Date

# PHYSICS

## SI Units

- There are 7 basic quantities and units:
  - Electrical Current – Amperes (A)
  - Luminous Intensity – Candela (cd)
  - Temperature – Kelvin. (K)
  - Mass – Kilogram (Kg)
  - Length – Metre (m)
  - Amount – Mole (mol)
  - Time – Second (s)

- Prefixes used for scalar & vector quantities:
  - [redacted]
  - Kilo : $10^3$ (K)
  - Deci : $10^{-1}$ (d)
  - Centi : $10^{-2}$ (c)
  - Milli : $10^{-3}$ (m)
  - Micro : $10^{-6}$ ($\mu$)
  - Nano : $10^{-7}$ (n)

# FORCES & ENERGY

- A force is simply an agent that produces or tends to produce motion and/or rest.

- Speed is the distance moved in a given period of time. Speed can be found using:

$$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$$

- Speed is a scalar quantity (has only magnitude). Velocity is speed in a certain direction, making it a vector quantity. Velocity can be found using:

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

- Alternatively, a vector quantity has both magnitude and direction.

- Acceleration is the measure of the rate of increase in velocity. It is also a vector quantity. Acceleration can be found using:

$$\text{acceleration} = \frac{\text{increase in velocity}}{\text{time taken}}$$

- Deceleration, or Retardation, is the rate of decrease in velocity.

- If an object decelerates at $3 m/s^2$, its acceleration is $-3 m/s^2$.

- Although $m/s^2$ is acceptable, the unit $ms^{-1}$ is more commonly accepted.

$$\frac{m}{s^2} = ms^{-1}$$

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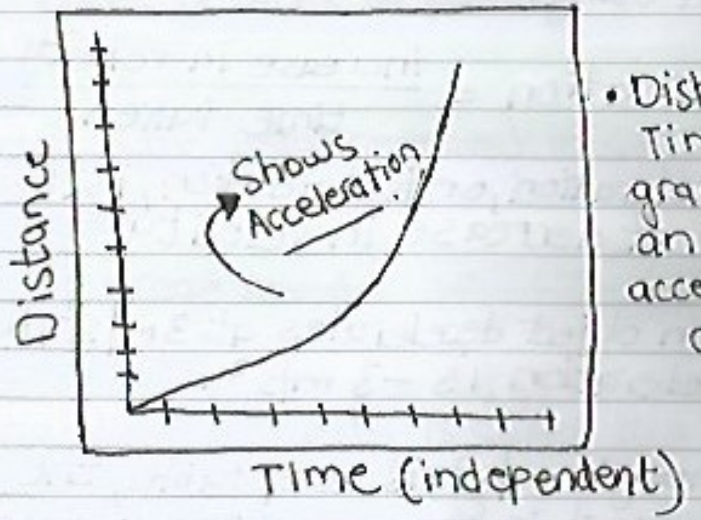
• A distance-time graph is plotted to show the increase in distance over time.




• Distance-Time graph for an accelerating car.

• The gradient of the distance-time graph shows the velocity of the car. This can be found using:

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

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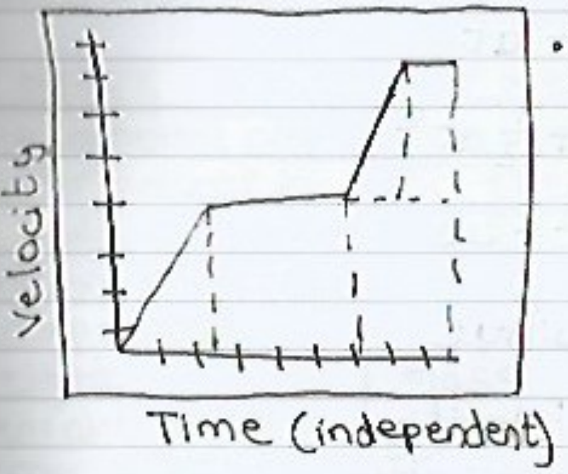
• A velocity-time graph shows the changing velocity over time.




• Velocity-Time graph of a moving car.

• The gradient of a velocity-time graph is the acceleration of that specific object (same formula)

• The area under a velocity-time graph is the distance that object has moved.

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- There are 3 main equations of motion. These are:

① $v = u + at$

② $S = ut + \frac{1}{2}at^2$

③ $v^2 = u^2 + 2as$

where

$v$ = final velocity
$u$ = initial velocity
$s$ = distance
$t$ = time
$a$ = acceleration

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- While they may be used interchangably, Mass and Weight are completely different things. The differences are:

| Mass | Weight |
|---|---|
| • The amount of matter present in a body. | • The force exerted on the ground. |
| • Unit => Kg (Kilograms) | • Unit => N (Newtons) |
| • Independent of weight. | • Dependent on mass |
| • Remains constant accross different gravitational strengths. | • Changes across different gravitational strengths. |
| • Formula: None | • Formula : $W = mg$ ($g$ = gravitational strength) |
| • Scalar quantity | • Vector quantity |
| • Independent of gravity | • Dependent on gravity |
| • Has no given direction | • Has given direction (downwards) |

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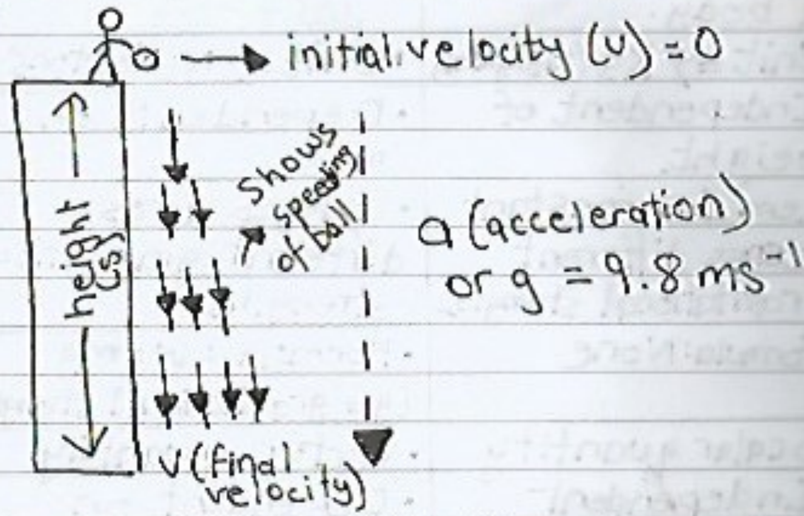
- The gravitational strength of Earth is almost constant → 9.8 m/s² or ms⁻¹. However, it should be noted that in the cases of free fall, a (acceleration) = g.

Common Example




A person on a building drops a ball (not throwing with force)

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- However, it should be noted that an object only accelerates until it reaches its terminal velocity. Terminal velocity is the highest attainable velocity of an object while falling through mid-air. It can be found using:

$$V = \sqrt{\frac{2mg}{\rho A C}}$$ , where

v = terminal velocity
m = mass of falling object
g = gravitational acceleration
ρ = density of fluid through which the object is falling
A = the projected area of the object
C = the drag coefficient

- The value of g varies slightly from place to place on Earth, but is roughly ≈ 9.8 ms⁻¹.

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· Gravity pulls all objects towards the earth at the same time naturally. However, some light objects fall slower due to air resistance. This is why all objects would fall together in a vacuum.

• Force, mass and acceleration are all relatable. Isaac Newton's 3 laws of motion best describes them.

· Newton's Laws of motion:

1) Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.
2) Force is equal to the change in momentum per change in time. For a constant mass, force equals mass times acceleration.
3) For every action, there is an equal and opposite reaction.

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· The first law of motion explains how everything has inertia to change in state of motion or rest. It will remain stationary or moving unless external forces act upon it.

· The second law can be summarized:

Force = mass x acceleration ($F=ma$),

or can be replaced by

Weight = mass x gravitational strength ($W=mg$)

· The third law of motion explains how the net result of every force is 0, due to an equal but opposite reaction.

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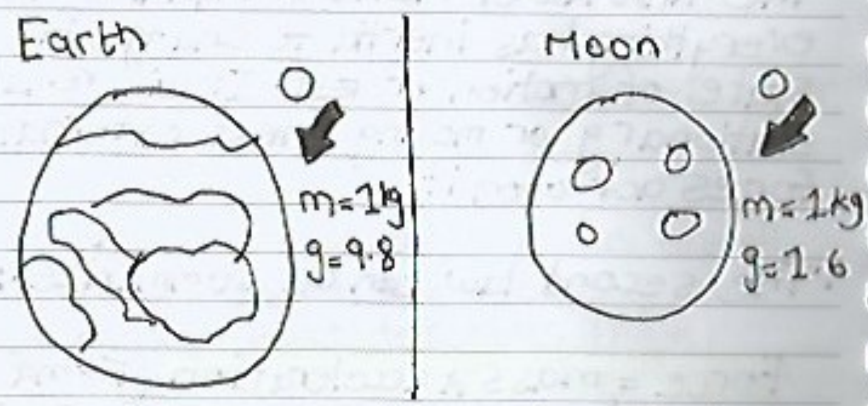
• How force/weight changes from Earth to moon ($f = w$, $g = a$)




W= 9.8 N

W = 1.6 N

Mass is constant, while weight changes

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• When materials try to slide across each other, a force called <u>friction</u> stops them. The types of friction are:
  • Static: The friction between objects that start to slide.
  • Dynamic: The friction during the sliding
  • Fluid: The friction caused when an object tries to slide inside a gas or a liquid.

