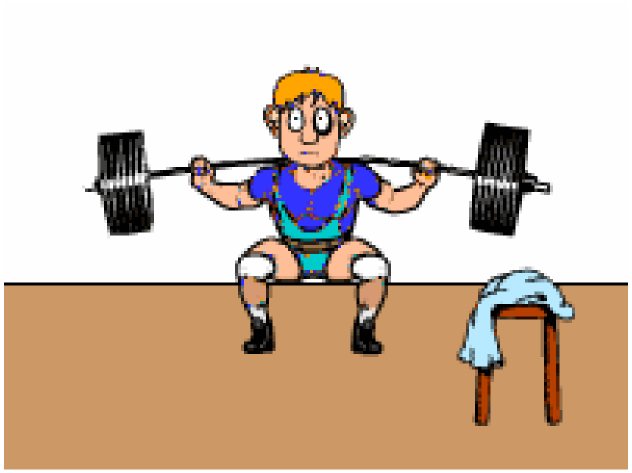
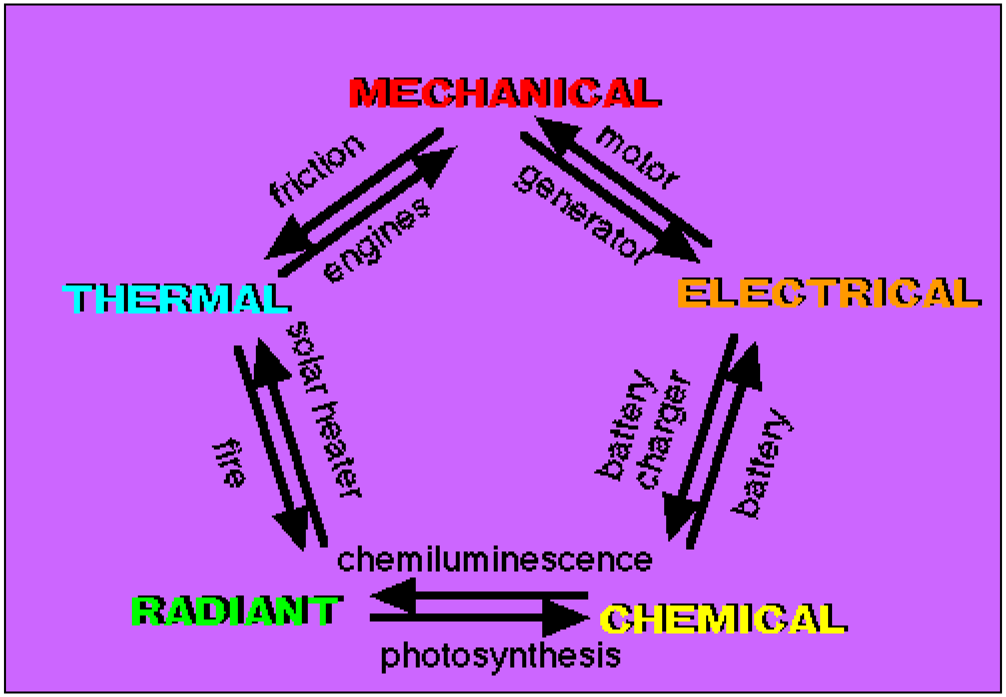
Work, Energy & Power

Honors Physics



There are many different TYPES of Energy.

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

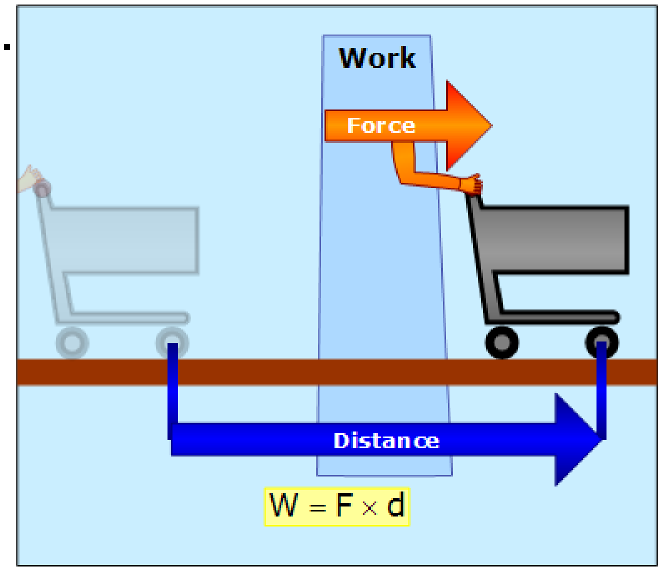


Work = *The Scalar Dot Product between Force and Displacement.*
So that means if you apply a force on an object and it covers a displacement you have supplied ENERGY or done WORK on that object.

