केन्द्रीय विद्यालय संगठन

KENDRIYA VIDYALAYA SANGATHAN

ZONAL INSTITUTE OF EDUCATION AND TRAINING

MYSURU

STUDY MATERIAL

SUBJECT PHYSICS

CLASS XII

SESSION 2023-24

सुश्री मीनाक्षी जैन/MS MENAXI JAIN

निदेशक /DIRECTOR

आंचलिक शिक्षा एवं प्रशिक्षण संस्थान, मैसूरु

ZONAL INSTITUTE OF EDUCATION AND TRAINING, MYSURU

COORDINATOR

MR DINESH KUMAR

TA PHYSICS

DIRECTOR'S MESSAGE FOR THE STUDY MATERIAL

It is with profound delight and utmost pride that I announce the publication of our study material for class XII Physics for the session 2023-24. It's my firm belief that access to quality education should know no boundaries, transcending social and economic constraints. Our collective vision is to empower all students with the tools for success and intellectual growth.

With their steadfast dedication PGT-Physics of Bangalore, Chennai, Ernakulam & Hyderabad regions of Kendriya Vidyalaya Sangathan have invested their knowledge, expertise, and passion into meticulously crafting these study materials to complement the classroom learning experience of the students. These materials serve as invaluable aids for self-study since they are comprehensive, well-structured, and presented in a manner that is easy to comprehend.

It is with pleasure that I place on record my commendation for the commitment and dedication of the team of teachers which included the Training Associate (Mr Dinesh Kumar) from ZIET Mysore who has been the Coordinator of this assignment and all the concerned PGT-Physics subject experts from the four feeder regions of ZIET Mysore.

Wishing you all the very best in your academic journey!

MENAXI JAIN

DIRECTOR

ZIET MYSORE

CONTENT DEVELOPER TEAM

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ELECTRIC CHARGES AND FIELDS	MR T MURALI	DGQA CHENNAI
ELECTROSTATIC POTENTIAL AND CAPACITANCE	MS UMA KARPOORAM	2 MADURAI
CURRENT ELECTRICITY	MR S KUMAR	CRPF AVADI
MOVING CHARGES AND MAGNETISM	MS R SUGUNA	AFS AVADI
MAGNETISM AND MATTER	MS MONY K R	1 PALAKKAD
ELECTROMAGNETIC INDUCTION	MS LAKSHMI DEVI S	SAP PEROORKADA
ALTERNATING CURRENT	MR SAJI R	ADOOR SHIFT 1
ELECTROMAGNETIC WAVES	MR SREEKANTH S	2 CALICUT
RAY OPTICS AND OPTICAL INSTRUMENTS	MS SALEENA JACKSON	ASC CENTRE
WAVE OPTICS	MS NISHA M MOHAN	HEBBAL
DUAL NATURE OF RADIATION AND MATTER	MR BIRENDER SINGH	AFS YELAHANKA
ATOMS		
NUCLEI	MS RASHMI K	MEG &CENTRE
SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS		
PRACTICE QUESTION PAPER 1	MRT BALA SURESH KUMAR	2 AFS DUNDIGAL
PRACTICE QUESTION PAPER 2	MR KTS SRIVATSA	WALTAIR
PRACTICE QUESTION PAPER 3	MR G GOPI KRISH	2 SRIVIJAYNAGAR
PRACTICE QUESTION PAPER 4	MR P V MAHESH KUMAR	KADAPA
PRACTICE QUESTION PAPER 5	MR SREEKANTH S	2 CALICUT

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PHYSICS Class XII (Code No.42) (2023-24)

Senior Secondary stage of school education is a stage of transition from general education to discipline-based focus on curriculum. The present updated syllabus keeps in view the rigor and depth of disciplinary approach as well as the comprehension level of learners. Due care has also been taken that the syllabus is comparable to the international standards. Salientfeatures of the syllabus include:

- Emphasis on basic conceptual understanding of the content.
- Emphasis on use of SI units, symbols, nomenclature of physical quantities andformulations as per international standards.
- Providing logical sequencing of units of the subject matter and proper placement ofconcepts with their linkage for better learning.
- Reducing the curriculum load by eliminating overlapping of concepts/content withinthe discipline and other disciplines.
- Promotion of process-skills, problem-solving abilities and applications of Physicsconcepts.

Besides, the syllabus also attempts to

- Strengthen the concepts developed at the secondary stage to provide firm foundationfor further learning in the subject.
- Expose the learners to different processes used in Physics-related industrial andtechnological applications.
- Develop process-skills and experimental, observational, manipulative, decisionmaking and investigatory skills in the learners.
- Promote problem solving abilities and creative thinking in learners.
- Develop conceptual competence in the learners and make them realize and appreciatethe interface of Physics with other disciplines

CLASS XII (2023-24)

PHYSICS (THEORY)

Time: 3 hrs. **Max Marks: 70**

		No. of Periods	Marks
Unit–I	**Electrostatics**	26	16
	Chapter–1: Electric Charges and Fields		
	Chapter–2: Electrostatic Potential and Capacitance		
Unit-II	**Current Electricity**	18	
	Chapter–3: Current Electricity		
Unit-III	**Magnetic Effects of Current and Magnetism**	25	17
	Chapter–4: Moving Charges and Magnetism		
	Chapter–5: Magnetism and Matter		
Unit-IV	**Electromagnetic Induction and Alternating Currents**	24	
	Chapter–6: Electromagnetic Induction		
	Chapter–7: Alternating Current		
Unit–V	**Electromagnetic Waves**	04	18
	Chapter–8: Electromagnetic Waves		
Unit–VI	**Optics**	30	
	Chapter–9: Ray Optics and Optical Instruments		
	Chapter–10: Wave Optics		
Unit–VII	**Dual Nature of Radiation and Matter**	8	12
	Chapter–11: Dual Nature of Radiation and Matter		
Unit–VIII	**Atoms and Nuclei**	15	
	Chapter–12: Atoms		
	Chapter–13: Nuclei		
Unit–IX	**Electronic Devices**	10	7
	Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits		
Total		**160**	**70**

Unit I: Electrostatics 26 Periods

Chapter–1: Electric Charges and Fields

Electric charges, Conservation of charge, Coulomb's law-force between two- point charges, forces betweenmultiple charges; superposition principle and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to adipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straightwire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Chapter–2: Electrostatic Potential and Capacitance

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electricdipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of aparallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor (no derivation, formulae only).

Unit II: Current Electricity 18 Periods

Chapter–3: Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relationwith electric current; Ohm's law, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, temperature dependence of resistance, Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's rules, Wheatstone bridge.

Unit III: Magnetic Effects of Current and Magnetism

25 PeriodsChapter–4: Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment.

Biot - Savart law and its application to current carrying circular loop. Ampere's law and its applications to infinitely long straight wire. Straight solenoid (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields. Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors- definition of ampere, torque experienced by a current loop in uniform magnetic field; Current loop as a magnetic dipole and its magnetic dipole moment,moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

Chapter–5: Magnetism and Matter

Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only), magnetic field intensity dueto a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only),

torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only), magneticfield lines.

Magnetic properties of materials- Para-, dia- and ferro - magnetic substances with examples, Magnetizationof materials, effect of temperature on magnetic properties.

Unit IV: Electromagnetic Induction and Alternating Currents

24 PeriodsChapter–6: Electromagnetic Induction

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Self and mutualinduction.

Chapter–7: Alternating Current

Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current. AC generator,Transformer

Unit V: Electromagnetic waves 04 Periods

Chapter–8: Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature(qualitative idea only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays)including elementary facts about their uses.

Unit VI: Optics 30 Periods

Chapter–9: Ray Optics and Optical Instruments

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflectionand optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker’s formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.

Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and theirmagnifying powers.

Chapter–10: Wave Optics

Wave optics: Wave front and Huygen’s principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen’s principle. Interference, Young'sdouble slit experiment and expression for fringe width (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only)

Unit VII: Dual Nature of Radiation and Matter

08 PeriodsChapter–11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric

equation-particle nature of light. Experimental study of photoelectric effect Matter waves-wave nature ofparticles, de-Broglie relation.