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• There are several types of motion:
  • Straight-line motion
  • Projectile motion
  • Centripetal motion

(like $y = x^2$)

(moving in circles)

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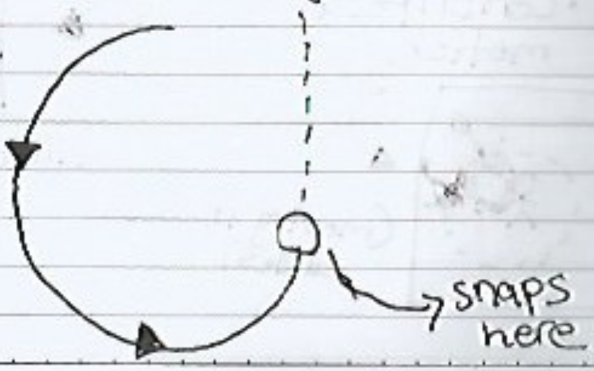
- Centripetal motion is circular motion produced by forces applied at right-angles. This can be found by:

$$\text{Centripetal force} = \frac{mv^2}{r}$$

r → radius of circle.

- Immediately after centripetal force, if the wire or what is causing right-angular motion stops doing so, the object will travel straight on due to centrifugal force:

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- The earth's gravity also causes objects such as satelites to travel in centripetal motion. To escape this, the object must reach escape velocity, which is 11,000 m/s.

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- The momentum of an object is its mass x velocity. It is the "quantity" of motion in a moving body:

① Momentum = mass x velocity

② $\text{Force} = \frac{mv - mu}{t}$, where

mv is the final momentum
mu is the initial momentum

so

Force = rate of change of momentum

Date

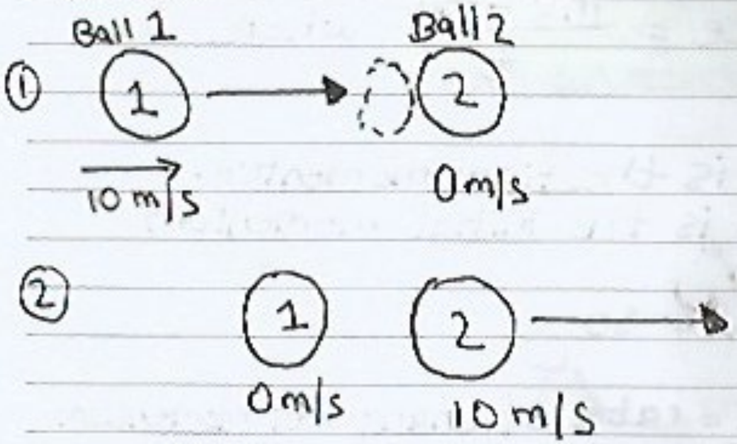
- This formula can be rearranged to say:

$$Ft = mv - mu$$

$Ft$ → Impulse; $mv - mu$ → Gain in momentum

- Impulse is really just the change in momentum.

- Momentum is conserved when two objects collide. Their sum remains the same:

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- This can be given from the formula

$$(m_1 \times u_1) + (m_2 \times u_2) = m_1 v + m_2 v$$

- $v$ is constant as the final velocity will remain the same.

- All this confirms Newton's $2^{nd}$ Law.

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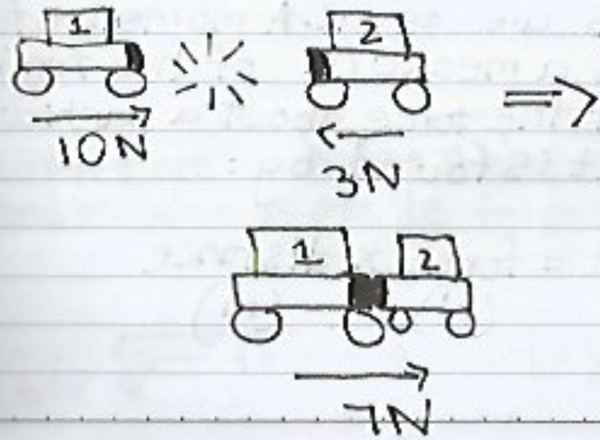
- Finding resultant forces between objects directly horizontal or vertical is simple addition/subtraction.



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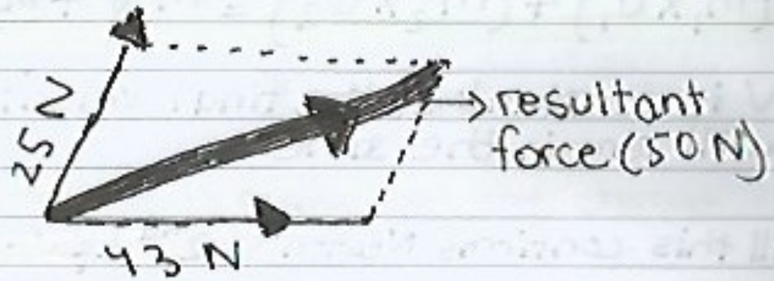
- The resultant forces of angular forces is found by the Parallelogram rule:




- Two forces can also be acting on the same object. If the object is straight, it is in a state of equilibrium, where the clockwise and anti-clockwise moments are equal. A moment of a force is a measure of the turning effect of the force about a particular point. It is found by:

Moment = force x distance
(Nm) (N) (m)

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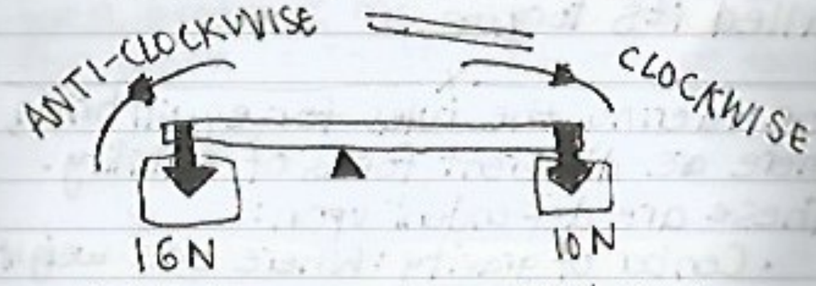
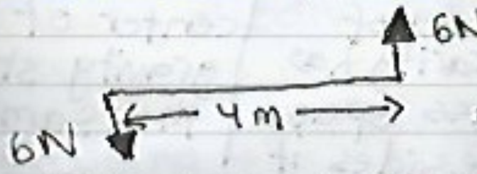
Example of Equilibrium:




16N x 2m
=> 32 Nm = 10N x 3.2m
32 Nm

- For equilibrium, the sum of forces in one direction must equal those of the other direction. Plus, the principle of moments must apply.

- Using the principle/concept of moments, couples are created? These are long, parallel yet opposite forces.




=> 6x4 = 24Nm

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- The moment amount of a couple is called its torque.

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- Considering the rules for equilibrium, there are different forms of stability. These are dependent upon:
  - Center of gravity: Where the weight of an object pulls.
  - Center of mass: The mean position of the mass of an object.

- There are 3 types of equilibrium:

| STABLE | UNSTABLE | NEUTRAL |
|---|---|---|
|  |  |  |
| center of gravity has space besides it | center of gravity has less space besides it | center of gravity stays the same. |

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- Work (in Physics) is done when a force produces movement. The SI unit for work is Joule. It can be found by:

$W = fs$

W → Weight
f → Force
s → Distance

- To work, everything needs energy. There are different types of these:
  - Thermal: Heat
  - Kinetic: Moving
  - Potential: stored
  - Electrical: Relating to current
  - Chemical: Relating to chemicals

- Kinetic energy is created when particles collide with one another, causing effective collision. This process can be sped up by providing more heat to the particles, and reducing their masses. Kinetic

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energy can be determined using the formula:

$$\text{Kinetic Energy} = \frac{1}{2} m v^2$$

- Potential energy is the stored energy and is found by:

$$\text{Potential Energy} = mgh$$

- Energy cannot be created or destroyed, it only converts into other forms. After the work is done, the energy is subsequently transferred.

