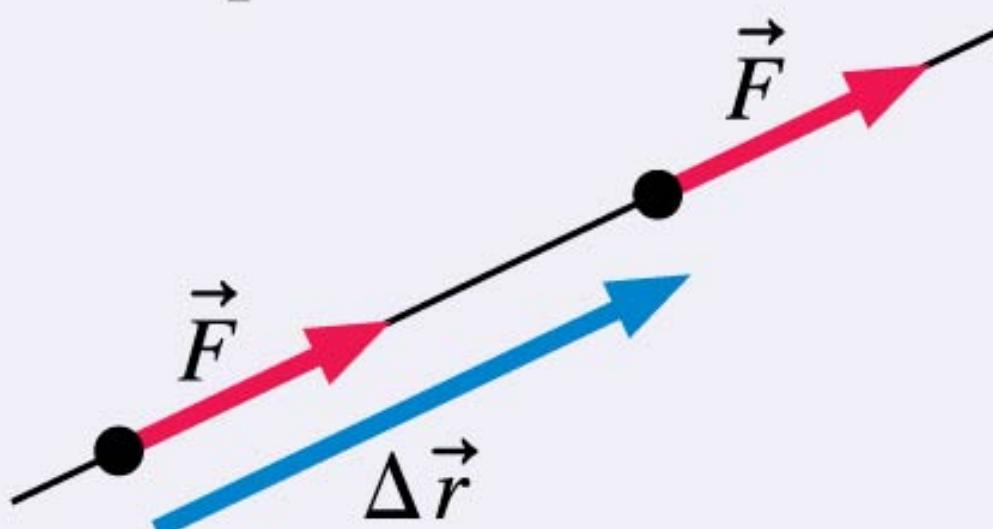


## What is work?

A process that **changes the energy of a system by mechanical means**—pushing or pulling on it—is called **work**.

Work  $W$  is done when a force pushes or pulls a particle through a displacement, thus changing the particle's kinetic energy.

Force does work on the particle



The **work** done by a force on a particle as it moves from  $s_i$  to  $s_f$  is

$$W = \int_{s_i}^{s_f} F_s ds = \text{area under the force curve}$$

The work done by a constant force is

$$W = \vec{F} \cdot \Delta \vec{r}$$

The work done by a spring is

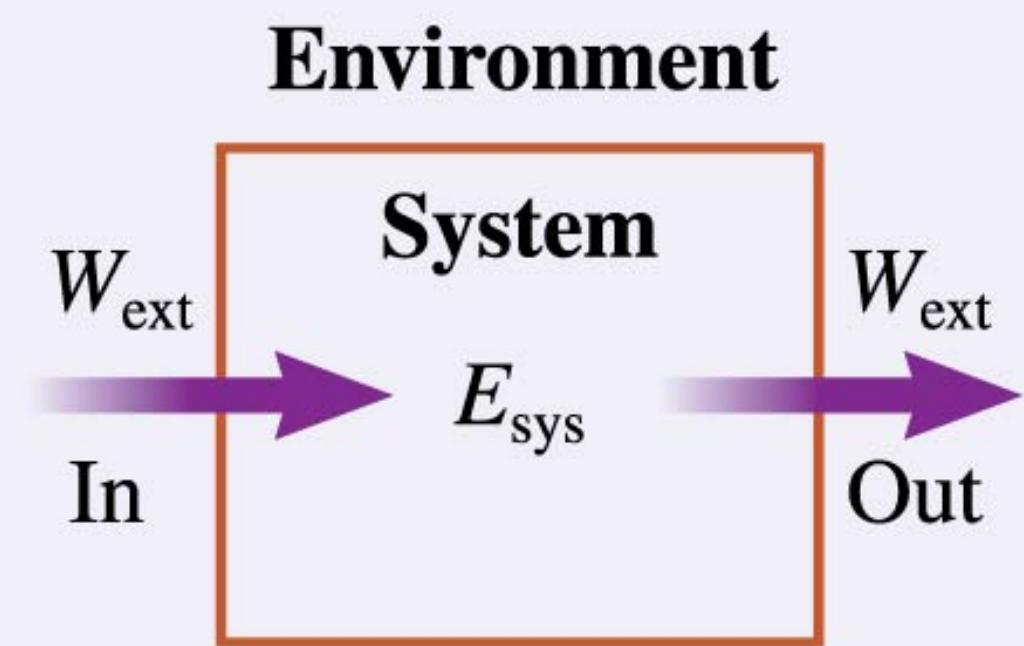
$$W = -\left(\frac{1}{2}k(\Delta s_f)^2 - \frac{1}{2}k(\Delta s_i)^2\right)$$

