Lecture 3

Chapter 11: Work

Reading Quiz: Chap 11

If you read chapter 11.1-5,9 before class these questions will be EASY

(the rest of the lecture might make more sense too

Reading Quiz

1) What new mathematical idea about vectors was introduced in this chapter?

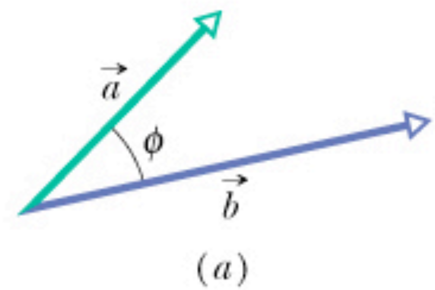
Reading Quiz

1) What new mathematical idea about vectors was introduced in this chapter?
   - Dot or Scalar Product

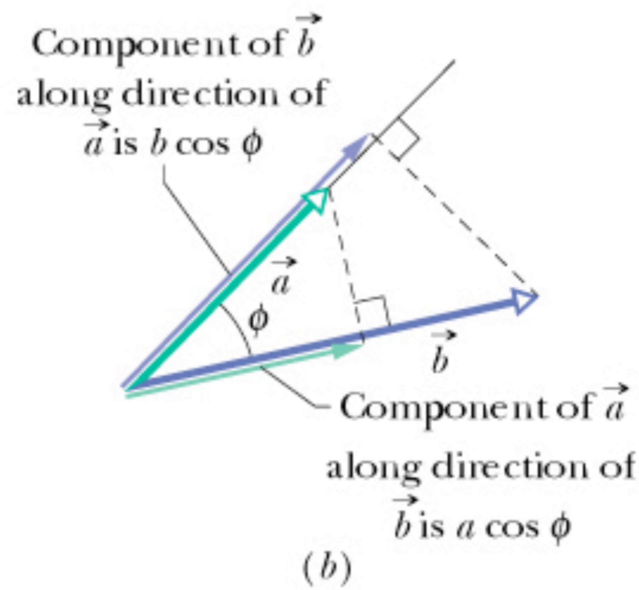
Vector review (cont)

Multiplying Vectors: dot or scalar product

$$\vec{a} \cdot \vec{b} = ab\cos\phi$$



The dot product can be considered as the magnitude of one of the vectors (a) times the scalar component of the second vector along the direction of the first (b cosϕ).



a, b aligned ==> $\vec{a} \cdot \vec{b} = ab$

a ⊥ b ==> $\vec{a} \cdot \vec{b} = 0$

Reading Quiz

2) The statement $\Delta K = W$ is called the

a. law of conservation of energy.

b. work-kinetic energy theorem.

c. kinetic energy equation.

d. weight-kinetic energy theorem.

Reading Quiz

2) The statement $\Delta K = W$ is called the

a. law of conservation of energy.

b. work-kinetic energy theorem.

c. kinetic energy equation.

d. weight-kinetic energy theorem.

Reading Quiz

3) The transfer of energy to a system by the application of a force is called _______.

Reading Quiz

3) The transfer of energy to a system by the application of a force is called _______.

- work

Reading Quiz

3) The transfer of energy to a system by the application of a force is called _______.

- Work

What units does work have?

Reading Quiz

3) The transfer of energy to a system by the application of a force is called _______.

- Work

What units does work have?

- Joules (J)

Student Learning Objectives

- To introduce and use the basic energy model.
  - Did this last lecture, today we will expand the model
- To recognize transformations between
  - Kinetic energy
  - Potential energy
  - Thermal energy.
- To define work & use the work-kinetic energy theorem.
- To develop a complete statement of the law of conservation of energy.
- To introduce and use the idea of power.

Physical Example

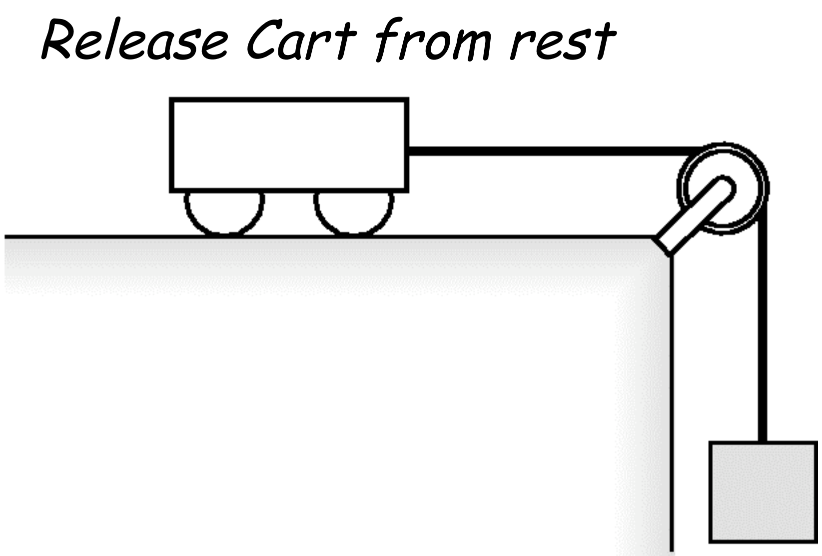
- In chapter 10 we introduce the idea of energy as a king of "Natural Money"
- Some questions remain to be answered as we continue to develop the concept of energy
  - How many kinds of energy are there?
  - Under what conditions is energy conserved?
  - How does a system gain or lose energy?
- For example: At the start of a bobsled run, the bobsled gains kinetic energy by the runners pushing it faster (not by losing potential energy). Today we will learn that the energy transfer by "pushes and pulls" is called work.