- The energy crisis has taken a step forward in the whole world, for which, new methods have to be come up with. But they are releasing carbon dioxide and causing Climate Change (see IDU topic).

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- The power of any energy source is the rate at which it gets work done. It can be measured by:

$$\text{Power} = \frac{\text{work done}}{\text{time}} = \frac{\text{energy transferred}}{\text{time}}$$

- It is measured by watts (w)

- In motion examples, it is true that:

$$\text{Power} = \text{force} \times \text{velocity}$$

- The efficiency of an energy source is hence also measured by:

$$\text{Efficiency} = \frac{\text{power output}}{\text{power input}}$$

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- In Physics, density refers to the degree of compactness of a substance. Pure water has a density of 1.00. Density is given by:

$$\rho = \frac{m \rightarrow \text{mass}}{V \rightarrow \text{volume.}}$$

$\rho \rightarrow$ density

- To find the relative density of a fluid (relative density is how many more times dense a fluid is compared to water), the following two formulae are used:

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water}}$$

$$\text{relative density} = \frac{\text{mass of substance}}{\text{mass of same volume of water}}$$



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- Unlike density, Pressure refers to the constant physical force exerted on an object by something in contact with it.

- Measured in Pascals (Pa). $1\,Nm^{-1} = 1$ Pa.

- Pressure is defined by:

$$p = \frac{f \rightarrow \text{Force}}{A \rightarrow \text{Area}}$$

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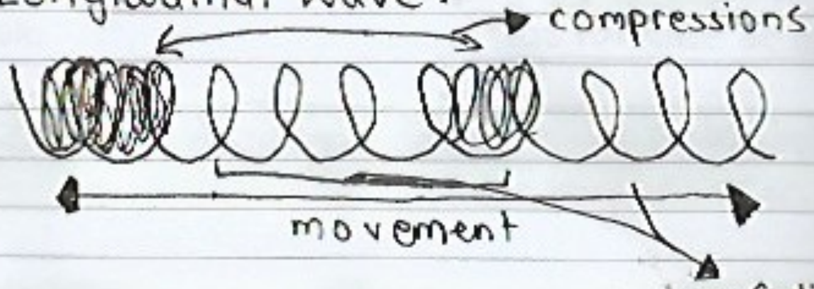
# WAVES

- Waves are mediums of transferring energy without particles. In layman's terms, they are disturbances propagating through space.

- Two types of waves:
  - Longitudinal (coils move horizontally)
  - Transverse (coils move vertically)

- Longitudinal Wave:

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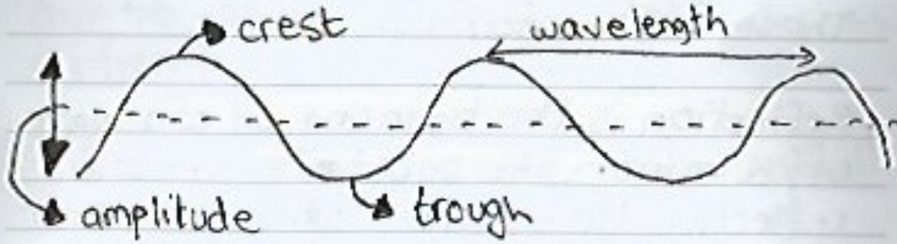
- Transverse wave:




- The wavelength is the distance from one point to the same in the next oscillation. (length of an oscillation) - $\lambda$

- The amplitude is the distance from the maximum or minimum point to the mean line.

- The time period of a wave is the time taken for an oscillation. The frequency (Hz) is the number of oscillations in one second. They are inversely proptinl.

$$T = \frac{1}{f} \quad , \quad f = \frac{1}{T}$$

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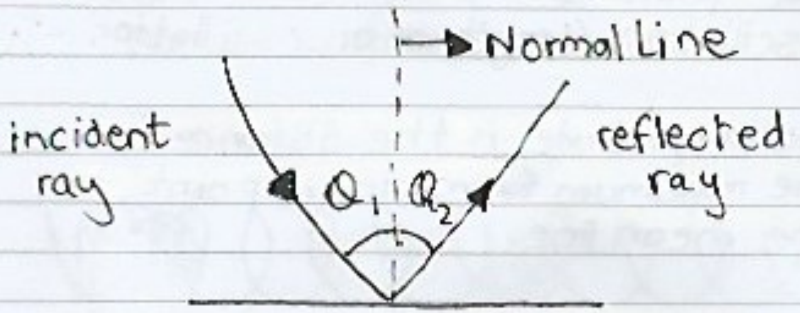
- There are 4 main phenomena of waves. These are as follows:

- Reflection is the bouncing off of a wave off a mirror-like substance. Specular reflection takes place when the mirror surface is smooth. Here, the angle of incidence = angle of refraction.




$$\theta_1 = \theta_2$$

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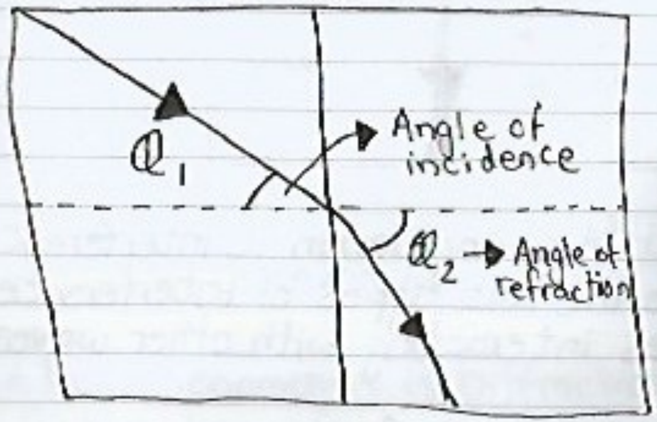
- Refraction is the bending of light due to varying speeds of light across different mediums.

- If the speed is faster, the ray will move away from the normal line.




- To find the refractive index, use:

$$n = \frac{c}{v}$$ c → speed of light in air; v → speed of light in medium

or

$$n = \frac{\sin \theta_1}{\sin \theta_2}$$

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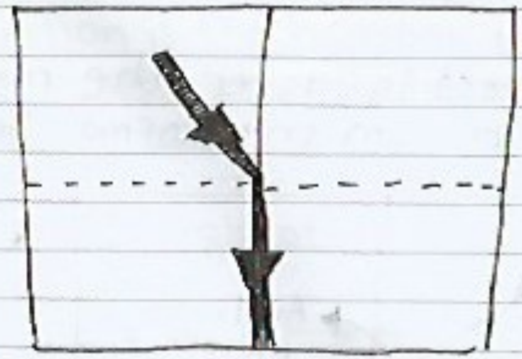
- The critical angle is the angle at which, if light refracts, it becomes straight.



- The third phenomenon is interference. There are two types of interference (waves interacting with other wavers):

- Constructive interference is crest on crest and trough on trough. This causes a bigger wave to be produced as a result. Destructive interference is crest on trough and vice versa. This causes a smaller wave or no wave at all as the net result.

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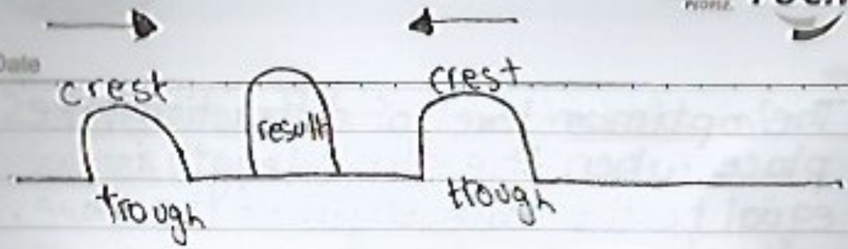
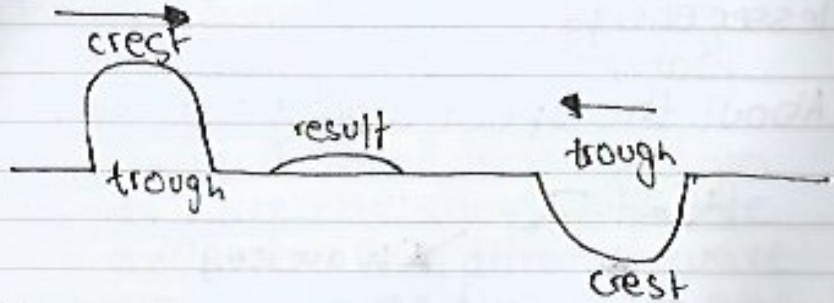



① — Constructive interference




② — Destructive interference

- The last phenomenon is Diffraction, which is the bending of waves as they move through a slit.

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- The optimum level of diffraction takes place when the slit's length is equal to the wavelength of the wave.

- A wave with longer wavelength has lesser energy.

