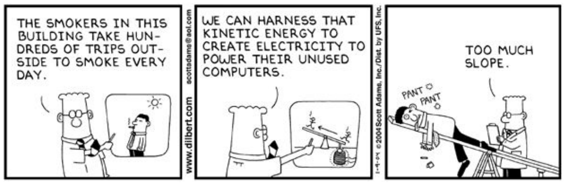
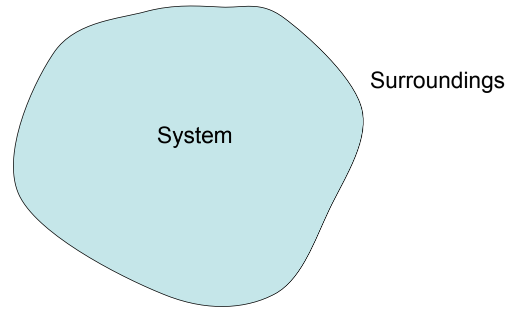
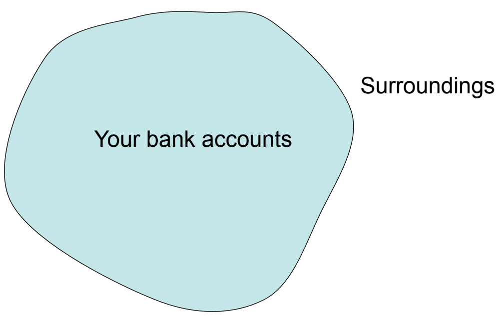


Chapter 5--Energy



Accounting Analogy



Conservation of Energy

$$\Delta E_{system} = \text{sum of energy inputs and outputs to/from the system}$$

Simplest System – a particle

A particle can only have two kinds of energy:

1. Kinetic energy (energy of motion)
2. Rest energy (associated with mass)

The sum of rest energy and kinetic energy is the total energy of the particle, called particle energy.

Particle Energy

A particle of mass m has a total energy E

$$E = \gamma mc^2$$

$$E = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} mc^2$$

It can be broken into two parts: energy at rest (**rest energy**) and energy of motion (**kinetic energy**).

Kinetic Energy - Energy of Motion

Objects that are moving have energy associated with their motion, called **kinetic energy**.

$$K = E - mc^2$$

Units are Joules (J). 1 J = 1 N m

$$K \approx \frac{1}{2}mv^2 \qquad v << c$$

Poll

A particle in a particle accelerator is accelerated from a speed of 1×10^7 m/s to 2.98×10^8 m/s, the kinetic energy of the particle

____ (increases, decreases, remains constant)

and therefore its **change** in kinetic energy is

____ (positive, negative, zero).

1. increases; positive
2. decreases; negative
3. remains constant; zero

Poll

You drive your car at a constant speed of 45 mph for 30 s. During this time interval, the **change** in your kinetic energy is

1. positive
2. negative
3. zero

Poll

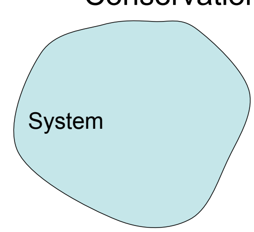
While in your car, you double your speed from 20 mph to 40 mph. Your kinetic energy at 40 mph is

1. the same as your kinetic energy at 20 mph
2. 2 times your kinetic energy at 20 mph
3. 4 times your kinetic energy at 20 mph
4. 8 times your kinetic energy at 20 mph

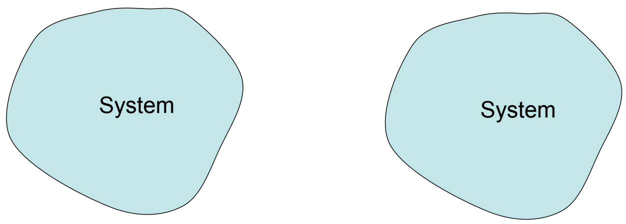
Energy, momentum, and mass

$$(mc^2)^2 = E^2 - (pc)^2$$

Conservation of Energy



Closed and Open Systems



closed system

open system

Work

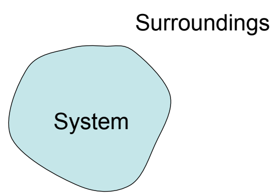
An (external) force on the system by the surroundings does **work** on the system, which either adds energy to the system or removes energy from the system.

Positive work transfers energy **to** the system **from** the surroundings.

Negative work transfers energy **from** the system **to** the surroundings.

Simple System -- A particle

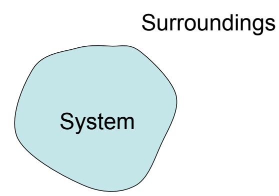
Consider a VERY simple system that only has kinetic energy and rest energy--(i.e. a particle).



Poll

If a force does **positive** work on the system, the kinetic energy of the system

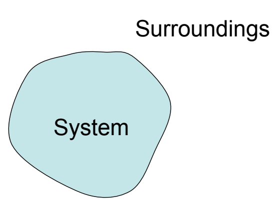
1. increases
2. decreases
3. remains constant



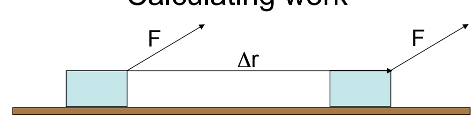
Poll

Consider a VERY simple system that only has kinetic energy. If a force does **negative** work on the system, the kinetic energy of the system

1. increases
2. decreases
3. remains constant



Calculating work



Only the component of the force **parallel** to the **displacement** (of the point of application of the force) does work on the system.

$$W = F_{||}|\Delta\vec{r}|$$

Work by a varying force along a varying path.

Example

During a training run, a person pushes the bobsled with a force of 100 N at an angle of 20° downward (from the horizontal) for a distance of 5 m. How much work did she do on the bobsled?

Example

How much work is needed to speed up an electron from 0.1c to 0.9c?

Example

A non-constant force <2x^2,y,0> N acts through a straight-line displacement <2,0,0 m. What is the work done by the force during the displacement?

Example

What is the work done by a spring on an object attached to the spring as the object moves from x_i to x_f (where x=0 is the position of the object when the spring is unstretched.)

Total Work

If more than one force does work on the system then the **total work** done on the system is the sum of the work done by each force.