Unit VIII: Atoms and Nuclei 15 Periods

Chapter–12: Atoms

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra(qualitative treatment only).

Chapter–13: Nuclei

Composition and size of nucleus, nuclear force

Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclearfission, nuclear fusion.

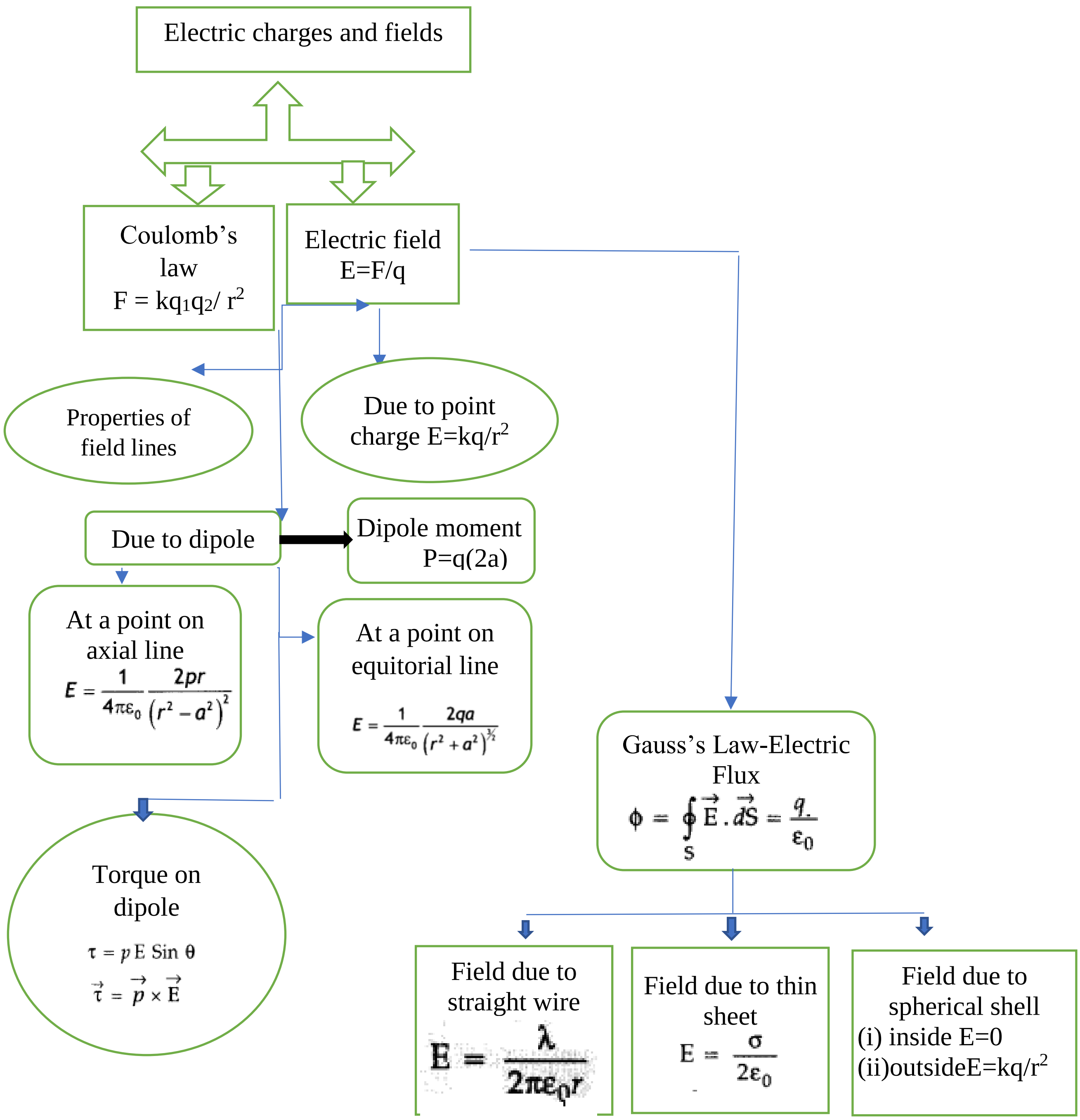
Unit IX: Electronic Devices 10 Periods

Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsicsemiconductors- p and n type, p-n junction

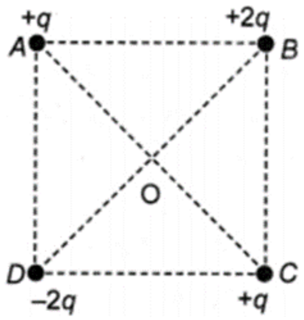
Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diodeas a rectifier

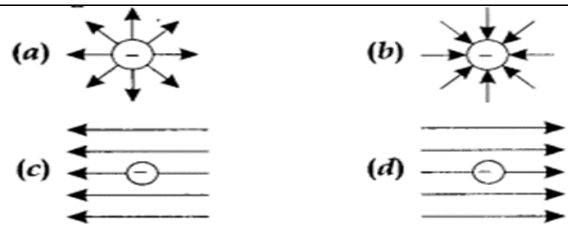
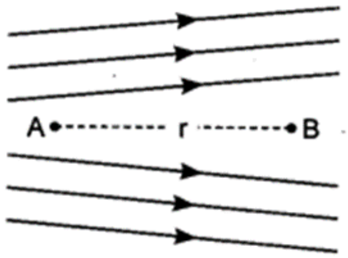
Chapter – 1- Electric charges and fields- Mind Map

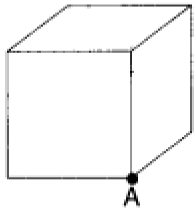
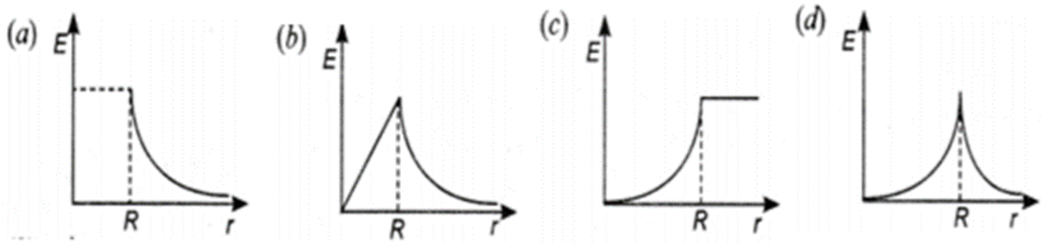


	Formulae
1	**Coulomb's force between two-point charges** $F = k\ \frac{q_1 q_2}{r^2}$ **Where k=$1/4\pi\varepsilon_0$=9x10^9**
2	**Dielectric constant of a medium** **K =** $\frac{F_0}{F_m}$
3	**Dielectric constant of a medium** **K =** $\frac{E_0}{E_m}$, **K=** $\frac{C_m}{C_0}$ **E_0 – electric field in vacuum,** **E_m – electic field in medium C_0-capacitance in air, c_m- capacitance with medium**
4	**Electric field** **E=** $\frac{Force(F)}{Charge(q)} = -\ \frac{dV}{dr} = -potential\ gradient$
5.	**Electric field due to a point charge** **E= kq / r^2**
6	**Resultant force due to multiple charges** **F=** $\sqrt{F1^2 + F2^2 + 2F1F2cos\theta}$
7	**Electric dipole moment** **P = (q) x (2a) It is vector. Direction is from negative to positive charge**
8	**Field due to dipole at axial point** $E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{\left(r^2 - a^2\right)^2}$
9	**Torque on dipole in uniform electric field** $\tau = pE\ \text{Sin}\ \theta$ $\vec{\tau} = \vec{p} \times \vec{E}$
10	**Electric field due to dipole at equatorial line** $E = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{\left(r^2 + a^2\right)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{\left(r^2 + a^2\right)^{3/2}}$
11	**Potential energy of electric dipole U = - pEcosθ**
12	$\phi = \oint_S \vec{E}.\vec{dS} = \frac{q}{\varepsilon_0}$ **Gauss's law, Electric flux**
13	**Field due to straight uniformly charged long wire** $\mathbf{E} = \frac{\lambda}{2\pi\varepsilon_0 r}$
14	**Electric flux** **φ = E A cosθ**

