10.2
Machines

Machine: a tool used to make work easier.

- Machines make work easier to do by providing some trade-off between the force applied and the distance over which the force is applied.
  - They change the **size** or the **direction** of the applied force.
  - EX: Bottle opener

Terms and Equations

- **Effort Force** (F_E) – the force applied to a machine
- **Effort Distance** (D_E) – the distance through which the machine moves
- **Work Input** (W_I) – work done on a machine

$$W_I = F_E \times D_E$$

- **Resistance Force** (F_R) – the force applied by the machine
- **Resistance Distance** (D_R) – the distance through which the object moves
- **Work Output** (W_O) – work done by a machine

$$W_O = F_R \times D_R$$

Machines

- Machines can multiply force.
- Machines do not multiply work.
- Work output cannot be greater than work input.
- Ideal Work: $W_I = W_O$

- **Mechanical Advantage** (M.A.) – the number of times a machine multiplies the effort force.

$$M.A. = F_R / F_E$$

Mechanical Advantage = F_R/F_E

- M.A. equal to 1:
  - machine does not multiply the effort force, it just changes the direction of the effort force.
  - EX: Simple pulley
- M.A. is less than one:
  - machine increases the distance an object is moved.
  - EX: Hockey stick
- M.A. greater than one:
  - machine increases the force applied by the person.
  - EX: Car jack

Mechanical Advantage:

$$M.A. = F_r / F_E$$

$$\text{Ideal } M.A. = d_E / d_r$$

Efficiency of a machine:

- The comparison of work output to work input
- Expressed as a percent
- Can never be greater than 100%
- Friction reduces the efficiency of a machine. Anything that reduces friction such as keeping a machine well lubricated increases efficiency.

Efficiency of a machine

% Efficiency = W_O / W_I x 100 = MA/IMA x 100

- Example: What is the efficiency of a machine where work input is 200 J, and work output is 100 J ?
- % Efficiency = 100 J / 200 J x 100 = 50%

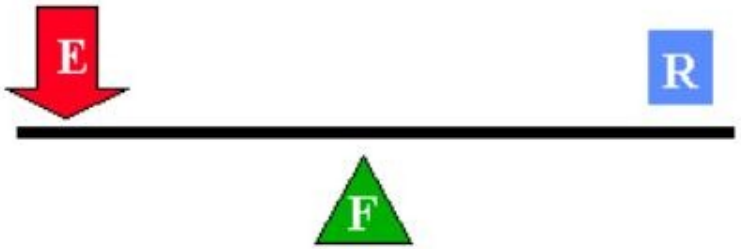
Compound Machine

- A machine consisting of two or more simple machines linked in such a way that the Fr of one machine becomes the effort force of the second.
  - EX: Bike p.270
- MA/IMA of a compound machine is the product of the MAs/IMAs of the simple machines.

