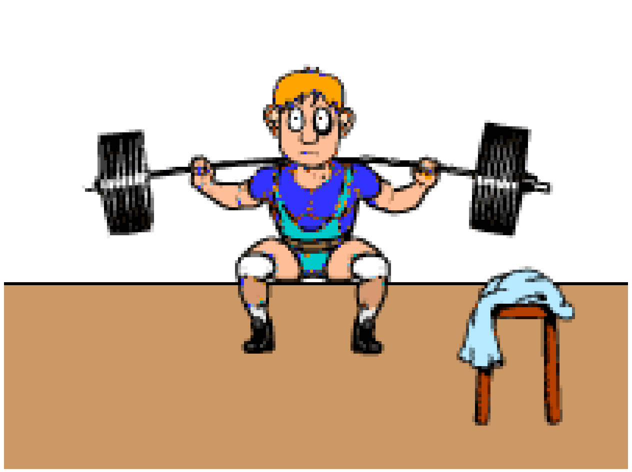
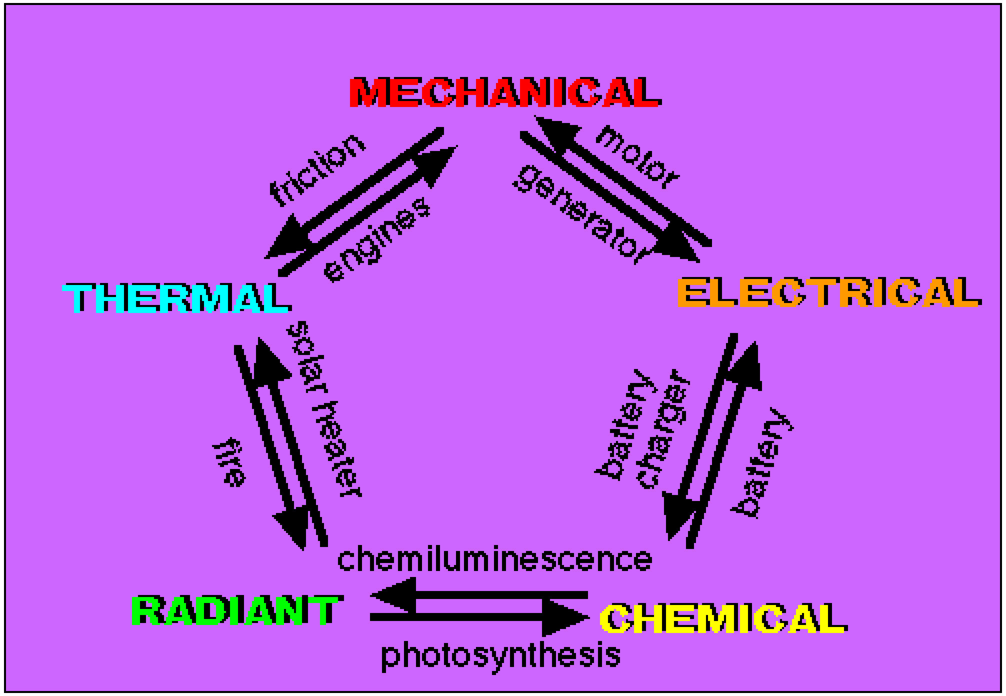
Work, Energy & Power

AP Physics 1



There are many different TYPES of Energy.

- Energy is expressed in JOULES (J)
- 1 J = 1 N*m
- Energy can be expressed more specifically by using the term **WORK(W)**



Work = ***The Scalar Dot Product between Force and Displacement.*** So that means if you apply a force on an object and it covers a displacement you have supplied ENERGY or done WORK on that object.

Scalar Dot Product?

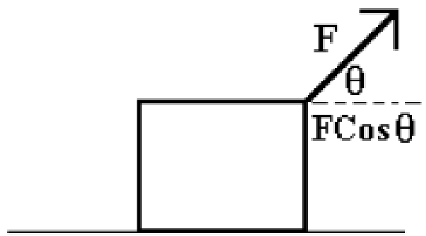
A product is obviously a result of multiplying 2 numbers. A scalar is a quantity with NO DIRECTION. So basically Work is found by multiplying the Force times the displacement and result is ENERGY, which has no direction associated with it.

$$W = \vec{F} \bullet \Delta\vec{x} \rightarrow \vec{F}\vec{x}\cos\theta$$

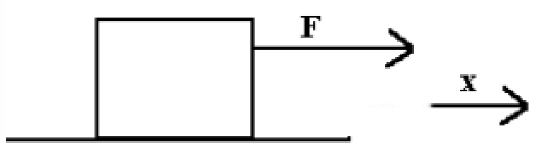
A dot product is basically a CONSTRAINT on the formula. In this case it means that F and x MUST be parallel. To ensure that they are parallel we add the cosine on the end.