- The focus of chapter 11 is how to compute work done (W) by various forces

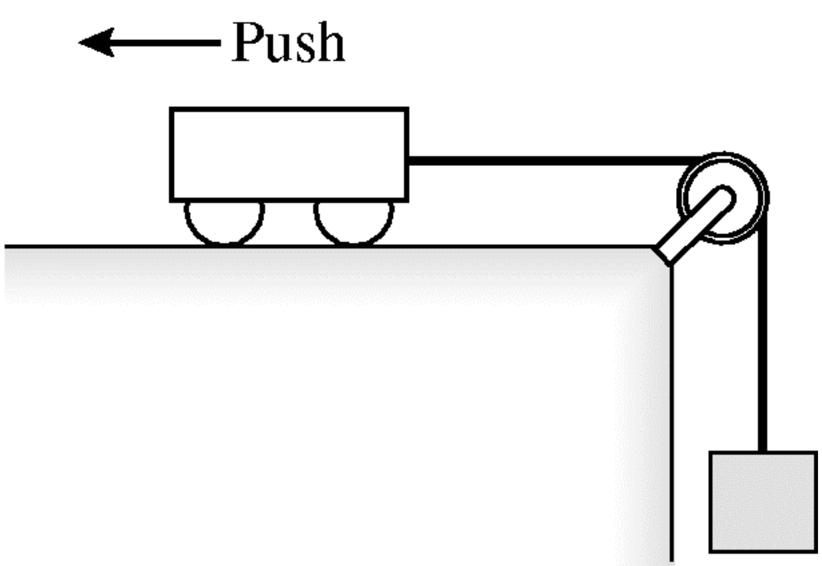
$$W = \int_{s_i}^{s_f} F_s ds$$

- For a constant force, F

$$W = F \cdot \Delta r = F \Delta r \cos\vartheta$$



- A low-friction car is attached by a string to a hanging mass
- Release the cart from rest
  - Does ΔK increase or decrease?
  - What is the sign of ΔK?
  - What forces act on the cart?
  - For each of the forces, is the work positive, negative, or zero?
  - Is W_{net} positive, negative, or zero?
  - Does this agree with ΔK?



- A low-friction car is attached by a string to a hanging mass
- Push cart away from pulley
  - Does ΔK increase or decrease?
  - What is the sign of ΔK?
  - What forces act on the cart?
  - For each of the forces, is the work positive, negative, or zero?
  - Is W_{net} positive, negative, or zero?
  - Does this agree with ΔK?

Example 1

- A 200 g ball is lifted upward on a string. It goes from rest to a speed of 2.0 m/s is a distance of 1.0 m. What is the tension (assumed to stay constant) in the string?

  - Can solve with Newton's 2nd law.
  - Can also solve with $\Delta E_{sys} = W$

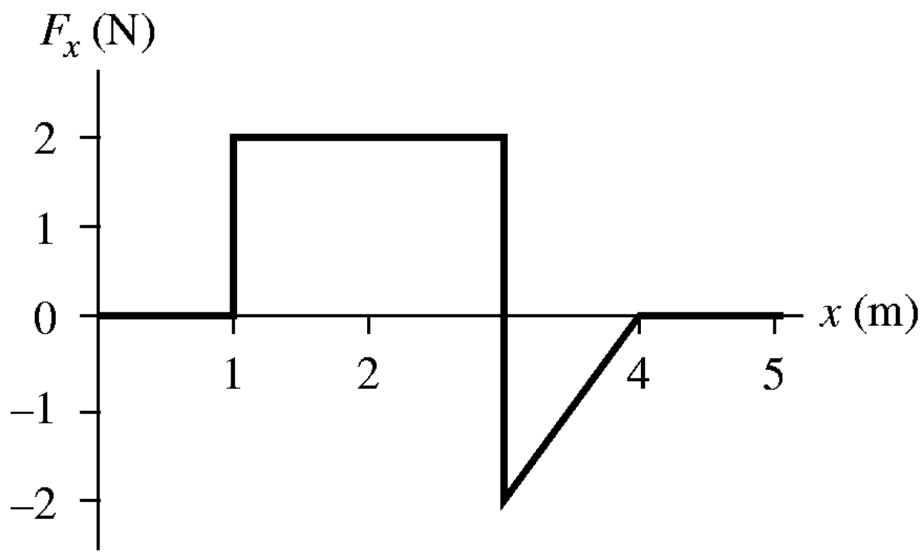
Example 2

- A 1000 kg car is rolling slowly across a level surface a 1.0 m/s, heading toward a small group of innocent children. The doors are locked so you cannot get inside to use the brakes. Instead, you run in front of the car and push on the hood at an angle of 30^o below the horizontal. How hard must you push to stop the car in a distance of 2.0 m?