15	**Field due to thin uniformly charged sheet** $$E = \frac{\sigma}{2\varepsilon_0}$$

S.NO	MCQ	MARKS
1	Which one of the following is the unit of electric charge? (a) Coulomb (b) Newton (c) Volt (d) N/C	1
2	An object has charge of 1C and gains 5 X 10^{18} electrons. The net charge on object becomes (a) – 0.80C (b) +0.80C (c) +1.80C (d) +0.20C	1
3	Two charges q_1 and q_2 are placed in vacuum at a distance d and the force acting between them is F. If a medium of dielectric constant 4 is introduced between them, the force now will be (a) F (b) F/2 (c) F/4 (d) 4F	1
4	Two similar spheres having +Q and -Q charges are kept at a certain distance. Force F acts between the two. If at the middle of two spheres, another similar sphere having +Q charge is kept, then it experiences a force (a) zero having no direction. (b) 8F towards +Q charge. (c) 8F towards -Q charge. (d) 4F towards +Q charge	1
5	Two charges of equal magnitudes kept at a distance r exert a force F on each other. If the charges are halved and distance between them is doubled, then the new force acting on each charge is (a) $\frac{F}{8}$ (b) $\frac{F}{4}$ (c) $4F$ (d) $\frac{F}{16}$	1
6	Four charges are arranged at the comers of a square ABCD, as shown. The force on a positive charge kept at the centre O is  (a) zero (b) along the diagonal AC (c) along the diagonal BD (d) perpendicular to side AB	1
7	Dielectric constant for a metal is (a) zero (b) infinite (c) 1 (d) 10	1
8	Which one of the following is the unit of electric field? (a) Coulomb (b) Newton (c) Volt (d) N/C	1
9	Which of the following figures represent the electric field lines due to a single negative charge?	1

		
10	Figure shows the electric lines of force emerging from a charged body. If the electric field at A and B are E_A and E_B respectively and if the displacement between A and B is r then  (a) $E_A > E_B$ (b) $E_A < E_B$ (c) $E_A = E_B / r$ (d) $E_A = E_B / r^2$	1
11	The force per unit charge is known as : (a) electric flux (b) electric field strength (c) electric potential (d) electric current	1
12	Electric field lines provide information about (a) field strength (b) direction (c) nature of charge (d) all of these	1
13	SI unit of permittivity of free space is (a) Farad (b) Weber (c) $C^2N^{-1}\,m^{-2}$ (d) $C^2N^{-1}\,m^{-2}$	1
14	The electric field required to keep a water drop of mass m just to remain suspended , when charged with one electron (a) Mg (b) mg/e (c) emg (d) em/g	1
15	Deuteron and alpha particle in air are at separation 1A^o. The magnitude of electric field intensity on alpha particle due to deuteron is (a) 5.76×10^{11} N/C (b) 1.44×10^{11} N/C (c) 2.828×10^{11} N/C (d) 0	1
16	If an electric dipole is kept in a uniform electric field then resultant electric force on it is (a) always zero (b) never zero (c) increases gradually (d) None	1
17	When placed in a uniform field, a dipole experience (a) a net force (b) a torque (c) both a net force and torque (d) neither a net force nor a torque	1
18	In non-uniform electric field, electric dipole experiences: (a) torque only (b) torque as well as net force (c) force only (d) None of these	1
19	The electric field at a point on the perpendicular bisector of a dipole is directed (a) Along the dipole moment (b) Perpendicular to the dipole moment (c)Opposite to the dipole moment (d)45° to the dipole moment	1
20	Torque is maximum when angle between dipole moment and electric field is (a) 0 (b) 60 (c) 90 (d) 180	1
21	The total flux through the faces of the cube with side of length a if a charge q is placed at corner A of the cube is	1

	 (a) $\frac{q}{8\varepsilon_0}$ (b) $\frac{q}{4\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) $\frac{q}{\varepsilon_0}$	
22	A cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by (a) $2\pi R^2 E$ (b) πr^2 (c) $\frac{\pi R^2 - \pi R}{E}$ (d) Zero	1
23	Which of the following graphs shows the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere? 	1
24	The surface considered for Gauss's law is called (a) Closed surface (b) Spherical surface (c) Gaussian surface (d) Plane surface	1
25	Which of the following statements is not true about Gauss's law? (a) Gauss's law is true for any closed surface. (b) The term q on the right-side side of Gauss's law includes the sum of all charges enclosed by the surface. (c) Gauss's law is not much useful in calculating electrostatic field when the system has some symmetry. (d) Gauss's law is based on the inverse square dependence on distance contained in the coulomb's law	1

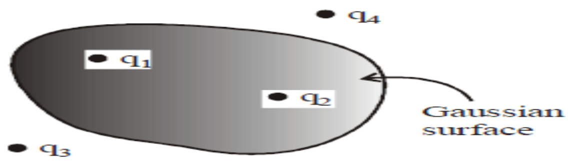
SOLUTION

1	**a**	**2**	**d**	**3**	**c**	**4**	**c**	**5**	**d**	**6**	**c**	**7**	**b**	**8**	**d**	**9**	**b**
10	**a**	**11**	**b**	**12**	**d**	**13**	**c**	**14**	**b**	**15**	**b**	**16**	**a**	**17**	**b**	**18**	**b**
19	**c**	**20**	**c**	**21**	**a**	**22**	**d**	**23**	**a**	**24**	**c**	**25**	**c**				

ASSERTION AND REASON

Two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.
a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
c) If Assertion is true but Reason is false.
d) If both Assertion and Reason are false.

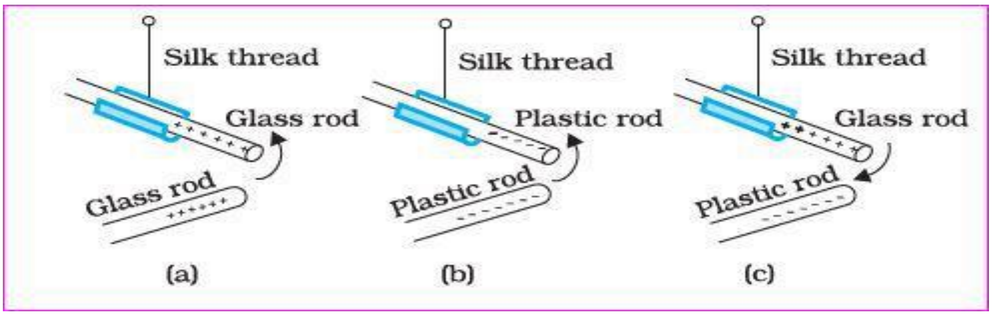
S.NO	Assertion and Reason	MARKS
1	**Assertion(A)**: The total amount of charge on a body equal to 4X10-19 C is not possible. **Reason(R)**: Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by *e*. Thus, charge *q* on a body is always given by $q = ne$	1
2	**Assertion(A)**: Electrostatic forces are conservative in nature. **Reason(R):** Work done by electrostatic force is path dependent	1
3	**Assertion (A)**: The electrostatics force increases with decrease the distance between the charges. **Reason (R)**: The electrostatic force of attraction or repulsion between any two stationary point charges is inversely proportional to the square of the distance between them.	1
4	**Assertion(A):** The Coulomb force between two points charges depend upon the dielectric constant of the intervening medium. **Reason(R):** Coulomb's force varies inversely with the dielectric constant of medium	1
5	**Assertion (A):** A comb run through one's dry hair attracts small bits of paper. **Reason(R)**: Molecules in the paper gets polarized by the charged comb resulting in net force of attraction	1
6	**Assertion(A)**: A proton is placed in a uniform electric field, it tend to move along the direction of electric field. **Reason(R)**: A proton is placed in a uniform electric field it experiences a force.	1
7	**Assertion(A):** Electric field at the surface of a charged conductor is always normal to the surface at every point. **Reason(R)**: Electric field gives the magnitude & direction of electric force ( ) experienced by any charge placed at any point.	1
8	**Assertion(A):** Electric filed lines not form closed loops. **Reason(R):** Electric filed lines are always normal to the surface of a conductor	1
9	**Assertion(A):** In the presence of external electric field the net electric field within the conductor becomes zero. **Reason(R):** In the presence of external electric field the free charge carriers move and charge distribution in the conductor adjusts itself	1
10	**Assertion(A)**: The net force on a dipole in a uniform electric dipole is zero. **Reason(R)**: Electric dipole moment is a vector directed from –q to +q.	1