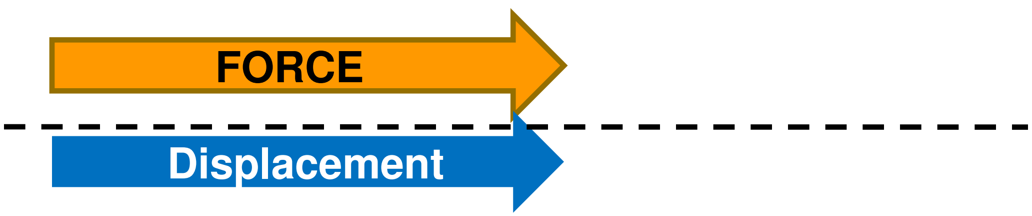
Scalar Dot Product?

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.



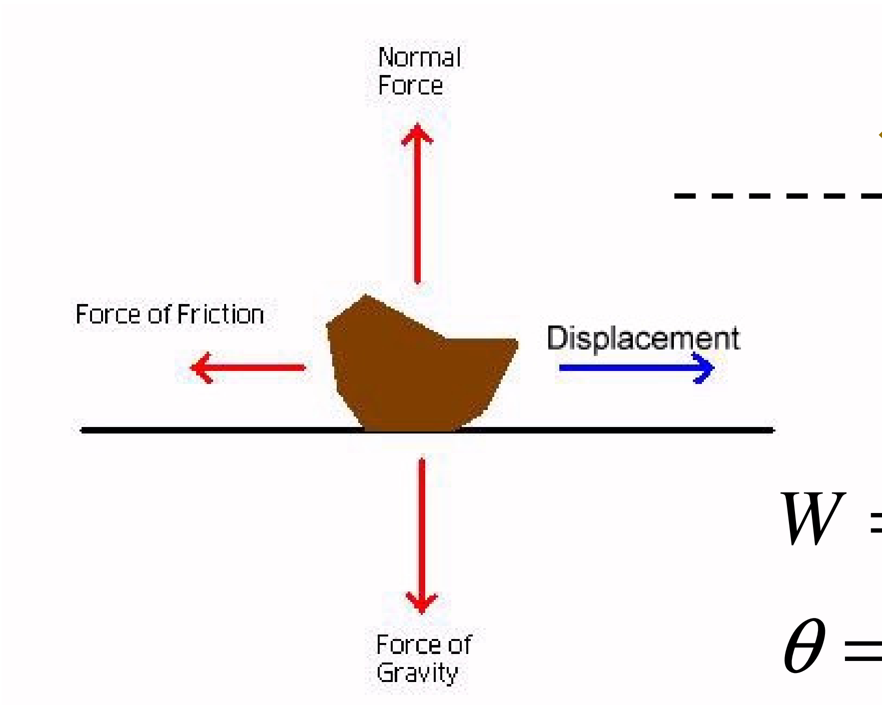
$$W = \vec{F} \bullet \Delta\vec{x} \rightarrow \vec{F}\vec{x}\cos\theta$$

