You can draw here

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!

You can draw here

You can draw here

Reminders/Announcements

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

Reminders/Announcements

	Homework (due Thurs 6 pm)	Test/Bonus Test (Thurs 6pm - Sat 6pm)	Learning Log (Sat 6pm)
Week 1	-	-	-
Week 2	HW01 - Intro to Mastering Physics	Test 0 **(not for marks)**	Learning Log 1
Week 3	HW02 - Chapter 2 HW03 - Chapter 3	Test 1 (on Chapters 2 & 3)	Learning Log 2
Week 4	HW04 - Chapter 4	Bonus Test 1	Learning Log 3
Week 5	HW05 - Chapter 5	Test 2 (on Chapters 4 and 5)	Learning Log 4
Week 6	N/A	N/A	N/A
Week 7	HW06 - Chapter 6	Bonus Test 2	Learning Log 5
Week 8	HW07 - Chapter 7	Test 3	Learning Log 6
Week 9	HW08 - Chapter 8	Bonus Test 3	Learning Log 7
Week 10	HW09 - Chapter 9 (deadline extended)	Test 4 (window moved to Sun Nov 15 - Tues Nov 17 due to Fall mini-break)	No Learning Log
Week 11	HW10	Bonus Test 4	Learning Log 8
Week 12	HW 11	Test 5	Learning Log 9
Week 13	HW 12	Bonus Test 5	Learning Log 10

Chapter 9
Important Concepts

Why is energy important?

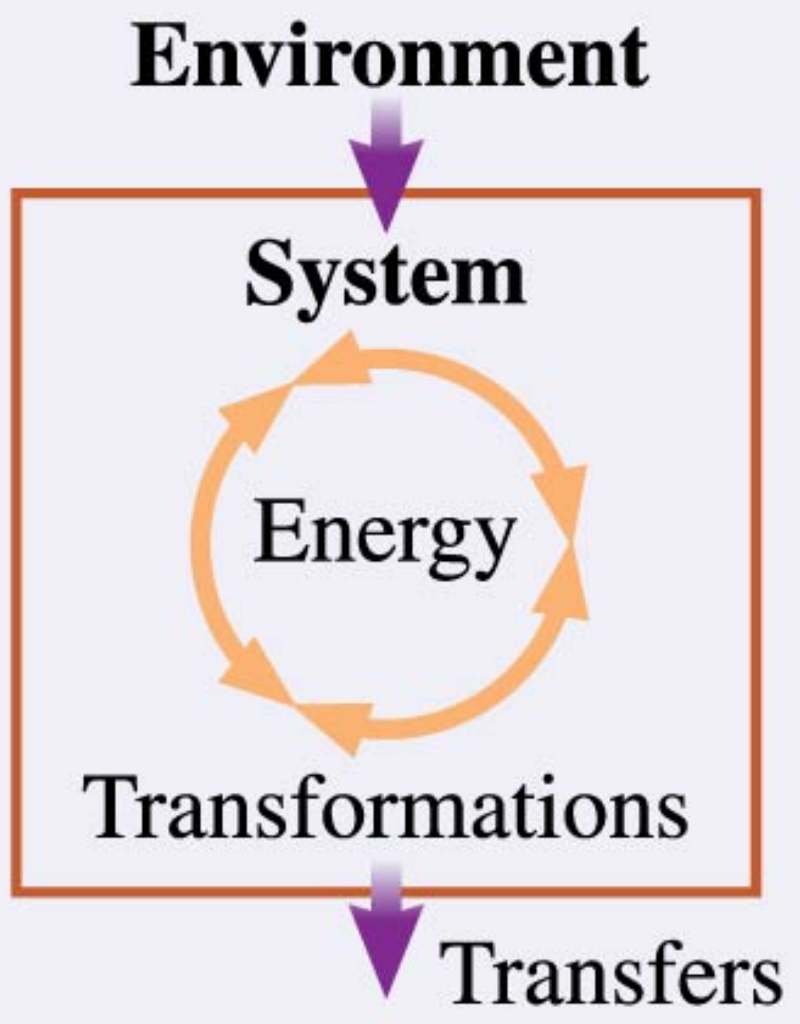
Energy is one of the most important concepts in science, engineering, and society. Some would say it is *the* most important. All life depends on energy, transformed from solar energy to chemical energy to us. Society depends on energy, from industry and transportation to heating and cooling our buildings. 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?

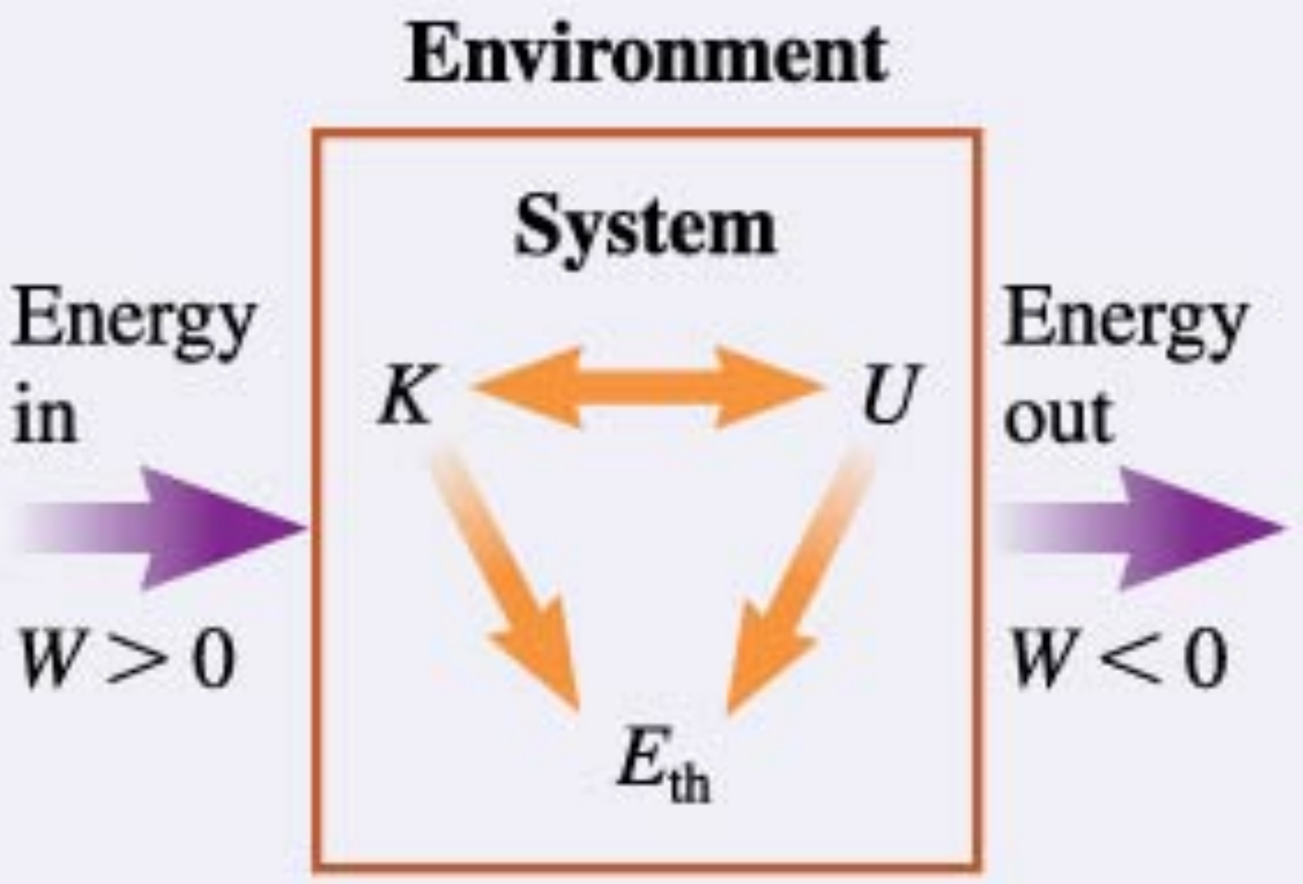
Chapters 9 and 10 will develop the basic energy model, a powerful set of ideas for using energy. A key distinction is between the system, which has energy, and the environment. Energy can be transferred between the system and the environment or transformed within the system.



