Work and Energy

Work (in Joules) → $W = Fd$ ← Force (in newtons); distance (in meters)

Work equals force times distance.

Work is applied energy. It takes work to move something and work can make energy. A force has to be in the direction of the motion (the distance) to cause work. For a force at an angle, you have to find the x-portion of the force ($Fx = F\cos\theta$), then multiply by the distance. Or, use this equation: $\mathbf{W = Fd(\cos\theta)}$.

How you know **WORK** is being done:
- There is a **force** (N) or a **distance** (m)
- There is **friction** (a force)
- The objects **slows down** or **speeds up**.

Ex: You push a 1000 newton car 5 meters at 30^o to the ground. How much work did you do?

$F = 1000$ N $d = 5$ m $W = ?$ $\theta = 30^o$	$W = Fd\cos\theta$ $W = (1000\text{ N})(5\text{ m})(\cos 30^o)$ $= 5{,}000\text{ J } (.866)$ $= 4330$ Joules

Potential Energy (in Joules) → $E_p = mgh$ ← mass (in kilograms); height (in meters); acceleration due to gravity (9.8 m/s^2)

Potential energy equals mass times gravity times height.

And since $F_w = mg$, then $E_p = F_w h$

Potential energy is **energy of position**. Any object above the ground or on a ledge has potential energy. This energy comes from the pull of gravity. For our problems use Ep for objects that move up or down.

How you know there is **Potential Energy**:
- An object is **above** the ground
- An object is **dropped or thrown up.**
- An object goes **up or down**.

Ex: How much potential energy does a 4 kg object have that is 5 meters off the ground?

$m = 4$ kg $h = 5$ m $g = 10$ m/s^2 $E_p = ?$	$E_p = mgh$ $E_p = (4\text{ kg})(10\text{ m/s}^2)(5\text{ m})$ $= (40\text{ kgm/s}^2)(5\text{ m})$ $= 200$ Joules

Kinetic Energy (in Joules) → $E_k = (½)mv^2$ ← mass (in kilograms); velocity (m/s)

Kinetic energy equals one-half times mass times velocity squared.

Kinetic Energy is energy of motion. An object has kinetic energy when it is moving, has more when it goes faster, and has none when stopped. An object gets kinetic energy from falling (from Ep) or by being pushed (from Work). It loses Ek by going up (due to gravity), friction, or a negative force.

How you know there is **Kinetic Energy**:
- An object is **moving (velocity)**
- An object **is thrown** or is **falling**
- An object **changes speed.**

Ex: How much kinetic energy does a 10 kg object traveling 3 m/s?

$m = 10$ kg $v = 3$ m/s $E_k = ?$	$E_k = ½mv^2$ $E_k = ½(10\text{ kg})(3\text{ m/s})^2$ $= (5\text{ kg})(9\text{ m}^2/\text{s}^2)$ $= 45$ Joules

Elastic Potential Energy (in Joules) → $PE_{El} = (½)kx^2$ ← spring constant (in N/m); distance stretched or compressed (in m)

Elastic Potential Energy equals one-half times the spring constant times the distance squared.

Elastic Potential Energy comes from springs or elastic objects (like rubber) that can push or pull when stretched or compressed. The spring constant (also called the force constant) will be given. The distance is how far it has been stretched or compressed from its resting position (a Δx).

How you know there is **Elastic Potential Energy**:
- There is a **spring** involved
- An object is **compressed**
- An object is **stretched**

Ex: A spring has a 4 N/m spring constant and a resting position of 0.5 m. If it is stretched to 2.5 m, find its elastic potential energy

$k = 4$ N/m $x_r = 0.5$ m $x_f = 2.5$ m $x = 2$ m	$PE_{el} = (½)kx^2$ $= ½(4\text{ N/m})(2\text{ m})^2$ $= (2\text{ N/m})(4\text{ m}^2/\text{s}^2)$ $= 8$ Joules

Power (in watts) → $P = \frac{W}{t}$ ← Work (in joules), ← Time (in seconds)

Power equals work divided by time.

Putting in the work equation: $P = \frac{Fd}{t}$

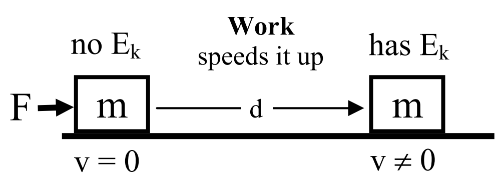
Power is how fast work is done. Something powerful does work faster. Something less powerful can do the same amount of work, but it will take longer.