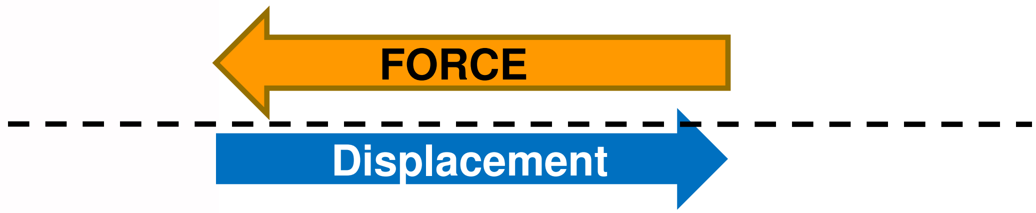
$$\theta = 0^\circ; \cos 0 = 1$$

$$W = \vec{F}\vec{x}$$

Work

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





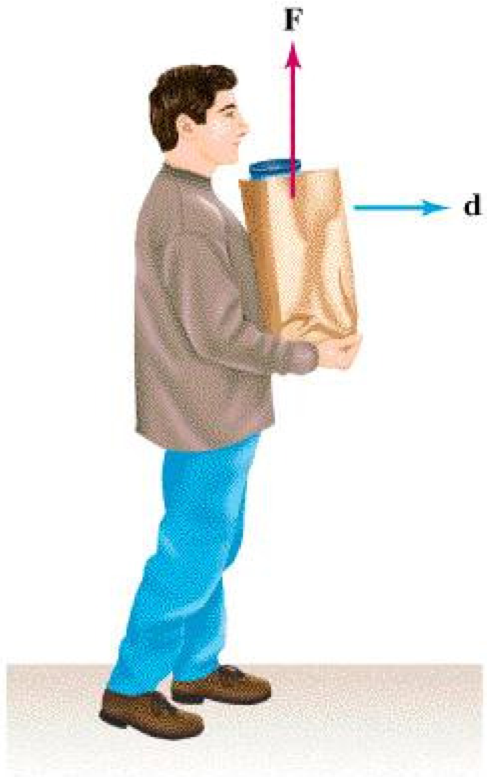
$$W = \vec{F} \bullet \Delta\vec{x} \rightarrow \vec{F}\vec{x}\cos\theta$$