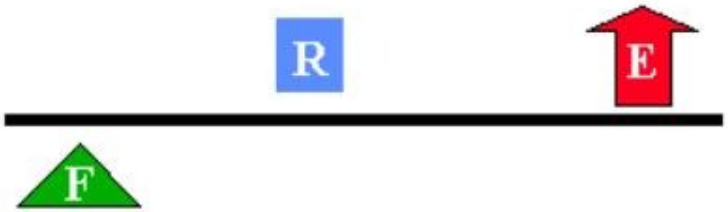
Lever

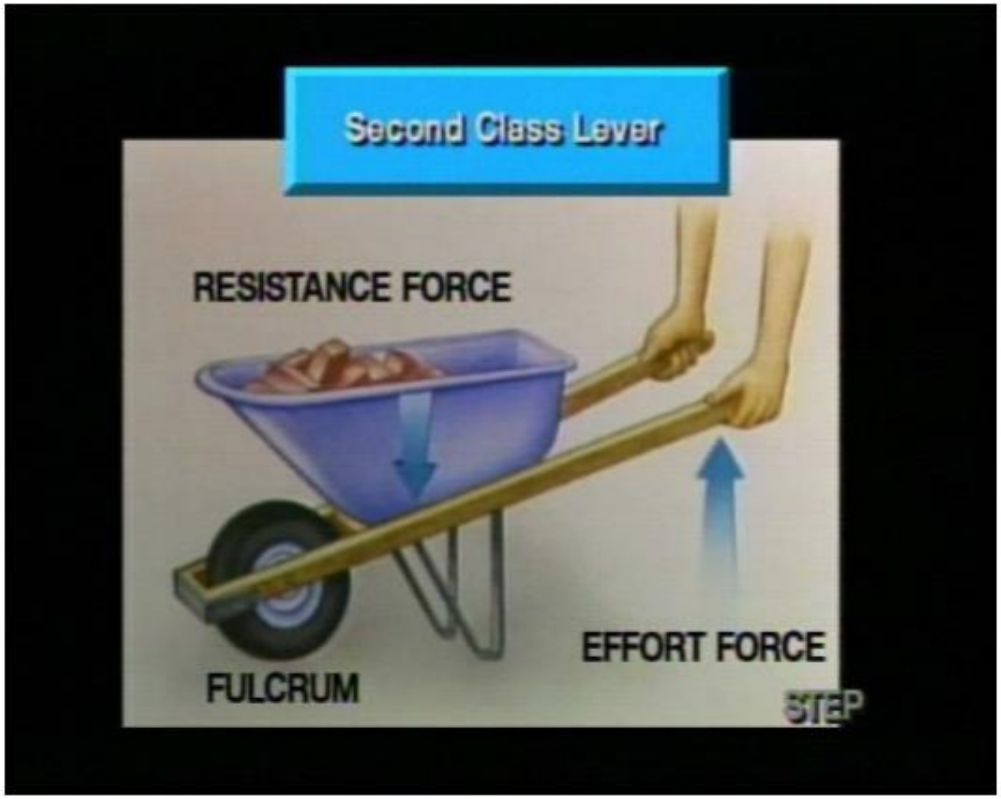
- A lever is a stiff rod that rotates around a pivot point.
  - Depending on where the pivot point is located, a lever can either change the force applied or the distance over which the force is applied.

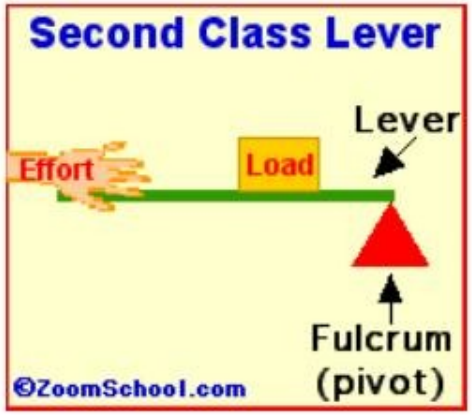
1st Class lever



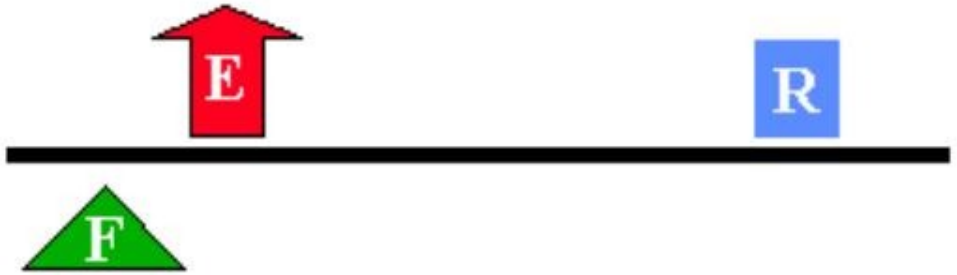
2nd Class lever



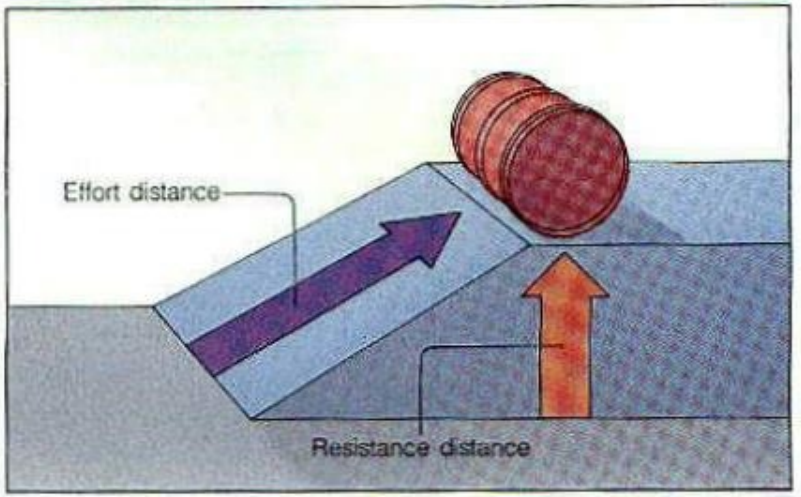




3rd Class Lever



Inclined Plane



- An inclined plane is a ramp used to gradually move an object up/down.