Example 3

- A 1.0 kg block moves across the x-axis. It passes zero with velocity 2.0 m/s. It is then subjected to a force as shown on graph.
  - Which of the following is true. The block gets to 5.0 m with a speed

    a) >2.0 m/s b) =2.0 m/s c) <2.0 m/s d) Block never gets to 5.0 m

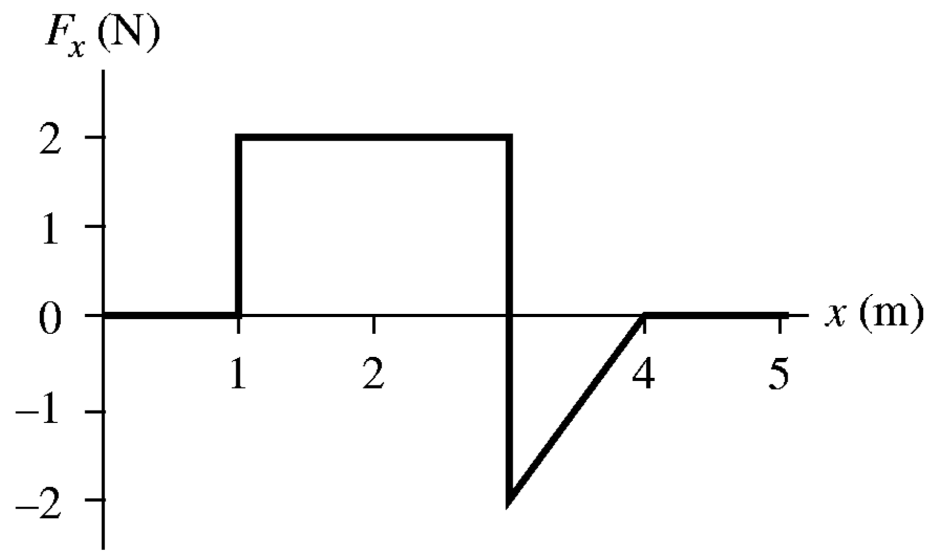


Example 3

- A 1.0 kg block moves across the x-axis. It passes zero with velocity 2.0 m/s. It is then subjected to a force as shown on graph.
  - Which of the following is true. The block gets to 5.0 m with a speed

    a) >2.0 m/s   b) =2.0 m/s   c) <2.0 m/s   d) Block never gets to 5.0 m

  - Calculate the block speed at x = 5.0 m



Example 4

- A 200 g block on a rough surface with μ_k= 0.80 is pushed against a spring with spring constant 500 N/m, compressing the spring 2.0 cm. If the block is released with what speed is the block shot away from the spring?

Example 5

- A rope with a tension of 30 N pulls a 2.0 kg box up a rough (μ_k = 0.30), 2.0 m long 30^o incline. What is the speed of the box at the top.
  - Again we could solve this with Newton's second law but let us use energy equation

Power

- Work is the transfer of energy between the environment and a system
- In many cases we would like to know how quickly this transfer occurs
- Power is the rate of transfer of energy between environment and system
  - $P = dE_{sys}/dt$
  - Units Watt (1 W = 1 J/s)

Example 6

- 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.