where  $\Delta s$  is the displacement of the end of the spring.

# What laws govern energy?

Working with energy is very much like accounting: A system's energy  $E$  changes by the amount of work done on the system. The mathematical statement of this idea is called the **energy principle**:

$$\Delta E_{\text{sys}} = W_{\text{ext}}$$



## The Energy Principle

Doing work on a system changes the **system energy**:

$$\Delta E_{\text{sys}} = W_{\text{ext}}$$

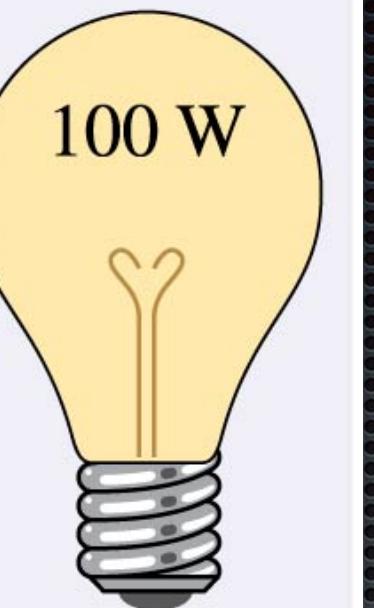
For systems containing only particles, no interactions,  $E_{\text{sys}} = K + E_{\text{th}}$ . All forces are external forces, so

$$\Delta K + \Delta E_{\text{th}} = W_{\text{tot}}$$

where  $W_{\text{tot}}$  is the total work done on all particles.

# What is power?

Power is the rate at which energy is transferred or transformed. For machines, power is the rate at which they do work. For electricity, power is the rate at which electric energy is transformed into heat, sound, or light. Power is measured in watts, where 1 watt is a rate of 1 joule per second.



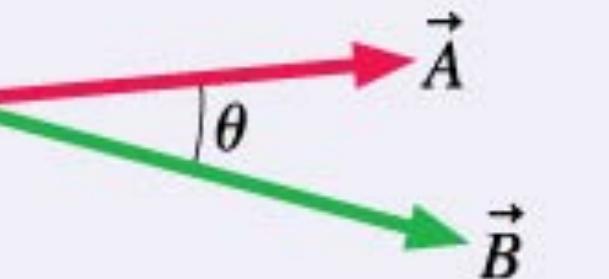
**Power** is the rate at which energy is transferred or transformed:

$$P = dE_{\text{sys}}/dt$$

For a particle with velocity  $\vec{v}$ , the power delivered to the particle by force  $\vec{F}$  is  $P = \vec{F} \cdot \vec{v} = Fv \cos \theta$ .

