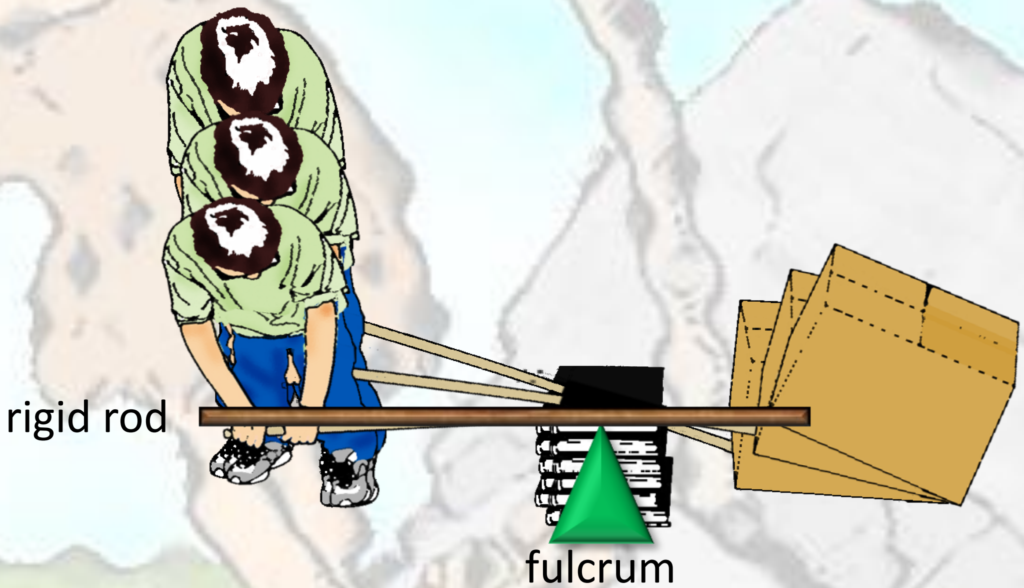
# Levers

# Definition

- A **lever** is a rigid rod that rotates about a point or fulcrum.

# Types of Levers

- There are three types of levers.
  - First class

  - Second class

  - Third class

# First Class Levers

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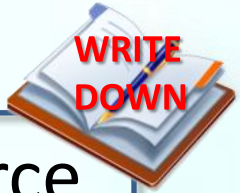
- A first class lever is a lever with the fulcrum located between the input force (effort) and the output force (resistance).
- Examples
  - Crowbar
  - See-saw
- Characteristics
  - Changes the direction of the force
  - May have a mechanical advantage greater than, equal to, or less than 1