Screw

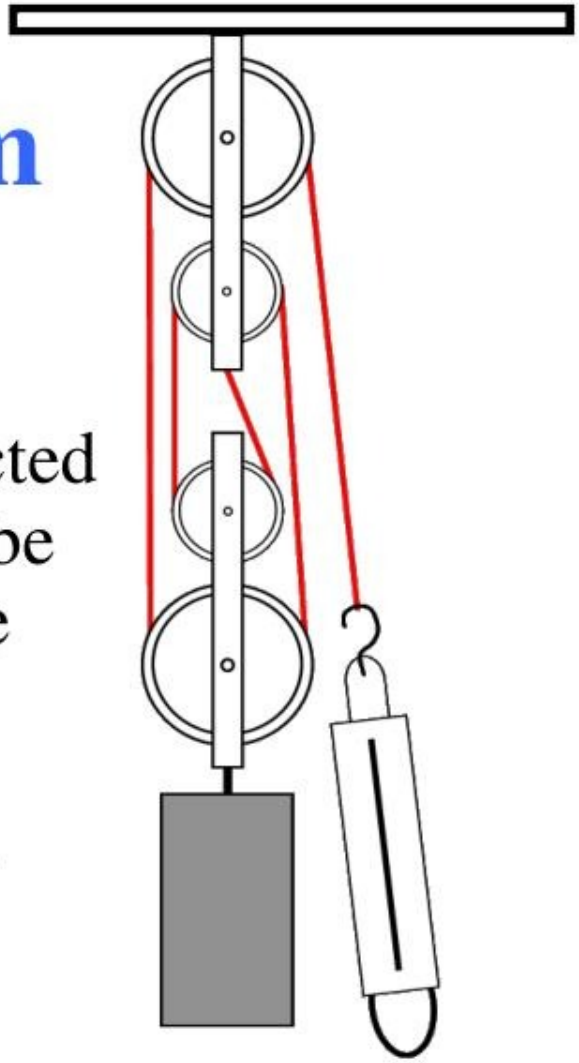
- An inclined plane wrapped to form a spiral
- It reduces effort force by increasing effort distance.

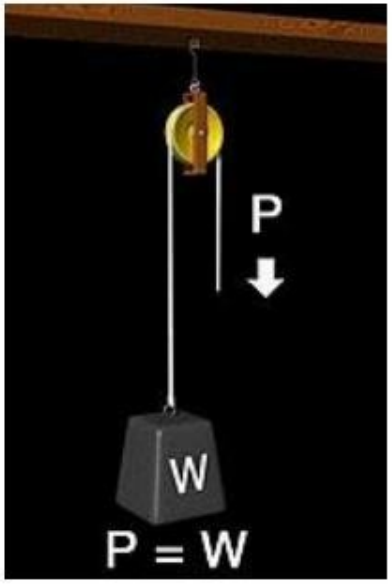
Wedge

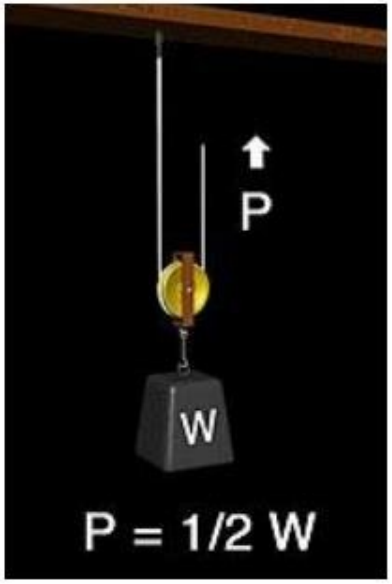
- A wedge converts motion in one direction into a splitting motion that acts at right angles to the blade.