## Dot product

$$\vec{A} \cdot \vec{B} = AB \cos \theta = A_x B_x + A_y B_y$$

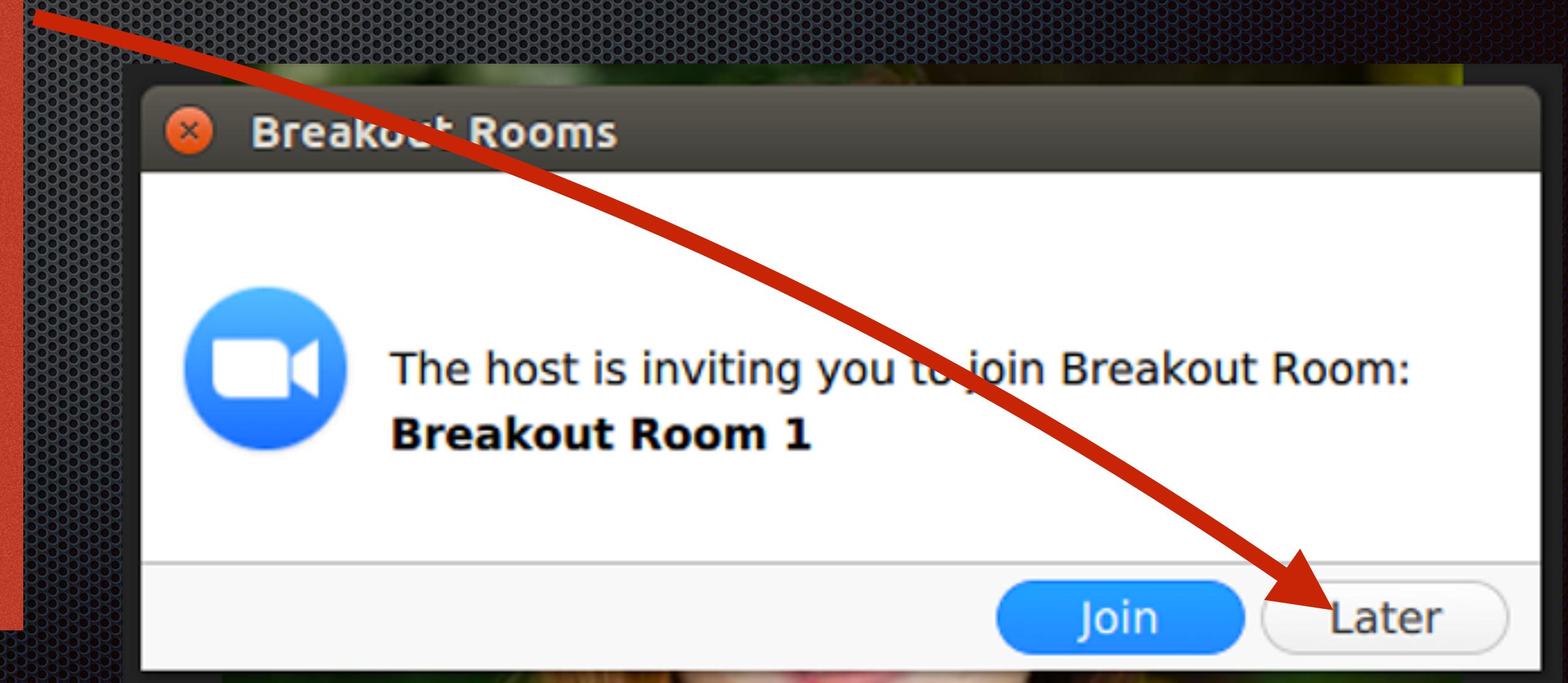


# Chapter 9

## Clicker Questions

Let's try this: If we do breakout rooms, and you do not want to participate with your peers, that's fine!

Stay in the main room and don't join the room!!