« 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.

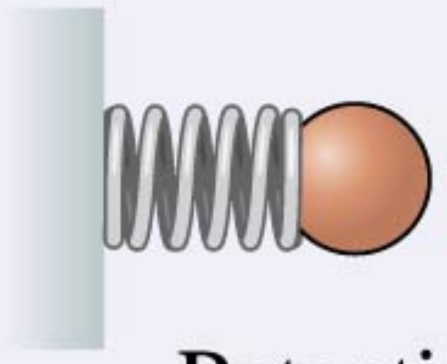


What are some important forms of energy?

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**.



Potential energy

Kinetic energy

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:

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

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.

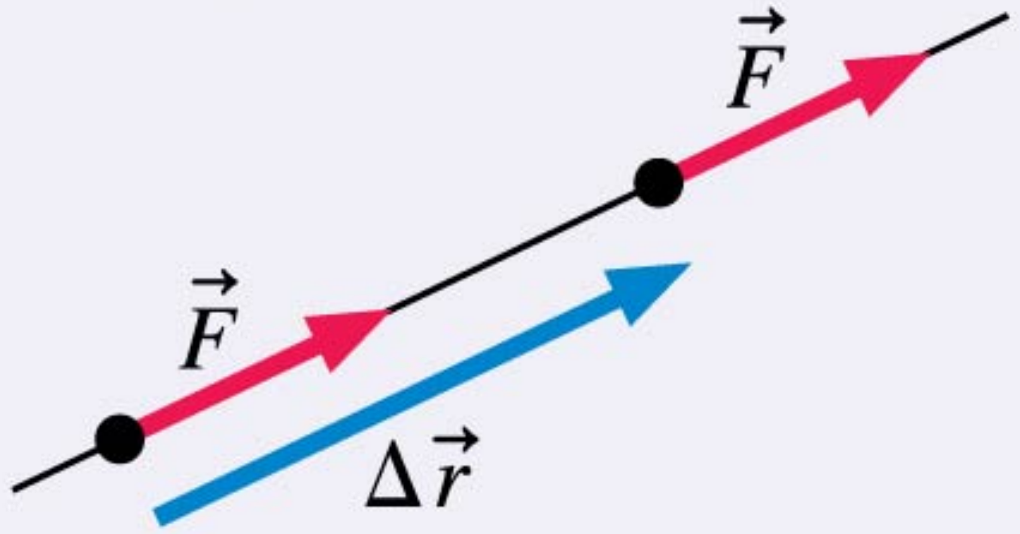
Thermal Energy E_{th}

- 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.



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

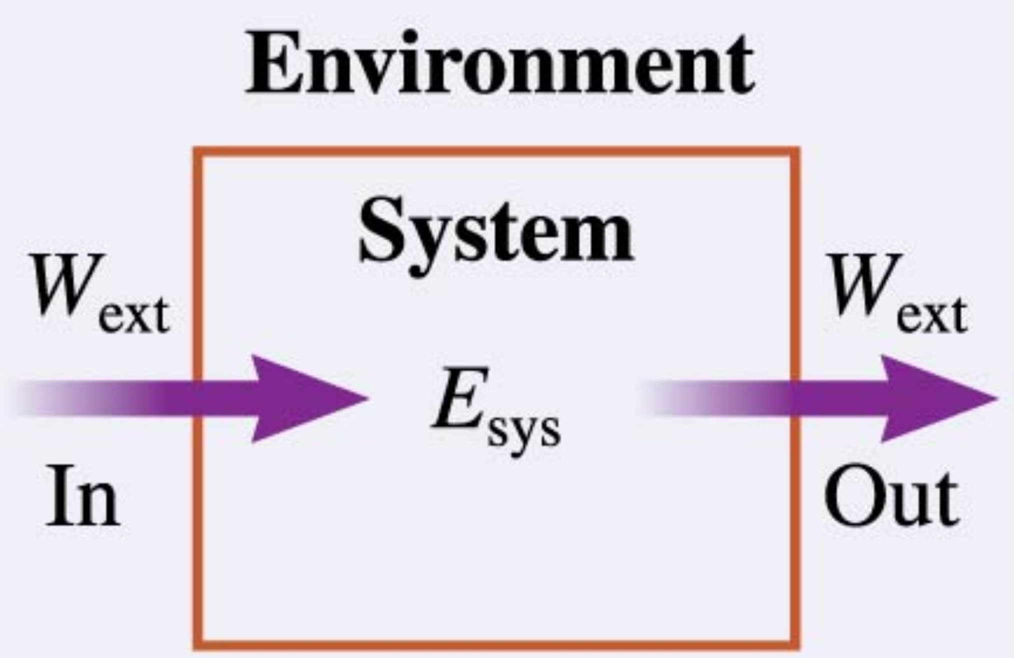
$$W = -\left(\tfrac{1}{2}k(\Delta s_f)^2 - \tfrac{1}{2}k(\Delta s_i)^2\right)$$

where Δs 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:

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



The Energy Principle

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

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

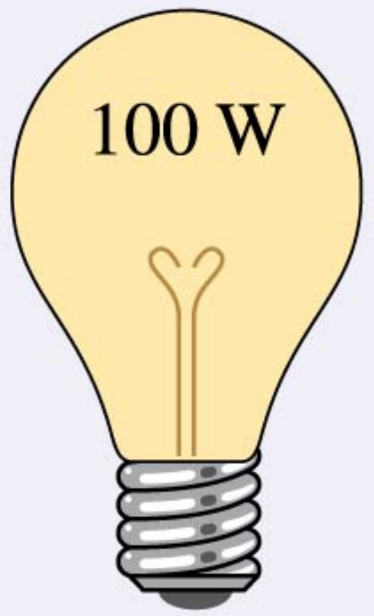
For systems containing only particles, no interactions, $E_{sys} = K + E_{th}$. All forces are external forces, so

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

where W_{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.



