A **lever** is a rigid rod that rotates about a point or fulcrum.
There are three types of levers.

- First class
- Second class
- Third class
A first class lever is a lever with the fulcrum located between the input force (effort) and the output force (resistance).

Examples
- Crowbar
- See-saw

Characteristics
- Changes the direction of the force
- May have a mechanical advantage greater than, equal to, or less than 1
Second Class Levers

- A second class lever is a lever with an output force (resistance) between the fulcrum and the input force (effort).

- Examples
  - Wheel barrow
  - Bottle opener

- Characteristics
  - Maintains direction of force
  - The mechanical advantage is always greater than 1
Third Class Levers

- A third class lever is a lever with an input force (effort) between the fulcrum and the output force (resistance).
- Examples
  - Fly swatter
  - Baseball bat
- Characteristics
  - Maintains direction of force
  - The mechanical advantage is always less than 1
  - Increases speed
• The input distance and resistance distance of a lever are arcs.

• The portion of a lever between the fulcrum and the force is called a lever arm.
  o The lever arm between the fulcrum and the effort force ($F_E$ or $F_{in}$) is called the effort arm ($A_E$).
  o The lever arm between the fulcrum and the resistance force ($F_R$ or $F_{out}$) is called the resistance arm ($A_R$).
Mechanical Advantage for Levers

- The input distance and the output distance are not convenient to use because they are arcs, and because they change depending on how far the lever is rotated.
- The input distance and the output distance stay proportional as the lever rotates, because their radii are the lever arms, and those are fixed lengths. *(NOTE: The larger lever arm makes a larger circle as it rotates, and the smaller one makes a proportionately smaller circle.)*
- As a result, \( \frac{d_{in}}{d_{out}} = \frac{A_{E}}{A_{R}} \)
- Since the IMA = \( \frac{d_{in}}{d_{out}} \), then the IMA = \( \frac{A_{E}}{A_{R}} \) for a lever.
Comparing Lever Types

- A first class lever can have a mechanical advantage greater than, equal to, or less than 1, because the position of the fulcrum can vary changing the relative size of the lever arms.
- A second class lever always has a mechanical advantage greater than 1 because the effort arm is always larger than the resistance arm.
- A third class lever always has a mechanical advantage less than 1 because the resistance arm is always larger than the effort arm.
Two children try to balance on a see-saw. Even if they don’t weigh the same thing, it is possible to balance by changing their positions.

This is similar to the way a doctor’s scale works.

- The doctor doesn’t change the weights.
- Instead, the weights are moved to different positions.
A **moment** is the product of a force and its distance from the fulcrum \(M = F \times A\).

A lever is balanced when the **moments** are the same on both sides of the fulcrum.

- This can be interpreted to mean the effort moment is equal to the resistance moment, or the clockwise moment is equal to the counter clockwise moment.
- Symbolically this is \(M_E = M_R\) or \(M_{cw} = M_{ccw}\).
- Expanded, this means \(F_E \times A_E = F_R \times A_R\) or \(F_{cw} \times A_{cw} = F_{ccw} \times A_{ccw}\).

As a result, a 720 N boy sitting 0.70 m from the fulcrum of a see saw could be balanced by a 500 N girl sitting 1.0 m from the fulcrum.

\[
720 \text{ N} \times 0.70 \text{ m} = 500 \text{ N} \times 1.0 \text{ m}
\]

\[
500 \text{ mN} = 500 \text{ mN}
\]

**Note:** Even though a moment is a force times a distance, it is not work, because it is not the distance something moves. The units are mN rather than Nm for this reason.
A meter stick balanced at the center has a 3 N weight hanging at the 10 cm mark and a 5 N weight hanging at the 25 cm mark. What size weight must be at the 90 cm mark?

• **Step 1:** Identify your variables and set up your equation.

\[ M_1 + M_2 = M_3 \quad \text{(The moments on both sides are equal.)} \]

\[ M_1 = F_1 \times A_1; \; M_2 = F_2 \times A_2; \; M_3 = F_3 \times A_3 \]

\[ F_1 = 3 \; \text{N}; \; A_1 = 40 \; \text{cm}^*; \; F_2 = 5 \; \text{N}; \; A_2 = 25 \; \text{cm}; \; F_3 = F_3; \; A_3 = 40 \; \text{cm}; \]

* From the 50 cm mark to the 10 cm mark is 40 cm

• **Step 2:** Substitute into the equation and solve

\[ M_1 + M_2 = M_3 \quad \text{and} \quad M_1 = F_1 \times A_1; \; M_2 = F_2 \times A_2; \; M_3 = F_3 \times A_3 \]

\[ (3 \; \text{N})(40 \; \text{cm}) + (5 \; \text{N})(25 \; \text{cm}) = (F_3)(40 \; \text{cm}) \]

\[ 120 \; \text{cmN} + 125 \; \text{cmN} = (F_3)(40 \; \text{cm}); \; 245 \; \text{cmN} = (F_3)(40 \; \text{cm}) \]

\[ F_3 = 6.125 \; \text{N} \]
• A large branch is placed over a small rock poking 0.1 m under an 11,000 N boulder, leaving 1.7 m of the branch sticking out.

• What is the ideal mechanical advantage?

\[
IMA = \frac{A_E}{A_R} = \frac{1.7 \text{ m}}{0.1 \text{ m}} = 17
\]

• How much force is needed to move the boulder?

\[
F_{in} = \frac{F_{out}}{MA} = \frac{11,000 \text{ N}}{17} = 647 \text{ N}
\]