- About the speed/velocity of a wave:

$$V = f\lambda$$

$f \rightarrow$ frequency

$\lambda \rightarrow$ wavelength

or

$$V = \frac{\lambda}{T}$$

$T \rightarrow$ Time period

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- There are several <u>characteristics</u> of sound. These are as follows.

- Pitch is the quality of sounds that distinguishes between grave and shrill sound. Pitch is directly proportional to the frequency.

- Quality in a sound is when two sounds have the same amplitude and frequency, but different wave patterns (such as flutes and pianos).

- Intensity is the sound energy transmitted per unit area, which is held perpendicular.

- Amplitude is directly proportional to energy, whereas wavelength is inversely proportional to energy.

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- How loud a sound depends on 5 factors:
  - Intensity
  - Amplitude
  - Surface Area of Vibrating body.
  - Sensation of your ear
  - Distance from vibrating body.

- For the intensity of a wave:

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}}$$

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- Waves can help in <u>imaging</u> as well. There are 2 types of <u>mirrors</u>:
  - Concave Converges
  - Convex Diverges

REMEMBER: CAPTAIN COLD VALUED DIAMONDS

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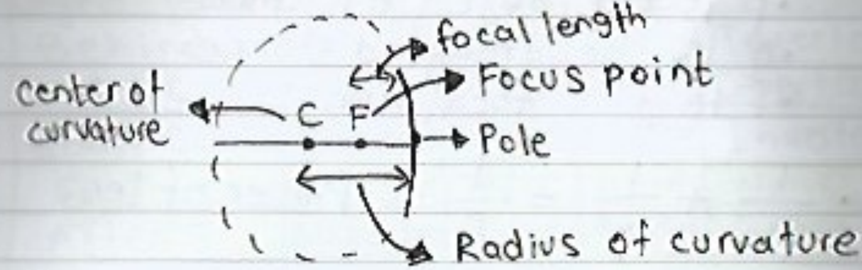
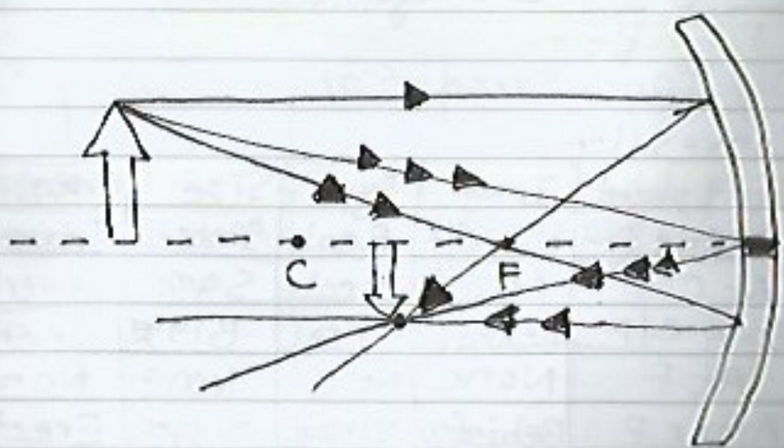
Example of Concave Mirror




<u>Types of rays + Appearances</u>



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- For ray diagrams:
  - p is the object distance
  - q is the image distance.
  - f is the focal length

- $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ = Power of lens

- $\frac{q}{p} = \frac{H_i}{H_o}$ = Magnification

Convex lens:

| Object placed | Image | Type | Size | Orientation |
|---|---|---|---|---|
| Behind C | Btwn C/F | Real | Smaller | Inverted |
| At C | At C | Real | Same | Inverted |
| Btwn C/F | Behind C | Real | Bigger | Inverted |
| At F | None | None | None | None |
| After F | Behind lens | Virtual | Bigger | Erect |

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Concave Mirror:

| Object placed | Image | Type | Size | Orientation |
|---|---|---|---|---|
| Behind C | Btwn C/F | Real | Smaller | Inverted |
| At C | At C | Real | Same | Inverted |
| Btwn C/F | Behind C | Real | Bigger | Inverted |
| At F | None | None | None | None |
| After F | Behind Mirror | Virtual | Bigger | Erect |

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Electromagnetic Spectrum

| Radio | Microwave | Infrared | Visible | UV | X-ray | Gamma |
|---|---|---|---|---|---|---|
| $10^2$ | $10^{-2}$ | $10^{-5}$ | $0.5\times10^{-8}$ | $10^{-8}$ | $10^{-10}$ | $10^{-12}$ |
| TV communication | Cell phones + Heating | Remotes | Help see | Insect Killer | Examining | Kill cancer cells |

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# ATOMIC PHYSICS

- The study of radioactive elements and their isotopes.

- The protons and neutrons stick together due to a binding force. Apart from the basic parts (protons, neutrons, electrons), they themselves are made up of tinier particles called quarks. There are 6 types of quarks:
    - Up
    - Down
    - Top
    - Bottom
    - Chare
    - Stem

- Radioactivity is the process of spontaneous disintegration of the nucleus of an atom with the emission of radioactive



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rays, including Alpha, Beta and Gamma.

- How to show an element:

Atomic Mass ← A

$$^{A}_{Z}\text{Na}$$ → Symbol

Atomic Number ← Z

- An element is only radioactive if it atomic mass is greater than 82 amu.

- Three main types of radioactive rays, Alpha ($\alpha$), Beta ($\beta$) and Gamma ($\gamma$).

- Alpha particles are fast-moving helium nuclei ($^{4}_{2}\alpha$). They have no electrons and are positive.

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- Beta particles are fast-moving electrons ($^{0}_{-1}e$), and are negative.

- Gamma rays have no charge, and are photons, or energy particles.

- Characteristics of Radioactive Rays:

- Ionization power is the number of charge ($\pm$) a ray can provide to the medium it flows in.
  - Alpha : Power of Ionization – 2
    This is because it is 2 electrons short from a full shell.
  - Beta : Power of Ionization – 1
    They gain one electron from the medium travelled in.
  - Gamma : Power of Ionization – >0
    Despite Gamma rays having no charge, they ionize the medium to a very low level due to their high speeds.

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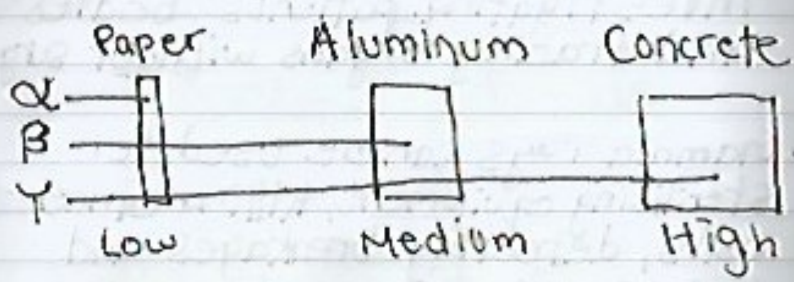
- Penetration Power (what different rays can pass through and what not:
  - Alpha : Low (stopped by paper)
  - Beta : Medium (stopped by Aluminum)
  - Gamma : High (Stopped by lead / concrete)

- 


- Speeds
  - Gamma – Speed of light ($3 \times 10^8$ m/s)
  - Beta – Approximately speed of light
  - Alpha – 10% of speed of light

- There are several uses of these radioactive rays.

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- Alpha rays are used for detecting the amounts of nutrients in certain crops.

- Beta rays can be used for investigating patients' bodies and tracing organs without surgery.

- Gamma rays can be used for sterilising equipment, killing cancer cells, detecting breakages and leakages in pipes etc.

- To determine whether a radioactive ray is Alpha, Beta or Gamma, a device called a Geiger Counter is used.

——— X ———

LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS

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- A radioactive isotope (an element with an unstable number of neutrons) can undergo Radioactive Decay, then become stable. There are 4 types of decay:

- Alpha Decay:

$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

- Beta Decay (electron):

$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$

- Beta Decay (positron):

$$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{1}e$$

- Gamma Decay:

Protons get closer to neutrons, Gamma ray is emmitted too.

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- Carbon Dating can be done on this principle (finding the age of a substance based on its emissions).

- Half-life (during which the number of atoms in a substance reduces to half). The time taken for number of atoms to get to 100% - 50%, 50% - 25%, 25% to 12.5% and so on is the same.


- What a typical half-life graph looks like.

Date

- A nuclear plant works on the principle of Nuclear Fission (the process of a neutron being bombarded onto a high-energy nucleus that splits).

- Two types of Nuclear Reactions:
  - Controlled (Nuclear Reactor)
  - Uncontrolled (Atomic Bomb)

- Example of a Nuclear Reaction.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 3\,^{1}_{0}n + \text{Energy}$$

- These 3 neutrons further carry out fission themselves.

