

Work

Read from **Lesson 1** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l1a.html>
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MOP Connection: Work and Energy: sublevel 1

- An **impulse** is a force acting over some amount of time to cause a change in momentum. On the other hand, **work** is a _____ acting over some amount of _____ to cause a change in _____.
- Indicate whether or not the following represent examples of work.


| | Work Done? |
|---|------------|
| a. A teacher applies a force to a wall and becomes exhausted. Explanation: _____ _____ | Yes or No? |
| b. A weightlifter lifts a barbell above her head. Explanation: _____ _____ | Yes or No? |
| c. A waiter carries a tray full of meals across a dining room at a constant speed. Explanation: _____ _____ | Yes or No? |
| d. A rolling marble hits a note card and moves it across a table. Explanation: _____ _____ | Yes or No? |
| e. A shot-putter launches the shot. Explanation: _____ _____ | Yes or No? |

- Work is a _____; a + or - sign on a work value indicates information about _____.
 - vector; the direction of the work vector
 - scalar; the direction of the work vector
 - vector; whether the work adds or removes energy from the object
 - scalar; whether the work adds or removes energy from the object



- Which sets of units represent legitimate units for the quantity *work*? Circle all correct answers.

| | |
|----------------------------|--|
| a. Joule | b. N x m |
| c. Foot x pound | d. kg x m/sec |
| e. kg x m/sec ² | f. kg x m ² /sec ² |



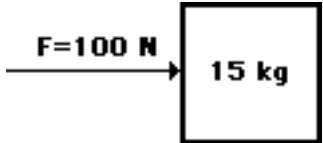
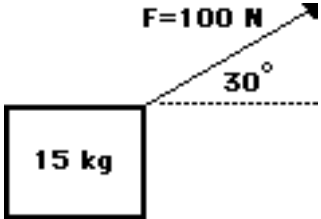
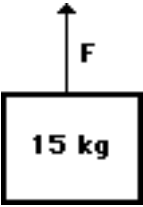
BEWARE

The amount of work (W) done on an object by a given force can be calculated using the formula

$$W = F d \cos \Theta$$

where F is the force and d is the distance over which the force acts and Θ is the angle between F and d . It is important to recognize that the angle included in the equation is not *just any old angle*; it has a distinct definition that must be remembered when solving such work problems.

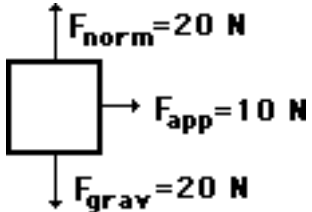
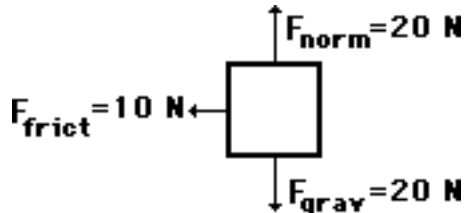
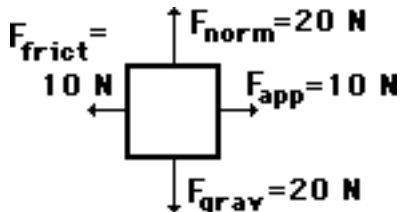
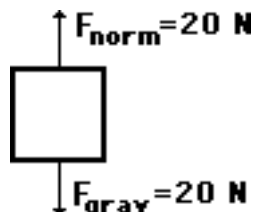
5. For each situation below, calculate the amount of work done by the applied force. **PSYW**

| | | |
|---|---|---|
|  |  |  |
| <p>A 100 N force is applied to move a 15 kg object a horizontal distance of 5 meters at constant speed.</p> | <p>A 100 N force is applied at an angle of 30° to the horizontal to move a 15 kg object at a constant speed for a horizontal distance of 5 m.</p> | <p>An upward force is applied to lift a 15 kg object to a height of 5 meters at constant speed.</p> |

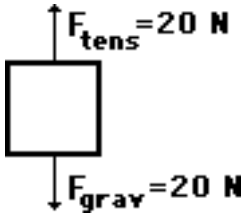
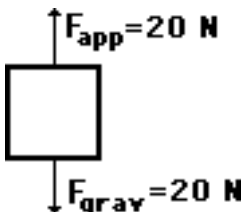
6. Indicate whether there is positive (+) or negative (-) work being done on the object.
- _____ a. An eastward-moving **car** skids to a stop across dry pavement.
 - _____ b. A freshman stands on his toes and lifts a **World Civilization book** to the top shelf of his locker.
 - _____ c. At Great America, a **roller coaster car** is lifted to the peak of the first hill on the Shock Wave.
 - _____ d. A catcher puts out his mitt and catches the **baseball**.
 - _____ e. A falling **parachutist** opens the chute and slows down.
7. Before beginning its initial descent, a roller coaster car is always pulled up the first hill to a high initial height. Work is done on the car (usually by a chain) to achieve this initial height. A coaster designer is considering three different angles at which to drag the 2000-kg car train to the top of the 60-meter high hill. Her big question is: which angle would require the most work?
 _____ Show your answers and explain.

| Angle | Force | Distance | Work |
|------------|-----------------------------|----------|------|
| 35° | $1.15 \cdot 10^4 \text{ N}$ | 105 m | |
| 45° | $1.41 \cdot 10^4 \text{ N}$ | 84.9 m | |
| 55° | $1.64 \cdot 10^4 \text{ N}$ | 73.2 m | |

8. The following descriptions and their accompanying free-body diagrams show the forces acting upon an object. For each case, calculate the work done by these forces; use the format of force • displacement • cosine(θ). Finally, calculate the total work done by all forces.

| Free-Body Diagram | Forces Doing Work on the Object Amount of Work Done by Each Force |
|--|---|
| <p>a. A 10-N force is applied to push a block across a frictionless surface for a displacement of 5.0 m to the right.</p>  | <p>$W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{total}} = \text{_____} \text{ J}$</p> |
| <p>b. A 10-N frictional force slows a moving block to a stop along a horizontal surface after a displacement of 5.0 m to the right.</p>  | <p>$W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{frict}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{total}} = \text{_____} \text{ J}$</p> |
| <p>c. A 10-N forces is applied to push a block across a frictional surface at constant speed for a displacement of 5.0 m to the right.</p>  | <p>$W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{frict}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{total}} = \text{_____} \text{ J}$</p> |
| <p>d. A 2-kg object is sliding at constant speed across a frictionless surface for a displacement of 5.0 m to the right.</p>  | <p>$W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$</p> <p>$W_{\text{total}} = \text{_____} \text{ J}$</p> |

Work, Energy, and Power

| Free-Body Diagram | Forces Doing Work on the Object Amount of Work Done by Each Force |
|--|---|
| <p>e. A 2-kg object is pulled upward at constant speed by a 20-N force for a vertical displacement of 5.0 m.</p>  | $W_{\text{tens}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{total}} = \text{_____} \text{ J}$ |
| <p>f. A 2-kg tray of dinner plates is held in the air and carried a distance of 5.0 m to the right.</p>  | $W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{total}} = \text{_____} \text{ J}$ |

9. When a force is applied to do work on an object, does the object always accelerate? _____
Explain why or why not.
10. Determine the work done in the following situations.
- Jim Neysweeper is applying a 21.6-N force downward at an angle of 57.2° with the horizontal to displace a broom a distance of 6.28 m.
 - Ben Pumpiniron applies an upward force to lift a 129-kg barbell to a height of 1.98 m at a constant speed.
 - An elevator lifts 12 occupants up 21 floors (76.8 meters) at a constant speed. The average mass of the occupants is 62.8 kg.