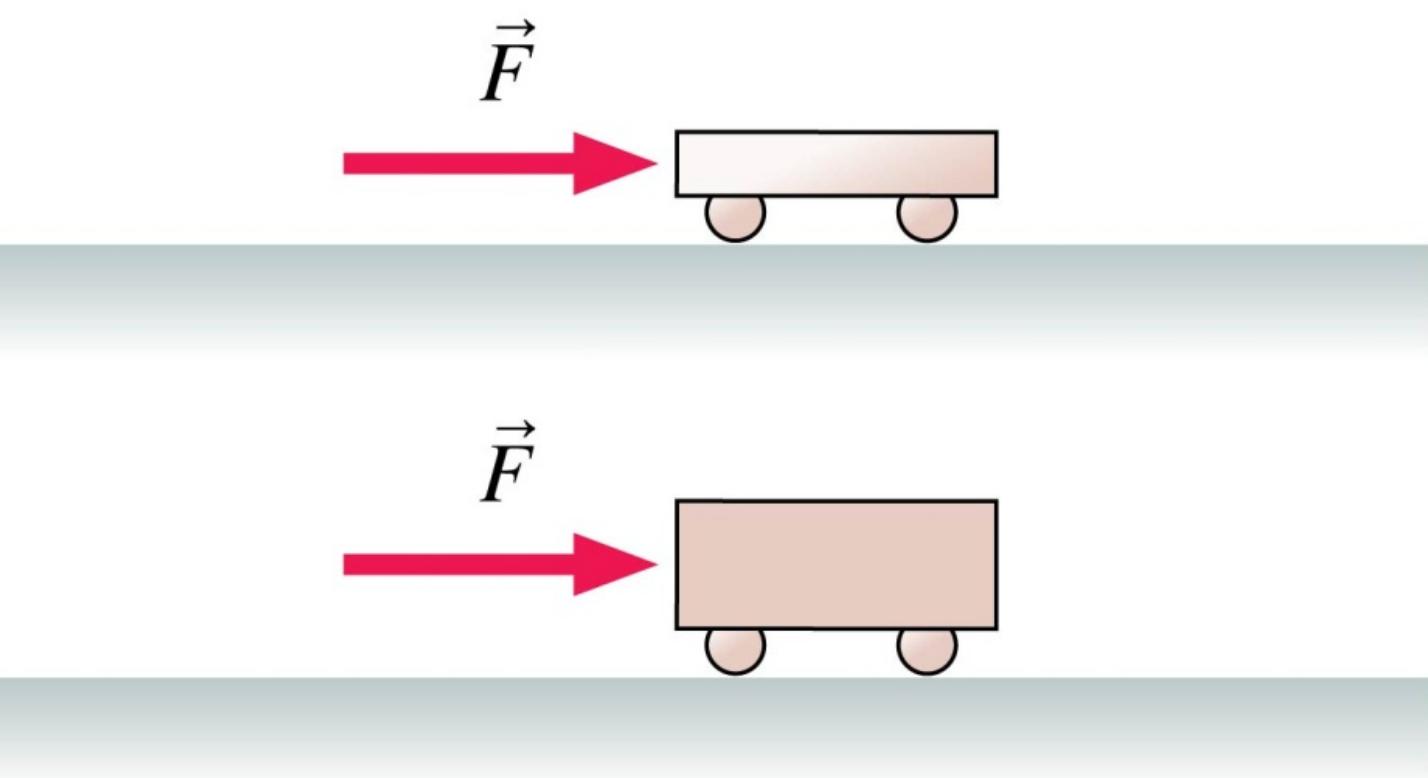


## QuickCheck 9.7

A light plastic cart and a heavy steel cart are both pushed with the same force for a distance of 1.0 m, starting from rest.

After the force is removed, the kinetic energy of the light plastic cart is \_\_\_\_\_ that of the heavy steel cart.