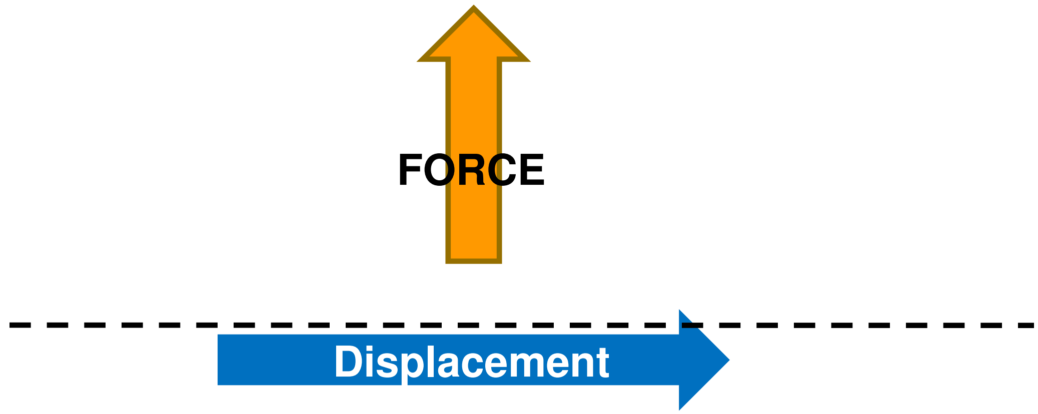
$$\theta = 180^{\circ}; \cos 180 = -1$$

$$W = -\vec{F}_f \vec{x}$$

Work

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





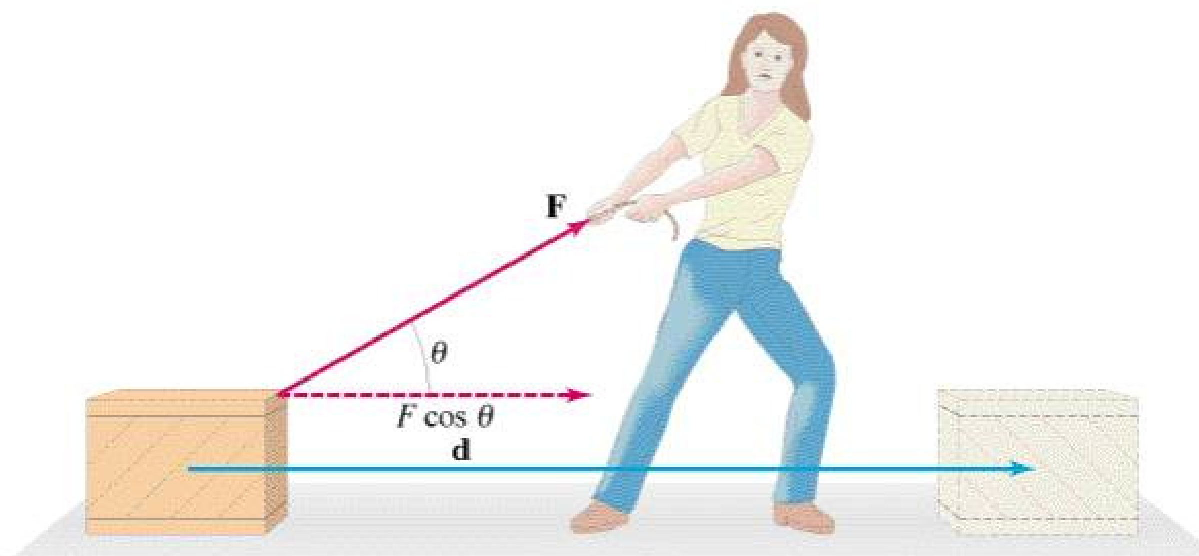
$$W = \vec{F} \bullet \Delta\vec{x} \rightarrow \vec{F}\vec{x}\cos\theta$$

$$\theta = 90^{\circ}; \cos 90 = 0$$

$$W = 0J$$

Work

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



In the figure above, we see the woman applying a force at an angle theta. Only the HORIZONTAL COMPONENT actually causes the box to move and thus imparts energy to the box. The vertical component (FsinΘ) does NO work on the box because it is NOT parallel to the displacement.

The Work Energy Theorem

Up to this point we have learned Kinematics and Newton's Laws. Let 's see what happens when we apply BOTH to our new formula for WORK!

1. **We will start by applying Newton's second law!**
2. **Using Kinematic #3!**
3. **An interesting term appears called KINETIC ENERGY or the ENERGY OF MOTION!**

$$K = \text{Kinetic Energy}$$

$$K = \frac{1}{2}mv^2$$

$$W = Fx \quad , F = ma$$

$$W = max$$

$$v^2 = v_o^2 + 2ax \rightarrow \frac{v^2 - v_o^2}{2} = ax$$

$$W = m\left(\frac{v^2 - v_o^2}{2}\right)$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 \rightarrow \Delta K$$

The Work Energy Theorem

And so what we really have is called the WORK-ENERGY THEOREM. It basically means that if we impart work to an object it will undergo a CHANGE in speed and thus a change in KINETIC ENERGY. Since both WORK and KINETIC ENERGY are expressed in JOULES, they are EQUIVALENT TERMS!

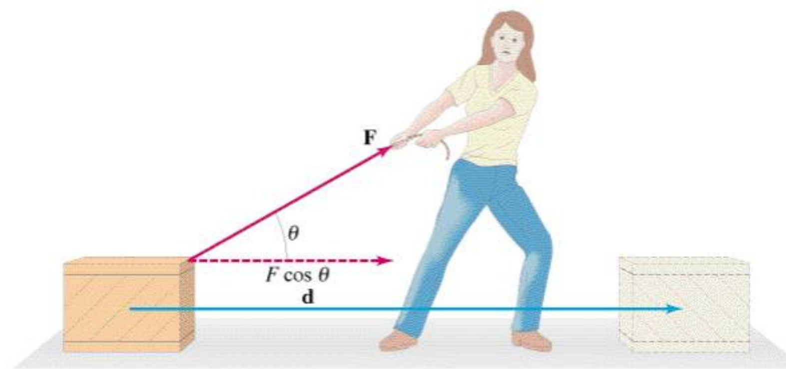
Work-Enegy Theorem

$$W = \Delta K, K = \tfrac{1}{2} mv^2$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2$$

" The net WORK done on an object is equal to the change in kinetic energy of the object."