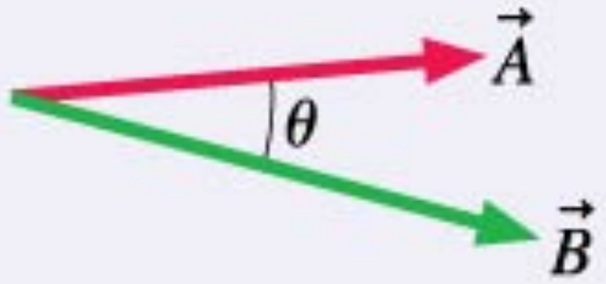
Power is the rate at which energy is transferred or transformed:

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

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

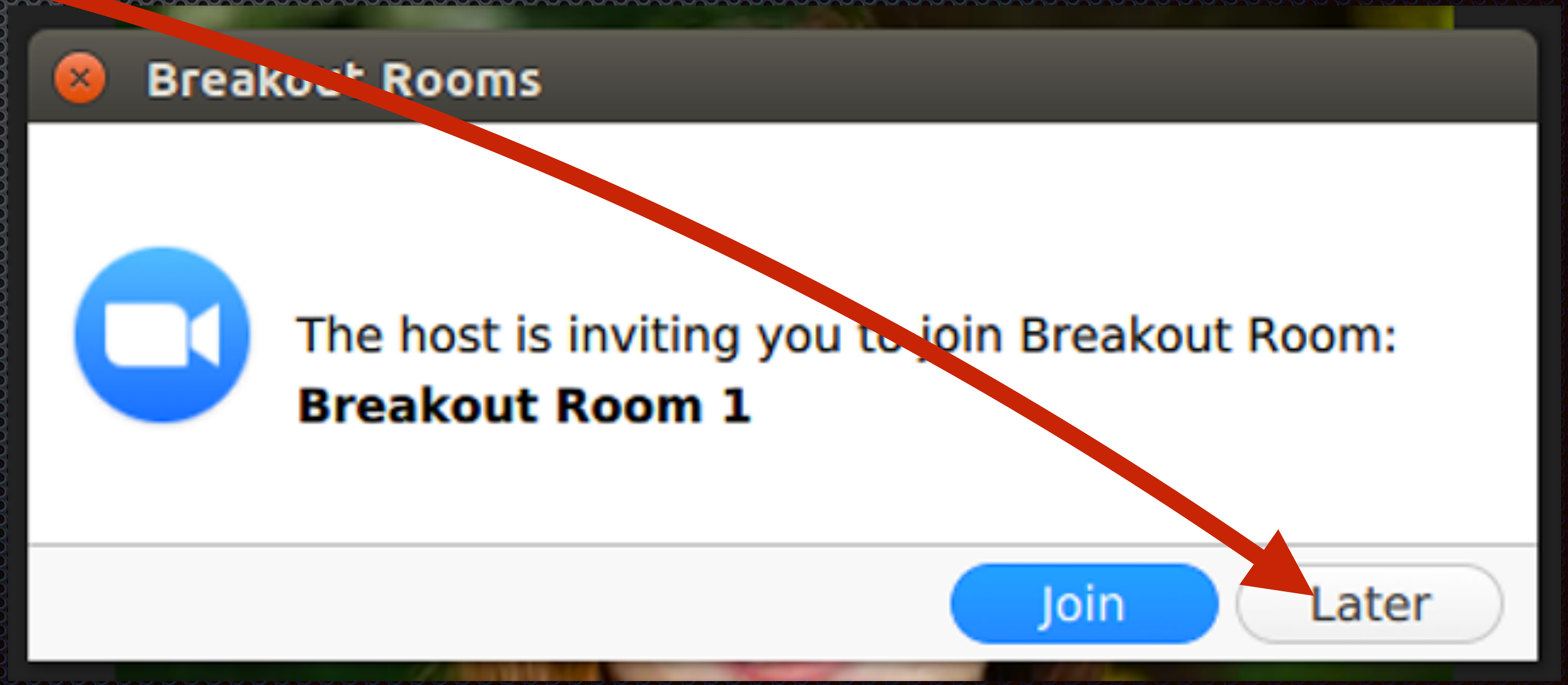
$$\vec{A} \cdot \vec{B} = AB\cos\theta = A_xB_x + A_yB_y$$



Chapter 9
Clicker Questions

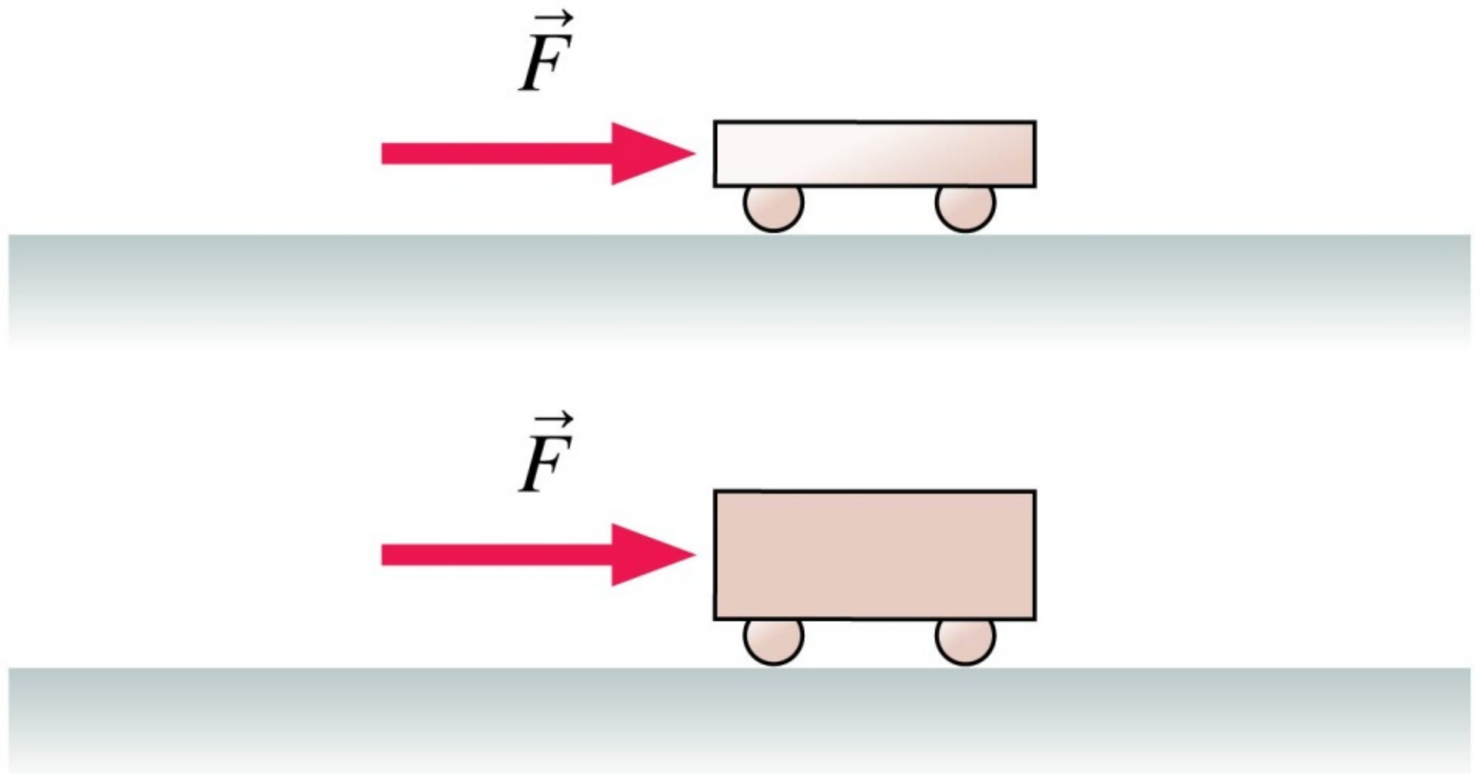
Let's try this: If we do breakout rooms, and you do not want to participate with your peers, that's fine!