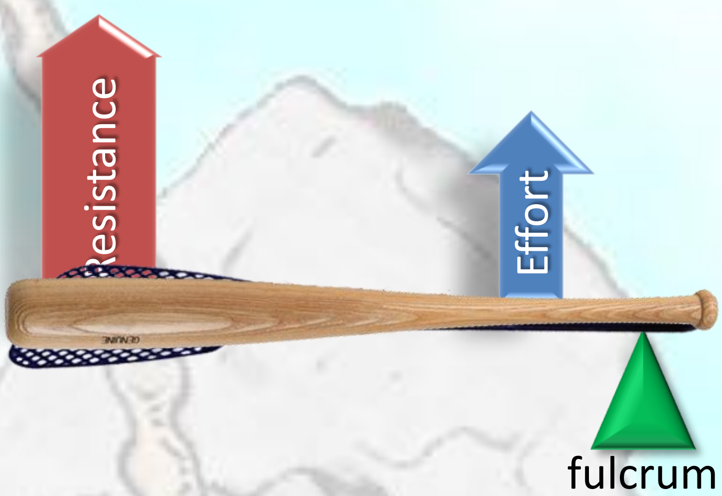
# Second Class Levers


- 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



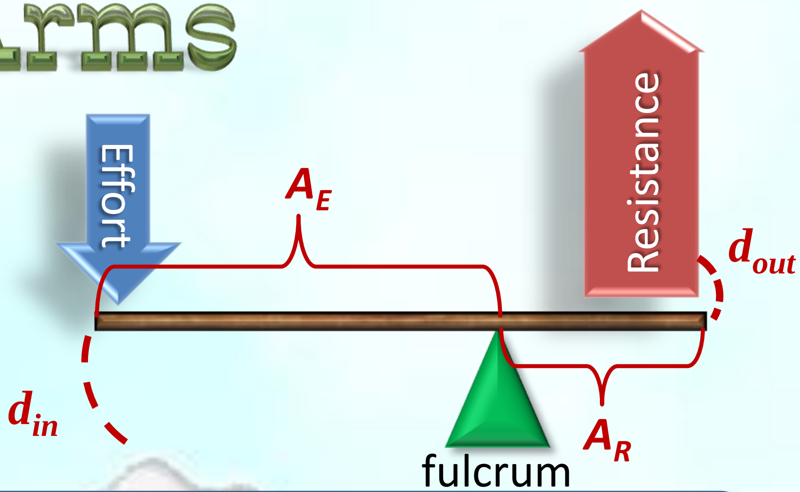

- A third class lever is a lever with an input force (effort) between the fulcrum and the output force (resistance) .
- Examples
  - Fly swatter
  - Baseball bat




- Characteristics
  - Maintains direction of force
  - The mechanical advantage is always less than 1
  - Increases speed

# Lever Arms

- 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**.
  - The lever arm between the fulcrum and the effort force ($F_E$ or $F_{in}$) is called the **effort arm** ($A_E$).
  - The lever arm between the fulcrum and the resistance force ($F_R$ or $F_{out}$) is called the **resistance arm** ($A_R$).

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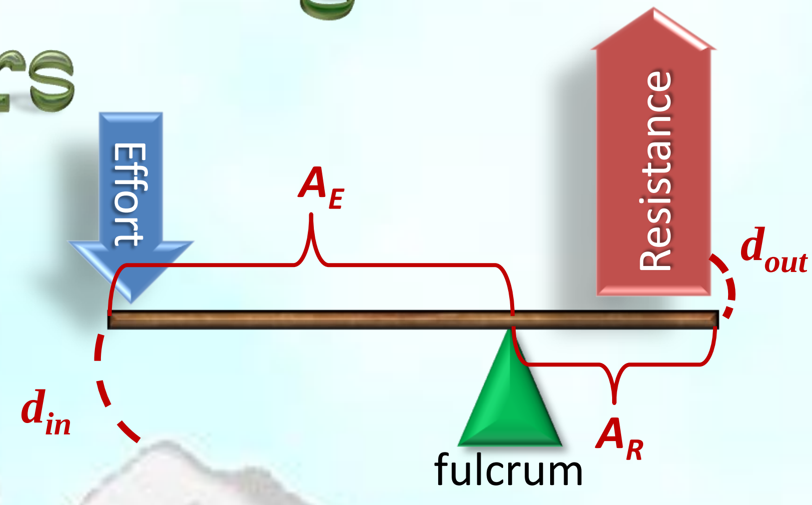
# Mechanical Advantage for Levers

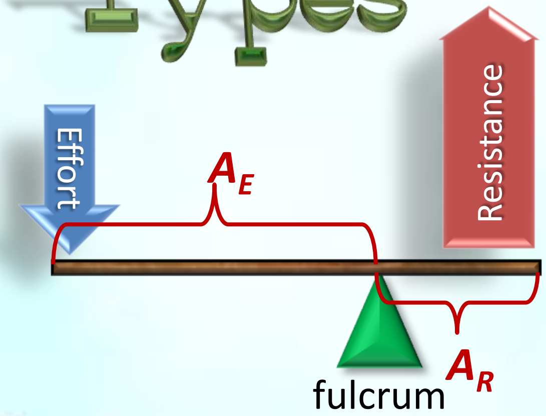


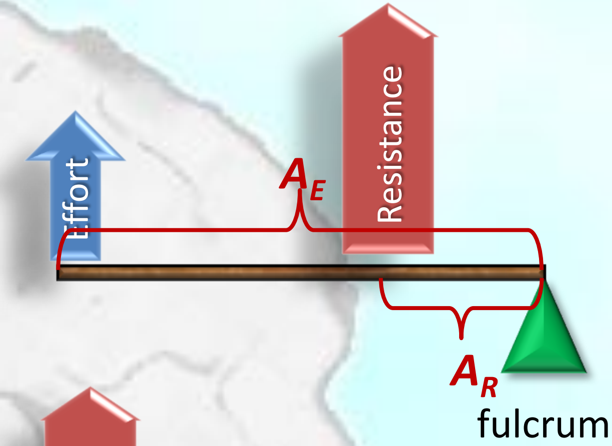

- The input distance and the output distance are not convenient to use because they are arcs, and because they change depending on how far the lever is rotated.
- The input distance and the output distance stay proportional as the lever rotates, because their radii are the lever arms, and those are fixed 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, $\frac{d_{in}}{d_{out}} = \frac{A_E}{A_R}$

