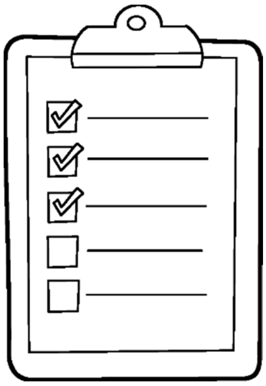
EXAM DAY CHECKLIST

COMPULSORY ITEMS

☐ Dark blue / black pen
☐ Soft pencil (type B or HB is recommended)
☐ Eraser
☐ Sharpener
☐ Scientific calculator
☐ Ruler (a transparent one is recommended)
☐ Protractor

FORBIDDEN ITEMS

☒ Staples
☒ Paper clips
☒ Glue
☒ Correction fluid (e.g., Blanco®)



NOTES:

- A soft pencil should be used for diagrams or graphs or MCQs answer sheet.
- It is advisable to have a spare pen.
- It is good to supplicate.

EXAM DAY ADVICE

- After completing your paper recheck the units in three ways:
  - Are any units missing?
  - Are units consistent when you put values in a formula?
  - Is output unit according to the input units?
- Answer according to the command words: state (brief answer), explain (give details), describe (visualize), etc.
- Your handwriting should be legible.

O LEVEL PHYSICS REVISION NOTES

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MEASUREMENT OF PHYSICAL QUANTITIES

- Physical quantities are either scalars or vectors.
  - Scalars don't have a direction.
  - Vectors have a direction.
- SI units
  - SI base units include:
    - m
    - kg
    - s
    - A
    - K
  - Derived units are based on base units, for example:
    - m/s
    - m/s^2
    - N (which really means kgm/s^2)
- Prefixes can be used if a unit is too big or too small for a purpose.
  - mega (M) means 1,000,000
  - kilo (k) means 1,000
  - deci (d) means $\frac{1}{10}$
  - centi (c) means $\frac{1}{100}$
  - milli (m) means $\frac{1}{1,000}$
  - micro (μ) means $\frac{1}{1,000,000}$
- Length measuring instruments
  - Ruler or measuring tape has an accuracy of ±1mm.
  - Vernier calipers has an accuracy of ±0.1mm.
  - Micrometer screwguage has an accuracy of ±0.01mm.

  Length = Main scale reading + Minor scale reading x Accuracy

  L = M + mA
- Time measuring instruments
  - Stopwatch has an accuracy of ±0.01s
  - Ticker-tape timer has an accuracy of ± $\frac{1}{50}s$ or ± $\frac{1}{60}s$.
  - Pendulum clock
- Pendulum
  - Oscillation is a vibration.
  - Time-period is the time taken for one oscillation.
  - Amplitude is the maximum displacement from central position.
  - A pendulum of a particular length has a constant time-period. It is not affected by amplitude.

SPEED, VELOCITY AND ACCELERATION

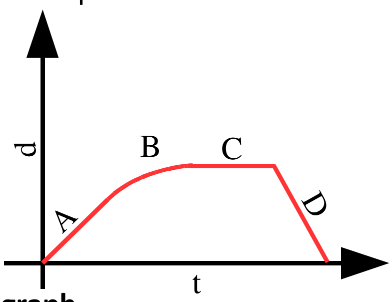
- **Speed:** It is the rate of change of distance with respect to time.

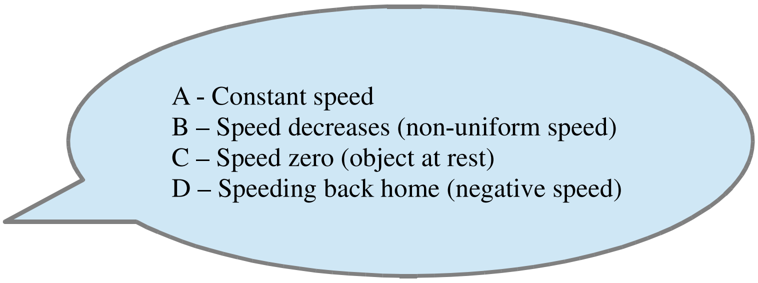
$$s = \frac{d}{t}$$

- **Velocity:** It is the rate of change of displacement with respect to time.
- **Acceleration:** It is the rate of change of velocity with respect to time.

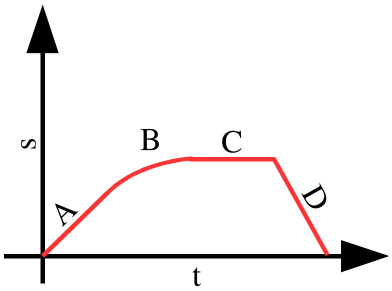
$$a = \frac{v_2 - v_1}{t}$$

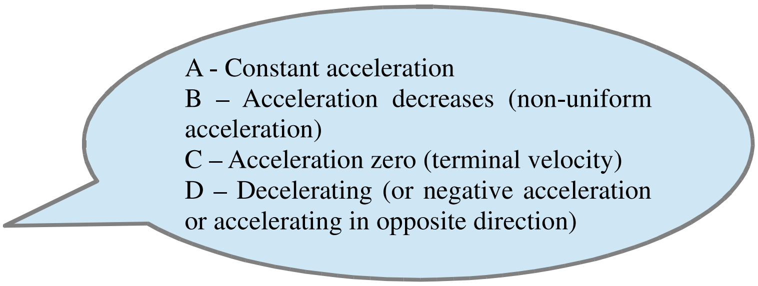
- **Non-uniform deceleration:** It is when there are unequal decreases in velocity in equal intervals of time.
- Graphs can be used to study motion.
  - **d-t graph**
    - Speed is equal to the gradient of such a graph. $s = \frac{d_2 - d_1}{t_2 - t_1}$
    - Example:





  - **s-t graph**
    - Acceleration is equal to the gradient of such a graph. $a = \frac{s_2 - s_1}{t_2 - t_1}$
    - Distance covered is equal to the the area under the graph.
    - Example:





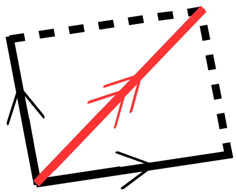
- Constant gradient or uniform speed or uniform acceleration is represented by a straight line.
- Acceleration can happen even when speed is constant if direction is changing.
- For an object going in a circle at constant speed, the resultant force is towards the center of the circle.
- Free-fall
  - Without air
    - Constant acceleration (of 10 m/s^2 on Earth).
    - Objects of different weights fall together.
  - With air
    - As the air resistance increases, the resultant force (of weight and air-resistance) decreases.
    - As resultant force decreases, the acceleration also decreases (according to Newton's Second Law of Motion).

- When the resultant force becomes zero, there is no acceleration and the body is said to be falling with terminal velocity.

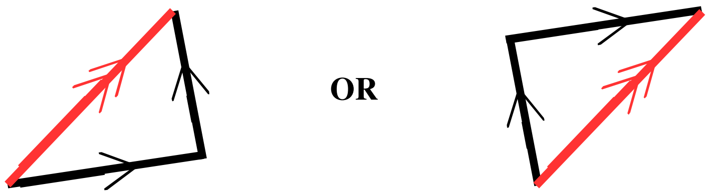
FORCES

- **Force:** It is a push or pull that one object exerts on another which produces, or tends to produce motion, stops or tends to stop motion.
  - Unit: N
  - Examples of forces are:

    weight; tension; magnetic force; electric force; contact force; friction; resistance;
- Addition of vectors
  - Simply add / subtract if vectors are acting in a line.
  - Law of Parallelogram:



  - Head-to-tail Rule:



- Newton's Laws of Motion
  - **First Law:** Every object continues in its state of rest or uniform motion in a straight line unless a resultant force acts on it to change its state.
  - **Second Law:** Acceleration of a mass is directly proportional to the resultant force.

    $F \propto a$ and $F = ma$

    Note: Acceleration has the same direction as the resultant force.
  - **Third Law:** To every action there is an equal and opposite reaction.
- Balanced forces
  - When there is no resultant force
    - acceleration will be zero (2^{nd} Law)
    - no change in state of motion (1^{st} Law)
- Unbalanced forces
  - When there is a resultant force
    - acceleration will NOT be zero (2^{nd} Law)
    - change in state of motion(1^{st} Law)
- **Friction:** It is the force that opposes motion.
  - It has advantages and disadvantages.
  - Friction is affected by
    - lubrication / oiling
    - how hard the surfaces are rubbed together
    - nature of the surfaces in contact
  - Types
    - Static friction is the friction when a body is not moving.
    - Limiting friction is the (maximum static) friction when a body is just about to move.
    - Dynamic friction is the friction when a body is moving.

    Note: Dynamic friction is always less than limiting friction.

MASS, WEIGHT AND DENSITY

- **Mass:** It is the amount of matter (substance) in a body.
- **Weight:** The downward force equal to product of mass and the gravitational field strength.

$$W = m\,g$$

- **Differences:**

Weight	Mass
It is a force.	It is the amount of matter in a body.
Measured in N	Measured in kg
Vector	Scalar (,i.e., no direction)
Changes from place to place	Constant regardless of location

- **Inertia:** It is the <u>reluctance</u> of mass to a change in its state of motion.
  - A truck has more mass and hence more inertia than a car.
- Gravitational field strength of Earth is 10 N/kg. This means that the strength of Earth's gravity is so strong that an object will have a weight of 10 N for every kg of mass that it has.
  - Unit: N/kg
- **Measuring instruments:**
  - **Spring balance:** Measures weight.
    Using the formula W=mg, it can have a scale for mass too. The value of 'g' is assumed in such a case.
  - **Beam balance:** Measures mass by <u>comparing</u> the weight of a mass with the weight of known masses (e.g., discs).
- **Density:** It is the mass per unit volume.

$$\rho = \frac{m}{V}$$

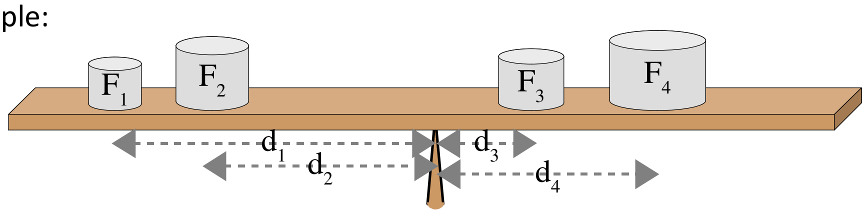
  - SI Unit: $\frac{kg}{m^3}$
- **Measurement of volume:** Volume can be found by:
  - Displacing a liquid
  - For regular shaped objects a formula may be used, for example:
    - Block: $V = l \times w \times h$
    - Cylinder: $V = \pi r^2 l$
    - Sphere: $V = \frac{4}{3} \pi r^3$
- Less dense liquids and gases rise above more dense liquids and gases respectively.