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 9.7

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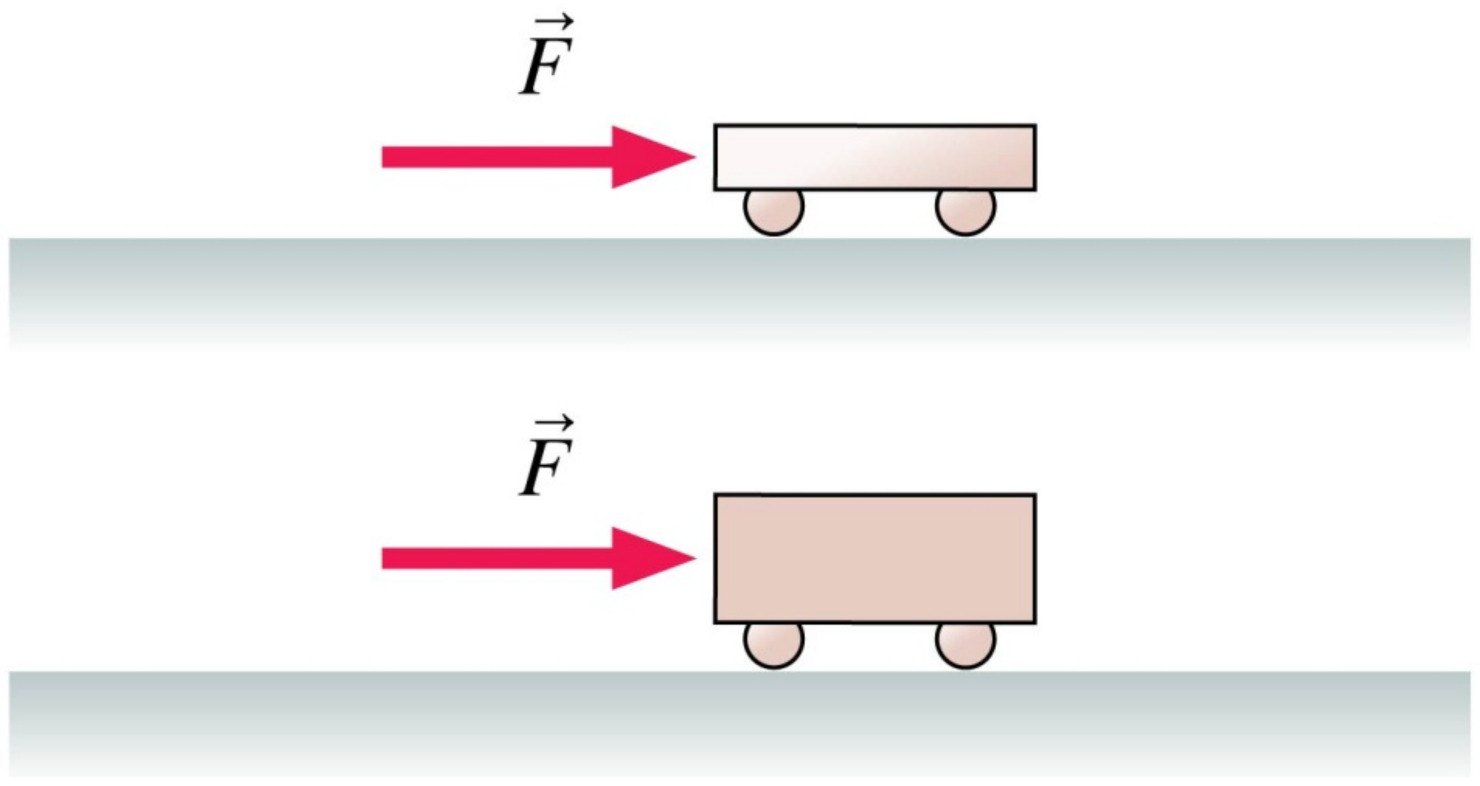
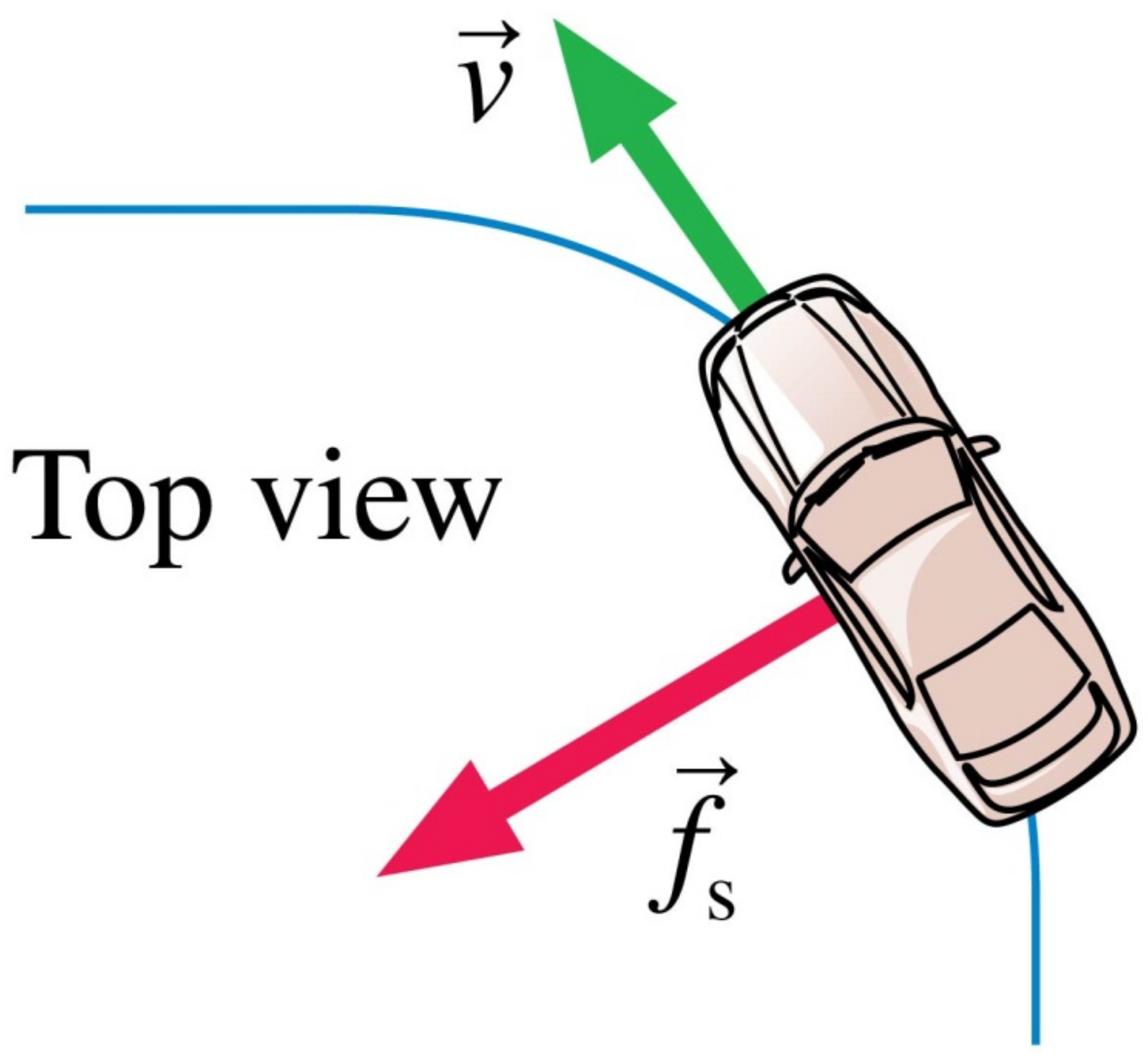