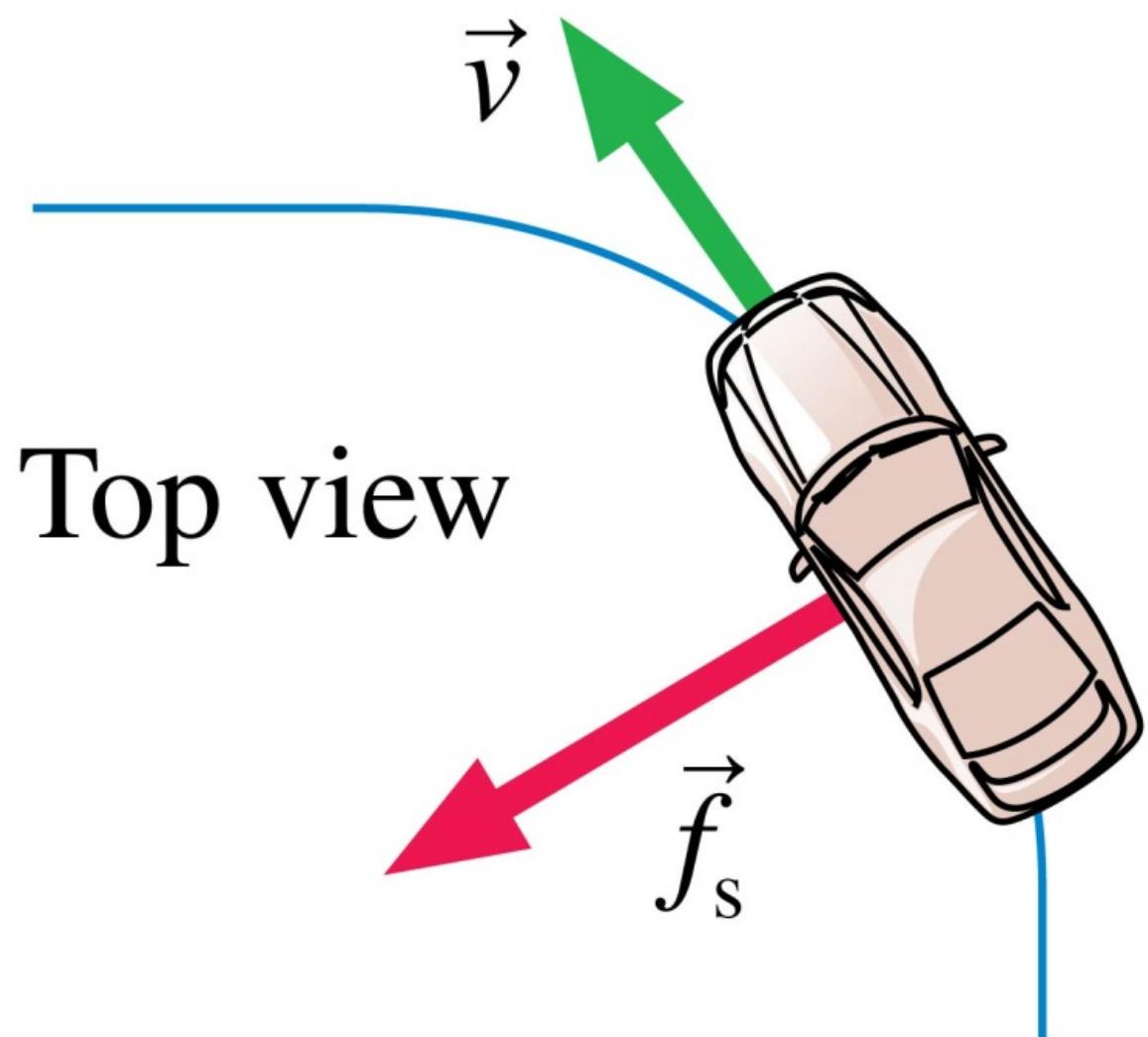
- A. greater than
- B. equal to
- C. less than
- D. Can't say. It depends on how big the force is.



## QuickCheck 9.8

A car on a level road turns a quarter circle ccw. You learned in Chapter 8 that static friction causes the centripetal acceleration. The work done by static friction is \_\_\_\_\_.

