Chapter Ten: Energy, Work, and Simple Machines
Section 2: Machines

Machine: a device that makes tasks easier by changing either the magnitude or the direction of the applied force

W_i = Work input – the work that you do
W_o = Work output – the work that the machine does

The machine is not a source of energy.

- The machine cannot receive more energy than what you put into the machine
- The machine only aids in the transfer of energy from you to the object (Ex. you opening a pop top with an opener)

Effort force (F_e): the force exerted by a person on a machine

Resistance force (F_r): the force exerted by the machine

Mechanical advantage (MA): the ratio of resistance force to effort force

$$MA = F_r/F_e$$

Ideal mechanical advantage (IMA): an ideal machine transfers all energy from person to machine

- A machine can increase force, but it cannot increase energy
- output work (W_o) = input work (W_i)
- Ratio of the displacement of the effort force to the displacement of the load
- IMA = d_e/d_r

Efficiency (*e*): of a machine is defined as the ratio of output work to input work

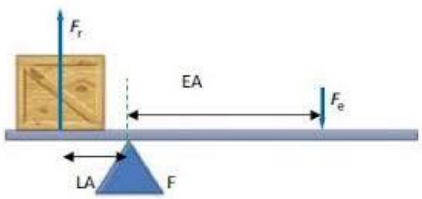
- Energy removed from the system through heat or sound means that there is less output work from the machine
- Science – the ratio of output work to input work
- Common usage – production without waste

Efficiency = *e* = W_o/W_i x 100 = MA/IMA x 100

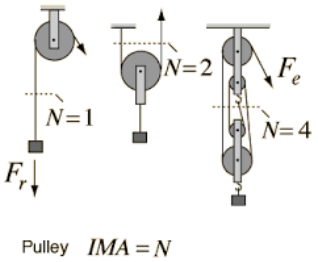
Efficiency = *e* = $W_o/W_i = F_r d_r/F_e d_e$

Simple Machines: makes work easier by chanig the direction or magnitude of the force…to calculate the IMA

1. Lever
    a. IMA = L_e/L_r
    b. L_e = length of the effort arm
    c. L_r = length of the resistance arm

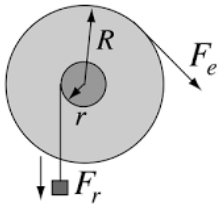


2. Pulley
    a. IMA = number of supporting ropes



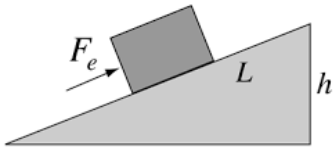
Pulley $IMA = N$

3. Wheel and axle
    a. IMA = r_e/r_r



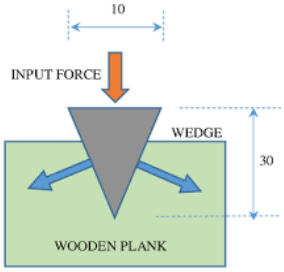
Wheel and axle $IMA = \frac{R}{r}$

4. Inclined plane
    a. IMA = L/h
    b. L = length of incline
    c. h = height of incline

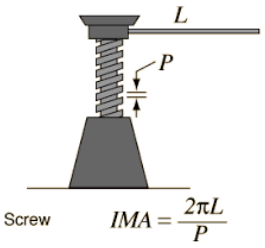


Incline $IMA = \frac{L}{h}$

5. Wedge
    a. IMA = L/W
    b. L = length of wedge
    c. W = width of wedge



6. Screw
    a. IMA = 2πr/d



Compound machine: a machine consisting of two or more simple machines linked in such a way that the resistance force of one machine becomes the effort force of the second machine

- Example – scissors (wedge and lever) and wheelbarrow (lever and wheel & axle)
- To calculate the mechanical advantage of a compound machine
    - $MA = MA_{machine1} \times MA_{machine2}$

- To calculate the ideal mechanical advantage of a wheel-and-axle machine, use the ratio of the distances moved
    - IMA for a bicycle
        - $IMA = \frac{\text{pedal radius}}{\text{wheel radius}}\left(\frac{\text{rear gear radius}}{\text{front wheel radius}}\right)$

When climbing a hill, the rider increases the IMA to increase the force that the wheel exerts on the road. To increase the IMA, the rear gear radius needs to be larger compared to the front rear radius. However, the rider must rotate the pedals through more turns for each revolution of the wheel.

Simple machines, in the form of levers, give humans the ability to walk and run. Four basic parts for each system:

1. A rigid bar (bone)
2. Source of force (muscle contraction)
3. Fulcrum or pivot (movable joints between bones)
4. Resistance (weight of the body or an object being lifted or moved)

Lever systems of the body are not very efficient, and mechanical advantages are low. This is why walking and jogging require energy (burn calories) and help people lose weight.