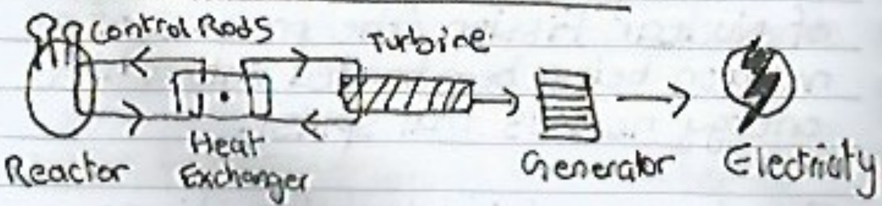
- To convert between mass and energy:

$$E = mc^2$$

Speed of light

Date

## How a Nuclear Plant Works:




- Uranium fuel is loaded into a reactor. This produces neutrons, splits atoms which makes chain reactions. The control rods are used to control the speed of the reaction. Water is pumped into this. The heated water passes through the heat exchanger. The heat exchanger in turn moves heated water towards the turbine. The turbine is linked to a generator. When it turns, the generator does too. The generator turns and produces electricity. This is transported through power grids.

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- Apart from Fission, Nuclear Fusion can be used as a power source too. Fusion is the process of two or more nuclei combining to a create a nucleus of greater mass. Example:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n \rightarrow \text{Can do fission}$$

Deuterium, Tritium → Isotopes of Hydrogen

- Since the two isotopes are positive, they repel. Hence, a temperature of 150 million °C is needed. Fission can be used to carry this out.

- Fusion has faults, such as high temperatures, high costs and uncontrollable reactions.

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# HEAT AND THERMODYNAMICS

- Heat is a form of energy that flows from one body to another - specifically from areas of high temperatures to lower temperatures. It's unit is joule. It is measured by a ~~temperature~~ thermometer (temperature) or a Calorimeter (amount of heat).

- Law of Heat Exchange: Heat lost by hot object = heat gained by cold object. Thermal equilibrium is reached when heat transfer, as both objects are then of the same temperature (the measure of the hotness/coldness of an object). Its units are:
  - Kelvin (K) — SI unit
  - Celsius (c) / Centigrade
  - Fahrenheit (F)



Date

- To convert between K and C:

$$K = C + 273$$

- To convert between C and F:

$$C = \frac{5}{9} \times (F - 32)$$

- Heat Capacity is the amount of heat required to raise the temperature of an object by 1°C or 1 K. It is the tendency of an object to absorb heat.

- Specific Heat capacity (c) is the amount of heat needed to raise the temperature of 1 kg of a substance by 1 K or 1°C.
  - Specific Heat Capacity of Water is 4.186.

Date

- For the amount of heat energy:

$$Q = mc\Delta T$$

$Q$ → Amount of heat energy
$m$ → Mass
$c$ → Specific Heat Capacity
$\Delta T$ → Change in temperature

- For the power of a body:

$$P = \frac{Q}{t}$$

$P$ → Power
$Q$ → Amount of heat energy
$t$ → Time

and

$$P = \frac{mc\Delta T}{t}$$

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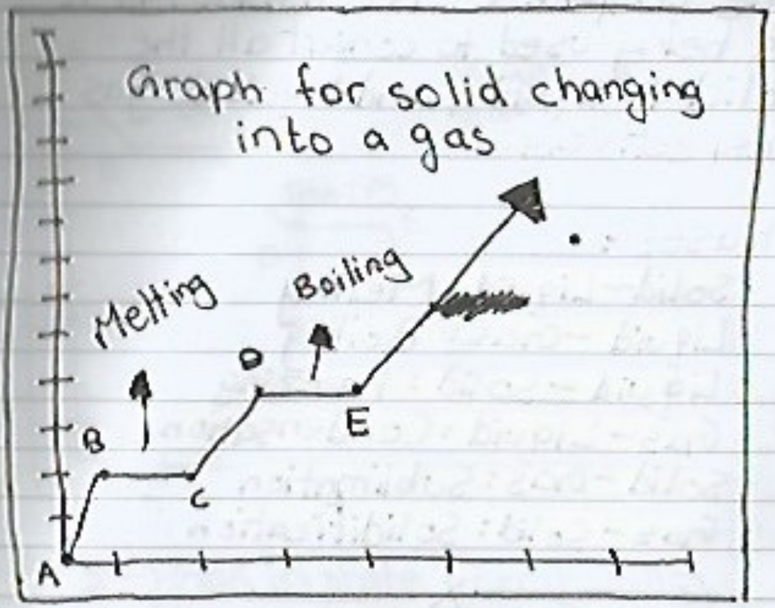
- The graph for changes of state:




- A–B → Solid in state (temp. rises)
- B–C → Phase change (melting)
- C–D → Liquid in state (temp. rises)
- D–C → Phase change (boiling)
- E onwards → Gas in state, temp. rises.

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- From points B – C, and D – E, the temperature is constant, as it is being used to convert all the solid to liquid, and liquid to gas respectively.

- Phases:
  - Solid – Liquid : Melting
  - Liquid – Gas : Boiling
  - Liquid – Solid : Freezing
  - Gas – Liquid : Condensation
  - Solid – Gas : Sublimation
  - Gas – Solid : Solidification

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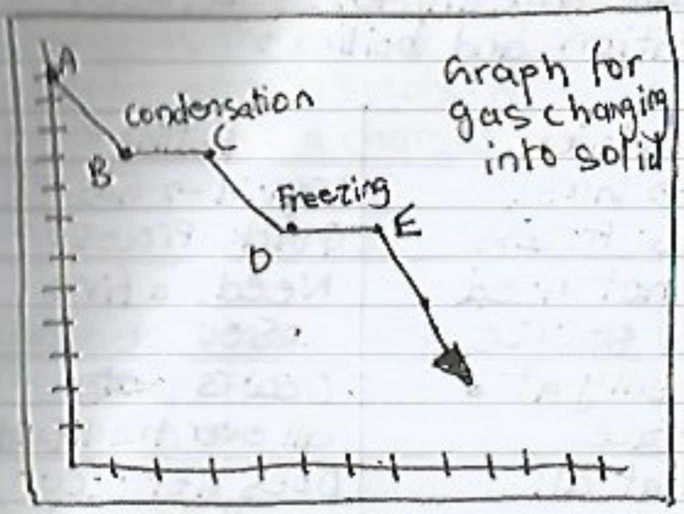
- Graph for changes of state:




- A – B → Gas in state (temp. falls)
- B – C → Phase change (condensation)
- C – D → Liquid in state (temp. falls)
- D – E → Phase change (freezing)
- E onwards → Solid in state (temp. falls)

Date

- Although they can used interchangeably, there are some differences between evaporation and boiling:

| Evaporation | Boiling |
|---|---|
| Liquid → Gas | Liquid → Gas |
| Slow Process | Quick Process |
| Does not need a fire source | Needs a fire source |
| Occurs only at surface | Occurs all over the liquid |
| Occurs at all temperatures | Does not occur at all temperatures |
| Does not have a definitive point at which it takes place | Has a definitive boiling point |
| Bubbles are not formed | Bubbles are formed. |
| Can be carried out by Sun and/or environment | Cannot be carried out by the environment |

Date

# ELECTRICITY AND MAGNETISM

- Charge is the tendency of atoms to attract other objects. A charge belongs to an ion, or a charged particle. An atom gets charged by loosing or gaining electrons.

- Coulomb's law deals with the intermolecular forces of attraction, and the repulsion between objects.

(1) — $F \propto q_1 q_2$

$F$ → Force

$q_1, q_2$ → Charge

The more the force of attraction, the more the product of the charges.

Date

(2) — $F \propto \frac{1}{r^2}$ → Distance

- The force is inversely proportional to the distance squared.

(3) — $F = K \frac{q_1 q_2}{r^2}$ → Coulomb's constant

- Coulomb's constant is approximately ~~[illegible]~~ $9 \times 10^9$ for air. It is the electric force constant.

- If the force is increased, the charge will increase too.

- It should be noted that Coulomb's constant varies across different mediums. For instance, it is lower for paper.

Date

- Static electricity is the charge in stationary (resting) objects. When an object rubs against something, due to heat, the electrons have enough energy to escape the object (object A, as it can be called). The free electrons stick to another object (we can refer to it as object B). Hence, object A is positive, while B is negative. When they both come into contact, a spark follows, and both objects become neutral.

- Electrostatic induction is the phenomenon in which, in a presence of a charged body, the charges on the insulator/other body are distributed in a such a way that like charges come on one side, while unlike charges come on the other end.

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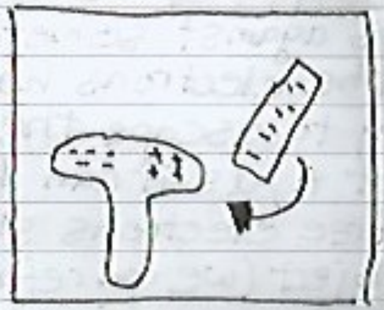
• Electrostatic induction:



• The word "electrostatic" means having to do with electric charges/fields of stationary objects.