TURNING EFFECT OF FORCES

- **Moment of a force:** It is the product of force and the perpendicular distance (between the line of action of the force and the pivot).

$$Moment\ of\ a\ force = F \times d$$

- Moments can be clockwise or anticlockwise.
- **The Principle of Moments:** For a body in equilibrium, the sum of clockwise moments is equal to the sum of anticlockwise moments.
  - Example:



sum of clockwise moments = sum of anticlockwise moments

$$(F_1 \times d_1) + (F_2 \times d_2) = (F_3 \times d_3) + (F_4 \times d_4)$$

- **Centre of mass:** It is the point through which the whole weight of an object seems to act for any orientation of the object.
  - Centre of mass of an object (such as ring) can lie outside the object.
  - Experiment to determine centre of mass of a plane lamina
    - The marking points are:
      - set metal swinging
      - allow to come to rest
      - use of plumb line from hole
      - mark line along plumb line (on metal)
      - hang from another hole
      - hang from 3 rd hole
      - line intersection is centre of mass
- **Stability:** It is the ability of an object to regain its original position after it has been tilted slightly.
  - Stability can be improved by
    - lowering the centre of mass
    - increasing the base area

WORK, ENERGY AND POWER

- **Energy:** It is the ability to do work.

$$E=W$$

- **Work:** It is the product of force and the distance moved in the direction of force.

$$W=F\times s$$

  - Unit: J
- **Forms of energy:**
  - chemical
  - nuclear
  - radiant
  - electrical
  - heat
  - mechanical
    - kinetic energy $E=\frac{1}{2}mv^2$
    - gravitational potential energy $E=Wh=mgh$
    - elastic potential energy
- **Principal of Conservation of Energy:** Energy can be converted from one form to another but the total amount remains constant.
- **Efficiency =** $\frac{useful\ energy\ output}{energy\ input}$ Multiply by 100 to get a percentage.
- **Power:** It is the rate of doing work. $P=\frac{W}{t}$

  OR

  It is the rate of energy conversion. $P=\frac{E}{t}$

  - Unit: W

PRESSURE

- **Pressure**: It is the force per unit area.
  - $P = \frac{F}{A}$
  - **Unit:** Pa
  - Examples
    - Swords exert high pressure because they concentrate the force on a small area.
    - Skis exert low pressure on the snow because the weight is spread over a large area.
- **Pressure of liquids**
  - Pressure of a liquid is due to weight of the liquid.
  - $P = h\rho g$
  - When something is immersed in a liquid, the liquid pushes it up. This upthrust is because the pressure near the top of the object is less and the pressure near the bottom of the object is more.
- **Hydraulic systems**: In such systems, pressure is transmitted between pistons using liquids because liquids are incompressible.

$$P_y = P_x$$

Pressure at both pistons is same.

$$\frac{F_y}{A_y} = \frac{F_x}{A_x}$$

P = F / A

$$F_y = F_x \times \frac{A_y}{A_x}$$

This means that force F_x will result in a bigger force F_y if $A_y > A_x$.

- **Pressure of gases**
  - Pressure of gases is due to molecular collisions.
  - Pressure of a gas can be changed by
    - changing temperature
    - changing mass
    - changing volume
  - Atmospheric pressure
    - At sea level it is:

$$1\, atmosphere = 1.0 \times 10^5\, Pa = 76\text{cm}\, of\ Hg = 760\text{mm}\, of\ Hg$$

    - On a mountain top it is less.
    - In a deep mine it is more.
- **Simple Mercury Barometer**: A simple mercury (Hg) barometer can be used to measure atmospheric pressure.
  - Working: Pressure of atmosphere is equal to the pressure of (additional height of) liquid.
- **Manometer**: A manometer can be connected to a gas container to measure the pressure of the gas inside the container.
  - Working:
    - $P_G = P_L + P_0$
      OR
    - $P_G + P_L = P_0$
- **Boyle's Law**: $P_1 V_1 = P_2 V_2$
  - This formula assumes that temperature or mass does not change.

- Some useful notes important from exams point of view
  - If you are finding the total pressure beneath the surface of a liquid then don't forget to add the atmospheric pressure to the pressure of the liquid.
  - If you are explaining a concept using ideas about molecules then there may be marks for writing:
    - Molecules vibrate.
    - When a molecule hits a surface it exerts a force.
    - When many molecules hit a unit area of the wall at the same time, their collective force over the unit area is pressure ($P=\frac{F}{A}$).
    - Pressure depends on frequency of collisions.
      - Frequency of collisions is affected by change in mass, temperature or volume.
        - When temperature increases, the speed of molecules increases. So more frequent (and more forceful) collisions.
        - When volume decreases, the average separation between molecules decreases. So more frequent collisions.
        - When mass increases, the average separation between molecules decreases. So more frequent collisions.
    - The pressure at a narrow end is the same as the pressure at a wide end because the ratio of force to area is the same.

MEASUREMENT OF TEMPERATURE

- **Temperature**: It is a measure of the average kinetic energy of the atoms or molecules in the system. Temperature is a measure of how hot or cold something is.
- **Heat:** Heat is the energy that is exchanged between two objects due to their difference in temperature.
- **Calibrating a thermometer:**
  - Step 1: To measure temperature we need a physical quantity that is affected by temperature. For example volume, e.m.f., resistance or pressure.
  - Step 2: Mark ice point and steam point.
  - Step 3: Divide the temperature range between the two points into 100 equal divisions.
- **Thermometric liquids:**

	Mercury	**Alcohol**
Advantages	• Good conductor • Does not wet glass • High boiling point	• Not poisonous • Cheap • Low freezing point
Disadvantages	• Poisonous • Expensive • High freezing point (-39°C)	• Bad conductor • Wets glass • Low boiling point (78°C)

- **Some definitions:**
  - Responsiveness: It is about how quickly you get the result.
  - Sensitivity: It is about how much does the thermometric property (e.g., volume) change per degree change in temperature.
  - Range: The minimum and maximum temperatures that can be measured.
  - Linearity: It is about whether each degree is an equal distance or not.
- **Liquid-in-glass thermometers:** In comparison to a laboratory thermometer, a clinical thermometer has:
  - a constriction
  - less range
  - greater sensitivity (divisions further apart)
  - triangular cross-section (for magnification)
- **Thermocouple thermometers:**
  - Construction: You should be able to draw figure 8.13.
  - Defining equation: $e.m.f. \propto \Delta\theta$
  - Advantages:
    - Large range
    - Measures temperature at a point
    - High responsiveness
    - Can be connected to computers because of electrical output

SIMPLE KINETIC THEORY OF MATTER

- **Properties of states of matter:**
  - Solids have a fixed volume and shape.
  - Liquids have a fixed volume but no fixed shape.
  - Gases have no fixed volume. They spread out to fill all the space available to them. Gases have least density. Unlike solids and liquids, gases can be compressed.
- **Kinetic theory of matter:** According to this theory, molecules of solids, liquids and gases are in continuous random motion.
  - In solids, molecules vibrate about fixed positions and they have minimum space between them. There are strong intermolecular forces between molecules.
  - In liquids, molecules are not fixed in their positions. Molecules have slightly more space between them compared to solids. Intremolecular forces are weaker than in solids <u>but still pretty strong</u>.
  - In gases, molecules have high kinetic energy and the intermolecular forces are negligible. Average distance between molecules is greatest.
- Evidence of molecular motion
  - Diffusion
  - Reflections from smoke particles in a glass cell are observed using a microscope. The smoke particles show random motion because of the air molecules bombarding them.
  - Observing pollen on the surface of water
- Kinetic theory of matter can be used to explain a range of phenomena including:
  - diffusion
  - evaporation
  - pressure of a gas
  - fixed shape of a solid
  - expansion

HEAT CAPACITY

- **Heat capacity:** It is the amount of heat energy required to raise the temperature of a body by 1 °C.

$$C = \frac{E}{\Delta\theta}$$

$\Delta\theta$ represents the difference in temperature ($\theta_2 - \theta_1$).

  - Unit: J/°C.
- **Specific heat capacity:** It is the amount of heat energy required to raise the temperature of 1 kg of a substance by 1 °C.

$$c = \frac{E}{m\Delta\theta}$$

  - Unit: J/(kg °C)
- Relationship between heat capacity and specific heat capacity

$$c = \frac{C}{m}$$

- Specific heat capacity of different materials is different.
  - For example, 1 kg of copper needs far less energy than 1 kg of water for a temperature rise of 1°C .
- Experiment to determine the specific heat capacity of a liquid:
  - Use the formula $c = \frac{E}{m\Delta\theta}$
  - Therefore,
    - Calculate the electrical energy that changes into heat.
    - Measure the mass of liquid.
    - Note the initial and final temperatures.
  - Precautions
    - Use lagging for heat insulation.
    - Stir liquid for uniform distribution of heat.
    - After switching off the heater, allow mercury thread to rise and consider the maximum value to be the final reading.

MELTING AND BOILING

- **Melting point:** It is the temperature at which a solid changes into a liquid.
- **Freezing point:** It is the temperature at which a liquid changes into a solid.
  Note: Melting point and freezing point are the same temperature. For water it is 0^oC.
- **Boiling point:** It is the temperature at which a liquid changes into a gas.
- **Condensation point:** It is the temperature at which a gas changes into a liquid.
  Note: Boiling point and condensation point are the same temperature. For water it is 100^oC.
- Changes of state
  - **Melting:** It is the change of state from solid to liquid without a change in temperature.
  - **Solidification / Freezing:** It is the change of state from liquid to solid without a change in temperature.
  - **Boiling:** It is the change of state from liquid to gas without a change in temperature.
  - **Condensation:** It is the change of state from gas to liquid without a change in temperature.
  - **Evaporation:** It is the change of state from liquid to gas at any temperature.
- Factors that affect melting and boiling points are:

Action	Freezing / melting point	Boiling point
Add impurity	Decreases	Increases
Add pressure	Decreases	Increases

- Latent heat means hidden heat. It is because as long as a change of state is going on, the heat supplied or taken does not produce a change in temperature.
- **Latent heat of fusion:** It is the heat energy required to change a solid to liquid or vice versa without any change in temperature.
  - Unit: J
- **Specific latent heat of fusion:** It is the heat energy required to change 1 kg of a solid to liquid or vice versa without a change in temperature.

$$l = \frac{E}{m}$$

  - Unit: J/kg
- **Latent heat of vaporisation:** It is the heat energy required to change a liquid to vapour or vice versa without any change in temperature.
  - Unit: J
- **Specific latent heat of vaporisation:** It is the heat energy required to change 1 kg of a liquid to gas or vice versa without any change in temperature.

$$l = \frac{E}{m}$$

  - Unit: J/kg
- Comparison between boiling and evaporation
  - Unlike boiling, evaporation happens at any temperature.
  - Unlike boiling, evaporation only happens at the surface.
  - Unlike boiling, evaporation is a slow process.
  - Unlike boiling, evaporation does not cause bubbling.
  - Unlike boiling, evaporation may not require a special heat source. The heat required for evaporation can come from the surroundings.
- Evaporation causes a decrease in temperature because higher energy molecules escape from the surface and the average kinetic energy of the molecules left in the liquid comes down.

- A refrigerator uses evaporation and condensation to work.
    - Freon condenses (when compressed) to release heat and evaporates when (decompressed) to absorb heat.
- Factors that increase the rate of evaporation are:
    - higher temperature
    - less humidity (which refers to the amount of moisture in the air)
    - more surface area
    - movement of air
    - lower atmospheric pressure
    - using another liquid with a lower boiling point

TRANSFER OF THERMAL ENERGY

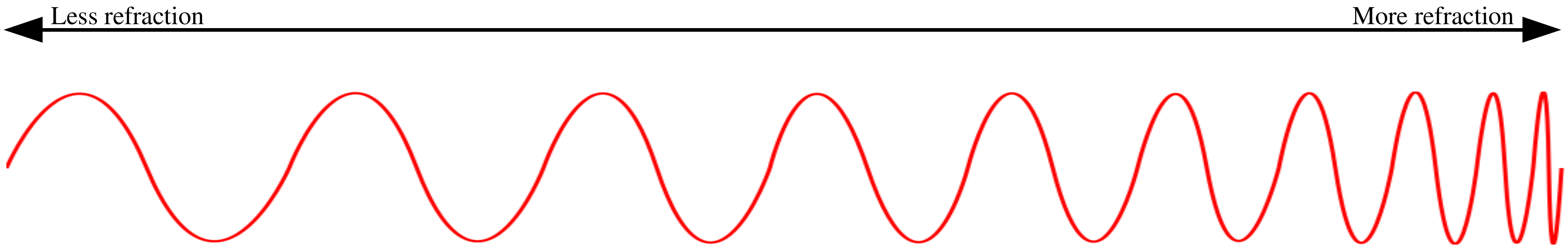
- Three methods of transfer of heat are conduction, convection and radiation.
- **Conduction:** It is the transfer of heat in which molecules with high kinetic energy collide with other molecules and transfer some of their energy. In this way energy is transferred from molecule to molecule.
  - Heat is also conducted by free-electrons.
  - Metals are better conductors than non-metals because of free-electron diffusion.
  - Metals feel cooler. Because they transfer heat away from our hand more quickly.
  - Solids are better conductors than liquids and gases because the particles (atoms or molecules) are packed more closely together.
- **Convection:** It is the transfer of heat in which a body of less dense fluid rises above a body of more dense fluid.
- **Radiation:** It is the transfer of heat by means of emission of infra-red waves from the surface of all bodies.
  - All bodies also absorb radiation. This causes a rise in temperature.
  - Generally, a good emitter of radiant heat is also a good absorber of radiant heat.
  - Radiations can travel through space because they don't require a material medium.
  - Factors that <u>increase</u> the rate of emission of radiation are:
    - Higher temperature of the surface
    - Greater surface area
    - Darker surface colour (e.g., black)
    - Dull texture of the surface
  - Black colour is the best absorber and emitter of radiation and white is the worst.
  - White is the best reflector of radiation and black is the worst.
- Applications, consequences, etc.
  - Conduction
    - Feathers, fur, woolen clothes, fiberglass, expanded polystyrene, etc. trap air so they are good insulators of heat.
    - In a vacuum flask (or thermos flask), the insulating materials, the vacuum between the double glass wall and the trapped air at the top minimize heat loss through conduction.
  - Convection
    - Sea water and land heat up or cool down at different rates. Convection causes a breeze...
      - from sea to land during the day and
      - from land to sea during the night
  - Radiation
    - On sunny days, wearing dull, black clothes will be uncomfortable.
    - Shiny teapots radiate less heat.
    - In a vacuum flask (or thermos flask), the glass is silvered to reflect the radiations back into the liquid.
    - In a greenhouse, (higher energy) higher frequency radiations pass through glass and warm up the plants and soil. Radiant heat from the plants and soil has less frequency so it cannot go out through the glass. The rise of temperature helps plants grow.

GENERAL WAVE PROPERTIES

- **Wave motion:** It is the transfer of energy without an overall transfer of material medium.
- Types of waves
  - Transverse waves are those waves in which the direction of wave-motion is perpendicular to the direction of vibration of source.
    - Examples: Rope waves, all kinds of electromagnetic radiations, water waves, etc.
  - Longitudenal waves are those waves in which the direction of wave-motion is parallel to the direction of vibration of source.
    - Examples: Sound waves, compressions and rarefactions in a slinky spring, etc.
- Some terminologies related to the study of wave-motion are:
  - Crests are the high points. For longitudenal waves the term compressions is used.
  - Troughs are the low points. For longitudenal waves the term rarefactions is used.
  - Amplitude (A) is the MAXIMUM displacement from the central position.
  - Phase: Two points are said to be in phase if they meet three conditions:
    - they are moving in the same direction
    - they are moving with the same speed
    - they have the same displacement from central position

    Note: Therefore, ANY two crests or troughs are in phase.
  - Wavelength (λ): Displacement between two consecutive crests or two consecutive troughs.
  - Frequency (f) is the number of waves per unit time.
    - Unit: Hz
  - Period (T) is the time taken to produce one complete wave.
  - Wavefront is the imaginary line on a wave that joins all the crests. Wavefronts can be
    - circular wavefronts
    - plane wavefronts
- Formulae / Relationships
  - $T=\frac{1}{f}$
  - $v=f\,\lambda$
- A ripple tank can help us study waves including
  - reflection
  - refraction
    - Remember SSS - Shallower Shorter Slower
    - Frequency of a wave cannot change because it depends on source
- Electromagnetic spectrum
  - Different range of wavelength have been given different names, e.g., radio waves, infrared, etc.
  - They are all transverse waves.
  - In vacuum they travel at 3,00,000,000 m/s.
  - They slow down in other mediums.
  - They carry no charge.
- Fluorescence is the visible light emitted during absorption of Ultraviolet, X-rays or Gamma rays. Hence it is a way of detecting these kinds of invisible radiations.

ELECTROMAGNETIC SPECTRUM



	Radiowaves	Microwaves	Infra-red	Visible-light (ROY G. BIV)	Ultraviolet	X-rays	Gamma rays
Speed in vacuum	3×10^8 ms^{-1}	Same	Same	Same	Same	Same	Same
Properties	● Low attenuation	● Low attenuation	● Transfers heat	● Can be detected by our eyes	● Can start some chemical reactions	● Penetrating ● Ionizing	● Penetrating ● Ionizing
Uses	● Radio and television communications	● Satellites and telephone networks communications ● Heating food ● Radars	● Remote controllers for household appliances ● Intruder alarms	● Optical fibres in telephone communication	● Sterilization ● Sunbeds ● Fluorescent tubes ● Vitamin D	● Medical imaging ● Killing cancerous cells ● Detecting cracks in metal ● Astronomy	● Killing cancerous cells (radiotherapy) ● Detecting cracks in metal

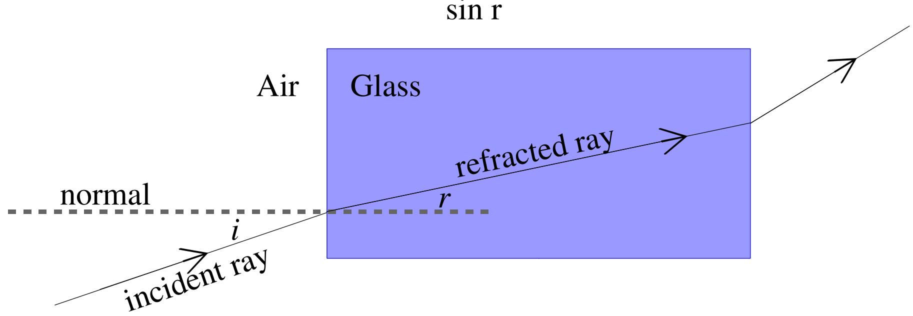
REFLECTION AND REFRACTION OF LIGHT

- **Beam:** It is a bundle of rays.
- **Shadows:** They are the dark areas that are formed when light is blocked.
- We can see
  - luminous objects because they produce light
  - non-luminous objects when they reflect light
- Regular and irregular reflections
  - Smooth, shiny and polished surfaces (e.g., mirror) give a regular reflection.
  - Rough, dull and unpolished surfaces (e.g., paper) give an irregular reflection.
- **Second Law of Reflection:** The angle of incidence is equal to the angle of reflection.

$$i=r$$

- Plane mirrors
  - Characteristics of image in a plane mirror
    - Same size as the object.
    - Same distance behind the mirror as the object in front of the mirror.
    - Upright
    - Virtual
    - Laterally inverted (i.e., left appears right and vice versa.)
  - Applications of plane mirrors
    - Eye-sight testing in a small room
    - Removing parallax error in instrument scales
- **Refraction:** It is the bending of light when it enters or exits a medium.
- When light slows down it bends towards the normal............when light speeds up it bends away from the normal.
- **Second Law of Refraction:** The ratio of the sine of the angle of incidence in one medium to the sine of the corresponding angle of refraction in the other medium is a constant value.

$$\frac{\sin i}{\sin r}=constant$$



- **Refractive index:** For a particular medium, it is the ratio of the sine of the angle of incidence in vacuum (or air) to the sine of the corresponding angle of refraction in the medium.

$$n=\frac{\sin i}{\sin r}$$

$$n=\frac{c}{v}$$

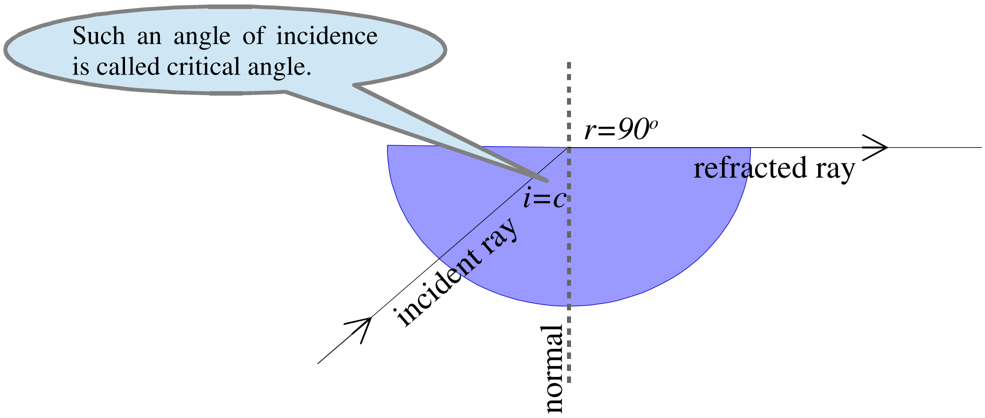
speed of light in vacuum / speed of light in the medium

With the condition that light is going from vacuum (or air) to that medium

  - You use the formula
    - $n=\frac{\sin i}{\sin r}$ when light goes from vacuum (or air) to an optically dense medium
    - $\frac{1}{n}=\frac{\sin i}{\sin r}$ when light goes from an optically dense medium to vacuum (or air)

- Values of n:
  - Value of n is always greater than 1.
  - A medium having a greater value of n means it is optically more dense (and hence shows greater refraction).
- Consequences of refraction
  - Swimming pools appear shallower.
  - Objects appear bent.
  - Mirages
  - Rainbows

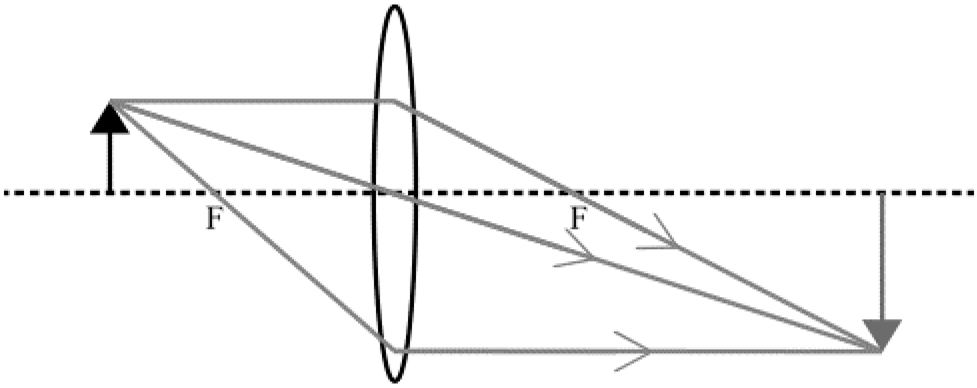
  Note: Rainbows are due to refraction, total internal reflection and dispersion of white light.
- **Critical angle:** It is the angle of incidence in the optically denser medium for which the angle of refraction in the optically less dense medium is 90°.



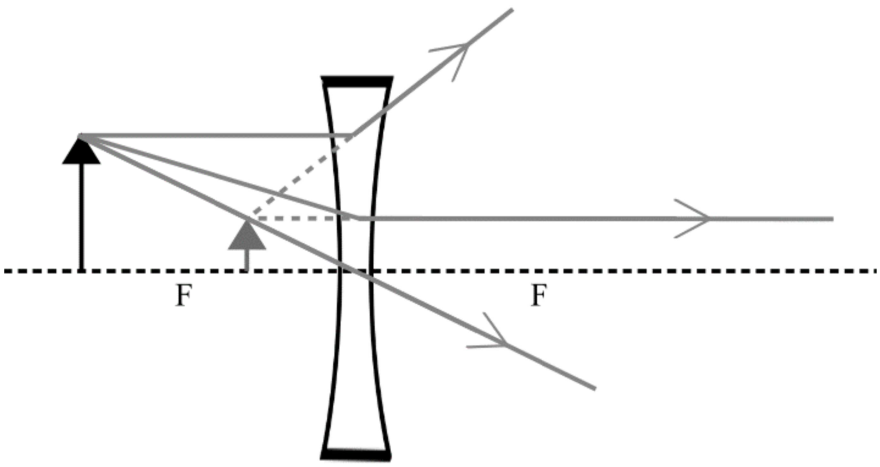
- **Total internal reflection:** It is the phenomenon in which all the ray reflects back (into the denser medium) when the angle of incidence in the optically denser medium is greater than the critical angle.
  - Applications
    - Binoculars (to form an erect image and to reduce the length of the instrument)
    - Optical fibres have a highly refractive glass or plastic core. Information can pass in the form of rays of light that show total internal reflection. Optical fibers are used in the telecommunications industries because in comparison to copper wires, they
      - can carry more signals (at one time)
      - have less attenuation
      - have less interference
      - are more secure

CONVERGING AND DIVERGING LENSES

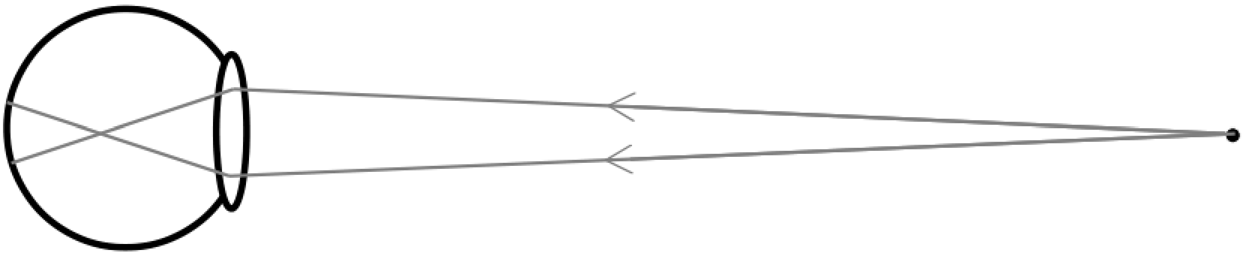
- **Converging lenses:** They are fatter at the center, e.g., biconvex lens, plano-convex lens, etc.
- **Diverging lenses:** They are thinner at the center, e.g., biconcave lens, plano-concave lens, etc.
- **Principal focus (or focal point):** It is the point where all rays close to and parallel to the principal axis converge after refraction from a converging lens.
- **Focal length:** Focal length is the distance between the optical center of the lens and the principal focus.
- Important rays for converging lens are:
  1. An incident ray that passes straight through optical centre.
  2. An incident ray parallel to principal axis is refracted to pass through principal focus (F).
  3. An incident ray passing through principal focus (F) is refracted to become parallel to principal axis.



- Important rays for diverging lens are:
  1. An incident ray that passes straight through optical centre.
  2. An incident ray parallel to principal axis is refracted such that it appears to be coming from the principal focus (F) on the side of the object.
  3. An incident ray aiming for principal focus (F) on far side is refracted to become parallel to principal axis.



- Human eye
  - Parts and their functions:
    - a crystalline biconvex lens to focus light
    - a retina having light sensitive cells acts as a screen
    - ciliary muscles to change the curvature of the lens
    - an iris controls the amount of light entering the eye
  - Working: The human eye can change the lens curvature (and hence the principal focus) to view objects that are far or near.
- **Shortsightedness (Myopia):** The eye can focus light from near objects but not from objects that are far.



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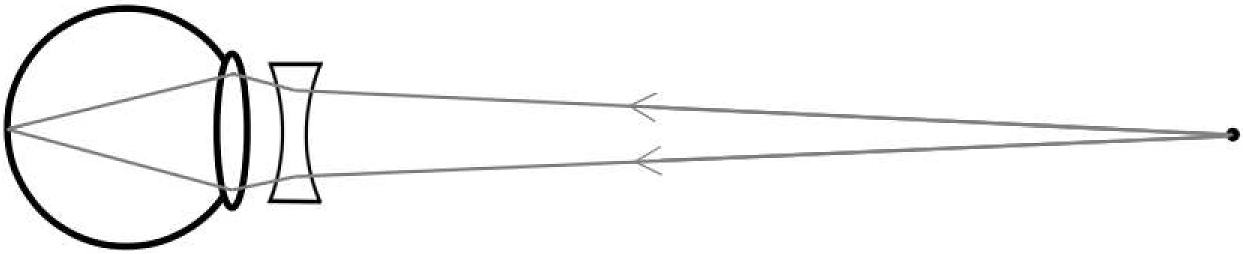
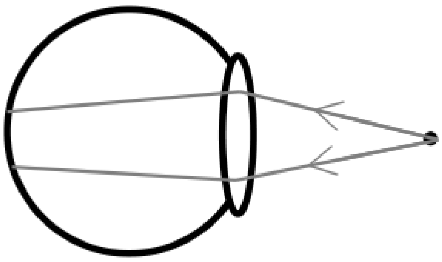


- **Farsightedness (Hyperopia):** The eye can focus light from far objects but not from those that are near.



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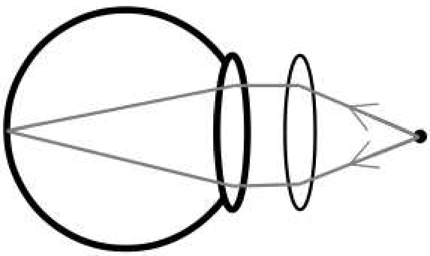


- Linear magnification (m)

$$m = \frac{\text{height of image}}{\text{height of object}} = \frac{\text{distance of image}}{\text{distance of object}}$$

  Note: "m = 1" means image is same size as the object. "m = 2" means image is twice the size of the object and so on...
- Properties of an image
  - inverted / upright
  - real / virtual
  - magnified / diminished / same size
  - greater / less distance from lens compared to the object
- Virtual images are always upright and real images are always inverted.
- Lenses are used in cameras, projectors, photocopiers, telescopes, etc.

SOUND

- **Sound:** It is a longitudinal wave that
  - emanates from a vibrating source
  - and requires a material medium
- Speed of sound
  - in air: 330 m/s
  - in liquids it is about 5 times faster (than in gases)
  - in solids it is about 15 times faster (than in gases)
- Factors affecting speed of sound are
  - Temperature
  - Humidity

  Note: pressure is NOT a factor
- Audibility
  - The human ear can detect sounds having a frequency between 20 Hz and 20 kHz.
  - The human ear cannot detect infra-sounds (below 20 Hz) and ultra-sounds (above 20 kHz).
- Applications of sound and ultrasound
  - Ultrasonic cleaning of machine parts
  - Medical examination of the body
  - Echoes are used to find depth or to detect mines or shoals of fish
- **Echo:** It is the reflection of sound.
- Reverberation is the effect in which you hear a prolonged sound because different echoes are reaching your ears one after the other (like in a large hall).
- Characteristics of sound
  - Loudness
    - It depends upon amplitude. Sounds can be soft or loud.
  - Pitch
    - It depends upon frequency. Sounds can be low or high.
  - Quality (or timbre)
    - Different audio-instruments playing the same note (same loudness and pitch) sound different.
    - This is because these instruments superimpose their own additional sounds (harmonics).
    - Therefore the resulting wave-forms from two different audio-instruments are different.
- Experiments
  - Measuring speed of sound in air
    - Method 1 is to use a stop watch and a pistol.
    - Method 2 is to use an echo from a wall.

    Note: In both methods use the formula $s=\frac{d}{t}$
  - Studying reflection of sound
    - Use two pipes next to a wall. Sound heard is loudest when angle of incidence equals angle of reflection.

STATIC ELECTRICITY

- When two materials are rubbed, one material gains electrons from the other and becomes negatively charged.
- The material that loses electrons becomes positively charged.
- Like charges repel and unlike charges attract each other.
- An atom with unequal number of electrons and protons is called an ion.
- Unit of charge is coulomb and it is denoted by C.

Electrical insulators	Electrical conductors
Charges cannot flow easily.	Charges can flow.
In insulators, the electrons of an atom are firmly bound to the nucleus of that atom.	In conductors, the outer (valence) electrons of an atom are 'free electrons'. The valence electrons are loosely bound.
After rubbing, the charge remains localized on the surface.	After rubbing, the charges do not remain confined to the surface.

- Neutralizing / discharging
  - Insulators discharge due to moisture in air or heating them
  - Conductors can be discharged by earthing them.
    - **earth** (as a verb)**:** It means to connect an object to zero potential.
    - **earth** (as a noun)**:** Any conductor (e.g., human body or ground) that can take or give electrons without being noticeably charged itself.
- **Electrostatic induction:** It is the process in which an object is charged by bringing a charged object close to it.
  - Example: If a negatively charged glass rod is brought close to a piece of paper then the near-side of the paper becomes positively charged and the far-side of the paper becomes negatively charged.
    <u>Notes:</u> If attraction between unlike charges is <u>greater</u> than the repulsion between like charges then the paper will be lifted (if the weight of the paper is overcome).
- Examination tips:
  - When students are asked to show distribution of charges, the examiner may be interested in seeing equal number of positive and negative charges.
  - The examiner may also be interested in the symmetry of charges.
- Electroscopes have a gold leaf next to a brass plate. If both are neutral then the gold-leaf is in a collapsed state. If both have the same charge then the gold-leaf diverges according to the size of repulsion.
- **Electric field:** It is the region of space where a unit positive charge experiences an electric force.
  - Electric lines of force are drawn in the direction of force on a unit positive charge.
- Examples where charging could be a problem
  - lightning
  - charged body of an aircraft
- Examples where charging could be useful
  - photocopier / laser printer
  - electrostatic precipitator for flu-as removal in coal-fired power stations

- Van de Graaff generators are used in electrostatic experiments. You should understand its construction and working.

CURRENT ELECTRICITY

- **Current:** It is the rate of flow of electric charge.

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

  - **Unit:** A
  - Current is measured using an ammeter or galvanometer.
- A short-circuit happens when load (resistance) is bypassed and excess current flows due to lack of resistance.
  - A short-circuit may cause heating and start a fire.
- **Electromotive force (e.m.f.) of a source:** It is the energy converted by a source from non-electrical form to electrical form in driving a unit charge round a complete circuit.

$$e.m.f. = \frac{E}{Q}$$

- **Potential difference between two points:** It is the energy converted from electrical to other forms when a unit charge passes between the two points.

$$V = \frac{E}{Q}$$

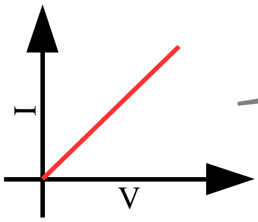
- **A comparison between e.m.f. and potential difference:**
  - Similarities
    - Both involve energy and charge
    - Both are measured in volts.
    - Both are measured by voltmeter.
  - Differences
    - In e.m.f. the energy change is from non-electrical to electrical. In p.d. the energy change is from electrical to non-electrical.
    - e.m.f. is property of source. p.d. is property of part of circuit.
- **Volt:** The potential difference between two points in a conductor is one volt if one joule of energy is converted from electrical to other forms when one coulomb of positive charge flows through it.
- A voltmeter is connected in parallel.
  - Voltmeters have a high resistance.
- An ammeter is connected in series.
  - Ammeters have a low resistance.
- **Resistance:** It is the ratio of potential difference across a material to the current flowing in it.

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

  - Unit: Ω
- Resistors are used in circuits to limit the flow of current. Their types are:
  - Fixed resistors
  - Variable resistors (rheostats)
- **Ohm's Law:** It states that current is directly proportional to potential difference provided that temperature does not change.

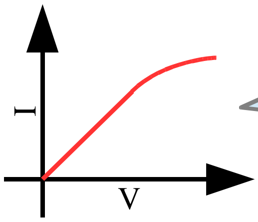
$$I \propto V$$

- Important graphs:
  - Pure metals at constant temperature



Pure metals obey Ohm's Law.

  - Filament lamp



As V increases, I also increases.

As I becomes sufficiently large, the temperature becomes significantly large.

As temperature increases, the resistance also increases.

That is why at high temperatures, I is not directly proportional to V.

- Resistance and resistivity

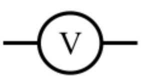
$$R = \rho \frac{l}{A}$$

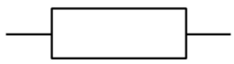
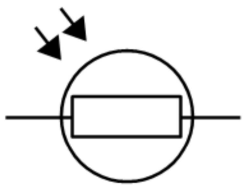
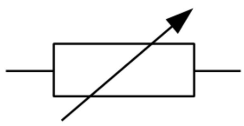
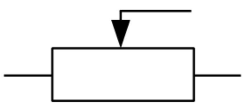
Resistance increases as length of a wire increases

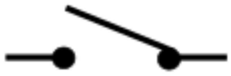
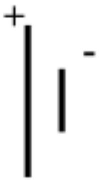
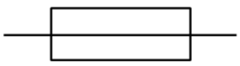
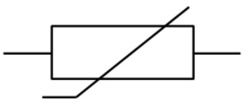
Resistance decreases as cross-sectional area of a wire increases

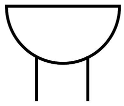
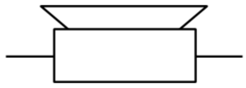
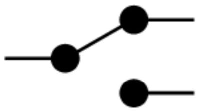
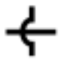
  - The constant called resistivity is denoted by ρ.
  - Every material has its own value of resistivity.
  - Resistivity can be used to tell good conductors from bad.
  - It is better to say that copper has low resistivity than to say copper has low resistance.

- Circuit symbols are given below:

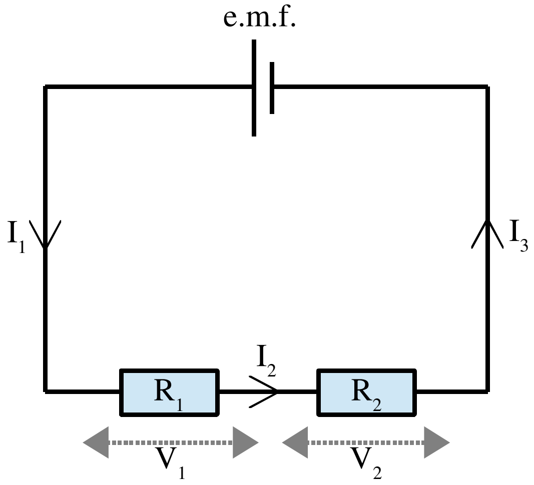
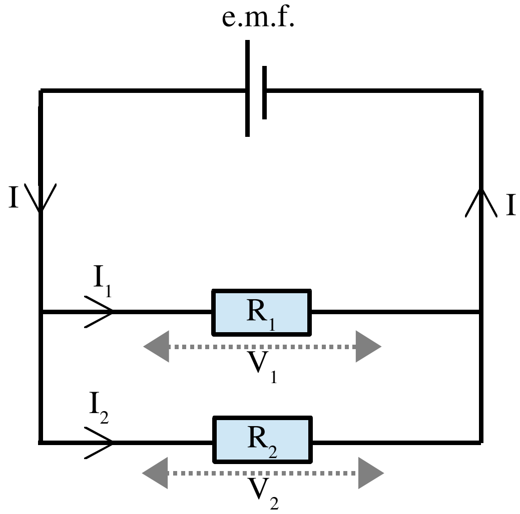
	Diode
	L.E.D.
	Bulb
	Ammeter
	Voltmeter

	Resistor
	L.D.R.
	Variable Resistor (Rheostat)
	Variable Resistor (Potentiometer)
	Transformer

	Switch (open)
	Motor
	Galvanometer
	Capacitor
	Cell
	A.C.
	Fuse
	Thermistor

	Buffer / Amplifier
	Buzzer
	Loudspeaker
	Two-way switch
	Earth
	Node
	Crossing

D.C. CIRCUITS

	Series Circuit	Parallel Circuit
Diagram		
Current	$I_1 = I_2 = I_3$	$I = I_1 + I_2$
Potential Difference	$e.m.f. = V_1 + V_2$	$e.m.f. = V_1 = V_2$
Resistance	$R = R_1 + R_2$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

- **Fact:** If the same resistors are connected in series and then in parallel, overall resistance (R) is always greater in series.

PRACTICAL ELECTRIC CIRCUITRY

- Nichrome is a high resistivity material that heats up when current passes through it.
  - Nichrome wire is used in electric irons, heaters, etc.
- A current carrying conductor in a magnetic field experiences a force.
  - This phenomenon is used in fans, motors, etc.
- Lamps
  - Filament lamps (also known as incandescent light-bulbs)
    - The filament is made of a material called tungsten which has high resistivity and a high melting point.
    - Filament is made thin to increase resistance. It is shaped like a coiled coil. This reduces convection.
    - Bulb is filled with an inert gas to prevent tungsten from reacting with oxygen.
  - Fluorescent lamps
    - By passing current through mercury vapour, ultraviolet as well as visible light are produced.
    - Fluorescent powder absorbs ultraviolet and releases more visible light.

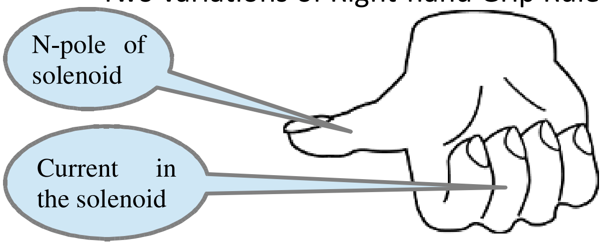
  Note: Fluorescent lamps are more efficient than filament lamps.
- Some formulas:
  - $P = IV$ — "Poison Ivy"
  - $P = I^2R$ — "دوپہر"

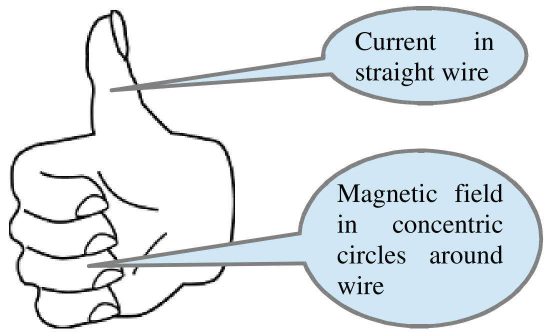
  If you get stuck in a question with these formulas, the answer may lie in substituting from the formula R=V/I.
- Measurement of electrical energy
  - $E = Pt$ — "Exercise is physcial training"
    - Joule is a small unit so in practice electricity bills use a unit called kilowatt-hours (kWh) to measure electrical energy used.
    - To get answer in kilowatt-hours, put value of "P" in kilowatts and put value of "t" in hours.
- Dangers of electricity
  - Damaged insulation
    - Touching the exposed live wire (with dangerously high potential) can result in electric shock.
  - Overheating of cables can cause fire.
    - Overheating can happen due to short-circuit or overloading.
  - Damp conditions
    - When hands are wet the resistance of the skin is reduced greatly.
- Fuses and circuit breakers are used to stop excessive current flow.
- Fuses, circuit breakers and switches are always fitted on the live wire so that appliances are not live when the circuit is broken. Otherwise, for example, a person repairing an electrical appliance can receive a shock.
- Fuses with a rating slightly higher than the expected current should be used.
- Wiring a plug
  - Colour code
    - Brown – Live wire
    - Blue – Neutral wire
    - Green / Yellow – Earth wire
  - Parts of a plug
    - Terminals
    - Cord grip
    - Wrap-round screws
- Appliances with "double insulation" normally have a casing made of plastic (or other non-metal).

- Earthing
  - If the casing is earthed:
    - When live wire touches the casing, excessive current will flow through the earth wire.
    - The fuse will melt and hence disconnect the appliance.
    - User will be safe.
  - If casing is not earthed:
    - When live wire touches the casing, the person touching it will receive an electric shock.

SIMPLE PHENOMENON OF MAGNETISM

- Four magnetic materials are nickel, iron, cobalt and steel.
- Poles are ends of a magnet where the magnetic field is strongest.
- Unlike poles attract each other.
- Like poles repel each other.
- Repulsion is the only sure way to find out if an object is a magnet or not.
- **Magnetic Induction:** When an unmagnetized material is attracted to a magnet, the material itself becomes a magnet. This phenomenon is called magnetic induction.
- Magnetic materials have tiny regions called domains which act as "mini-magnets". When these domains are lined up, the material becomes a magnet. If the domains point in random directions then the material does not behave as a magnet.
- Methods of making magnets are:
  - stroking a steel bar repeatedly with a permanent magnet
  - putting the steel bar in a solenoid (coil) having direct current (D.C.)
- Methods of demagnetization of magnets are:
  - heat until red-hot
  - hammer repeatedly (or subject to some other impact)
  - Alternating current (A.C.) in a solenoid (coil) with the magnet inside of it
    - Remove magnet slowly from inside of the coil OR
    - Gradually decrease the current to zero
- Two variations of Right-hand Grip Rule:

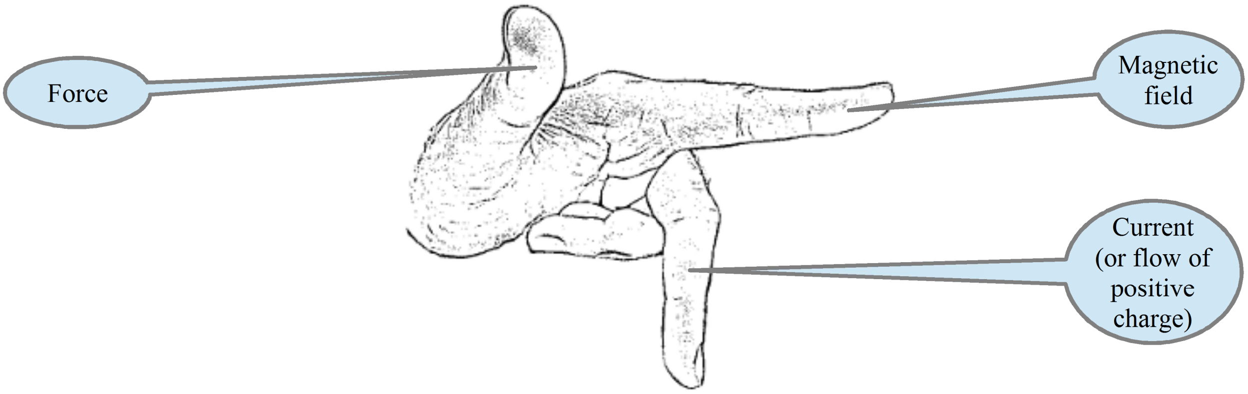




- **Magnetic field:** It is the region of space where a magnetic object experiences a magnetic force.
- Experiment to plot field lines of a magnetic field.
  - Mark at one end of compass needle.
  - Move compass so that the other end of compass needle is on the mark AND re-mark.
  - Repeat along one line and join the dots.
  - Repeat with different start points to draw more lines.
  - Direction of field lines is from N-pole to S-pole.
- Iron is easier to magnetize and demagnetize than steel. This means that iron makes a stronger magnet when placed inside a current carrying solenoid. It also loses magnetism when the current is switched off.
- An electromagnet consists of insulated copper wire wound on a core of soft iron.
- The strength of magnetic field of a solenoid can be increased by:
  - increasing number of turns
  - increasing current
  - using iron core
- Iron is used to shield sensitive equipment from magnetic fields. It carries those fields along the metal.
- Reed switch consists of two pieces of soft iron called reeds. When these reeds are magnetized they are attracted to each other. Current flows when they make contact.

FORCE ON CONDUCTOR IN A MAGNETIC FIELD

- When two different magnetic fields (for example from a solenoid and a permanent magnet) interact with one another, a force is experienced from a region of stronger magnetic field to a region of weaker magnetic field.
- **Left-hand Rule:** Directions of current, magnetic field and force are all perpendicular to each other.



- Two parallel wires with current in same direction are attracted to each other.
- Two parallel wires with current in opposite directions are repelled from each other.
- Working of loudspeaker
  - Cone produces compressions and rarefactions in the air because it vibrates with the coil.
  - The coil vibrates because
    - Current in coil produces magnetic field
    - Poles of coil are reversed when the current changes direction
    - The coil experiences attraction and repulsion from the N (or S)-pole of permanent magnet.
- Working of D.C. Motor
  - When current flows through coil, it becomes a magnet.
  - Its magnetic field interacts with the magnetic field of the permanent magnet. Hence it experiences forces.
  - To keep the coil rotating, the forces need to be reversed after every half turn. Therefore, split-ring commutator reverses the direction of current after every half turn.

ELECTROMAGNETIC EFFECTS

- **Electromagnetic induction:** It is the phenomenon of inducing an e.m.f. in a circuit due to a changing magnetic field.
- **Faraday's law:** The magnitude of induced e.m.f. is proportional to the rate of change of magnetic flux linking the circuit.
- **Lenz's Law:** The direction of induced e.m.f. (and hence current) is such as to oppose the change producing it.
- **A.C. Generator**
  - Types
    - A coil can be rotated next to a magnet. OR
    - A magnet can be rotated next to a coil.
  - Working
    - There is a magnetic field around permanent magnet.
    - As coil rotates, the coil cuts the magnetic flux of the permanent magnet.
    - Therefore, e.m.f. is induced.
    - When N-pole approaches, the e.m.f. (or current) is in one direction.
    - When N-pole goes away, the e.m.f. (or current) is in the opposite direction.

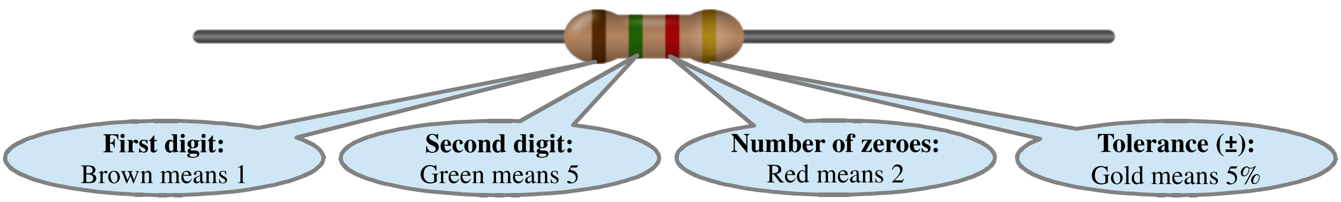
    } Explanation of the word "alternating"
  - Facts to remember
    - Doubling the number of turns on coil doubles the peak voltage.
    - Doubling the frequency (speed) of rotation doubles the peak voltage.
  - You can increase the peak voltage by
    - increasing turns on coil
    - increasing frequency of rotation
    - increasing the strength of magnetic field by
      - using soft iron core
      - using stronger magnet
      - bringing coil and magnet closer
- **Transformer:** It is a device that changes a high alternating voltage at low current to a low alternating voltage at high current or vice-versa.
  - Construction
    - Two coils (primary and secondary).......................one has more turns than the other.
    - Soft iron core
    - Use alternating voltage symbol ~ on primary side
  - Types
    - A transformer that steps up voltage.
    - A transformer that steps down voltage.
  - Transformer equation: $\frac{V_s}{V_p}=\frac{N_s}{N_p}=\frac{I_p}{I_s}$ where N is the number of turns.
- Transmission of electrical power over long distances
  - **The challenge:** To reduce loss of electrical energy in the form of heat on the power lines.
  - **Solutions:**
    - We can use very thick cables but this increases the cost of cables and supporting structures.
    - We can use a transformer to step up voltage and thereby reduce current. Relevant formula is:

$$P=I^2R$$

where P is power loss as Joule heating

INTRODUCTORY ELECTRONICS

- **Thermionic emission:** It is the effect in which when a metal is heated, some of the 'free' electrons gain enough kinetic energy to escape from the metal surface.
- **Cathode-Ray Oscilloscope**
  - Construction:
    - Electron gun
      - heated filament
      - cylindrical anode for accelerating the ejected electrons
    - X-plates and Y-plates
    - Fluorescent screen
  - Working:
    - When “time-base” is on, X-plates are supplied with a saw-tooth voltage that deflects the electron-beam horizontally.
    - Y-plates are connected to an external circuit, for example a mic or a cell. Y-plates deflect the electron-beam vertically.
    - “Gain” setting adjusts the volts/division on the screen.
- Circuit components
  - **Resistor:** Its purpose is to limit the flow of current.
    - **Colour-code:** A resistor has colour bands to show its resistance and tolerance.
      - For example, this is a 1500 Ω resistor:



    - **Power rating of a resistor:** It is the maximum amount of electrical energy per second (J/s or W) that the resistor can convert into heat without getting damaged.
      - Usually power rating depends on the size of the resistor.
      - Using resistors with large power ratings means that they will occupy more space on the circuit board.
      - Using resistors with lower (just enough) power ratings means that they may become damaged easily due to small fluctuations.
  - **Thermistor:** Its resistance decreases as the temperature increases.
  - **Light-dependent resistor (L.D.R.):** Its resistance decreases as brightness of light increases.
  - **Capacitor:** It can store charge. It takes time to get fully charged but then it can discharge instantly. Therefore, it has use in time-delay circuits.
- Potential division
  - When resistors are connected in series, each resistor gets a share of the e.m.f. according its share of the total resistance.
    - For example, if three resistors R_1, R_2 and R_3 are connected in series then potential difference across R_1 can be calculated as:

$$V_1 = \frac{R_1}{R_1 + R_2 + R_3} \times e.m.f.$$

RADIOACTIVITY AND THE NUCLEAR ATOM

- **Characteristics of nuclear radiations:**

	Alpha (α)	Beta (β)	Gamma (γ)
Nature	Helium nucleus	High speed electron	Electromagnetic wave
Ionizing effect	High	Medium	Low
Penetration	Low (may be blocked by paper or few cm of air)	Medium (may be blocked by 0.5 cm of aluminum)	High (may be blocked by 2 cm of lead)
Deflection in magnetic field	Yes (use Left-hand-rule)	Yes (use Left-hand-rule)	No
Deflection in electric field	Yes	Yes	No

- **Radioactive decay:** It is the break down of unstable nuclei in order to become more stable. In the process α, β or γ radiations are emitted.
  - Types:
    - Alpha-decay: ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + energy$
    - Beta-decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + energy$
    - Gamma-decay: $({}^{A}_{Z}X)^{*} \rightarrow {}^{A}_{Z}X + gamma\ rays$
      - Asterisk (*) indicates that the nucleus is excited. Gamma rays are usually emitted at the same moment as either an alpha or beta particle.
- Radioactivity is a phenomenon that is random in terms of:
  - time (You can't exactly predict when a nucleus will decay.)
  - space (You can't predict which nucleus will decay next.)
  - direction of emission
- Methods of detecting radioactivity
  - Photographic plates are fogged.
  - Charged electroscope is neutralized because some ions made in air are attracted to it.
  - Diffusion cloud chamber shows tracks formed by alpha, beta or gamma radiations because alcohol vapour condenses on the ions formed.
  - GM-tube connected to a ratemeter or scaler.
    - Construction: See Fig 25.8 on page 398.
    - Working: When radiation ionizes argon gas inside GM-tube, an electrical pulse is produced.
- **Background radiation:** It is the radiation in our surroundings due to:
  - cosmic rays from stars
  - underground radioactive rocks
- **Half-life:** It is the time taken for half of the unstable nuclei to decay.
- Uses of radioactive materials
  - tracers
  - penetrating radiation for thickness control or to reveal faults in weldings
  - nuclear fuel (e.g., Uranium-235)
  - treating cancer (by using gamma radiations)
  - archaeological dating (also known as carbon dating)
- Hazards of radiations: Overexposure may lead to radiation burns, eye-cataracts, leukaemia (blood cancer), genetic mutations or even death.

- Precautions
  - Keep distance by using forceps
  - Wear lead lined suits
  - Avoid eating and drinking
- Conclusions from Geiger Marsden experiment (alpha scattering by gold foil):
  - Most alpha particles passed straight through. Therefore, most of the space in an atom is empty.
  - Few alpha particles were deflected by huge angles. Therefore, there must be a place (nucleus) where positive charges (protons) are concentrated.
- **Nucleon number (mass number) (A):** It is the sum of the number of protons and the number of neutrons in an atomic nucleus.
- **Proton number (atomic number) (Z):** It is the number of protons in an atomic nucleus.
- **Isotopes:** Isotopes of an element are atoms which have the same proton number but different nucleon numbers.
- Energy and mass can be inter-converted according to the formula:

$$E = mc^2$$

where c is the speed of light in vacuum.

- **Nuclear fission:** It is the process in which heavy unstable nuclides break up to produce energy.
  - Some related equations:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U$$

$$^{236}_{92}U \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n + energy$$

  Note: If the 3 neutrons are made to collide with other Uranium-235 atoms, a chain-reaction starts.

- **Nuclear fusion:** It is the process in which lighter nuclides fuse together to form a heavier nucleus with the release of energy.

POINT SCORING

In questions related to "ACCELERATION":

……………………..…. compare magnitude of forces ……………….………… compare direction of forces (same / opposite) ……………………………..… comment on resultant force (forward / backward / zero / etc.)

In questions related to "WORK":

………………………you may answer in terms of energy or energy changes ………….……………

In questions related to "PRESSURE USING IDEAS ABOUT MOLECULES":

……………….. collides with _____________ ………………………….. exerts force ………………….. kinetic energy ………………… more / less forceful collisions (due to temperature) ………………….. average separation …………….frequently……………. Force over an area is called pressure.

In questions related to "CONDUCTION":

………..……… molecules vibrate……………..... molecules collide …………………… K.E. transferred …………….………… from molecule to molecule…………..

In questions related to "CONVECTION":

…………………………. expands / contracts …………………………..…. becomes less / more dense ……………………….…. rises / falls……………. convection currents set up ………….

In questions related to "HEAT INSULATION":

……………..… traps air …………….. air is a bad conductor

OR

……………………….. white colour or shiny surface does not absorb infrared ………………………….. infrared reflected back ……………….

In questions related to “CHARACTERISTICS OF THERMOMETER”:

……………….. sensitivity (increase in thermometric property per degree rise in temperature) …………………………. responsiveness ……………………..……. linearity (each degree is an equal distance or appropriate graph a straight line) ………………………………. range ……………………

In questions related to “REFRACTION”:

……………….…… each colour ……………………..…….. slows down / speeds up ……………………….. bends towards / away from normal ……………………. according to its own refractive index ……………………………. in the optically more / less dense medium……………………

In questions related to “IMAGE CHARCTERISTICS”:

…………..…. upright / inverted ………………. diminished / magnified …………….real / virtual ………..less / same /more distance from lens

In questions related to “COMPARISON OF e.m.f. AND POTENTIAL DIFFERENCE”:

……………………… is / is not property of source …………………… same unit of volt ………………….. both work done per unit positive charge…………………. energy converted from electrical to non-electrical or vice versa……………………

In questions related to “ELECTRICAL SAFETY”:

…………….…………… casing becomes live ………………….……. high current through earth wire …………….…………… fuse blows …………….…………… appliance disconnected ……………………… (plastic) is a bad conductor ………………………….. user safe / shocked………………………

In questions related to “ALTERNATING CURRENT OR ELECTROMAGNETIC INDUCTION”:

…………….………… magnetic field……………..…….. flux cuts coil…………………… e.m.f. induced …………………when N approaches coil, current is in one direction and when N leaves coil, current is in the opposite direction……………….

SIGNIFICANT FIGURES

We need to understand the concept of "significant figures" because <u>measurements need to be recorded in a proper way.</u>

RULES
Significant figures are the number of digits from the “first nonzero” to the “last position”.
The “last position” is the last number’s position if the measurement has a decimal point. Otherwise, the “last position” is the last non-zero’s position.

Note: In case of large integers, e.g. 54000, with zeroes at the end, the trailing zeroes may or may not be significant. That is why it is better to use scientific notation.

HOW TO USE SIGNIFICANT FIGURES IN CALCULATIONS

- When <u>multiplication or division</u> happens between two numbers:
  - Rule: See which of the two numbers has the least number of **significant figures**. The answer should have the same number of significant figures.
  - Example 1: Multiply 28.2 with 1.2366
    The calculator will show 34.87212 but you will round off and write the value as 34.9.
  - Example 2: Divide 99 by 3.14
    The calculator will show 31.52866242038217 but you will round off and write the value as 32.
- When <u>addition or subtraction</u> happens between two numbers:
  - Rule: See which of the two numbers has the least number of **digits to the right of the decimal point**. The answer should have the same number of digits to the right of the decimal point.
  - Example 1: Add 89.321 to 1.1
    The calculator will show 90.421 but you will round off and write the value as 90.4.
  - Example 2: Subtract 36.5325 from 191.13
    The calculator will show 154.5975 but you will round off and write the value as 154.60.

STAR FORMATION

THEORIES

- A star is born within a giant cloud of dust (called nebula).
- Turbulence deep within these clouds gives rise to knots with sufficient mass that the gas and dust can begin to collapse under its own gravitational attraction.
- Friction raises temperature.
- When the temperature is high enough, nuclear fusion of hydrogen starts and a star is born.

Orion Nebula

A PAST PAPER QUESTION

(b) As clouds of gas and dust come together to form a star, there is an energy change similar to the energy change as a ball falls to the ground.

The temperature in the clouds of dust and gas becomes so high that nuclear fusion occurs.

In one such reaction, two isotopes of hydrogen, ${}^{2}_{1}H$ and ${}^{3}_{1}H$, fuse together.

(i) Explain why the gas and dust come together. [1]

(ii) State the energy change that causes the rise in temperature as the gas and dust come together. [2]

(iii) Explain why high temperatures are needed for nuclear fusion to occur. [2]

(iv) Describe the structure of a nucleus of ${}^{3}_{1}H$. [2]

(v) State which element is created by the fusion of two hydrogen nuclei. [1]

(vi) State **one** effect of nuclear fusion on a star. [1]

MARKING SCHEME

(b)	**(i)**	gravity	B1
	b	potential energy to kinetic energy	B1
		kinetic energy to heat/thermal energy	B1
		OR potential energy to heat/thermal energy	**OR** B2
		-1 each clearly wrong answer beyond 2	
	(iii)	nuclei repel **or** nuclei are positive	B1
		nuclei need high speed/ K.E. (so high temperature)	B1
	(iv)	1 proton **or** proton number = 1	B1
		2 neutrons **or** neutron number = 2 (electron(s) **max 1**)	B1
	(v)	He **or** helium	B1
	(vi)	energy/heat produced **or** raises temperature **or** becomes hot **or** causes star to expand **or** counters gravitational collapse **or** loses mass	B1

SOME TOPICS TO SKIP

25. Electronic Systems

Note: There is no compulsory question set on Section 25 of the syllabus. Questions set on topics within Section 25 are always set as an alternative within a question.

Content

25.1 Switching and logic circuits

25.2 Bistable and astable circuits

Learning outcomes

Candidates should be able to:

(a) describe the action of a bipolar npn transistor as an electrically operated switch and explain its use in switching circuits.

(b) state in words and in truth table form, the action of the following logic gates, AND, OR, NAND, NOR and NOT (inverter).

(c) state the symbols for the logic gates listed above (American ANSI Y 32.14 symbols will be used).

(d) describe the use of a bistable circuit.

(e) discuss the fact that bistable circuits exhibit the property of memory.

(f) describe the use of an astable circuit (pulse generator).

(g) describe how the frequency of an astable circuit is related to the values of the resistive and capacitative components.

Structure of C.R.O and capacitors are also excluded.

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O LEVEL PHYSICS FORMULAE

Formulae	Comments
$s=\frac{d}{t}$	• 'd' is distance. • 't' is time. • 's' is speed. • Sometimes 'v' is used instead of 's'. • '<v>' means average speed which is total distance covered divided by total time taken.
$s=\frac{d_2-d_1}{t_2-t_1}$	• For use in a distance-time graph. • Difference can also be written using a 'Δ' sign, e.g., 'Δd'. • Adapted from slope: $m=\frac{y_2-y_1}{x_2-x_1}$
$a=\frac{v-u}{t}$	• 'a' is acceleration. • 'v' is final velocity. • 'u' is initial velocity. • 'v-u' can also be written as 'Δv'. • Negative values of 'a' show deceleration. In other words, acceleration is opposite to direction of motion.
$a=\frac{v_2-v_1}{t_2-t_1}$	• For use in a velocity-time graph. • Adapted from slope: $m=\frac{y_2-y_1}{x_2-x_1}$
$F=ma$	• 'F' is the resultant force. SI unit is Newton which is a derived quantity.......... kg m/s^2 • Acceleration is always in the direction of resultant force. • Put negative value of force when force is against the direction of motion.
$W=mg$	• 'W' is the weight. • 'g' is gravitational field strength. SI unit is N/kg. It is 10 N/kg on earth and 1.67 N/kg on the moon. • 'g' can also be called acceleration of free fall. SI unit is m/s^2. • Adapted from $F=ma$
$F \propto l$	• 'l' is not any length but the increase in length of an elastic body by a force 'F'. • Hooke's Law holds true up to the elastic limit.

$\rho = \frac{m}{V}$	• 'ρ' is density. SI unit is kg/m^3. • Volume of regularly shaped objects: ◦ Cube: $V = l^3$ ◦ Cuboid: $V = l \times b \times h$ ◦ Cylinder: $V = \pi r^2 l$ ◦ Sphere: $V = \frac{4}{3} \pi r^3$
$Moment\ of\ a\ force = F \times d$	• 'd' is the perpendicular distance between pivot and the line of action of force. • Moment of a force is also called torque. SI unit is Nm.
$\sum\ of\ C.W.\ moments = \sum\ of\ A.C.W.\ moments$	• This is called the Principle of Moments and it holds true for an object in equilibrium.
$W = F \times s$	• 'W' is work. • 's' is distance moved in the direction of the constant force 'F'. • SI unit of work is Joule.
$E = \frac{1}{2} m v^2$	• For kinetic energy.
$E = (mg) h$ $E = W h$	• When 'E' is potential energy.
$Efficiency = \frac{useful\ energy\ output}{total\ energy\ input}$	• Efficiency can also be expressed as a percentage by multiplying the ratio with 100. Do this only when specifically asked.
$P = \frac{W}{t} = \frac{E}{t}$	• 'P' is power. SI unit is Watt. • 'W' is work. • 'E' is energy. • 't' is time.
$P = \frac{F}{A}$	• 'P' is pressure. SI unit is pascal which is N/m^2. • Pressure of a gas can be expressed as the height of a liquid. • Millibars are used to measure atmospheric pressure. 1 bar = 100, 000 Pa.
$P = h \rho g$	• Formula for hydrostatic pressure. It is the pressure of a liquid at a depth (when the liquid is in a state of equilibrium).
$P_{piston\ A} = P_{piston\ B}$	• In a hydraulic system, pressure at piston A is equal to the pressure at piston B (at the same height of the liquid).
$P_{gas} = P_{atmosphere} + P_{liquid}$ $P_{gas} + P_{liquid} = P_{atmosphere}$	• You should be able to make such equations for a manometer.

$\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100$	• For temperature, the symbols 'θ', 'T' or 't' may be used. • 'X' is a quantity like length or pressure or e.m.f. or resistance that varies uniformly with temperature. So you can replace 'X' with 'l' or 'P' or 'V' or 'R' depending on the situation. • You are not required to know temperature scales other than Celcius but you may keep in mind: ◦ For Kelvin scale, $K = C + 273$ ◦ For Fahrenheit scale, the difference between lower and upper fixed points is divided into 180 parts. ▪ 0 °C = 32 °F ▪ 100 °C = 212 °F.
$E \propto \Delta\theta$	• 'E' is e.m.f. • This is the defining equation for a thermocouple thermometer.
$P \propto \frac{1}{V}$ $PV = constant$ $P_1 V_1 = P_2 V_2$	• These are related to Boyle's Law. • These hold true for a fixed mass and temperature of a gas. • 'P_1' and 'V_1' are initial pressure and initial volume of a gas respectively. • 'P_2' and 'V_2' are final pressure and final volume of a gas respectively.
$C = \frac{E}{\Delta\theta}$	• The three formulas are used when the temperature changes. • 'C' is heat capactity. • 'E' is heat energy absorbed in Joules.
$c = \frac{E}{m\Delta\theta}$ $c = \frac{C}{m}$	• 'c' is specific heat capacity.
$l = \frac{L}{m}$	• This formula is used when the temperature does not change (, only state changes). • If subscripts are used then: ◦ 'l_f' is specific latent heat of fusion. ◦ 'L_f' is latent heat of fusion expressed in joules. You <u>may</u> find its value by finding the value of 'Q' or 'E' in other formulas. ◦ 'l_v' is specific latent heat of vaporization. ◦ 'L_v' is latent heat of vaporization expressed in joules. You <u>may</u> find its value by finding the value of 'Q' or 'E' in other formulas.

$f = \frac{1}{T}$	• 'f' is frequency. • 'T' is time-period.
$v = f\,\lambda$	• 'v' is the speed of the wave. In vacuum the speed of all electromagnetic radiations is 3 x 10^8 m/s. • 'λ' is the wave-length.
$i = r$	• 'i' is angle of incidence. • 'r' is angle of reflection.
$constant = \frac{\sin i}{\sin r}$	• This is Snell's Law. • Here 'r' is angle of refraction (and not angle of reflection).
$n = \frac{\sin i}{\sin r}$ $n = \frac{1}{\sin c}$ $n = \frac{c}{v}$	• 'n' is refractive index. • The difference is that there is now the condition that a ray of light passes from vacuum (or air) to another medium. • In the lower formula ◦ 'c' is not the critical angle. It is the speed of light in vacuum which is $3 \times 10^8 m/s$. ◦ 'v' is speed of light in the optically denser medium. • **Important:** When light enters air (or vacuum) from another medium, we replace n with $\frac{1}{n}$.
$linear\ magnification = \frac{image\ height}{object\ height}$ $linear\ magnification = \frac{image\ distance}{object\ distance}$	• Linear magnification has no unit because it is a ratio between similar quantities.
$I = \frac{Q}{t}$	• 'I' is current. • 'Q' is charge in coulombs (C). • 't' is time.
$E = \frac{W}{Q}$	• 'E' is e.m.f. in volts (V). • 'W' is energy converted to electrical form • 'Q' is positive charge
$V = \frac{W}{Q}$	• 'V' is potential difference between two points in a circuit. Its unit volt is also denoted by V. • 'W' is energy converted to non-electrical form between the two points. • 'Q' is positive charge

$R=\frac{V}{I}$	• The ratio V to I is constant (R) under steady physical conditions. This is Ohm's Law. • 'R' is resistance of the material in ohms (Ω).
$R \propto l$ $R \propto \frac{1}{A}$ $R=\rho \frac{l}{A}$	• 'l' is length of the conductor. • 'A' is the cross-sectional area. • 'ρ' is resistivity. It is specific to a material. Better conductors have lower values of resistivity.
For a series circuit, $E=V_1+V_2+...$ $I=I_1=I_2=...$ $R=R_1+R_2+...$	• 'E' is e.m.f. • 'R' is effective resistance (meaning overall resistance).
For a parallel circuit, $E=V_1=V_2=...$ $I=I_1+I_2+...$ $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+...$	• The potential difference across each branch is the same.
$P=IV$	• 'P' is power in watts. • Memorization: “poison ivy”

$E=Pt$	• 'E' is (electrical) energy.
	  ◦ If you put 'P' in watts and 't' in seconds then the result will be in joules.
	  ◦ If you put 'P' in kilowatts and 't' in hours then the result will be in kilowatt-hours.
	• Memorization: “Exercise is physical training”

$P=I^2 R$	• Memorization: “دوپیر” • In this formula and the preceding two formulas, if two variables are unknown then also use the formula $R=\frac{V}{I}$ to find the answer. • In case of electrical transmission, if you adapt this formula to show power loss due to heat, you will see why it is important to use a step-up transformer to reduce current (by stepping up the voltage). $P_{loss}=I^2 R$
$\frac{V_s}{V_p}=\frac{N_s}{N_p}=\frac{I_p}{I_s}$	• 'N' is the number of turns in the primary or secondary coil of the transformer. • You may be able to solve some questions more quickly if you remember that power for each of the two coils is the same. It is because: $I_s V_s=I_p V_p$ $P_s=P_p$

$V_x = (\frac{R_x}{R_1 + R_2 + ...}) \times V$	• When resistors are in series, potential is divided among them according to the proportion of each resistance.
x AND y	• Output is '1' only if all inputs are '1'.
x OR y	• Output is '0' only if all inputs are '0'.
$NOT\ x$	• Output is opposite to the input.
$x\ NAND\ y$	• Output is opposite to that of an AND gate.
$x\ NOR\ y$	• Output is opposite to that of an OR gate.
$E = mc^2$	• 'c' is the speed of light in vacuum. • Einstein suggested that mass and energy can interconvert.
${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + energy$	• α decay
${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + energy$	• β decay
$({}^{A}_{Z}X)^{*} \rightarrow {}^{A}_{Z}X + gamma\ rays$	• γ decay • Asterisk (*) indicates that the nucleus is excited. Gamma rays are usually emitted at the same moment as either an alpha or beta particle.