Example



Suppose the woman in the figure above applies a 50 N force to a 25-kg box at an angle of 30 degrees above the horizontal. She manages to pull the box 5 meters.

a)Calculate the WORK done by the woman on the box
b)The speed of the box after 5 meters if the box started from rest.

$$W = \vec{F}\vec{x}\cos\theta$$

$$W = (50)(5)\cos 30 =$$

216.5 J

$$W = \Delta KE = \frac{1}{2}mv^2$$

$$W = \frac{1}{2}(25)v^2$$

$v =$ **4.16 m/s**

Lifting mass at a constant speed

Suppose you lift a mass upward at a constant speed, $\Delta v = 0$ & $\Delta K=0$. What does the work equal now?

Since you are lifting at a constant speed, your APPLIED FORCE equals the WEIGHT of the object you are lifting.

Since you are lifting you are raising the object a certain "y" displacement or height above the ground.

$$W = Fx, F = mg, x = y(h)$$

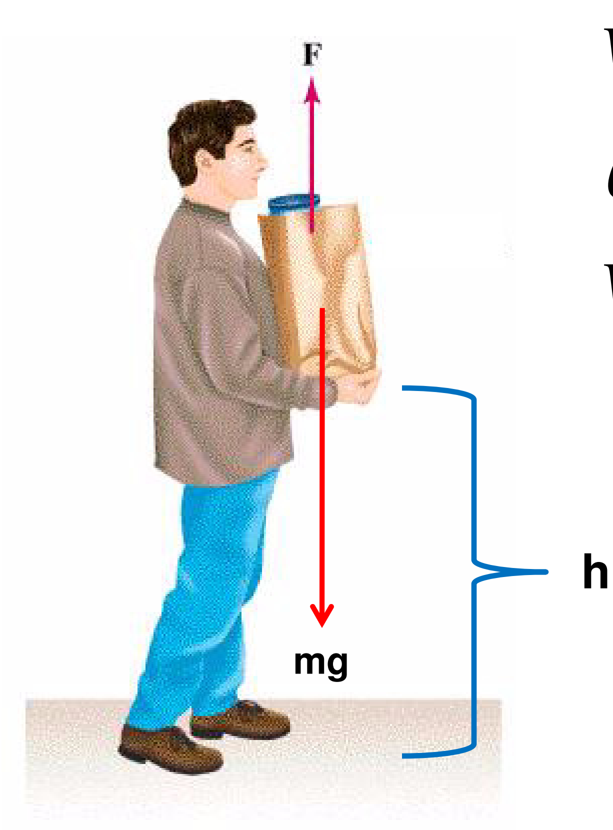
$$W = mgh = U$$

$$U = \text{Potential Energy}$$

$$W=\Delta U=mgh-mgh_o$$

When you lift an object above the ground it is said to have POTENTIAL ENERGY

Potential Energy



$$W = \vec{F}\vec{x}\cos\theta \quad F = mg; x = h$$

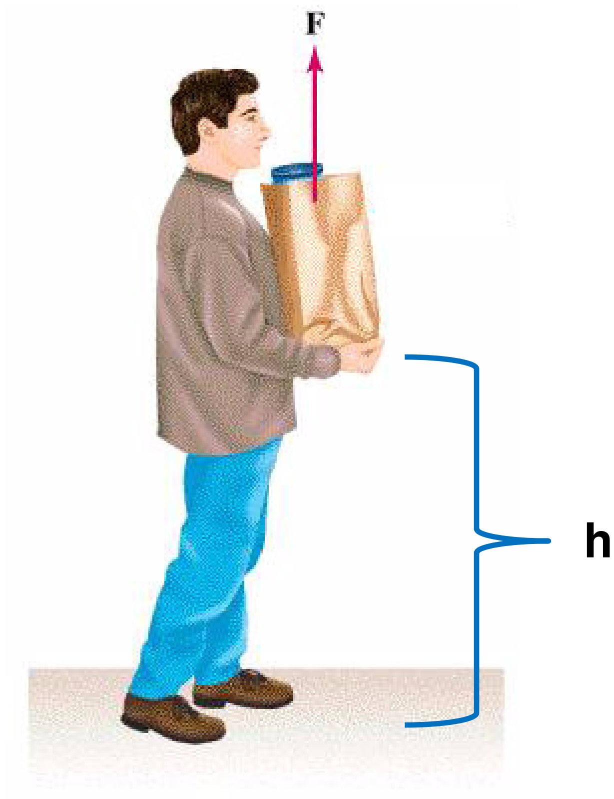
$$\theta = 0, \cos 0 = 1$$

$$W = mgh = PE$$

Since this man is lifting the package upward at a CONSTANT SPEED, the kinetic energy is NOT CHANGING. Therefore the work that he does goes into what is called the ENERGY OF POSITION or POTENTIAL ENERGY.

