

## The Physics of Work

### Lesson Notes

#### Learning Outcomes

- What is meant by *work* and how can you know if work is being done on an object?
- What is the equation for work?
- How are *positive* work and *negative* work distinguished from each other?

#### Definition of Work

Work is a means of transferring energy into or out of a system. Work occurs when ...  
... a **force** acts on a moving (or **displaced**) object - either "with it" or "against it" - to cause or resist its motion.

#### Requirements for Work

- There must be a force (**F**)
- There must be a displacement (**d**)
- The **F** must have a component in the same or opposite direction as the **d**.

#### Examples of Work:

- Two students **push** on an out-of-gas car **to move it** towards a gas pump.
- A freshman **exerts a force** on a World Civilization book **to lift it up** towards the top shelf of the locker.
- A book **free falls** off the table and **accelerates to the ground**.

#### Non-Examples of Work:

- A teacher **applies a force** to a wall in an unsuccessful effort to move it.
- A child **pulls on a dog chain** in an effort to pull his dog along the sidewalk but the dog doesn't budge.
- A student sits in her desk, listening attentively to her physics teacher.

#### The Work Equation:

The work done (**W**) depends on three variables:

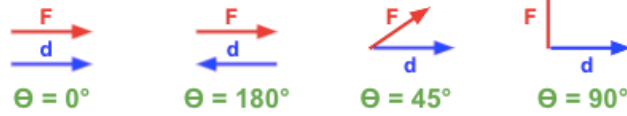
1. The amount of force (**F**).
2. The amount of displacement (**d**).
3. The angle between the force and displacement (**Θ**).

Work = Force • Displacement • Cosine (Θ)

$$W = F \cdot d \cdot \cos(\Theta)$$

In the Work equation, the angle *theta* ( $\Theta$ ) is the angle between the force and the displacement vectors.

Meaning of  $\Theta$ :



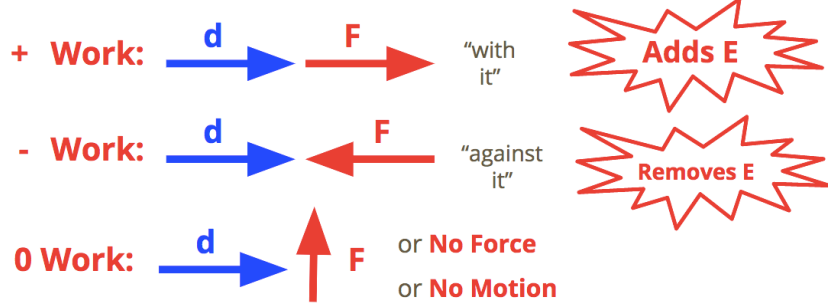
**Unit of Work:**

Standard metric unit = Joule (abbreviated J)

1 Joule = 1 Newton•meter                      or                      1 J = 1 N•m

**Positive vs. Negative Work:**

- Work is a scalar quantity; there is no direction associated with it.
- Yet work can have a positive or a negative value.
- Positive work occurs when there is a component of force in the direction of the motion.
- Negative work occurs when there is a component of force in the opposite direction of the motion.



**When  $\Theta = 90^\circ$**

Consider this:

A waiter carries a tray full of meals above his head by one arm straight across the room at constant speed.

Is work done by the waiter on the tray while moving at constant speed?

A vertical force can never cause a horizontal displacement; thus, a vertical force does not do work on a horizontally displaced object!!