11	**Assertion(A)** : Polar molecules have permanent dipole moment. **Reason(R)** : In polar molecules, the centres of positive and negative charges coincide even when there is no external field	1
12	**Assertion(A) :** Four point charges q1, q2, q3 and q4 are as shown in figure. The flux over the shown Gaussian surface depends only on charges q1 and q2  **Reason(R) :** Electric field at all points on Gaussian surface depends only on charges q1 and q2.	1
13	**Assertion(A) :** The electric flux of the electric field $\oint$ E.dA is zero. The electric field is zero everywhere on the surface. **Reason (R) :** The charge inside the surface is zero.	1

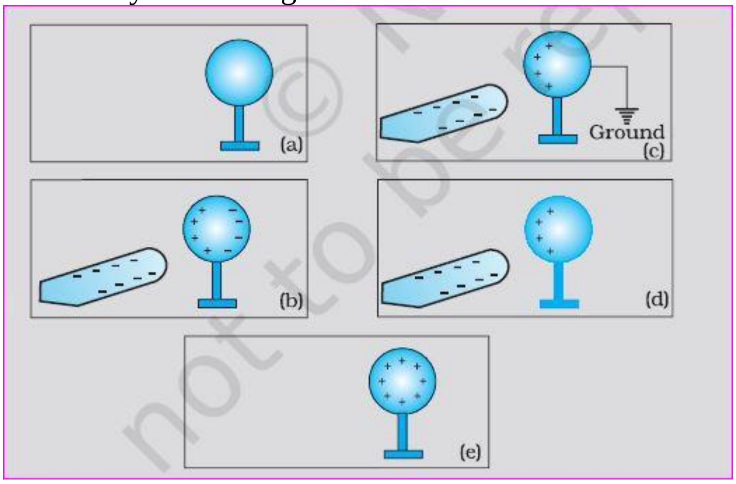
SOLUTION

1	a	2	c	3	a	4	a	5	a
6	b	7	b	8	b	9	a	10	b
11	c	12	d	13	d				

CASE STUDY

S.NO	CASE STUDY	MARKS
1	When a glass rod is rubbed with silk, the rod acquires one kind of charge and the silk acquires the second kind of charge. This is true for any pair of objects that are rubbed to be electrified. Now if the electrified glass rod is brought in contact with silk, with which it was rubbed, they no longer attract each other. They also do not attract or repel other light objects as they did on being electrified.  Thus, the charges acquired after rubbing are lost when the charged bodies are brought in contact. What can you conclude from these observations? It just tells us that unlike charges acquired by the objects neutralise or nullify each other's effect. Therefore, the charges were named as positive and negative by the American scientist Benjamin Franklin. We know that when we add a positive number to a negative number of the same magnitude, the sum is zero. This might have been the philosophy in naming the charges as positive and negative. By convention, the charge on glass rod or cat's fur is called positive and that on plastic rod or silk is termed negative. If an object possesses an electric charge, it is said to be electrified or charged. When it has no charge it is said to be electrically neutral. (1) When you charge a balloon by rubbing it on your hair this is an example of what method of charging? (a)Friction (b)Conduction (c)Grounding (d)Induction (2) Neutral atoms contain equal numbers of positive __ and negative __. (a)Electrons and Protons (b)Protons and Electrons (c)Neutrons and Electrons (d)Protons and Neutrons (3) Which particle in an atom can you physically manipulate? (a)protons b)electrons (c)neutrons (d)you can't manipulate any particle in an atom (4) If a negatively charged rod touches a conductor, the conductor will be charged by what method? (a) Friction (b)Conduction (c)Induction (d)Convection	4
2	Figure (a) shows an uncharged metallic sphere on an insulating metal stand. If we Bring a negatively charged rod close to the metallic sphere, as shown in Fig. (b). As the rod is brought close to the sphere, the free electrons in the sphere move away due to repulsion and start piling up at the farther end. The near end becomes positively charged due to deficit of electrons. This process of charge distribution stops when the net force on the free electrons inside the metal is zero. Now if we Connect the sphere to the ground by a conducting wire. The electrons will flow to the ground while the positive charges at the near end will remain held there due to the attractive force of the negative charges on the rod, as shown in Fig. (c). Disconnect the sphere from the ground. The positive charge continues to be held at the near end Fig.(d). if we remove the electrified rod. The	4

positive charge will spread uniformly over the sphere as shown in Fig. (e). In this experiment, the metal sphere gets charged by the process of induction and the rod does not lose any of its charge.



(1) What do you call the process of charging a conductor by bringing it near another Charged object?

(a) Induction (b) Polarisation (c) neutralization (d) conduction

(2) Transferring a charge without touching is ___

(a)Conduction (b)Induction (c)Grounding (d)Newton's 3rd law

(3) Due to electrostatic induction in aluminium rod due to charged plastic rod, the total charge on the aluminium rod is

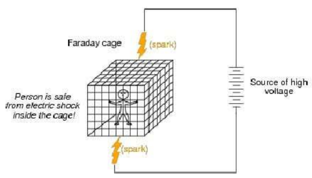
(a)Zero (b)Positive (c) Negative (d) Dual

(4) If we bring charged plastic rod near-neutral aluminium rod, then rods will

(a)Repel each other (b)Attract each other

(c)Remain their position (d) Exchange charges

3 Faraday cages shield their contents from static electric fields. An electric field is a force field surrounding a charged particle, such as an electron or proton. These cages often look distinctly, well, cage like. Some are as simple as chain-link fences or ice pails. Others use a fine metallic mesh. Regardless of their exact appearance, all Faraday cages take electrostatic charges, or even certain types of electromagnetic radiation, and distribute them around the exterior of the cage. **4**



(1)Which of the following material can be used to make a Faraday cage?

(a) Plastic (b) Glass (c) Copper (d) Wood

(2). Example of a real-world Faraday cage is

(a) car (b) plastic box (c) lightning rod (d) metal rod

(3)What is the electrical force inside a Faraday cage when it is struck by lightning?

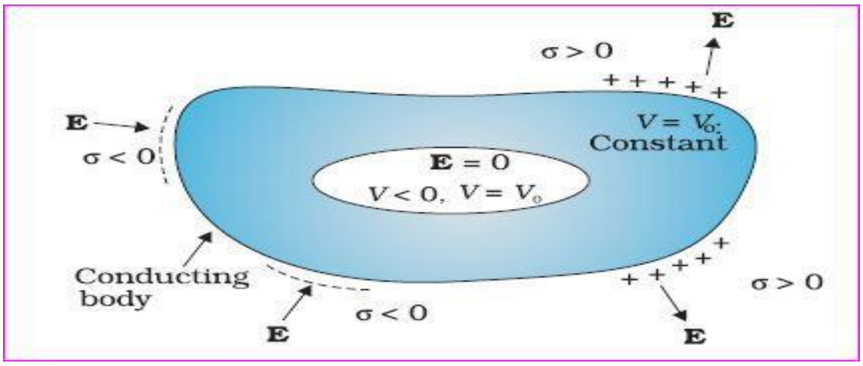
(a) The same as the lightning (b) Half that of the lightning

(c) Zero (d) A quarter of the lightning

<table>
<tr><td></td><td>(4)An isolated point charge +q is placed inside the Faraday cage. Its surface must have charge equal to
(a) Zero b) +q c) – q d) +2q</td><td></td></tr>
<tr><td>4</td><td>

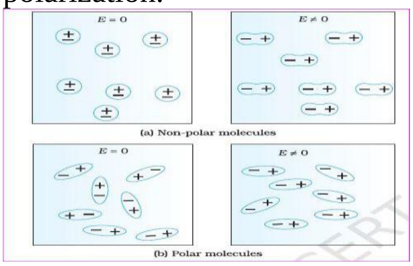
The electric field inside the cavity is zero, whatever be the size and shape of the cavity and whatever be the charge on the conductor and the external fields in which it might be placed. The electric field inside a charged spherical shell is zero. But the vanishing of electric field in the (charge-free) cavity of a conductor is, as mentioned above, a very general result. A related result is that even if the conductor is charged or charges are induced on a neutral conductor by an external field, all charges reside only on the outer surface of a conductor with cavity.