All potential energy is considering to be energy that is STORED!

Potential Energy



The man shown lifts a 10 kg package 2 meters above the ground. What is the potential energy given to the package by the man?

$$PE = mgh$$

$$PE = (10)(9.8)(2) =$$

196 J

Suppose you throw a ball upward

$$W = \Delta KE = \Delta PE$$

What does work while it is flying through the air?

GRAVITY

Is the CHANGE in kinetic energy POSITIVE or NEGATIVE?

NEGATIVE

Is the CHANGE in potential energy POSITIVE or NEGATIVE?

POSITIVE

$$-\Delta KE = \Delta PE$$

$$-(KE - KE_o) = PE - PE_o$$

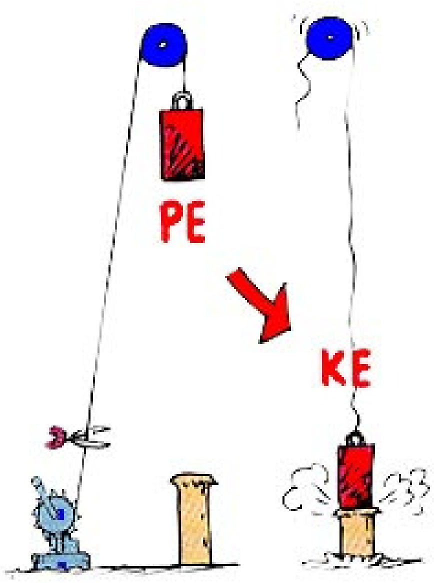
$$-KE + KE_o = PE - PE_o$$

$$KE_o + PE_o = KE + PE$$

$$\sum Energy_{Before} = \sum Energy_{After}$$

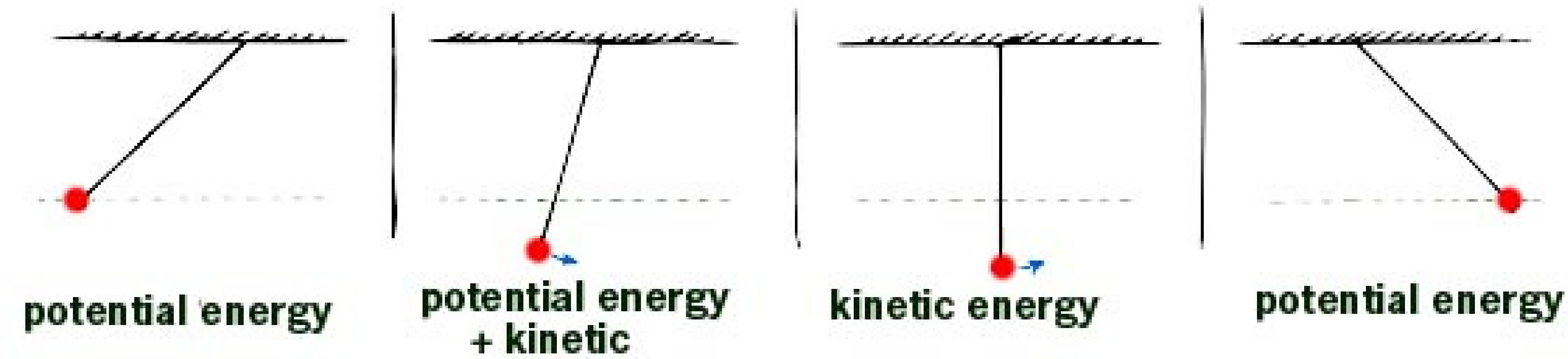
ENERGY IS CONSERVED

The law of conservation of mechanical energy states: ***Energy cannot be created or destroyed, only transformed!***



Energy Before	Energy After
Am I moving? If yes, K_o	Am I moving? If yes, K
Am I above the ground? If yes, U_o	Am I above the ground? If yes, U

Conservation of Energy



A B C D

In Figure A, a pendulum is released from some height above the ground position.