A. greater than
✔ **B. equal to**
C. less than
D. Can't say. It depends on how big the force is.

Same force, same distance → same work done
Same work → change of kinetic energy

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

QuickCheck 9.8

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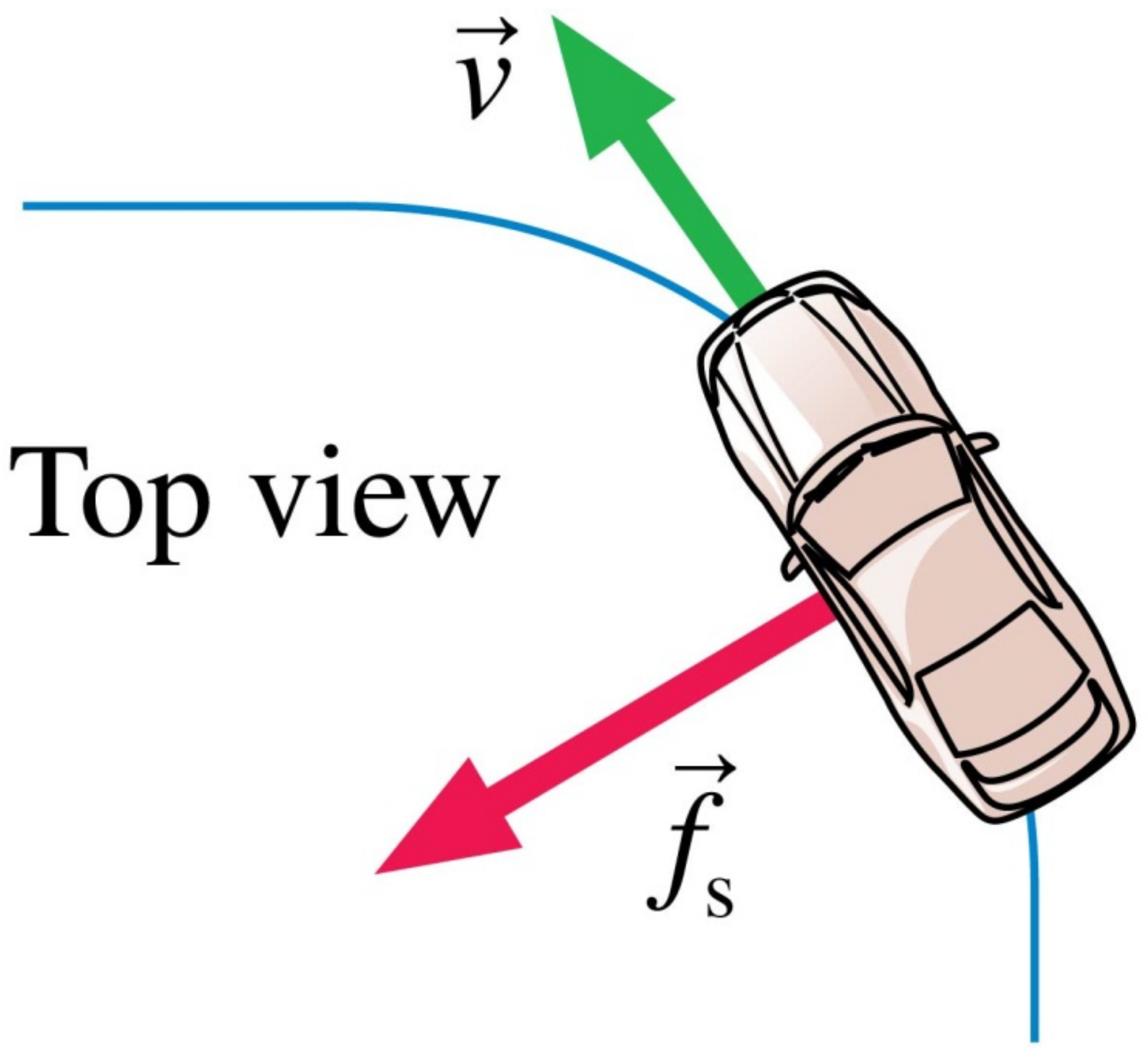
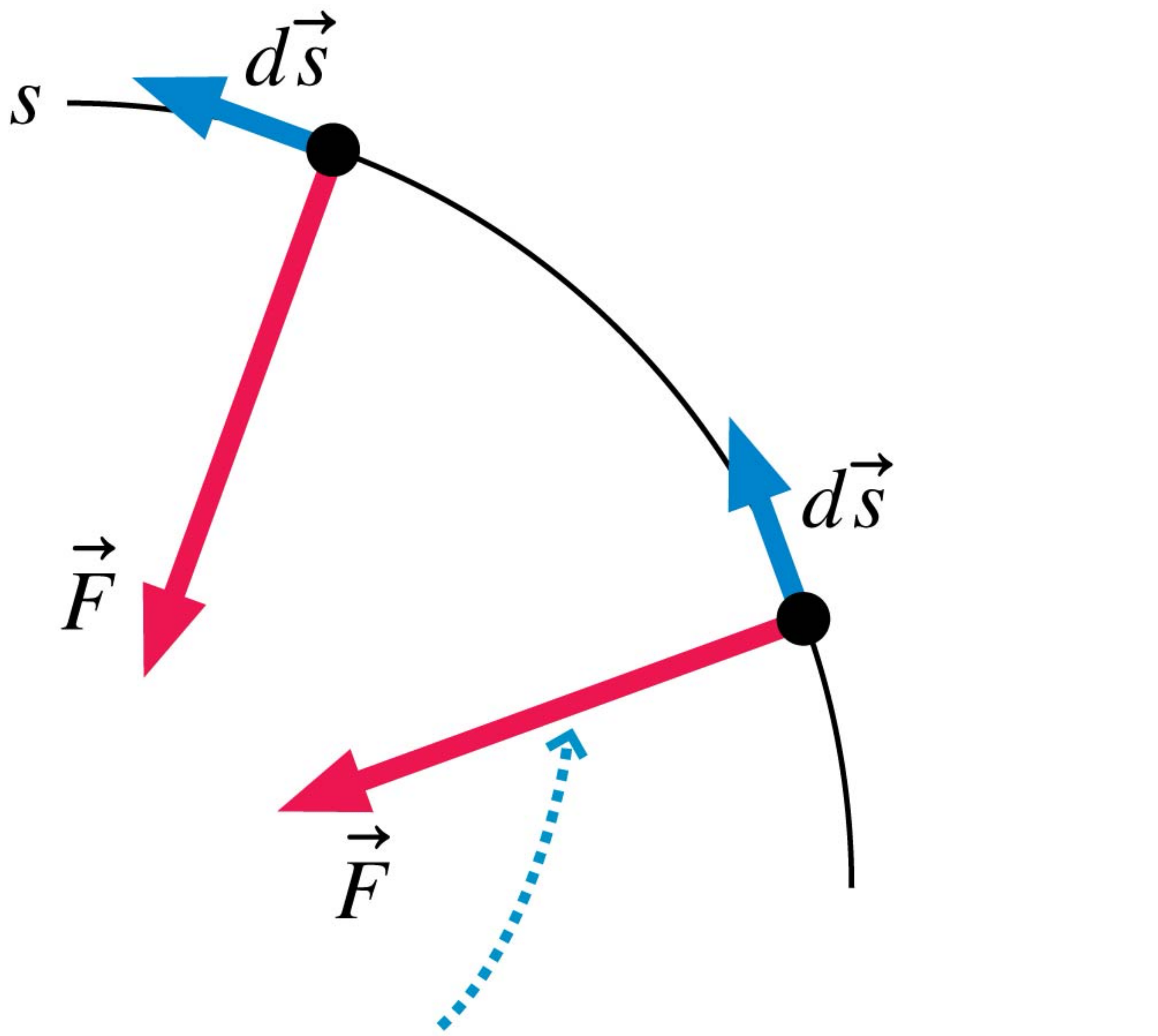


