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ECZ GRADE 12 PHYSICS SUMMARISED NOTES (PURE) FOR 5124 AND 5054.

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G12 PHYSICS NOTES AND EXERCISES WITH ANSWERS

Here you will find Physics notes, exam tips and exercises with answers designed for passing ECZ exams.
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ELECTROMAGNETIC INDUCTION

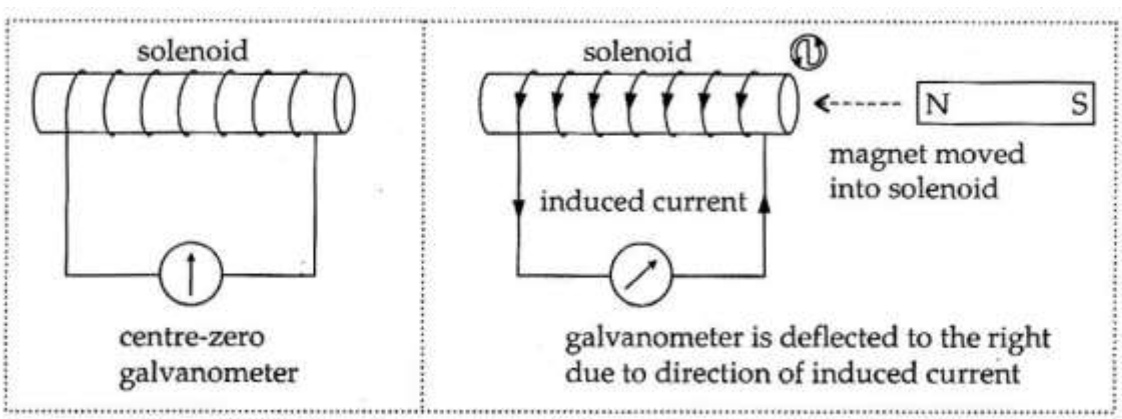
Faraday's Law of Electromagnetic Induction

CONCEPT: A current can be produced in a conductor by the motion of a magnetic field.

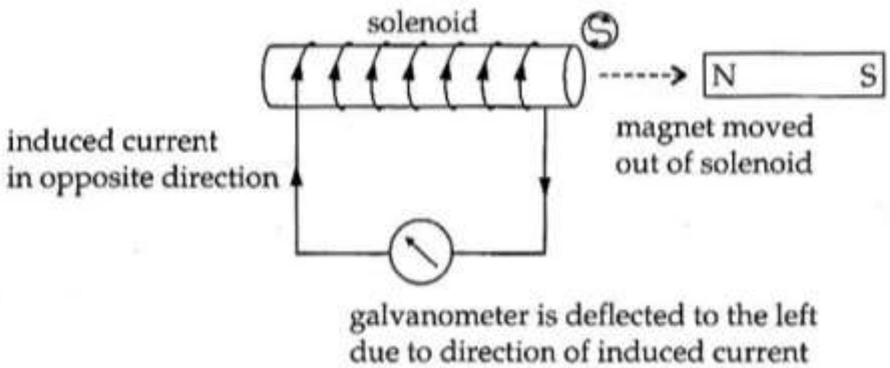
Electromagnetic induction occurs:

1. **When there is a changing or varying magnetic field near a close circuit.**
2. **When the magnetic field lines of force linking the circuit induces an electromotive force (e.m.f) thus, an induced current is produced.**

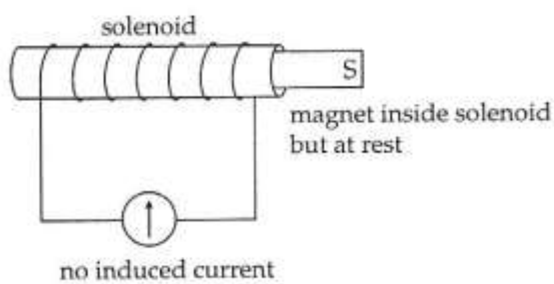
- In the following figure, a zero-current solenoid is set up with a centre-zero galvanometer.
- A stationary bar magnet is put inside the solenoid.
- When the magnet with **known poles** is moved into the solenoid, the pointer of the galvanometer is deflected in one direction by an induced current.
- Hence, an induced e.m.f is produced in the solenoid.



- The direction of induced current is **reversed** when the same magnet is moved **out** of the solenoid.



- No e.m.f is induced if:
  1. **The magnet is at rest outside or inside the solenoid.**
  2. **The magnet and the solenoid move with the speed in the same direction.**



Ways of Increasing the Induced e.m.f (Deflection in Galvanometer):

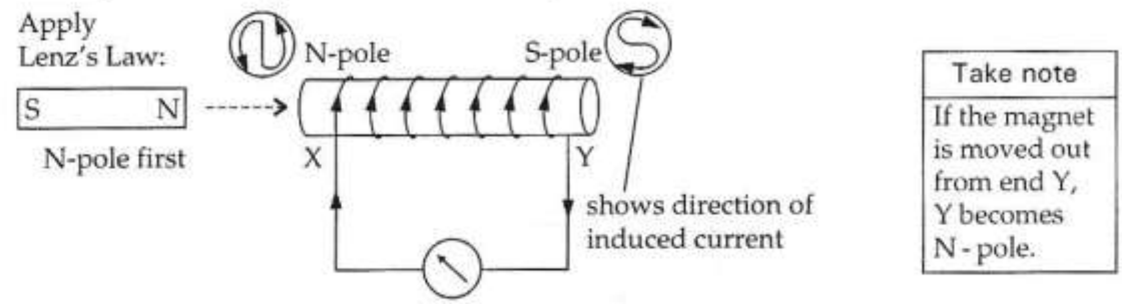
1. **Increasing the speed at which the magnet is moved.**
2. **Increasing the number of turns in the solenoid.**
3. **Using a stronger magnet.**

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION: The strength of the induced e.m.f is proportional to the rate of change of magnetic lines of force linking the circuit.

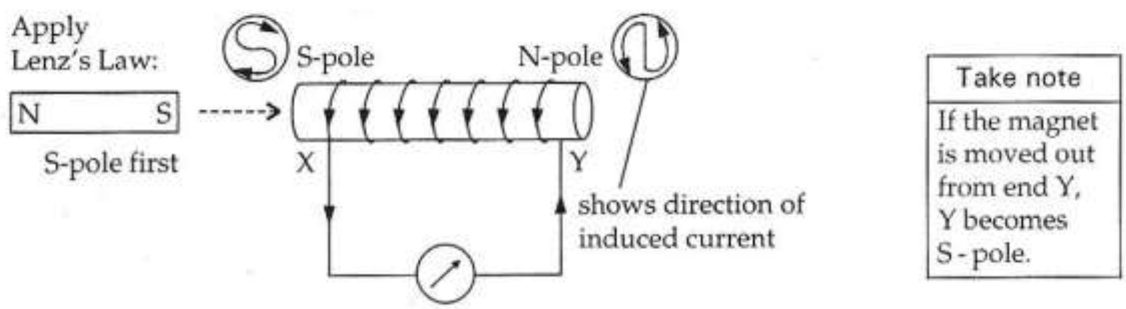
LENZ'S LAW

STATES: An induced current flows in a direction so as to **oppose** the change or motion producing it.

If it is the N-pole that is moved into the solenoid first, to OPPOSE this motion, the induced current must produce a N-pole at end X (and S-pole at end Y) of the solenoid.

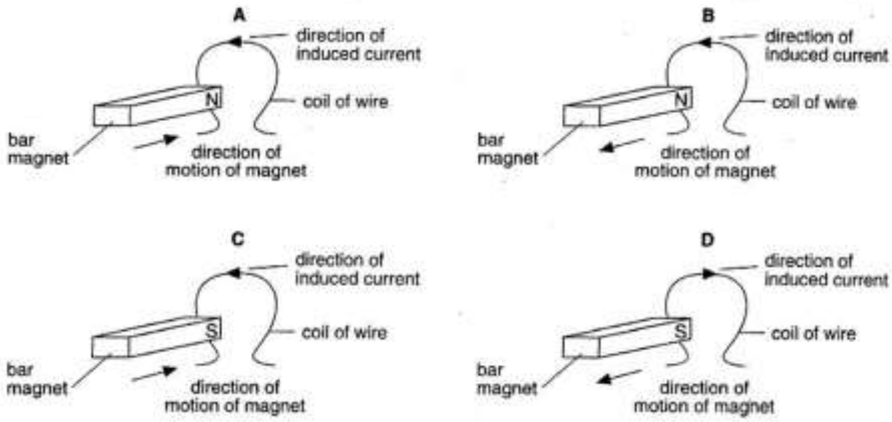


If it is the S-pole that is moved into the solenoid first, to OPPOSE this motion, the induced current must produce a S-pole at end X (and N-pole at end Y) of the solenoid.



Example

[Q] Which diagram correctly gives the direction of the induced current when the magnet is moved as shown? In each case, the coil of wire is connected in a complete circuit.

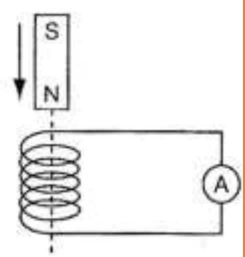


[Ans] **A** According to Lenz's Law, when the N-pole of the magnet is approaching the coil, the N-pole of the magnetic field due to the coil must face the N-pole of the magnet in order to oppose the change.

Example

[Q] A small coil is connected to a sensitive ammeter. The ammeter needle can move to either side of the zero position. When the magnet is allowed to fall towards the coil, the ammeter needle moves quickly to the right of the zero position.

The magnet moves through the coil. How does the ammeter needle move as the magnet falls away from the coil?



A It does not move.

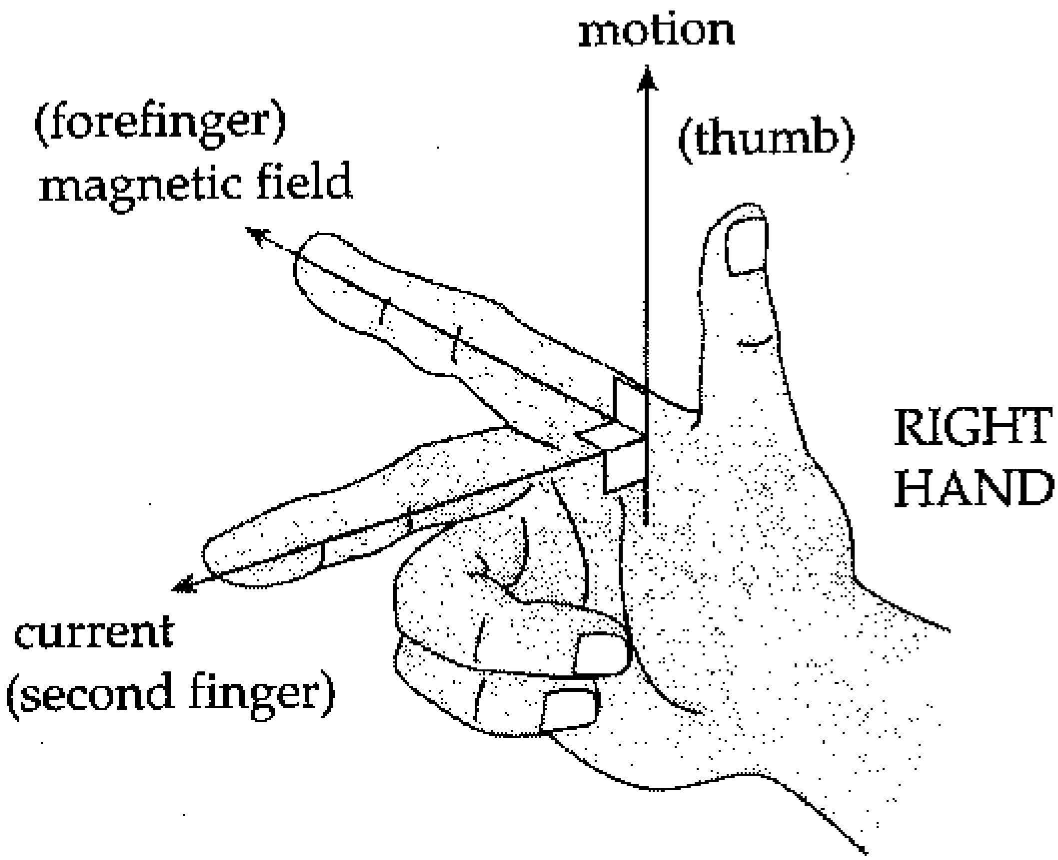
B It gives a steady reading to the right.

C It moves quickly to the left of the zero position and then returns to zero.

D It moves quickly to the right of the zero position and then returns to zero.

[Ans] **C** When the magnet falls towards the coil, a N-pole is induced at the upper end of the coil according to Lenz's Law. When the magnet falls away from the coil, the induced N-pole is at the lower end of the coil to attract the magnet. Hence, the current is reversed.

FLEMING'S RIGHT HAND RULE



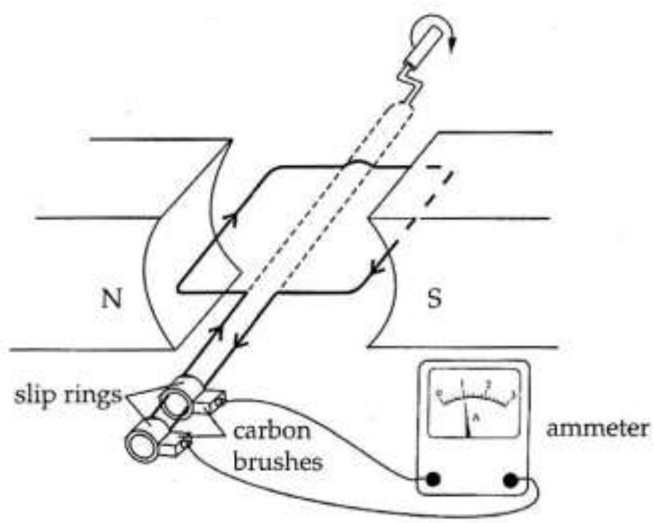
SIMPLE A.C GENERATOR (DYNAMO)

Parts of a Simple Alternating Current (A.C) Generator

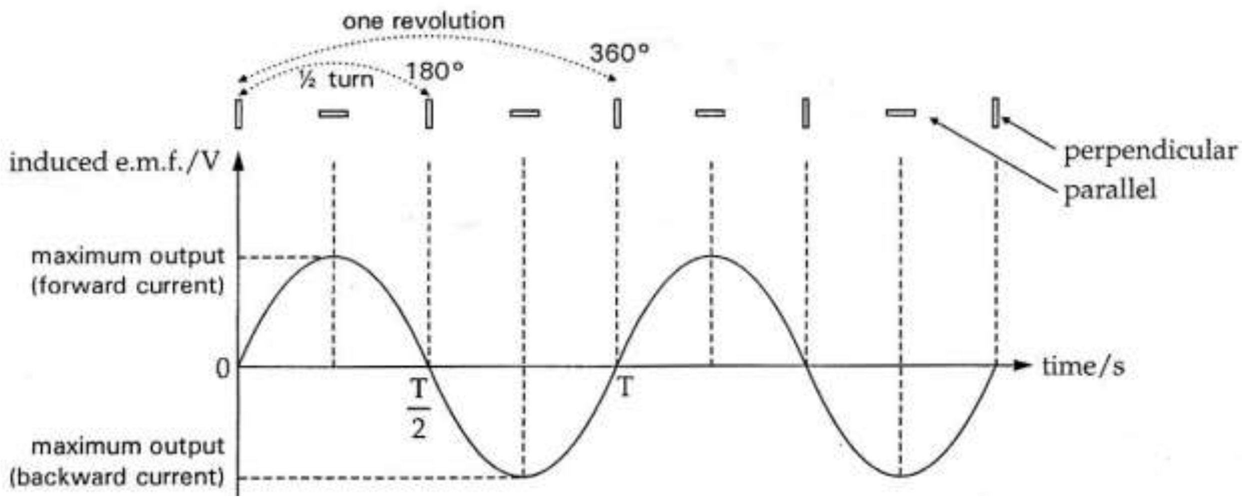
- two permanent magnets with circular poles (N and S),
- a rectangular coil of wire mounted on an axle with a handle,
- a pair of slip rings and carbon brushes.

How it Works

- By turning the handle, the coil rotates between the poles (N and S) of the magnets. The pair of slip rings rotate with the coil.
- The carbon brushes are in continuous contact with the slip rings when the axle is rotating.
- As the coil rotates, the upward as well as downward motions of the arms cut the magnetic field lines and an alternating e.m.f. is induced.
- The alternating induced current passes through the carbon brushes to the external circuit (such as an ammeter).



- The **direction** of the induced current changes **every half turn** of the coil.
- The induced e.m.f has **maximum** output when the plane of the coil is **parallel** to the magnetic field. There is **no** induced e.m.f when the plane of the coil is **perpendicular** to the magnetic field.



1. The **period** is the time taken for one revolution of the coil. The **frequency** of rotation is the number of revolutions of the coil per second.

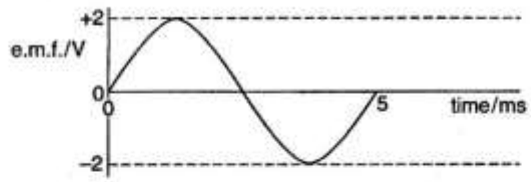
$f = \frac{1}{T}$, where f: frequency; T: period;

Ways of Increasing Induced e.m.f:

1. **Rotating the coil faster i.e increasing the frequency of rotation.**
2. **Increasing the number of turns on the coil.**
3. **Winding the coil round a soft iron core so that the magnetic field is stronger.**
4. **Using a stronger magnet, or using a powerful electromagnet to make the field stronger.**

Example

[Q] The diagram shows how the e.m.f. of a simple generator varies with time.



What is the frequency and the maximum value of the e.m.f.?

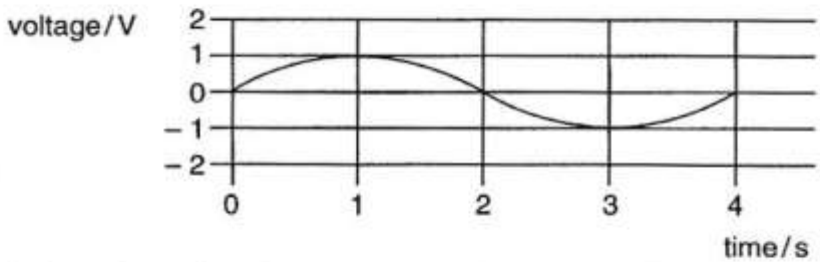
	frequency / Hz	maximum e.m.f./V
A	200	2.0
B	200	4.0
C	400	2.0
D	400	4.0

[Ans] **A** Maximum e.m.f. = peak voltage = 2V

Frequency = 1/period = 1/5 ms = 1/0.005 s = 200 Hz

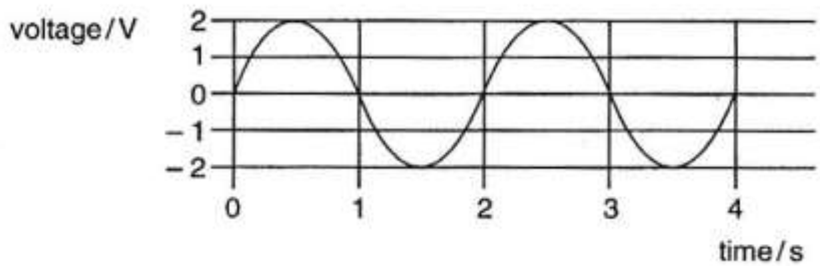
Example

[Q] A simple a.c. generator produces a voltage that varies with time as shown.

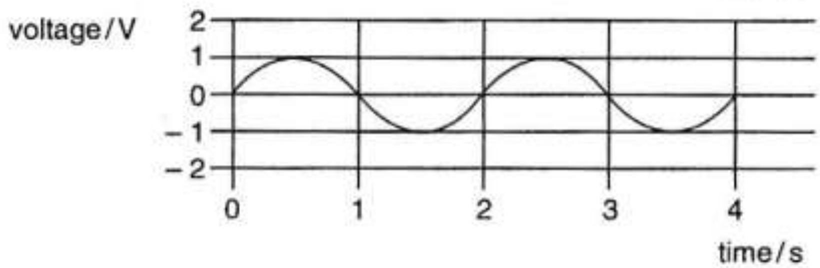


Which graph shows how the voltage varies with time when the generator rotates at twice the original speed?

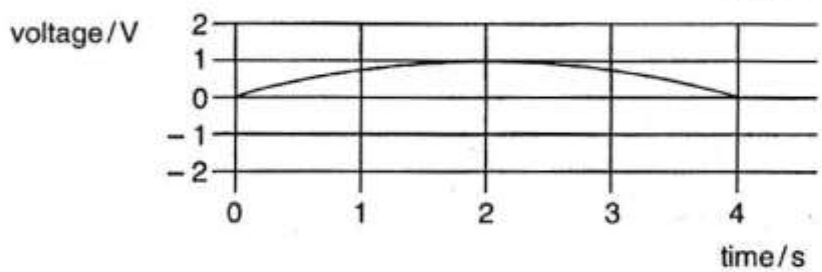
A



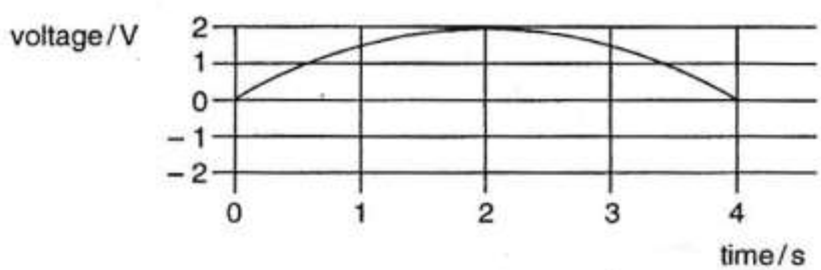
B



C



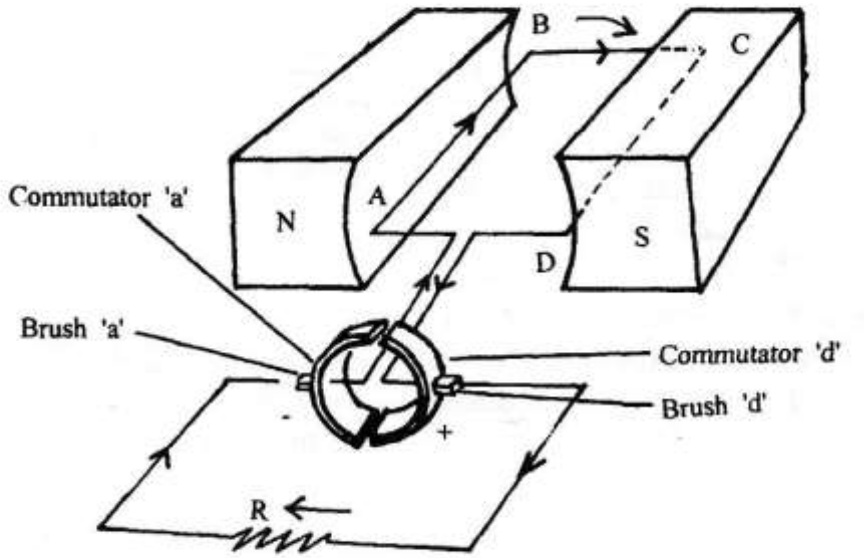
D



[Ans] **A** Since the speed is doubled, the amplitude or maximum output of the a.c. voltage is doubled and the period (T) of the voltage is halved.

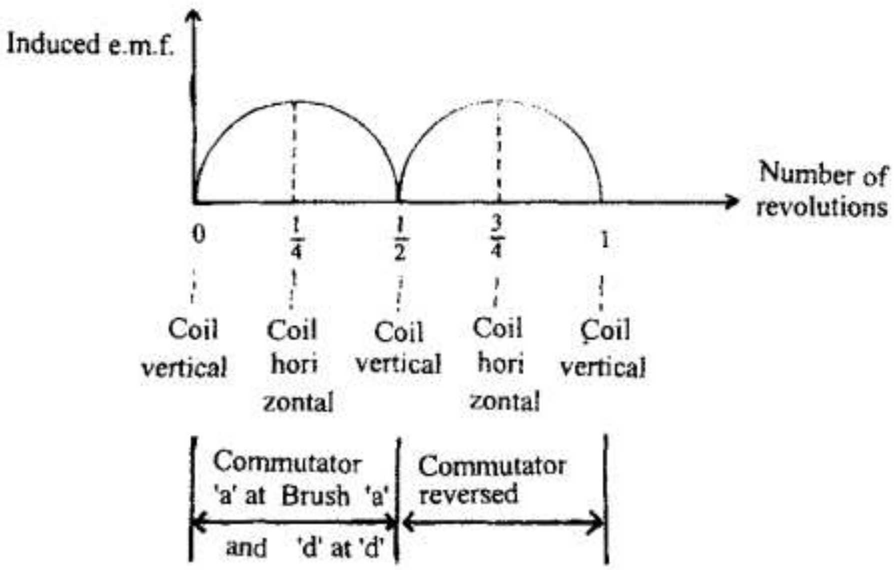
SIMPLE D.C GENERATOR

Parts of a Simple Direct Current Generator



How it Works

- The e.m.f is **zero** when the coil is vertical.
- It increases to the maximum during the first quarter turn and reduces back to zero during the second quarter turn.
- The current leaves the generator via brush ***d*** hence this brush is positive.


Induced e.m.f.
Number of revolutions
0
1/4
1/2
3/4
1
Coil vertical
Coil horizontal
Coil vertical
Coil horizontal
Coil vertical
Commutator 'a' at Brush 'a' and 'd' at 'd'
Commutator reversed

As the coil continues rotating from the second quarter turn to the third the commutators change positions. Commutator *a* is now in contact with brush *a* while commutator *d* is in contact with brush *d* but the current continues flowing in clockwise direction. Brush *d* remains positive and brush *a* remains negative and hence the current through *R* continues in the same direction although it reverses in the coil itself. The *e.m.f* induced between the beginning of the third and the end of the fourth quarter of a revolution varies in the same way as that between the beginning of the rotation and the end of the first half of the rotation.

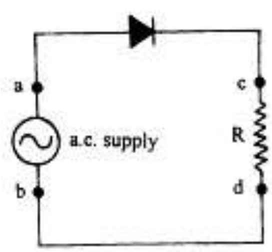
Difference between Dynamos and Motors

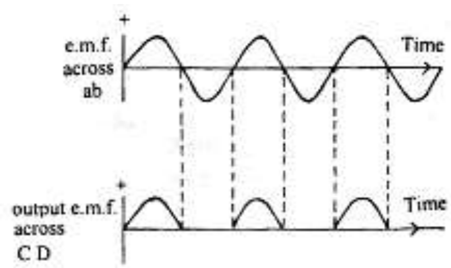
When a **dynamo** is rotated it **produces electricity.** A **motor** is **supplied with electricity** for it to rotate.

RECTIFIERS

This is a device that changes alternating current (A.C) into direct current (D.C).
Symbols:

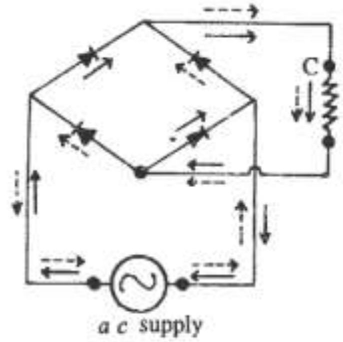
Half-wave Rectification

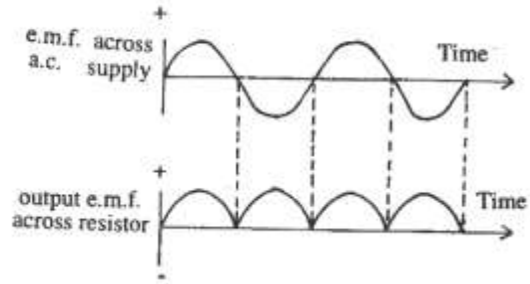




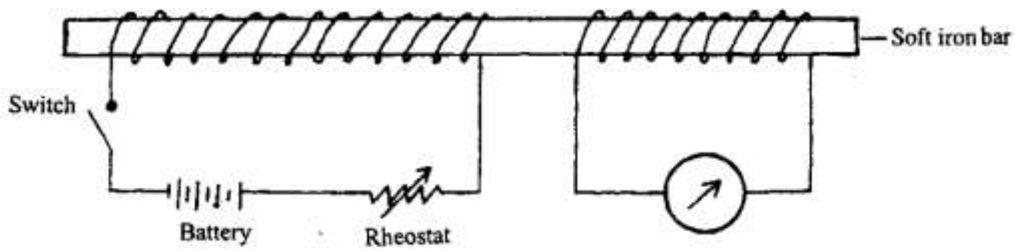
The input e.m.f across the resistor is represented by only **half the wave.**

Full-wave Rectification





MUTUAL INDUCTION

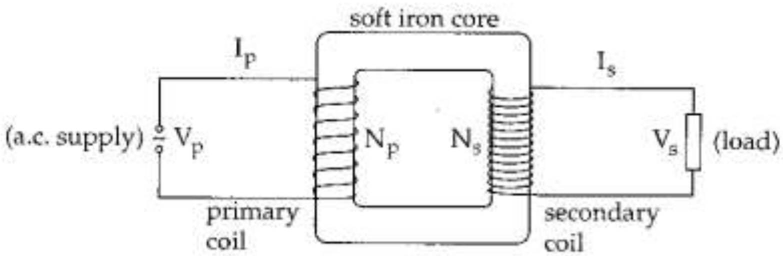


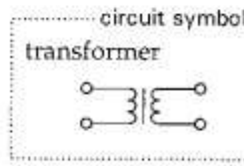
- When you switch the current **on**, the galvanometer needle kicks to one side and then returns to zero.
- When you switch the current **off**, the galvanometer needle kicks to one side and then returns to zero.
- As you increase the current with the rheostat the needle deflects to one side. Reducing the current produces a deflection in the opposite direction.
- The process by which a changing current in the circuit induces an e.m.f in a nearby circuit is called **mutual induction.**

THE TRSANSFORMER

Principle of a Transformer

- A **transformer** is a device used to **vary** the voltage of an a.c supply.
- The basic structure of a transformer consists of a primary coil and a secondary coil wound on a soft iron core.





where V_p = primary input voltage

I_p = alternating current in primary coil

N_p = number of turns in primary coil

N_s = number of turns in secondary coil

I_s = alternating induced current in secondary coil

V_s = secondary output voltage

How it Works

- An alternating current supply (input voltage, $\mathbf{V_p}$) is needed in a transformer.
- The alternating current ($\mathbf{I_p}$) flows in the primary coil and **sets up a changing magnetic field.**
- In the secondary coil, **an alternating e.m.f is induced.** The alternating induced current ($\mathbf{I_s}$) then flows to the load (output voltage $\mathbf{V_s}$).

- The induced e.m.f in the secondary coil may be **greater or less than** the e.m.f of the primary coil depending on the number of turns, $\mathbf{N_s}$ and $\mathbf{N_p}$.

The induced e.m.f. in the secondary coil may be GREATER OR LESS THAN the e.m.f. of the primary coil depending on the number of turns, N_s and N_p.

- ☐ If $N_s > N_p$ then $V_s > V_p$: this is a STEP-UP transformer.
- ☐ If $N_s < N_p$ then $V_s < V_p$: this is a STEP-DOWN transformer.
- ☐ Therefore $\frac{V_s}{V_p}$ is directly proportional to $\frac{\text{number of turns in secondary coil}}{\text{number of turns in primary coil}}$ or $\frac{V_s}{V_p} = \frac{N_s}{N_p}$.

If a transformer is 100% efficient, then OUTPUT POWER = INPUT POWER.

Equation (100% efficient)	output power = input power $V_sI_s = V_pI_p$ (or) $\frac{V_s}{V_p} = \frac{I_p}{I_s}$ (and) $\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$	by applying Equation $P = VI$

Example

A step-down transformer reduces the voltage from 220 volts to 11 volts. The input power is 110 watts and losses are negligible. (a) If the turns in the primary are 660, how many are in the secondary? (b) How much current flows in each coil?

Solution

(a) $\frac{V_2}{V_1} = \frac{N_1}{N_2}$

$\frac{11}{220} = \frac{N_2}{660}$

$N_2 = 33\text{turns.}$

(b) $P_1 = V_1 I_1$

$110 = 220I$

$I_1 = 0.50\text{A}$

$P_2 = P_1;\ V_1 I_1 = 110$

$I_2 = \frac{110}{11} = 10\text{A}$

Efficiency of a Real Transformer

The efficiency of a real transformer is always **less than 100%**

Equation (less than 100% efficient)	$\text{efficiency} = \frac{\text{output power}}{\text{input power}} \times 100\% = \frac{V_s I_s}{V_p I_p} \times 100\%$

e.g. If a transformer is only 90% efficient, then $\frac{V_s I_s}{V_p I_p} = 0.9$.

Because: 1. Energy is lost in the form of heat in the primary and secondary coils, and in the soft iron core. 2. There is leakage of magnetic field lines between the primary and secondary coils.

Ways of Increasing Efficiency

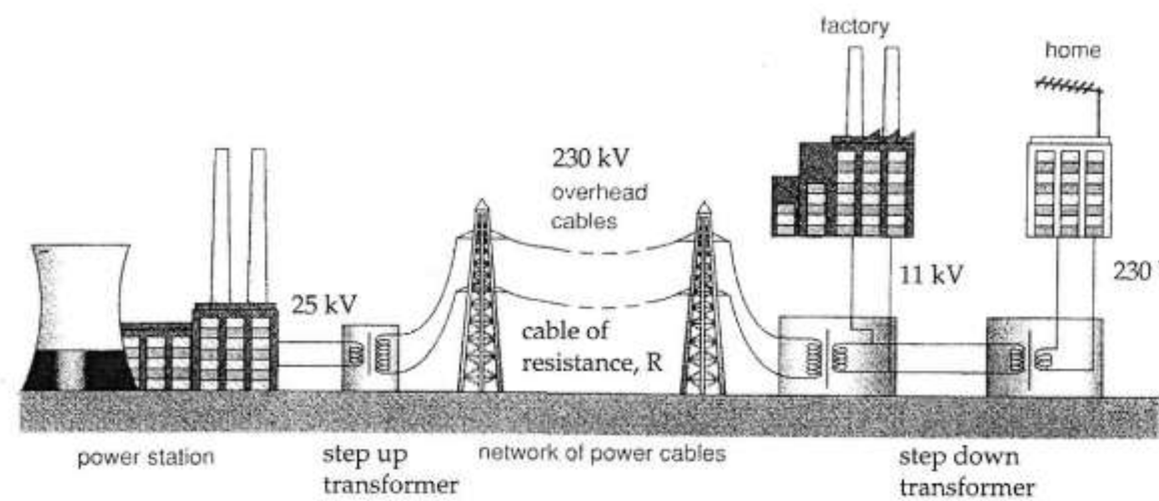
1. Use low-resistance (thicker) copper wire for primary and secondary coils to **reduce heating effect.**
2. Primary and secondary coils are wound on the same part of the soft iron core to **reduce leakage** of magnetic flux.

TRANSMISSION OF ELECTRICAL POWER

Energy loss:

- Electrical energy generated in a power station is transmitted through long cables.
- Due to resistance in the cables, some energy is lost in the form of heat.
- To reduce power loss due to resistance, the output a.c voltage from the generator in the power station is stepped up to a very high voltage (e.g 230 kV) by a step-up transformer.
- The current in the cables is reduced and this reduces power loss.
- The high voltage is then stepped down to 230 V by a series of step-down transformers so that it is safe for consuming
- **Power loss in the cables is calculated using:**

$$P = I^2R \quad where, P: power; \ I: current; R: resistance;$$



Example

[Q] Electrical energy is transmitted at high alternating voltages.

Which of the following is not a valid reason for doing this?

A At high voltage, a.c. is safer than d.c.

B For a given power, there is a lower current with a higher voltage.

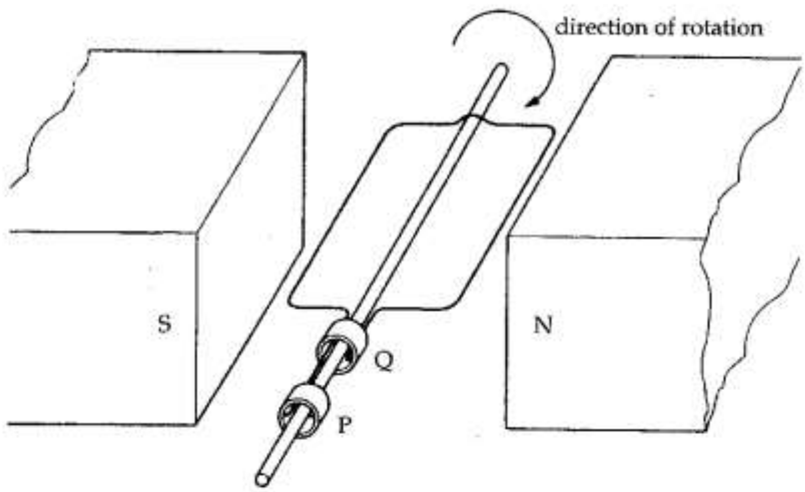
C There is a smaller energy loss at higher voltage and lower current.

D The transmission lines can be thinner with a lower current.

[Ans] **A** At high voltages, both a.c. and d.c. cause electric shock. Both of them are dangerous.

CHALLENGING QUESTIONS – 1

1. The figure is a diagram of a simple a.c. generator.



(a) Explain

(i) why an e.m.f. is induced in the coil as it rotates,

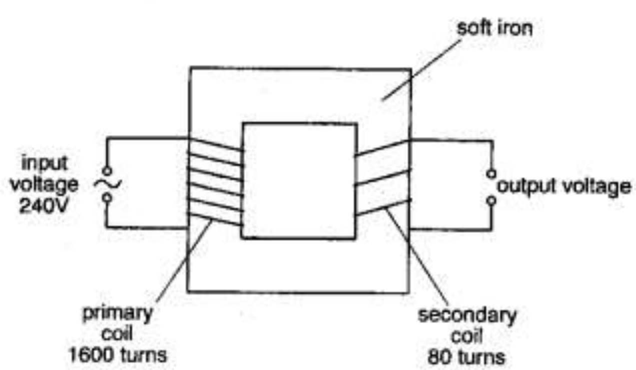
(ii) how we know that at the instant shown in the figure, the slip-ring P is positive,

(iii) why work has to be done to keep the coil rotating when the slip-rings P and Q are connected across a resistor. [5]

(b) The coil of the generator rotates 2.5 times in each second; at this speed, the maximum value of the induced e.m.f. is 20 mV. On graph paper, sketch a graph of e.m.f. against time for a time intervals of 1 s from the instant shown in the figure. [4]

2. Fig 2.1 shows a transformer being used to step down a 240 V alternating supply, in order to operate a low voltage lamp.

Fig. 2.1



(a) (i) Explain how the transformer works and how it is able to step down the input voltage.

(ii) The primary coil has 1600 turns and the secondary coil has 80 turns.Show that the output voltage across the secondary coil is 12 V. [7]

(b) (i) A lamp is connected to the secondary coil of the transformer by longleads which have a resistance of 2.5 Ω, as shown in Fig. 2.2. (In this diagram, the resistance of the leads is shown as a single resistor of value 2.5 Ω.)

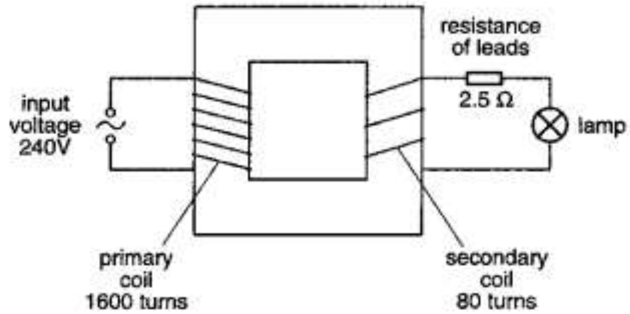


Fig. 2.2

The power input to the primary coil is 40 W, and the transformer is 100% efficient.

(i) Calculate the current in the secondary coil of the transformer.

(ii) Calculate the voltage across the resistance of the leads.

(iii) Calculate the electrical power dissipated in the lamp. [6]

(c) High voltages are used to transmit electrical energy through long-distance cables. Explain the advantage of using high voltages. [2]

3. Fig. 3.1 shows a coil of wire wound on a piece of soft iron. A magnet is rotated in the gap in the soft iron as shown.

When the magnet rotates, the lamp connected to the coil glows. The magnet takes 0.20 s to make one complete revolution.

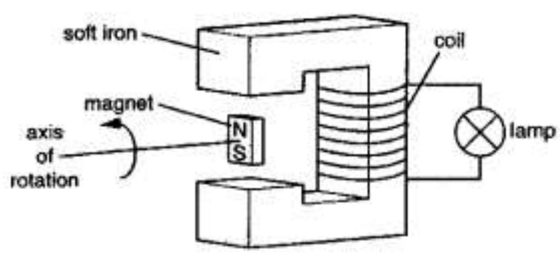
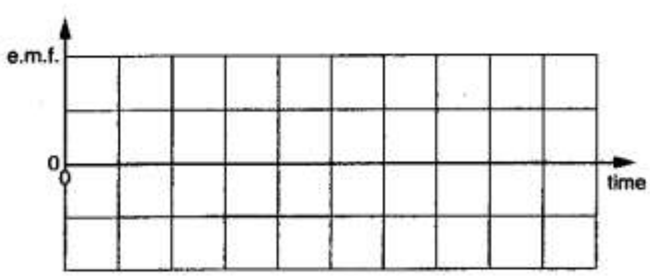


Fig. 3.1

(a) Explain why an e.m.f. is produced in the coil when the magnet rotates. [2]

(b) Using the axes provided, sketch a graph to show how the e.m.f. produced in the coil varies with time. Mark a scale along the time axis. [2]



(c) State two changes that increase the size of the e.m.f. produced. The parts of the apparatus shown in Fig. 3.1 may be altered. [2]

4. Fig 4.1 shows a transformer connected to an alternating current supply. The primary coil has 50 turns and the secondary coil 100 turns. Both coils are made of insulated copper wire and are wound on a soft-iron core.

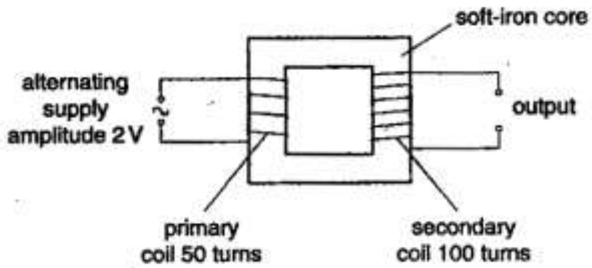


Fig. 4.1

(a) State

(i) why the coils are made of copper,

(ii) why the core is made of soft iron,

(iii) the cause of the magnetic field in the soft-iron core. [4]

(b) Fig 4.2 shows the variation of the output voltage of the transformer with time.

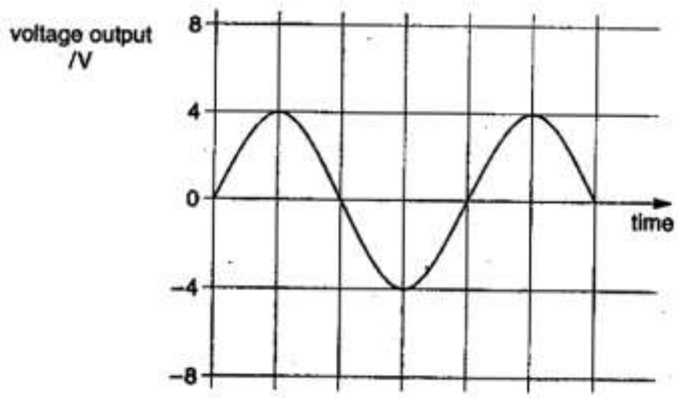


Fig. 4.2

The number of turns on the secondary coil is increased to 150, but the number of turns on the primary coil and the input voltage are unchanged.

On Fig 4.2 draw the variation with time of the output voltage after this increase. [2]

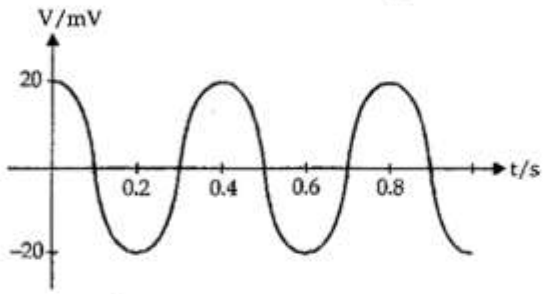
SOLUTIONS:

1. (a) (i) As the coil rotates, the wires of the coil cut across the magnetic field lines resulting in a change of magnetic flux linkage in the coil. Induced e.m.f. is produced in the coil due to electromagnetic induction.

(ii) Applying Fleming's Right Hand Rule to the wire of the coil to determine the direction of current flow.

(iii) Induced current flows through the resistor causing electrical energy to be converted to internal energy in the resistor. Since the electrical energy comes from the kinetic energy of the coil, work has to be done to keep the coil rotating.

(b)



(a) (i) Only the two long wires of the coil would have induced current as the direction of motion is perpendicular to the magnetic field lines.

(ii) Conventional current flows from positive to negative terminals.

(iii) The kinetic energy of the rotating coil is from an external source. If you turn the coil, the energy comes from your body.

(b) Frequency of rotation = 2.5 Hz

The period of rotation = 1/f = 1/2.5 = 0.40 s

The graph is a cosine curve as maximum e.m.f. is produced when the coil is in a horizontal position. There is no induced e.m.f. when the coil is in a vertical position.

2. (a) (i) When an alternating current flows through the primary coil, a changing magnetic field is produced in the secondary coil through the soft iron core. There is a changing magnetic flux linkage in the secondary coil. An induced a.c. voltage is produced in the secondary coil due to electromagnetic induction. Since the number of turns in the secondary coil is less than that in the primary coil, the voltage is stepped down.

(ii) $V_S = \frac{N_s}{N_P} \times V_P = \frac{80}{1600} \times 240 = 12 \text{ V}$

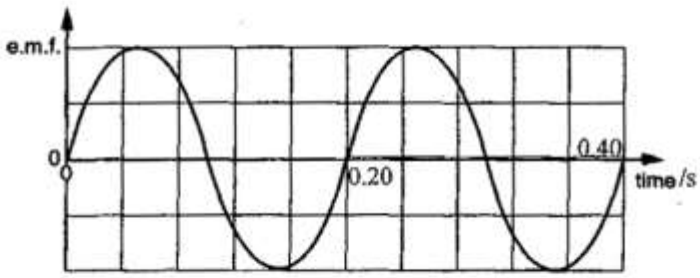
(b) (i) $I_S = \frac{P}{V} = \frac{40}{12} = 3.33 \text{ A}$ (ii) $V = IR = (3.33)(2.5) = 8.33 \text{ V}$

(iii) $P = I_S V = (3.33)(12 - 8.33) = 12.2 \text{ W}$

(c) At high voltages, the same electrical power can be transmitted at smaller currents. This reduces the power loss in the cables and thinner cables can be used to save costs.

3. (a) When the magnet rotates, there is a change in magnetic flux linkage in the coil. Hence an induced e.m.f. is produced due to electromagnetic induction.

(b)



(c) 1. Use a stronger magnet. 2. Rotate the magnet at a faster rate.

(b) The e.m.f.-time graph must be sinusoidal and has a period of 0.20 s. At least 2 complete cycles are drawn.

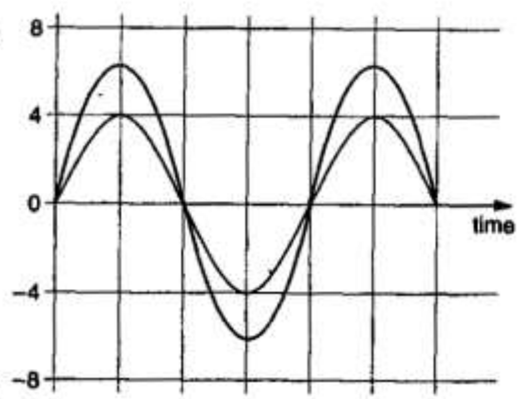
(c) Another acceptable answer is to increase the number of turns of the coil.

4. (a) (i) Copper is a good electrical conductor.

(ii) Soft iron can be magnetized and demagnetized easily. It can increase the magnetic flux linkage between the primary and secondary coils.

(iii) The current flowing through the primary coil produces a changing magnetic field which passes through the iron core.

(b)



(a) (ii) The core must be a soft magnetic material.

(b) When the number of turns on the secondary coil is increased to 150, the amplitude of the output voltage = 150/50 × 2 = 6 V. The frequency remains unchanged.

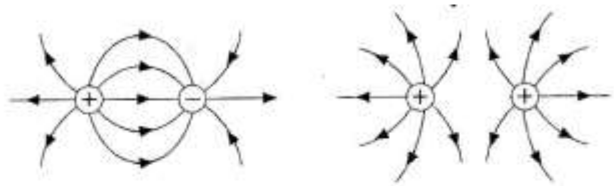
STATIC ELECTRICITY

ELECTROSTATIC FORCES

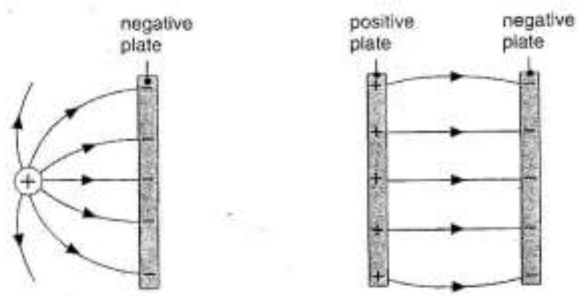
- Charges are either **positive** or **negative.**
- **Like charges repel, unlike charges attract.**
- SI Unit of **Electric Charge: Coulomb (C).**

ELECTRIC FIELD

- This is **a region where a small charge experiences an electric force.** (Like charges experience repulsive force, unlike charges experience attractive force.)
- Electric fields are represented by **electric field lines.**
- These arrow-marked lines (one arrow for one line) represent the direction of electric force of a free-moving **positive** charge. The closer parts of the lines (the regions nearer to the charge) indicate stronger electric force.
- The figures below show the electric field lines of **positive charge** (**+ sign**) and a **negative charge** (**- sign**).

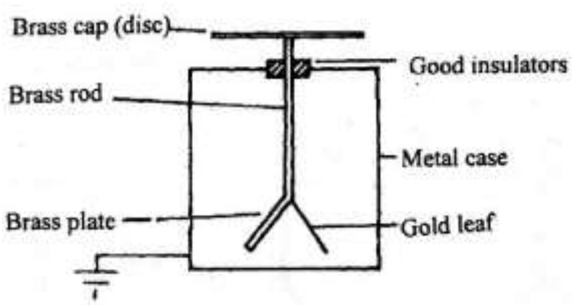


The electric field pattern of 2 oppositely-charged plates (parallel to each other) has straight field lines at the central region.



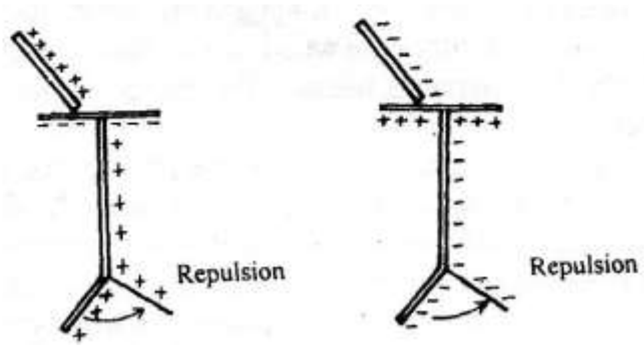
THE GOLD-LEAF ELECTROSCOPE

- It is a very sensitive instrument used for detecting and testing small electrostatic charges.
- The metal case is earthed. It can be earthed by placing it on a wooden table.



How to Charge an Electroscope by Contact

- Touch the brass cap with a charged rod of either sign.
- The leaf diverges from the brass plate, since the **brass plate and gold leaf are similarly charged**.
- The divergence persists for a long time even after the rod is removed.

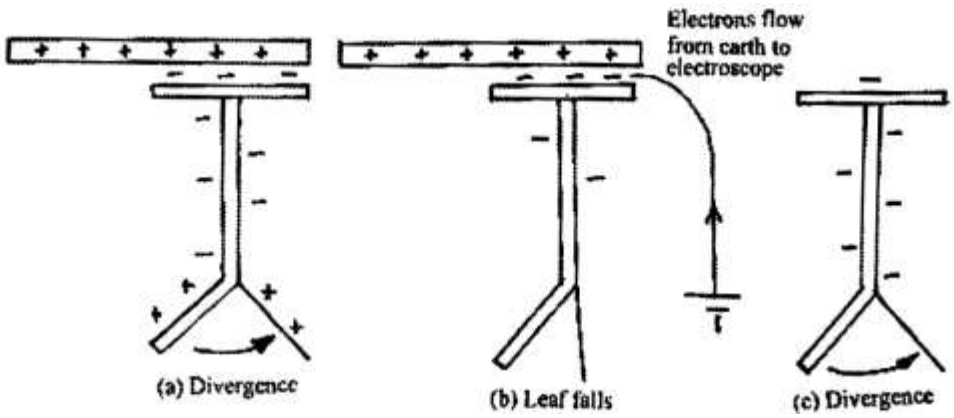


How to Test the Sign of Charge on a Rod

- Charge the electroscope positively.
- Bring a positively charged Perspex rod near but **not** touching.
- A positive rod will increase the divergence while a negative rod will decrease the divergence.
- **Discharge the electroscope by touching it with your finger** and note that the leaf collapses.

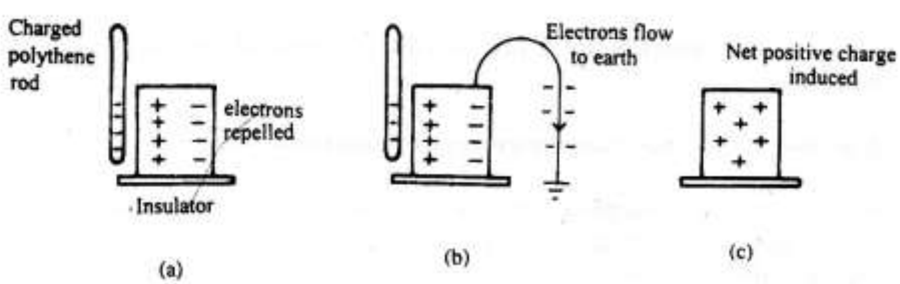
How to Charge an Electrode by Induction

- Bring a positively charged rod near the cap of an uncharged electroscope.
- The leaf diverges as the charged rod attracts the electrons upward, leaving similar charges in the plate and the gold leaf.
- Touch with your finger to earth it.
- The leaf collapses as the electrons neutralise.
- Remove the finger and remove the rod.
- A large divergence results as the extra negative charge obtained from the earth distributes throughout the electroscope.
- Therefore, the electroscope has been charged negatively.
- To charge it positively, repeat the above with a negative rod.

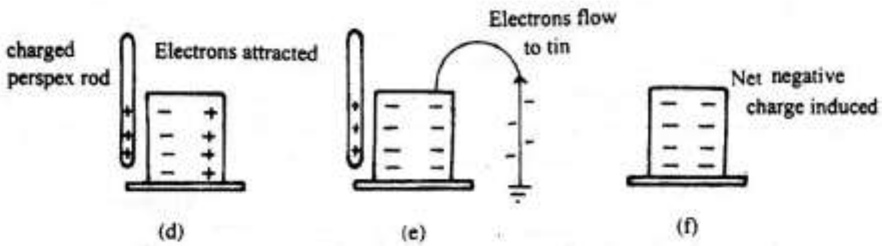


How to Charge a Body by Induction

For charging it positively:



For charging it negatively:



ELECTROSTATIC INDUCTION

Definition: Electrostatic induction is a process whereby a **conductor** becomes charged when a charged body is brought near it but **not in direct contact** with it.

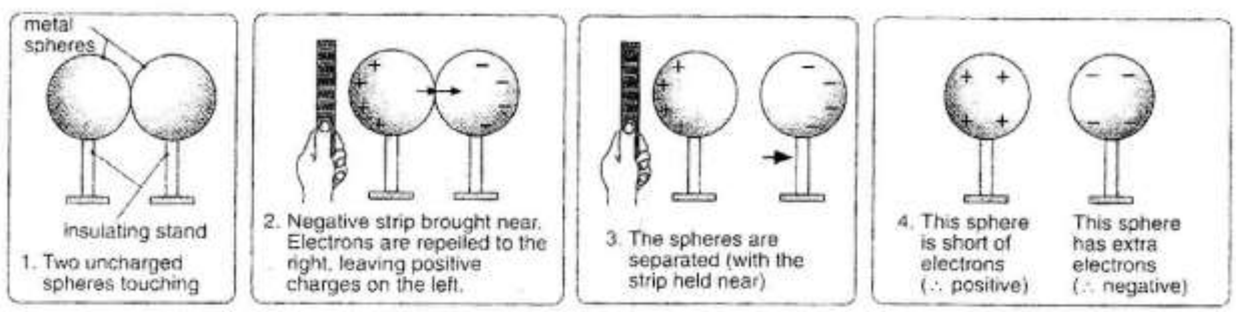
How to Charge Two Conductors by Induction

① Two uncharged (neutral) metal spheres with insulating stands are touching each other.

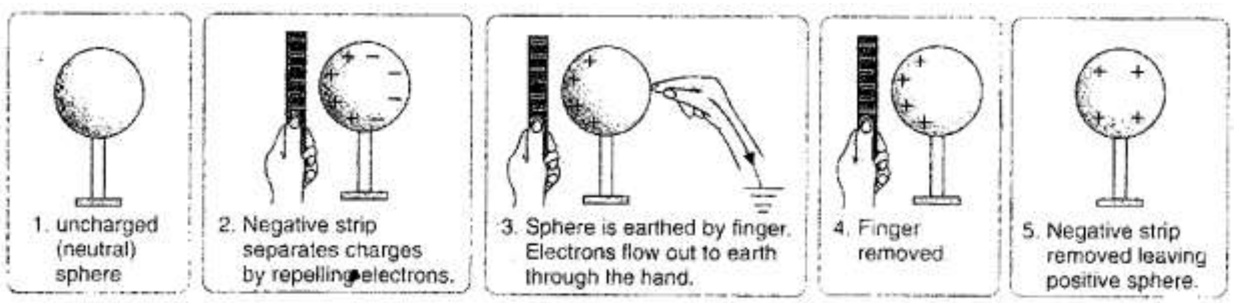
② A negative strip is brought near the left sphere but not touching it. *Induction takes place, electrons are repelled to the right sphere, leaving positive charges on the left sphere.*

③ With the strip still holding near the left sphere, separate the two spheres.

④ Move away the negative strip. *The left sphere is short of electrons (becomes positively charged) and the right sphere has extra electrons (becomes negatively charged).*



How to Charge One Sphere



Example

[Q] An electrostatically charged object will pick up small pieces of paper. Which of the following will not pick up pieces of paper?

A an earthed metal rod rubbed with a duster

B a plastic comb pulled through dry hair

C a polythene rod rubbed with a woolen cloth

D a rubber balloon rubbed on a nylon shirt

[Ans] **A** All charges will be removed if the metal rod is earthed.

Example

[Q] Why is a positively charged object made neutral (discharged) by someone touching it?

A Electrons flow from the object.

B Electrons flow on to the object.

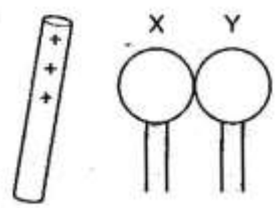
C Protons flow from the object.

D Protons flow on to the object.

[Ans] **B** Positive object is deficient in electrons. Electrons are from the earth.

Example

[Q] Two insulated and uncharged metal spheres X and Y are touching. While a positively charged rod is near X, the spheres are moved apart. After this action, X has a negative charge.



What will be the charge on Y?

A negative and smaller than that on X

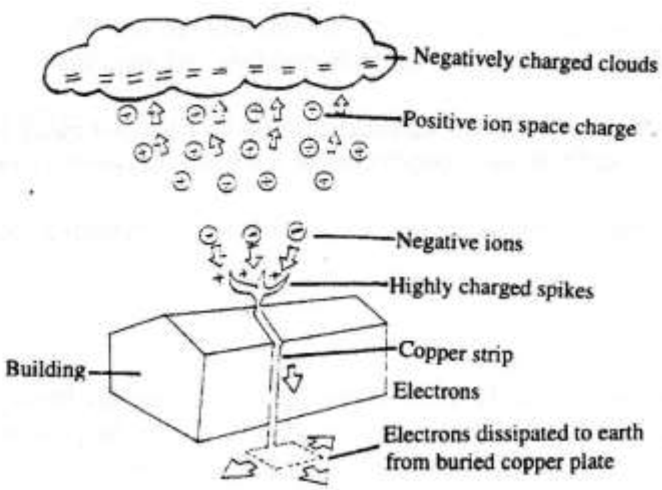
B negative and the same size as that on X

C positive and smaller than that on X

D positive and the same size as that on X

[Ans] **D** Two set of induced charges with be produced on X and Y. These induced charges will be opposite in sign but equal in magnitude.

LIGHTNING



This is the discharge of electrons occurring between two charged clouds or between a cloud and earth.

CHALLENGING QUESTIONS – 2

1. An experiment to show charging by induction uses a metal sphere mounted on an insulated support. The sphere is initially uncharged and is shown in Fig. 1.1.

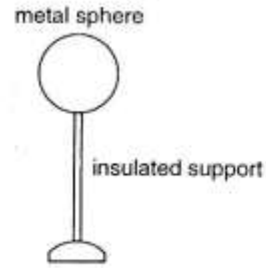


Fig. 1.1

(a) A negatively charged rod is brought near the sphere, as shown in Fig. 1.2.

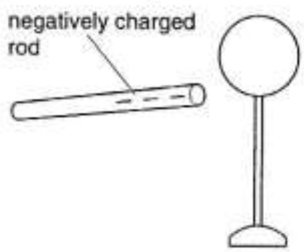


Fig. 1.2

(i) State and explain the movement of electrons in the sphere that occurs as the rod is brought near.

(ii) On Fig. 1.2, draw the charges on the metal sphere. [3]

(b) The metal sphere is now touched at point A by a wire connected to earth, as shown in Fig. 1.3.

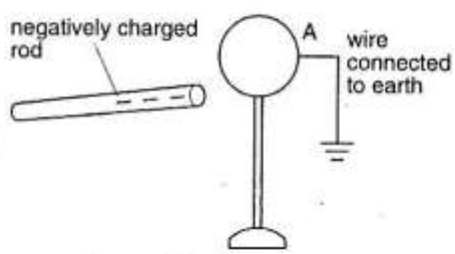


Fig. 1.3

On Fig. 1.3, draw the charges on the metal sphere. [1]

(c) The wire connected to earth is removed. Then the negatively charged rod is also removed, as shown in Fig. 1.4.

Fig. 1.4

On Fig. 1.4, draw the charges on the metal sphere. [1]

(d) The support is made from an insulator. State one material that may be used to make the support. [1]

2. Two vertical metal plates are connected to a high voltage power supply, as shown in Fig. 2.1. An electric field exists in the space between the plates.

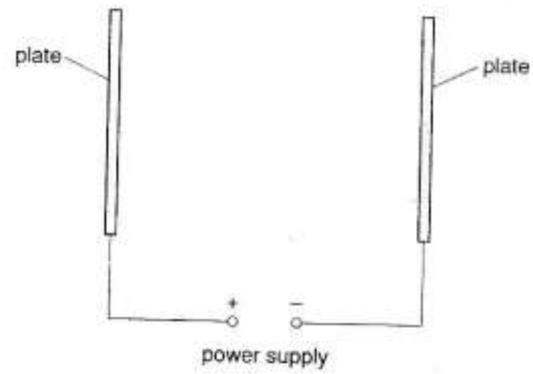


Fig. 2.1

(a) (i) State what is meant by the *electric field* between the plates.

(ii) On Fig. 2.1 draw lines of force to show the electric field between the two plates. [3]

(b) An uncharged metal ball is hung by an insulating thread between the two plates, as shown in Fig. 2.2.

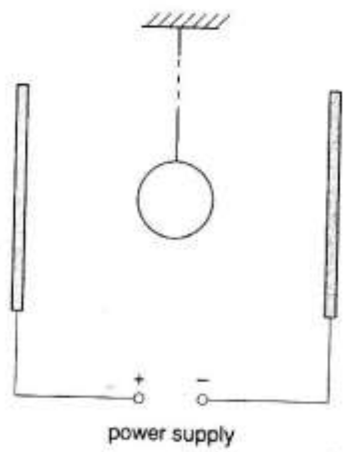


Fig. 2.2

On fig. 2.2.

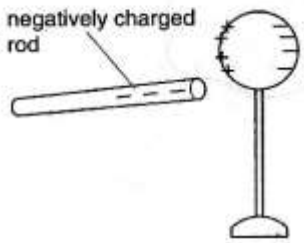
(i) draw the distribution of charge that will be found on the metal ball,

(ii) draw lines of force to show the new electric field between the plates. [2]

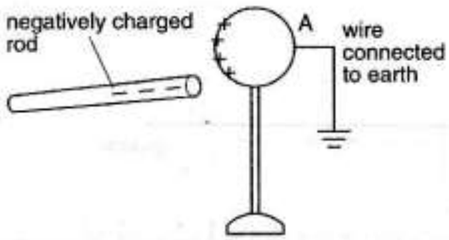
SOLUTIONS:

1. (a) (i) Electrons in the sphere move from left to right of sphere since there is an electric force of repulsion between the electrons on the rod and electrons on the sphere.

(ii)



(b)

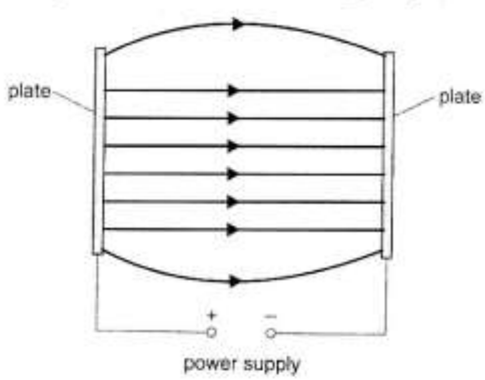


(c)

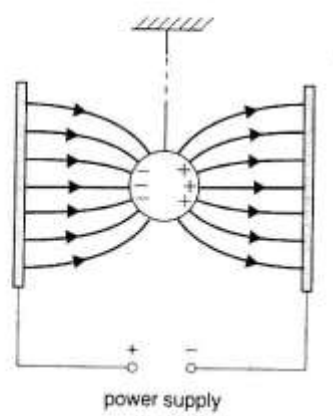
(d) plastic

2. (a) (i) A region where an electric charge experiences a force.

(ii)



(b) (i)(ii)

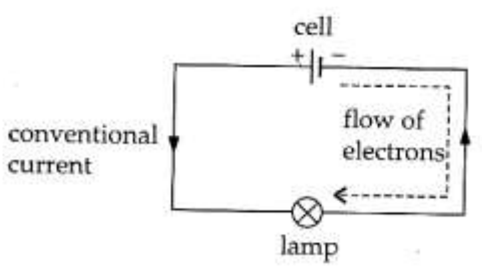


CURRENT, POTENTIAL DIFFERENCE AND RESISTANCE

ELECTRIC CURRENT AND CONVENTIONAL CURRENT

Concept: The **flow of electrons along the conducting wires** in a circuit produces an electric current.

- Electrons **always** flow from the negatively charged end to the positively charged end.



- Long ago, scientists thought that current flows from positive to negative.
- **Remember: Electron Flow (Negative to Positive)** is in the opposite direction to the **Conventional Current (Positive to Negative)**

Measuring Electric Current

- The unit with which we measure the rate of flow of electricity, or size of **Current** is the **Ampere (A).**
- **Electricity** is simply the flow of electrons through a conductor
- The total quantity of electricity is **Charge**
- The charge flowing past any given point in one second when one ampere is flowing is called the **coloumb.**

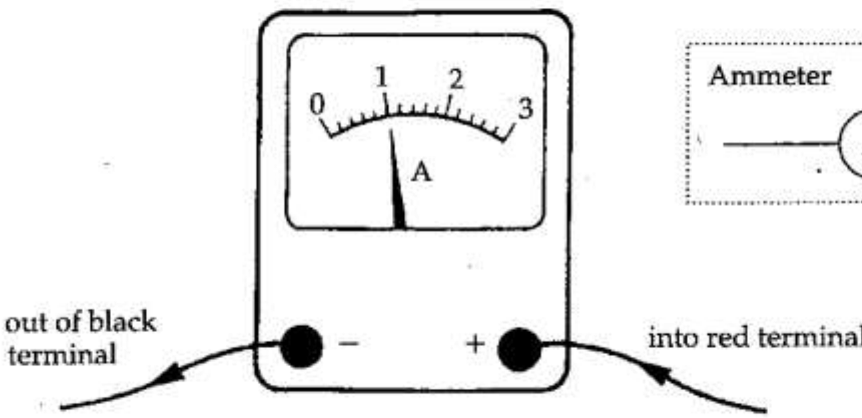
Definition	Current (I) is the *rate of flow of charge (Q)*.

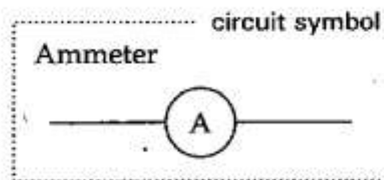
Equation	$I = \frac{Q}{t}$ (or $Q = It$)	where I: current Q: charge flow in coulomb (C) t: time in second (s)

Take note	The value of current (I) is taken from ammeter which shows amount of charge flow per second.

SI unit of current: ampere (A)

The SIZE of the electric current in a circuit can be measured by an ammeter as shown.





POTENTIAL DIFFERENCE

- Energy carried by electric charges is consumed in components in a circuit.
- **Potential Difference** (p.d) across a component **is the measure of the energy converted per unit charge passing through a component**

$$p.d = \frac{energy\ converted\ to\ other\ forms\ in\ the\ component}{charges\ flow\ through\ the\ component}$$

$$V = \frac{E}{Q} \qquad where\ p.d(V); E = Energy\ Converted; Q = Charge$$

- **SI Unit of potential difference:** Volt (V).

Example

[Q] The amount of energy transferred when 10 C of charge passes through a p.d. of 20 V is the same as the energy needed to raise a 2 kg mass through a distance *X*. What is the value of *X*?

[gravitational field strength = 10 N/kg]

A 0.1 m **C** 10 m

B 1 m **D** 100 m

[Ans] C E = VQ

potential energy required = mgx

$$mgx = VQ$$

$$x = \frac{QV}{mg} = \frac{(10)(20)}{(2)(10)} = 10\text{ m}$$

ELECTROMOTIVE FORCE (e.m.f)

- The **electromotive force** of a cell is the **energy supplied (E) to** **each** **coulomb of charge (Q) within it.**

$$\left(\text{e.m.f.} = \frac{\text{energy supplied by the cell}}{\text{charges flow through the cell}}\right)$$

Equation	$\varepsilon = \frac{E}{Q}$	where ε: electromotive force (e.m.f.) E: energy supplied by the cell Q: charges flow through the cell

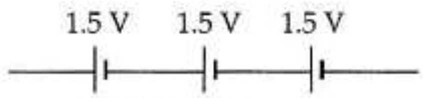
Take note	The value of e.m.f. (ε) is taken from voltmeter which shows the amount of energy needed to drive one unit of charge (1C) round a complete circuit.

SI unit of e.m.f.: joules per coulomb (JC^{-1}) or volt (V). ($1\text{ V} = 1\text{ J}C^{-1}$)

CELLS IN SERIES

- When cells are connected in **series,** the **combined e.m.f.** used to drive the electric charges is the sum of all the individual cell's e.m.f.

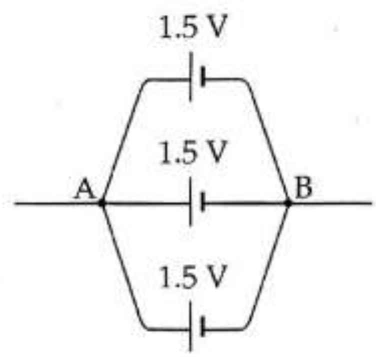
- With **more cells,** the circuit will have **more power** to drive the electric charges.



cells in series:
combined e.m.f. 4.5 V

CELLS IN PARALLEL

- When cells are connected in **parallel,** the combined e.m.f used to drive the electric charges is the e.m.f of one individual cell (i.e. each cell contributes an equal amount of e.m.f).
- With **more cells,** the circuit will have **longer time** to drive the electric charges.

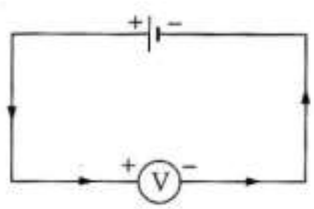


cells in parallel:
combined e.m.f. 1.5 V
(each cell contributes 0.5 V)

VOLTMETER

To measure electromotive force:

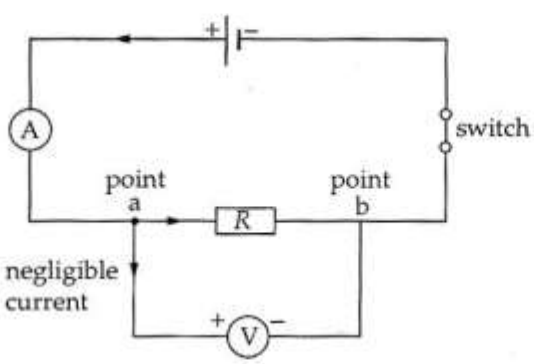
- The e.m.f. of a cell can be measured by a voltmeter ***connected directly across*** the terminals of the cell.

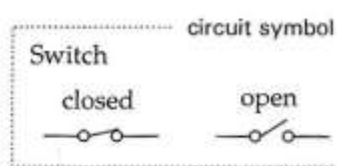


- The positive terminal of the cell is connected to the positive terminal (red) of the voltmeter and the negative terminal (black) of the cell is connected to the negative terminal of the voltmeter.

To measure potential difference (p.d)

- To measure the p.d. across a component (or between two points separated by a load), the voltmeter is ***connected in parallel*** to the component (load).





e.m.f & p.d IN A SIMPLE CIRCUIT

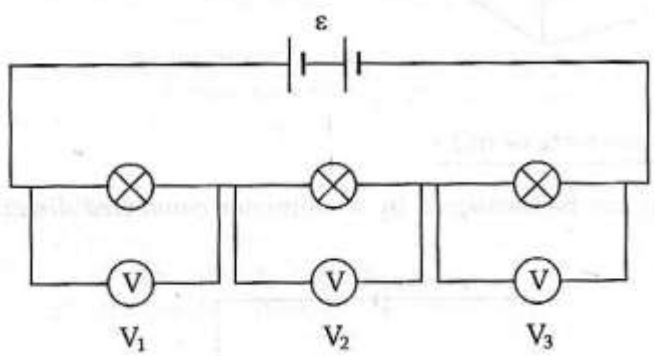
- The **e.m.f (Ɛ)** of the power supply must be **equal** to the sum of **p.d (V) across all circuit components.**

E.m.f. is the amount of energy gained by one coulomb of charges when they pass through the power supply.

As the charges flow round the circuit, they lose their energy to the circuit components.

Taking the circuit as a whole, total electrical energy gained by the charges must be the SAME as total energy lost to the circuit components.

For example, in the circuit shown, $\varepsilon = V_1 + V_2 + V_3$



RESISTANCE

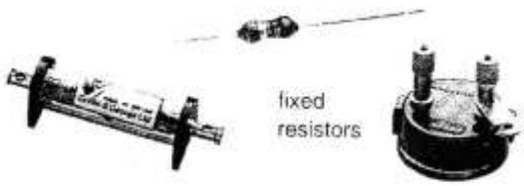
- All metals have some resistance. In an electric circuit, resistance reduces the size of the current.
- A **resistor** is a conductor with known value of resistance. It can be used to control the size of current flowing in a circuit.
- **Resistance,** therefore is a measure of how difficult it is for the current to pass through the circuit.
- **DEFINITION:** The **resistance (R)** of a component is the ratio of potential difference (V) across it to the current (I) flowing through it.

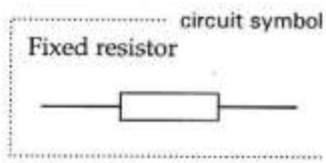
Equation	$R = \frac{V}{I}$ (or $V = IR$)	where R: resistance (Ω) V: p.d. (V) I: current (A)

The formula is derived from **Ohm's Law. SI Unit of Resistance: ohm (Ω).**

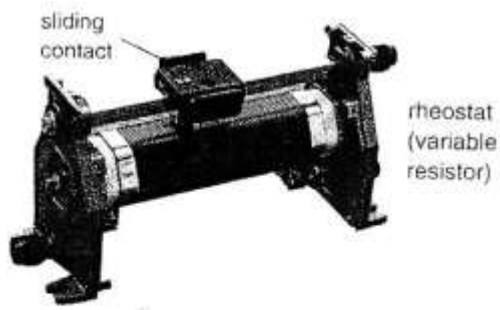
RHEOSTAT

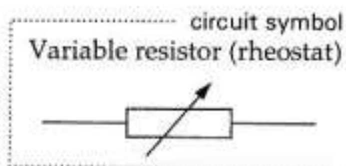
- **Resistors** have fixed values of resistance.





- **Rheostats** are variable resistors commonly used in a circuit to vary the control of electric current.





FACTORS AFFECTING RESISTANCE OF A WIRE

1. Length

For a wire of uniform cross-sectional area (A), the resistance (R) is ***directly proportional*** to the length (ℓ) of the wire. In symbols, $R \propto \ell$ (when A is uniform).

So the longer the wire the higher the resistance.

2. Cross Sectional Area

For a wire of fixed length, its resistance (R) is ***inversely proportional*** to the cross-sectional area (A). In symbols, $R \propto \frac{1}{A}$ (with same length).

So the thinner the wire the higher the resistance.

3. Material

Resistance depends on the kind of substance.

Copper is a good conductor and is used for connecting wires.

Nichome has more resistance and is used in the heating elements of electric heater.

4. Temperature

The resistance of a wire also changes as the temperature changes.

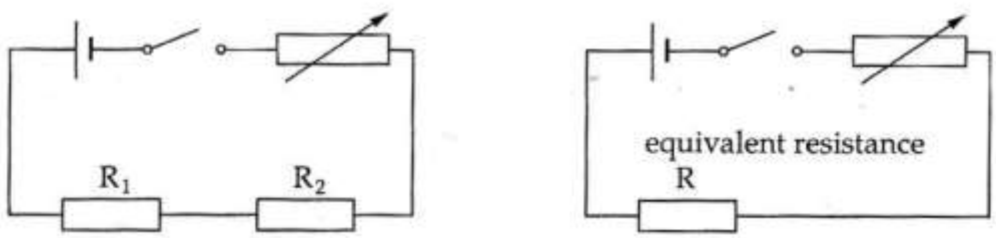
For metallic wires, as temperature increases, the resistance increases.

But for some materials like silicon and germanium, as temperature increases, the resistance decreases.

RESISTORS IN SERIES

The total resistance (R) of the resistors connected in series circuit is equal to the sum of the separate resistance.

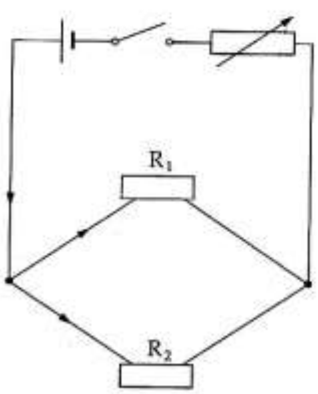
The two resistors in the figure below are connected in SERIES.

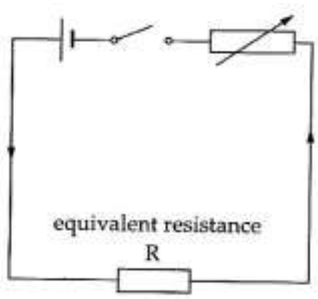


If R is the equivalent resistance (total resistance) of the two resistors, then

$$R = R_1 + R_2$$

RESISTORS IN PARALLEL





The total resistance (R) of the resistors connected in series circuit is equal to the sum of the separate resistance.

The two resistors in the figure below are connected in PARALLEL.

If R is the equivalent resistance (total resistance) of the two resistors, then

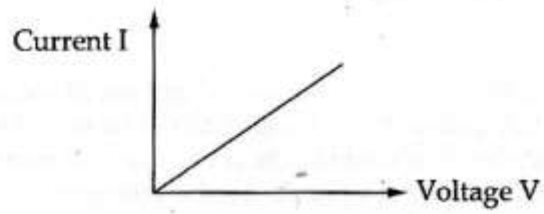
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

OHM'S LAW

STATES THAT: The current (I) flowing through a conductor is directly proportional to the potential difference (V) across it, provided that the physical conditions and temperature remain constant.

In symbols, | $I \propto V$ | (constant physical conditions & temperature) |

If we plot a graph of the current (I) passing through a resistor against the p.d. (V) across it, sometimes we can get a STRAIGHT LINE through the origin.



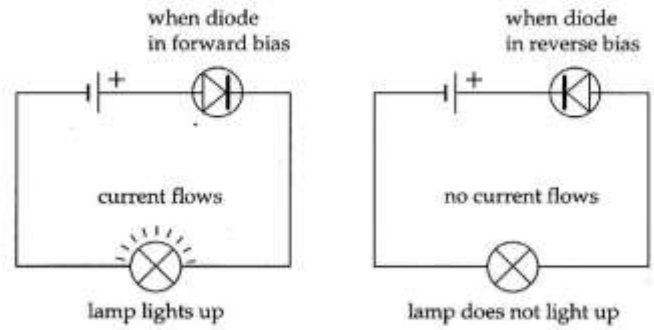
This means that the current, I, is directly proportional to the voltage, V.

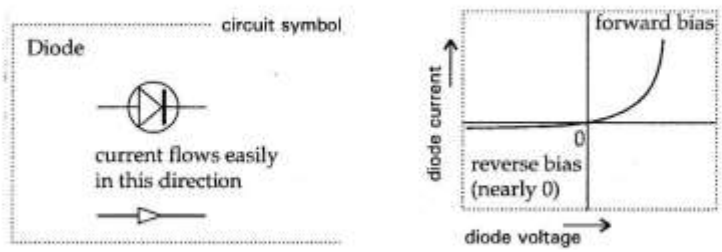
Therefore, the resistance, $R = \frac{V}{I}$ is a constant. $\frac{I}{V} = \frac{1}{R}$ is also a constant.

This is *OHM'S LAW.*

DIODES

- A **diode** allows the electric current to flow only in **one** direction.





- The forward arrow on the diode symbol shows that the diode is **forward biased. The current flows easily.**
- The reverse arrow shows that the diode is **reverse biased. The current is nearly zero.**

RECTIFIER

- In a direct current (d.c) circuit, the current flows in one direction.
- In an alternating current (a.c) circuit, the current can flow in both forward and reversed directions for short periods of time.
- Since a diode only lets current flow in the forward direction and stops all the reverse current, **a.c can be changed into d.c using a diode called a rectifier.**

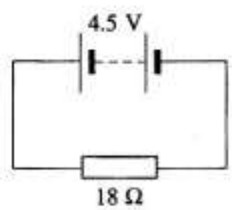
CHALLENGING QUESTIONS - 2

1. A copper wire of length 1.5 m and diameter 1.2×10^{-4} m has a resistance of 2.0 Ω.
Determine the resistances of copper wires
(a) of length 2.5 m and diameter 1.2×10^{-4} m,
(b) of length 1.5 m and diameter 2.4×10^{-4} m. [5]

2. (a) (i) How much energy is transferred by a battery of e.m.f. 4.5 V when 1.0 C of charge passes through it?
(ii) How much power is developed in a battery of e.m.f. 4.5 V when a current of 1.0 A is passing through it? [2]

(b) Figure shows a battery of e.m.f. 4.5 V connected to a resistor of resistance 18 Ω.

Determine, for the resistor,
(i) the voltage across it,
(ii) the current in it. [3]



3. A d.c. supply of 2.0 V is connected across part of a resistance wire. As contact C is moved along the wire, the length l of the wire and the current I through the wire are measured. The voltage across the wire is constant.
The circuit is shown in Fig. 3.1 and the results of the experiment are shown in Fig. 3.2.

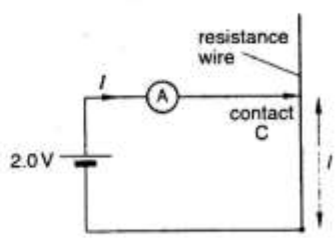
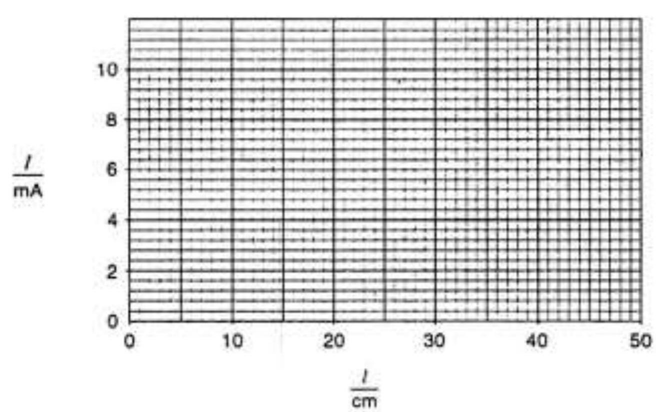


Fig. 3.1

l/cm	I/mA
10.0	8.6
20.0	4.3
30.0	2.9
40.0	2.2

Fig. 3.2

(a) On the axes, plot the data given in Fig. 3.2 and draw a smooth curve through the points. [2]



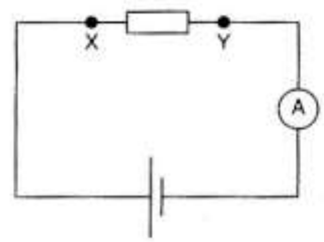
(b) For a length l of wire of 25.0 cm, determine

(i) the value of the current I,

(ii) the resistance of this length of wire. Given your value for the resistance to a sensible number of significant figures. [3]

(c) Determine the resistance of a 25.0 cm sample of wire of the same material as used in (b) but which has ten times the cross-sectional area. [1]

4. Figure shows a circuit set up to test whether electrical resistance changes when temperature rises.



Two components, a length of metal wire and a thermistor, are tested. They are each tested in turn, by placing them between terminals X and Y. As the temperature changes, the current readings on the ammeter are noted. The results are shown in the table.

component under test	current at 0 °C / A	current at 50 °C / A	current at 100 °C / A
metal wire	0.100	0.090	0.080
thermistor	0.002	0.004	0.080

(a) (i) On the figure, draw a voltmeter to show how it is connected to measure the potential difference across XY.

(ii) State how you would use the apparatus to obtain a value for the resistance of the component.

(iii) State whether the resistance of each of the components **increases** or **decreases** as it is heated.

1. metal wire

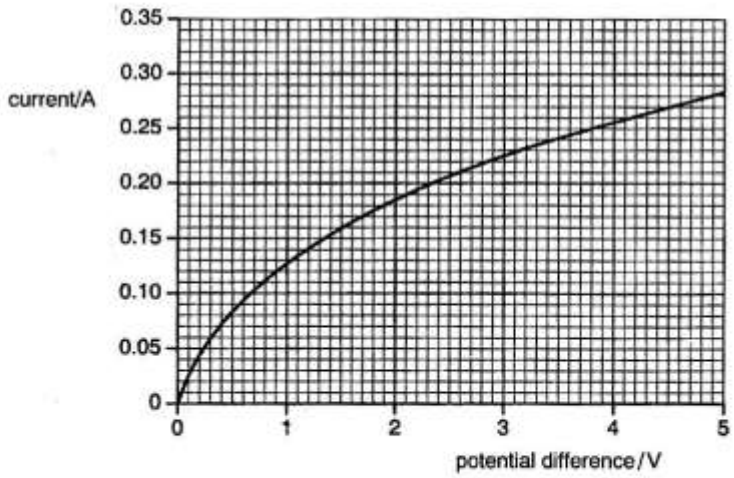
2. thermistor [4]

(b) The current through each component changes with temperature. The current values are used to set up a temperature scale. Each circuit then acts as a thermometer, reading temperatures between 0 °C and 100 °C. Using information from the table, state, giving a reason in each case, which component would make a thermometer with

(i) the greater sensitivity,

(ii) the greater linearity. [2]

5.



The graph shows how the current in the filament of a lamp depends on the potential difference across it.

(a) Calculate the resistance of the filament when the current is 0.25 A. Give your answer to an appropriate number of significant figures. [3]

(b) Explain how the figure shows that the *resistance* of the filament increases with *temperature rise.* [2]

SOLUTIONS

1. (a) $\frac{\text{Resistance of 2.5 m wire}}{\text{Resistance of 1.5 m wire}} = \frac{2.5}{1.5}$

$\text{Resistance of 2.5 m wire} = \frac{2.5}{1.5} \times 2.0$

$= 3.3\Omega$

(b) $\frac{\text{Resistance of thicker wire}}{\text{Resistance of thinner wire}} = \frac{\text{Cross sectional area of thinner wire}}{\text{Cross sectional area of thicker wire}}$

$$\text{Resistance of thicker wire} = \frac{\pi\left(\frac{1.2\times10^{-4}}{2}\right)^2}{\pi\left(\frac{2.4\times10^{-4}}{2}\right)^2} \times 2.0$$

$= 0.5\ \Omega$

(a) For wires of same material and cross-sectional area, their resistances are directly proportional to the length.

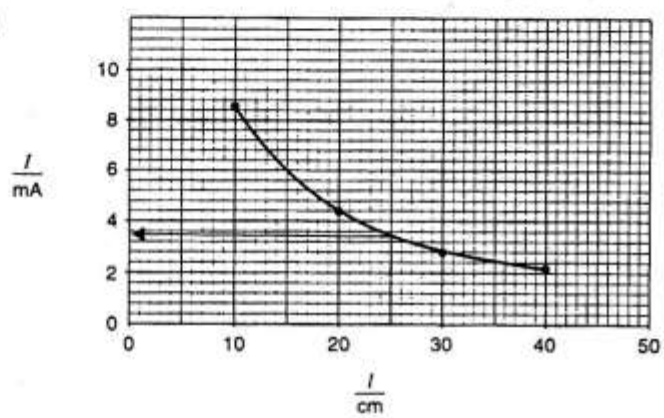
(b) For wires of the same material and length, their resistances are inversely proportional to cross-sectional area but not diameter or radius.

2. (a) (i) $E = QV = (1.0)(4.5) = 4.5\ J$ (ii) $P = IV = (1.0)(4.5) = 4.5\ W$

(b) (i) Voltage = 4.5 V (ii) $I = \frac{V}{R} = \frac{4.5}{18} = 0.25\ A$

(b) (i) Since there is only one resistor in the circuit, the voltage across the resistor must be equal to the e.m.f. of the battery.

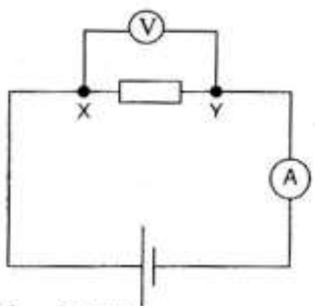
3. (a)



(b) (i) I = 3.5 mA (ii) $R = \frac{V}{I} = \frac{2.0}{3.5\times10^{-3}} = 5.7\times10^2\Omega$

(c) $R = \frac{5.7\times10^2}{10} = 57\Omega$

4. (a) (i)



(ii) Resistance of the component $= \dfrac{\text{Voltmeter reading}}{\text{Ammeter reading}}$

(iii) 1. increase

2. decrease

(b) (i) component: thermistor

reason: a bigger change in current for the entire temperature range

(ii) component: metal wire

reason: change in current is directly proportional to change in temperature

---

(a) (i) Voltmeter must be connected in parallel with the component.

(ii) No explanation needed if you are asked to state something.

(iii) $R = \dfrac{V}{I}$

V is a constant for this case. R increases when I decreases.

(b) (i) A greater sensitivity means a bigger change in current for the same temperature change.

(ii) For every 50 °C increase in temperature, the current is increased by the same amount.

5. (a) Potential difference = 3.8 V

$$R = \frac{V}{I} = \frac{3.8}{0.25} = 15\ \Omega$$

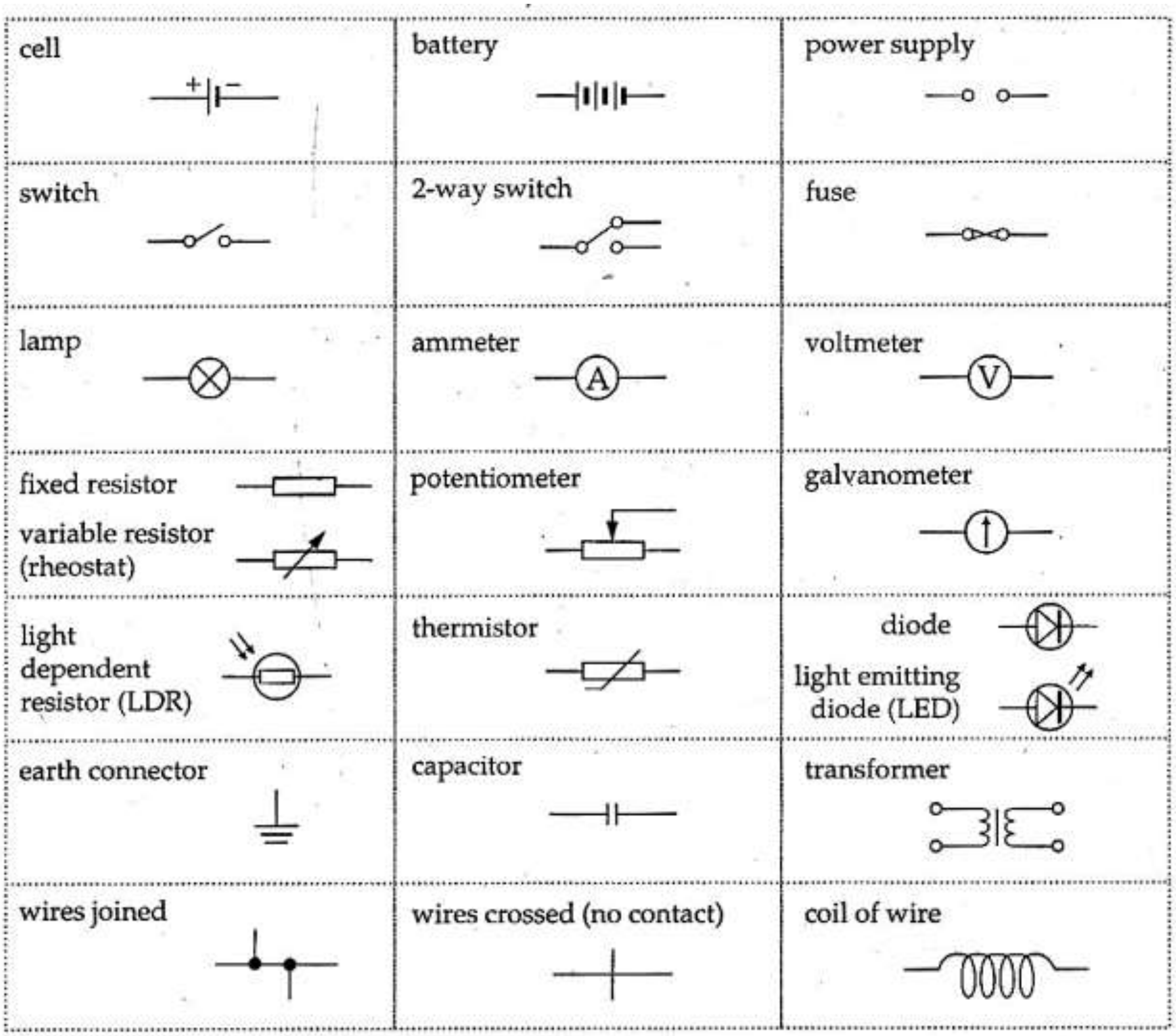
(b) The increase in current decreases for constant increase in potential difference.

(a) The answer is given to 2 sig. fig. since V and I are given to 2 sig. fig.

(b) The increase in current decreases means that the resistance of the filament increases.

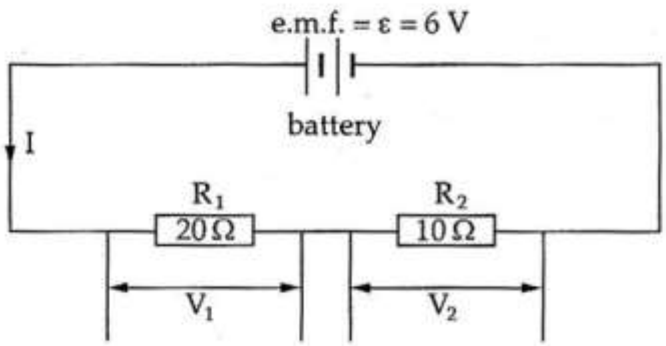
CIRCUITS

CIRCUIT SYMBOLS OF COMPONENTS OF A D.C CIRCUIT



CURRENT AND POTENTIAL DIFFERENCE IN CIRCUITS

I, R, V_1 and V_2 represent the total current, total resistance, voltage across R_1 and voltage across R_2 respectively.



Fact	$\varepsilon = V_1 + V_2 = 6\text{ V}$ $R = R_1 + R_2 = 20 + 10 = 30\,\Omega$ $V_1 = \frac{20}{30} \times 6 = 4\text{ V}$ $V_2 = \frac{10}{30} \times 6 = 2\text{ V}$ $I = \frac{V}{R} = \frac{6}{30} = 0.2\text{ A}$

Fact	**In a SERIES circuit, the higher the resistance of a resistor, the higher the voltage across it.**

If we apply | Equation | $V = IR$ | to the individual resistor R_1 and R_2, then

Fact	$V_1 = IR_1$ $V_2 = IR_2$

The e.m.f., ε, is equal to the total potential difference (V) of the circuit.

Thus we have | Fact | $\varepsilon = IR$ |

Since total resistance $R = R_1 + R_2$, we obtain | Fact | $\varepsilon = I(R_1 + R_2)$ |

Fact	**Total current (I) is the same at every point in a SERIES circuit.** (The number of resistors connected does not matter. Resistors only reduce the size of the current.)

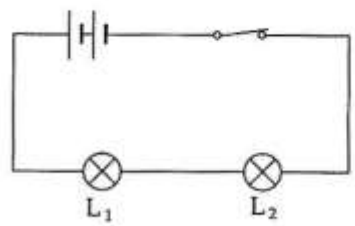
SERIES AND PARALLEL CIRCUITS

SERIES CIRCUITS

Consider a circuit which has two lamps connecting to a cell.

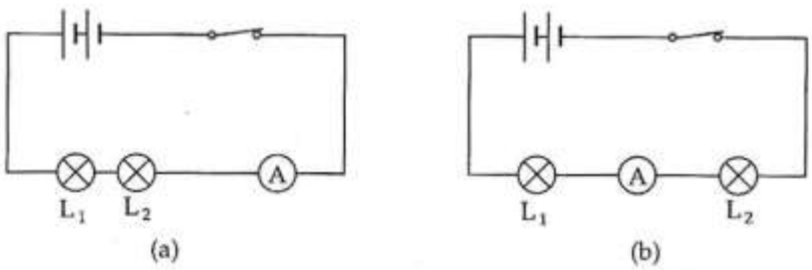
There is only ONE path through which the electric charge can flow. We say that the lamps are connected in SERIES.

If you unscrew one lamp in the circuit, the other lamp will not light up. There is NO current if there is a break anywhere in a SERIES circuit.



Current

Now, we add an ammeter to the above circuit. Move the ammeter to different positions.

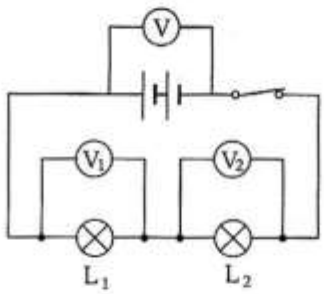


It is noticed that in both cases, the ammeter has the same reading.

Conclusion	**The size of current flow is the SAME throughout the SERIES circuit.**

Potential Difference

Now, we add three voltmeters to the circuit. Voltmeter V shows the potential difference across the battery, while voltmeters V_1 and V_2 show the potential differences across lamps L_1 and L_2 respectively.

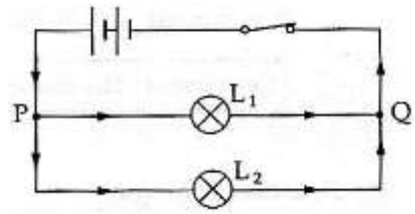


From the readings of the voltmeters, we can draw the conclusion that $V = V_1 + V_2$

Conclusion	**In a SERIES circuit, sum of the potential differences across individual components is equal to the potential difference across the whole circuit.**

PARALLEL CIRCUITS

- There is more than one path for the electric charge to flow. They are connected in parallel.
- If you unscrew one lamp, the other lamp will still light up



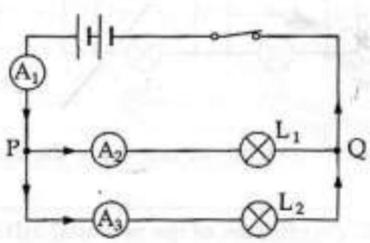
Current

- From the readings of the ammeters, we can draw the conclusion that

$I_1 = I_2 + I_3$

Ammeter A_1 measures the total current of the circuit. Ammeters A_2 and A_3 measure the current through lamps L_1 and L_2 respectively.

When the switch is closed, the current flows through the circuit (A_1 reads I_1) and splits up at junction P (A_2 reads I_2, A_3 reads I_3). The currents join together again at junction Q (A_1 reads I_1).

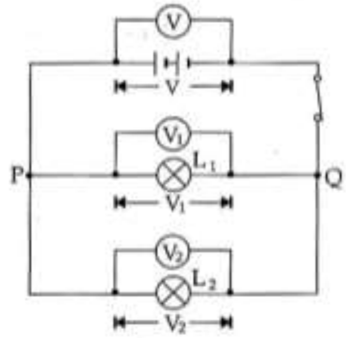


From the readings of the ammeters, we can draw the conclusion that $I_1 = I_2 + I_3$

Conclusion	In a PARALLEL circuit, the current in the main circuit is the sum of the currents in the separate branches.

Potential Difference

Voltmeter V measures the potential difference across the battery while voltmeters V_1 and V_2 measure the potential differences across the lamps L_1 and L_2 respectively.



From the readings of the voltmeters, we can draw the conclusion that $V = V_1 = V_2$

Conclusion	**In a PARALLEL circuit, each component connected (also apply to resistors with different values) has the SAME potential difference across it.**

Example

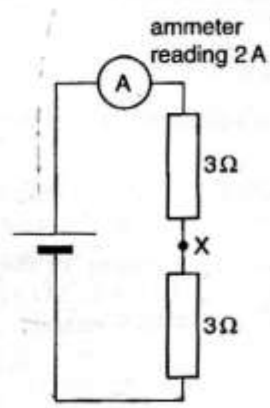
[Q] The diagram shows an electrical circuit.
What is the current at point X?

A 1 A

B 2 A

C 3 A

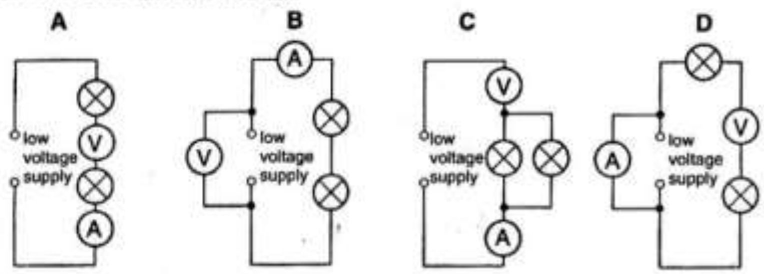
D 4 A



[Ans] **B** Current at point X is same as the ammeter reading 2 A.

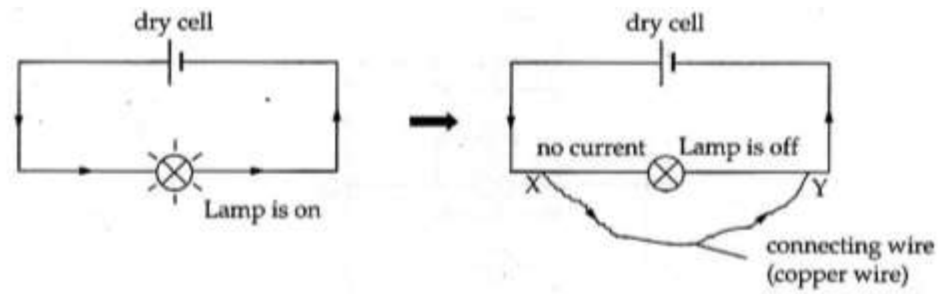
Example

[Q] A circuit contains a low voltage supply in series with 2 bulbs. An ammeter in the circuit measures the current in the bulbs and voltmeter measures the voltage of the supply. Which diagram shows the correct circuit?



[Ans] **B** Voltmeter must be connected in parallel with the power supply and the ammeter must be connected in series with the bulbs.

SHORT CIRCUITS

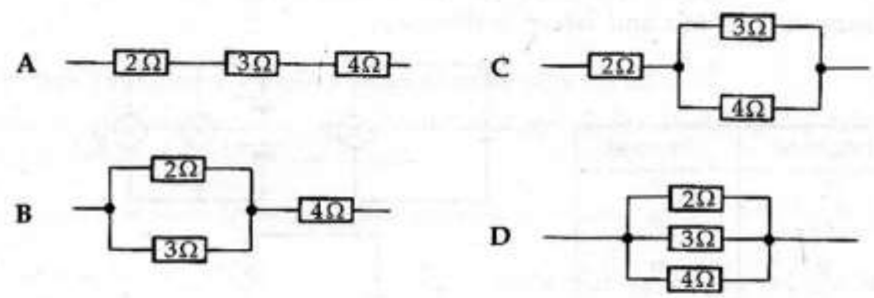


The copper wire has shorted the lamp or caused a SHORT CIRCUIT. The copper wire has less resistance to the flow of electrons than the lamp. So the current flows through the copper wire instead of the lamp.

Take note	Electricity travels by the easiest path, i.e. the one with the ***lowest resistance***, not necessarily the shortest path.

Example

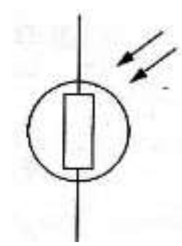
[Q] Which resistor combination has the **lowest** resistance?



[Ans] D A: 9 Ω B: 5.2 Ω C: 3.7 Ω D: 0.92 Ω

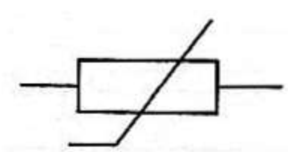
LIGHT DEPENDENT RESISTORS (LDR)

- A light dependent resistor (LDR) has a resistance that varies with the amount of light shining on it.
- **The resistance decreases as the amount of light shining on the LDR increases.**



THERMISTORS

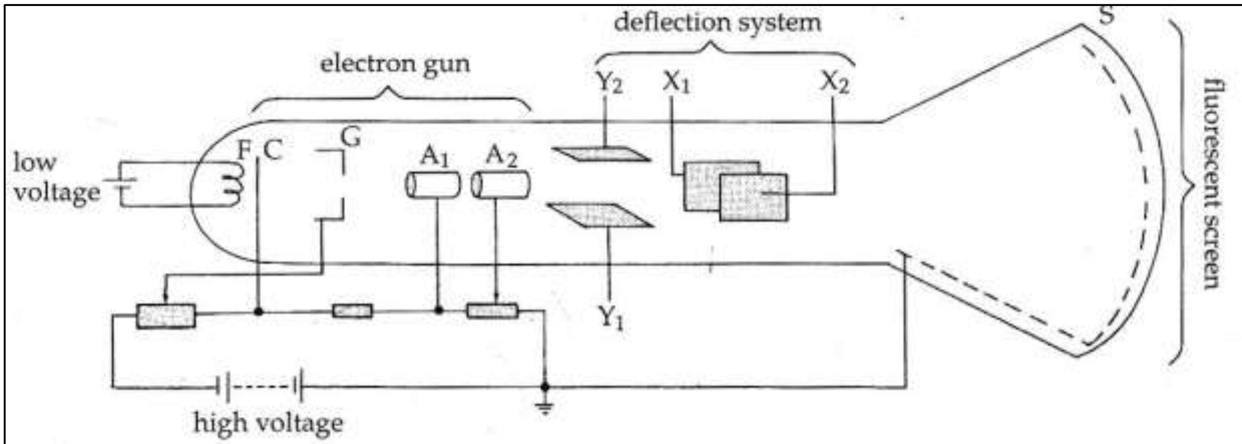
- A thermistor is a device whose resistance is affected by temperature.
- **The resistance of a thermistor decreases with increasing temperature.**



USE OF CATHODE-RAY OSCILLOSCOPE (CRO)

Operating C.R.O

- A CRO makes use of a cathode-ray tube. In it, an electron gun sends electrons through the vacuum to a fluorescent screen and a light spot appears on the screen.

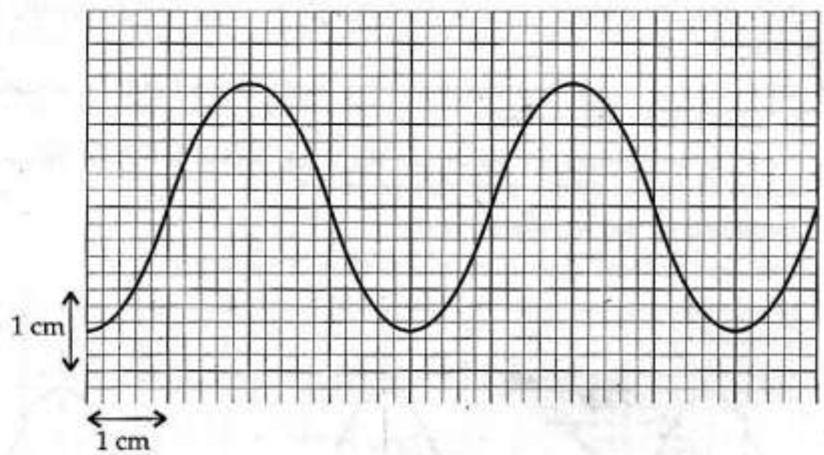


The table summarises the names and functions of different parts of a C.R.O.

Component		Name	Function
electron gun	F	filament	heating up cathode (ready to emit electron beam)
	C	cathode	emitting electrons by thermionic emission
	G	grid	brightness control by controlling amount of electrons passing through it
	A_1, A_2	anode	① focusing of electron beam ② accelerating electron beam
deflection system (Y-plates followed by X-plates)	Y_1, Y_2	*Y-plates* *(Y-gain setting)*	*with Y-gain setting, they deflect electron beam in the vertical direction*
	X_1, X_2	*X-plates* *(Time base setting)*	*with time base setting, they sweep the light spot across the screen horizontally*
fluorescent screen	S	fluorescent screen	display of waveform

Example

[Q] The diagram shows a trace on an oscilloscope set at 5 V/cm on the vertical axis.



What is the maximum value of the potential difference being measured?

A 1.5 V

B 3.0 V

C 7.5 V

D 15 V

[Ans] C Maximum value of the p.d. = peak voltage = 1.5 × 5 = 7.5 V

CHALLENGING QUESTIONS – 3

1. (a) Figure 1.1 shows a d.c. series circuit. The e.m.f. of the battery is 12 V and the maximum resistance of the variable resistor is 75 W.

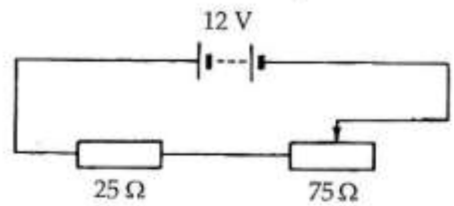


Fig. 1.1

Determine

(i) the minimum possible current through the circuit,

(ii) the maximum possible current through the circuit,

(iii) the minimum possible voltage across the 25 Ω fixed resistor,

(iv) the maximum possible voltage across the 25 Ω fixed resistor,

(v) the maximum power which can be dissipated in the 25 Ω fixed resistor. [8]

(b) The variable resistor of Fig. 1.1 is replaced by a thermistor. The variation of resistance with temperature of the thermistor is given in Fig. 1.2.

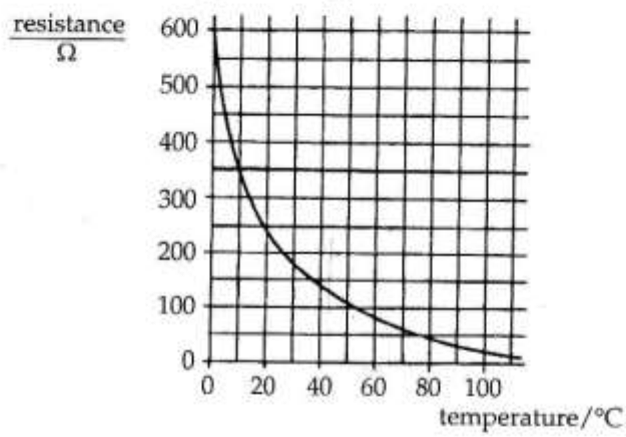


Fig. 1.2

The thermistor is placed first in melting pure ice and then in steam at standard atmospheric pressure. In each case the temperature of the thermistor is allowed to become constant.

(i) What is the resistance of the thermistor at the temperature of melting pure ice?

(ii) What is the resistance of the thermistor at the temperature of the steam?

(iii) At which of these temperatures does the resistance of the thermistor change more rapidly with temperature? Give your reasons for your answer.

(iv) What is the change in voltage across the thermistor as its temperature increases from the ice temperature to the steam temperature? Show your working clearly. [7]

2. The figure shows a circuit consisting of a battery of e.m.f. 6.0 V and two pairs of 3.0 W resistors in series, these pairs of resistors being connected in parallel.

(a) (i) What is the total resistance of the path **KLM**?

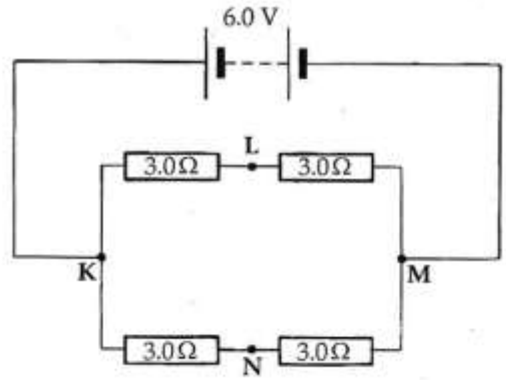
(ii) What is the total resistance of the path **KNM**?

(iii) What is the resistance of the circuit between **K** and **M**?

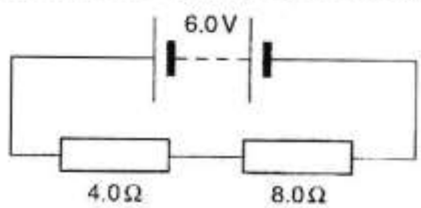
(b) Calculate

(i) the current through the battery,

(ii) the power developed in the battery.



3. The figure shows a battery of e.m.f. 6.0 V in series with resistors of resistance 4.0 Ω and 8.0 Ω.



For the circuit shown in the figure,

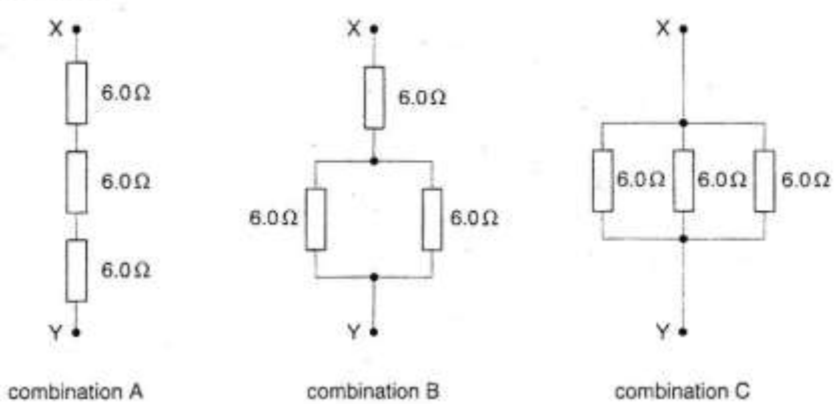
(i) explain what is meant by an 'e.m.f. of 6.0 V',

(ii) calculate the current through the battery,

(iii) calculate the power developed in the battery,

(iv) calculate the voltage across the 4.0 Ω resistor and that across the 8.0 Ω resistor. [8]

4. Fig 4.1 shows three combinations of resistors, connected between points X and Y. All the resistors have resistance 6.0 Ω



(a) Calculate the total resistance between the points X and Y of each combination.

(i) total resistance of combination A

(ii) total resistance of combination B

(iii) total resistance of combination C [4]

(b) Points X and Y in combination B are connected to a battery that provides a potential difference of 1.35 V across XY, as shown in Fig. 4.2. Calculate the currents I_1, I_2 and I_3 in each resistor of the combination. [3]

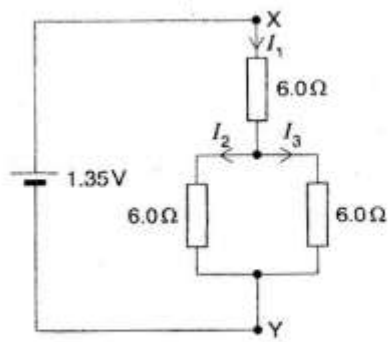
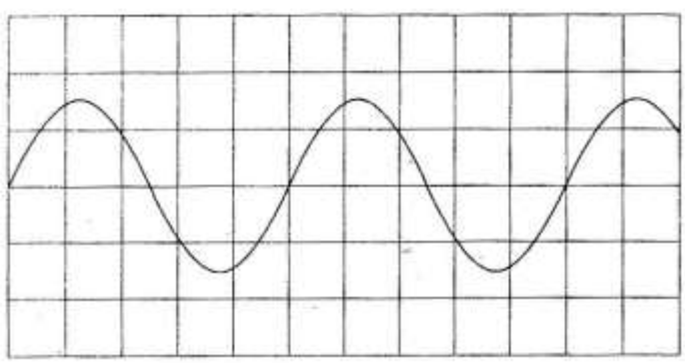


Fig. 4.2

5. The figure shows a trace obtained on an oscilloscope screen.



The time-base is set at 10 ms/cm.

(i) Determine the time for one complete oscillation on the screen.

(ii) Calculate the frequency of the signal applied to the oscilloscope.

(iii) With the same signal applied to the oscilloscope, the time-base setting is altered to 20 ms/cm. State what effect this has on the trace shown on the screen. [5]

6. In Fig. 6.1, a thermistor, T, is connected in series with a 4.0 Ω resistor.

Fig. 6.1

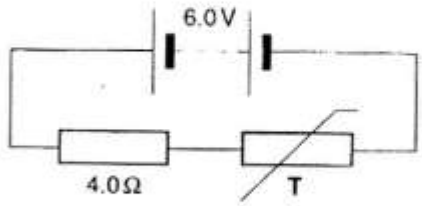
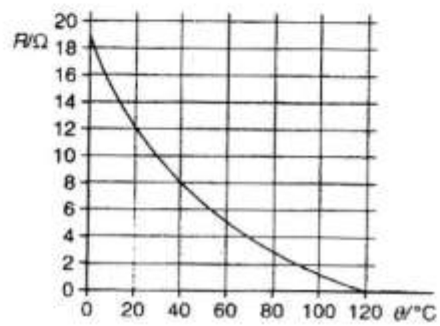


Fig 6.2 shows how the resistance R of the thermistor varies with temperature θ

Fig. 6.2



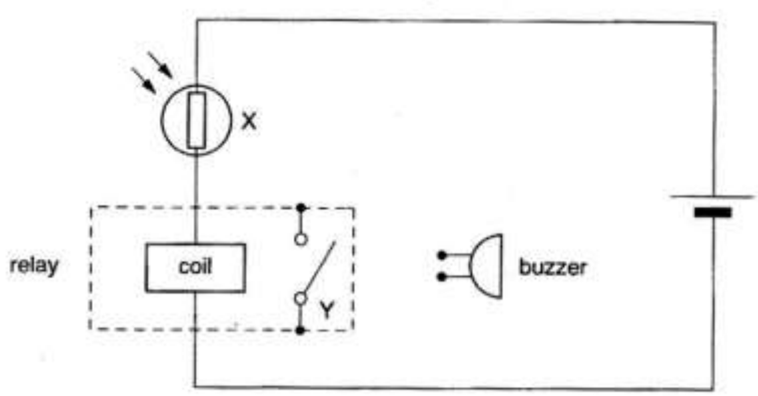
(i) Describe in words the way in which the resistance of the thermistor varies with temperature.

(ii) Determine the resistance of the thermistor when its temperature is 0 °C and when its temperature is 100 °C.

(iii) Determine the maximum power and minimum power developed in the 4.0 Ω resistor when the temperature of the thermistor is allowed to vary between 0 °C and 100 °C. [7]

7. The circuit shown in Fig. 7.1 acts as a light sensitive switch.

Fig. 7.1



The component X is a light dependent resistor (LDR). The connections to the buzzer and to the switch Y inside the relay have not been drawn. Switch Y is shown open in Fig. 7.1.

(i) On Fig. 7.1, draw the connections to the buzzer, the switch Y and the cell that will allow the buzzer to sound when the switch Y inside the relay closes.

(ii) Complete the table below stating

1. whether the resistance of the LDR is high or low in the light and in the dark.
2. whether the current through the relay coil is high or low in the light and in the dark.

	resistance of LDR	current through relay coil	relay switch Y	buzzer
light			closed	ON
dark			open	OFF

[4]

8. A student designs an electrical circuit to turn on a fan motor when the temperature is high. The motor is designed to operate normally from a 12 V supply, and has a resistance of 4.0 Ω.

(a) The student's first design is shown in Fig. 8.1.

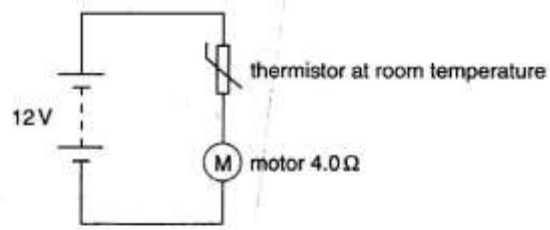


Fig. 8.1

(i) Describe and explain what happens to the current in the circuit when the temperature in the room rises.

(ii) For the thermistor of resistance 500 Ω, calculate

1. the current in the circuit,
2. the potential difference across the motor. [7]

(b) The student then improves the design and uses a relay, as shown in Fig. 8.2.

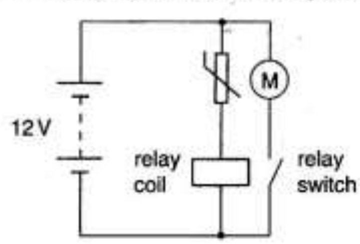


Fig. 8.2

(i) Explain how the motor is made to operate as the temperature rises.

(ii) The relay switches when the current through the coil is 0.10 A and the potential difference across the coil is 2.0 V.

Calculate, for the conditions when the relay switches,

1. the potential difference across the thermistor
2. the resistance of the thermistor. [6]

(c) Explain why the circuit of Fig. 8.2 is better than the circuit of Fig. 8.1. [2]

SOLUTIONS:

1. (a) (i) Minimum possible current $= \dfrac{\text{voltage}}{\text{max. possible total resistance}}$

$$= \frac{12}{25+75}$$

$$= 0.12 \text{ A}$$

(ii) Maximum possible current $= \dfrac{\text{voltage}}{\text{min. possible total resistance}}$

$$= \frac{12}{25+0}$$

$$= 0.48 \text{ A}$$

(iii) Minimum possible voltage across 25 Ω fixed resistor

= minimum possible current × resistance

$= 0.12 \times 25$

$= 3$ V

(iv) Maximum possible voltage across 25 Ω fixed resistor

= maximum possible current × resistance

$= 0.48 \times 25$

$= 12$ V

(v) Maximum power dissipated in the 25 Ω fixed resistor $= \dfrac{V^2 \max}{R} = \dfrac{12^2}{25} = 5.8$ W

(b) (i) 600 Ω (ii) 20 Ω

(iii) The resistance of the thermistor changes more rapidly with temperature at 0 °C because the gradient of the graph at 0 °C is greater than that at 100 °C.

(iv) At 0 °C, voltage across the thermistor $= \dfrac{600}{600+25} \times 12 = 11.52$ V

At 100 °C, voltage across the thermistor $= \dfrac{20}{20+25} \times 12 = 5.33$ V

Hence the change in voltage across the thermistor as the temperature increases from 0 °C to 100 °C is 11.52 V − 5.33 V = 6.2 V (2 s.f.)

2. (a) (i) Total resistance KLM = 3.0 + 3.0 = 6.0 Ω

(ii) Total resistance KNM = 3.0 + 3.0 = 6.0 Ω

(iii) Resistance between K and M $= \frac{6.0 \times 6.0}{6.0 + 6.0} = 3.0\ \Omega$

(b) (i) Current through the battery $= \frac{V}{R} = \frac{6.0}{3.0} = 2.0\ A$

(ii) Power = VI = (6.0)(2.0) = 12 W

(b) (ii) Alternative methods:

Power = $I^2R = 2.0^2 \times 3.0 = 12$ W OR Power $= \frac{V^2}{R} = \frac{6.0^2}{3.0} = 12$ W

3. (i) The battery converts 6 J of chemical energy to electrical energy when one coulomb of charge flows through the battery.

(ii) $I = \frac{V}{R} = \frac{6.0}{4.0 + 8.0} = 0.5\ A$

(iii) P = IV = (0.5)(6.0) = 3.0 W

(iv) $V_{4\Omega}$ = IR = (0.5)(4.0) = 2.0 V

$V_{8\Omega}$ = IR = (0.5)(8.0) = 4.0 V

(a) (i) Students should not mix up e.m.f. with potential difference. For e.m.f., it is the amount of electrical energy gained by 1 coulomb of charge after passing through the battery.

4. (a) (i) R = 6.0 + 6.0 + 6.0 = 18.0 Ω

(ii) $R = 6.0 + \frac{6.0 \times 6.0}{6.0 + 6.0} = 9.0\ \Omega$

(iii) $R = \left(\frac{1}{6.0} + \frac{1}{6.0} + \frac{1}{6.0}\right)^{-1} = 2.0\ \Omega$

(b) I_1 = total current $= \frac{V}{R} = \frac{1.35}{9.0} = 0.15A$

$I_2 = I_3 = \frac{I_1}{2} = 0.075\ A$

(b) The total current I_1 is equal to the sum of currents $(I_2 + I_3)$ from all the paths in parallel. $I_2 = I_3$ because the two resistors are identical (6 Ω).

5. (i) Time for one complete oscillation = 5 × 10 = 50 ms

(ii) Frequency $= \frac{1}{\text{Period}} = \frac{1}{50 \times 10^{-3}} = 20\ \text{Hz}$

(iii) One complete waveform is only 2.5 cm. Twice as many waveforms as before can be seen on the screen.

(i) Time for one complete oscillation = period of the waveform

(ii) Don't forget to convert ms to s. 1 ms = 0.001 s

(iii) Distance for one complete waveform = 50/20 = 2.5 cm. The amplitude of the waveform remains unchanged.

6. (i) The resistance of the thermistor decreases as the temperature increases.

(ii) At 0 °C, resistance is 19 Ω.

At 100 °C, resistance is 1.2 Ω.

(iii) Maximum power is developed in the 4.0 Ω resistor when the resistance of thermistor is 1.2 Ω.

Current of the circuit $= \frac{6}{4.0 + 1.2} = 1.15\ \text{A}$

$P = I^2R = (1.15)^2(4.0) = 5.3\ \text{W}$

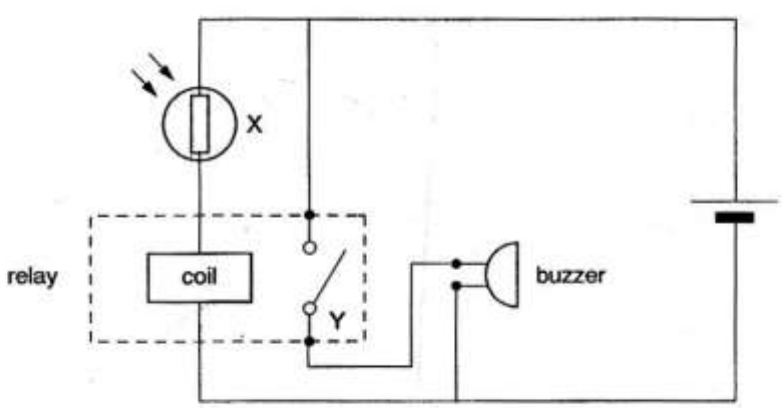
Minimum power is developed in the 4.0 Ω resistor when the resistance of thermistor is 19 Ω.

Current of the circuit $= \frac{6}{4.0 + 19} = 0.26\ \text{A}$

$P = I^2R = (0.26)^2(4.0) = 0.27\ \text{W}$

(iii) The equation I = V/R is used to find the total current of the circuit. This is also the current flowing through the 4.0 Ω resistor. The power developed can then be determined by the equation $P = I^2R$. The power is maximum when the current is maximum. It occurs when the total resistance is lowest. The power is minimum when the current is minimum. It happens when the total resistance is highest.

7. (i)



(ii)

	resistance of LDR	current through relay coil	relay switch Y	buzzer
light	**low**	**high**	closed	ON
dark	**high**	**low**	open	OFF

(i) The buzzer must be connected in series with the switch Y. If they are connected in parallel, the buzzer is always on even when the switch Y is open.

(ii) Switch Y is closed only when there is a bigger current flowing through the coil.

8. (a) (i) As temperature in the room rises, the resistance of the thermistor decreases. The total resistance of the circuit decreases and so the current in the circuit increases.

(ii) 1. $I = \frac{V}{R} = \frac{12}{500 + 4} = 0.024 \text{ A}$

2. $V = IR = (0.024)(4.0) = 0.096 \text{ V}$

(b) (i) When the temperature in the room rises, the resistance of the thermistor decreases. The current flowing through the relay coil increases until the switch is closed and the motor is switched on.

(ii) 1. p.d. across thermistor = $12 - 2 = 10 \text{ V}$

2. $R = \frac{V}{I} = \frac{10}{0.10} = 100 \ \Omega$

(c) The motor is under normal operation in the circuit of Fig. 8.2 because the p.d. across the motor is 12 V which is the operating voltage of the motor. In the circuit of Fig. 8.1, the p.d. across the motor is less than 12 V as it is connected in series with the thermistor.

(a) (i) Total resistance of the circuit is the sum of the two resistances as they are connected in series.

(c) If the motor is operated at a lower power, its turning speed is slower than expected.

INTRODUCTION TO ELECTRONICS

CATHODE RAY OSCILLOSCOPE

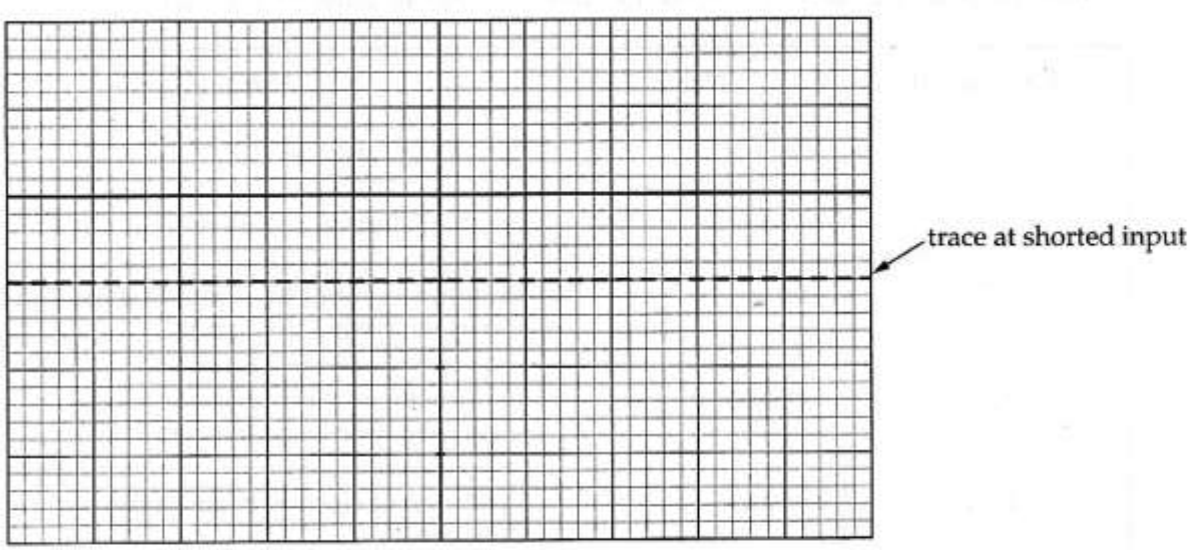
- It can be used for measuring voltages, displaying waveforms and measuring time intervals.

Measuring Voltages, Displaying Waveforms and Measuring Time Intervals

- One division in the C.R.O screen is 1 cm for both vertical and horizontal scales.
- Peak voltage is from the horizontal axis to the peak value.

Measuring Voltages

A C.R.O. shows a trace of a d.c. voltage as in the following diagram. The time base setting is 20 ms/cm and the Y-gain setting is 5 V/cm.



Amplitude of the waveform = 1 cm

The voltage is given by

V = (5)(1) = 5 V

The waveform corresponds to a +5V d.c. input voltage.

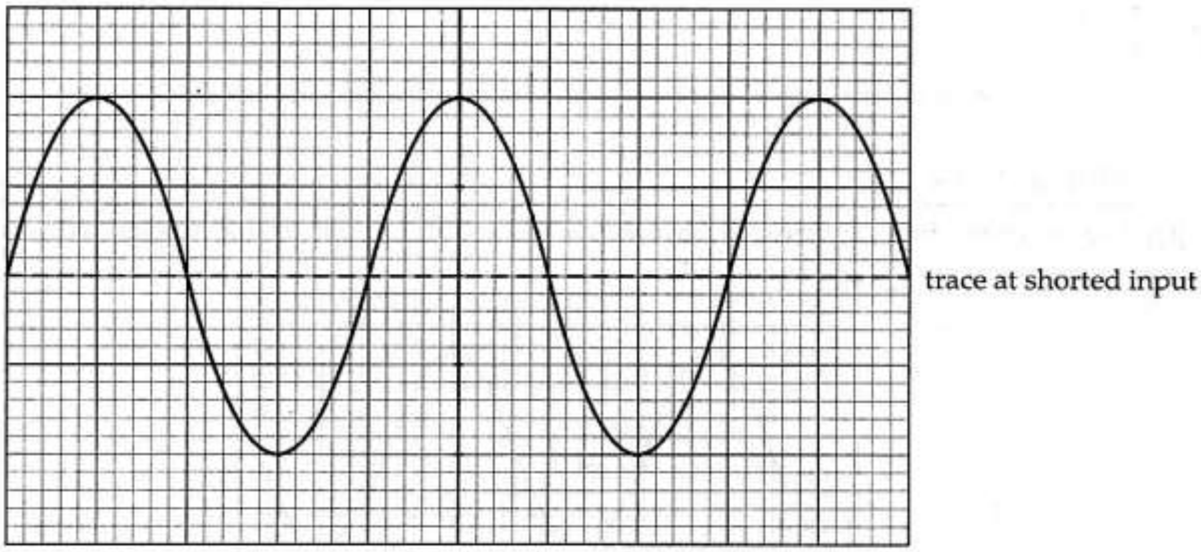
When an a.c. voltage is connected to the Y-gain of the C.R.O., a waveform as shown below is displayed on the screen. The time-base setting is 5ms/cm and the Y-gain setting is 1 V/cm.

Amplitude of the waveform = 2 cm

The peak voltage is given by

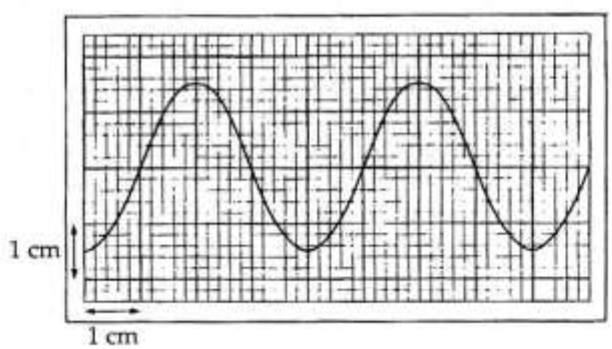
V = (1)(2) = 2 V

The waveform corresponds to an a.c. input with a peak voltage of 2 V.



Example

[Q] The diagram shows a trace on an oscilloscope set at 5 V/cm on the vertical axis.



What is the maximum value of the potential difference being measured? (J95/P1/Q35)

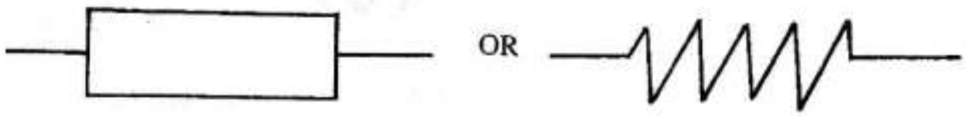
A 1.5 V C 7.5 V

B 3.0 V D 15 V

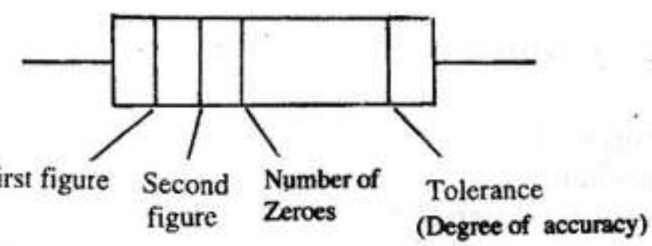
[Ans] C Maximum value of the p.d. = peak voltage = 1.5 × 5 = 7.5 V

ACTION AND USE OF CIRCUIT COMPONENTS

RESISTORS



A colour code facilitates the computation of the resistance of carbon resistors. The bands of colours shown on such resistors represent specific figures.



Carbon resistor

The colour code and tolerance of carbon resistors is shown in Table 8.1 below.

Colour	Figure
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

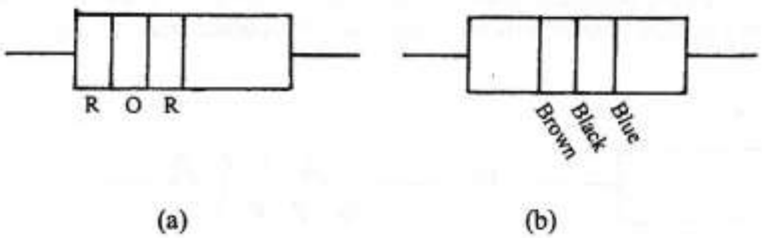
Tolerance

Gold= ±5% accuracy
Silver = ±10% accuracy
No colour =±20% accuracy
Brown = ±1 % accuracy
Red = ± 2% accuracy etc.

Colour code and tolerance

Example

1. Find the resistance of the two resistors (a) and (b) below.



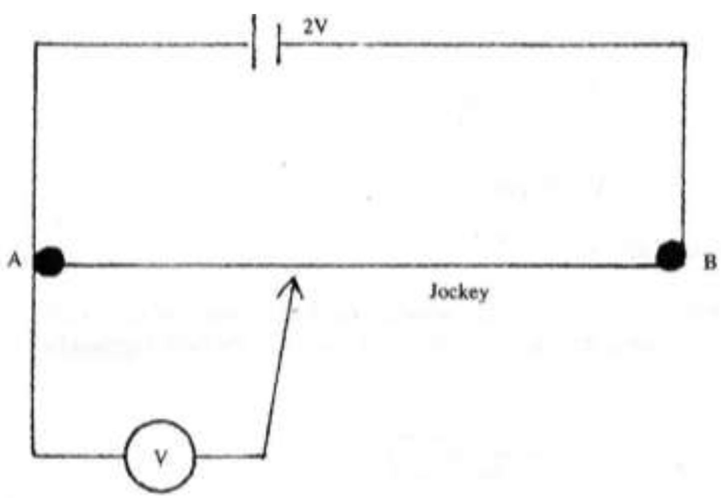
Solution

(a) Since the first line represents the first digit and in this case, it is red, then the first digit is 2. The second line represents the second digit. In this case Orange, then the digit is 3. The third line represents the number of zeroes. In this case it is represented by Red, then we have two zeroes.

The resistance = 23 00 W

POTENTIAL DIVIDER (POTENTIOMETER)

- A potential divider varies the voltage across a device.



The potential difference across each centimeter (1/100 m) length of the resistance wire is 2V/100 = 0.02V. A potential difference of 1V is obtained when the connection is made to the mid-point of the wire (0.02V X 50cm = 1V). The potential difference obtained when the connection is made at 10 cm is 0.2V.

Example

I. In the circuit what would be the voltmeter reading when the jockey is connected 35 cm away from *A*.

Solution

The P.D. across each cm = $\frac{5}{100}$ = 0.05V.

P.D. across 35 cm = 0.05 X 35
= 1.75V

2. Find the distance *X* at which the jockey should be connected from A in order to obtain a potential difference of 9.5V in the circuit.

Solution

P.D across each cm = $\frac{12}{100}$ = 0.12V

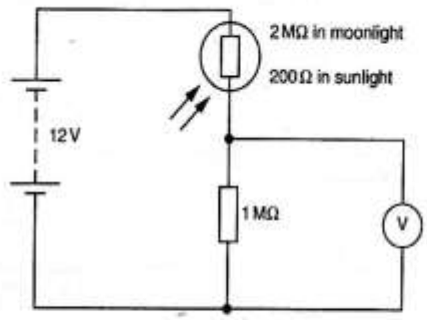
P.D. across *X*= 9.5 V = 0.12 X X
0.12*X*= 9.5

$X = \frac{9.5}{0.12} = \frac{950}{12}$

X = 79 cm

Example

[Q] A circuit with a light-dependent resistor is used to detect changes in light levels. What are the approximate voltmeter readings in moonlight and in sunlight? (N2000/P1/Q35)



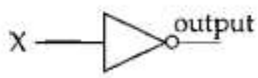
	reading in moonlight / V	reading in sunlight / V
A	4	0
B	4	12
C	8	0
D	8	4

[Ans] **B** In moonlight, reading $= \frac{1}{2+1} \times 12 = 4$ V

In sunlight, reading $= \frac{1}{0.0002+1} \times 12 = 12$ V

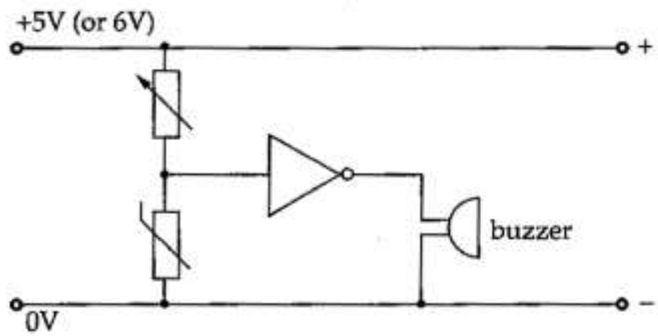
LOGIC GATES AND COMBINATIONS

- When the output is **high,** the output is said be in logical state ‘**1**’**.**
- When the output is **low,** the output is said to be in logical state ‘**0**’.

<table>
<tr><th>Logic gate</th><th>Symbol</th><th>Truth table</th><th>Action of logic gate</th></tr>
<tr><td>NOT</td><td></td><td><table><tr><th>X</th><th>Output</th></tr><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td></tr></table></td><td>The output is high if the input is not high. The output is always the opposite of the input. It is an inverter.</td></tr>
<tr><td>AND</td><td></td><td><table><tr><th>X</th><th>Y</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>The output is high only if input X and input Y are high.</td></tr>
<tr><td>OR</td><td></td><td><table><tr><th>X</th><th>Y</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>The output is high when either X or Y or both are high.</td></tr>
<tr><td>NAND</td><td></td><td><table><tr><th>X</th><th>Y</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td><td>The output is not high only if input X and input Y are high.</td></tr>
<tr><td>NOR</td><td></td><td><table><tr><th>X</th><th>Y</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td><td>The output is not high if either input X or input Y are high.</td></tr>
</table>

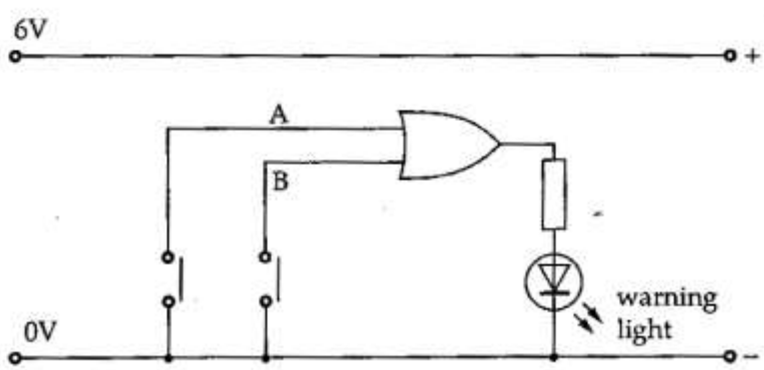
APPLICATIONS OF LOGIC GAETS

Example 1: A simple fire alarm



1. When the thermistor is cold, it has a high resistance and hence the potential difference across it is high.
2. The input to the NOT gate is 1 and the output is 0. The buzzer does not sound.
3. When there is a fire, the temperature of the thermistor increases. Its resistance drops and so does the potential difference across it.
4. The input to the NOT gate is changed to 0 and the output becomes 1. The buzzer sounds.
5. The variable resistor is used to adjust the sensitivity of the alarm.

Example 2: A car door warning signal circuit

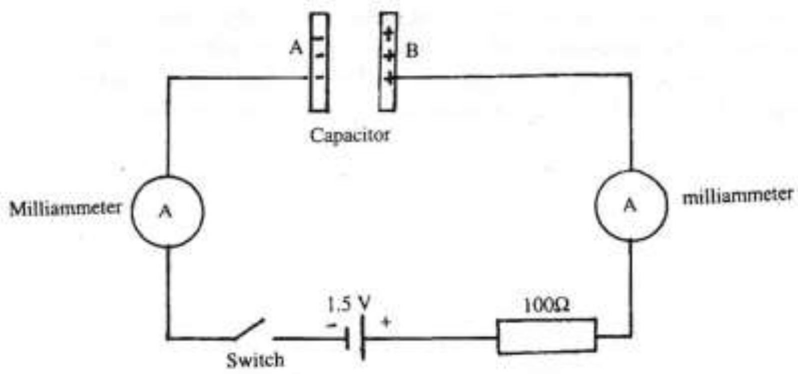


1. By default, any unconnected input is set to 1.
2. When a car door is closed, the corresponding switch is also closed. The input to the NOR gate is changed to 0.
3. If either one of the two doors is not closed, the output of the NOR gate is 1 and the warning light will glow.
4. The warning light will switch off only when both doors are closed. The two inputs of the NOR gate become zero.

CAPACITORS

- It is a device that stores electric charge.
- The unit of capacitance is the **farad (F).** For practical purposes we use the micro farad (**µf**). **1µf = 10 $^{-6}$ F**.
- A capacitor has a capacitance of **1 µf** if it stores an electric charge of **1 micro coulomb.**

Charging a Capacitor



Electrons from the negative terminal of the cell flow to the plate A and give it a negative charge. Those from plate B are attracted to the positive terminal and leave B with a net positive charge. The pointers of the milliammeters are deflected momentarily and then return to zero when the potential difference of the capacitor equals that of cell.

Discharging a Capacitor

If the plates of the capacitor are joined together to form a circuit like the one in Figure 8.7, a current will flow for a short time from plate *A* to *B*. Electrons from the negatively charged plate *A* flow round the circuit to the positively charged plate *B*. The system becomes neutral. When this happens, the capacitor is said to be discharged

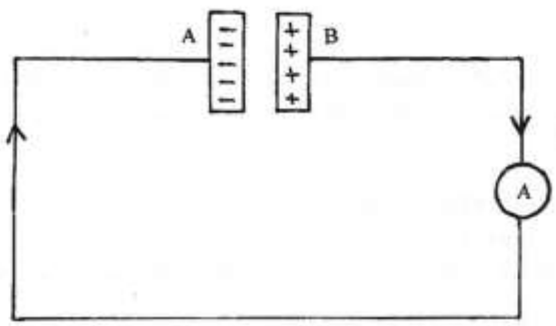


Figure 8.7 Discharging a capacitor

THE REED SWITCH

This switch is operated by a magnet. It consists of two strips of iron, called reeds, sealed in a glass tube. Its contacts may be normally open(NO) or normally closed(NC).

To operate a burglar alarm the magnet and reed switch are positioned as in Figure 8.8. When the door is opened the magnet, which has been holding the NC contacts open, moves away and allows the contacts to close and switch on the alarm.

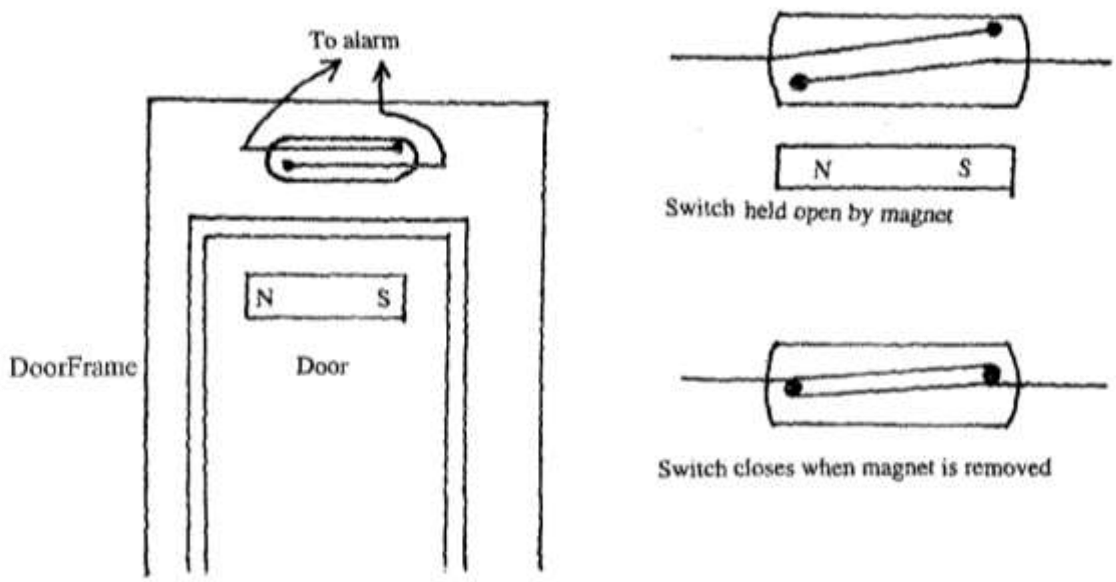
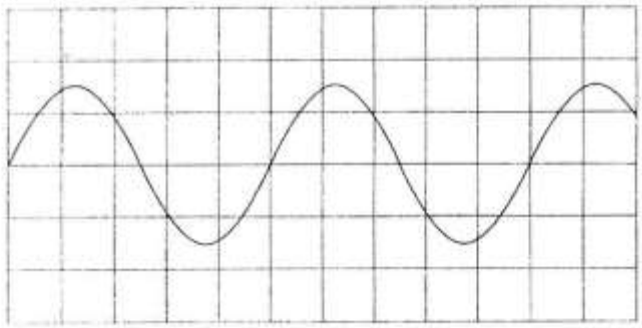


Fig. 8.8 Action of a reed switch.

CHALLENGING QUESTIONS – 4

1. The figure shows a trace obtained on an oscilloscope screen.



The time-base is set at 10 ms/cm.

(i) Determine the time for one complete oscillation on the screen.

(ii) Calculate the frequency of the signal applied to the oscilloscope.

(iii) With the same signal applied to the oscilloscope, the time-base setting is altered to 20 ms/cm. State what effect this has on the trace shown on the screen. [5]

2. In Fig. 2.1, a thermistor, T, is connected in series with a 4.0 Ω resistor.

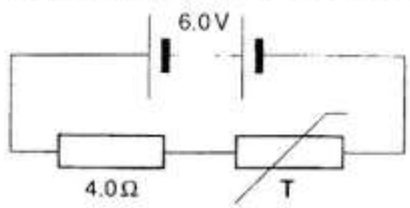


Fig. 2.1

Fig 2.2 shows how the resistance R of the thermistor varies with temperature θ.

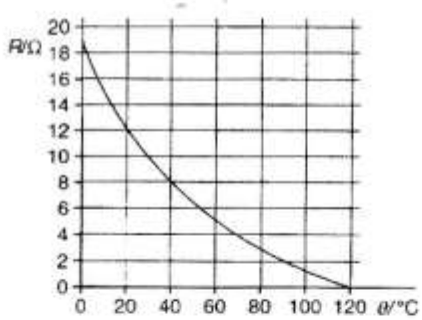


Fig. 2.2

(i) Describe in words the way in which the resistance of the thermistor varies with temperature.

(ii) Determine the resistance of the thermistor when its temperature is 0 °C and when its temperature is 100 °C.

(iii) Determine the maximum power and minimum power developed in the 4.0 Ω resistor when the temperature of the thermistor is allowed to vary between 0 °C and 100 °C. [7]

3. (a) The circuit shown in Fig. 3.1 acts as a light sensitive switch.

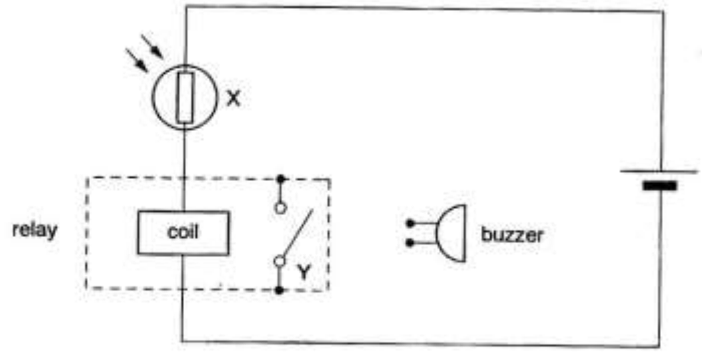


Fig. 3.1

The component X is a light dependent resistor (LDR). The connections to the buzzer and to the switch Y inside the relay have not been drawn. Switch Y is shown open in Fig. 3.1.

(i) On Fig. 3.1, draw the connections to the buzzer, the switch Y and the cell that will allow the buzzer to sound when the switch Y inside the relay closes.

(ii) Complete the table below stating

1. whether the resistance of the LDR is high or low in the light and in the dark.
2. whether the current through the relay coil is high or low in the light and in the dark.

	resistance of LDR	current through relay coil	relay switch Y	buzzer
light			closed	ON
dark			open	OFF

[4]

(b) (i) State the names of the logic gates shown in Fig. 3.2.

Fig. 3.2

(ii) Describe the difference in the action of the two logic gates when HIGH (1) and LOW (0) signals are applied to their inputs. [4]

4. A student designs an electrical circuit to turn on a fan motor when the temperature is high. The motor is designed to operate normally from a 12 V supply, and has a resistance of 4.0 Ω.

(a) The student's first design is shown in Fig. 4.1.

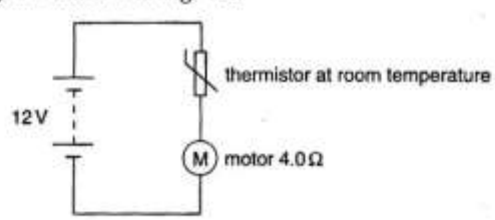


Fig. 4.1

(i) Describe and explain what happens to the current in the circuit when the temperature in the room rises.

(ii) For the thermistor of resistance 500 Ω, calculate

1. the current in the circuit,
2. the potential difference across the motor. [7]

(b) The student then improves the design and uses a relay, as shown in Fig. 4.2.

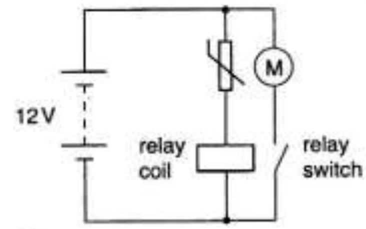


Fig. 4.2

(i) Explain how the motor is made to operate as the temperature rises.

(ii) The relay switches when the current through the coil is 0.10 A and the potential difference across the coil is 2.0 V.

Calculate, for the conditions when the relay switches,

1. the potential difference across the thermistor
2. the resistance of the thermistor. [6]

(c) Explain why the circuit of Fig. 4.2 is better than the circuit of Fig. 4.1.

5. (a) Write out truth tables for

(i) an AND gate,

(ii) an OR gate,

(iii) a NAND gate. [3]

(b) Each of the circuits shown in Fig. 5.1 and in Fig. 5.2 forms a logic gate.

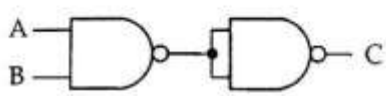


Fig. 5.1

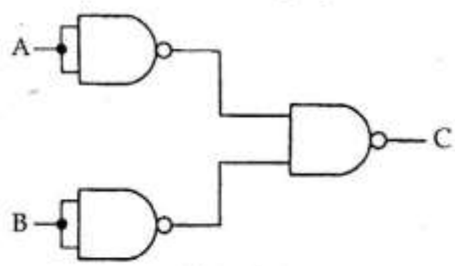


Fig. 5.2

What type of logic gate is formed by the circuit shown in

(i) Fig. 5.1

(ii) Fig. 5.2? [2]

SOLUTIONS:

1. (i) Time for one complete oscillation = 5×10 = 50 ms

(ii) Frequency $= \frac{1}{\text{Period}} = \frac{1}{50 \times 10^{-3}} = 20\text{ Hz}$

(iii) One complete waveform is only 2.5 cm. Twice as many waveforms as before can be seen on the screen.

(i) Time for one complete oscillation = period of the waveform

(ii) Don't forget to convert ms to s. 1 ms = 0.001 s

(iii) Distance for one complete waveform = 50/20 = 2.5 cm. The amplitude of the waveform remains unchanged.

2. (i) The resistance of the thermistor decreases as the temperature increases.

(ii) At 0 °C, resistance is $19\,\Omega$.

At 100 °C, resistance is $1.2\,\Omega$.

(iii) Maximum power is developed in the $4.0\,\Omega$ resistor when the resistance of thermistor is $1.2\,\Omega$.

Current of the circuit $= \frac{6}{4.0 + 1.2} = 1.15\text{ A}$

$P = I^2R = (1.15)^2(4.0) = 5.3\text{ W}$

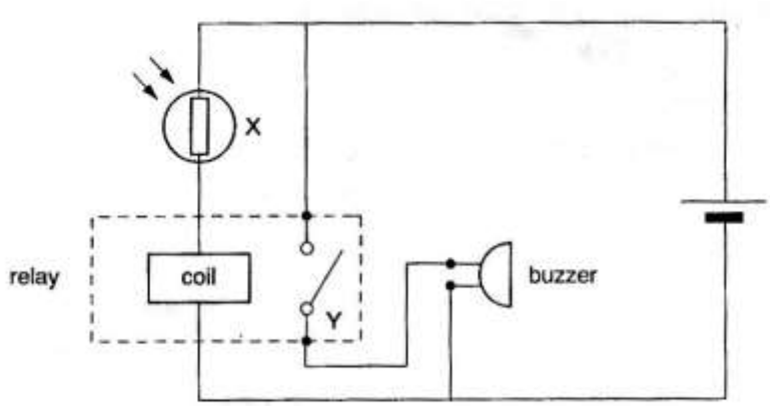
Minimum power is developed in the $4.0\,\Omega$ resistor when the resistance of thermistor is $19\,\Omega$.

Current of the circuit $= \frac{6}{4.0 + 19} = 0.26\text{ A}$

$P = I^2R = (0.26)^2(4.0) = 0.27\text{ W}$

(iii) The equation I = V/R is used to find the total current of the circuit. This is also the current flowing through the 4.0 Ω resistor. The power developed can then be determined by the equation $P = I^2R$. The power is maximum when the current is maximum. It occurs when the total resistance is lowest. The power is minimum when the current is minimum. It happens when the total resistance is highest.

3. (a) (i)



(ii)

	resistance of LDR	current through relay coil	relay switch Y	buzzer
light	**low**	**high**	closed	ON
dark	**high**	**low**	open	OFF

(b) (i) Logic gate A: AND gate

Logic gate B: NAND gate

(ii) The output of the AND gate is 0 whereas the output of the NAND gate is 1. The output from the NAND gate is always opposite to the output from the AND gate.

(a) (i) The buzzer must be connected in series with the switch Y. If they are connected in parallel, the buzzer is always on even when the switch Y is open.

(ii) Switch Y is closed only when there is a bigger current flowing through the coil.

(b) (ii) NAND gate is actually an AND gate + a NOT gate.

4. (a) (i) As temperature in the room rises, the resistance of the thermistor decreases. The total resistance of the circuit decreases and so the current in the circuit increases.

(ii) 1. $I = \frac{V}{R} = \frac{12}{500 + 4} = 0.024\ A$

2. $V = IR = (0.024)(4.0) = 0.096\ V$

(b) (i) When the temperature in the room rises, the resistance of the thermistor decreases. The current flowing through the relay coil increases until the switch is closed and the motor is switched on.

(ii) 1. p.d. across thermistor = $12 - 2 = 10\ V$

2. $R = \frac{V}{I} = \frac{10}{0.10} = 100\ \Omega$

(c) The motor is under normal operation in the circuit of Fig. 4.2 because the p.d. across the motor is 12 V which is the operating voltage of the motor. In the circuit of Fig. 4.1, the p.d. across the motor is less than 12 V as it is connected in series with the thermistor.

(a) (i) Total resistance of the circuit is the sum of the two resistances as they are connected in series.

(c) If the motor is operated at a lower power, its turning speed is slower than expected.

5. (a) (i) AND gate

Input 1	Input 2	Output
0	0	0
0	1	0
1	0	0
1	1	1

(ii) OR gate

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	1

(iii) NAND gate

Input 1	Input 2	Output
0	0	1
0	1	1
1	0	1
1	1	0

(b) (i) Truth table for Fig. 5.1

A	B	Input 1 / 2nd gate	Input 2 / 2nd gate	C
0	0	1	1	0
0	1	1	1	0
1	0	1	1	0
1	1	0	0	1

The logic gate formed by the circuit is AND gate.

(ii) Truth table for Fig. 5.2

A	B	Input 1 / 2nd gate	Input 2 / 2nd gate	C
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

The logic gate formed by the circuit is OR gate.

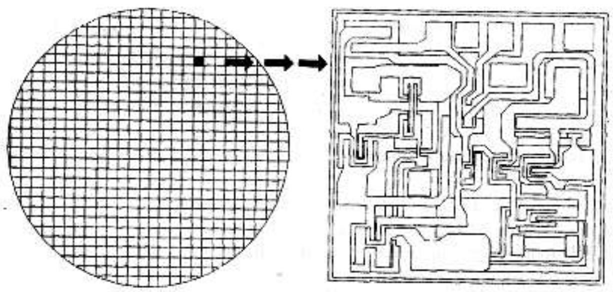
THE TRANSISTOR

SEMI-CONDUCTORS

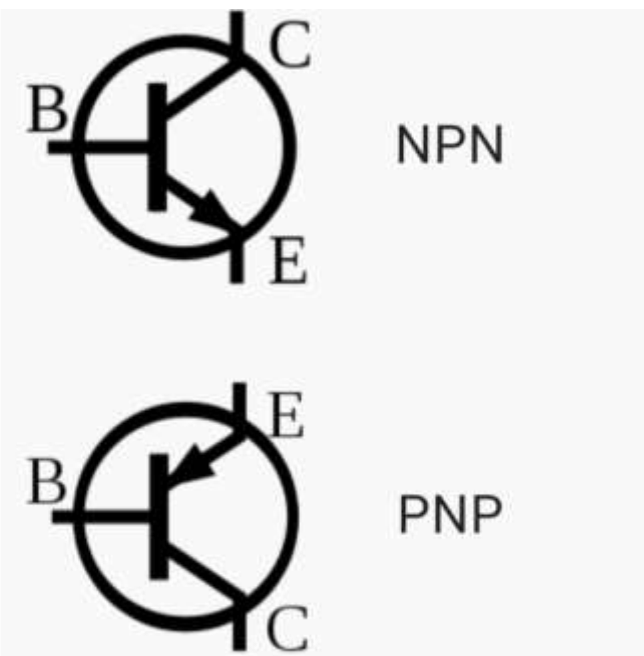
- Semi-conductors are used to make diodes, transistors and other electronic devices.
- They are neither good nor bad conductors.

WHAT IS A TRANSISTOR?

- It is an electronic device that can be used as an automatic switch.



- It has **three parts: the collector, emitter and base.**
- **Types of resistors: npn** and **pnp.** They are shown below.



The arrow shows the direction of the conventional current, which is in the opposite of the flow of electrons.

B = Base

C = Collector

E = Emitter

TRANSISTOR AS A SWITCH

When used as a very sensitive switch, a transistor can be switched on by heat, light or sound if a thermistor, photocell or microphone respectively is used.

An electric current flows from the collector to the emitter and viceversa only if a small current is made to flow through the base. This base current should reach a particular value before it can cause a large current to flow through the emitter-collector junction.

The transistor can also be controlled by varying the base voltage using a potential divider. In Figure 9.2 the voltage across R_2 (base voltage) can be adjusted by varying the resistance of R_2. When it reaches 0.7V for a silicon transistor or 0.3 V for a germanium transistor, the bulb lights.

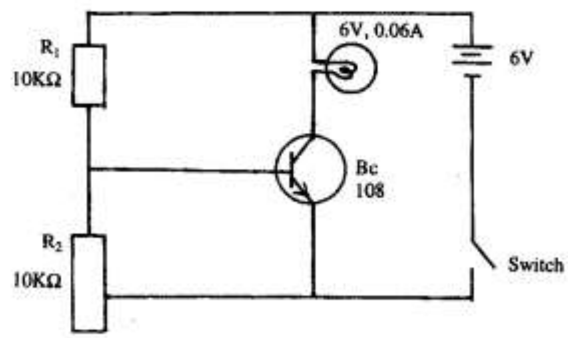


Figure 9.2 Transistor as switch.

LIGHT OPERATED SWITCH

In Figure 9.3 the bulb lights when the LDR is in the dark because of the increase in the resistance of the LDR, which increases the base voltage (p. d. across the LDR) to more than 0.7V. The base current therefore increases and switches the transistor on to light the bulb.

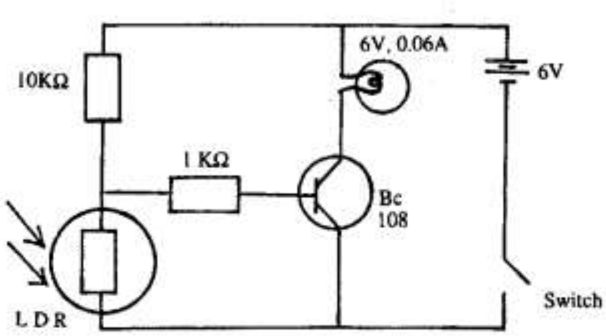


Figure 9.3 Light-operated switch.

HEAT OPERATED SWITCH

In Figure 9.4 the bulb lights the thermistor is heated. As the resistance of the thermistor reduces with heat, the base current increases and switches the transistor on.

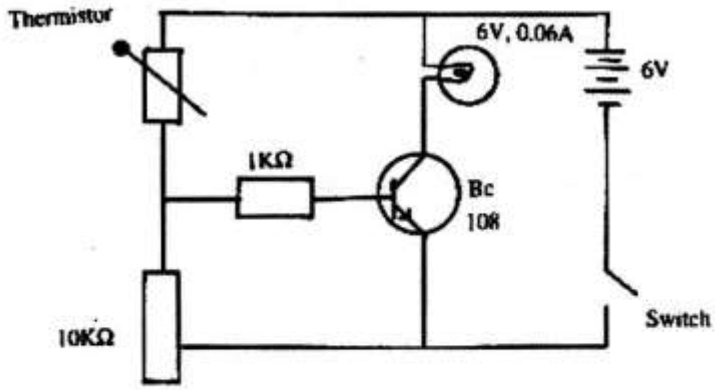
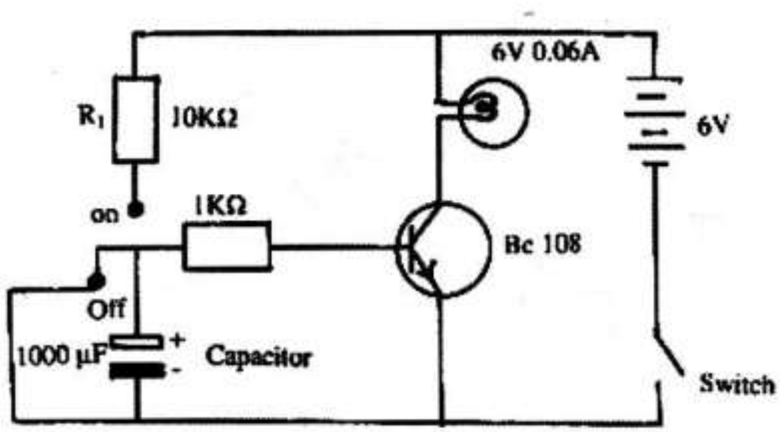


Figure 9.4 Heat-operated switch

TIME SWITCH

Figure 9.5 shows how a capacitor is connected in a time-delay switch. When the switch is in the OFF position a charge capacitor discharges and the variation of the voltage with time is shown in Figure 9.6. When the switch is in the ON position the capacitor is charged and the voltage rises as in Figure 9.7



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