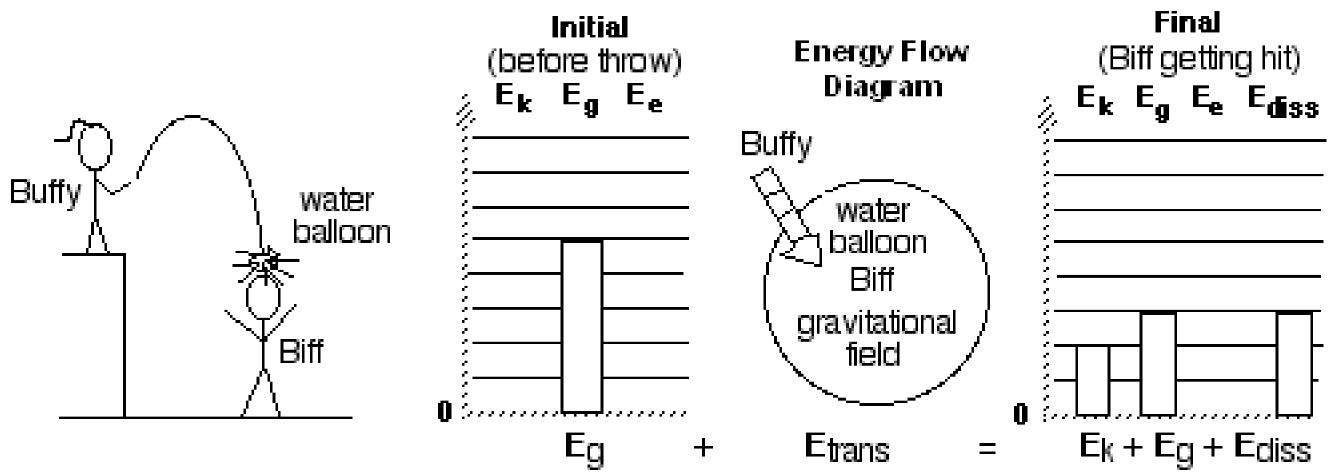
Energy Model

Key Ideas:

Energy is a conserved, substance-like quantity with the capability to produce change in physical systems.

Energy is measured in Joules (J). A Joule is N*m or kg*m^2/s^2.

Energy can be stored and it can be transferred from one storage mechanism to another. This can be represented with an *energy conservation bar graph diagram.* Beginning with the energy flow diagram, the objects involved in energy storage for a particular situation are listed inside the circle. Objects transferring energy into the system or receiving energy from the system are listed outside of the circle. Initial quantities of stored energy are represented with the bars on the left graph, bars of energy entering or leaving the system are shown on the energy flow diagram, and final quantities of stored energy are represented with bars on the left graph.



The total initial energy, plus or minus any energy transferred into or out of the system, must equal the total final energy. This is the first law of thermodynamics.

Perpetual motion devices or “free energy” machines cannot exist: they would have more final energy than initial energy without any energy transferred into the system, violating the first law of thermodynamics.

Energy Storage:

Energy stored in the arrangement of matter in a force field is Potential Energy

Gravitational potential energy: $E_g = mg\Delta h$ (g = gravitational field strength and Δh = height)

Elastic potential energy: $E_{el} = ½\ k\Delta x^2$ (k = spring constant: the stiffness of the spring in N/m)

Chemical potential energy is quantified through many techniques, some of which you studied in chemistry. In this class we will use a substance’s *energy density*, i.e. gasoline: 1.3x10^8 J/gallon.

Energy stored in motion is Kinetic Energy: $E_k = ½\ mv^2$

Kinetic energy of bulk matter (a moving car, flowing water) is easily transferred to other methods of storage. Random kinetic energy of molecules (heat and sound) can rapidly spread out to more molecules and become untransferrable to other storage modes. Unrecoverable internal energy in a system is called $E_{dissipated}$, and incorrectly but commonly referred to as energy "lost." Friction is a mechanism for dissipating the kinetic energy of bulk matter to random molecular kinetic energy of thermal and sonic energy storage. $E_{diss} = F\Delta x$ where the force and the motion are in opposite directions.

Once energy has been dissipated, it cannot be transferred back to useful energy storage mechanisms. This is the second law of thermodynamics.

Energy Transfer:
Energy can be transferred in or out of a physical system in three ways:
A. working – energy is transferred by forces that cause displacements.
    $E_{trans\ by\ working} = F\Delta x$ where the force and the motion are in the same direction
    On a force vs. displacement graph, $E_{trans\ by\ working}$ is the area under the graph.
B. heating – temperature is a measure of the average kinetic energy of the molecules of a substance. Temperature differences between a system and its surroundings cause energy to be transferred from the warmer object to the cooler object.
C. electromagnetic radiation (such as visible light, microwaves, ultraviolet light and infrared light) can transfer energy. Matter loses kinetic energy as it emits electromagnetic radiation and gains kinetic energy when absorbing electromagnetic radiation.

Power is the rate of energy transfer, measured in Watts. A Watt is a Joule of energy transferred per second. A 60 Watt light bulb transfers 60 Joules of electrical potential energy to light and heat each second.

Energy and Society:
Earth has finite resources: air, water, fossil fuels, arable land, etc . . .
The trend of increasing consumption of finite resources is unsustainable.
Population growth is the most significant factor increasing resource consumption.

Useful Numbers:
1 horsepower (hp) is equal to 746 Watts

A kilowatt-hour (kWh) is a kW x 1 hour or 3,600,000 Joules. One kWh costs an average of 7.6 cents in the U.S.

A food Calorie is 4186 Joules. One Calorie is the amount of energy required to raise the temperature of 1 kg of water 1˚Celsius.

1 British Thermal Unit (BTU) is the amount of energy required to raise the temperature of 1 pound of water 1˚Farenheit. 1 BTU = 1055 Joules.

1 Quad = 1 Quadrillion BTU's = 10^{15} BTU's. This is a useful unit for world energy use.