A. positive

B. negative

✔ **C. zero**

Zero-Work Situations



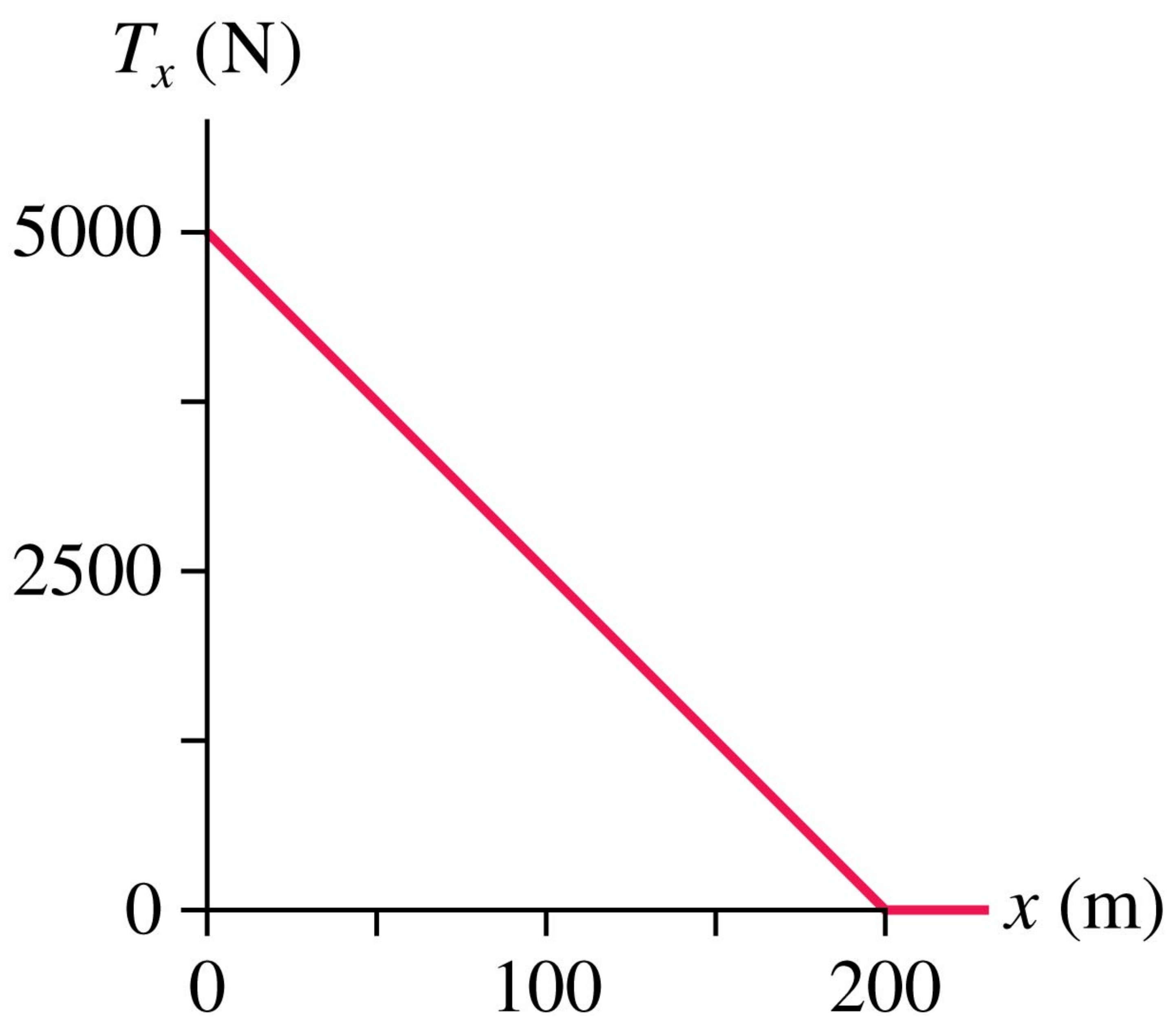
- The figure shows a particle moving in uniform circular motion.
- At every point in the motion, F_s, the component of the force parallel to the instantaneous displacement, is zero.
- The particle's speed, and hence its kinetic energy, doesn't change, so $W = \Delta K = 0$.
- **A force everywhere perpendicular to the motion does no work.**

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.