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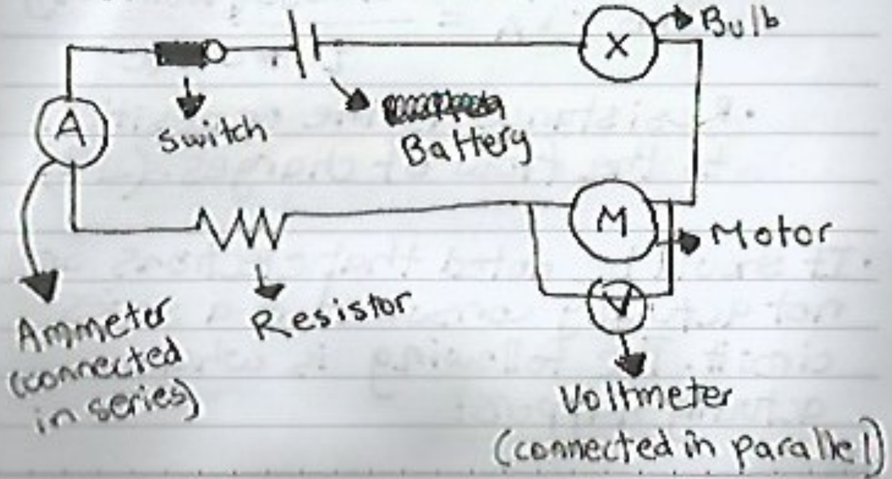
• A circuit is an enclosed path through which electricity flows. On the other hand, current is the rate of flow of negative/positive charges. Current is measured by an ammeter in Amperes (A).

Date

• Electrons flow in a circuit that carry energy. The nucleas of an atom, inside a circuit serves no purpose. Howeves if it becomes unbalanced, the substance can become radioactive.

• There are 2 types of circuits:
  • Series: Only one path in which current/electricity can flow through.
  • Parallel: Multiple paths.

• Example of Series circuit:



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• In a Series circuit, the voltage changes across different resistors, but the current stays constant.

- Voltage is defined as the energy that is consumed. It can also be the difference between two points, or the work done or energy given to a charge in moving from a point to another against the field. Electric potential is the same. Findable using: (V)

$$V_B - V_A = \frac{\text{Energy (Work Done)}}{q \rightarrow \text{charge}}$$

- Resistance is the opposition to the flow of charges. ($\Omega$)

• It should be noted that electrons are not actually consumed in a series circuit. The following is what actually happens:

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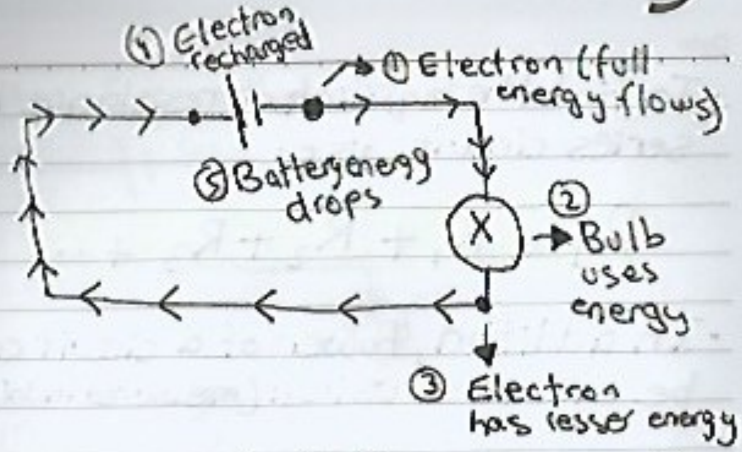


• So, overusage of a battery causes it to drain.

• Current, voltage and Resistance are interrelatable using Ohm's law:

$$\underset{\text{Current}}{I} = \frac{V \rightarrow \text{voltage}}{\underset{\text{Resistance}}{R}} \quad , \quad V = IR$$

$$, \quad R = \frac{V}{I}$$

Date

• To find the equivalent resistance in a series circuit, use:

$$R_T = R_1 + R_2 + R_3 + \dots$$

• In addition, Power of a circuit can be calculated using: (measured in Watts)

$$P = VI \quad \text{or} \quad P = \frac{V^2}{R}$$

$$\text{or} \quad P = I^2 R$$

• A resistor is the tool that provides resistance to a circuit. It basically converts electrical energy into heat energy. It divides the electric potential. The circuit divider is called the potential divider.



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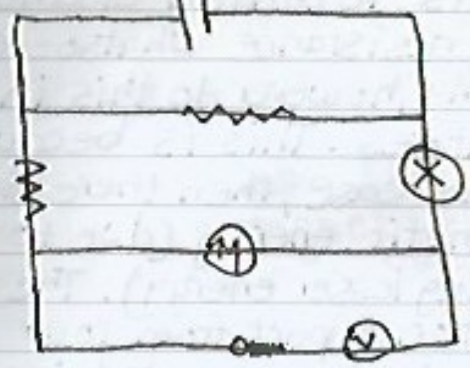
• Example of parallel circuit:



• To find the equivalent resistance in a parallel circuit:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

• Electromotive Force (EMF) is the energy that is supplied by a battery to a unit coulomb charge. It is only the energy, not actually a force.

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• Superconductivity is the ability of "superconductors" to conduct electricity without any resistance whatsoever. They can only, however do this in low temperatures. This is because if this is the case, then there shall be lesse kinetic energy (due to the particles having lesser energy). The other condition, apart from low temperatures, is the current being AC current (Alternating Current). Only metals can be superconductors, since they have a whole sea of mobile electrons. Hence they have more electronmobility. This means that the electrons are able to move about more freely.

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Date

• "Electromagnetic" refers to anything that has to do with the phenomenon of the interaction of electric currents or fields and magnetic fields.

• Electromagnetic Induction is the ability of a magnetic field to create current inside a conductor. A change in magnetic field causes current to be created. It causes the production of an EMF across an electric conductor in a changing magnetic field.

• Magnetic flux is a measurement of the total magnetic field which passes through a given area. Faraday's Law States that a change in maghetic flux can induce an EMF.

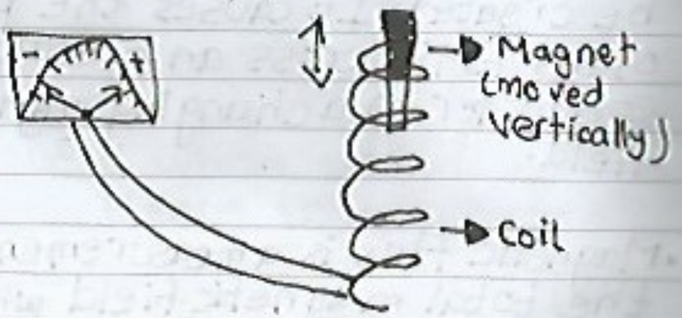
Date

- Faraday's Law:

$$N = \frac{-\Delta \Phi}{\Delta t}$$

$N$ → induced EMF
$\Delta \Phi$ → change in magnetic flux
$\Delta t$ → change in time

- Diagram of this process:




- The electrons move back and forth. Adding the magnet sends the reading in +, but then returns to zero. Once pulled out, it goes into –. This is due to the changes in magnetic flux. If the magnet

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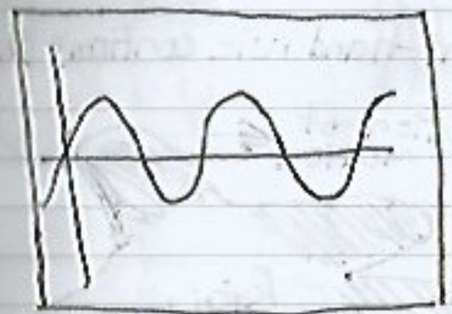
is pulled back and forth, the electrons will travel that way too, producing an emf. The graph of the emf will look similar to that of $y = \sin x$.



- This is Alternating (AC) Current.

- Factors affecting this process:
  - Strength of magnet: Higher will cause higher emf.
  - Number of coils: Higher will cause higher emf.