Conceptual Questions

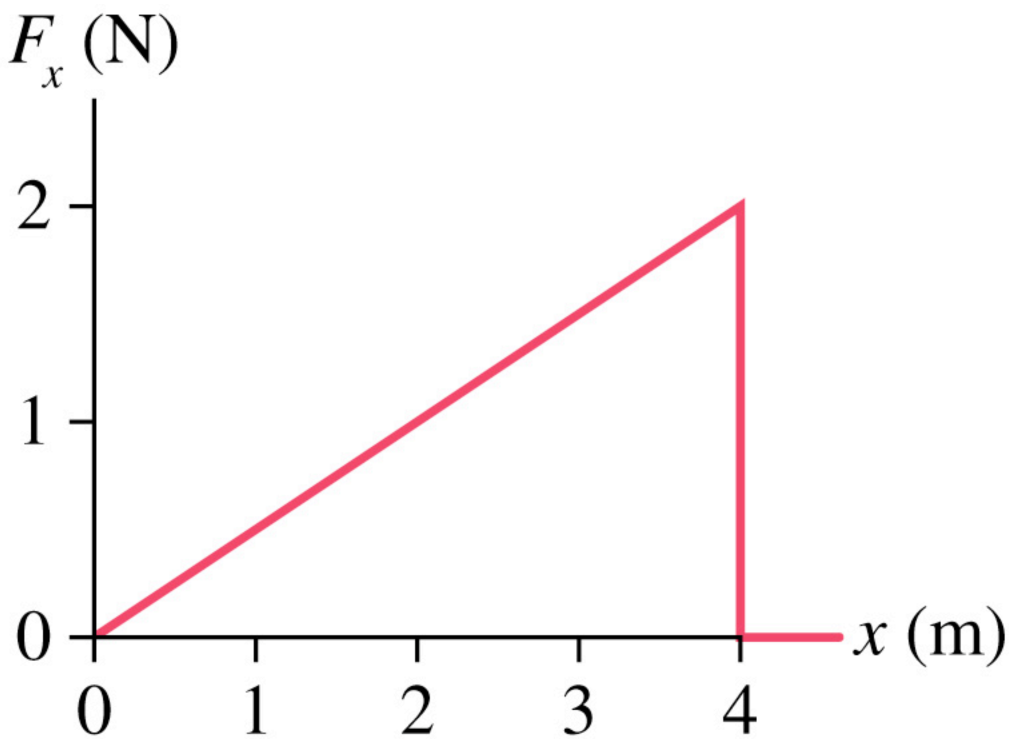
A child slides down a playground slide at constant speed. The energy transformation is

1. $U \rightarrow K$.
2. $U \rightarrow E_{th}$.
3. $K \rightarrow U$.
4. $K \rightarrow E_{th}$.
5. There is no transformation because energy is conserved.

A child slides down a playground slide at constant speed. The energy transformation is

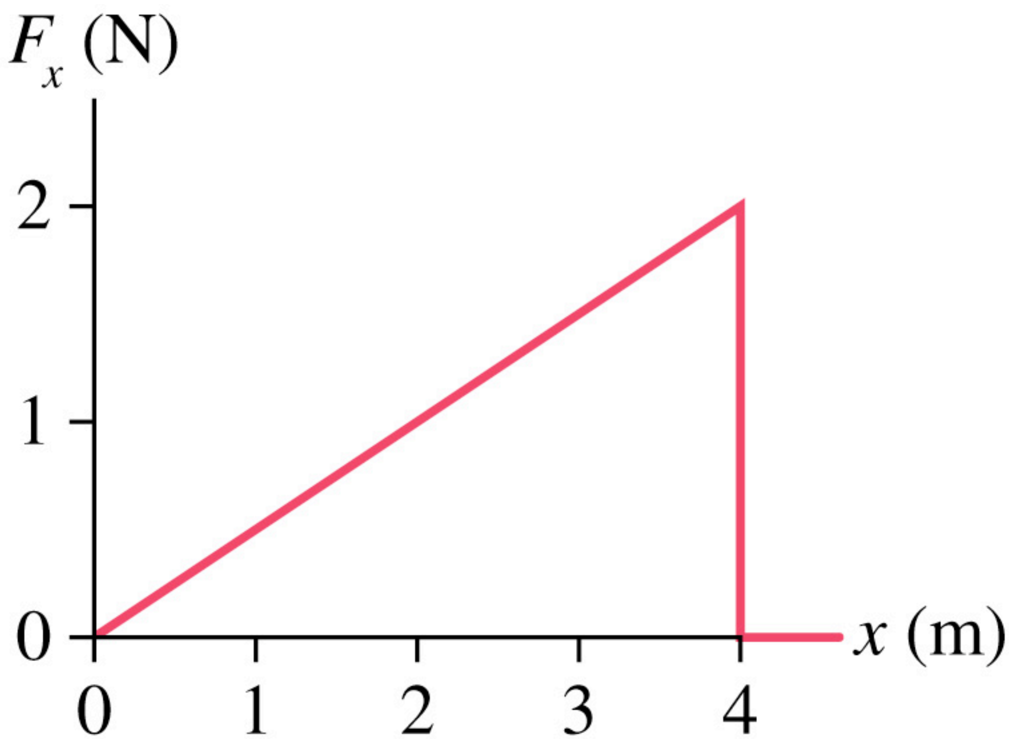
1. $U \rightarrow K$.
2. ✔ **$\boldsymbol{U \rightarrow E_{th}}$.**
3. $K \rightarrow U$.
4. $K \rightarrow E_{th}$.
5. There is no transformation because energy is conserved.

A particle moving along the x-axis experiences the force shown in the graph. If the particle has 2.0 J of kinetic energy as it passes $x = 0$ m, what is its kinetic energy when it reaches $x = 4$ m?



1. – 2.0 J
2. 0.0 J
3. 2.0 J
4. 4.0 J
5. 6.0 J

A particle moving along the x-axis experiences the force shown in the graph. If the particle has 2.0 J of kinetic energy as it passes $x = 0$ m, what is its kinetic energy when it reaches $x = 4$ m?