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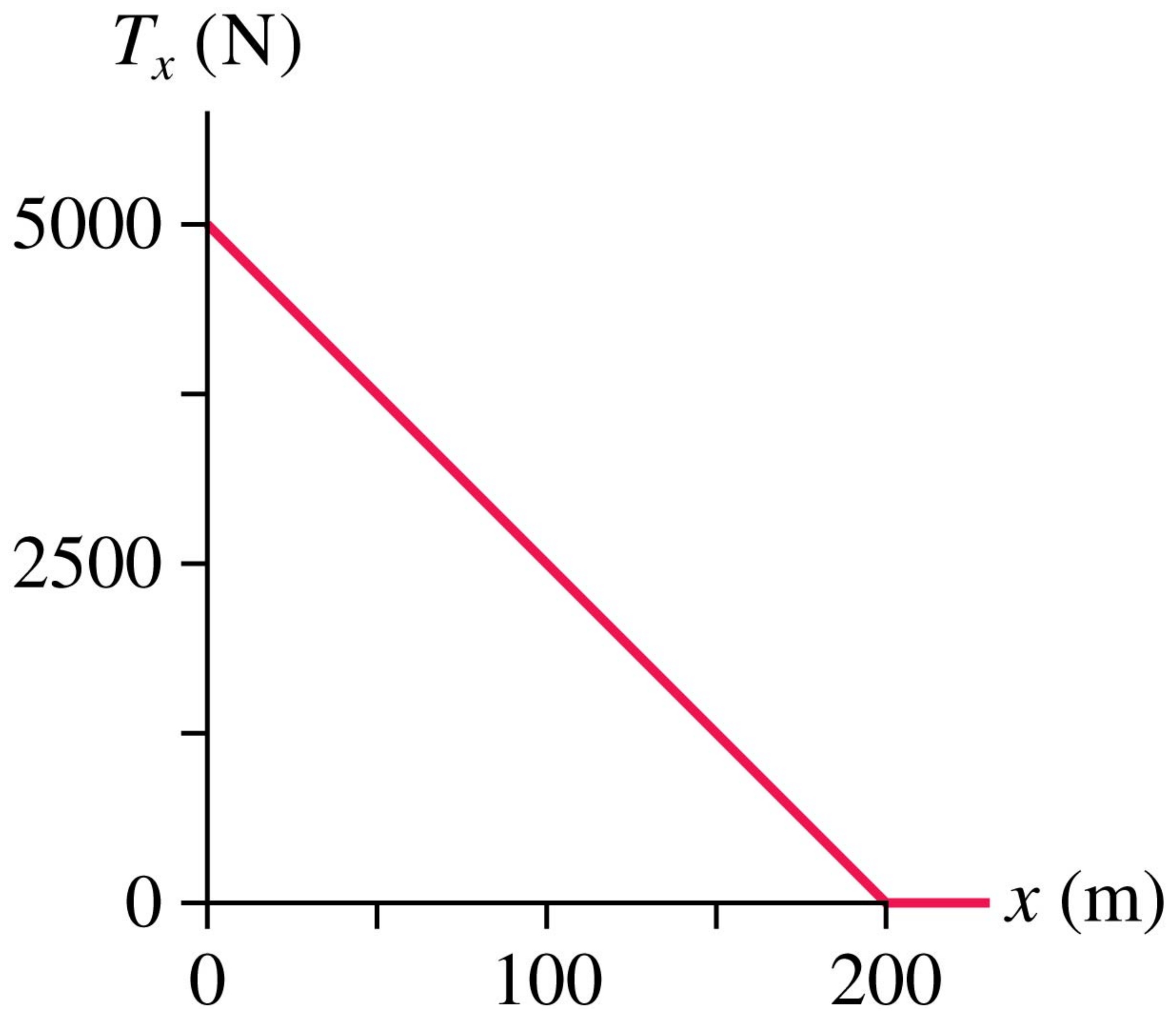

EXAMPLE 9.7 Using work to find the speed of a car

SOLVE We can solve this problem with the energy principle, $\Delta K = K_f - K_i = W$, where W is the work done by the tension force, but the force is not constant so we have to use the full definition of work as an integral. In this case, we can do the integral graphically:

$$W = \int_{0\text{ m}}^{200\text{ m}} T_x\,dx$$

$$= \text{area under the force curve from 0 m to 200 m}$$

$$= \tfrac{1}{2}(5000\text{ N})(200\text{ m}) = 500{,}000\text{ J}$$

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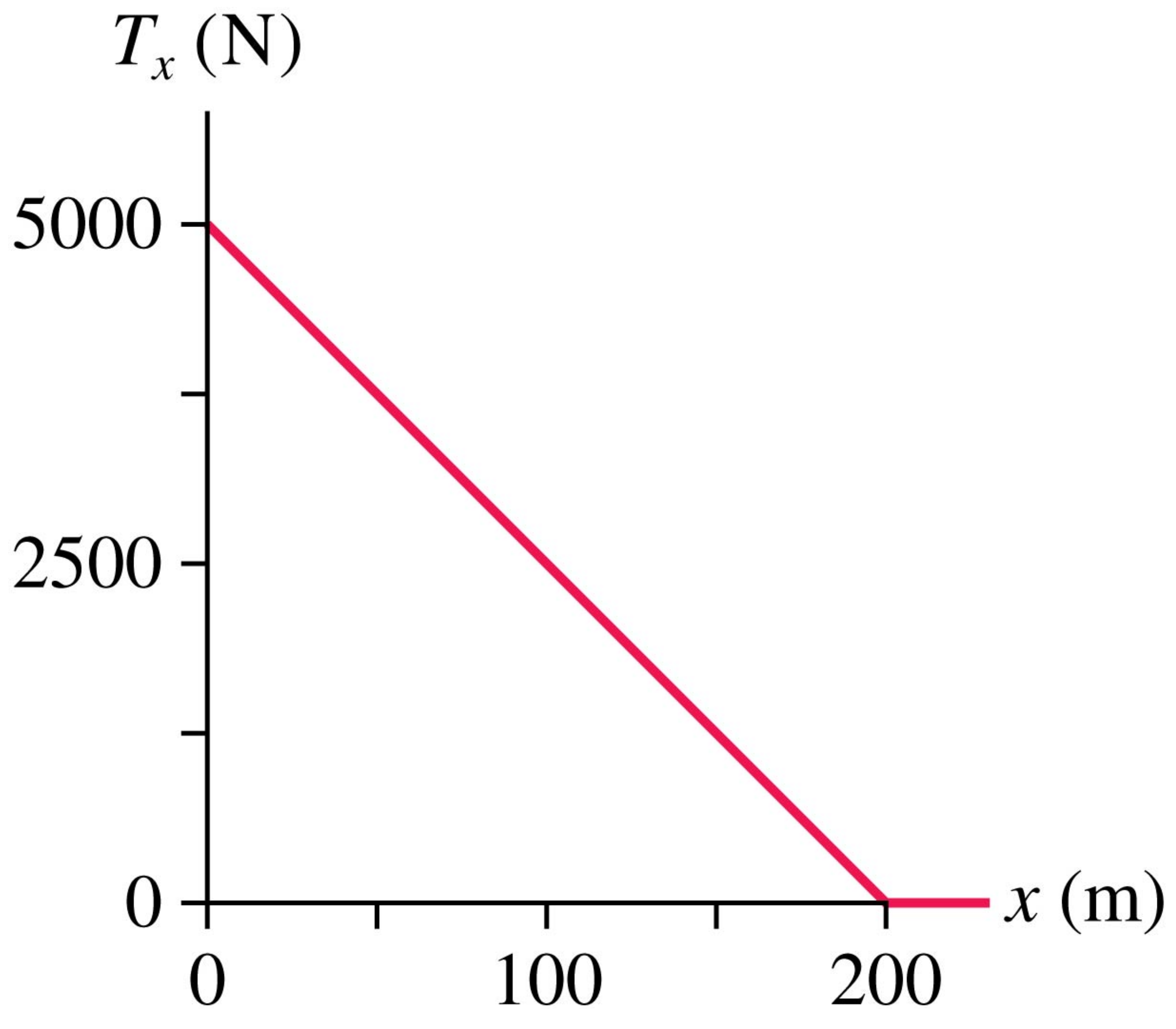

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EXAMPLE 9.7 work to find the speed of a car

SOLVE The initial kinetic energy is zero, so the final kinetic energy is simply the energy transferred to the system by the work of the tension: $K_f = W = 500{,}000$ J. Then, from the definition of kinetic energy,

$$v_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2(500{,}000\text{ J})}{1500\text{ kg}}} = 26\text{ m/s}$$

ASSESS 26 m/s ≈ 55 mph is a reasonable final speed after being towed 200 m.

