Work and Energy

What does **Work** mean to you?

What does Energy mean to you?

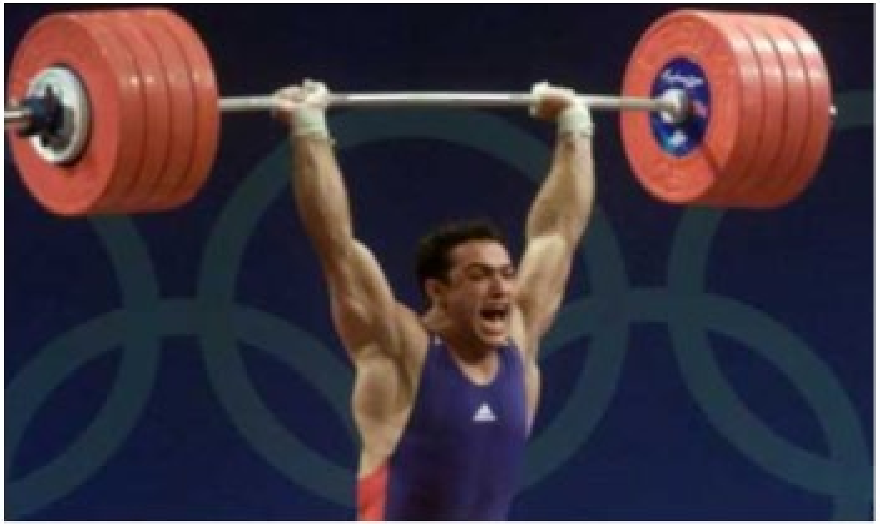
What takes more work?

Lifting a goat or a boat?

*We deduce that ____

What takes more work?

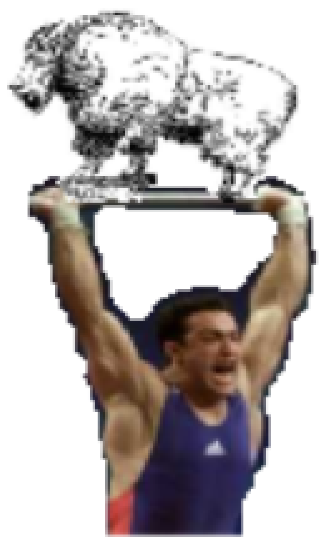
Lifting a mass up to your knees, or above your head?



***We deduce that ___________________________________**

What takes more work?

Lifting a goat on Earth or on the moon?



Earth

Moon

*We deduce that ___________________________________

We can go further and actually derive a formula for work:

We know that work is directly proportional to mass:

$$W \propto m$$

and that work is directly proportional to displacement moved:

$$W \propto \vec{d}$$

and that work is directly proportional to the field strength (an acceleration):

$$W \propto \vec{a}$$

If we put these three proportionalities together, we get

$$W = m\vec{a}\vec{d}$$

or

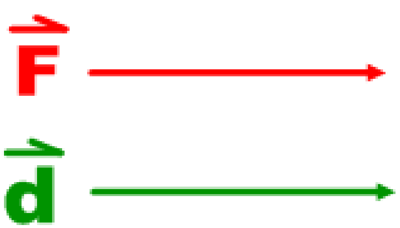
$$W = \vec{F}\vec{d}$$

where:

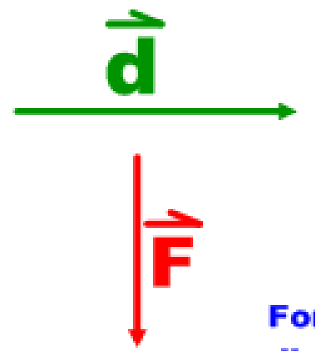
$\vec{F}$ = force $\vec{d}$ = displacement

Work is a scalar, meaning it only has magnitude. However, the direction of the force and displacement are important.

The force must be in the same direction as the displacement in order for work to be done.



Force and displacement in same direction = work done.



Force and displacement in different direction = no work done.

What are the units of work?

The units of force is the newton, the unit of distance is the metre, so it would follow that work is measured in Nm, otherwise called a joule (J).

James Prescott Joule

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

where:

$\vec{F}$ = force $\vec{d}$ = displacement

Ex 1) How much work is done in lifting a 25 kg ______ to a height of 15 m?

Ex 2) How much work is needed, after lifting the ______, to carry it horizontally 250 m?

What is work?

Work takes place anytime energy is transferred. Mathematically, we can write this as

$$W = \Delta E$$

where:

W = work **E = energy**

This is a huge statement.