1. – 2.0 J
2. 0.0 J
3. 2.0 J
4. 4.0 J
5. **6.0 J** ✔

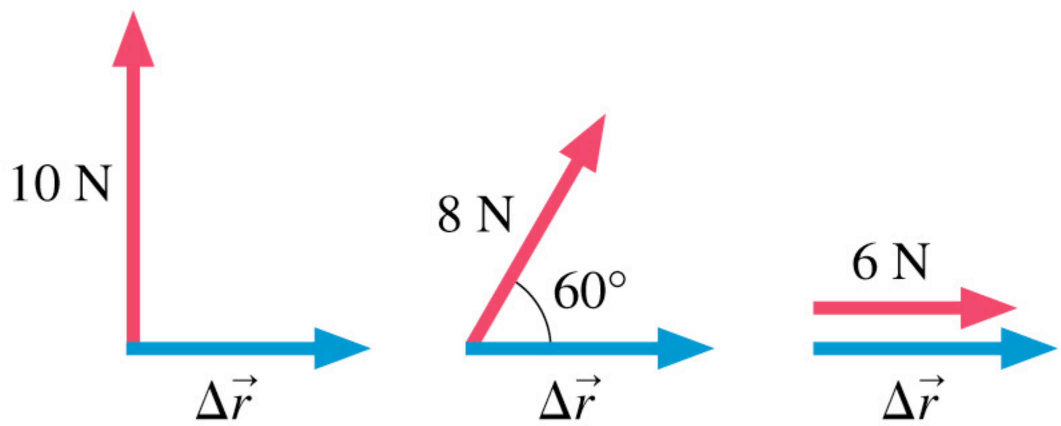
A crane lowers a steel girder into place at a construction site. The girder moves with constant speed. Consider the work W_g done by gravity and the work W_T done by the tension in the cable. Which of the following is correct?

1. W_g is positive and W_T is positive.
2. W_g is negative and W_T is negative.
3. W_g is positive and W_T is negative.
4. W_g and W_T are both zero.
5. W_g is negative and W_T is positive.

A crane lowers a steel girder into place at a construction site. The girder moves with constant speed. Consider the work W_g done by gravity and the work W_T done by the tension in the cable. Which of the following is correct?

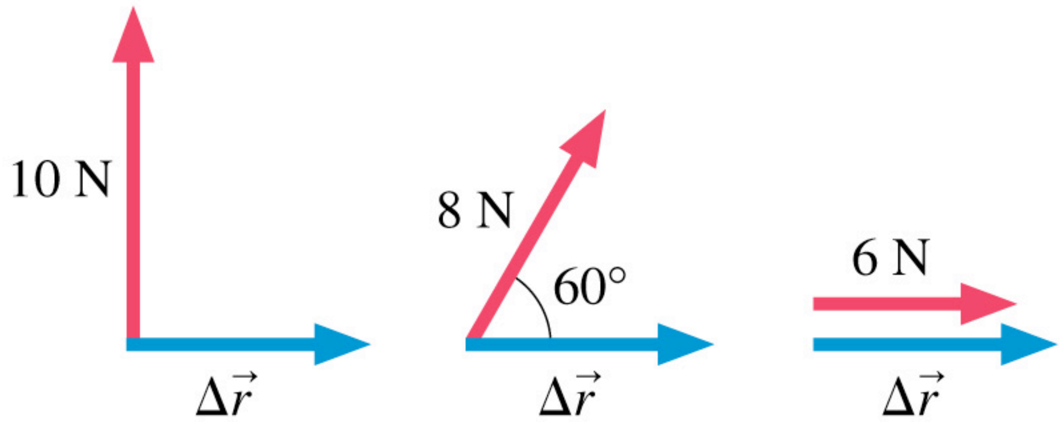
1. W_g is positive and W_T is positive.
2. W_g is negative and W_T is negative.
3. ✔ **W_g is positive and W_T is negative.**
4. W_g and W_T are both zero.
5. W_g is negative and W_T is positive.

Which force does the most work?



1. The 6 N force.
2. The 8 N force.
3. The 10 N force.
4. They all do the same amount of work.

Which force does the most work?