It has only potential energy.

In Figure B, a pendulum is still above the ground position, yet it is also moving.

It has BOTH potential and kinetic energy.

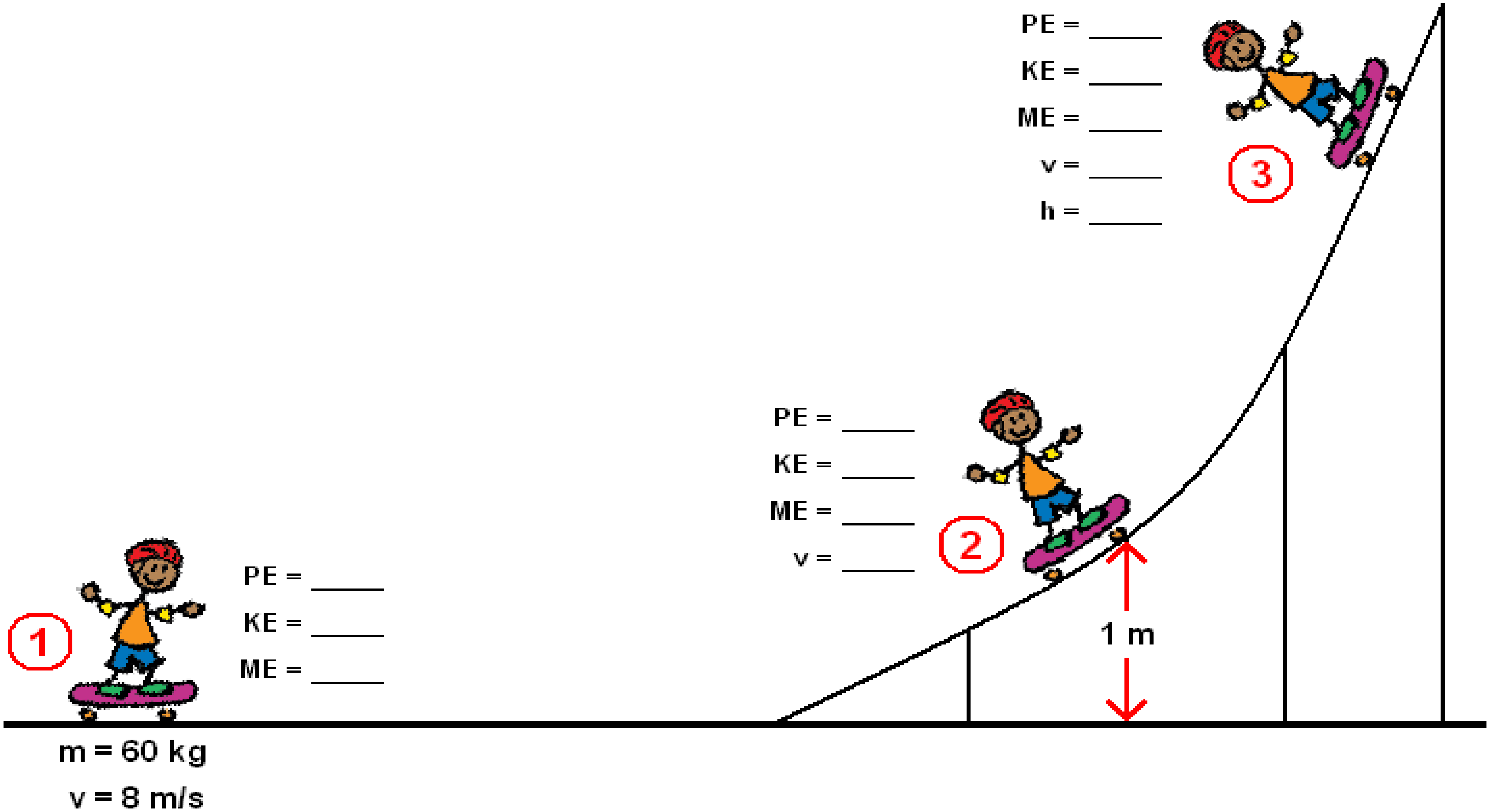
In Figure C, a pendulum is at the ground position, yet it is moving with maximum velocity.