Energy Review

*Energy is the capacity to do work on an object or the environment, to change either in some way.

*Energy can be converted from one form to another.

*A change in energy is called work

Kinds of Energy

There are many different forms of energy, but none of them are distinct. We simply have different ways of determining how much energy is present in different situations.

$$W = \Delta E$$

***Types of energy:**

- **Mechanical Energy (kinetic and potential)**
- **Nuclear Energy**
- **Energy stored in chemical bonds**
- **Energy produced by electricity**
- **Thermal Energy**

Gravitational Potential Energy

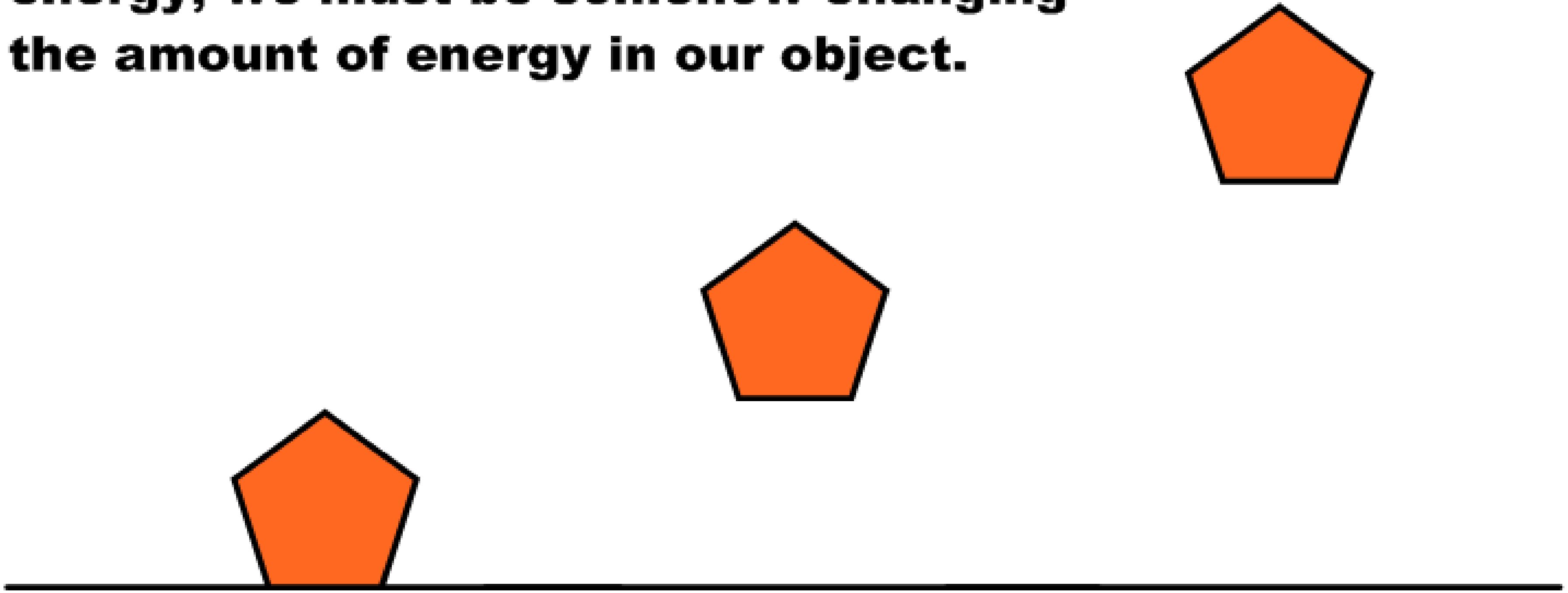
Imagine raising an object to some height *h* above a reference level (say, the ground) which we will call zero.

The force of gravity will be resisting this move (there is a force in the same direction as the distance moved), which means it must take work to elevate this object.

$g = 9.81\ m/s^2$

This is the acceleration due to gravity. It is a constant, and therefore does not count towards sig-digs. It is the rate at which all things fall to the ground. If you take Physics 20 next year, you will learn more about this number.

The higher we move an object, the more work it takes. As work is a change in energy, we must be somehow changing the amount of energy in our object.



h = 0
W = 0

It would also follow that this energy is directly proportional to height.

If there is work done on an object, we say the object has gained some amount of energy. Work means there was a change in energy. The energy gained by raising an object against the gravitational field of the earth is called <u>potential energy</u> (E_p or PE).