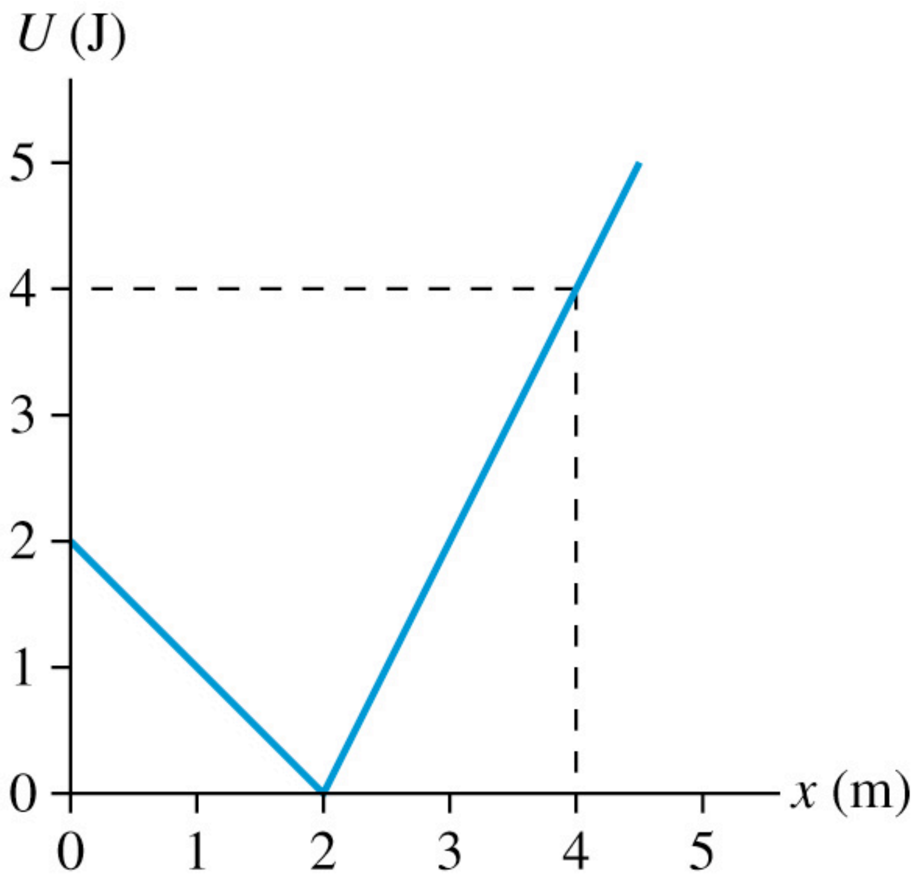
✔ **1. The 6 N force.**

2. The 8 N force.

3. The 10 N force.

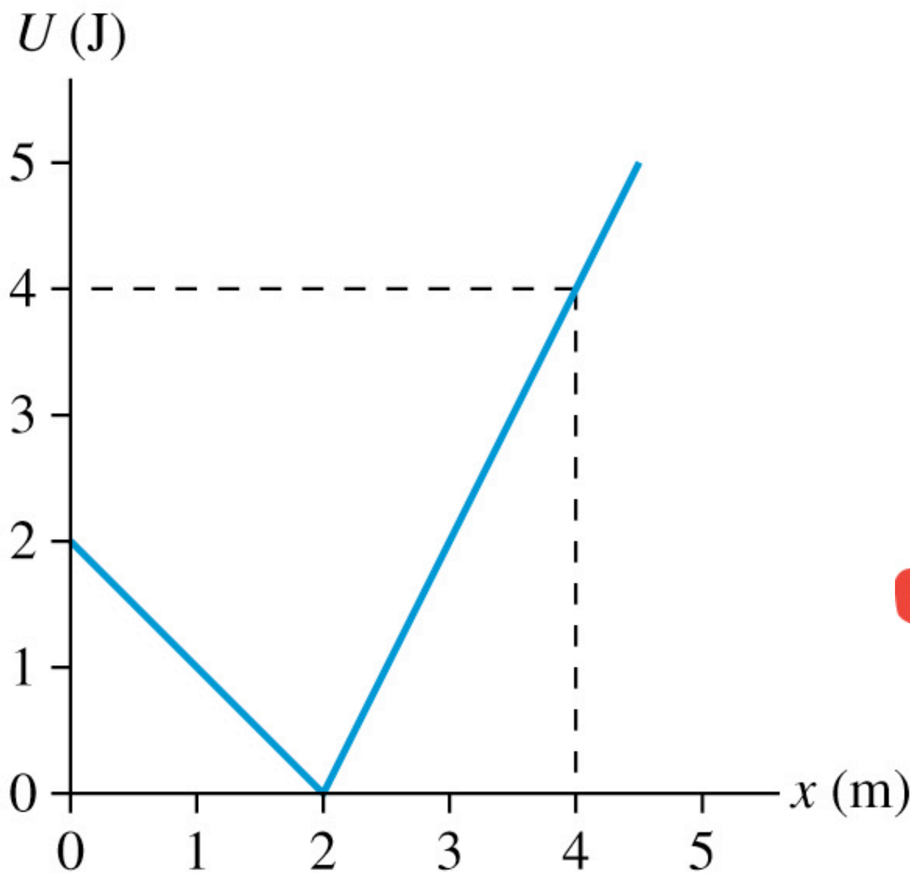
4. They all do the same amount of work.

A particle moves along the x-axis with the potential energy shown. The force on the particle when it is at $x = 4$ m is



1. 4 N.
2. 2 N.
3. 1 N.
4. –1 N.
5. –2 N.

