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PREFACE

" The woods are lovely, dark and deep. "
But I have promises to keep, and
miles to go before I sleep
\- Robert Frost

Respected Principals, Correspondents, Head Masters / Head Mistresses, Teachers,

From the bottom of our heart, we at SURA Publications sincerely thank you for the support and patronage that you have extended to us for more than a decade.

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God Bless all.

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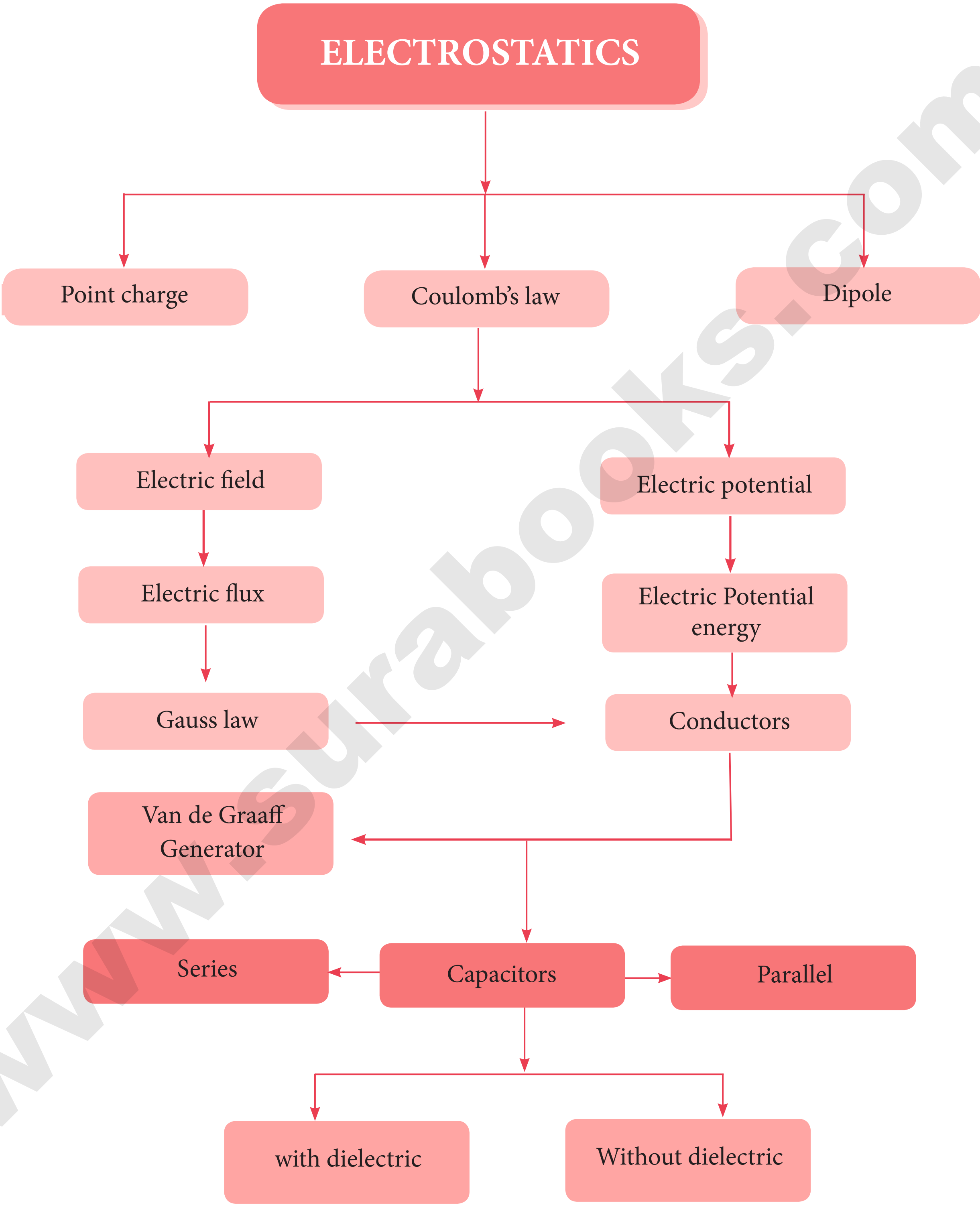
UNIT 1 ELECTROSTATICS

CHAPTER SNAPSHOT

CONCEPT MAP


ELECTROSTATICS
Point charge
Coulomb's law
Dipole
Electric field
Electric potential
Electric flux
Electric Potential energy
Gauss law
Conductors
Van de Graaff Generator
Series
Capacitors
Parallel
with dielectric
Without dielectric

MUST KNOW DEFINITIONS

Electrostatics : Study of electric charges at rest or stationary charged bodies.

Electric charge : A basic property of some substances due to which they can exert a force of electrostatic attraction or repulsion on other charged bodies at a distance.

Frictional electricity :
- **600 B.C.** Thales, a Greek Philosopher - amber with fur - electrification
- **17th century** William Gilbert - glass, ebonite exhibit charging by rubbing.
- **Elektron** (Greek word) - means amber

Positive charge	Negative charge
Glass rod	Silk cloth
Fur cap	Ebonite rod
Woollen cloth	Plastic object

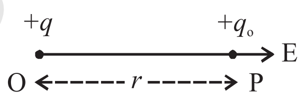
Superposition principle : In an isolated system, the total force on a given charge is the vector sum of the individual forces exerted on it by all other charges, each individual force calculated by Coulomb's law.

$$\vec{F}_1^{tot} = k\left[\frac{q_1q_2}{r_{21}^2}\hat{r}_{21} + \frac{q_1q_3}{r_{31}^2}\hat{r}_{31} + \ldots\ldots + \frac{q_1q_n}{r_{n1}^2}\hat{r}_{nl}\right]$$

Properties of charges :
- Quantisation of charge $q = ne$ [n = 0, ±1, ±2, ±3,....]
- Charges are additive $Q = \Sigma Q_n$
- Conservation of charges Q = Constant

A point charge : The dimension of the charged object is very small and neglected in comparison with the distances involved.

Electric field due to a point charge :



$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

Direction of E is along line joining OP : Points outward for $+q$ at O
Points inward for $-q$ at O

Definition of Coulomb : It is defined as the quantity of charge which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge experiences a repulsive force of 9×10^9 N.

Test charge : A charge which, on introduction in an existing field, does not alter the field.

Electric field : It is the space or the region around the source charge in which the effect of the charge can be felt.

Electric field intensity : Force experienced by a unit positive charge kept at that point in the field.

Charge (q)	Mass(m)
Can be zero, +ve or –ve	Can never be zero, only +ve
Force between two charges can be positive or negative	Force between any two masses is always attractive in nature
Value of constant depends upon $\varepsilon, \varepsilon_r, \varepsilon_0$	Value of constant G is always fixed.

FORMULAE

(1) Electrostatic force between charges q_1 and q_2, F = $\vec{F}_{12} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}$

(2) Value of $k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

(3) Value of $\varepsilon = 8.854 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$

(5) Total charge $q = n \times e$; Number of electrons × Charge of an electron

(6) Components of force F, $F_1 = F\cos\theta$; $F_2 = F\sin\theta$; $|F| = \sqrt{F_1^2 + F_2^2}$

(7) Relative permittivity or Dielectric constant $\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$

(8) Force between charges in medium $F_m = \frac{F_{air}}{\varepsilon_r}$

(9) Electrostatic field, $E = \frac{\text{force}}{\text{charge}} = \frac{F}{q} \Rightarrow F = qE$

(10) Electric field due to a point charge $E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r}$

(11) Electric dipole moment, $\vec{p} = q \times 2a\,\hat{i}$

(12) (i) Electric field due to a dipole at a point on the axial line, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ $(r >> a)$

(ii) Electric field due to a dipole at a point on the equatorial line $E = \vec{E}_{tot} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$ $(r >> a)$

(13) Magnitude of torque $\tau = \vec{p} \times \vec{E} = pE\sin\theta$ $(p = q\,2a)$

(14) Electric potential at a point due to a point charge, $V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$

(15) Electric potential energy of dipole $U = -pE\cos\theta = -\vec{p}.\vec{E}$

(16) Electric potential at a point due to an electric dipole $V = \frac{p}{4\pi\varepsilon_o}\frac{\cos\theta}{r^2}$

(17) Electric flux $= \frac{q}{\varepsilon_o} \Rightarrow \phi_E = \vec{E}.\vec{A} = EA\cos\theta$

(18) Electric field due to infinite long straight charged wire, $E = \frac{\lambda}{2\pi\varepsilon_o r}$

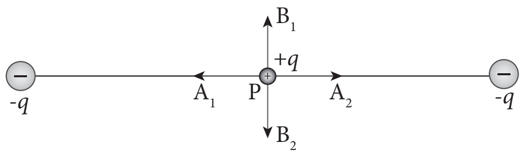
(19) Electric field due to plane sheet of charge $E = \frac{\sigma}{2\varepsilon_o} = \frac{q}{A}\frac{1}{2\varepsilon_o}$ Vector form, $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

Unit 1

EVALUATION

I. MULTIPLE CHOICE QUESTIONS :

1. Two identical point charges of magnitude $-q$ are fixed as shown in the figure below. A third charge $+q$ is placed midway between the two charges at the point P. Suppose this charge $+q$ is displaced a small distance from the point P in the directions indicated by the arrows, in which direction(s) will $+q$ be stable with respect to the displacement?



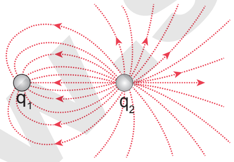
(a) A_1 and A_2 (b) B_1 and B_2
(c) both directions (d) No stable

[**Ans.** (b) B_1 and B_2]

2. Which charge configuration produces a uniform electric field? *[HY-2019;Aug-2021;FRT-'22]*
(a) point Charge
(b) uniformly charged infinite line
(c) uniformly charged infinite plane
(d) uniformly charged spherical shell

[**Ans.** (c) uniformly charged infinite plane]

3. What is the ratio of the charges $\left|\frac{q_1}{q_2}\right|$ for the following electric field line pattern?



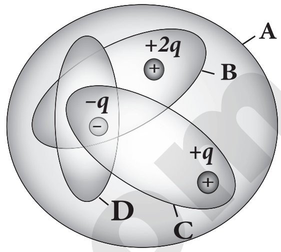
(a) $\frac{1}{5}$ (b) $\frac{25}{11}$ (c) 5 (d) $\frac{11}{25}$

[**Ans.** (d) $\frac{11}{25}$]

4. An electric dipole is placed at an alignment angle of 30° with an electric field of 2×10^5 N C^{-1}. It experiences a torque equal to 8 N m. The charge on the dipole if the dipole length is 1 cm is *[QY-2019; July-'22]*
(a) 4 mC (b) 8 mC
(c) 5 mC (d) 7 mC

[**Ans.** (b) 8 mC]

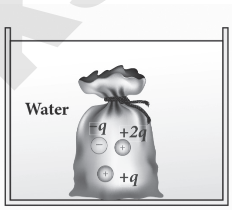
5. Four Gaussian surfaces are given below with charges inside each Gaussian surface. Rank the electric flux through each Gaussian surface in increasing order.



(a) D < C < B < A (b) A < B = C < D
(c) C < A = B < D (d) D > C > B > A

[**Ans.** (a) D < C < B <A]

6. The total electric flux for the following closed surface which is kept inside water



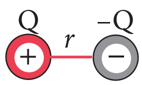
(a) $\frac{80q}{\varepsilon_o}$ (b) $\frac{q}{40\varepsilon_o}$
(c) $\frac{q}{80\varepsilon_o}$ (d) $\frac{q}{160\varepsilon_o}$

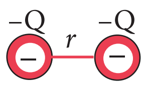
[**Ans.** (b) $\frac{q}{40\varepsilon_o}$]

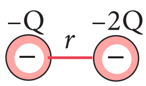
7. Two identical conducting balls having positive charges q_1 and q_2 are separated by a center to center distance r. If they are made to touch each other and then separated to the same distance, the force between them will be *(NSEP 04-05)* *[Sep-2020; FRT-'22]*
(a) less than before (b) same as before
(c) more than before (d) zero

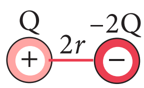
[**Ans.** (c) more than before]

8. Rank the electrostatic potential energies for the given system of charges in increasing order. *[PTA-4]*

(a) 

(b) 

(c) 

(d) 

(a) 1 = 4 < 2 < 3 (b) 2 = 4 < 3 < 1
(c) 2 = 3 < 1 < 4 (d) 3 < 1 < 2 < 4

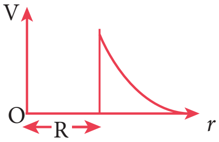
[**Ans.** (a) 1 = 4 < 2 < 3]

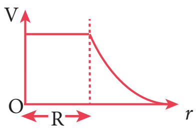
9. An electric field $\vec{E} = 10x\hat{i}$ exists in a certain region of space. Then the potential difference $V = V_0 - V_A$, where V_0 is the potential at the origin and V_A is the potential at $x = 2$ m is:

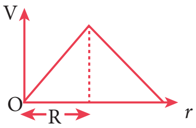
(a) 10 V (b) – 20 V
(c) +20 V (d) –10 V

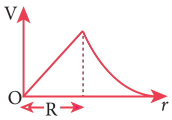
[Ans. (c) +20 V]

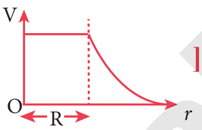
10. A thin conducting spherical shell of radius R has a charge Q which is uniformly distributed on its surface. The correct plot for electrostatic potential due to this spherical shell is *[PTA-1]*

(a) 

(b) 

(c) 

(d) 

[Ans. (b) 

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11. Two points A and B are maintained at a potential of 7 V and –4 V respectively. The work done in moving 50 electrons from A to B is

(a) 8.80×10^{-17} J (b) -8.80×10^{-17} J
(c) 4.40×10^{-17} J (d) 5.80×10^{-17} J

[Ans. (a) 8.80×10^{-17} J]

12. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion. *[Govt. MQP-2019; Mar-2020]*

(a) Q remains the same, C is doubled
(b) Q is doubled, C doubled
(c) C remains same, Q doubled
(d) Both Q and C remain same

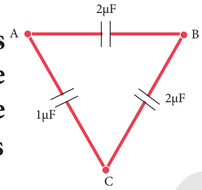
[Ans. (c) C remains same, Q doubled]

13. A parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the parallel plate capacitor and the distance between the plates are each doubled then which is the quantity that will change? *[QY-2019; Sep-2020; FRT-'22]*

(a) Capacitance (b) Charge
(c) Voltage (d) Energy density

[Ans. (d) Energy density]

14. Three capacitors are connected in triangle as shown in the figure. The equivalent capacitance between the points A and C is



(a) 1μF
(b) 2 μF
(c) 3 μF
(d) $\frac{1}{4}$μF

[Ans. (b) 2 μF]

15. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2} C and 5×10^{-2} C respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is *(AIIPMT -2012; May-2022)*

(a) 3×10^{-2} C (b) 4×10^{-2} C
(c) 1×10^{-2} C (d) 2×10^{-2} C

[Ans. (a) 3×10^{-2} C]

II. Short Answer Questions :

1. **What is meant by quantisation of charges?**

Ans. (i) The charge q on any object is equal to an integral multiple of the fundamental unit of charge e.

$$q = ne$$

(ii) Where n is any integer (0, ±1, ±2, ±3, ±4..........). This is called quantisation of electric charge.

2. **Write down Coulomb's law in vector form and mention what each term represents.**

Ans. (i) According to Coulomb, the force on the point charge q_2 exerted by another point charge q_1 is

$$\vec{F}_{21} = k\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

where $\hat{r}_{12}$ is the unit vector directed from charge q_1 to charge q_2 and k is the proportionality constant.

(ii) Also $k = \frac{1}{4\pi\varepsilon_0}$ and its value is $k = 9\times10^9 \text{Nm}^2\text{C}^{-2}$. Here ε_0 is the permittivity of free space or vacuum and its value is

$$\varepsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$$

3. What are the differences between Coulomb force and gravitational force? *[QY; HY - 2019]*

Ans.

S. No	Coulomb	Gravitational
i)	It may be attractive or repulsive.	It is always attractive in nature.
ii)	It depends upon medium	It does not depend upon the medium
iii)	It is always greater in magnitude because of high value of $K = 9 \times 10^9$ Nm² C⁻²	It is lesser than coulomb force because value of G is 6.67×10^{-11} Nm² kg⁻²
iv)	The force between the charges will not be same during motion or rest.	It is always same whether the two masses are rest or motion

4. Write a short note on superposition principle.

Ans. According to this superposition principle, the total force acting on a given charge is equal to the vector sum of forces exerted on it by all the other charges.

Consider a system of n charges, namely q_1, q_2, q_3....q_n. The force on q_1 exerted by the charge q_2

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}$$

The force on q_1 exerted by the charge q_3 is

$$\vec{F}_{13} = k\frac{q_1 q_2}{r_{31}^2}\hat{r}_{31}$$

The total force acting on the charge q_1 due to all other charges is given by

$$\vec{F}_1^{tot} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + ...\vec{F}_{1n}$$

$$\vec{F}_1^{tot} = k\left\{\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21} + \frac{q_1 q_3}{r_{31}^2}\hat{r}_{31} + \frac{q_1 q_4}{r_{41}^2}\hat{r}_{41} + ... \right.$$
$$\left. .... + \frac{q_1 q_n}{r_{n1}^2}\hat{r}_{n1}\right\}$$

5. Define 'electric field'.

Ans. (i) The electric field at the point P at a distance r from the point charge q is the force experienced by a unit charge and is given by

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

(ii) Here $\hat{r}$ is the unit vector pointing from q to the point of interest P.

(iii) The electric field is a vector quantity.

(iv) SI unit is Newton per Coulomb (NC^{-1}).

6. What is mean by 'electric field lines'?

Ans. Electric field vectors are visualized by the concept of electric field lines. They form a set of continuous lines which are the visual representation of the electric field in some region of space.

7. The electric field lines never intersect. Justify. *[PTA-4]*

Ans. If some charge is placed in the intersection point, then it has to move in two different directions at the same time, which is physically impossible. Hence, electric field lines do not intersect.

8. Define 'electric dipole'. Give the expression for the magnitude of its electric dipole moment and the direction. *[PTA-5]*

Ans. (i) Two equal and opposite charges separated by a small distance constitute an electric dipole.

(ii) The magnitude of the electric dipole moment is equal to the product of magnitude of one of the charges and the distance between them.

$|\vec{p}| = 2qa$ and it is directed from $-q$ to $+q$

9. Write the general definition of electric dipole moment for a collection of point charge.

Ans. The electric dipole moment for a collection of 'n' point charges is given by, $\vec{P} = \sum_{i=1}^{n} q_i \vec{r}_i$

where $\vec{r}_i$ is the position vector of charge q_i from the origin.

10. Define 'electrostatic potential'. *[PTA-6; Aug-2021]*

Ans. The electric potential at a point P is equal to the work done by an external force to bring a unit positive charge with constant velocity from infinity to the point P in the region of the external electric field $\vec{E}$.

11. What is an equipotential surface?

Ans. An equipotential surface is a surface on which all the points are at the same electric potential.

12. What are the properties of an equipotential surface?

Ans. (i) The work done to move a charge q between any two points A and B, $W = q (V_B - V_A)$.

(ii) If the points A and B lie on the same equipotential surface, work done is zero because $V_A = V_B$.

(iii) The electric field is normal to an equipotential surface. If it is not normal, then there is a component of the field parallel to the surface.

13. Give the relation between electric field and electric potential. *[PTA-6]*

Ans. Consider a positive charge q kept fixed at the origin. To move a unit positive charge by a small distance dx towards q in the electric field E, the work done is given by $dW = -E\,dx$. The minus sign implies that work is done against the electric field. This work done is equal to electric potential difference. Therefore,

$$dW = dV$$

$$\text{(or)} \quad dV = -E\,dx$$

$$\text{Hence } E = -\frac{dV}{dx}$$

The electric field is the negative gradient of the electric potential.

14. Define 'electrostatic potential energy'.

Ans. Electric potential energy is defined as the work done in bringing the various charges to their respective positions from infinitely large mutual separation.

15. Define 'electric flux'

Ans. (i) The number of electric field lines crossing a given area kept normal to the electric field lines is called electric flux.

(ii) It is a scalar quantity

(iii) Its unit is Nm^2C^{-1}

16. What is meant by electrostatic energy density?

Ans. The energy stored per unit volume of space is defined as energy density $u_E = \frac{U}{\text{Volume}}$. From equation $u_E = \frac{1}{2}\varepsilon_0 E^2$.

17. Write a short note on 'electrostatic shielding'.

Ans. (i) Consider a cavity inside the conductor. Whatever be the charges at the surfaces and whatever be the electrical disturbances outside, the electric field inside the cavity is zero.

(ii) A sensitive electrical instrument which is to be protected from external electrical disturbance can be kept inside this cavity. This is called electrostatic shielding.

18. What is Polarisation?

Ans. (i) Polarisation $\vec{p}$ is defined as the total dipole moment per unit volume of the dielectric.

$$\vec{p} = \chi_e \vec{E}_{ext}$$

(ii) χ_e = electric susceptibility.

19. What is dielectric strength?

Ans. The maximum electric field the dielectric can withstand before it breakdowns is called dielectric strength.

20. Define 'capacitance'. Give its unit.

Ans. (i) The capacitance C of a capacitor is defined as ratio of the magnitude of charge on either of the conductor plates to the potential difference existing between them.

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

(ii) The SI unit of capacitance is coulomb per volt or farad.

21. What is Corona discharge? *[Mar-2020; May-2022]*

Ans. (i) The electric field near the edge is very high and it ionizes the surrounding air.

(ii) The positive ions are repelled at the sharp edge and negative ions are attracted towards the sharper edge.

(iv) This reduces the total charge of the conductor near the sharp edge. This is called action of points or corona discharge.

III. Long Answer Questions :

1. Discuss the basic properties of electric charges.

Ans. (i) **Electric charge :**

(i) Most objects in the universe are made up of atoms, which in turn are made up of protons, neutrons and electrons.

(ii) These particles have mass, an inherent property of particles. Similarly, the electric charge is another intrinsic and fundamental property of particles.

(iii) The SI unit of charge is coulomb.

(iii) –Q are transferred from negative terminal to the right plate of C_3 which pushes the electrons of same amount –Q from left plate of C_3 to the right plate of C_2 due to electrostatic induction. At the same time, electrons of charge –Q are transferred from left plate of C_1 to positive terminal of the battery.

(iv) The capacitances of the capacitors are in general different, so that the voltage across each capacitor is also different and are denoted as V_1, V_2 and V_3 respectively. The sum of the voltages across the capacitor must be equal to the voltage of the battery.

$$V = V_1 + V_2 + V_3 \quad ...... (1)$$

$$\text{Since } Q = CV; \; V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$= Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \quad ...... (2)$$

(v) If three capacitors in series are considered to form an equivalent single capacitor C_s shown in Figure (b), then we have $V = \frac{Q}{C_s}$ Substituting this expression into equation (2), we get

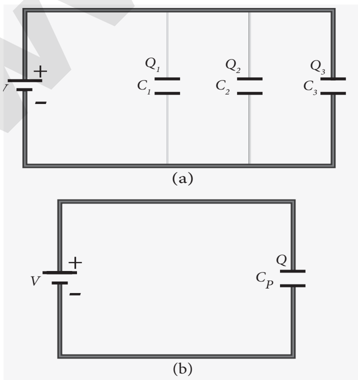
$$\frac{Q}{C_s} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad ...... (3)$$

This equivalent capacitance C_s is always less than the smallest individual capacitance in the series.

Capacitor in parallel :

Consider three capacitors of capacitance C_1, C_2 and C_3 connected in parallel with a battery of voltage V as shown in Figure (a).



(a) Capacitors in parallel
(b) Equivalent capacitance with the same total charge

Since capacitances of the capacitors are different, the charge stored in each capacitor is not the same. Let the charge stored in the three capacitors be Q_1, Q_2, and Q_3 respectively. According to the law of conservation of total charge, the sum of these three charges is equal to the charge Q transferred by the battery,

$$Q = Q_1 + Q_2 + Q_3 \quad ...... (1)$$

Since Q = CV we have

$$Q = C_1V + C_2V + C_3V \quad ...... (2)$$

If these three capacitors are considered to form a single equivalent capacitance C_p which stores the total charge Q as shown in the Figure(b), then we can write $Q = C_pV$. Substituting this in equation (2), we get

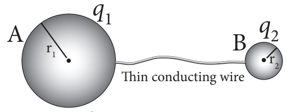
$$C_pV = (C_1V + C_2V + C_3V)$$

$$C_p = C_1 + C_2 + C_3$$

Thus, the equivalent capacitance of capacitors connected in parallel is equal to the sum of the individual capacitances. The equivalent capacitance C_p in a parallel connection is always greater than the largest individual capacitance.

21. Explain in detail how charges are distributed in a conductor, and the principle behind the lightning conductor.

Ans. **(i)** Consider two conducting spheres A and B of radii r_1 and r_2 respectively connected to each other by a thin conducting wire as shown in the Figure. The distance between the spheres is much greater than the radii of either spheres.



Two conductors are connected through conducting wire

(ii) If a charge Q is introduced into any one of the spheres, this charge Q is redistributed into both the spheres such that the electrostatic potential is same in both the spheres. Let q_1 be the charge residing on the surface of sphere A and q_2 is the charge residing on the surface of sphere B such that $Q = q_1 + q_2$.

The electrostatic potential at the surface of the sphere A is given by

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} \qquad ...(1)$$

(iii) The electrostatic potential at the surface of the sphere B is given by

$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2} \qquad ...(2)$$

(iv) The surface of the conductor is an equipotential. Since the spheres are connected by the conducting wire, the surfaces of both the spheres together form an equipotential surface. This implies that

$$V_A = V_B$$

or $$\frac{q_1}{r_1} = \frac{q_2}{r_2} \qquad ...(3)$$

(v) Let the charge density on the surface of sphere A be σ_1 and that on the surface of sphere B be σ_2. This implies that $q_1 = 4\pi r_1^2\sigma_1$ and $q_2 = 4\pi r_2^2\sigma_2$. Substituting these values into equation (3), we get

$$\sigma_1 r_1 = \sigma_2 r_2 \qquad ...(4)$$

from which we conclude that

$$\sigma r = \text{constant} \qquad ...(5)$$

(vi) Thus the surface charge density σ is inversely proportional to the radius of the sphere. For a smaller radius, the charge density will be larger and vice versa.

Lightning conductors :

(i) This is a device used to protect tall buildings from lightning strikes. It works on the principle of action at points or corona discharge.

(ii) This device consists of a long thick copper rod passing from top of the building to the ground. The upper end of the rod has a sharp spike or a sharp needle.

(iii) The lower end of the rod is connected to copper plate which is buried deep into the ground. When a negatively charged cloud is passing above the building, it induces a positive charge on the spike.

(iv) Since the induced charge density on thin sharp spike is large, it results in a corona discharge. This positive charge ionizes the surrounding air which in turn neutralizes the negative charge in the cloud.

(v) The negative charge pushed to the spikes passes through the copper rod and is safely diverted to the Earth.

(vi) The lightning arrester does not stop the lightning; rather it diverts the lightning to the ground safely.

22. Explain in detail the construction and working of a Van de Graaff generator.

[QY-2019; FRT, July-'22]

Ans. It is a machine which produces large electrostatic potential difference of the order of 10^7 V.

Principle:

Electrostatic induction and action at points.

Construction:

(i) A large hollow spherical conductor is fixed on the insulating stand as shown in the figure.

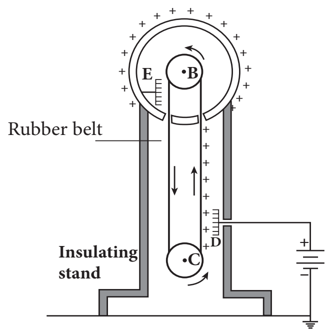
(ii) A pulley B is mounted at the centre of the hollow sphere and another pulley C is fixed at the bottom.

(iii) A belt made up of insulating materials like silk or rubber runs over both pulleys. The pulley C is driven continuously by the electric motor.

(iv) Two comb shaped metallic conductors E and D are fixed near the pulleys.

(v) The comb D is maintained at a positive potential of the order of 10^4 volt.

(vi) The upper comb E is connected to the inner side of the hollow metal sphere.



Working:

(i) Because of the high electric field near the comb D, the air gets ionized.

(ii) The negative charges in air move towards the needles and positive charges are repelled towards the belt due to action of points.

(iii) The +ve charges stuck to the belt moves up end and reaches near the comb E.

(iv) E acquires negative charge and the sphere acquires positive charge due to electrostatic induction.

(v) The acquired +ve charge is distributed on the outer surface of the sphere.

(vi) Thus the machine, continuously transfers the positive charge to the sphere.

(vii) The leakage of charges from the sphere can be reduced by enclosing it in a gas filled steel chamber at a very high pressure.

(viii) The high voltage can be used to accelerate positive ions for the purpose of nuclear disintegrations and other applications.

Exercises :

1. When two objects are rubbed with each other, approximately a charge of 50 nC can be produced in each object. Calculate the number of electrons that must be transferred to produce this charge. *[PTA-6]*

Sol.:

Given: Charge produced $q = 50\ nC = 50 \times 10^{-9}$ C;

Charge of an electron $e = 1.6 \times 10^{-19}$ C

To find: No. of electrons n = ?

We know $q = ne$

$$n = \frac{q}{e} = \frac{50\times10^{-9}}{1.6\times10^{-19}} = 31.25 \times 10^{10} \text{ electrons.}$$

2. The total number of electrons in the human body is typically in the order of 10^{28}. Suppose, due to some reason, you and your friend lost 1% of this number of electrons. Calculate the electrostatic force between you and your friend separated at a distance of 1m. Compare this with your weight. Assume mass of each person is 60 kg and use point charge approximation.

Sol.:

Given:

Number of electrons in human body = 10^{28}

Number of electrons in me and my friend after loss of 1% (ie)

1% of charge on 10^{28} electrons

$$= \frac{1}{100} \times 10^{28} = 10^{26} \text{ electrons.}$$

$d = r = 1m$

Charge of each person $q = ne$

$\therefore$ Charge of each person $q = 10^{26} \times 1.6 \times 10^{-19}$C

$= 1.6 \times 10^{7}$C

Electrostatic force between us is $F_e = \frac{Kq_1q_2}{r^2}$

$$= \frac{9\times10^9\times(1.6\times10^7)^2}{1^2} = 9 \times 2.56 \times 10^9 \times 10^{14}$$

$F_e = 23.04 \times 10^{23}$ N $= 23 \times 10^{23}$ N

Also mass of the person m = 60 kg

$\therefore$ weight = mg

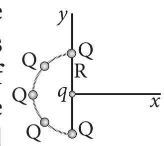
= 60 × 9.8 [$\because g = 9.8\ ms^{-2}$]

W = 588 N

$$\therefore \frac{F_e}{F_g} = \frac{F_e}{W} = \frac{23.04\times10^{23}}{588} = 3.9183 \times 10^{21}$$

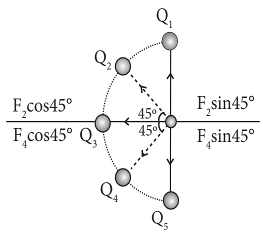
$= 3.9 \times 10^{21}$

3. Five identical charges Q are placed equidistant on a semicircle as shown in the figure. Another point charge *q* is kept at the centre of the circle of radius R. Calculate the electrostatic force experienced by the charge *q*.



Sol.:

The forces acting on q, due to Q_1 and Q_5 are F_1 and F_5. These forces are equal and opposite direction. So cancel to each other



Forces due to Q_2 and Q_4 on q is resolved into two components.

(i) Vertical component : $Q_2 \sin\theta$ and $Q_4 \sin\theta$ are equal and opposite. So they are cancel to each other.

(ii) Horizontal Component : $Q_2 \cos\theta$ and $Q_4 \cos\theta$ an equal and same direction. So they can get added.

$$\therefore F_{24} = K\frac{qQ_2}{R^2}\cos 45° + K\frac{qQ_4}{R^2}\cos 45°$$

Total force acting on q due to Q_3 is

$$F_3 = K\frac{qQ_3}{R^2}$$

Here $Q = Q_1 = Q_2 = Q_3 = Q_4 = Q_5$

Resultant net force $F = F_{15} + F_{24} + F_3$

$= 0 + F_{24} + F_3$

$= F_3 + F_{24}$

Total force

$$F = k.\frac{qQ_2}{R^2} + k.\frac{qQ_2}{R^2}.\cos 45° + \frac{kqQ}{R^2}.\cos 45°$$

$$= \frac{kqQ}{R^2}\left[1+\frac{2}{\sqrt{2}}\right] \qquad [\because Q = Q_3 = Q_2 = Q_4]$$

Invector form,

$$\text{Total } \vec{F} = \frac{kqQ}{R^2}[1+\sqrt{2}]\hat{i}$$

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{R^2}[1+\sqrt{2}]\hat{i}\ \text{N} \qquad \left[\because k = \frac{1}{4\pi\varepsilon_0}\right]$$

4. Suppose a charge +*q* on Earth's surface and another +*q* charge is placed on the surface of the Moon. (a) Calculate the value of q required to balance the gravitational attraction between Earth and Moon (b) Suppose the distance between the Moon and Earth is halved, would the charge *q* change? (Take $m_E = 5.9 \times 10^{24}$ kg, $m_M = 7.9 \times 10^{22}$ kg)

***Sol.:* Given:**

(a) Mass of the earth $m_E = 5.9 \times 10^{24}$ kg

Mass of the moon $m_M = 7.9 \times 10^{22}$ kg

Charge placed on earth and moon is q

To find: The amount of charge required to balance gravitational attraction between earth & moon = ?

If q is the charge placed on the moon & earth, then

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q \times q}{r^2} \qquad ...(1)$$

$$F_g = G.\frac{m_E \times m_M}{r^2} \qquad ...(2)$$

$$F_e = F_g$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q\times q}{r^2} = G.\frac{m_E \times m_M}{r^2}$$

$$q_2 = \frac{G\,m_E \times m_M}{\left(\frac{1}{4\pi\varepsilon_0}\right)}$$

$$q = \sqrt{\frac{Gm_E \times m_M}{\left(\frac{1}{4\pi\varepsilon_0}\right)}}$$

$$q = \sqrt{\frac{6.67\times10^{-11}\times5.9\times10^{24}\times7.9\times10^{22}}{9\times10^9}}$$

$[\because G = 6.67 \times 10^{-11}\ \text{Nm}^{-2}\ \text{kg}^{-2}]$

$\left[\because \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\right]$

$$q = \sqrt{\frac{6.67\times5.9\times7.9\times10^{35}}{9\times10^9}}$$

$$q = \sqrt{34.532\times10^{26}}$$

$$q = 5.87 \times 10^{13}\ \text{C.}$$

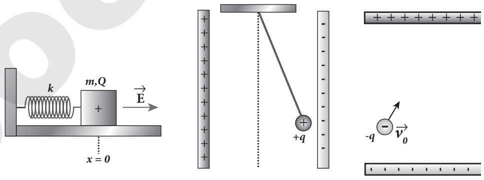
(b) To find : The distance between moon & earth is halved, the charge q = ?

$$\frac{1}{4\pi\varepsilon_0}.\frac{q_1q_2}{\left(\frac{r}{2}\right)^2} = G.\frac{m_E.m_M}{\left(\frac{r}{2}\right)^2} \Rightarrow \frac{1}{4\pi\varepsilon_0}q_1q_2 = Gm_Em_M.$$

$\therefore q = 5.87 \times 10^3$ C (Similar to (a) part)

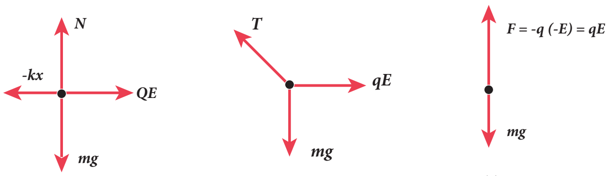
There will not be any change in the charge q.

5. Draw the free body diagram for the following charges as shown in the figure (a), (b) and (c).



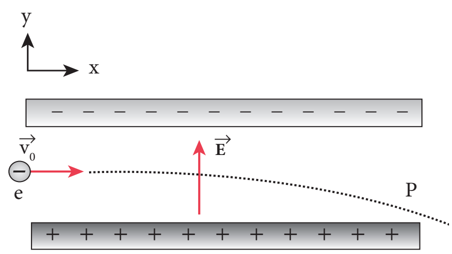
(a) (b) (c)

Sol.:



(a) (b) (c)

6. Consider an electron travelling with a speed v_o and entering into a uniform electric field $\vec{E}$ which is perpendicular to $\vec{v}_o$ as shown in the Figure. Ignoring gravity, obtain the electron's acceleration, velocity and position as functions of time.



Sol.: Given : Speed of an electrons $= v_0$

Unifrom Electric field $= \vec{E}$

(a) Electron's Acceleration:

According to Newton's II law, F = ma $\Rightarrow a = \frac{F}{m}$

The force on the electrons due to uniform electric field is F = eE $\Rightarrow$ $a = \frac{F}{m} = \frac{Ee}{m}$

Therefore the down acceleration of electron due to electric field, $a = -\frac{Ee}{m}$

$\therefore$ Acceleration in vector form, $\vec{a} = -\frac{eE}{m}.\hat{j}$

(b) Electron's Velocity:

We know equation of motion $v = u + at$

Here speed of electron in horizontal direction $u = v_0$

$$\Rightarrow \quad v = v_0 + \left(\frac{-eE}{m}\right)t$$

$$\Rightarrow \quad v = v_0 - \frac{-eE}{m}t$$

$\therefore$ Velocity in vector form $\vec{\upsilon} = v_0\,\hat{i} - \frac{eE}{m}.t.\hat{j}$

(c) Position of an electron:

We know equation of motion, $s = ut + \frac{1}{2}at^2$

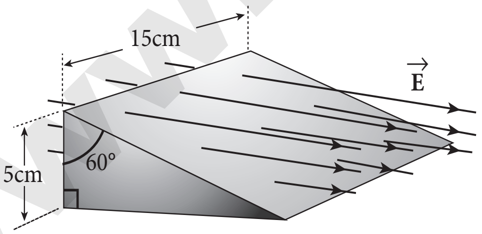
Here $s = r =$ the position of an electron, $u = v_0$

$$\therefore r = v_0 t + \frac{1}{2}.\left(-\frac{eE}{m}\right)t^2 = v_0 t - \frac{eE}{2m}t^2$$

$\therefore$ Position in vector form

$$\vec{r} = v_0 t\,\hat{i} - \frac{Ee}{2m}.t^2\,\hat{j}$$

7. A closed triangular box is kept in an electric field of magnitude E = 2 × 10³ N C⁻¹ as shown in the figure.



Calculate the electric flux through the (a) vertical rectangular surface (b) slanted surface and (c) entire surface.

Sol.: **Given:**

The magnitude of electric field $E = 2 \times 10^3$ NC^{-1}

Area of the surface $A = 0.15 \times 0.05$

[From the diagram l = 15 cm = 0.15 m, b = 5 cm = 0.05m]

To find:

The electric flux through

a) Vertical rectangular surface $\phi_{vert} = ?$

According to Gauss law $\phi = E A \cos\theta$

$\phi_{\text{vertical surface}} = 2 \times 10^3 \times 0.15 \times 0.05 \times \cos 0°$

$= 0.015 \times 10^3 = 15$ Nm² C⁻¹

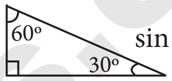
b) Electric flux through slanted surface

$\phi_{\text{slanted surface}} = ?$

$\phi_{\text{slanted surface}} = E A \cos\theta$

$\theta = 60° \Rightarrow \cos 60° = \frac{1}{2}$

From the diagram,



$\sin 30° = \frac{\text{opposite}}{\text{hyp}}$

Opposite = 5 cm. hyp $= \frac{\text{opposite}}{\sin 30°}$

$$\text{hyp.} = \frac{5 \times 10^{-2}}{\frac{1}{2}} = 2 \times 0.05$$

$= 0.10$ m

Area of the slanted surface

$A = (0.10 \times 0.15)$ m²

$\phi_{\text{slanted surface}} = EA\cos\theta$

$\phi_{\text{slanted surface}} = 2 \times 10^3 \times (0.10 \times 0.15) \times \cos 60°$

$= 0.015 \times 10^3 = 15$ Nm² C⁻¹

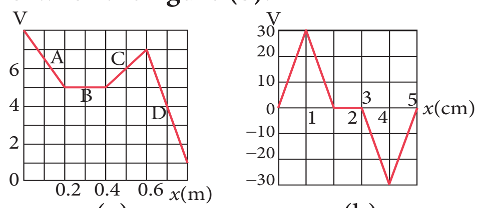
c) Entire surface $\phi_{tot} = ?$

$\phi_{tot} = \phi_{vs} + \phi_{s.s} + \phi_{H.S}$ [Here $\phi_{H.S} = EA\cos\theta$

$= -15 + 15 + 0$ $\quad \theta = 90°$; $\cos 90° = 0$

$\phi_{tot} = 0.$ $\quad \therefore \phi_{ends} = 0$]

8. The electrostatic potential is given as a function of *x* in figure (i) and (ii). Calculate the corresponding electric fields in regions A, B, C and D. Plot the electric field as a function of *x* for the figure (b).



(a) (b)

Sol.: (a) $E_x = -\frac{dV}{dx} = \frac{V_2 - V_1}{x_2 - x_1}$

(i) **Region A**

$$\frac{dV}{dx} = \frac{5-8}{0.2-0} = \frac{-3}{0.2} = -15$$

$\therefore E_x = -(-15) = 15$ Vm⁻¹

(ii) Region B

$$\frac{dV}{dx} = \frac{5-5}{0.4-0.2} = \frac{0}{0.2} = 0 \qquad \therefore E_x = 0$$

(iii) Region C

$$\frac{dV}{dx} = \frac{7-5}{0.6-0.4} = \frac{2}{0.2} = 10$$

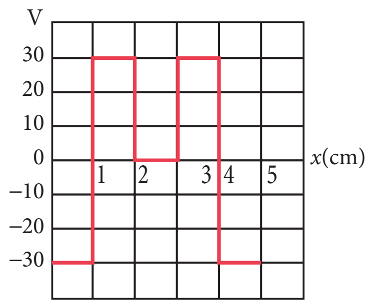
$$E_x = -\frac{dV}{dx} = (-10)Vm^{-1}$$

(iv) Region D

$$\frac{dV}{dx} = \frac{1-7}{0.8-0.6} = \frac{-6}{0.2} = -30$$

$$E_x = -\frac{dV}{dx} = -(-30) = 30Vm^{-1}.$$

(b)



***Ans.* (b)** $E_{01} = -\frac{(30-0)}{1-0} = -30Vcm^{-1}$

$$E_{12} = -\frac{(0-30)}{2-1} = +30Vcm^{-1}$$

$$E_{23} = -\frac{(0-0)}{3-2} = 0Vcm^{-1}$$

$$E_{34} = -\frac{(-30-0)}{4-3} = +30Vcm^{-1}$$

$$E_{45} = -\frac{(0-(-30))}{5-4} = -30Vcm^{-1}$$

9. A spark plug in a bike or a car is used to ignite the air-fuel mixture in the engine. It consists of two electrodes separated by a gap of around 0.6 mm gap as shown in the figure.

To create the spark, an electric field of magnitude 3×10^6 Vm^{-1} is required. (a) What potential difference must be applied to produce the spark? (b) If the gap is increased, does the potential difference increase, decrease or remains the same? (c) find the potential difference if the gap is 1 mm.

Sol.: **Given:**

(a) The distance between two electrodes x = 0.6mm = 0.6×10^{-3} m

The magnitude of electric filed E = 3×10^6 Vm^{-1}

To find:

Potential difference need to produce spark

(ie) V = ?

Formula: $E = \frac{V}{x}$

$$\therefore V = E \cdot x = 0.6 \times 10^{-3} \times 3 \times 10^6 = 1800 \text{ V.}$$

(b) Since V α x, we come to know when the gap is increased, potential also increases.

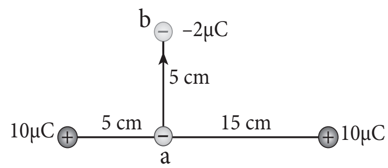
(c) The distance, r = 1 mm = 1×10^{-3} m

Electric field, E = 3×10^6 Vm^{-1}

New potential difference due to increase in the gap.

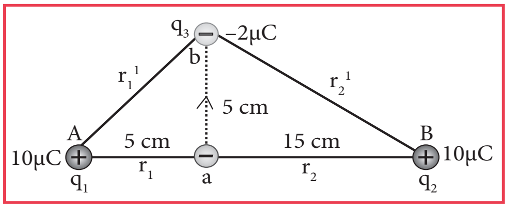
$V = E.\,d = 3 \times 10^6 \times 1 \times 10^{-3} = 3000$ V.

10. A point charge of +10 μC is placed at a distance of 20 cm from another identical point charge of +10 μC. A point charge of –2 μC is moved from point a to b as shown in the figure. Calculate the change in potential energy of the system? Interpret your result.



Sol.: $\Delta Aab = r_1' = \sqrt{5^2 + 5^2} = 5\sqrt{2}$ cm

$\Delta aBb = r_2' = \sqrt{15^2 + 5^2} = 5\sqrt{10}$ cm



$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$

$$V_1 = 9 \times 10^9 \left[\frac{10 \times 10^{-6}}{5 \times 10^{-2}} + \frac{10 \times 10^{-6}}{15 \times 10^{-2}}\right]$$

b) E along equatorial line at 20 cm

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3} = 9 \times 10^9 \times \frac{80\times10^{-9}}{(20\times10^{-2})^3} = 0.09 \times 10^6 = 9 \times 10^4 \text{ NC}^{-1}$$

ADDITIONAL QUESTIONS AND ANSWERS

Choose the Correct Answer — 1 Mark

1. **Based on Franklin's convention amber rods are ________**

(a) positively charged (b) negatively charged
(c) neutral (d) none of the above

[*Ans.* (b) negatively charged]

2. **The electrostatic force obeys ________**

(a) Newton's I law (b) Newton's II law
(c) Newton's III law (d) none of the above

[*Ans.* (c) Newton's III law]

3. **In electrostatics if the charges are in motion, another force named ________ comes into play in addition to coulomb force.**

(a) Lorentz force (b) Repulsive force
(c) Attractive force (d) electromagnetic force

[*Ans.* (a) Lorentz force]

4. **The value of constant 'K' in coulomb law is**

(a) 0.9×10^9 Nm^2 C^2 (b) 9×10^{-9} Nm^{2}C^2
(c) 9×10^9 Nm^{-2} C^{-2} (d) 9×10^9 Nm^2 C^{-2}

[*Ans.* (d) 9×10^9 Nm^2 C^{-2}]

5. **The electrostatic force is always greater in magnitude than gravitational force for ______ object**

(a) bigger size (b) smaller size
(c) medium size (d) all the above

[*Ans.* (b) smaller size]

6. **The relative permittivity of water is ______**

(a) $\varepsilon_r = 70$ (b) $\varepsilon_r = 75$
(c) $\varepsilon_r = 80$ (d) $\varepsilon_r = 85$

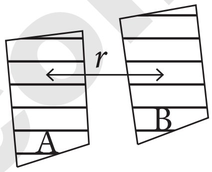
[*Ans.* (c) $\varepsilon_r = 80$]

7. **______and Coulomb's law form fundamental principles of electrostatics**

(a) Newton's law of gravitation
(b) Superposition principle
(c) Ohm's law (d) Kepler's law

[*Ans.* (b) Superposition principle]

8. **The figure shows two parallel equipotential surface A and B kept at a small distance 'r' apart from each other. A point change of Q coulomb is taken from the surface A to B. The amount of net work done will be**

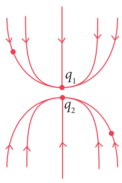


(a) $W = \frac{-1}{4\pi\varepsilon_0}\frac{q}{r}$ (b) $W = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
(c) $W = \frac{-1}{4\pi\varepsilon_0}\frac{q}{r^2}$ (d) zero

[*Ans.* (d) zero]

Hint:
$W = (V_A - V_B)\, q$
$\therefore V_A = V_B$ for equipotential surface
$W = O \times q = 0$

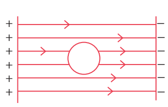
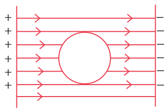
9. **The given figure is a plot of lines of force due to two charges q_1 & q_2. Find out the sign of charges**

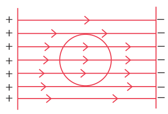
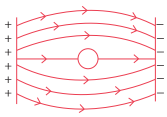


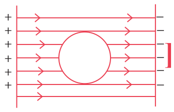
(a) both negative
(b) both positive
(c) upper positive and lower negative
(d) upper negative and lower positive

[*Ans.* (a) both negative]

10. **An uncharged metal sphere is placed between two equal and oppositely charged metal plates. The nature of lines of force will be**

(a)  (b) 

(c)  (d) 

[*Ans.* (b) ]

11. An isolated metal sphere of radius 'r' is given a charge 'q'. The potential energy of the sphere is

(a) $\frac{q^2}{4\pi\varepsilon_0 r}$ (b) $\frac{q}{4\pi\varepsilon_0 r}$

(c) $\frac{q}{8\pi\varepsilon_0 r}$ (d) $\frac{q^2}{8\pi\varepsilon_0 r}$

[**Ans.** (d) $\frac{q^2}{8\pi\varepsilon_0 r}$]

Hint:

$$P.E = \frac{1}{2}CV^2 \quad [\because C = 4\pi\varepsilon_0 r]$$

$$V = \frac{q}{4\pi\varepsilon_0 r}$$

$$P.E = \frac{1}{2} \times (4\pi\varepsilon_0 r) \times \left(\frac{q}{4\pi\varepsilon_0 r}\right)^2$$

$$P.E = \frac{q^2}{8\pi\varepsilon_0 r}$$

12. In a hydrogen atom the electron revolves around the proton in an orbit of 0.53 Å . The potential produced by the electron on the nuleus is

(a) 6.8 V (b) 13.6 V

(c) 54.4 V (d) 27.2 V

[**Ans.** (d) 27.2 V]

Hint:

$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{r}$$

$$= (9 \times 10^9) \times \frac{1.6\times10^{-19}}{0.53\times10^{-10}} = 27.2\text{ V}$$

13. Which one of these is a vector quantity?

(a) Electric charge (b) Electric field

(c) Electric flux (d) Electric potential

[**Ans.** (b) Electric field]

14. The force experienced by a unit charge is called

(a) Electric potential (b) Electric flux

(c) Electric field (d) Static electricity

[**Ans.** (c) Electric field]

15. The electric field created by a ______ is basically a non-uniform electric field.

(a) Test charge (b) Positive charge

(c) Negative charge (d) Point charge

[**Ans.** (d) Point charge]

16. The expression for electric field in vector form is

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\hat{r}$ (b) $\frac{-1}{4\pi\varepsilon_0}\frac{q}{r}\hat{r}$

(c) $\frac{-1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

[**Ans.** (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$]

17. Eight mercury droplets having a radius of 1 mm and charge of 0.066 pC each merge to form one droplet. Its potential is

(a) 2.4 V (b) 1.2 V

(c) 3.6 V (d) 4.8 V

[**Ans.** (a) 2.4 V]

Hint:

$$8 \times \text{volume of one droplet of Hg} = \frac{4}{3}\pi R^3$$

$$8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$2^3 \times r^3 = R^3$$

$$(2r)^3 = (R)^3$$

$$R = 2r \quad [\because r = 1\text{ mm}]$$

$$R = 2 \times \frac{1}{q/R} \times 10^{-3}\text{ m (or) 2 mm} \quad [\because q = ne]$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{R}$$

$$V = \frac{9\times10^9\times0.066\times10^{-12}\times8}{2\times10^{-3}}$$

$$V = 2.4\text{ V}$$

18. A force of 40 N is acting between two charges in air if the space between them is filled with glass $\varepsilon_r = 8$. Then the force between them is

(a) 20 N (b) 10 N (c) 5 N

(d) the same and does not change [**Ans.** (c) 5 N]

Hint:

$$F_a = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}$$

$$F_g = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\cdot\frac{q_1q_2}{r^2}$$

$$\frac{F_g}{F_a} = \frac{1}{\varepsilon_r} = \frac{1}{8}$$

$$F_g = \frac{F_a}{8} = \frac{40}{8} = 5\text{ N}$$

19. The concept of 'Field' was introduced by

(a) Faraday (b) Gauss

(c) Maxwell (d) None

[**Ans.** (a) Faraday]

20. The electric potential V as a function of distance x (metres) is given by V = ($5x^2 + 10x - 9$) volt. The value of electric field at a point x = 1m is

(a) 20 Vm^{-1} (b) 6 Vm^{-1}

(c) 11 Vm^{-1} (d) – 23 Vm^{-1}

[**Ans.** (a) 20 Vm^{-1}]

Hint:

We know that, $E = \frac{dV}{dx}$

$V = 5x^2 + 10x - 9$

Differentiating w.r. to 'x' on both sides

$\frac{dV}{dx} = 10x + 10 = E$

At a point, $x = 1$m,

$\frac{dV}{dx} = 10(1) + 10$

$\therefore E = \frac{dV}{dx} = 20 \text{ Vm}^{-1}$

21. Two condensers (capacitors) of capacity C_1 and C_2 are connected in parallel. A charge Q given to then is shared. The ratio of the charges Q is

(a) $\frac{C_2}{C_1}$ (b) $\frac{C_1}{C_2}$

(c) $C_1 . C_2$ (d) $\frac{1}{C_1 \times C_2}$

[Ans. (b) $\frac{C_1}{C_2}$]

Hint:

As they are in parallel, the potential is same across the two,

$\therefore Q_1 = C_1V$ and $Q_2 = C_2V$

$\therefore \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$

22. Charge per unit volume is called

(a) Linear charge density (λ)

(b) Surface charge density (σ)

(c) Volume charge density (ρ)

(d) Electric flux

[Ans. (c) Volume charge density (ρ)]

23. What will happen if two conducting spheres are separately charged and then brought in contact?

(a) Total charge on the two spheres is conserved

(b) The total energy is conserved

(c) Both charge and energy are conserved

(d) The final potential is the mean of the original potentials.

[Ans. (a) Total charge on the two sphercs is conserved]

Hint: This is in accordance with the law of conservation of charge.

24. A condenser is charged to a potential of 200V and has a charge of 0.1C. The energy stored in it is

(a) 1 J (b) 2 J (c) 10 J (d) 20 J

[Ans. (c) 10 J]

Hint:

Energy stored, $U = \frac{1}{2}CV^2$

$U = \frac{1}{2}(CV)V \quad [\because q = CV]$

$U = \frac{1}{2}qV = \frac{1}{2} \times 0.1 \times 200$

$U = 10$ J

25. Increasing the charge on the plates of a capacitor means

(a) increasing the capacitance

(b) increasing the potential difference between the plates

(c) both (a) and (b) above

(d) none of the above

[Ans. (b) increasing the potential difference between the plates]

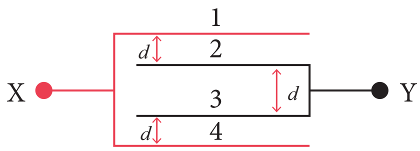
26. A positively charged body 'A' has been brought near a brass cylinder 'B' mounted on a glass stand as shown in the figure. The potential of 'B' will be

(a) Zero (b) Negative

(c) Positive (d) Infinite

[Ans. (c) Positive]

27. Four plates each of area 'A' are separated by a distance 'd'. The connection is as shown in figure. What is equivalent capacitance between X and Y?



(a) $\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$

(c) $\frac{3\varepsilon_0 A}{d}$ (d) $\frac{4\varepsilon_0 A}{d}$

[Ans. (b) $\frac{2\varepsilon_0 A}{d}$]

Hint: They constitute two parallel plate capacitors in parallel with each other.

28. **The expression for the electric field due to a surface of total charge 'Q' is given by**

(a) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma dA}{r^2}\hat{r}$ (b) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho dA}{r^2}\hat{r}$

(c) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\lambda dl}{r^2}\hat{r}$ (d) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r^2}\hat{r}$

[***Ans.*** **(a) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma dA}{r^2}\hat{r}$**]

29. **The dipole is called point dipole when the distance**

(a) $2a$ approaches infinity and q approaches zero
(b) $2a$ approaches zero and q approaches infinity
(c) $2a$ approaches zero and q approaches zero
(d) $2a$ approaches infinity and q approaches infinity.

[***Ans.*** **(b) $2a$ approaches zero and q approaches infinity**]

30. **The magnitude of torque on dipole is maximum if**

(a) $\theta = 0°$ (b) $\theta = 90°$
(c) $\theta = 180°$ (d) $\theta = 180°$

[***Ans.*** **(b) $\theta = 90°$**]

31. **The expression for electric potential difference is**

(a) $\int_R^P +\vec{E}.\vec{dr}$ (b) $-\int_\infty^P \vec{E}.\vec{dr}$

(c) $\int_\infty^P \vec{E}.\vec{dr}$ (d) $\int_R^P -\vec{E}.\vec{dr}$

[***Ans.*** **(d) $\int_R^P -\vec{E}.\vec{dr}$**]

32. **The magnitude of electric dipole moment of water molecule is**

(a) 6×10^{-30} Cm (b) 6.2×10^{-30} Cm
(c) 6.1×10^{-30} Cm (d) 5.9 5 10^{-30} Cm

[***Ans.*** **(c) 6.1×10^{-30} Cm**]

33. **The potential due to a single point charge falls as**

(a) $\frac{1}{r^2}$ (b) $\frac{1}{r^3}$

(c) $\frac{1}{r}$ (d) $-\frac{1}{r}$

[***Ans.*** **(c) $\frac{1}{r}$**]

34. **The unit for electric flux is**

(a) $C^2 N^{-1}m^{-2}$ (b) $Nm^2 C^{-2}$
(c) $Nm^2 C^{-1}$ (d) $Nm^{-2}C^{-1}$

[***Ans.*** **(c) $Nm^2 C^{-1}$**]

35. **The electric flux is negative, if the angle between $\vec{dA}$ and $\vec{E}$ is**

(a) Less than 90° (b) greater than 90°
(c) equal to 90° (d) equal to 0°

[***Ans.*** **(b) greater than 90°**]

36. **The time taken by a conductor to reach electrostatic equilibrium is in the order of**

(a) 10^{-18} (b) 10^{-14} s
(c) 10^{-16} s (d) 10^{-20} s

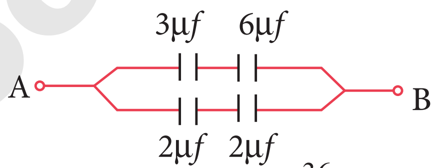
[***Ans.*** **(c) 10^{-16} s**]

37. **A non-conducting material which has no free electrons is called**

(a) capacitor (b) Dielectric
(c) conductor (d) Inductor

[***Ans.*** **(b) Dielectric**]

38. **In the given cricuit the effective capacitance between A and B will be**



(a) 3μ*f* (b) $\frac{36}{13}$ μ*f*
(c) 13 μ*f* (d) 7 μ*f*

[***Ans.*** **(a) 3μ*f***]

Hint:
$$C = \left(\frac{3\times6}{3+6}\right) + \left(\frac{2\times2}{2+2}\right)$$
$$= 2+1$$
$$C = 3\mu f$$

39. **The unit for electric susceptibility is**

(a) $Nm^2 C^{-2}$ (b) $C^2 N^{-1} m^{-2}$
(c) $C^{-2}Nm^2$ (d) $N^{-1} m^{-2}C^2$

[***Ans.*** **(b) $C^2 N^{-1} m^{-2}$**]

40. **The direction of electric field at a point on the equatorial line due to an electric dipole is**

(a) along the equatorial line towards the dipole.
(b) along the equatorial line away from the dipole.
(c) parallel to the axis of the dipole and opposite to the direction of dipole moment.
(d) parallel to the axis of the dipole and in the direction of dipole moment.

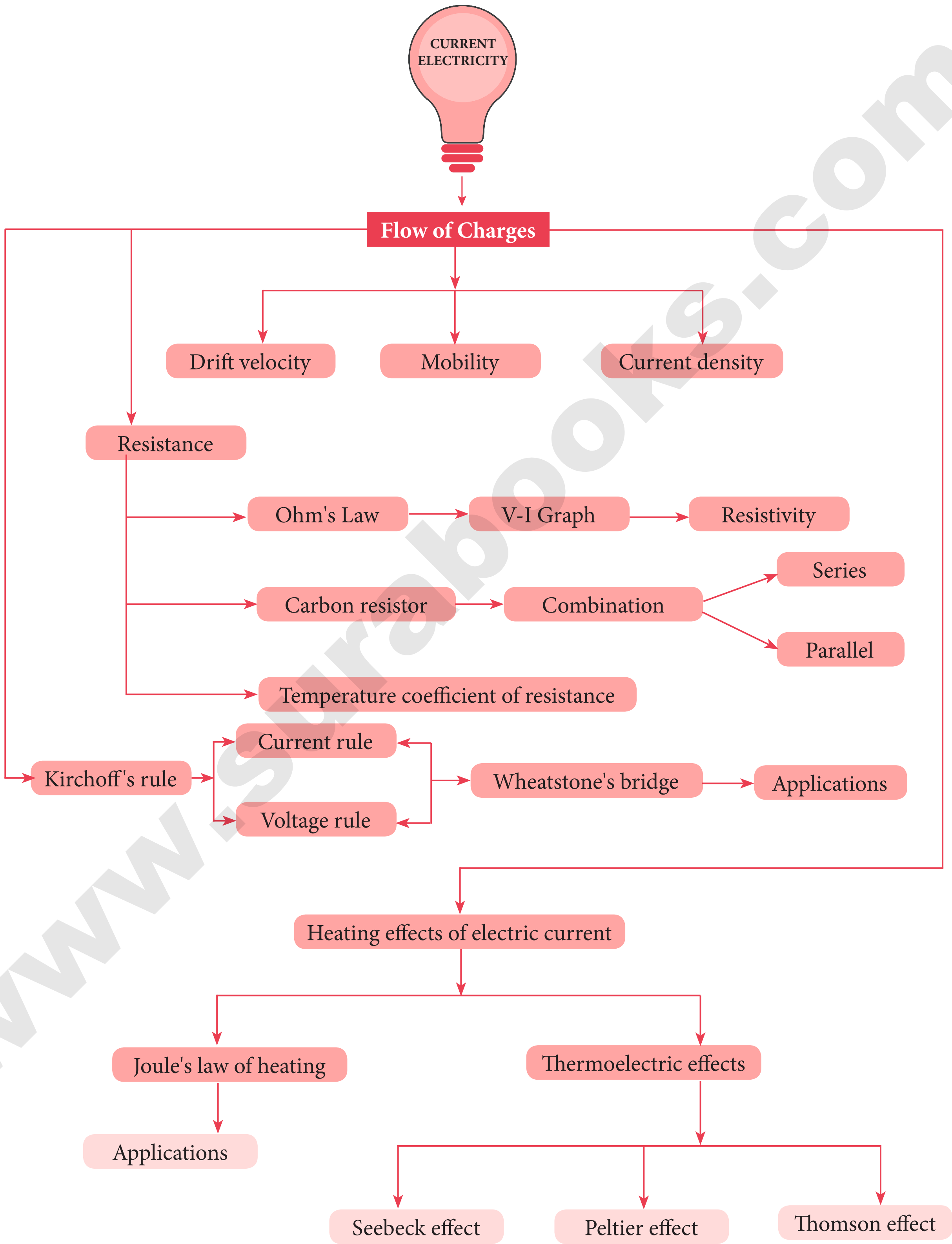
[***Ans.*** **(c) parallel to the axis of the dipole and opposite to the direction of dipole moment.**]

ELECTROSTATICS

UNIT 2 CURRENT ELECTRICITY

CHAPTER SNAPSHOT

CONCEPT MAP


CURRENT ELECTRICITY
Flow of Charges
Drift velocity
Mobility
Current density
Resistance
Ohm's Law
V-I Graph
Resistivity
Series
Carbon resistor
Combination
Parallel
Temperature coefficient of resistance
Current rule
Kirchoff's rule
Wheatstone's bridge
Applications
Voltage rule
Heating effects of electric current
Joule's law of heating
Thermoelectric effects
Applications
Seebeck effect
Peltier effect
Thomson effect

MUST KNOW DEFINITIONS

Branch of physics that deals with the study of motion of electric charges within the material is called **current electricity.**

Electromotive force (emf) is not a force, but it is the work done in moving a unit charge from one end to the other, in a conductor.

The **external energy** necessary to drive the free electrons in a definite direction inside a conductor is termed emf.

Electric current : It is the rate of flow of charges across any cross sectional area of a conductor. $I = \frac{Q}{t}$

Drift velocity : It is the velocity with which free electrons are drifted towards the positive terminal, inside a conductor when an electric field is applied.

If τ is the average time between two successive collisions and the acceleration experienced by the electron be 'a', then the drift velocity is, $v_d = a\tau$.

Current density (J) at a point : It is the quantity of charge passing per unit time inside a conductor through unit area, perpendicular to the direction of flow of charge at that point.

Ohm's law : At a constant temperature, the steady current flowing through a conductor is directly proportional to the potential difference between the two ends of the conductor.

Resistance : It is the ratio of potential difference across the conductor to the current flowing through it. The unit is ohm(Ω).

Conductance : It is the reciprocal of resistance. Its unit is mho (Ω^{-1}).

Specific resistance (electrical resistivity) of a material : It is defined as the resistance offered to the current flow by a conductor of unit length having unit area of cross section (ρ). Its unit is ohm-m (Ωm).

Conductivity $\sigma = \frac{1}{\rho}$: It is the reciprocal of electrical resistivity. Its unit is mho m^{-1} ($\Omega^{-1}\ m^{-1}$).

The conventional **current direction** is the direction in which positive charges move inside a conductor.

The direction of current is always opposite to that of motion of electrons.

The **Conductivity of metals and their alloys** is due to flow of electrons.

The conductivity of **electrolytes** is due to motion of positive and negative ions.

Charges flow from a body of higher electrical potential to that at a lower electrical potential.

The **direction** of flow of charges does not depend upon the quantity of charges of the two bodies. It depends upon the potential difference between them.

Superconductivity : It is the ability of certain metals, their compounds and alloys to conduct electricity with zero resistance at very low temperature.

FORMULAE

(1) Instantaneous current $I = \frac{dq}{dt}$;

(2) Amount of current $I = \frac{ne}{t}$

(3) Acceleration of electron $a = \frac{eE}{m}$;

(4) Drift velocity $v_d = \frac{eE}{m}\tau$

(5) Mobility $\mu = \frac{e\tau}{m}$;

(6) Current density $J = nev_d$

(7) Potential difference V= IR;

(8) Resistance of the wire $R = \frac{\rho l}{A}$

(9) Specific resistance $\rho = \frac{RA}{l}$;

(10) Current through conductor $I = nAev_d$

(11) Current through conductor $I = \frac{nAe^2}{mL}\tau V$

(12) Conductivity $\sigma = \frac{1}{\rho} = \frac{l}{RA}$

(13) Ratio between resistances of the same material wires $\frac{R_2}{R_1} = \frac{(l_2 r_1^2)}{(l_1 r_2^2)}$

(14) Conditions to balance Wheatstone's network $\frac{P}{Q} = \frac{R}{S}$

(15) Colour code for carbon resistors

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

(16) Tolerance

Silver : ±10% ; Gold : ±5%

Red : ±2% ; Brown : ±1%

(17) **Resistors in series :** Current (I) is same across each resistors R_1, R_2, R_3, R_4

Equivalent resistance $R_s = R_1 + R_2 + R_3 + R_4$

$V_1 = IR_1$; $V_2 = IR_2$; $V_3 = IR_3$; $V_4 = IR_4$

(18) **Resistors in parallel :** Potential difference (V) same across each resistance R_1, R_2, R_3, R_4

Equivalent resistance $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$; $I_1 = \frac{V}{R_1}$; $I_2 = \frac{V}{R_2}$; $I_3 = \frac{V}{R_3}$; $I_4 = \frac{V}{R_4}$

(19) Resistance of a conductor at a temperature t °C, $R_T = R_o[1+\alpha(T - T_0)]$

(20) Temperature coefficient of resistance $\alpha = \frac{R_T - R_o}{R_o.\Delta T} = \frac{\Delta R}{R_o \Delta T}$ Interms of resistivity $\alpha = \frac{\rho_T - \rho_0}{\rho_0 \Delta T}$

(21) Metals – Positive temperature coefficient of resistance.
Insulators, Semiconductors – Negative temperature coefficient of resistance.

(22) Internal resistance r of a cell, $r = \left(\frac{\varepsilon - V}{V}\right) R$

(23) Condition for bridge balance in a Wheatstone's bridge $\frac{P}{Q} = \frac{R}{S}$

(24) In Metre bridge : Unknown resistance $P = Q\frac{l_1}{l_2}$

(25) Specific resistance $\rho = \frac{P\pi r^2}{L}$; Where 'P' is the unknown resistance
Potential difference across the wire = I r l

(26) Potentiometer : $\varepsilon \propto l \Rightarrow \varepsilon = Irl$

(27) Unknown emf $\varepsilon_2 = \varepsilon_1 \frac{l_2}{l_1}$

(28) Electric power, $P = VI = I^2R = \frac{V^2}{R}$

(29) Heating effect : Joule's law

$H = VIt$; $H = I^2Rt$; $H = \frac{V^2}{R}t$

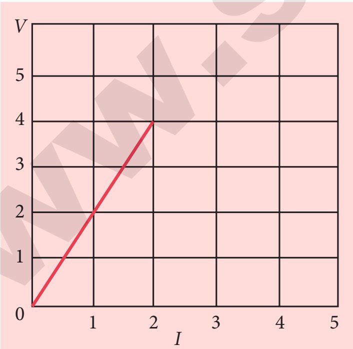
(30) Seebeck effect
Thermoelectric series of metals is Bi, Ni, Pd, Pt, Cu, Mn, Hg, Pb, Sn, Au, Ag, Zn, Cd, Fe, Sb

(31) Unit of emf = Volts.

Evaluation

I. Multiple choice questions :

1. The following graph shows current versus voltage values of some unknown conductor. What is the resistance of this conductor?

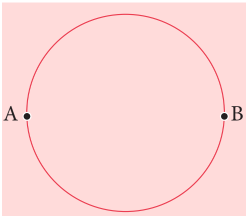


(a) 2 ohm (b) 4 ohm
(c) 8 ohm (d) 1 ohm

[Ans. (a) 2 ohm]

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

2. A wire of resistance 2 ohms per meter is bent to form a circle of radius 1m. The equivalent resistance between its two diametrically opposite points, A and B as shown in the figure is



(a) $\pi\ \Omega$ (b) $\frac{\pi}{2}\ \Omega$
(c) $2\pi\ \Omega$ (d) $\frac{\pi}{4}\ \Omega$

[Ans. (a) $\pi\ \Omega$]

3. A toaster operating at 240 V has a resistance of 120 Ω. Its power is

(a) 400 W (b) 2 W
(c) 480 W (d) 240 W

[Ans. (c) 480 W]

Hint: $P = V \times I$

4. **A carbon resistor of (47 ± 4.7) k Ω to be marked with rings of different colours for its identification. The colour code sequence will be** *[PTA-2]*

(a) Yellow – Green – Violet – Gold
(b) Yellow – Violet – Orange – Silver
(c) Violet – Yellow – Orange – Silver
(d) Green – Orange – Violet - Gold

[*Ans.* (b) Yellow – Violet – Orange – Silver]

5. **What is the value of resistance of the following resistor?**

(a) 100 k Ω (b) 10 k Ω
(c) 1k Ω (d) 1000 k Ω

[*Ans.* (a) 100 k Ω]

6. **Two wires of A and B with circular cross section made up of the same material with equal lengths. Suppose $R_A = 3 R_B$, then what is the ratio of radius of wire A to that of B?** *[Govt. MQP-2019]*

(a) 3 (b) $\sqrt{3}$
(c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{3}$

[*Ans.* (c) $\frac{1}{\sqrt{3}}$]

7. **A wire connected to a power supply of 230 V has power dissipation P_1. Suppose the wire is cut into two equal pieces and connected parallel to the same power supply. In this case power dissipation is P_2. The ratio $\frac{P_2}{P_1}$ is** *[July-'22]*

(a) 1 (b) 2
(c) 3 (d) 4

[*Ans.* (d) 4]

8. **In India electricity is supplied for domestic use at 220 V. It is supplied at 110 V in USA. If the resistance of a 60W bulb for use in India is R, the resistance of a 60W bulb for use in USA will be** *[FRT & May-'22]*

(a) R (b) 2R
(c) $\frac{R}{4}$ (d) $\frac{R}{2}$

[*Ans.* (c) $\frac{R}{4}$]

Hint: 1. $P = \frac{V^2}{R}$; 2. $R = \frac{V^2}{P}$

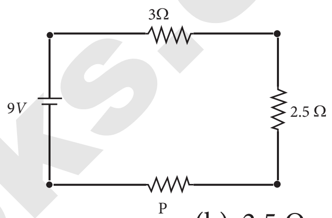
9. **In a large building, there are 15 bulbs of 40W, 5 bulbs of 100W, 5 fans of 80W and 1 heater of 1kW are connected. The voltage of electric mains is 220V. The maximum capacity of the main fuse of the building will be** *(IIT-JEE 2014)*

(a) 14 A (b) 8 A
(c) 10 A (d) 12 A

[*Ans.* (d) 12 A]

Hint: $P = VI \Rightarrow \frac{V}{P}$

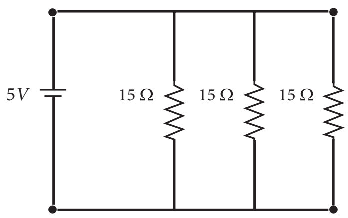
10. **There is a current of 1.0 A in the circuit shown below. What is the resistance of P ?** *[PTA-3]*



(a) 1.5 Ω (b) 2.5 Ω
(c) 3.5 Ω (d) 4.5 Ω

[*Ans.* (c) 3.5 Ω]

11. **What is the current drawn out from the battery?**



(a) 1A (b) 2A
(c) 3A (d) 4A

[*Ans.* (a) 1A]

12. **The temperature coefficient of resistance of a wire is 0.00125 per °C. At 20°C, its resistance is 1 Ω. The resistance of the wire will be 2 Ω at** *[FRT, July-'22]*

(a) 800 °C (b) 700 °C
(c) 850 °C (d) 820 °C

[*Ans.* (d) 820 °C]

Hint:
Given = $R_2 = 2\,\Omega$; $R_1 = 2\,\Omega$; $t_1 = 20\,°C$; $t_2 = ?$
$\alpha = 0.00125 / °C$
$R_2 = R_1 (1 + \alpha \Delta t)$; $2 = 1 (1 + 0.00125 \Delta t)$
$= 1 + 0.00125\ \Delta t$; $\therefore \Delta t = \frac{1}{0.00125} = 800$
$\Delta t = t_2 - t_1$
$\therefore \Delta t_2 = \Delta t + t_1 = 800 + 20 = 820$

13. **The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is** *[PTA-4; Aug. 2020]*
(a) 0.2 Ω (b) 0.5 Ω
(c) 0.8 Ω (d) 1.0 Ω
[**Ans.** (b) 0.5 Ω]

Hint:	Resistivity α temperature for current and Resistivity α $\frac{1}{\text{Temperature for semiconductor}}$

14. **A piece of copper and another of germanium are cooled from room temperature to 80 K. The resistance of** *[FRT-'22]*
(a) each of them increases
(b) each of them decreases
(c) copper increases and germanium decreases
(d) copper decreases and germanium increases
[**Ans.** (d) copper decreases and germanium increases]

15. **In Joule's heating law, when R and *t* are constant, if the H is taken along the y axis and I^2 along the *x* axis, the graph is** *[PTA-2; QY-2019]*
(a) straight line (b) parabola
(c) circle (d) ellipse
[**Ans.** (a) straight line]

II. Short Answer Questions :

1. **Why current is a scalar?**

Ans. Current has both magnitude and direction. But the direction of current does not obey vector laws of addition. So, current is a scalar quantity.

2. **Define current density.**

Ans. The current density (J) is defined as the current per unit area of cross section of the conductor.

$$J = \frac{1}{A}$$

The S.I unit of current density is $\frac{A}{m^2}$ (or) Am^{-2}

3. **Distinguish between drift velocity and mobility.** *[HY-2019]*

Ans.

	Drift velocity	Mobility
i.	The drift velocity is the average velocity acquired by the electrons inside the conductor when it is subjected to an electric field.	Mobility of an electron is defined as the magnitude of the drift velocity per unit electric field.
ii.	$\vec{V}_d = \vec{a}_\tau$	$\mu = \frac{e\tau}{m}$ or $\mu = \frac{\lvert\vec{V}_d\rvert}{\lvert\vec{E}\rvert}$
iii.	It's unit is ms^{-1}	It's unit is $m^2 V^{-1} s^{-1}$

4. **State microscopic form of Ohm's law.**

Ans. $\vec{J} = \sigma\vec{E}$ J is the current density, E is the Electric Field, σ is the conductivity. where $\sigma = \frac{ne^2\tau}{m}$

5. **State macroscopic form of Ohm's law.**

Ans. V = IR, V is the potential difference, I is the current and R is the resistance across the given conductor.

6. **What are ohmic and non ohmic devices?**

Ans.

Ohmic Devices	Non Ohmic Devices
Materials for which the current versus voltage graph is a straight line through the origin, are said to obey Ohm's law and their behaviour is said to be ohmic.	Materials or devices that do not follow Ohm's law are said to be non-ohmic.

7. **Define electrical resistivity.** *[QY-2019; May-2022]*

Ans. Electrical resistivity of a material is defined as the resistance offered to current flow by a conductor of unit length having unit area of cross section.

$\rho = \frac{RA}{L}$. Unit : ohm-metre (Ω m)

8. **Define temperature coefficient of resistance.** *[PTA-4]*

Ans. It is defined as the ratio of increase in resistivity per degree rise in temperature to its resistivity at T_0.

$\alpha = \frac{\Delta\rho}{\rho_0\Delta T}$. Its unit is per ^0C

9. **Write a short note on superconductors.**

Ans. The resistance of certain materials become zero below certain temperature T_c. This temperature is known as critical temperature or transition temperature. The materials which exhibit this property are known as superconductors.

2. If an electric field of magnitude 570 NC^{-1}, is applied in the copper wire, find the acceleration experienced by the electron. *[Sep-2020]*

Sol.: Acceleration, $a = \frac{qE}{m}$

Electric field intensity, E = 570 NC^{-1}

We know. each electron has a charge $q = 1.6 \times 10^{-19}$ coulombs

Mass of an electron, $m = 9.1 \times 10^{-31}$ kg

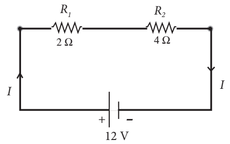
$$\therefore a = \frac{570 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}} = \frac{912 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$= \mathbf{100.2 \times 10^{12}\ m/s^2}$

3. What is thermistor? *[FRT-'22]*

Ans. A semiconductor with a negative temperature coefficient of resistivity is called a thermistor.

4. Calculate the equivalent resistance for the circuit which is connected to 12 V battery and also find the potential difference across 2Ω and 4Ω resistors in the circuit. *[July-'22]*



Sol. Since the resistors are connected in series, the effective resistance in the circuit

$= 2\ \Omega + 4\ \Omega = 6\ \Omega$

current I in the circuit $= \frac{V}{R_{eq}} = \frac{12}{6} = 2.0$ A

Voltage across 2Ω resistor

$V_1 = IR_1 = 2.0\ A \times 2\ \Omega = 4$ V

Voltage across 4 Ω resistor

$V_2 = IR_2 = 2.0\ A \times 4\ \Omega = 8$ V

SHORT ANSWER QUESTIONS — 3 MARKS

1. Obtain a relation between current and drift velocity. *[May-2022]*

Ans. The drift velocity of the electrons = v_d

If the electrons move through a distance dx within a small interval of dt, then

$$v_d = \frac{dx}{dt}; \quad dx = v_d\, dt \quad ...(1)$$

Since A is the area of cross section of the conductor, the electrons available in the volume of length dx is = volume × number of electrons per unit volume

$= A dx \times n$ ...(2)

Substituting for dx from equation (1) in (2)

$= (A\, v_d\, dt)\, n$

Total charge in the volume element dQ = (charge) × (number of electrons in the volume element)

$dQ = (e)(A\, v_d dt)\, n$

Hence the current $I = \frac{dQ}{dt}$; $I = ne A v_d$ ...(3)

LONG ANSWER QUESTIONS — 5 MARKS

1.* A Copper wire of cross-sectional area 0.5 mm^2 carries a current of 0.2 A. If the free electron density of copper is $8.4 \times 10^{28}\ m^{-3}$ then compute the drift velocity of free electrons. *[Aug-2021]*

Sol. The relation between drift velocity of electrons and current in a wire of cross sectional area A is

$$v_d = \frac{I}{neA}$$

$$= \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}}$$

$$= 0.03 \times 10^{-3} ms^{-1}$$

* Part of 5 marks question

ADDITIONAL QUESTIONS AND ANSWERS

CHOOSE THE CORRECT ANSWER — 1 MARK

1. The colour code on a carbon resistor is red - red - black. The resistance of the resistor is?

(a) 2.2 Ω (b) 22 Ω

(c) 220 2.2 Ω (d) 2.2 k Ω

[Ans. (b) 22 Ω]

2. The electrical resistivity of a thin copper wire and a thick copper wire are respectively P_1 Ω m and P_2 Ω m. Then

(a) $P_1 > P_2$ (b) $P_2 > P_1$

(c) $P_1 = P_2$ (d) $\frac{P_1}{P_2}$ **[Ans. (c) $P_1 = P_2$]**

Hint: Resistivity is not α structure of the material

3. When 'n' resistors of equal resistance (R) are connected in series and in parallel respectively, then the ratio of their effective resistance is

(a) $1 : n^2$ (b) $n^2 : 1$

(c) $n : 1$ (d) $1 : n$ **[Ans. (b) $n^2 : 1$]**

Hint: $R_s = nR$

$R_p = \frac{R}{n}$ $\quad \frac{R_s}{R_p} = \frac{nR}{\frac{R}{n}} = \frac{n^2}{1}$

$\therefore R_s : R_p = n^2 : 1$

4. Which of the following has negative temperature coefficient of resistance?
(a) copper (b) tungsten
(c) carbon (d) silver **[Ans. (c) carbon]**

5. The temperature co-efficient of resistance for alloys is
(a) low (b) very low
(c) high (d) very high **[Ans. (a) low]**

6. Which of the following material has the highest specific resistance?
(a) rubber (b) silver
(c) germanium (d) glass
[Ans. (a) rubber]

7. An electron gun in a TV shoots out a beam of electrons. The beam current is 10μ A. The charge that strikes the screen in 1 minute is
(a) + 600 μC (b) – 600 μC
(c) + 10 μC (d) – 10 μC
[Ans. (b) – 600 μC]

Hint: $q = It$
$= 10 \times 10^{-6} \times 60 = -600\ \mu C$

8. If the specific resistance of a potentiometer wire is 10^{-7} Ωm and current flowing through it is 0.1 amp, cross - sectional area of wire is 10^{-6} m², then potential gradient will be
(a) 10^{-2} v/m (b) 10^{-4} v/m
(c) 10^{-6} v/m (d) 10^{-8} v/m
[Ans. (a) 10^{-2} v/m]

Hint:

Potential gradient $= \frac{V}{l} = \frac{IR}{l}$

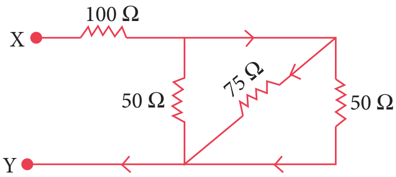
We know that, $R = \frac{\rho l}{A}$ $\therefore \frac{R}{l} = \frac{\rho}{A}$

$\therefore \frac{V}{l} = I \times \frac{\rho}{A} = \frac{0.1 \times 10^{-7}}{10^{-6}} = 10^{-2}$ V/m

9. Temperature co-efficient of resistance for metals is
(a) constant (b) positive
(c) zero (d) negative
[Ans. (b) positive]

10. A metallic block has no potential difference applied across it, then the mean velocity of free electrons is
(a) proportional to T
(b) proportional for $\sqrt{T}$
(c) finite but independent of temperature
(d) zero **[Ans. (d) zero]**

11. In an electrical arrangement as shown the equivalent resistance between X and Y will be



(a) 158.75 Ω (b) 118.75 Ω
(c) 218 .75 Ω (d) 318.75 Ω
[Ans. (b) 118.75 Ω]

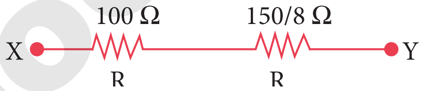
Hint:

Let $R_1 = 50\Omega$, $R_2 = 75\Omega$, $R_3 = 50\Omega$, $R_4 = 100\Omega$

Here R_1, R_2, R_3 are parallel $\therefore \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_p} = \frac{1}{50} + \frac{1}{75} + \frac{1}{50} = \frac{8}{150}$

$R_p = \frac{150}{8}\ \Omega$



(Both are in series)

$R_s = 100 + \frac{150}{8} = R_4 + R_p$

Equivalent $R_s = 118.75\ \Omega$ resistance

12. The emf of a battery is 3 volts and internal resistance 0.125 Ω . The difference of potential at the terminal of battery when connected across an external resistance of 1 Ω is
(a) 1.67 V (b) 0.67 V
(c) 2.67 V (d) 3.67 V
[Ans. (c) 2.67 V]

Hint:

$r = 0.125\ \Omega$, $R = 1\ \Omega$
$\varepsilon = 3V$, $V = ?$

Internal resistance,

$r = \frac{(\varepsilon - V)R}{V} \Rightarrow Vr = \varepsilon R - VR$

$Vr + VR = \varepsilon R$

$V(r + R) = \varepsilon R$

$V = \frac{\varepsilon R}{r + R}$

$V = \frac{3 \times 1}{1 + 0.125} = \frac{3}{1.125}$

$= 2.67$ V.

CURRENT ELECTRICITY

13. A square aluminum rod is 1 m long and 5 mm on edge. What must be the radius of another aluminum rod whose length is 1 m and which has the same resistance as that of square Aluminum rod?

(a) 1.4 mm (b) 2.8 mm
(c) 4.2 mm (d) 5.6 mm

[Ans. (b) 2.8 mm]

Hint:

First rod length $\rightarrow l$; Second rod length $\rightarrow l'$
First rod radius $\rightarrow r$; First rod radius $\rightarrow r'$
Here $l = l_1 = 1$ m
As both have the same material, so same registivity, $P = P' \Rightarrow R = R'$

$$\Rightarrow \frac{pl}{A} = \frac{p'l'}{A'} \quad \Rightarrow \quad \frac{1}{A} = \frac{1}{A'}$$

$$\Rightarrow A' = A$$

$$\Rightarrow \pi r^2 = 5 \times 5 \times 10^{-6}$$

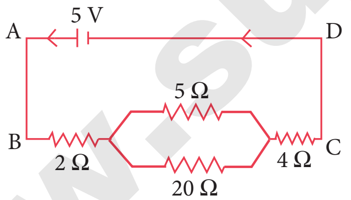
$$r^2 = \frac{25 \times 10^{-6}}{\pi}$$

$$r = \frac{5 \times 10^{-3}}{\sqrt{3.14}} = 2.82 \times 10^{-3} \text{ m} = 2.82\text{mm.}$$

14. Four resistances are connected to a 5V battery of negligible internal resistance as shown what is the potential across 2Ω ?

(a) 0.5 V (b) 1.5 V
(c) 1.0 V (d) 2.0 V

[Ans. (c) 1.0 V]

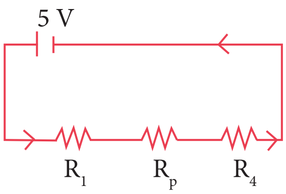


Hint: Let $R_1 = 2\Omega$, $R_2 = 5\Omega$, $R_3 = 20\Omega$, $R_4 = 4\Omega$ & $V = 5V$

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{20} = \frac{20+5}{100} = \frac{25}{100}$$

$$\frac{1}{R_p} = \frac{1}{4} \Rightarrow Rp = 4\Omega$$



$\therefore R_s = R_1 + R_p + R_4$

$R_s = 2 + 4 + 4 = 10\Omega$

$$\therefore I = \frac{V}{R_s}$$

$$I = \frac{5}{10} = \frac{1}{2} A$$

$\therefore$ Potential across 2Ω is

$$V_{R_1} = \frac{1}{2} \times 2 = 1V. \quad [\because V_{R_1} = I_{R_1}]$$

15. An unknown resistance is connected in parallel with a 15Ω resistance and a 12 V battery. What is the value of the unknown resistance if the current in the circuit is 2A?

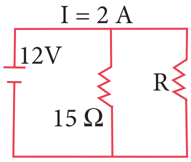
(a) 10 Ω (b) 20 Ω
(c) 30 Ω (d) 40 Ω

[Ans. (a) 10 Ω]

Hint:

$$\frac{1}{R_p} = \frac{1}{15} + \frac{1}{R} \Rightarrow \frac{R+15}{15R}$$

$$R_p = \frac{15R}{15+R}$$



$$V = IR_p$$

$$12 = 2 \times \frac{15R}{15+R} = \frac{30R}{15+R}$$

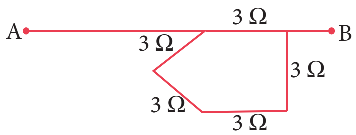
$12(15 + R) = 30R$; $180 + 12R = 30R$
$180 = 30R - 12R$; $180 = 18R$
$R = 10\ \Omega$

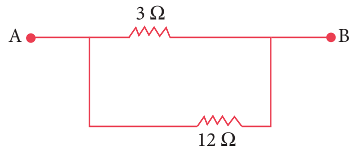
16. Five 3 Ω resistances are arranged in a polygon (5 sides). What is the resistance between any two corners?

(a) 2.4 Ω (b) 3 Ω (c) 9 Ω (d) 5 Ω

Hint:

[Ans. (a) 2.4 Ω]





$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{12} = \frac{4+1}{12} = \frac{5}{12}$$

$$R_p = \frac{12}{5} = 2.4\ \Omega$$

17. How many 160 Ω resistor in parallel are required to carry a current of 5 A on a 100 V line?

(a) 2 (b) 4 (c) 6 (d) 8

[Ans. (d) 8]

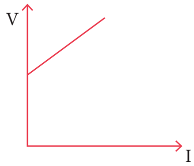
Hint: $R_p = \frac{V}{I} = \frac{100}{5} = 20\ \Omega$

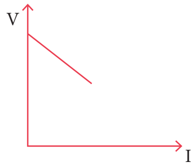
Also $R_p = \frac{R}{n}$

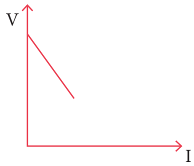
$20 = \frac{R}{n} \Rightarrow n = \frac{R}{20} = \frac{160}{20}$

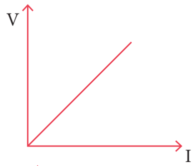
$\therefore n = 8.$

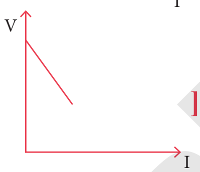
18. The potential difference across the terminals of a cell varies with the current drawn from the cell according to the graph.

(a) 

(b) 

(c) 

(d) 

[*Ans.* (c) ]

19. In an experiment with potentiometer when the galvanometer deflection is zero, then no current flows in

(a) the wire of potentiometer
(b) the primary circuit
(c) the galvanometer circuit
(d) accumulator cell

[*Ans.* (c) the galvanometer circuit]

20. Kirchoff's I law i.e. Σi= 0, at a junction, deals with the conservation of

(a) charge (b) energy
(c) momentum
(d) angular momentum [*Ans.* (a) charge]

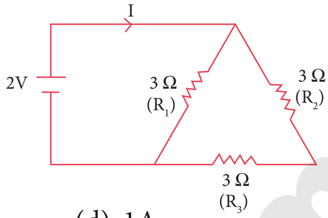
21. The potential gradient of the potentiometer wire depends on

(a) only on the current that flows
(b) only on the resistance per unit length of the wire
(c) both the above mentioned
(d) none of the above

[*Ans.* (c) both the above mentioned]

Hint: $\varepsilon = Irl ; \frac{\varepsilon}{l} = Ir$

22. The current in the given circuit is



(a) $\frac{1}{8}$ A
(b) $\frac{2}{9}$ A
(c) $\frac{2}{3}$ A (d) 1A

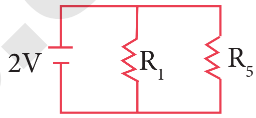
[*Ans.* (d) 1A]

Hint: $R_s = R_2 + R_3 = 3 + 3 = 6\Omega$

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_s} = \frac{1}{3} + \frac{1}{6} = \frac{6+3}{18}$

$R_p = \frac{18}{9} = 2\ \Omega$

$I = \frac{V}{R_p} = \frac{2}{2} = 1\ A.$



23. Resistance increases with increase in temperature for

(a) conductor (b) semiconductors
(c) insulators (d) superconductor

[*Ans.* (a) conductor]

24. Which of the following is identical?

(a) germanium, silicon
(b) silver, wood
(c) aluminum, constantan
(d) bakelite, iron

[*Ans.* (a) germanium, silicon]

25. A potential difference is applied on the ends of a metallic wire. If the potential difference is doubled, the drift velocity

(a) will be doubled
(b) will be halved
(c) will be quadrupled
(d) will remain unchanged

[*Ans.* (a) will be doubled]

Hint: $I = nAev_d$

$v_d = \frac{I}{nAe}$ $[\because I = \frac{V}{R}]$

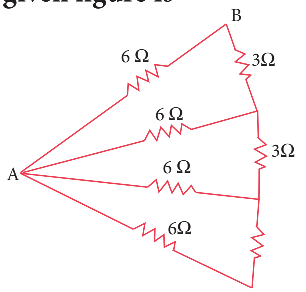
$v_d = \frac{V}{nAeR}$

$\Rightarrow v_d$ is directly proportional to V.

$\therefore$ If V is doubled v_d is also doubled.

CURRENT ELECTRICITY

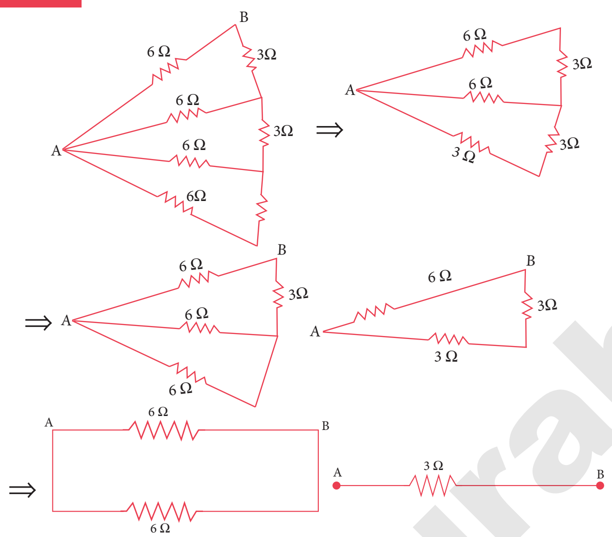
26. **Resistance between the points A and B in the given figure is**



(a) 9 Ω (b) 2 Ω (c) 3 Ω (d) 6 Ω

[*Ans.* (c) 3 Ω]

Hint:



27. **Conductors which obey ohm's law are called .**

(a) dielectrics (b) superconductors
(c) ohmic conductors (d) semiconductors

[*Ans.* (c) ohmic conductors]

28. **A bird sitting on an insulated wire carrying a current feels quite safe because.**

(a) the bird is a non-conductor of electricity
(b) resistance of the bird is very large
(c) there is a large potential difference between bird and wire
(d) there is no potential difference between bird and wire

[*Ans.* (d) there is no potential difference between bird and wire]

29. **Conductivity is the reciprocal of**

(a) resistance (b) specific resistance
(c) conductance
(d) potential difference

[*Ans.* (b) specific resistance]

30. **Electrical resistance is given by**

(a) $R = \frac{Al}{\sigma}$ (b) $R = \frac{l}{\sigma A}$
(c) $R = \frac{\sigma A}{l}$ (d) $R = \frac{\sigma}{Al}$

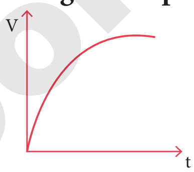
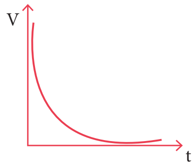
[*Ans.* (b) $R = \frac{l}{\sigma A}$]

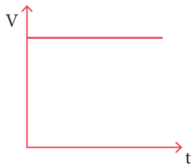
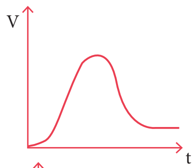
31. **Nichrome wire is used as the heating element because it has**

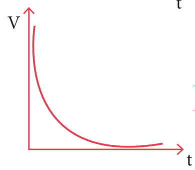
(a) low specific resistance
(b) low melting point
(c) high specific resistance
(d) high conductivity

[*Ans.* (c) high specific resistance]

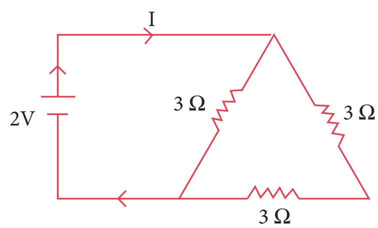
32. **An ideal cell is connected to a capacitor through a voltmeter. The reading V of the voltmeter is plotted against time. Which of the following best represents the resulting curve?**

(a)  (b) 

(c)  (d) 

[*Ans.* (b) ]

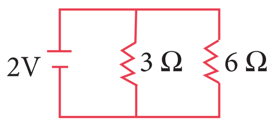
33. **The value of current I in the network as shown is**



(a) $\frac{1}{9}$ A (b) $\frac{2}{9}$ A (c) $\frac{3}{9}$ A (d) 1A

[*Ans.* (d) 1A]

Hint:



Very Short Answer Questions 2 Marks

1. Define current.

Ans. current is equal to rate of flow of net charge $I = \frac{Q}{t}$

2. Define instantaneous current.

Ans. The instantaneous current I is defined as the limit of the average current, $\Delta t \to 0$.

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

3. Define Ampere.

Ans. 1 ampere of current is equivalent to 1 coulomb of charge passing through a perpendicular cross section in a conductor in one second.

4. Define Mean free time τ.

Ans. The average time between successive collisions is called the mean free time denoted by τ.

5. Why are household appliances connected in parallel?

Ans. House hold appliances are always connected in parallel so that even if one is switched off, the other devices could function properly.

6. What is the function of Electric fuses?

Ans. Fuses are connected in series in a circuit to protect the electric devices from the heat developed by the passage of excessive current. It is a short length of a wire made of a low melting point material. It melts and breaks the circuit if current exceeds a certain value. Lead and copper wire melts and burns out when the current increases above 5 A and 35 A respectively.

7. What are free electrons?

Ans. Atoms in metals have one or more electrons which are loosely bound to the nucleus. These electrons are called free electrons and can be easily detached from the atoms by applying small energy.

8. What is conductor?

Ans.
(i) The substances which have an abundance of free electrons are called conductors.
(ii) These free electrons move randomly throughout the conductor at a given temperature.
(iii) In general due to this random motion, there is no net transfer of charges from one end of the conductor to other end and hence no current.
(iv) When a potential difference is applied by the battery across the ends of the conductor, the free electrons drift towards the positive terminal of the battery, producing a net electric current.

9. What is meant by conventional current?

Ans. By convention, the flow of current in the circuit should be from the positive terminal of the battery to the negative terminal. This current is called the conventional current or simply current and is in the direction in which a positive test charge would move.

10. Define resistance.

Ans. The resistance is the ratio of potential difference across the given conductor to the current passing through the conductor.
It's unit is ohm (Ω) $R = \frac{V}{I}$

11. What is the effective resistance of resistors connected in series?

Ans. When several resistors are connected in series, the total or equivalent resistance is the sum of the individual resistances.

$$R_s = R_1 + R_2 + ...+R_n$$

12. Is the direction of current along the direction of flow of electrons?

Ans. No, Electrons flow from negative potential to positive potential. But the direction of conventional current is from positive potential to negative potential.

13. The resistivity of materials depends upon what parameters?

Ans. The resistivity of materials is
(i) inversely proportional to the number density (n) of the electrons
(ii) inversely proportional to the average time between the collisions (τ).

14. Define electric energy and state its commercial units.

Ans. The total electrical energy used by any device is obtained by multiplying the power and duration of the time when it is ON. Unit of the energy will be in joules. (or) watt second. Electrical energy is measured in kilowatt hour (kWh). 1 kWh is known as 1 unit of electrical energy. (1 kWh = 1000 Wh = (1000 W) (3600 s), 1 kWh = 3.6×10^6 J).

15. What does the voltage rating refers? What is it's use?

Ans. Voltage rating refers AC RMS voltages. For a given bulb, if the voltage drop across the bulb is greater than voltage rating, the bulb will fuse.

16. Is battery a source of electrons?

Ans. No. Battery is a source of electrical energy, due to which the electrons in the conducting wire flow in a particular direction.

17. Define the term electric power and give its SI unit.

Ans. The electrical power P is the rate at which the electrical potential energy is delivered,

$$P = \frac{dU}{dt} = \frac{(V.dQ)}{dt} = V\frac{dQ}{dt} \quad ...(1)$$

Since the electric current $I = \frac{dQ}{dt}$

So the equation (1) can be rewritten as

$$P = VI$$

This expression gives the power delivered by the battery to any electrical system, where I is the current passing through it and V is the potential difference across it. The SI unit of electrical power is watt.

18. What do you mean by a series combination of cells?

Ans. Several cells can be connected to form a battery. In series connection, the negative terminal of one cell is connected to the positive terminal of the second cell, the negative terminal of second cell is connected to the positive terminal of the third cell and so on. The free positive terminal of the first cell and the free negative terminal of the last cell become the terminals of the battery.

19. What do you mean by parallel combination of cells?

Ans. In parallel connection all the positive terminals of the cells are connected to one point and all the negative terminals to a second point. These two points form the positive and negative terminals of the battery.

20. State the sign convention for applying Kirchhoff's first rule.

Ans. The charges that enter a given junction in a circuit must leave that junction since charge cannot build up or disappear at a junction. Current entering the junction is taken as positive and current leaving the junction is taken as negative.

21. Explain sign convention for applying Kirchhoff's second rule.

Ans. Second rule follows from the law of conservation of energy for an isolated system (The energy supplied by the emf sources is equal to the sum of the energy delivered to all resistors). The product of current and resistance is taken as positive when the direction of the current is followed. Suppose if the direction of current is opposite to the direction of the loop, then product of current and voltage across the resistor is negative. The emf is considered positive when proceeding from the negative to the positive terminal of the cell.

22. What do you mean by end resistance? How can it be rectified?

Ans. The bridge wire is soldered at the ends of the copper strips. Due to imperfect contact (P, Q), some resistance might be introduced at the contact. These are called end resistances. This error can be eliminated, if another set of readings are taken with P and Q interchanged and the average value of P is found.

23. What is meant by Heating effect of electric current?

Ans. When current flows through a resistor, some of the electrical energy delivered to the resistor is converted into heat energy and it is dissipated. This heating effect of current is known as Joule's heating effect.

24. What is thermoelectric effect?

Ans. Current produces thermal energy but thermal energy may also be suitably used to produce an electromotive force. This is known as thermoelectric effect.

25. Discuss some appliances of Joule's heating effect. Name few electric heating devices & state on what principle do they work.

Ans. Electric iron, electric heater, electric toaster are some of the home appliances that utilize the heating effect of current.

In these appliances, the heating elements are made of nichrome, an alloy of nickel and chromium. Nichrome has a high specific resistance and can be heated to very high temperatures without oxidation. These are all working on the principle of joule's heating effect.

26. Why nickel is used as heating element?

Ans. The heating elements are made of nichrome, an alloy of nickel and chromium. Nichrome has a high specific resistance and can be heated to very high temperatures without oxidation.

27. What is the disadvantage of electric fuse?

Ans. The only disadvantage with the fuses is that once fuse wire is burnt due to excessive current, they need to be replaced. Nowdays in house, circuit breakers (trippers) are used instead of fuses. Whenever there is an excessive current produced due to faulty wire connection, the circuit breaker switch opens. After repairing the faulty connection, we can close the circuit breaker switch.

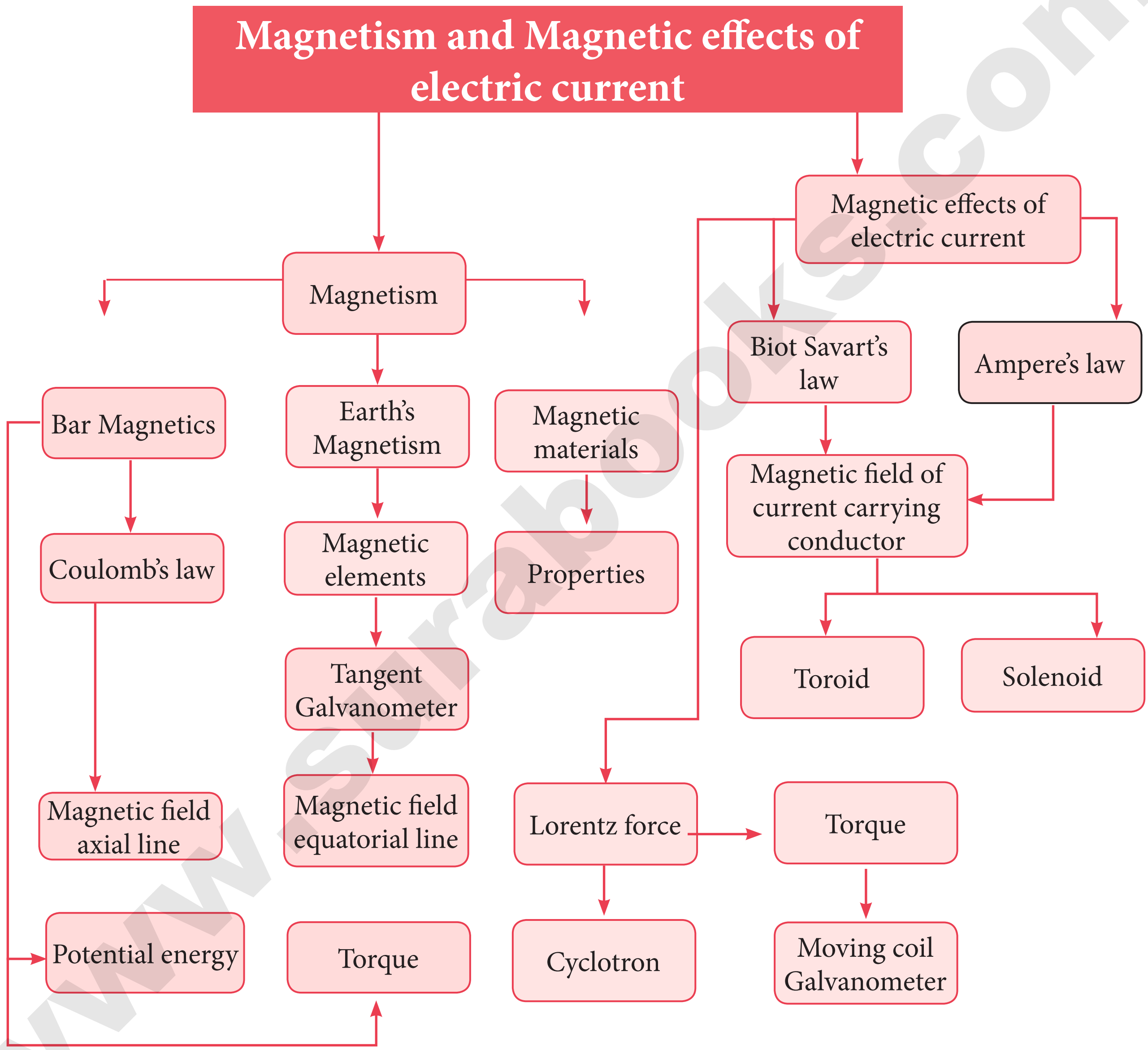
28. What is the use of electric furnace?

Ans. Furnaces are used to manufacture a large number of technologically important materials such as steel, silicon carbide, quartz, gallium arsenide, etc). To produce temperatures up to 1500°C, molybdenum-nichrome wire wound on a silica tube is used. Carbon arc furnaces produce temperatures up to 3000 °C.

UNIT 3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

CHAPTER SNAPSHOT

CONCEPT MAP


Magnetism and Magnetic effects of electric current
Magnetism
Magnetic effects of electric current
Bar Magnetics
Earth's Magnetism
Magnetic materials
Biot Savart's law
Ampere's law
Coulomb's law
Magnetic elements
Properties
Magnetic field of current carrying conductor
Tangent Galvanometer
Toroid
Solenoid
Magnetic field axial line
Magnetic field equatorial line
Lorentz force
Torque
Potential energy
Torque
Cyclotron
Moving coil Galvanometer

MUST KNOW DEFINITIONS

Maxwells's right hand cork screw rule	:	If a right handed cork screw is rotated to advance along the direction of the current through a conductor, then the direction of rotation of the screw gives the direction of the magnetic lines of force around the conductor.
Biot - Savart Law	:	The magnetic induction dB at a point P due to the element of length *dl* is directly proportional to the current (I) and length *dl*. Directly proportional to the sine of the angle between *dl* and the line joining the element *dl* and the point P (sinθ) inversely proportional to the square of the distance of the point from the element $\left(\frac{1}{r^2}\right)$. $dB = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2}$
Tangent galvanometer	:	It is a device used to measure current. It works on the principle of tangent law.
Tangent law	:	It states that a magnetic needle suspended at a point where there are two crossed fields at right angles to each other, will come to rest in the direction of the resultant of the two fields. $B = B_h \tan\theta$
Ampere's circuital law	:	It states that the line integral $\oint \vec{B} . \vec{dl}$ for a closed curve is equal to μ_0 times the net current I_0 through the area bounded by the curve.
Right hand palm rule	:	The coil is held in the right hand so that the fingers point in the direction of the current in the windings. The extended thumb, points in the direction of magnetic field. This is applied for solenoid to find the direction of 'B'
End rule	:	When looked from one end, if the current through the solenoid is along clockwise direction, the nearer end corresponds to south pole and the other end is north pole. When looked from one end, if the current through the solenoid is along anticlockwise direction, the nearer end corresponds to north pole and the other end is south pole.
Magnetic Lorentz force	:	The force experienced by a charged particle moving inside a magnetic field. $F = q(\vec{v} \times \vec{B}) = Bqv\sin\theta$
Cyclotron	:	Device used to accelerate charged particles to high energies. It works on the principle that a charged particle moving normal to a magnetic field experiences a magnetic Lorentz force due to which the particle moves in a circular path.
Fleming's left hand rule	:	The forefinger, the middle finger and the thumb of the left hand are stretched in mutually perpendicular directions. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of current, then the thumb points in the direction of the force on the conductor.

Ampere	:	It is defined as that constant current which when flowing through two parallel infinitely long straight conductors of negligible cross section, and placed in air or vacuum at a distance of one metre apart, experience a force of 2×10^{-7} newton per unit length of the conductor.
Moving coil galvanometer	:	It is a device used for measuring the current in a circuit. It works on the principle that a current carrying coil placed in a magnetic field experiences a torque.
Current sensitivity of a galvanometer	:	It is defined as the deflection produced when unit current passes through the galvanometer. A galvanometer is said to be sensitive if it produces large deflection for a small current.
Voltage sensitivity of a galvanometer	:	It is defined as the deflection per unit voltage applied. Shunt is a low resistance connected in parallel with the galvanometer. Ideal ammeter has zero resistance. Ideal voltmeter offers infinite resistance to current.
Ampere's hypothesis	:	It states that all magnetic phenomena is due to circulating electric current.
Magnetic moment of a current loop	:	It is defined as the product of the current and the loop area. $P_m = IA$ Its direction is perpendicular to the plane of the loop. Magnetic moment of electron. It is the vector sum of the orbital magnetic moment and its spin magnetic moment.
Bohr magneton	:	Minimum value of magnetic moment.

Unit 3

FORMULAE

(1) **Biot Savart law**

In vector form $d\vec{B} = \frac{\mu_o}{4\pi}\frac{I\vec{dl}\times\hat{r}}{r^2}$; In air, $dB = \frac{\mu_o}{4\pi}\frac{I.\,dl\sin\theta}{r^2}$

(2) Magnetic induction due to infinitely long straight conductor carrying current $B = \frac{\mu_o I}{2\pi a}$. In medium, $B = \frac{\mu I}{2\pi a}$ (or) $\vec{B} = \frac{\mu_0 I}{2\pi a}\hat{n}$ (in vector form)

(3) Magnetic induction along the axis of a circular coil carrying current $B = \frac{\mu_0 IR^2}{2\pi(R^2+z^2)^{\frac{3}{2}}}\times k$ at the centre $B = \frac{\mu_0 I}{2R}$

(4) Tangent galvanometer reduction factor $k = \frac{2kB_H}{\mu_0 N}$

(5) Current I through n turns of Tangent Galvanometer $I = \frac{2RB_h}{\mu_0 N} = K\tan\theta$

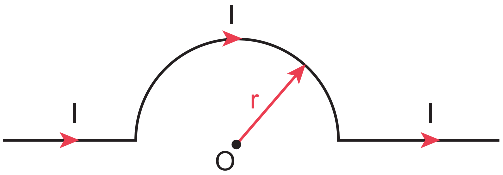
(6) (a) Ampere's circuital law $\oint \vec{B}\,.\,\vec{dl} = \mu_0 I_{enclosed}$.

(b) Magnetic field due to infinitely long current carrying wire using ampere's law $\vec{B} = \frac{\mu_0 I}{2\pi r}\hat{n}$

Evaluation

I. Multiple choice questions

1. The magnetic field at the center O of the following current loop is *[PTA-2]*



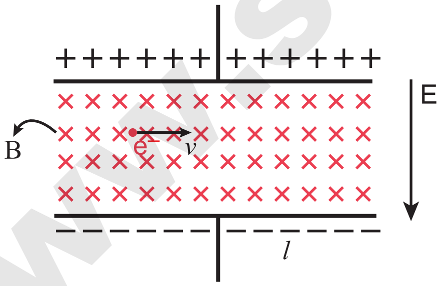
(a) $\frac{\mu_0 I}{4r}\otimes$ (b) $\frac{\mu_0 I}{4r}\odot$

(c) $\frac{\mu_0 I}{2r}\otimes$ (d) $\frac{\mu_0 I}{2r}\odot$

[Ans. (a) $\frac{\mu_0 I}{4r}\otimes$]

Hint: $B = \frac{\mu_0 I}{2\pi R}$; Here $R = \frac{2r}{\pi}$

2. An electron moves in a straight line inside a charged parallel plate capacitor of uniform charge density σ. The time taken by the electron to cross the parallel plate capacitor undeflected when the plates of the capacitor are kept under constant magnetic field of induction $\vec{B}$ is



(a) $\varepsilon_0 \frac{elB}{\sigma}$ (b) $\varepsilon_0 \frac{lB}{\sigma l}$

(c) $\varepsilon_0 \frac{lB}{e\sigma}$ (d) $\varepsilon_0 \frac{lB}{\sigma}$

[Ans. (d) $\varepsilon_0 \frac{lB}{\sigma}$]

Hint: $F = BIl$

3. A particle having mass m and charge q accelerated through a potential difference V. Find the force experienced when it is kept under perpendicular magnetic field $\vec{B}$. *[Mar-2020; Aug-2021]*

(a) $\sqrt{\frac{2q^3BV}{m}}$ (b) $\sqrt{\frac{q^3B^2V}{2m}}$

(c) $\sqrt{\frac{2q^3B^2V}{m}}$ (d) $\sqrt{\frac{2q^3BV}{m^3}}$

[Ans. (c) $\sqrt{\frac{2q^3B^2V}{m}}$]

Hint: Horentz force $F = q = \left(\vec{V}\times\vec{B}\right)$

4. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly *[PTA-3; FRT, July-'22]*

(a) 1.0 A m^2 (b) 1.2 A m^2

(c) 0.5 A m^2 (d) 0.8 A m^2

[Ans. (b) 1.2 A m^2]

Hint: Dipole moment P = IA

5. A thin insulated wire forms a plane spiral of N = 100 tight turns carrying a current I = 8 m A (milli ampere). The radii of inside and outside turns are a = 50 mm and b = 100 mm respectively. The magnetic induction at the centre of the spiral is

(a) 5 μT (b) 7 μT

(c) 8 μT (d) 10 μT

[Ans. (b) 7 μT]

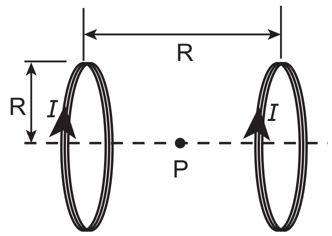
6. Three wires of equal lengths are bent in the form of loops. One of the loops is circle, another is a semi-circle and the third one is a square. They are placed in a uniform magnetic field and same electric current is passed through them. Which of the following loop configuration will experience greater torque? *[PTA-1, 3]*

(a) Circle (b) Semi-circle

(c) Square (d) All of them

[Ans. (a) Circle]

7. Two identical coils, each with N turns and radius R are placed coaxially at a distance R as shown in the figure. If I is the current passing through the loops in the same direction, then the magnetic field at a point P at a distance of $\frac{R}{2}$ from the centre of each coil is



(a) $\frac{8N\mu_0 I}{\sqrt{5}R}$ (b) $\frac{8N\mu_0 I}{5^{3/2}R}$

(c) $\frac{8N\mu_0 I}{5R}$ (d) $\frac{4N\mu_0 I}{\sqrt{5}R}$

[***Ans.*** (b) $\frac{8N\mu_0 I}{5^{3/2}R}$]

Hint: $B = \frac{\mu_0 I_2}{2\pi r}$

8. A wire of length l carrying a current I along the Y direction is kept in a magnetic field given by $\vec{B} = \frac{\beta}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})T$. The magnitude of Lorentz force acting on the wire is *[Govt. MQP-2019; May-2022]*

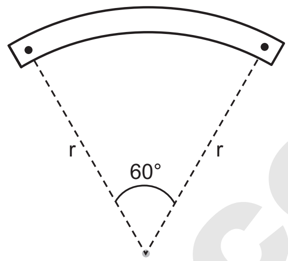
(a) $\sqrt{\frac{2}{3}}\beta I l$ (b) $\sqrt{\frac{1}{\sqrt{3}}}\beta I l$

(c) $\sqrt{2}\beta I l$ (d) $\sqrt{\frac{1}{2}}\beta I l$

[***Ans.*** (a) $\sqrt{\frac{2}{3}}\beta I l$]

Hint: Lorentz force $F = q = (\vec{V}\times\vec{B})$ and $\vec{B} = \left[\frac{B}{\sqrt{3}}(i+j+k)\tau\right]$

9. A bar magnet of length l and magnetic moment p_m is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be *(NEET 2013)*



(a) p_m (b) $\frac{3}{\pi}p_m$

(c) $\frac{2}{\pi}p_m$ (d) $\frac{1}{2}p_m$

[***Ans.*** (b) $\frac{3}{\pi}p_m$]

Hint: Magnetic moment $M = ml \Rightarrow l = \frac{\pi r}{3}$

$\therefore r = \frac{3l}{\pi}$ New moment $M' = m \times r$

10. A non-conducting charged ring carrying a charge of q, mass m and radius r is rotated about its axis with constant angular speed ω. Find the ratio of its magnetic moment with angular momentum is *[QY-2019]*

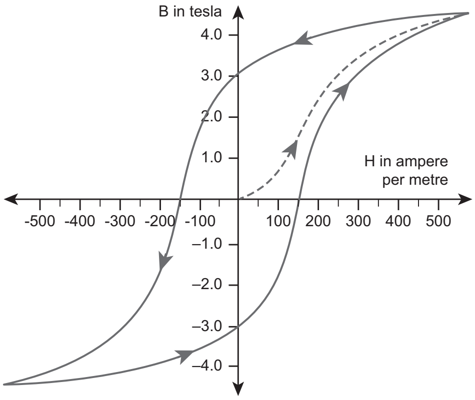
(a) $\frac{q}{m}$ (b) $\frac{2q}{m}$

(c) $\frac{q}{2m}$ (d) $\frac{q}{4m}$

[***Ans.*** (c) $\frac{q}{2m}$]

Hint: $\frac{M}{l} = \frac{e}{zm}$

11. The BH curve for a ferromagnetic material is shown in the figure. The material is placed inside a long solenoid which contains 1000 turns/cm. The current that should be passed in the solenonid to demagnetize the ferromagnet completely is



(a) 1.00 m A (b) 1.25 mA
(c) 1.50 mA (d) 1.75 mA

[*Ans.* (c) 1.50 mA]

Hint: $H = \frac{nI}{2r}$

12. Two short bar magnets have magnetic moments 1.20 Am² and 1.00 Am², respectively. They are kept on a horizontal table parallel to each other with their north poles pointing towards south. They have a common magnetic equator and are separated by a distance of 20.0 cm. The value of the resultant horizontal magnetic induction at the mid-point O of the line joining their centres is (Horizontal components of Earth's magnetic induction is 3.6×10^{-5} Wb m^{-2})

(NSEP 2000-2001)

(a) 3.60×10^{-5} Wb m^{-2}
(b) 3.5×10^{-5} Wb m^{-2}
(c) 2.56×10^{-4} Wb m^{-2}
(d) 2.2×10^{-4} Wb m^{-2}

[*Ans.* (c) 2.56×10^{-4} Wb m^{-2}]

13. The vertical component of Earth's magnetic field at a place is equal to the horizontal component. What is the value of angle of dip at this place?

[HY-2019]

(a) 30° (b) 45° (c) 60° (d) 90°

[*Ans.* (b) 45°]

Hint: $B \sin\theta = B \cos\theta$

14. A flat dielectric disc of radius R carries an excess charge on its surface. The surface charge density is σ. The disc rotates about an axis perpendicular to its plane passing through the centre with angular velocity ω. Find the magnitude of the torque on the disc if it is placed in a uniform magnetic field whose strength is B which is directed perpendicular to the axis of rotation

(a) $\frac{1}{4}\sigma\omega\pi BR$ (b) $\frac{1}{2}\sigma\omega\pi BR^2$
(c) $\frac{1}{4}\sigma\omega\pi BR^3$ (d) $\frac{1}{4}\sigma\omega\pi BR^4$

[*Ans.* (d) $\frac{1}{4}\sigma\omega\pi BR^4$]

15. The potential energy of magnetic dipole whose dipole moment is $\vec{p}_m = (-0.5\hat{i} + 0.4\hat{j})$ Am² kept in uniform magnetic field $\vec{B} = 0.2\hat{i}$ T.

(a) −0.1 J (b) −0.8 J
(c) 0.1 J (d) 0.8 J

[*Ans.* (c) 0.1 J]

Hint: $U = \vec{P}_m \cdot \vec{B}$

II. Short Answer Questions :

1. **What is magnetic field?**

Ans. The region surrounding magnet where magnetic pole of strength unity experience a force is known as magnetic field. It is a vector quantity and denoted by $\vec{B}$. Its unit is NA^{-1} m^{-1}.

2. **Define magnetic flux.**

Ans. The number of magnetic field lines crossing normally through a given area is called magnetic flux Φ_B.

$$\Phi_B = \vec{B}.\vec{A} = BA\cos\theta = B_\perp A$$

where θ is the angle between $\vec{B}$ and $\vec{A}$.

3. **Define magnetic dipole moment.**

Ans. The magnetic dipole moment is defined as the product of its pole strength and magnetic length.

$$\vec{P}_m = q_m \vec{d}$$

4. State Coulomb's inverse law.

Ans. The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them. Mathematically, we can write

$$\vec{F} \alpha \frac{q_{m_A} q_{m_B}}{r^2} \hat{r}$$

5. What is magnetic susceptibility?

Ans. Magnetic susceptibility is defined as the ratio of the intensity of magnetisation ($\vec{M}$) induced in the material to the magnetising field ($\vec{H}$)

$$\chi_m = \frac{|\vec{M}|}{|\vec{H}|}$$

6. State Biot-Savart's law.

Ans. The magnitude of magnetic field $d\vec{B}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies

(i) directly as the strength of the current I

(ii) directly as the magnitude of the length element $d\vec{l}$.

(iii) directly as the sine of the angle θ between $d\vec{l}$ and $\hat{r}$.

(iv) inversely as the square of the distance r between the point P and length element $d\vec{l}$.

This is expressed as $dB \alpha \frac{Idl}{r^2} \sin\theta$.

7. What is magnetic permeability?

Ans. The magnetic permeability can be defined as the measure of ability of the material to allow the passage of magnetic field lines through it or measure of the capacity of the substance to take magnetisation or the degree of penetration of magnetic field through the substance.

8. State Ampere's circuital law.

[PTA-4, 6; QY-2019; Sep-2020; Aug-2021]

Ans. **Ampère's law:** The line integral of magnetic field over a closed loop is μ_0 times net current enclosed by the loop.

$$\oint_C \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

9. Compare dia, para and ferro-magnetism.

[PTA-5 ; Sep-2020; QY-2019]

Ans.

	Dia magnetic materials	Para magnetic materials	Ferro magnetic materials
1.	Magnetic susceptibility is negative	Magnetic susceptibility is positive and small	Magnetic susceptibility is positive and large
2.	Relativbe permeability is slightly less than unity	Relative permeability is greater than unity	Relative permeability is large
3.	The magnetic field lines are repelled or expelled by diamagnetic materials when placed in a magnetic field	The magnetic field lines are attracted into paramagnetic materials when placed in a magnetic field	The magnetic field line are strongly attracted into the ferromagnetic materials when placed in a magnetic field
4.	Susceptibility is nearly temprature independent Ex : Bismuth, Copper and Water	Susceptibility is inversely preportional to temperature Ex : Aluminium, Platinum and Chromium	Susceptibility is inversely proportional to temperature. Ex : Iron, Nickel and Cobalt

10. What is meant by hysteresis? *[HY-2019]*

Ans. The phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis. Hysteresis means 'lagging behind'.

11. Define magnetic declination and inclination.

Ans. **Magnetic declination :**

The angle between magnetic meridian at a point and geographical meridian is called magnetic declination (D).

Magnetic Inclination:

The angle subtended by the Earth's total magnetic field $\vec{B}$ with the horizontal direction in the magnetic meridian is called **dip** or magnetic inclination (I) at that point.

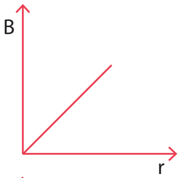
12. What is resonance condition in cyclotron?

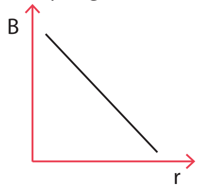
Ans. The important condition in cyclotron operation is that when the frequency f at which the positive ion circulates in the magnetic field must be equal to the constant frequency of the electrical oscillator f_{osc}. This is called resonance condition.

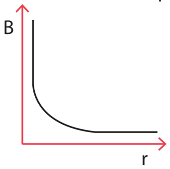
ADDITIONAL QUESTIONS AND ANSWERS

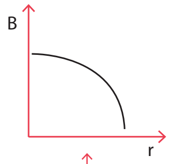
Choose the Correct Answer — 1 Mark

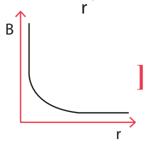
1. Which of the following graphs shows the variation of magnetic induction B with distance 'r' from a long wire carrying current?

(a) 

(b) 

(c) 

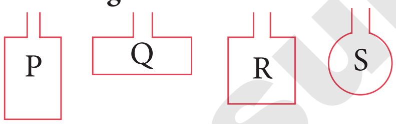
(d) 

[*Ans.* (c) 

]

Hint: $B \propto \frac{1}{r}$

2. Four wires each of length 2m are bent into four loops P, Q, R and S and then suspended into uniform magnetic field. Same current is passed in each loop. On which loop the couple will be the highest?



(a) P (b) Q
(c) R (d) S [*Ans.* (d) S]

Hint: Couple of force on loop S is maximum because for a given perimeter, area of the loop will be maximum and magnetic moment of the loop (=IA) will also be maximum for loop 'S'.

3. When current is doubled deflection is also doubled in

(a) moving coil galvanometer
(b) tangent galvanometer
(c) both of them (d) neither of two

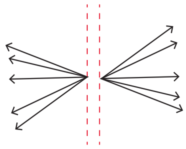
[*Ans.* (a) moving coil galvanometer]

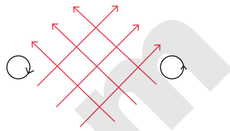
4. A current carrying conductor is associated with

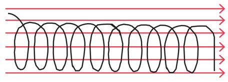
(a) electric field (b) magnetic field
(c) electro magnetic (d) all these

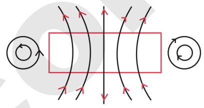
[*Ans.* (b) magnetic field]

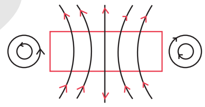
5. Which one of the following represents correct magnetic field lines?

(a) 

(b) 

(c) 

(d) 

[*Ans.* (d) ]

6. The most suitable metal for permanent magnet is

(a) copper (b) aluminium
(c) steel (d) iron

[*Ans.* (c) steel]

Hint: In M.C.G, $I \propto \theta$ but in T.G $I \propto \tan\theta$

7. An electron of mass 0.90×10^{-30}kg under the action of a magnetic field moves in a circle of 2cm radius at a speed of 3×10^{6} m/s. If a proton of mass 1.8×10^{-27} kg was to move in a circle of the same radius in the same magnetic field, then its speed will be

(a) 3.0×10^{6} m/s (b) 1.5×10^{3} m/s
(c) 6.0×10^{4} m/s
(d) cannot be estimated from the same data

[*Ans.* (b) 1.5×10^{3} m/s]

Hint:

$Bqv = \frac{mv^2}{r} \Rightarrow Bqr = mV$

for electrons and protons, B, q, r same

$\therefore \; mv$ = a constant

$m_e V_e = m_p v_p$

$v_p = \frac{m_e V_e}{m_p}$

$v_p = \frac{0.90 \times 10^{-30} \times 3 \times 10^{6}}{1.8 \times 10^{-27}}$

$v_p = 1.5 \times 10^{3}$ m/s

8. A long straight conductor carrying a current lies along the axis of a ring. The conductor will exert a force on the ring, if the ring -

(a) carries a current
(b) has uniformly distributed charge
(c) has non-uniformly distributed
(d) none of the above

[*Ans.* (d) none of the above]

9. Direction of magnetic force on a positive charge moving in a magnetic field is given by

(a) thumb rule (b) left hand rule
(c) right hand rule (d) cork screw rule

[*Ans.* (c) right hand rule]

10. If a current I is flowing in a straight wire parallel to X- axis and magnetic field is in Y-axis then the wire experiences

(a) in Z-direction (b) in Y- direction
(c) no force (d) in X- direction

[*Ans.* (a) in Z-direction]

11. Consider the motion of a charged particle in a uniform magnetic field directed into the paper. If velocity *v* of the particle is in the plane of the paper, the charged particle will describe a

(a) straight line (b) circle
(c) ellipse (d) hyperbola

[*Ans.* (b) circle]

12. Lorentz force generally refers to force experienced by a charge due to combined action of

(a) magnetic fields
(b) electric fields
(c) electric, magnetic & gravitational fields
(d) electric and magnetic fields

[*Ans.* (d) electric and magnetic fields]

13. Cyclotron is used to

(a) accelerate charged particles or ions to low voltages
(b) decelerate charged particles or ions to high voltages
(c) accelerate charged particles or ions to high energies
(d) accelerate charged particles or ions to high voltages

[*Ans.* (c) accelerate charged particles or ions to high energies]

14. The unit of magnetic field is

(a) ampere-turn (b) ampere
(c) newton coulomb (d) tesla

[*Ans.* (d) tesla]

15. The direction of magnetic field close to a straight conductor carrying current will be

(a) along the length of the conductor
(b) radially outward
(c) circular in a plane perpendicular to the conductor
(d) helical

[*Ans.* (c) circular in a plane perpendicular to the conductor]

16. When the current flowing in a circular coil is doubled and the number of turns of the coil in it is halved, the magnetic field at its centre will become

(a) four times (b) same
(c) half (d) double

[*Ans.* (b) same]

17. The forces existing between two parallel current carrying conductors is F. If the current in each conductor is doubled, then the value of force will be

(a) 2F (b) 4F (c) 5F (d) $\frac{F}{2}$

[*Ans.* (b) 4F]

18. The deflection in a galvanometer falls from 50 to 20 divisions when 12Ω shunt is applied. The galvanometer resistance is,

(a) 18Ω (b) 36Ω
(c) 24Ω (d) 30Ω

[*Ans.* (a) 18Ω]

19. Two thin long parallel wires separated by a distance 'a' are carrying current I amp each. The magnitude of the force per unit length excited by one wire on the other is

(a) $\frac{\mu_0 I^2}{a^2}$ (b) $\frac{\mu_0 I^2}{2\pi a}$
(c) $\frac{\mu_0 I}{2\pi a}$ (d) $\frac{\mu_0 I}{2\pi a^2}$

[*Ans.* (b) $\frac{\mu_0 I^2}{2\pi a}$]

20. Graph of force per unit length between long parallel current carrying conductors, and the distance between them is

(a) straight line (b) parabola

(c) ellipse

(d) rectangular hyperbola

[*Ans.* (d) rectangular hyperbola]

21. A galvanometer coil has a resistance of 15Ω and gives full scale deflection for a current of 4mA. To convert it to an ammeter of range 0 to 6 amp.

(a) 10mΩ resistance is to be connected in parallel to the galvanometer

(b) 10mΩ resistance is to be connected in series with the galvanometer

(c) 0.1mΩ resistance is to be connected in series with the galvanometer

(d) 0.1mΩ resistance is to be connected in parallel to the galvanometer

[*Ans.* (d) 0.1mΩ resistance is to be connected in parallel to the galvanometer]

22. The deflection in moving coil galvanometer is reduced to half when it is shunted with a 40Ω coil. The resistance of the galvanometer is

(a) 60Ω (b) 10Ω

(c) 40Ω (d) 20Ω

[*Ans.* (c) 40Ω]

23. At a given place the horizontal component of earth's field is 0.2×10^{-4} Tesla. If a vertical wire carries a current of 30A upward, what is the magnitude and direction of the force on 1m of wire?

(a) 6 East to West

(b) 6×10^{-2} East to West

(c) 6×10^{-3} East to West

(d) 6×10^{-4} East to West

[*Ans.* (a) 6 East to West]

24. If the temperature of hot junction is increased beyond inversion temperature the thermo emf

(a) is constant (b) increases

(c) decreases (d) becomes zero

[*Ans.* (b) increases]

25. In which of the following pairs of metals of the thermocouple, the emf is maximum?

(a) Fe-Cu (b) Cu-Zn

(c) Pt-Ag (d) Sb-Bi

[*Ans.* (d) Sb-Bi]

26. Thermopile is used to

(a) measure temperature

(b) measure current

(c) detect thermal radiation

(d) measure pressure

[*Ans.* (a) measure temperature]

27. In the following thermocouple, the direction of the thermo electric current at the hot junction is from

(a) Sb to Bi (b) Ni to Fe

(c) Fe to Cu (d) Zn to Pt

[*Ans.* (b) Ni to Fe]

28. For a given thermocouple for a given cold junction temperature, the inversion temperature is 220°C. When the cold junction temperature is increased by 20°C, then the inversion temperature is

(a) 200°C (b) 220°C

(c) 240°C (d) 110°C

[*Ans.* (a) 200°C]

29. When the hot and cold junctions of a thermo couple are interchanged then the thermo emf

(a) increases

(b) remain unchanged (c) decreases

(d) increases or decreases according to nature of metals used [*Ans.* (b) remain unchanged]

30. Which one of the following pair of particles move with same velocity along the same circular path in a uniform magnetic field?

(a) electron, proton

(b) proton, deutron

(c) proton, alpha particle

(d) deutron, alpha particle

[*Ans.* (d) deutron, alpha particle]

31. Which one of the following is correct. According to Biot-Savart law, the magnetic induction is directly proportional to

(a) Square of the current

(b) Square root of the current

(c) Length of the current element

(d) Square of the distance

[*Ans.* (c) Length of the current element]

32. This works on the principle of Tangent Law

(a) Tangent Galvanometer

(b) Galvanometer (c) Potentiometer

(d) Metre Bridge

[*Ans.* (a) Tangent Galvanometer]

33. **The magnetic induction at the center of a circular coil having 5 turn and radius 2π cm carrying a current of 50 mA is**

(a) $2\pi \times 10^{-7}$T (b) $50\pi \times 10^{-7}$T
(c) 25×10^{-7}T (d) 2.5×10^{-7}T

[**Ans.** (c) 25×10^{-7}T]

34. **The magnetic induction at the center of a circular coil carrying current is**

(a) $\frac{\mu n I}{2a}$ (b) $\frac{\mu I}{2\pi a}$
(c) $\frac{\mu I}{2na}$ (d) $\frac{\mu I}{2na}$

[**Ans.** (b) $\frac{\mu I}{2\pi a}$]

35. **Magnetic flux density at the center of a circular coil of diameter 20 cm carrying a current 5 A kept in air is**

(a) $4\pi \times 10^{-7}$ tesla (b) 3.14×10^{-5} tesla
(c) 10^{-7} tesla (d) $2\pi \times10^{-7}$tesla

[**Ans.** (b) 3.14×10^{-5} tesla]

36. **When the number of turns (n) in a galvanometer is doubled, current sensitivity**

(a) remains constant (b) decreases twice
(c) increases twice
(d) increases four times

[**Ans.** (c) increases twice]

37. **In a T.G the magnetic needle is small so that**

(a) the circular scale is small
(b) the compass box is small
(c) it can be easily deflected
(d) it remains in uniform magnetic field

[**Ans.** (d) it remains in uniform magnetic field]

38. **In a T.G experiment, if the number of turns is increased 10 times, to produce the same deflection, the value of the current should be**

(a) increased by 20 times
(b) increased by 10 times
(c) decreased by 20 times
(d) decreased by 10 times

[**Ans.** (d) decreased by 10 times]

39. **The Tangent Galvanometer is more sensitive for this angle of deflection**

(a) 3.14 radian (b) 45 radian
(c) 0.785 radian (d) 1.57 radian

[**Ans.** (c) 0.785 radian]

40. **Two T.G's having reduction factor K_1 and K_2 are connected inseries and give deflections $\theta_1$and θ_2 respectively. Then $K_1 : K_2$**

(a) $\theta_1 : \theta_2$ (b) $\tan\theta_1 : \tan\theta_2$
(c) $\theta_2 : \theta_1$ (d) $\tan\theta_2 : \tan\theta_1$

[**Ans.** (d) $\tan\theta_2 : \tan\theta_1$]

41. **Ampere's circuital law is another form of**

(a) Tangent law
(b) Biot-Savart law
(c) Ampere's Swimming rule
(d) End rule

[**Ans.** (b) Biot-Savart law]

42. **What is the current passing through a coil of radius of 8 cm having 50 turns, when a magnetic intensity at the centre of the coil is 125 A turns m^{-1}?**

(a) 0.1 ampere (b) 0.4 ampere
(c) 1 ampere (d) 4 ampere

[**Ans.** (b) 0.4 ampere]

43. **In Ampere's circuital law, the value of line integral $\oint \overline{B} \cdot dl$**

(a) depends on share of the current path
(b) depends on the position of the wire within the magnetic field
(c) depends on the direction of the current
(d) is zero, when the closed path does not encircle the wire

[**Ans.** (d) is zero, when the closed path does not encircle the wire]

44. **Calculate the current passing through a coil of diameter 20 cm, having 50 turns, when the field at the centre of the coil is 200 ampere-turns/meter**

(a) 80 ampere (b) 1.6 ampere
(c) 0.8 ampere (d) 160 ampere

[**Ans.** (c) 0.8 ampere]

45. **The direction of the magnetic field due to a solenoid is given by**

(a) Amperes circuital law
(b) Biot-Savart law
(c) Right hand palm rule
(d) Flemings right hand law

[**Ans.** (c) Right hand palm rule]

NEET BASED QUESTIONS

1. The moment of inertia of a collapsing star changes to one-third of its initial value. The ratio of the new rotational kinetic energy to the initial rotational kinetic energy is_____

(A) 3 : 1 (B) 1 : 3 (C) 9 : 1 (D) 1 : 9

2. A body of 10 kg is dropped from infinite height towards earth's surface. What will be its velocity just before touching the earth's surface. (Gravitational potential energy of the body at earth's surface is $6{\cdot}25 \times 10^8$ Joule).

(A) 22·4 km/sec (B) 11·2 km/sec
(C) 6·4 km/sec (D) Infinite

3. The vertical escape velocity of a body from earth's surface is 11·2 km/sec. If the body is projected at an angle of 45° from the vertical, its escape velocity will be ______.

(A) $11{\cdot}2 \times \sqrt{2}$ km/s (B) $\frac{11{\cdot}2}{\sqrt{2}}$ km/s
(C) $11{\cdot}2 \times 2$ km/s (D) 11·2 km/s

4. Which of the following equations represents a simple harmonic wave ?

(A) $y = a \sin \omega t$ (B) $y = a \sin \omega t \cos kt$
(C) $y = a \sin (\omega t - kx)$ (D) $y = a \cos kx$

5. The focal length of a convex lens is f. When it is divided in two parts by a plane parallel to the principal axis, focal length of each part will be _________

(A) f (B) $\frac{f}{2}$ (C) $2f$ (D) Zero

6. During negative β-decay _________.

(A) Atom electron is ejected
(B) Electron, already present in the nucleus is ejected
(C) Neutron of the nucleus decays ejecting the electron
(D) A part of binding energy is converted into an electron

7. The maximum intensity in the interference pattern of two equal and parallel slits is I. if one of the slits is closed, the intensity at the same point is l_0. Then _________.

(A) $l = l_0$ (B) $l = 2l_0$
(C) $l = 4l_0$
(D) There is no relation between l and l_0

8. X-rays coming out of an X-ray tube _________.

(A) Are monochromatic
(B) Have all wavelengths below a certain minimum wavelength
(C) Have all wavelengths above a certain minimum wavelength
(D) Have all wavelengths between a certain minimum and maximum wavelength

9. The current amplification of common base N–P–N transistor is 0·96. What will be the current gain if it is used as common emitter amplifier ?

(A) 16 (B) 24 (C) 20 (D) 32

10. Who discovered neutron and positron respectively ?

(A) Thomson and Rutherford
(B) Rutherford and Thomson
(C) Anderson and Chadwick
(D) Chadwick and Anderson

11. Amplification factor of a triode is 20 and its plate resistance is 20 kΩ. Its mutual conductance will be _________.

(A) 2×10^5 mho (B) 2×10^4 mho
(C) 500 mho (D) 2×10^{-3} mho

12. The co-ordinates of a moving particle at time t are given by $x = at^2$, $y = bt^2$ The speed of the particle is _________.

(A) $2(a + b)t$ (B) $(a^2 + b^2)^{1/2} \times t$
(C) $2(a^2 + b^2)^{1/2} \times t$ (D) $(a + b)t$

13. If p is the pressure of a gas and ρ is its density, then dimension² of velocity is given by ________.

(A) $p^{1/2} \rho^{-1/2}$ (B) $p^{1/2} \rho^{1/2}$
(C) $p^{-1/2} \rho^{1/2}$ (D) $p^{-1/2} \rho^{-1/2}$

14. If R, X and Z represent respectively the resistance, reactance and impedance of an electric circuit carrying alternating current, then the power factor is given by ________

(A) $\frac{R}{Z}$ (B) $\frac{Z}{R}$ (C) $\frac{R}{X}$ (D) $\frac{X}{R}$

15. If the horizontal range of a projectile is equal to the maximum height reached, then the corresponding angle of projection is ________.

(A) $\tan^{-1} 1$ (B) $\tan^{-1} \sqrt{3}$
(C) $\tan^{-1} 4$ (D) $\tan^{-1} 12$

16. Two electrons move parallel to each other with equal speeds *v*. The ratio of magnetic and electrical forces between them is ________.

(A) $\frac{v}{c}$ (B) $\frac{c}{v}$ (C) $\frac{v^2}{c^2}$ (D) $\frac{c^2}{v^2}$

17. The acceleration of a particle performing S.H.M. is 12 cm/s² at a displacement of 3 cm from the mean position. Its time period is ________.

(A) 6·28 s (B) 3·14 s (C) 10·0 s (D) 5·0 s

18. The displacement of a particle is given by $x = 6 \cos \omega t + 8 \sin \omega t$ metre This equation respresents a S.H.M. having amplitude ________.

(A) 14 m (B) 12 m (C) 10 m (D) 5 m

19. An electron of mass 9×10^{-31} kg revolves in a circle of radius 0·53 Å around the nucleus of hydrogen atom with a velocity of $2{\cdot}2 \times 10^6$ ms^{-1}. What is the angular momentum of the electron ?

(A) $\frac{h}{2\pi}$ (B) $\frac{3h}{3\pi}$ (C) $\frac{h}{\pi}$ (D) $\frac{h}{3\pi}$

20. To maintian a rotor at uniform angular speed of 200 rad. s^{-1}, an engine needs to transmit a torque of 180 Nm. The required power of the engine is ________.

(A) 36 W (B) 63 W
(C) 36 KW (D) 63 KW

21. According to Rutherford model of atom the atom consists of ________

(A) Positively charged nucleus surrounded by a cloud of negative charge
(B) Electrons orbiting a positively charged nucleus in definite orbits
(C) Same as (B) with electrons spinning
(D) A rigid sphere only

22. The magnetic moment of a circular orbit of radius *r* carrying a charge *q* and rotating with velocity *v* is given by ______.

(A) $\frac{qvr}{2\pi}$ (B) $\frac{qvr}{2}$ (C) $qv\pi r$ (D) $qv\pi r^2$

23. Along with β-particle emission from a radioactive nucleus one more particle with zero charge is emitted to conserve the energy and momentum. This particle is called ________

(A) Meson (B) Positron
(C) Antineutrino (D) Neutron

24. In a cyclotron the time required to move a charged particle of charge *q* and mass *m* in a plane perpendicular to the magnetic field B in a semicircular path is ________.

(A) $t = \frac{m\pi}{Bq}$ (B) $t = \frac{Bqv}{\pi m}$
(C) $t = \frac{B}{\pi mq}$ (D) $t = \pi m Bq$

25. A doubly ionised lithium atom is hydrogen like with atomic number Z = 3. The wavelength of radiation required to excite the electron in Li^{2+} from first to third Bohr orbit will be ________. (Ionisation energy of hydrogen atom is 13·6 eV)

(A) 72·53 Å (B) 113·74 Å
(C) 212·52 Å (D) 17·72 Å

26. A parallel monochromatic beam of light is incident normally on a formed on a screen placed perpendicular to the direction the incident beam. At the first minimum of diffraction pattern the phase difference between the rays coming from the two edges of the slit is ________.

(A) 0 (B) $\frac{\pi}{2}$ (C) π (D) 2π

27. A current carrying coil is freely suspended in a uniform magnetic field. The coil tends to set its plane ________.

(A) Parallel to the magnetic field
(B) Perpendicular to the magnetic field
(C) Inclined to the magnetic field
(D) Continuously rotating

12th STD.

INSTANT SUPPLEMENTARY EXAM - JULY- 2022

PART III - PHYSICS

(With Answers)

TIME ALLOWED : 3.00 Hours] [MAXIMUM MARKS : 70

Instructions : (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART - I

Note : (i) Answer **all** the questions.

(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer. **(15 × 1 = 15)**

1. The ratio between the radius of first three orbits of hydrogen atom is:
(a) 1 : 2 : 3 (b) 1 : 2 : 2
(c) 1 : 4 : 9 (d) 1 : 3 : 5

2. Two coherent monochromatic light beams of intensities I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are:
(a) 5I and I (b) 5I and 3I
(c) 9I and I (d) 9I and 3I

3. A wire connected to a power supply of 230V has power dissipation P_1. Suppose the wire is cut into two equal pieces and connected parallel to the same power supply. In this case power dissipation is P_2. The ratio $\frac{P_2}{P_1}$ is :
(a) 1 (b) 2 (c) 3 (d) 4

4. Stars twinkle due to :
(a) Reflection
(b) Total internal reflection
(c) Refraction (d) Polarisation

5. The instantaneous values of alternating current and voltage in a circuit are $i = \frac{1}{\sqrt{2}} \sin (100\pi t)$ A and $v = \frac{1}{\sqrt{2}} \sin \left(100\pi t + \frac{\pi}{3}\right)$ V.
The average power in watts consumed in the circuit is :
(a) $\frac{1}{4}$ (b) $\frac{\sqrt{3}}{4}$ (c) $\frac{1}{2}$ (d) $\frac{1}{8}$

6. If the mean wavelength of light from Sun is taken as 550nm and its mean power as 3.8×10^{26} W then, the average number of photons received by the human eye per second from Sunlight is of the order of :
(a) 10^{45} (b) 10^{42} (c) 10^{54} (d) 10^{51}

7. An electric dipole is placed at an alignment angle of 30° with an electric field of 2×10^5 NC^{-1}. It experiences a torque equal to 8 Nm. The charge on the dipole if the dipole length is 1 cm is:
(a) 4 mC (b) 8 mC (c) 5 mC (d) 7mC

8. Fraunhofer lines are an example of ______ spectrum.
(a) line emission (b) line absorption
(c) band emission (d) band absorption

9. The mass of a $^7_3$Li nucleus is 0.042 u less than the sum of the masses of all its nucleons. The average binding energy per nucleon of $^7_3$Li nucleus is nearly
(a) 46 MeV (b) 5.6 MeV
(c) 3.9 MeV (d) 23 MeV

10. The temperature co-efficient of resistance of a wire is 0.00125 per °C. At 20°C, its resistance is 1Ω. The resistance of the wire will be 2 Ω at:
(a) 800 °C (b) 700 °C
(c) 850 °C (d) 820 °C

11. The particle size of ZnO material is 30 nm. Based on the dimension it is classified as :
(a) Bulk material (b) Nanomaterial
(c) Soft material
(d) Magnetic material

12. The value of L, C and R of an AC circuit are 1 H, 9 F and 3Ω respectively. The quality factor for this circuit is :
(a) 1 (b) 9 (c) $\frac{1}{9}$ (d) $\frac{1}{3}$

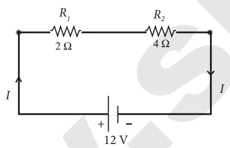
13. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly :
(a) 1.0 Am^2 (b) 1.2 Am^2
(c) 0.5 Am^2 (d) 0.8 Am^2

14. Two radiations with photon energies 0.9 eV and 3.3 eV respectively are falling on a metallic surface successively. If the work function of the metal is 0.6 eV, then the ratio of maximum speeds of emitted electrons in the two cases will be :
   (a) 1 : 4 (b) 1 : 3 (c) 1 : 1 (d) 1 : 9
15. If a positive half –wave rectified voltage is fed to a load resistor, for which part of a cycle of the input signal there will be current flow through the load?
   (a) 0^o - 90^o (b) 90^o - 180^o
   (c) 0^o - 180^o (d) 0^o - 360^o

PART - II

Note: Answer **any six** questions. Question number **24** is **compulsory.** **(6 × 2 = 12)**

16. Mention the ways of producing induced emf.
17. Define stopping potential.
18. Give two uses of UV radiation.
19. Pure water has refractive index 1.33. What is the speed of light through it?
20. Define ampere in terms of force.
21. Whats is rectification?
22. State Gauss Law.
23. Define atomic mass unit.
24. Calculate the equivalent resistance for the circuit which is connected to 12 V battery and also find the potential difference across 2Ω and 4Ω resistors in the circuit.



PART - III

Note: Answer **any six** questions. Question number **33** is **compulsory.** **(6 × 3 = 18)**

25. Obtain an expression for energy stored in the parallel plate capacitor.
26. An electron moving perpendicular to a uniform magnetic field 0.500T undergoes circular motion of radius 2.50 mm. What is the speed of electron?
27. Give the construction and working of a photo emissive cell.
28. Mention the differences between interference and diffraction.
29. What is Zener diode? Mention any two uses of Zener diode.
30. What is Seebeck effect? State the applications of Seebeck effect.
31. What are the properties of Cathode rays?
32. AC is advantageous than DC. Explain.
33. Light travels from air into a glass slab of thickness 50 cm and refractive index 1.5. What is the speed of light in the glass slab and what is the time taken by the light to travel through the glass slab?

PART - IV

Note: Answer **all** the questions **(5 × 5 = 25)**

34. (a) Obtain the condition for bridge balance in Wheatstone's bridge.

OR

   (b) (i) What is half-life and mean life of a radioactive nucleus?
   (ii) Calculate the number of nuclei of carbon-14 undecayed after 22,920 years in the initial number of carbon-14 atoms is 10,000. The half-life of carbon-14 is 5730 years.
35. (a) Describe the Fizeau's method to determine the speed of light.

OR

   (b) (i) Write down the properties of electromagnetic waves.
   (ii) The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.
36. (a) Explain in detail the construction and working of a Van de Graaff generator.

OR

   (b) Explain about Compound Microscope and obtain the equation for the magnification.
37. (a) Show that the mutual inductance between a pair of coils is same ($M_{12} = M_{21}$).

OR

   (b) State and Prove De Morgan's first and second theorem.
38. (a) (i) Obtain Einstein's photoelectric equation with necessary explanation.
   (ii) List out the characteristics of photons.

OR

   (b) Derive the expression for the force on a current carrying conductor in a magnetic field.

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