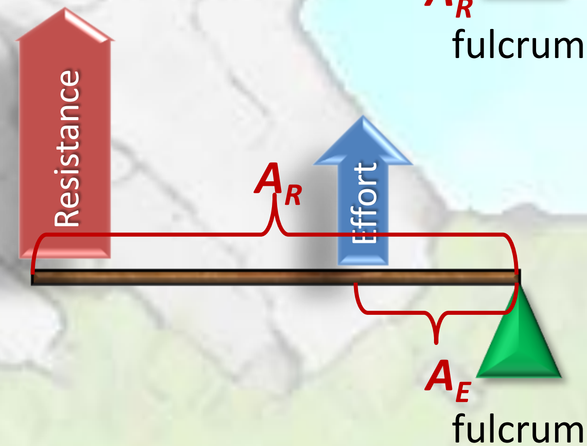

- Since the IMA $= \frac{d_{in}}{d_{out}}$, then the IMA $= \frac{A_E}{A_R}$ for a lever.

# 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.

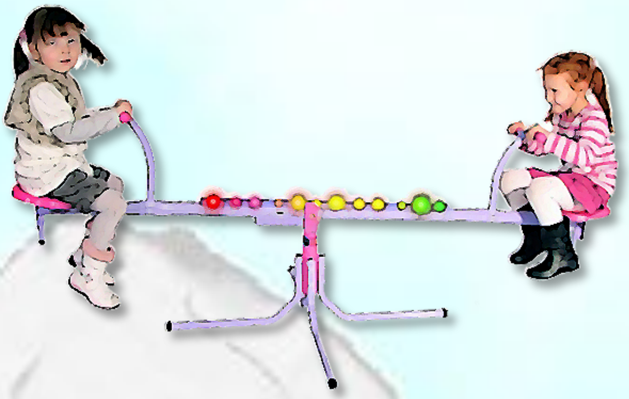


# Balanced Levers

- 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.

# Moments


- 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 N × 0.70 m = 500 N × 1.0 m
500 mN = 500 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 Balanced Lever Problem

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?



- **<u>Step 1</u>**: Identify your variables and set up your equation.

  $M_1 + M_2 = M_3$ (The moments on both sides are equal.)

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

  $F_1 = 3$ N; $A_1 = 40$ cm*; $F_2 = 5$ N; $A_2 = 25$ cm; $F_3 = F_3$; $A_3 = 40$ cm;

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

- **<u>Step 2</u>**: Substitute into the equation and solve

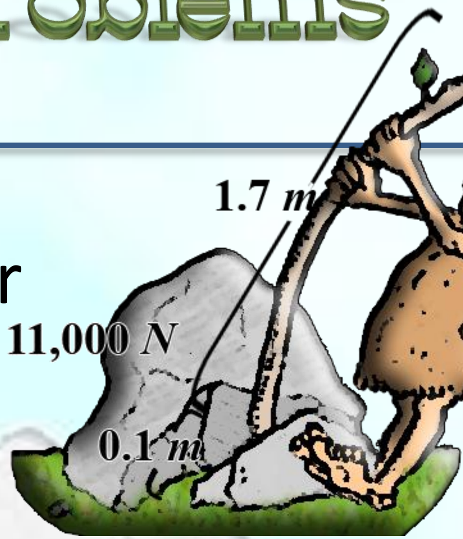
  $M_1 + M_2 = M_3$ and $M_1 = F_1 \times A_1$; $M_2 = F_2 \times A_2$; $M_3 = F_3 \times A_3$

  (3 N)(40 cm) + (5 N)(25 cm) = $(F_3)$(40 cm)

  120 cmN + 125 cmN = $(F_3)$(40 cm); 245 cmN = $(F_3)$(40 cm)

  $F_3 = 6.125$ N

# Other Lever Problems




- 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?

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