A particle moves along the x-axis with the potential energy shown. The force on the particle when it is at $x = 4$ m is



1. 4 N.
2. 2 N.
3. 1 N.
4. –1 N.
5. **–2 N.**

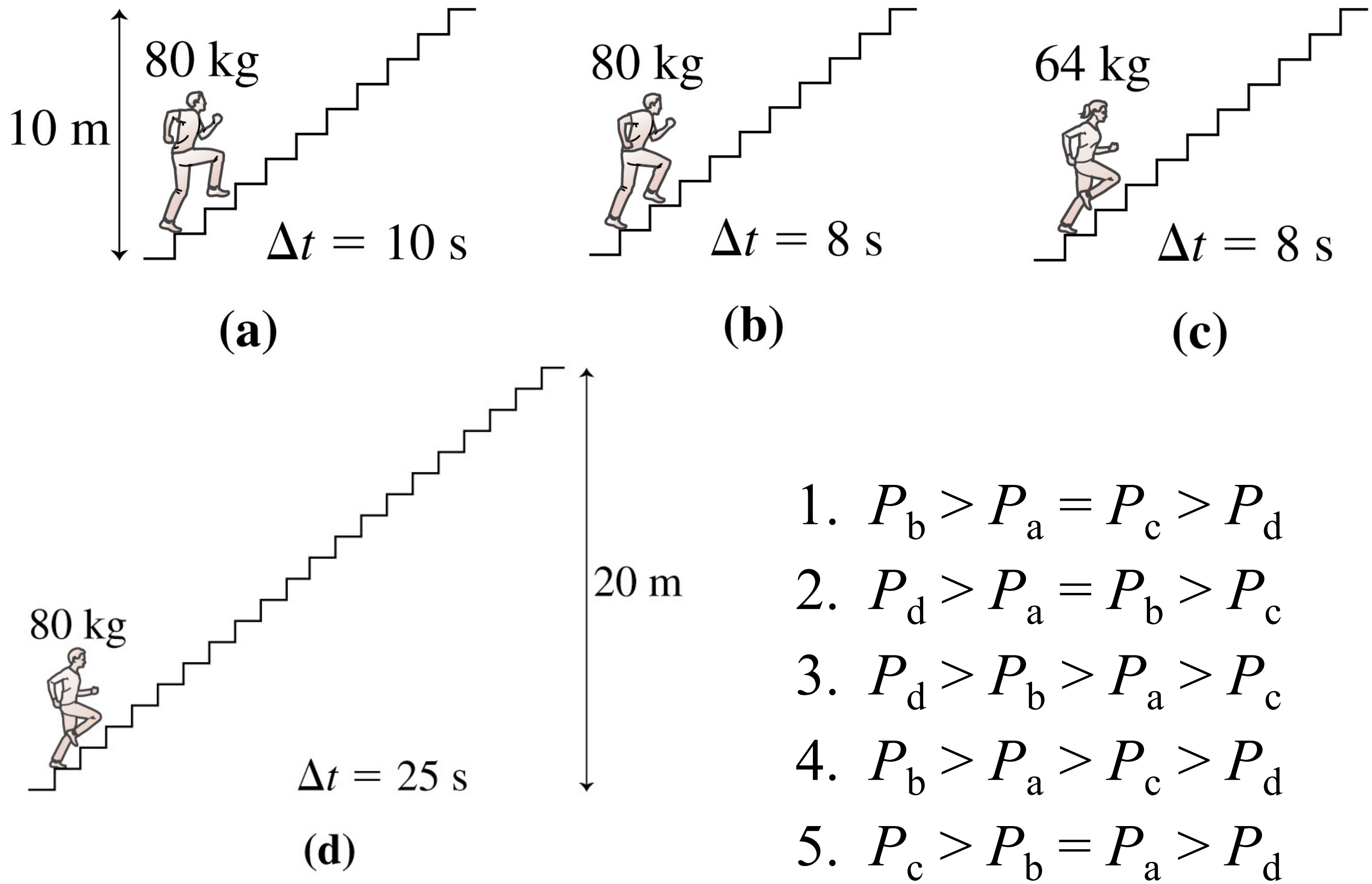
A child at the playground slides down a pole at constant speed. This is a situation in which

1. $U \rightarrow E_{th}$. E_{mech} is conserved.
2. $U \rightarrow K$. E_{mech} is not conserved but E_{sys} is.
3. $K \rightarrow E_{th}$. E_{mech} is not conserved but E_{sys} is.
4. $U \rightarrow E_{th}$. E_{mech} is not conserved but E_{sys} is.
5. $U \rightarrow W_{ext}$. Neither E_{mech} nor E_{sys} are conserved.