It has only kinetic energy.

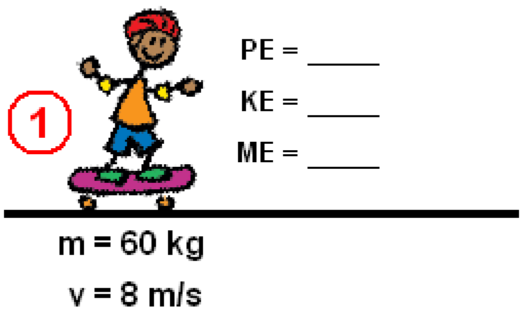
In Figure D, the pendulum has attained the same height above the ground position as A.

It has only potential energy.

Energy consistently changes forms



Energy consistently changes forms



Am I above the ground? **NO, h = 0, U = 0 J**

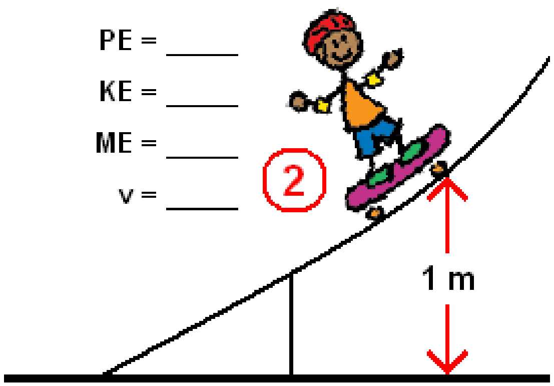
Am I moving? **Yes, v = 8 m/s, m = 60 kg**

$$K = \tfrac{1}{2}mv^2 \rightarrow \tfrac{1}{2}(60)(8)^2$$

$$K = 1920J$$

Position	m	v	U	K	ME (= U+K)
1	**60 kg**	**8 m/s**	**0 J**	**1920 J**	**1920 J**

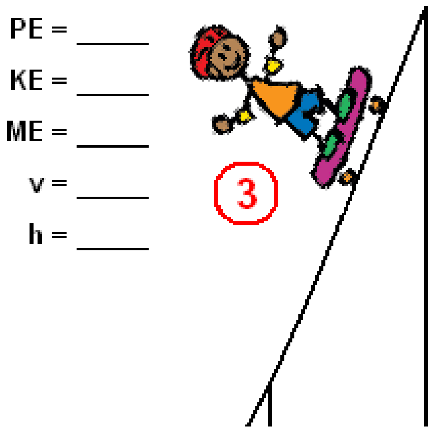
Energy consistently changes forms



Energy Before	= Energy After
K_O	$= U + K$
$1920 =$	$(60)(9.8)(1) + (.5)(60)v^2$
$1920 =$	$588 + 30v^2$
1332	$= 30v^2$
44.4	$= v^2$
v	$= 6.66$ m/s

Position	m	v	U	K	ME
1	60 kg	8 m/s	0 J	1920 J	1920 J
2	60 kg	**6.66 m/s**	**588 J**	**1332 J**	**1920 J**

Energy consistently changes forms



Am I moving at the top? **No, v = 0 m/s**

E_B	= E_A
Using	position 1
K_o	$= U$
1920	$= mgh$
1920	$=(60)(9.8)h$
h	$= 3.27$ m

Position	m	v	U	K	ME
1	60 kg	8 m/s	0 J	1920 J	1920 J
2	60 kg	6.66 m/s	588 J	1332 J	1920 J
3	60 kg	**0 m/s**	**1920 J**	**0 J**	1920 J

Power

One useful application of Energy is to determine the **RATE** at which we store or use it. We call this application **POWER**!

As we use this new application, we have to keep in mind all the different kinds of substitutions we can make.

Unit = WATT or Horsepower

$$P = \frac{W}{t} \rightarrow \frac{Fx}{t} \rightarrow Fv$$

$$P = \frac{mgh}{t}$$

$$P = \frac{\frac{1}{2}mv^2}{t}$$