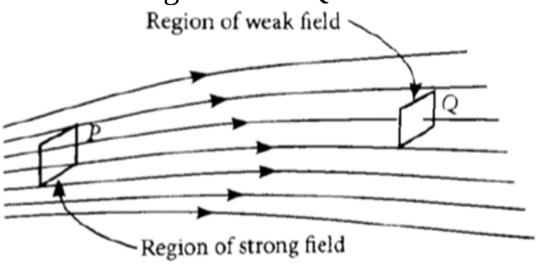
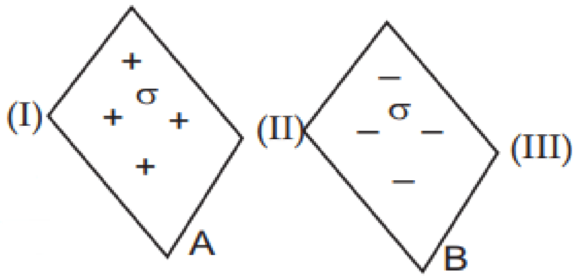
The proofs of the results noted in Fig. are omitted here, but we note their important implication. Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric influence: the field inside the cavity is always zero. This is known as electrostatic shielding. The effect can be made use of in protecting sensitive instruments from outside electrical influence.



(1) A metallic shell having inner radius R1 and outer radii R2 has a point charge Q kept
inside cavity. Electric field in the region R1 < r < R2 where r is the distance from the centre is given by
(a) depends on the value of r (b) Zero
(c) Constant and nonzero everywhere (d) None of the above
(2) The electric field inside the cavity is depend on
(a) Size of the cavity (b) Shape of the cavity
(c) Charge on the conductor (d) None of the above
(3) Electrostatic shielding is based
(a) electric field inside the cavity of a conductor is less than zero
(b) electric field inside the cavity of a conductor is zero
(c) electric field inside the cavity of a conductor is greater than zero
(d) electric field inside the cavity of a plastic is zero
(4) During the lightning thunderstorm, it is advised to stay
(a) inside the car (b) under trees (c) in the open ground (d) on the car

</td><td>4</td></tr>
<tr><td>5</td><td>For electrostatics, the concept of electric field is convenient, but not really necessary. Electric field is an elegant way of characterizing the electrical environment of a system of charges. Electric field at a point in the space around a system of charges tells you the force a unit positive test charge would experience if placed at that point</td><td>4</td></tr>
</table>

	(without disturbing the system). Electric field is a characteristic of the system of charges and is independent of the test charge that you place at a point to determine the field. The term field in physics generally refers to a quantity that is defined at every point in space and may vary from point to point. Electric field is a vector field, since force is a vector quantity. (1) Which of the following statement is correct? The electric field at a point is (a) Always continuous. (b) Continuous if there is a charge at that point. (c) Discontinuous only if there is a negative charge at that point. (d) Discontinuous if there is a charge at that point. (2) The force per unit charge is known as (a) electric flux (b) electric field (c) electric potential (d) electric current (3) The SI unit of electric field is (a) N/m (b) N-m (c) N/C (d) N/C^2 (4) The magnitude of electric field intensity E is such that, an electron placed in it would experience an electrical force equal to its weight is given by (a) mge (b) mg/e (c) e/mg (d) e^2g/m^2	
6	Dielectric with polar molecules also develops a net dipole moment in an external field, but for a different reason. In the absence of any external field, the different permanent dipoles are oriented randomly due to thermal agitation; so the total dipole moment is zero. When an external field is applied, the individual dipole moments tend to align with the field. When summed overall the molecules, there is then a net dipole moment in the direction of the external field, i.e., the dielectric is polarised. The extent of polarisation depends on the relative strength of two factors: the dipole potential energy in the external field tending to align the dipoles mutually opposite with the field and thermal energy tending to disrupt the alignment. There may be, in addition, the 'induced dipole moment' effect as for non-polar molecules, but generally the alignment effect is more important for polar molecules. Thus in either case, whether polar or non-polar, a dielectric develops a net dipole moment in the presence of an external field. The dipole moment per unit volume is called polarization.  (1) The best definition of polarisation is (a) Orientation of dipoles in random direction (b) Electric dipole moment per unit volume (c) Orientation of dipole moments (d)Change in polarity of every dipole (2) Calculate the polarisation vector of the material which has 100 dipoles per unit volume in a volume of 2 units. (a) 200 (b) 50 (c) 0.02 (d) 100 (3) The total polarisation of a material is the (a) Product of all types of polarisation (b) Sum of all types of polarisation (c)Orientation directions of the dipoles (d)Total dipole moments in the material (4) Dipoles are created when dielectric is placed in ___________ (a) Magnetic Field (b) Electric field (c) Vacuum (d) Inert	4

	Environment	
7	Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in given figure, the electric field at P is stronger than at Q.  (1) Electric lines of force about a positive point charge are (a) radially outwards (b) circular clockwise (c) radially inwards (d) parallel straight lines (2) Which of the following is false for electric lines of force? (a) They always start from positive charge and terminate on negative charges. (b) They are always perpendicular to the surface of a charged conductor. (c) They always form closed loops. (d) They are parallel and equally spaced in a region of uniform electric field. (3) Which one of the following patterns of electric line of force is not possible in field due to stationary charges? (4) Electric field lines are curved (a) in the field of a single positive or negative charge (b) in the field of two equal and opposite charges. (c) in the field of two like charges. (d) both (b) and (c)	4
8	Surface Charge Density. Surface charge density is defined as the charge per unit surface area the surface (Arial) charge symmetric distribution and follow Gauss law of electro statics mathematical term of surface charge density $\sigma=\Delta Q/\Delta S$  Two large thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite sign (± s). Having magnitude 8.8×10^{-12} cm^{-2} as shown here. The intensity of electrified at a point is E $=\sigma/\varepsilon_0$ and flux is $\Phi=E.\Delta S$, where ΔS = 1 m^2 (unit arial plate) (1) E in the outer region (I) of the first (A) plate is (a) 1.7×10^{-22} N/C (b) 1.1×10^{-12} V/m (c) Zero (d) Insufficient data	4

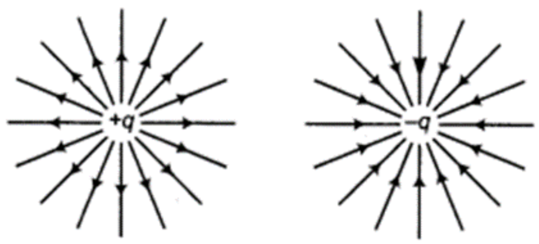
	(2) E in the outer region (III) of the second plate (B) is (a) 1 N/C (b) 0.1 V/m (c) 0.5 N/C (d) zero (3) E between (II) the plate is (a) 1 N/C (b) 0.1 V/m (c) 0.5 N/C (d) None of these (4) The ratio of E from left side of plate A at distance 1 cm and 2 m respectively is (a) 1 : 2 (b) 10 : 2 (c) 1 : 1 (d) 20 : 1	

SOLUTION

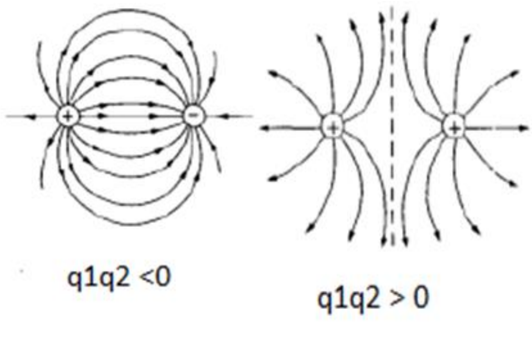
	CASE -1	CASE -2	CASE -3	CASE -4	CASE -5	CASE -6	CASE -7	CASE -8
1	a	a	c	b	b	b	A	c
2	b	b	a	d	b	a	C	d
3	b	a	c	b	c	b	C	d
4	b	b	c	a	b	b	d	c

DIAGRAMS

<table>
<tr>
<td>Field lines due to positive and negative charges



</td>
<td>Field lines due to charges (i)q1q2>0 and (ii) q1q2 < 0



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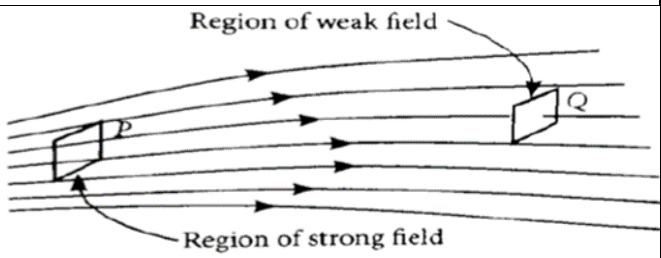
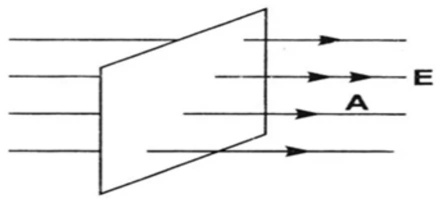


</td>
<td>Electric Flux:- Number of field line passing normally through a closed surface



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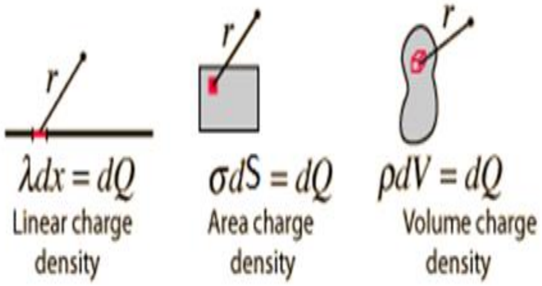
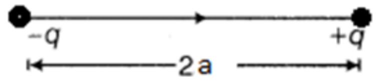
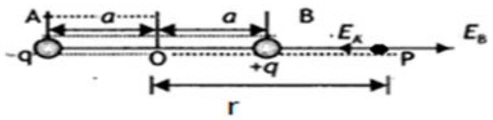
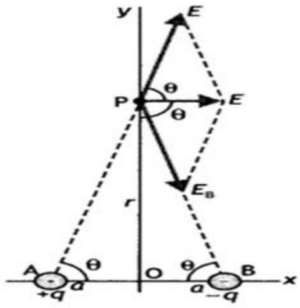
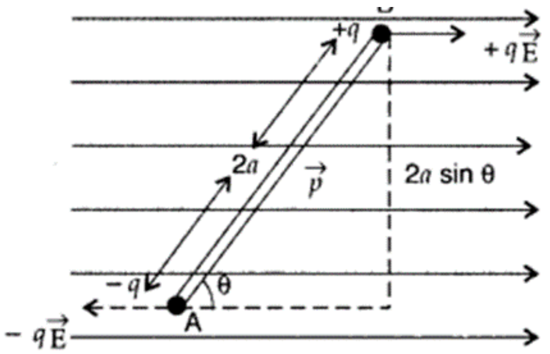
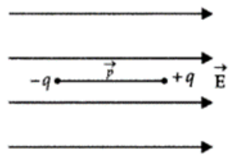
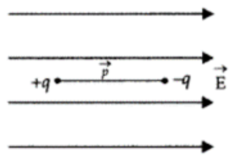
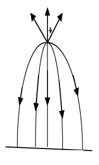
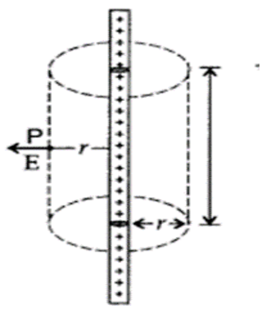
	Electric dipole 
The field of an electric dipole for points on the axis 	The field of an electric dipole for points on the equatorial plane 
Torque on a dipole in uniform external field 	(a) For stable equilibrium, the angle between p and E is 0°  (*b*) For unstable equilibrium, the angle between p and E is 180°, 
Sketch the electric field lines, when a positive charge is kept in the vicinity of an uncharged conducting plate 	field due to an infinitely long straight uniformly charged wire 
Field due to a uniformly charged infinite plane sheet	Field due to a uniformly charged thin spherical shell

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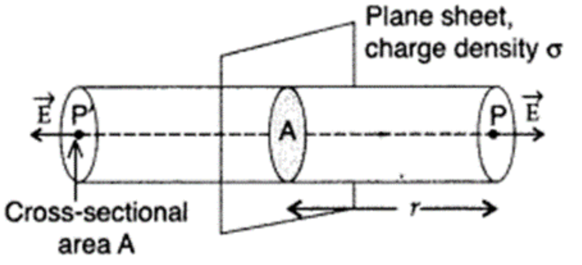
<td>
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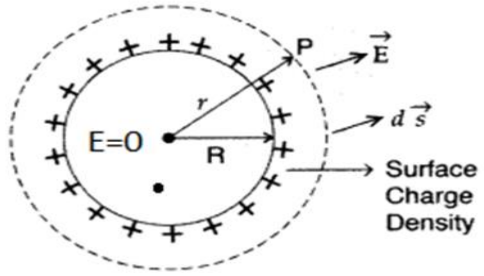
<td>
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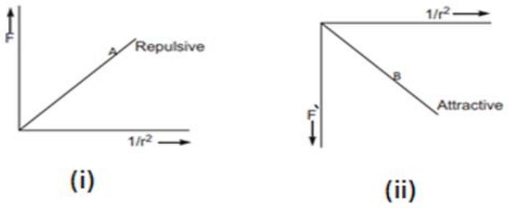
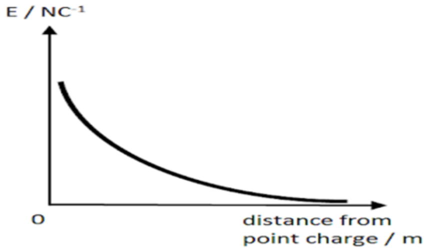
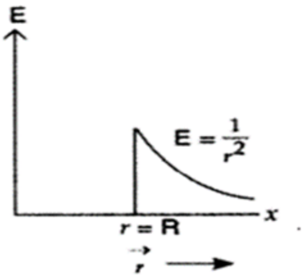
</table>

GRAPHS

<table>
<tr>
<td>Both charges will repel each other, as they are of same sign, hence slope is positive (ii) Both charges are of opposite sign, therefore they will attract each other, hence the slope is negative.

</td>
<td>E versus r graph

</td>
</tr>
<tr>
<td>Electric field due to a spherical shell

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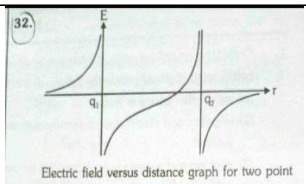
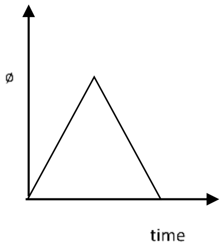
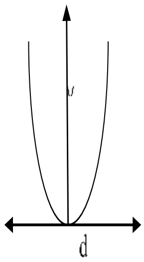
<td>

Electric field versus distance graph for two point charges is given then :-
(1) q_1 → positive, q_2 → positive
(2) q_1 → negative, q_2 → positive
(3) q_1 → positive, q_2 → negative
(4) q_1 → negative, q_2 → negative</td>
</tr>
<tr>
<td>A uniformly charged rod with linear charge density λ of length L is inserted into a hollow cubical structure of side 'L' with constant velocity and moves out from the opposite face. Draw the graph between flux and time

</td>
<td>Draw a graph showing the variation of potential with distance from the positive charge to negative charge of a dipole, by choosing the mid-point of the dipole as the origin

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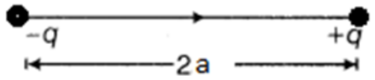
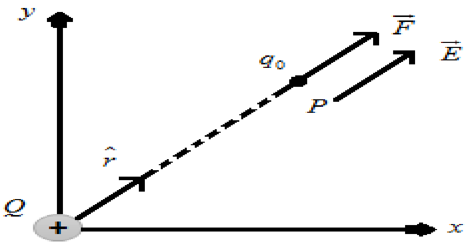
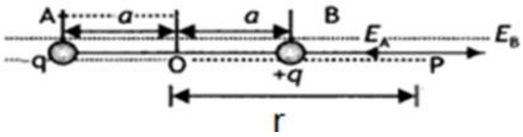
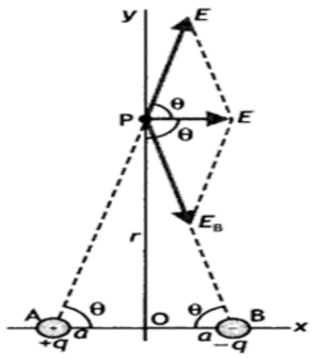
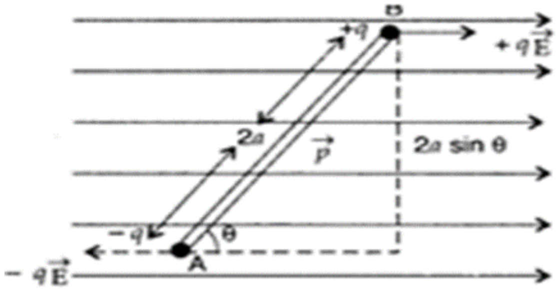
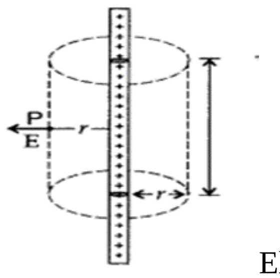
STATEMENT BASED QUESTIONS

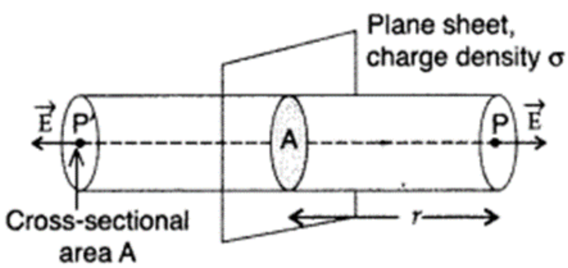
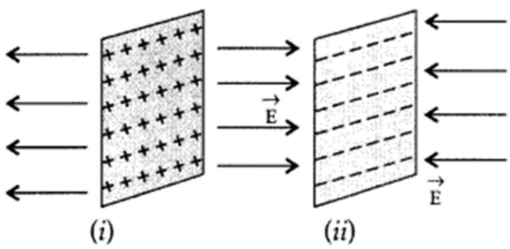
S NO	STATEMENT BASED QUESTIONS AND ANSWER	MARKS
1	State Coulomb's Law. It states that the electrostatic force of attraction or repulsion between two stationary point charges kept apart in air or vacuum is given by $F = \frac{1}{4\pi \varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$ 	2
2	List out the Properties of electric field lines 1. Electric field lines start from a positive charge and end at a negative charge, In case of a single charge, electric field lines end at infinity 2. In a charge-free region, electric field lines are continuous and smooth 3. Two electric field lines never intersect or cross each other, as if they do, there will be two vectors depicting two directions of the same electric field, which is not possible 4. Electric field lines never form a closed loop.	2
3	Define electric field intensity. Connect it with electrostatic force. Give its SI unit Force experienced by a unit positive charge. It is a vector. SI unit is NC^{-1}. $E = \frac{F}{q}$	2
4	What is the physical significance of electric field intensity? An electric field is an elegant way of characterising the electrical environment of a system of charges	2
5	Define electric dipole. Two equal and opposite charges separated by a small distance 	2
6	Define electric dipole moment. Is it scalar or a vector quantity? What is its SI unit? Product of magnitude of either charge and distance of separation between them. It is a vector. SI unit: Coulomb-metre, $\vec{p}$= (q) $2\vec{a}$; direction of $\vec{p}$ is from negative charge to positive charge.	2
7	Define electric flux. Write its SI unit. Scalar or vector It is defined as the number of field lines crossing the surface normally. $\emptyset = \overrightarrow{\Delta S}.\vec{E} = E\ (\Delta S) cos\theta$; It is a scalar; SI unit: $N\ m^2C^{-1}$	2
8	State Gauss theorem. : It states that total electric flux passing through an enclosed surface is numerically equal to 1 / ε_0 times the net charge enclosed... $\emptyset_{total} = = \frac{q_{total}}{\epsilon_0}$	2

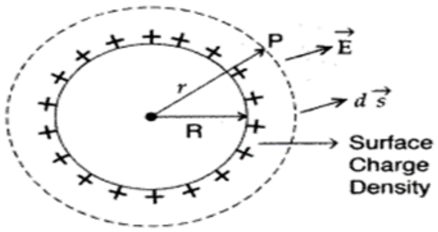
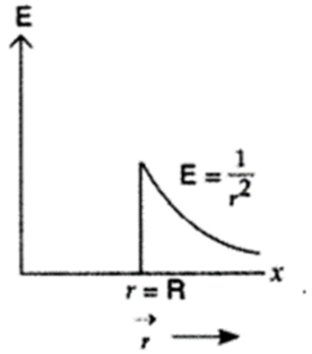
DERIVATION QUESTIONS

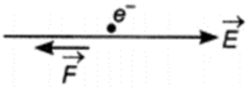
S NO	DERIVATION QUESTIONS	MARKS
1	Derive an expression for electric filed intensity at a point due to a point charge  Force at P, $F = k\frac{Qq_0}{r^2}$ We know that, $E = \frac{F}{q_0}$ Thus, Electric field due to a point charge , $E = k\frac{Q}{r^2}$	**2**
2	Derive an expression for the electric field at a point on the axis of an electric dipole of dipole moment $\vec{p}$.  $E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$ and $E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}$ The two fields at P are in opposite directions. Thus, the resultant electric field at P is given by $E = E_B - E_A$ $E = \left[\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\right]$ $= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$ $= \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2-(r-a)^2}{(r^2-a^2)^2}\right]$ Solving we have $E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2}$ ...(1)	3

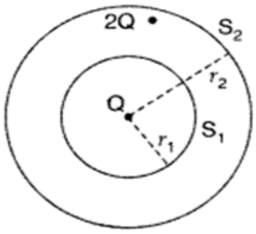
	If the dipole is short then r >> a, therefore, ‘a’ is neglected as compared to r, hence $$E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{r^4} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}. \quad ...(2)$$ Field is in the direction of the dipole moment.	
3	Derive the expression for the electric field at a point on the equatorial line of an electric dipole  The two electric fields have magnitudes $$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$ in the direction of AP $$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$ in the direction of PB. The two fields are equal in magnitude but have different directions. Resolving the two fields E_A and E_B into their rectangular components, i.e. perpendicular to and parallel to AB. The components perpendicular to AB, i.e. E_A sinθ and E_B sinθ being equal and opposite cancel out each other while the components parallel to AB, i.e. E_A cos θ and E_B cos θ being in the same direction add up as shown in the figure. Hence the resultant electric field at point P is given by $E = E_A\cos\theta + E_B\cos\theta$ $$= 2E_A\cos\theta = \frac{1}{4\pi\varepsilon_0}\frac{2q}{(r^2+a^2)}\cos\theta \quad ...(5)$$ $$E = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{(r^2+a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}}$$ $\cos\theta = a(r^2+a^2)^{1/2}$ and q 2a = p For a short dipole r^2,>>a^2 therefore $$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}.$$	3
4	Derive an expression for the torque experienced by an electric dipole kept in a	3

	uniform electric field Consider an electric dipole consisting of charges + q and – q and of length 2a placed in a uniform electric field E making an angle θ with it. It has a dipole moment of magnitude  $p = q \times 2a$ Force exerted on charge + q by field, $\vec{F} = q\vec{E}$ (along $\vec{E}$) Force exerted on charge − q by field, $\vec{F} = q\vec{E}$ (opposite to $\vec{E}$) $\therefore \vec{F}_{total} = +q\vec{E} - q\vec{E} = 0$ Hence the net translating force on a dipole in a uniform electric field is zero. But the two equal and opposite forces act at different points of the dipole. They form a couple which exerts a torque. Torque = Either force × Perpendicular distance between the two forces = qE × 2a sin θ = pE sin θ [∵ p = q × 2a; p is dipole moment] $\tau = pE \sin\theta$ $\vec{\tau} = \vec{p} \times \vec{E}$	
5	A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for the electric field through the surface of the cylinder  Electric field due to an infinitely long thin straight wire is radial. The Gaussian surface for a long thin wire of uniform linear charge density λ. The surface includes charge equal to λl.	2

