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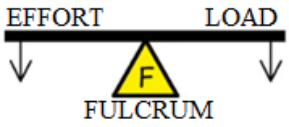
Science: Lesson 11 – Machines

Levers: Simple machines that are used to increase the force applied in doing work on a load.

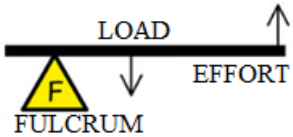
- It can also be used to increase the amount of movement/speed about a fixed point.
- **Fulcrum** is the fixed point.
- **The force** (effort) is applied on one end on a load.

Three Classes of Levers[1]

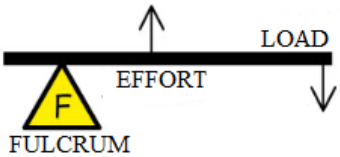
- **First Class Levers:** The fulcrum is between the load and effort (or force applied).
  - The mechanical advantage (MA) can either be less than 1 or greater than 1.
    - This means there is a gain in force (effort arm longer) or gain in speed (effort arm shorter).
  - Examples: seesaw, pry bar, scissors.



- **Second Class Levers:** The load is between the fulcrum and the effort.
  - MA is always greater than 1.
    - This means there is gain in force but loss in speed.
  - Examples: wheelbarrow, nutcracker, staplers.



- **Third Class Levers:** The effort is between the fulcrum and the load.
  - The MA is always less than 1.
    - This means there is gain in speed but loss in force.
  - Examples: fishing rod, baseball bat, tweezers.



[1] The images were snipped from Requirements for Movement (HL) | HL IB Biology Revision Notes 2025 | Save My Exams website. The wordings were edited and adjusted to the vocabulary used in this handout.

Calculating Mechanical Advantages of Levers:

$$MA = \frac{\text{Resistance force (load)}}{\text{Effort applied}}$$

$$MA = \frac{\text{effort distance}}{\text{load distance}}$$

Most times both formulas are combined to solve a particular problem related to levers.

Inclined Planes: are ramps designed to move a load from the horizontal plane to an intended height.

- They are right triangles
- The mechanical advantage of inclined planes is calculated as the ratio of the distance covered in moving the load to the vertical distance the load is lifted.

$$MA = \frac{\text{Resistance force (load)}}{\text{Effort applied}}$$

OR

$$MA = \frac{\text{distance load is moved}}{\text{load height}}$$

When the angle of inclination of the inclined plane is given (like the image above[2]), we use:

$$MA = \frac{\text{Resistance force (load)}}{\text{Effort applied}} = \frac{\text{distance load is moved}}{\text{load height}} = \frac{1}{\sin\theta}$$

Efficiency: of a simple machine is calculated as follows:

$$Eff = \frac{MA}{VR} \times 100\%$$

- *MA* is mechanical advantage
- *VR* is the velocity ratio.
  - **Velocity Ratio:** the distance to be covered by the load to the load height.

[2] The figure was snipped from What are inclines? (article) | Khan Academy website.

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Science: Lesson 12 – Introduction to Electricity

Electricity is the flow/movement of electric charges (electrons) through a conductor.

- There are positive (protons) and negative (electrons) electric charges.
- Positive and positive or negative and negative charges (like charges) repel each other.
- Opposite charges attract each other.
- Electricity can either be static or dynamic.

Electric Circuits: are a pathway through which electric current flows.

- **A simple circuit** is a circuit that has only a battery and a resistor. There are two types of simple circuits:
  - **A series circuit** is a circuit where current flows in only one direction. The total resistance (effective resistance) is the sum of all the resistors.

$$R = R_1 + R_2 + R_3$$

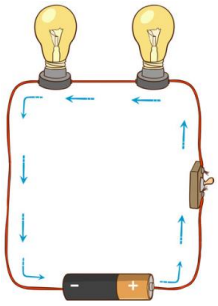

Figure 1: a series circuit[1]

  - **Parallel circuit:** current flows in more than one path. The total resistance is the sum of the reciprocal of each resistor.

$$R = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

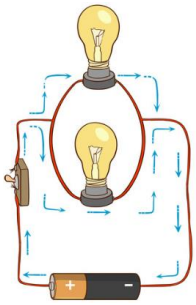

Figure 2: a parallel circuit[2]

[1]The figure was snipped from An In-Depth Dive Into Series vs. Parallel Circuits | Advanced PCB Design Blog | Cadence website.

[2] This figure was also snipped from An In-Depth Dive Into Series vs. Parallel Circuits | Advanced PCB Design Blog | Cadence website.

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Other Important Definitions

- **Electrical load** is an electrical component or portion of a circuit that consumes (active) electric power.
    - Examples: appliances and lights.
- **A switch**: a device that can break the path of electricity in an electric circuit.
- Two types of Electric currents:
    - **Direct Current:** current (flow of electrons) always flowing in one direction.
    - **Alternating Current:** current (flow of electrons) changes direction

Videos:

- Types of Electrical Circuits (youtube.com)
- Direct Current versus Alternating Current (youtube.com)

Science: Lesson 13 – Electricity: Formulas and Calculations

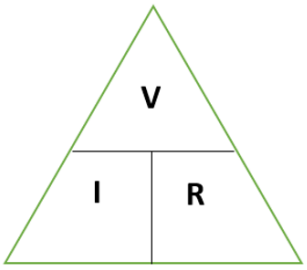
Ohm's Law

- **Voltage** is the difference in electric potential between two points.
  - It also determines how much current will flow through a circuit.
  - It is usually represented as *V* and its unit is the Volts, *V*.