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 9.10

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. $W \rightarrow K$

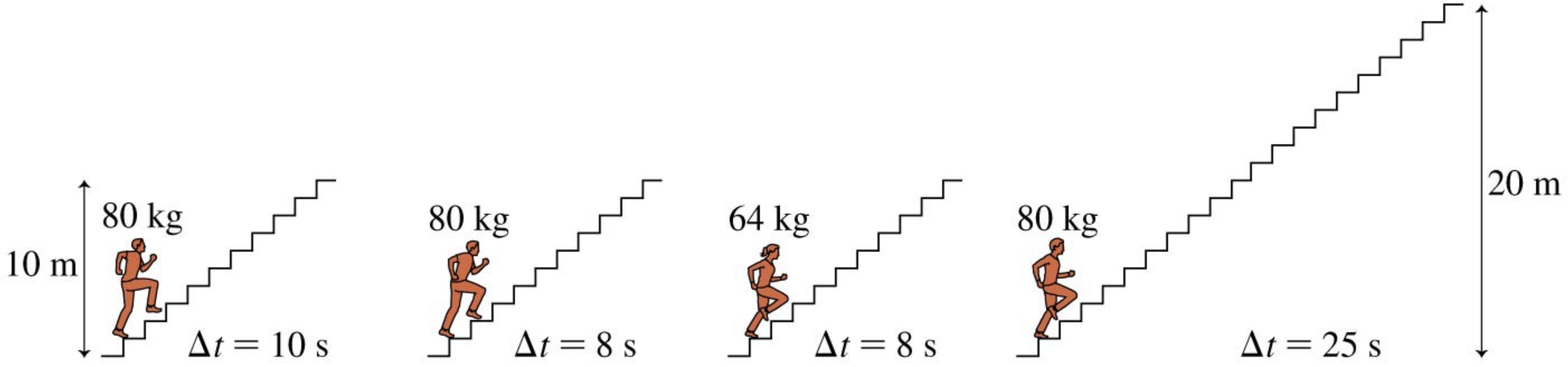
C. $W \rightarrow E_{\text{th}}$

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?



A.

B.

C.

D.

QuickCheck 9.11

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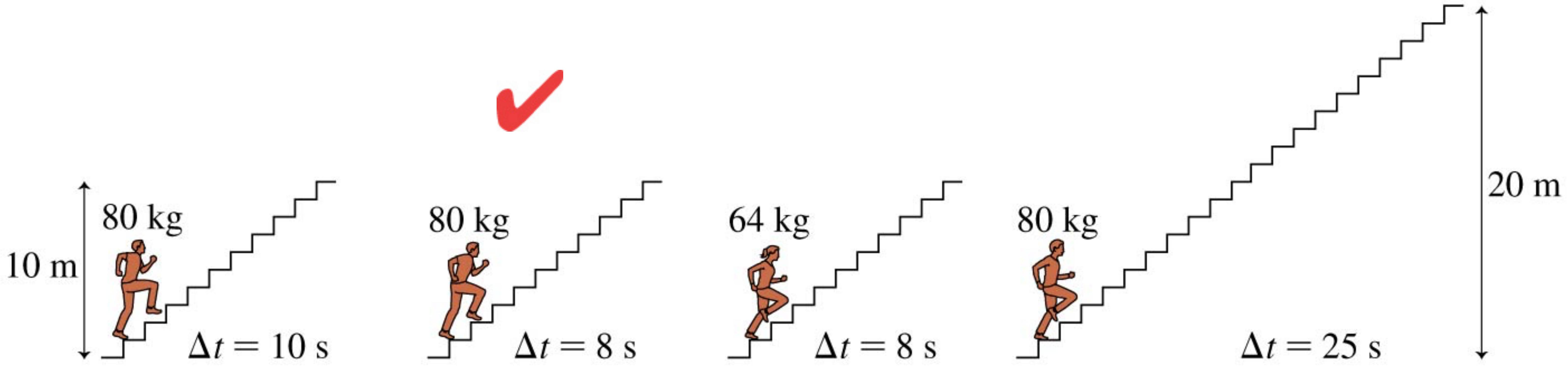


A.
B. ✔
C.
D.

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.

Example 9.11 Power Output of a Motor

EXAMPLE 9.11 | **Power output of a motor**

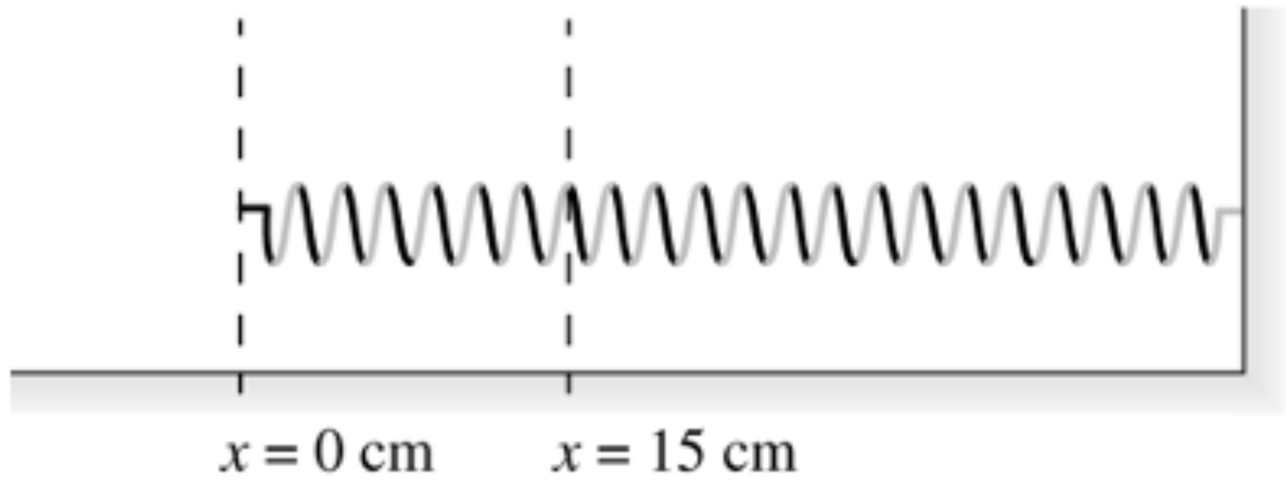
SOLVE The force applied by the motor, through the cable, is the tension force $\vec{T}$. This force does work on the machine with power $P = Tv$. The machine is in equilibrium, because the motion is at constant velocity, hence the tension in the rope balances the friction and is

$$T = f_k = \mu_k mg$$

The motor's power output is

$$P = Tv = \mu_k mgv = 882 \text{ W}$$

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



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.