- A. positive
- B. negative
- C. zero

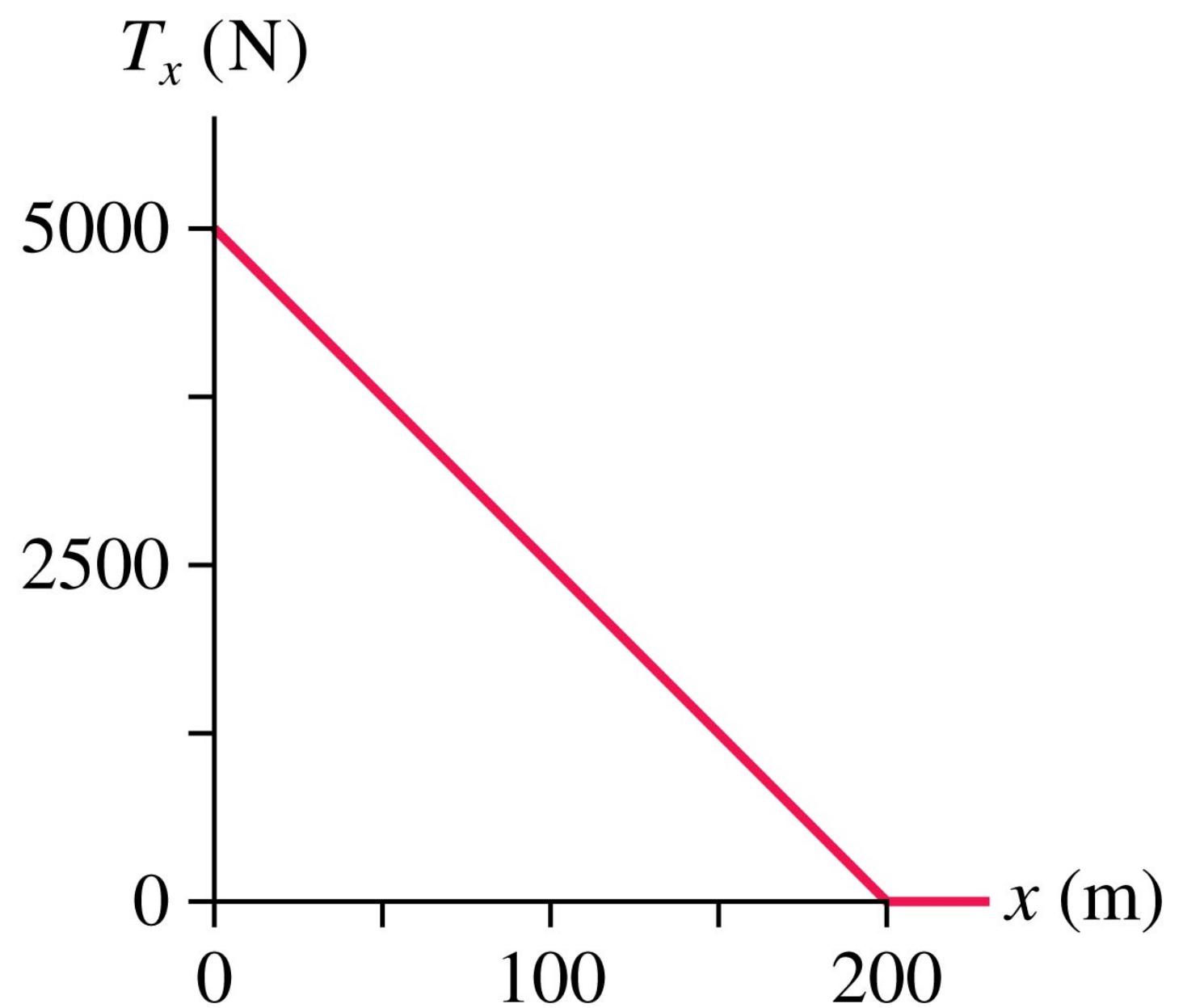


# Example 9.7 Using Work to Find the Speed of a Car

## EXAMPLE 9.7 | Using work to find the speed of a car

A 1500 kg car is towed, starting from rest. **FIGURE 9.16** shows the tension force in the tow rope as the car travels from  $x = 0$  m to  $x = 200$  m. What is the car's speed after being pulled 200 m?