- Important points to remember:
  - Friction is parallel to the surface (motion), no matter if the surface is level or inclined.
  - Gravitational force or a component may be parallel to motion.
  - Applied forces or components may be parallel to motion.
  - Angle is measured between force and direction of motion.
- $\cos 0^o = 1$, $\cos 180^o = -1$, $\cos 90^o = 0$

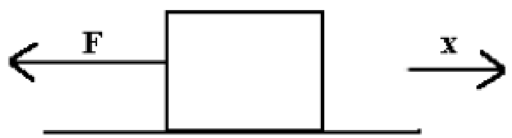
Work



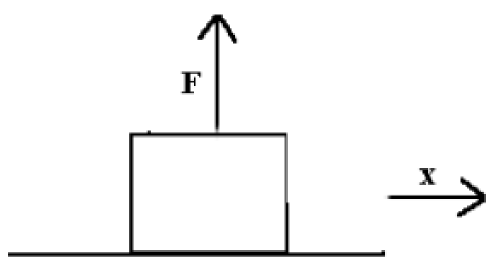
The VERTICAL component of the force DOES NOT cause the block to move the right. The energy imparted to the box is evident by its motion to the right. Therefore ONLY the HORIZONTAL COMPONENT of the force actually creates energy or WORK.



When the FORCE and DISPLACEMENT are in the SAME DIRECTION you get a POSITIVE WORK VALUE. The ANGLE between the force and displacement is ZERO degrees. **What happens when you put this in for the COSINE?**



When the FORCE and DISPLACEMENT are in the OPPOSITE direction, yet still on the same axis, you get a NEGATIVE WORK VALUE. **This negative doesn't mean the direction!!!!** IT simply means that the force and displacement oppose each other. The ANGLE between the force and displacement in this case is 180 degrees. **What happens when you put this in for the COSINE?**



When the FORCE and DISPLACEMENT are PERPENDICULAR, you get NO WORK!!! The ANGLE between the force and displacement in this case is 90 degrees. **What happens when you put this in for the COSINE?**

Example

A 15 kg crate is moved along a horizontal floor by a worker who is pulling on a rope that makes a 30^0 angle above the horizontal. The tension in the rope is 70 N and the crate moves a distance of 10 m. The coefficient of friction between the floor and crate is 0.40.

a) How much work is done by gravity and the normal force?
b) How much work is done by the worker?
c) How much work is done by friction?
d) Is the crate speeding up or slowing down? Justify.

Example

- A box slides down an inclined plane (37^0). The mass of the block is 35 kg, the coefficient of friction between the box and ramp is 0.30, and the length of the ramp is 8 m.

a) How much work is done by gravity?
b) How much work is done by the normal force?
c) How much work is done by friction?
d) What is the net work done?

The Work Energy Theorem

- Doing work on an object transfers energy to that object.
- When energy is transferred the object's motion will change.
- Forces that are applied in the same direction as the motion transfer energy to the object. (working for; increases the velocity)
- Forces that are applied in the opposite direction as the motion transfer energy from the object. (working against; decreases the velocity)

The Work Energy Theorem

- However, to really analyze if the motion will change we must look at the net work.

- If the net work is zero, then the object’s motion is maintained.
  - Various forces may be doing work, but the amount of work and transfer of energy is balanced.
  - No change in an object’s motion when this condition is met.

Work Energy Theorem

- The net work on an object is equal to the object's change in energy.

- $\Delta E = W$
  - Cause/effect: work causes a change in energy

Types of Energy

- Kinetic Energy
  - Energy due to an object's motion
  - $K = \frac{1}{2} mv^2$
  - Velocity has a greater effect on amount of work needed to change an object's kinetic energy than mass.

- Potential Energy
  - Energy due to an interaction between two items. Gravitational, Elastic, Chemical, Electrical. More details forthcoming.

Example W=Fxcosθ

A 70 kg base-runner begins to slide into second base when moving at a speed of 4.0 m/s. The coefficient of kinetic friction between his clothes and the earth is 0.70. He slides so that his speed is zero just as he reaches the base (a) How much work is done on the runner as he slides? (b) How far does he slide? (c) how would the stopping distance change if his velocity were doubled?

$$a)\, W_f = \Delta K$$

$$W_f = 0 - \tfrac{1}{2} m v_o^2 \rightarrow -\tfrac{1}{2}(70)(4)^2$$

$W_f =$ **-560 J**

$$F_f = \mu F_n \rightarrow \mu m g$$

$$= (0.70)(70)(9.8)$$

= 480.2 N

$$W_f = F_f x \cos\theta$$

$$-560 = (480.2)x(\cos 180)$$

$x =$ **1.17 m**

Power

- The rate at which work is done, or the rate at which energy is transferred.

- $\Delta E / t = P$ Unit is a Watt (W) = J/s

- Doing the same amount of work in a shorter time interval requires a larger power output.
- Transferring more energy in the same time interval requires a larger power output.