Lets derive an equation for E_p:

Hydroelectric Dam in Baie-Comeau, Quebec

$$W = \Delta E$$

$$\vec{F}\vec{d} = \Delta E$$

$$m\vec{g}\vec{d} = \Delta E$$

$$m\vec{g}\vec{h} = E_p$$

As we call the distance moved the height, h, in metres.

Where E_p = potential energy, measured in joules (J).

Reference Levels

The height you measure is always with respect to some reference level. The reference may be the floor, the table, or some other point in space.

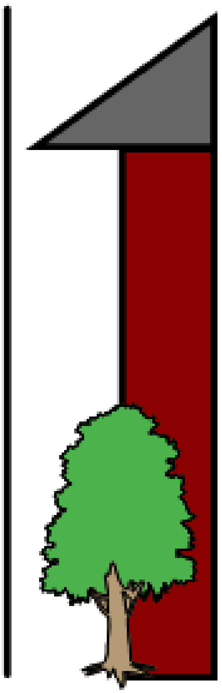
Where we measure from is not terribly important as we are just calculating the change in energy from one point to another.

ex) Young Mr.P (m = 70 kg) climbed ladders for a living. Mr.P climbed a 12 m ladder on one particular job. Calculate Mr.P's PE with respect to:

a) The ground.

b) The roof (11 m above the ground)

c) A tree, 7.0 m below the top of the ladder.



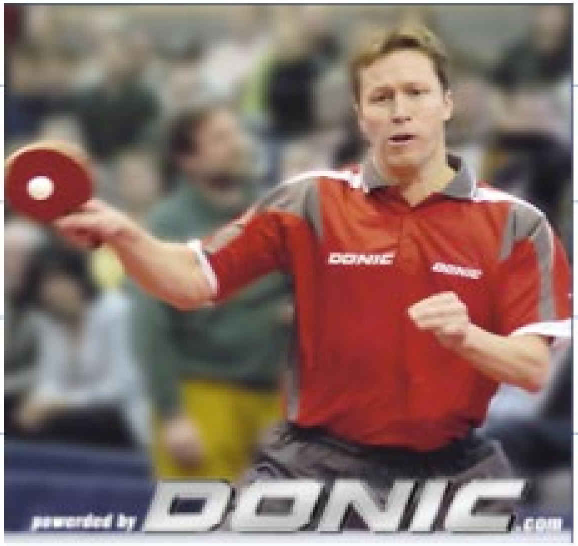
Kinetic Energy

Energy of Motion (kinetic is Greek for "motion")

Kinetic energy is the energy produced by accelerating an object. In P20, we only deal with constant acceleration, and we assume that the object starts at rest ($\vec{v}_I = 0$ m/s).

What has more

energy:



A ping-pong ball...

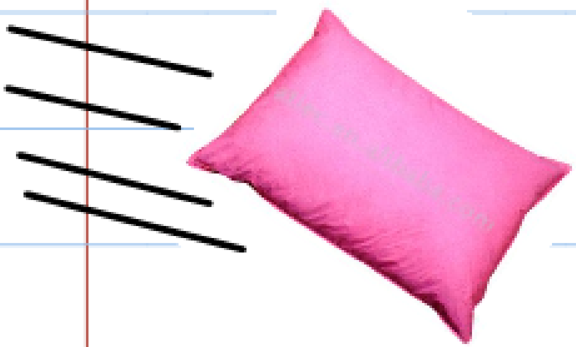
or a cannon ball

moving at the same velocity?

*We deduce that ______________________________

What has more

energy:



A slow moving pillow… or a fast moving pillow

of equal mass?

*We deduce that ___________________________________

From these experiments, we can conclude that:

a) KE must be proportional to mass.

$$KE \propto m$$

b) KE must be proportional to velocity.

$$KE \propto \vec{v}$$

We can now derive an equation for the E_k:

Kinetic Energy

- energy by virtue of speed/motion
- notice the squared term!

$$KE = 1/2m\vec{v}^2$$

Don't forget to square the velocity! (Or square root if solving for velocity.)

Sometimes an object does not start at rest. In these cases, the object already has some kinetic energy, E_{ki}, and then gains some more energy (by having work done upon it) to go to a final kinetic energy, E_{kf}.

The work done on the object causes a change in energy.

This statement is the basic premises of the Work-Energy theorem, which we study in more detail later.

ex) A 10.0 N melon is accelerated uniformly from rest at a rate of 2.50 m/s^2. What is the kinetic energy of this object after it has accelerated a distance of 15.0 m?

ex) An 8.0 kg rock is dropped from a height of 7.0 m. What is the kinetic energy of this rock as it hits the ground?

ex) By what factor must the KE of an object be increased to cause the speed to triple?