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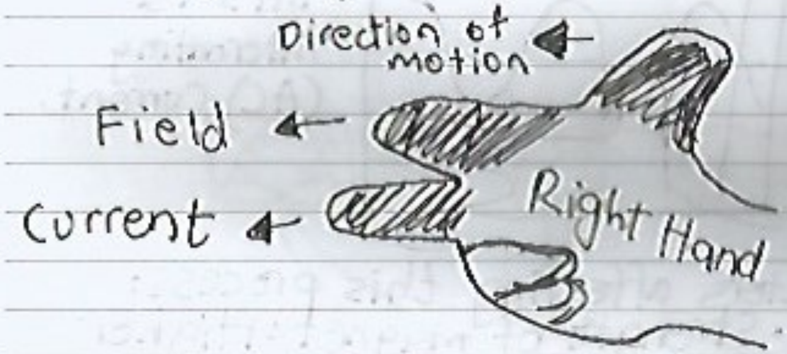
- Lenz's Law states that the direction of an induced current is always such as to oppose the changes in the circuit or the magnetic field that produces it (perpendicular to it)

- Fleming's right-hand rule confirms this:




- On the principles of electromagnetic induction, electricity can be produced on very large scale. All that is needed is a huge rotor and magnet.

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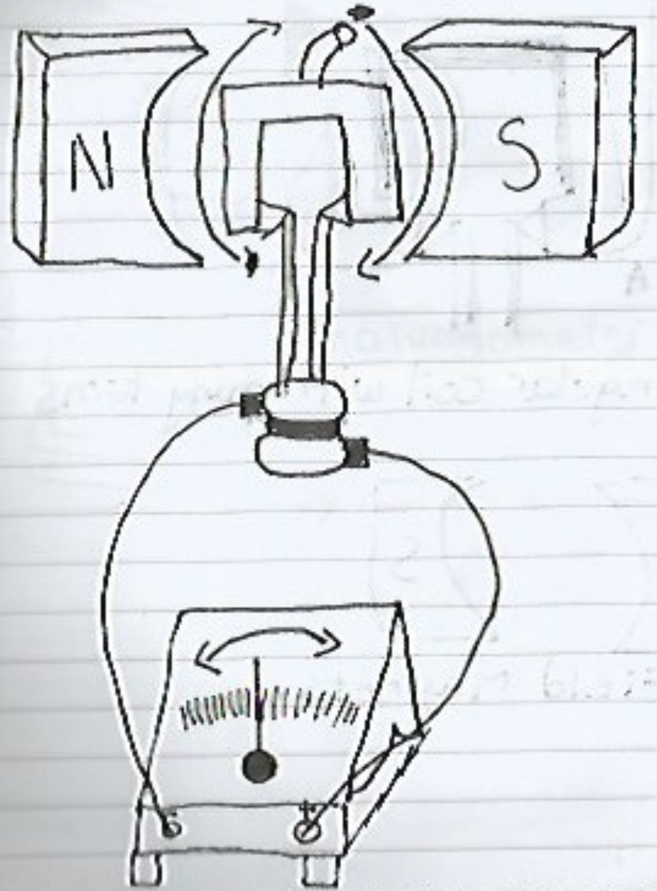
- An AC generator is a rotor that spins and turns mechanical energy into electrical energy.



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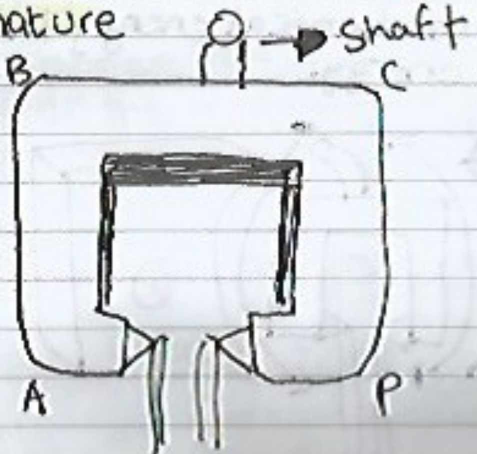
# Parts of AC Generator

① Armature




Rectangular coil with many turns

②


Field Magnets



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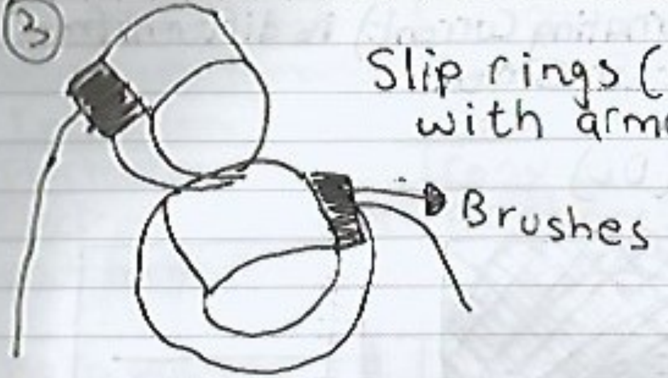
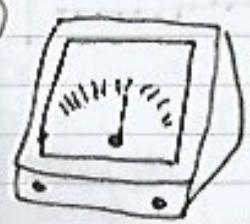
③




Slip rings (rotate with armature)

④



Galvanometer/Load

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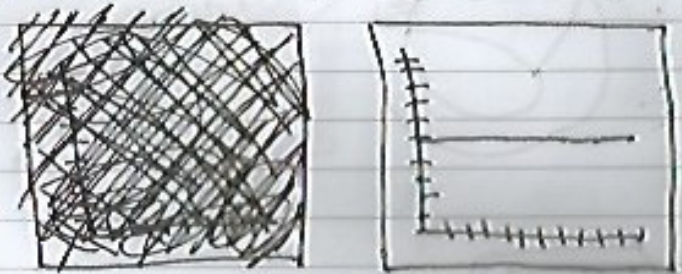
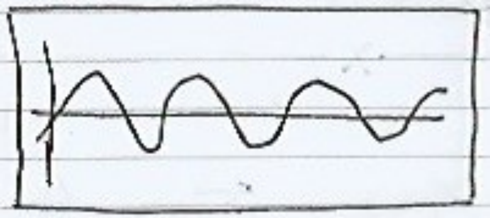
• AC (Alternating Current) is different from DC (Direct Current.

• Graph (DC)



• Graph (AC)



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| Alternating Current | Direct Current |
|---|---|
| Source : Electromagnetic Induction | Source : Batteries, Solar Power etc. |
| Fluctuates | Constant |
| Electrons move back and forth | Electrons only move in one direction |
| Both positive and negative | Only positive |
| Dangerous | Harmless |
| Good for long-range transportation through power grid | Not good for long range transportation. |
| Efficiently used in transformers | Inefficiently used in transformers. |

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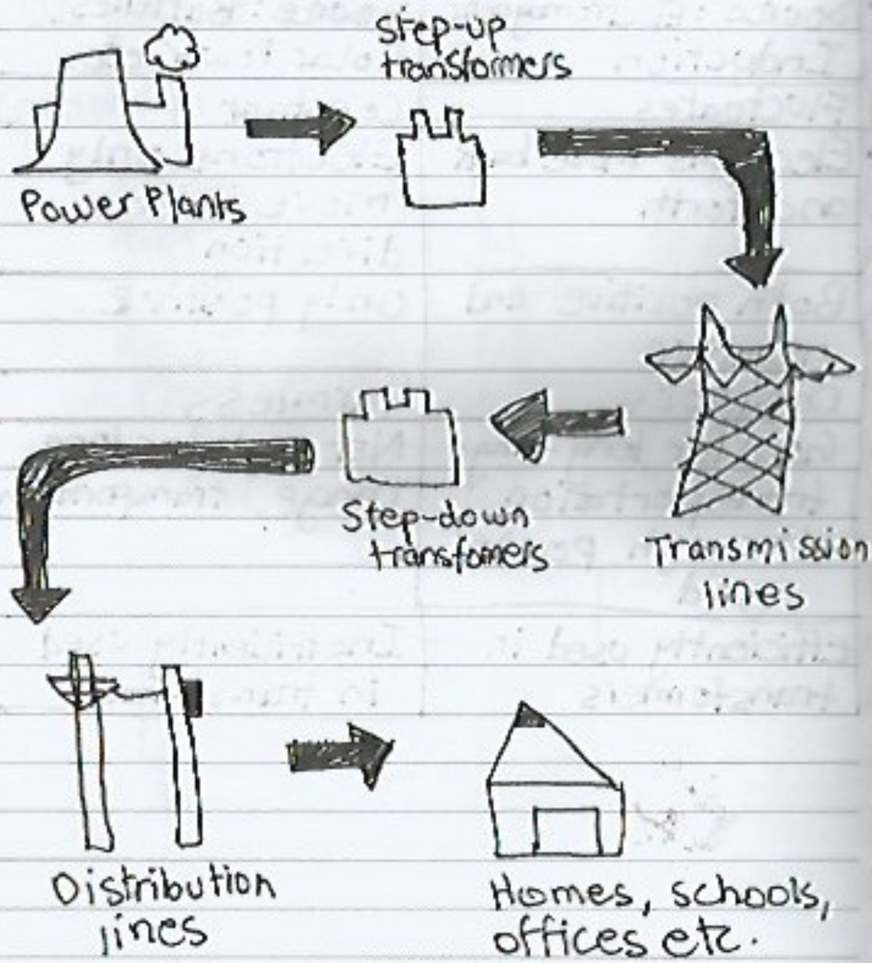
• How electricity is distributed:



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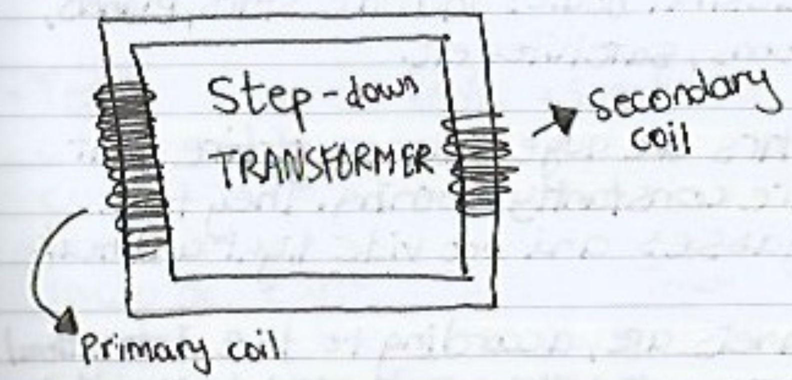
• Transformers are devices that increase/decrease voltage. There are 2 types:
  - Step-up : Increase voltage for long-distance travelling
  - Step-down : Decrease voltage so it is usable in homes etc.




$$\frac{\text{Voltage of sec. coil}}{\text{Voltage of pri. coil}} = \frac{\text{\# of loops in sec. coil}}{\text{\# of loops in pri. coil}}$$

# ASTROPHYSICS

- Astrophysics is the study of stars, planets, moons and other celestial bodies, including their satellites.

- Celestial bodies include stars, planets, moons, satellites etc.

- Stars are huge masses of fire that are constantly burning. They fuse gasses and provide light and heat.

- Planets are, according to the International Astronomical Union, celestial bodies that:
  - Orbit a star around a circular/oval-like path.
  - Are (nearly) round
  - Are not any other planet's moon
  - Do not have debris around their orbit.

- There are an estimated $10^{24}$ planets in the Observable universe. There are 2 types of planets:
  - Terrestial: Small and Rocky
  - Jovian: Giant, made of gasses
  - There are 36 sub-categories of planets.

- Terrestial planets have a smaller size and mass. They have a heavy molten core and topological features like volcanoes and craters. Examples include Earth, Mars etc. They make up the inner part of our Solar System. They are rocky.

- Jovian Planets have larger sizes. They only have small amounts of rocks in cores, and are mostly made of gasses (Hydrogen and Helium in atmosphere). They include Jupiter, Saturn etc. (outer planets).

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- All planets revolve around a star and rotate on different axes. Scientists stay that planets continue to rotate in the same manner in which they were when they collided, due to inertia.

- Dwarf Planets are the same as normal planets, except they have debris in their outer surroundings.

- Scientists say planets were formed by the collision and vibration of rocky substances. Due to their great masses, they turned circular.

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- A satellite is a moon, planet or star that orbits a planet or star. Moons are generally regarded as "Natural Satellites".

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- There are many types of satellites:
  - Natural Satellites → Naturally orbit stars or planets
  - Low Earth Orbits → 160 km away from Earth. Complete an orbit in 90 minutes. Used by military to locate tanks.
  - Geosynchronous → 24 hours for an orbit. Used for communication at high altitudes.
  - Geostationary → Majority of communication satellites. Orbit once in 24 hours, 14788 km above the Earth.
  - Sun-synchronous → 15-16 orbits daily. They, in polar orbits, make weather predictions, being fixed relative to the Sun.

- Satellites work by reflecting signals back to Earth. An uplink is sent from earth to the satellite,

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after which data is processed. Transponders are used to avoid incoming and outgoing signals. Finally, a downlink is used to send the data from the satellites back to Earth.

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- Everything, according to the Big Bang Theory, came into existence about 13.7 billion years ago. It says that at the time there was infinitely dense and small "dot" that "burst" into existence. It also states that all galaxies are spreading apart from one another. After the dot "burst", it was spreading. There was no actual explosion, just the stretching of the universe. That dot ~~[illegible]~~ stretched into gluons, then quarks, and matter was able to "triumph" over antimatter. Then, the 4 essential forces were formed (Electromagnetic, Strong & weak Nuclear and Gravity).

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Within $10^{-9}$ seconds of the event, the universe was already a billion km in diameter. Quarks started producing neutrons and protons. Within a second, the universe had already spread over a 100 billion km, and synthesized the first atom - Hydrogen. It was around 10 billion °C at the time. Within a few minutes, atoms formed stars, galaxies, planets etc.

- Some people question as to what existed before the Big Bang. It is important that we understand that the Big Bang did not just create Space, but Space - Time. Meaning that time did not exist before the Big Bang.

- Scientists "travel back in time" to the Big Bang using the Redshift Theory. This suggests that as

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galaxies spread out, their wavelengths become larger. Scientists reversed this to "see in the past"

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- A telescope is an optical instrument that makes distant objects (celestial bodies) appear ~~to~~ be nearer. It contains an arrangement of lenses and mirrors, and focuses rays onto one point. Types of telescopes:
  - Astrograph: For photographing distant astronomical objects
  - Comet Seeker: Searching comets
  - Go To: Automatically points to distant objects/celestial bodies.
  - Infrared: Uses infrared rays.
  - Etc.

- There are two main categories of telescopes: Refractive and Reflective.



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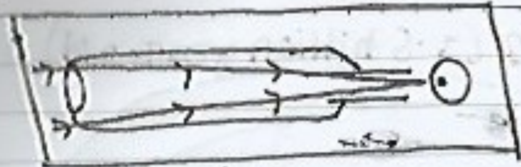
- 

Refractive

- 

Reflective

- A telescope basically works by gathering light. The "objective" is the lens that collects light. The bigger it is, the more light is collected. If there is more light, one can see farther.

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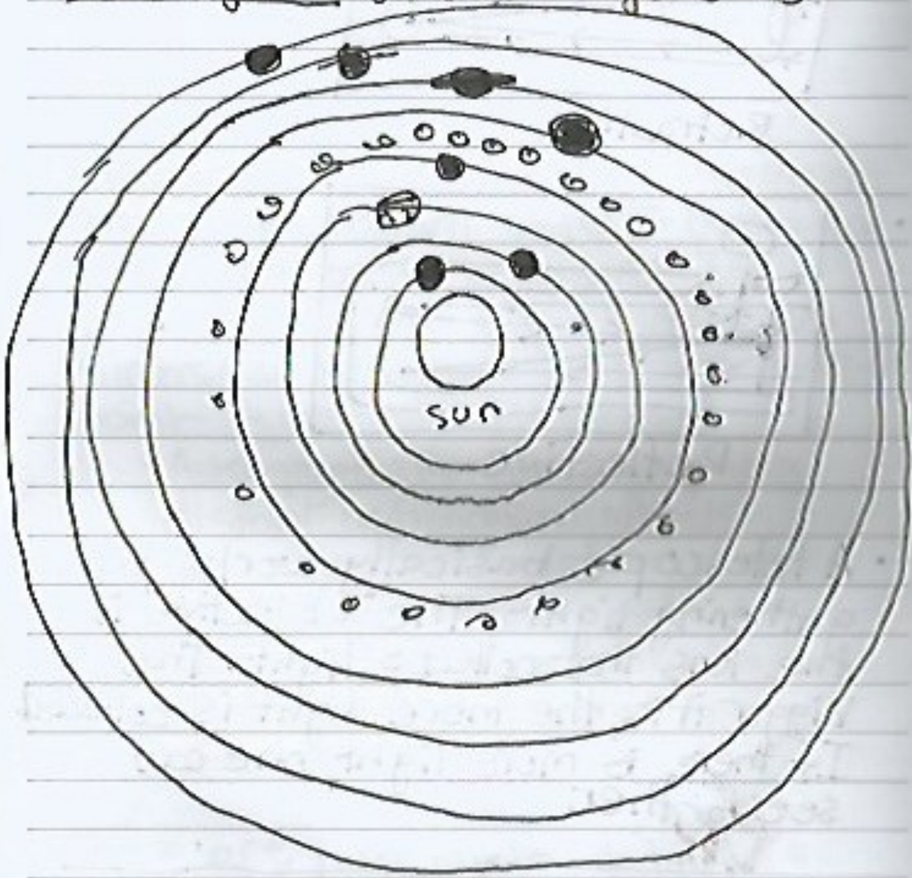
• Solar System (4.5 billion years old):




• Mercury, Venus, Earth, Mars, Asteroid Belt, Jupiter, Saturn, Uranus and Neptune.

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• Life Cycle of a star: