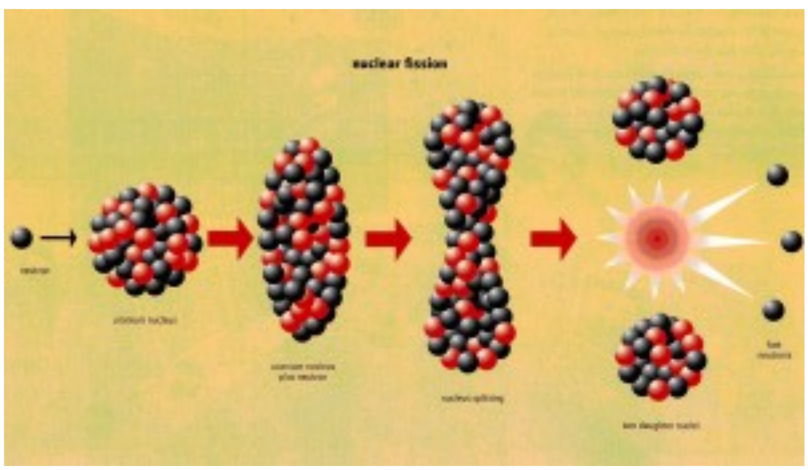
Physics 106 – Everyday Physics **Fall 2013**
Energy and Power Prelab
Media links are provided in each section. If the link doesn't work, copy and paste URL into your browser window. Be patient with the ads – you know, it'youtube (sometimes).

Watch: http://video.pbs.org/video/2220837749//

Introduction:
Energy takes many forms:
• kinetic energy, the energy of motion
• thermal energy the combined kinetic energy of all the molecules in an object and related to temperature

• gravitational energy, which is converted to kinetic energy as something falls
• chemical energy, for example stored and released by gasoline and other fossil fuels as well as food
• nuclear energy, energy stored in the nucleus can be converted into thermal energy to drive turbines in power plants

• electrical energy produced by moving charges



http://investingreenenergy.com/nuclear-power-as-green-energy/

Let start here: when you apply a force over some distance – for example slowly lifting a weight a certain distance *h*, you exert energy (You know this because after a few reps, you get tired.).

We say you do work – work is energy. The amount of work is W=weight x distance - mgh.

The force you apply is the weight mg, and the work you do is the force times the distance. Where does this energy come from? For you, it comes from energy stored in your muscles (the specific energy-storage molecule is ATP), i.e. it comes from energy stored in chemical bonds.

Your muscles convert stored chemical energy into work required to change the gravitational energy of the weight you're lifting.

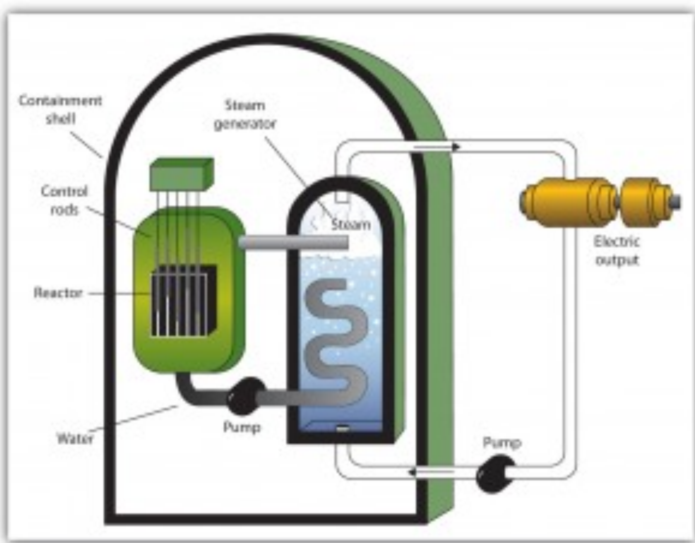
Now if you let go of the object, it falls a distance *h*, and gravity is the force that does the work: $W=mgh$ – the same amount of energy. And after falling the distance *h*, the object is moving and has kinetic energy EQUAL to the work done by gravity. This is an example of gravitational energy being converted to kinetic energy: $1/2mv^2$. This is also an example of one of the most coveted principles of physics: conservation of energy, which means that energy does not appear or disappear from a *closed system* it is converted from one form to another.

Thermal energy or *heat* is the total kinetic energy of all the atoms in an object: $H=1/2\ Nmv$. The motion of an atom can take several forms: 1) the *translation* or linear motion of the atom or its molecule, 2) vibration of the atoms within the molecules and 3) rotation of the molecule. The velocity *v* is the total of all these motions.

The SI unit of energy is Joules (J); however thermal energy is often measured in calories (cal). 1000 calories is a kcal, which is the unit commonly used for the energy content of FOOD: "counting calories" really means counting kcal. Some other common units are BTU, foot-pound and kilowatt-hour.

Power is the *rate* at which energy is transferred or converted from one form to another – usually for useful purposes. The SI unit of power is the watt (W). 1 W= 1 J/s. Thus the kilowatt-hour (the unit of used by US electric companies for billing) is 1000 W x 3600 sec=3.6×10^6 J or 2.6 MegaJoules.

Energy and power can be understood through electric power generation. In the first video, you learned that nuclear fusion results in kinetic energy of the fission products converted into heat which boils or vaporizes water to turn a turbine in an electric generator. Here the energy stored in the bonds in the nucleus is converted into kinetic energy (heat) which is transferred to the water to make steam (also heat) and then into the energy of the moving turbine. The generator is a device that converts motion into electric power. We will learn a lot more about generators, and even make one later in the term.



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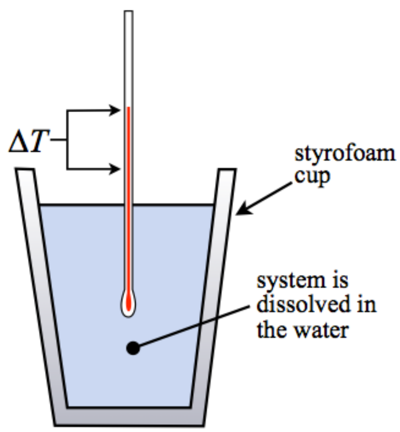
In this experiment you will do experiments with different forms of energy making use of the principle of *calorimetry*. Our calorimeter will be a small volume of water for which we will measure the change in temperature when energy is transferred. This requires understanding a few important principles:

1. When a warmer object comes in contact with a cooler one, the warmer will cool (and the cooler will warm up) until the temperatures are equal – we say the two objects come to *thermal equilibrium* or *equilibrate* So dropping a warm object into water will warm up the water as energy is transferred from the hotter object to the cooler water.

2. The amount of energy transferred Q is proportional to the change in temperature of the water: ΔT Q=C$m\Delta$T. C is a constant for water, and is called the heat capacity. For water, C= 1 cal/gm/°C=4.19 kJ/kg/°C.

3. Conservation of energy requires that for a well insulated system, the heat Q transferred from the hotter object is EQUAL to the heat transferred *to* the cooler object. So (a little algebra): $m_1C_1\Delta T_1 = m_2C_2\Delta T_2$.



coffe-cup calorimeter

http://ch301.cm.utexas.edu/thermo/thermochemistry/thermochem-all.php

4. A calorimeter can measure power, for example the electrical power converted to heat in a resistor. When the resistor is powered, the electrical power is $P=IV$, where I is the current in ampere (amps) and V is the voltage in volts. When the resistor is powered for a time Δt the heat produced is $Q=P\,\Delta t=IV\,\Delta t$.

Physics 106 Fall 2013 Energy and power worksheet

Name:______________ Group # ___ Members: ______________________________

Today you will assemble simple calorimeters and measure the energy deposited in a known amount of water (~100 ml) from different energy sources. The calorimeter consists of the water in a *Styrofoam* cup and a thermometer. Recall (from your prelab reading) that the amount of energy transferred to the H_2O is $Q = mC\Delta T$, with the specific heat C=1 kcal/kg/°C or 1 cal/ml/°C or 4.19 J/ml/°C.

1. Which of the following is NOT a unit of energy? (circle all that apply)

   Joules kW foot-pound N-m calorie N

2. Assemble the calorimeter with 200 ml of H_2O and let it sit long enough that the water temperature *equilibrates*, i.e. doesn't change more than 1°C over one minute. (Actually equilibration takes forever, but we will take this as the time it takes to get to a change of less than 1°C per minute.)

3. Place a HOT brass mass into the calorimeter and note the following:

   Water: $T_{initial}$ ___________ ΔT_{water} __________ Equilibration time: __________
   Brass: $T_{initial}$ ____________ ΔT_{brass} __________
   Water+Brass: T_{final} _______

4. Use your data to determine the specific heat of the brass in units of cal/gm/°C (see prelab for how to do this.)

5. **Electrical energy and power:** Connect a resistor to the power supply using clip-leads with alligator clips. *Do not turn on supply yet!* Immerse the resistor in the calorimeter and secure the leads with tape, and then turn on the supply to ~14 V for 5 min (300 s). Note the current and voltage:
   voltage: _________ V current: ___________ A electrical power: _______ W
   electrical energy _________ J = _________ cal

6. Note the temperature rise of the water: ΔT= _________, and find the energy transferred Q= _________ cal. What do you observe compared to your expectation? (be quantitative)

7. **Gravitational energy → kinetic energy → heat energy.**
   Drop the lead shot. An instructor will help you with the apparatus. Drop the shot at least 20 meters (turn the tube over **25** times) and measure the temperature change. The gravitational energy is *mgh*, where *h* is the total distance dropped. Use $Q = mC\Delta T$ to find C_{Pb} =________ kcal/kg/°C.
8. Ride the exercise bike: once you get going with all lights turned OFF, have a partner turn on one or more. What you experience is the effective power needed to produce 100 W or 200 W of useful power. The table on the back, developed for weight management shows some estimates of the Calories (kcal) burned for various activities. Compare, e.g. cycling or rowing to running: as the power output doubles, does the Calorie rate always double?

Example: 140lb person walking 3mph (20min/mile pace) for 15 minutes = 0.07 x 64.6kg x 15 = 67 calories

Activity	**Power (per kg)** (kcal/kg/min)	**Activity**	**Power (per kg)** (kcal/kg/min)
Racquetball (recreational)	0.07	Cycling (10-12 mph)	0.10
Kayaking (leisure)	0.04	Cycling (19 mph)	0.21
Dancing (general)	0.08	Cycling stationary (50W)	0.05
Golf (walking + bag)	0.09	Cycling stationary (100W)	0.09
Running (12 min/mile)	0.12	Cycling stationary (200W)	0.18
Running (9 min/mile)	0.19	Calisthenics	0.08
Running (7 min/mile)	0.24	Circuit Training	0.14
Running (6 min/mile)	0.28	Weight Training (light)	0.05
Chopping Wood	0.09	Weight Training (hard)	0.10
Mowing Lawn	0.08	Rowing (50W)	0.06
Raking Leaves	0.07	Rowing (200W)	0.21
Weeding/Gardening	0.07	Stretching/Yoga	0.06
Sitting Activities	0.03	Aerobics (low impact)	0.09
Standing (very light)	0.04	Aerobics (high impact)	0.12
Walking (20 min/mile)	0.06	Volleyball (recreational)	0.05
Walking (15 min/mile)	0.08	Bathing/Dressing	0.04
Sweeping	0.05	Swimming (light)	0.10
Washing Car	0.07	Swimming (moderate)	0.14
House Cleaning	0.06	Cooking	0.04
Washing Dishes/Ironing	0.04	Carrying Groceries	0.07
Kissing	0.02		

http://www.acefitness.org/updateable/update_display.aspx?pageID=593