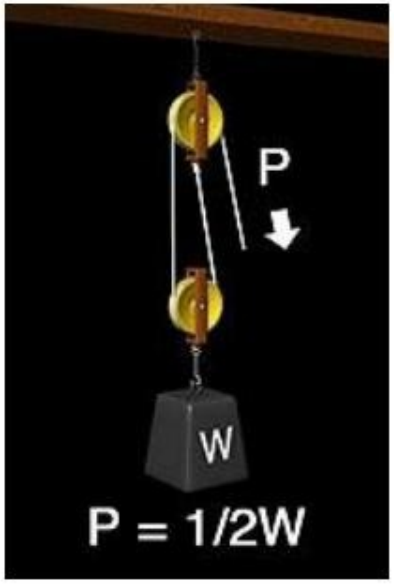
Pulley System

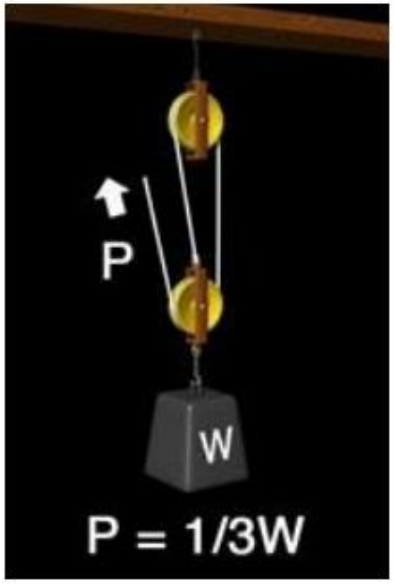
- A single pulley simply reverses the direction of a force.
- When two or more pulleys are connected together, they permit a heavy load to be lifted with less force by increasing the distance.
- The M.A. of a pulley system is approximately equal to the amount of supporting ropes or strands.

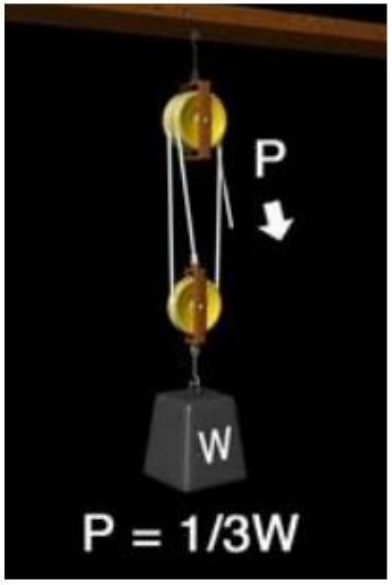


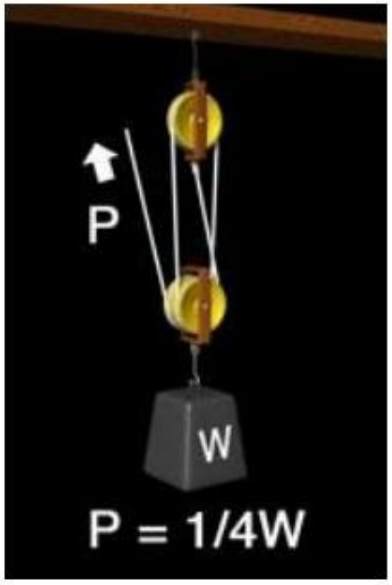

P
W
P = W

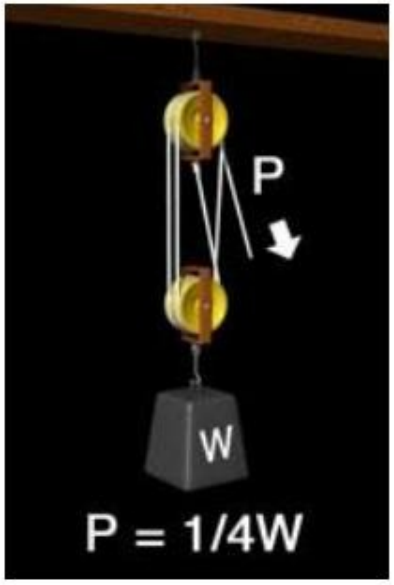

P
W
P = 1/2 W

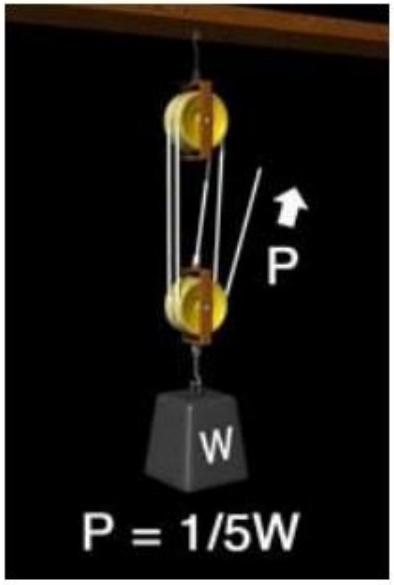

P
W
P = 1/2W


P
W
P = 1/3W


P
W
P = 1/3W


P
W
P = 1/4W


P
W
P = 1/4W


P
W
P = 1/5W

Wheel and axle

- A **wheel and axle** is a lever that rotates in a circle around a center point or fulcrum. The larger wheel rotates around the smaller wheel (axle).
  - EX: Bicycle wheels.

- EX: The rear wheel on your bike has a radius of 35.6 cm and has a gear with a radius of 4 cm. When the chain is pulled with a force of 155 N, the wheel rim moves 14 cm. The efficiency of this part of the bike is 95%.
- a) What is the IMA of the wheel and gear?
- b) What is the MA of the wheel and gear?
- c) What is the resistance force?
- d) How far was the chain pulled to move the rim 14 cm?