Ex: You do 120 joules of work in 2 seconds. Find your power.	
W = 120 J t = 2 sec P = ?	P = W/t = 120 J/2 sec = 60 watts

Law of Conservation of Energy: "Energy is never created nor destroyed, just transformed into other forms of energy."

Many questions can be answered using this law. The tricky part is figuring out *which* form of energy to use. Remember: E_k if it's moving; E_p if it is off the ground; PE_{el} if it's elastic; W if there is a force, a horizontal distance, or friction.

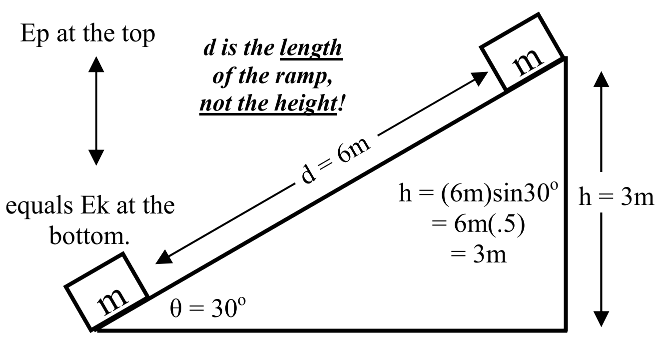
If energy *seems* to be gained or lost, then work must have been done on the object!



Ex. A 2 kg ball going 6 m/s stops in 4 m. Find the force of the friction that stopped it.	
m = 2 kg v = 6 m/s d = 4 m F_k = ? (F_k because it is moving)	It has E_k before because it is moving. Friction does work to stop it. $E_k = W$ $(1/2)mv^2 = Fd$ $(1/2)2(6)^2 = F(4)$ $1(36) = F(4)$ $36/4 = F$ $F = 9$ N

Remember that the height of Ep must be straight up!

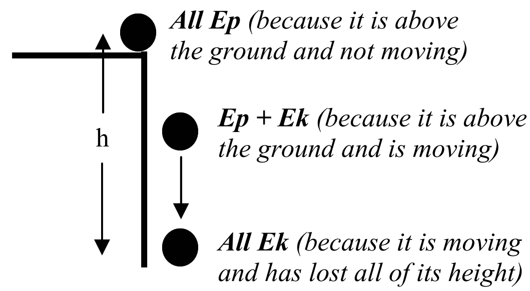
If you know its "h" before, you can find "v" after or if you know "v" before, you can find "h" after.



E_p (at the top) = E_k (at the bottom), *if there is no friction*.
If friction slows it down, then: $E_B = E_A + W_{Friction}$.
And since $W_{Friction} = Fd$, F is $F_{friction}$ and d = 6m (not 3m).

Dropped or Thrown Objects

If an object is dropped, its potential energy (due to height) is transformed into kinetic energy (due to velocity). In the absence of friction these two amounts are equal: Ep = Ek Partway down it will have both Ep and Ek. If you know the height of the object at the top or its velocity at the bottom, you can find the other.



The energy at each of these positions is the same.
The Law of Conservation of Energy says that
$E_{before} = E_{after}$ OR $E_{top} = E_{bottom} = E_{partwaydown}$

Ex. A 4 kg ball is thrown into the air. It reaches a height of 1.8 meters. How fast was it going when thrown into the air?	
h = 1.8 m m = 4 kg g = 9.8 m/s² (use g = 10) v = ?	The Law of Conservation of Energy says that the E_p at the top = E_k at the bottom. $E_p = E_k$ $\cancel{m}gh = (1/2)\cancel{m}v^2$ $gh = (1/2)v^2$ $2gh = v^2$ → $2(10)(1.8) = v^2$ $2(18) = v^2 = 36$ $v = \sqrt{36}$ v = 6 m/s

Ex. A 4 kg ball is dropped from 12 m. How fast is it going halfway down	
h_{top} = 12 m m = 4 kg g = 10 m/s² $h_{1/2}$ = 6 m v = ?	The Law of Conservation of Energy says that the E_p at the top = E_k at the bottom. $E_{top} = E_{halfway\ down}$ $E_p = E_p + E_k$ $\cancel{m}gh_{top} = \cancel{m}g(h/2) + (1/2)\cancel{m}v^2$ $10(12) = 10(6) + (1/2)v^2$ → $120 = 60 + (1/2)v^2$ $60 = (1/2)v^2$ $120 = v^2$ $v = \sqrt{120}$ v = 11 m/s