- **Electric Current:** the flow of charged particles such as electrons or ions moving through an electrical conductor.
  - It is usually represented as *I* and its unit is Amperes, *A*.
- **Electrical resistance** is a property of a material that opposes the flow of electric current through it.
  - The unit of resistance is Ohms represented by the Greek symbol, Ω.

Ohm's Law: the current passing through a conductor between two points is directly proportional to voltage across the two points.

$$V = IR$$



- **Electrical Power:** the rate of energy use, or the amount of energy used per unit time.
  - Electrical power is measured in Watts.
  - Electrical power: calculated by multiplying the voltage and the current.

$$P = VI$$

  - Electrical power: calculated using the formula (from the above definition):

$$Power\ (W) = \frac{Energy\ (J)}{Time\ (s)}$$

  - One Watt is equal to one Joule per second.

$$1\ Watt = \frac{1\ Joule}{Second}$$

Cost of Electrical Usage

The formula used to calculate electrical usage cost is the rate multiplied by the energy.

$$Cost = Rate \times Energy$$

- Cost is measured in cents
- Rate is measured in cents per kilowatts hour
- Energy is measured in kilowatts hour (kWh).

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Science: Lesson 10 – Machines

Machine: any device that helps us to do work.
Simple Machine: a mechanical device that helps us in performing work by multiplying or transforming the force.

- It is called simple because the machines operate on basic principles that involves one movement.
- Examples: a knife, bottle opener, axe etc.
- There are six types of simple machines:
    1. Inclined plane (examples include ramps, escalators, stairs).
    2. Wedge (examples include are saw, knife).
    3. Screw (examples include jar lid, corkscrew).
    4. Lever (examples include scissors, wheelbarrow).
    5. Pulley (examples include elevators, garage doors).
    6. Wheel and axle (examples include electric fan, drill).

Compound Machine: a combination of more than one simple machines.

- Examples: a car engine, tractors operating on a farm etc.

Mechanical Advantage: the ratio of the force output (load) to the force input (effort applied to the load).

- A value greater than 1 means that the effort is multiplied (less force is needed).
- A value less than 1 means the speed is multiplied but greater force is required.

$$\text{M. A.} = \frac{\text{Force output}}{\text{Force input}}$$

- Mechanical advantage measures the efficiency of a machine. It could also be related to the distance through the formula:

$$\text{M. A.} = \frac{\text{Effort arm}}{\text{Load arm}}$$

- These two formulas can be combined into one formula which is useful for solving problems related to levers.

$$\frac{\text{Resistance force (load)}}{\text{Effort force}} = \frac{\text{effort distance}}{\text{resistance distance}}$$

Videos:

- Mechanisms: Levers, Axles, and Pulleys
- Mechanisms: Inclined Planes, Wedges, and Screws
- Mechanisms: Compound Machines

A Gear: a wheel (circle-like object) with teeth.

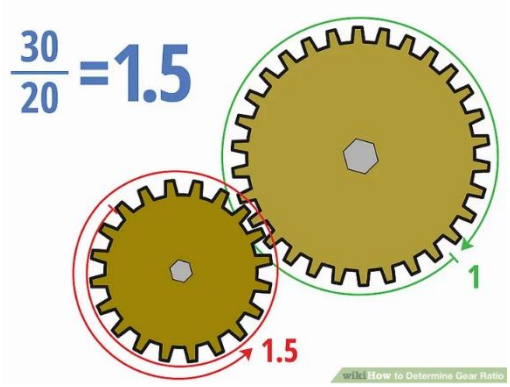
- Teeth are used to connect two or more gears. They ensure one gear doesn't fall off another.
- **Driver:** the gear that is forced to move.
- **Driven** (or Follower): is the gear that moves because of the first gear (driver).
- **Gear ratio** is the ratio of the driven (follower) gear to the driver gear.
    - It indicates how many times a gear must turn for another gear to turn once.
    - Gear ratios reduces the torque by increasing the speed and vice versa.

$$\text{Gear Ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}} = \frac{\text{Number of turns on driven gear}}{\text{Number of turns on driver gear}}$$

Example:

- See figure 1
- Divide the driven gear teeth by the driver gear teeth
    - $\frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}}$
    - $\frac{30}{20}$ = 1.5
    - written as a ratio 1.5:1
- The small gear rotates 1.5 times for every 1 time that the large gear rotates

Figure 1[1]



Gear ratio is the mechanical advantage for gears.

Video: Simple Machines – Gears

[1] Figure 1 retrieved from 4 Easy Ways to Determine Gear Ratio (with Pictures) (wikihow.com)