Work, Power and Machines.

Work is the amount of energy required to move an object, or released by the motion of an object, a certain distance; motion must be in the same direction of the applied force. If work is done on an object by its surroundings, the work is positive. When work is done by an object on its surroundings, the work is negative. The sign of the work indicates the direction of motion of energy.

The **Work-energy theorem** states that work equals the change in kinetic energy. This idea can also be manipulated to include potential energy as well. When an object is placed a certain height above the ground it has gravitational potential energy. When allowed to fall gravity does work on the object, causing it to fall. As the object speeds up it gains kinetic energy as it loses an equal amount of potential energy. So:

$\mathbf{W = \Delta KE}$ $\mathbf{\Delta KE = -\Delta PE}$ (the negative indicating loss of energy)

From this we can determine that **work** is the applied force multiplied by the distance traveled, both in the same direction:

$$W = F \cdot \Delta X \text{ or } W = F \cdot d$$

UNITS of energy and work

USCS --> ft·lb; calorie; Calorie

SI --> Newton-meter (N·m) or Joule (J)

POWER - The rate at which work is done.

$$P = \frac{W}{\Delta t}$$

The SI unit of power is the **watt (W)** which is simply a **Joule/second**

Machine Language:

Any device that makes work easier to perform is known as a **machine**. A **simple machine** uses only one movement. A machine makes work easier by altering the force (magnitude or/and direction) that must be applied to the situation in order to get the same amount of work out of the machine as you would without the machine.

The force applied to the machine is called the **input** or **effort force**. The force applied by the machine is called the **output** or **resistance force**.

For example to raise a **100 N** box 1 m, **100 J** of work must be done. If you were to lift the box straight up, you would have to exert **100 N** of **effort force** to move the **100 N resistance force** of the box's weight. If you used a machine such as a ramp, you may be able to reduce your **effort force** to **50 N** as you push the box up the ramp, but you would have to push the box **2 m**. This is because **100 J** of work is still required to get the job done. The machine just makes it easier (in terms of force you must exert.)

Work input is the amount of work (energy) that goes into the machine. This work comes from the force that is applied to the machine, effort force.
Work output is the amount of work (energy) that comes out of the machine. This work is used to overcome the resistance force.
Machines cannot increase the amount of work that is put into them. This would violate the *law of conservation of energy*. The work input must always be larger than or equal to the work output in order for the machine to work properly. If the work input equals the work output the machine is said to be ideal, or 100% efficient.

The **efficiency** of a machine is defined as the ratio of work output to work input.

$$\mathrm{EFF} = \frac{W_{out}}{W_{in}} \cdot 100$$

The closer the work out is to the work in, the more efficient the machine is.

Another important measure of a machine is the number of times it changes the effort force. This is called the **mechanical advantage** of the machine.

$$\mathrm{MA} = \frac{\vec{F}_r}{\vec{F}_e}$$

Simple Machines

There are two main categories of simple machines: the inclined plane and the lever. All simple machines fall into one of the two categories. With each type of machine is an equation for its ***ideal* mechanical advantage (IMA)**, a 100% efficient machine. An ideal machine assumes the absence or neglecting of friction and other extraneous forces. The basic equation for **IMA** is

$$\mathrm{IMA} = \frac{d_e}{d_r}$$

Where $\mathbf{d}_e$ is the effort (input) distance and $\mathbf{d}_r$ is the resistance (output) distance, yes, it rhymes.

Look at each of the machine specific IMA equations below and identify how each part corresponds with the basic IMA equation.

Refer to this Power Point for some detailed diagrams of each machine.

Mechanical Advantage Formulas

Inclined planes

The ramp: an incline used to assist lifting

$$IMA = \frac{\text{length of ramp}}{\text{height of ramp}}$$

The wedge – Double incline that may move

The screw – incline (threads) wrapped around a post

Levers

$$IMA = \frac{\text{effort arm}}{\text{resistance arm}}$$

also written as: $IMA = \frac{d_i}{d_o}$

The lever: 3 classes of levers

1) **First class** - Fulcrum is between effort and resistance forces: shovel.
2) **Second class** - Fulcrum at one end, effort force is at other end, resistance in middle: Wheelbarrow.
3) **Third class** - Fulcrum at one end, resistance force at other end, effort in the middle: Rake, broom.

Wheel and axle;

$$IMA = \frac{(wheel\ radius)}{(axle\ radius)}$$

Gear:

$$IMA = \frac{output}{input}$$

Pulley: the pulley is the fulcrum, the strands are the effort and resistance arms.

IMA = number of supporting strands