A child at the playground slides down a pole at constant speed. This is a situation in which

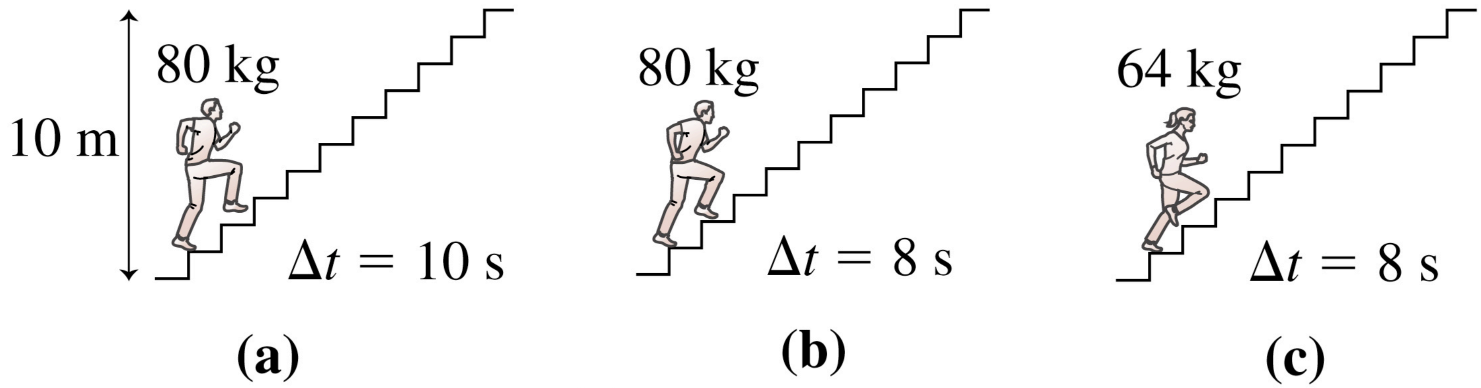
1. $U \rightarrow E_{th}$. E_{mech} is conserved.
2. $U \rightarrow K$. E_{mech} is not conserved but E_{sys} is.
3. $K \rightarrow E_{th}$. E_{mech} is not conserved but E_{sys} is.
4. **$U \rightarrow E_{th}$. E_{mech} is not conserved but E_{sys} is.** ✔
5. $U \rightarrow W_{ext}$. Neither E_{mech} nor E_{sys} are conserved.

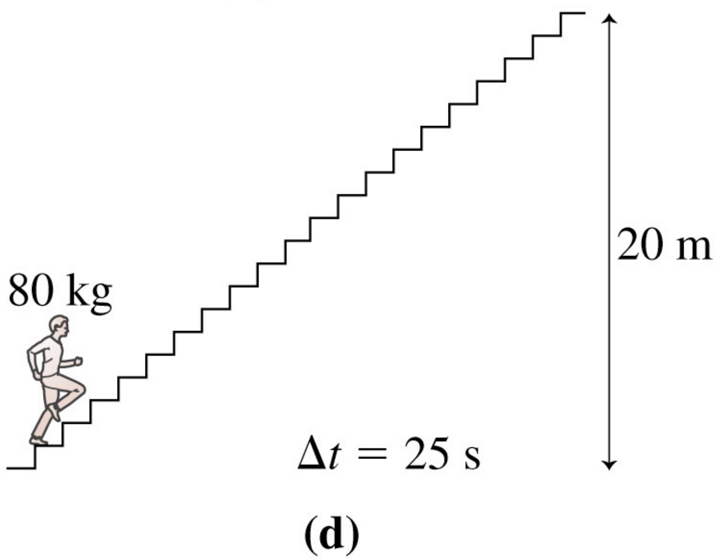
Four students run up the stairs in the time shown. Rank in order, from largest to smallest, their power outputs P_a to P_d.



1. $P_b > P_a = P_c > P_d$
2. $P_d > P_a = P_b > P_c$
3. $P_d > P_b > P_a > P_c$
4. $P_b > P_a > P_c > P_d$
5. $P_c > P_b = P_a > P_d$

Four students run up the stairs in the time shown. Rank in order, from largest to smallest, their power outputs P_a to P_d.





1. $P_b > P_a = P_c > P_d$
2. $P_d > P_a = P_b > P_c$
3. $P_d > P_b > P_a > P_c$
4. $P_b > P_a > P_c > P_d$
5. $P_c > P_b = P_a > P_d$

Chapter 11
Reading Quiz

The statement $\Delta K = W$ is called the

1. law of conservation of energy.
2. work-kinetic energy theorem.
3. kinetic energy equation.
4. weight-kinetic energy theorem.

The statement $\Delta K = W$ is called the

1. law of conservation of energy.
✔ **2. work-kinetic energy theorem.**
3. kinetic energy equation.
4. weight-kinetic energy theorem.

The transfer of energy to a system by the application of a force is called

1. Dot product.
2. Power.
3. Work.
4. Watt.
5. Energy transformations.

The transfer of energy to a system by the application of a force is called

1. Dot product.
2. Power.
3. **Work.** ✔
4. Watt.
5. Energy transformations.