**MODEL** Let the system consist of only the car, which we model as a particle. We'll neglect rolling friction. Two vertical forces, the normal force and gravity, are perpendicular to the motion and thus do no work.



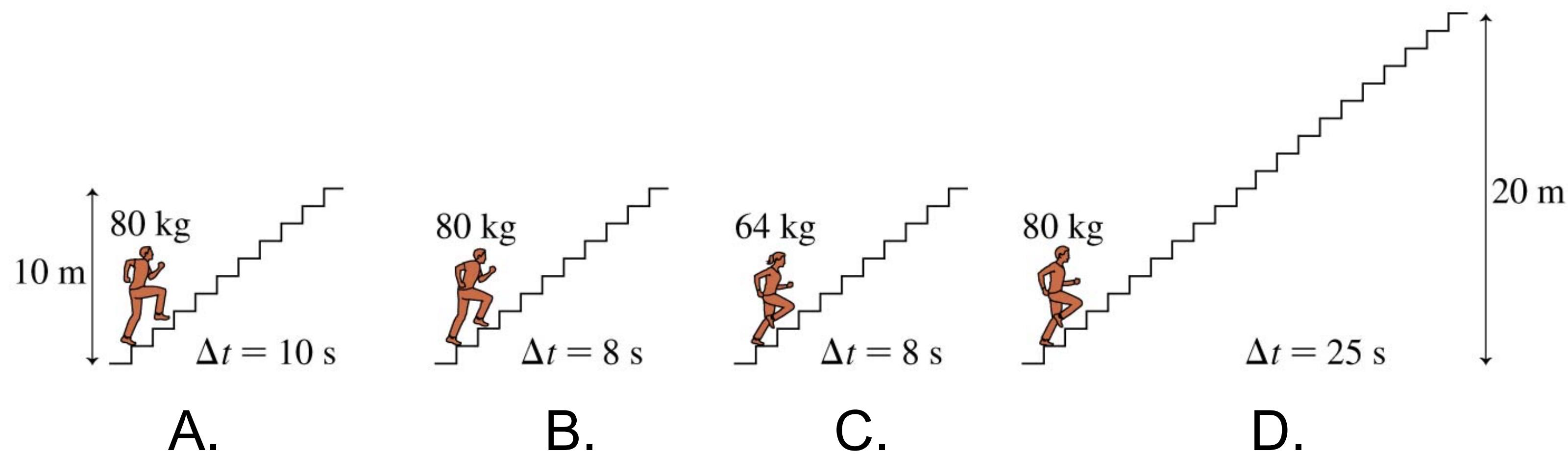
## QuickCheck 9.10

A tow rope pulls a skier up the slope at constant speed.  
What energy transfer (or transfers) is taking place?

- A.  $W \rightarrow U$
- B.  $W \rightarrow K$
- C.  $W \rightarrow E_{\text{th}}$
- D. Both A and B
- E. Both A and C

## QuickCheck 9.11

Four students run up the stairs in the time shown.  
Which student has the largest power output?



# Example 9.11 Power Output of a Motor

## EXAMPLE 9.11

### Power output of a motor

A factory uses a motor and a cable to drag a 300 kg machine to the proper place on the factory floor. What power must the motor supply to drag the machine at a speed of 0.50 m/s? The coefficient of friction between the machine and the floor is 0.60.

Hooke's law describes an ideal spring. Many real springs are better described by the restoring force  $(F_{Sp})_s = -k\Delta s - q(\Delta s)^3$ , where  $q$  is a constant. Consider a spring with  $k = 350 \text{ N/m}$  and  $q = 850 \text{ N/m}^3$ .

▼ Part A

How much work must you do to compress this spring 15 cm? Note that, by Newton's third law, the work you do *on* the spring is the negative of the work done *by* the spring.