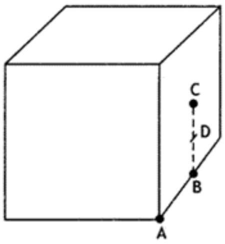
	Gauss's law then gives, $$E \times 2\pi r l = \lambda l / \varepsilon_0$$ *i.e.* $$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$$	
6	Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it. How is the field directed if (i) the sheet is positively charged, (ii) negatively charged? Consider a thin, infinite plane sheet of charge with uniform surface charge density σ. We wish to calculate its electric field at a point P at distance r from it  By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P and F equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2r with its axis perpendicular to the sheet. As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is: $$\phi E = EA + EA = 2EA$$ Charge enclosed by the *Gaussian surface,* $$q = \sigma A$$ According to *Gauss's theorem,* $$\phi_E = \frac{q}{\varepsilon_0} \quad \therefore\ 2EA = \frac{\sigma A}{\varepsilon_0} \text{ or } E = \frac{\sigma}{2\varepsilon_0}$$ Clearly, E is independent of *r*, the distance from the plane sheet. 	3
7	A thin conducting spherical shell of radius R has charge Q spread uniformly over its surface. Using Gauss's law,(i) derive an expression for an electric field at a point outside the shell (ii) And at a point inside the shell (i)To find out electric field at a point outside a spherical charged shell we imagine a symmetrical Gaussian surface in such a way that the point lies on it.	5

	From Gauss's theorem, $\phi = \oint_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$ Flux ϕ through S′ $\phi = \oint_{S'} \vec{E}.d\vec{S} = \oint_{S'} EdS = E.4\pi r^2$ $\Rightarrow E.4\pi r^2 = \frac{q}{\varepsilon_0}$ $\Rightarrow E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2}$   (ii)At a point inside the shell, q=0 so E = 0	
S NO	**HIGH ORDER THINKING SKILL**	**MARKS**
1	A charge +Q fixed on the Y axis at a distance of 1m from the origin and another charge +2Q is fixed on the X axis at a distance of m from the origin. A third charge –Q is placed at the origin. What is the angle at which it moves? Ans: Force due to both the changes are equal = KQ^2 & to each other so the resultant force will make 45^o with X-axis.	2
2	Is the force acting between two-point electric charges q_1 and q_2 kept at some distance apart in air, attractive or repulsive when? (i) $q_1q_2 > 0$ (ii) $q_1q_2 < 0$? Ans: (i) When $q_1q_2 > 0$, force is repulsive. (ii) When $q_1q_2 < 0$, force is attractive	2
3	The force on an electron kept in an electric field in a particular direction is F. What will be the magnitude and direction of the force experienced by a proton kept at the same point in the field? Mass of the proton is about 1836 times the mass of the	2

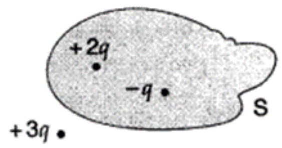
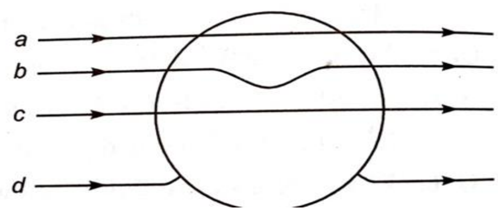
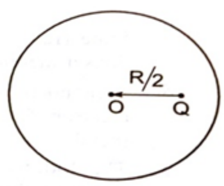
<table>
<tr><td></td><td>electron.


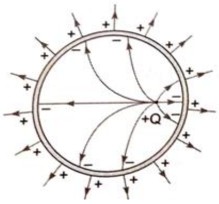
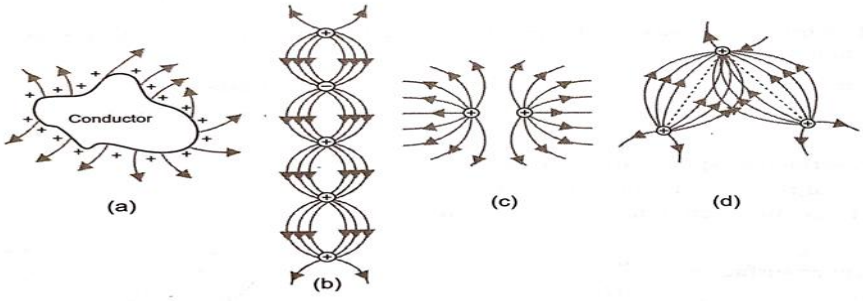
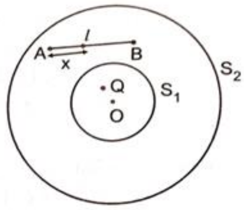
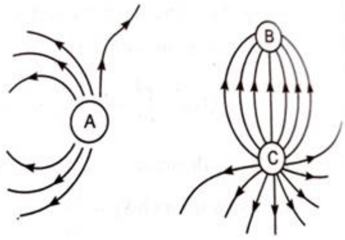
Ans: Magnitude remain same but direction is opposite (along field direction)
Since F = qE</td><td></td></tr>
<tr><td>4</td><td>A sphere S1 of radius r1 encloses a net charge Q. If there is another concentric sphere S2 of radius r2 ($r_2 > r_1$) enclosing charge 2Q, find the ratio of the electric flux through S1 and S2. How will the electric flux through sphere S1 change if a medium of dielectric constant K is introduced in the space inside S2 in place of air?


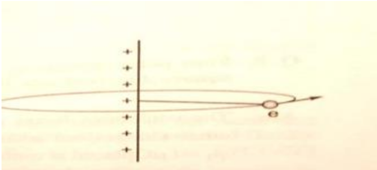
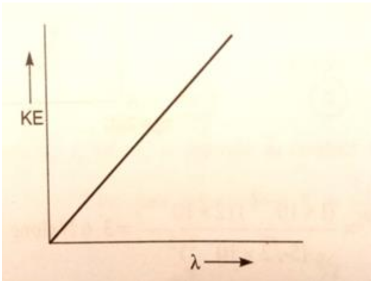
$$\text{Flux through } S_1(\phi_1) = \frac{Q}{\epsilon_0} \quad \ldots(i)$$
$$\text{Flux through } S_2(\phi_2) = \frac{Q+2Q}{\epsilon_0} = \frac{3Q}{\epsilon_0} \quad \ldots(ii)$$
$$\therefore \quad \text{Ratio of flux} = \frac{\phi_1}{\phi_2} = \frac{Q/\epsilon_0}{3Q/\epsilon_0} = \frac{1}{3}$$
Therefore, there will be no change in the flux through S1 on introducing dielectric medium inside the sphere S2.</td><td>2</td></tr>
<tr><td>5</td><td>What will be the total flux through the faces of the cube (figure) with the side of length ‘a’ if a charge q is placed at

(a) A: a corner of the cube.
(b) B: mid-point of an edge of the cube.
(c) C: centre of the face of the cube.
(d) D: mid-point of B and C.


Answer:
(a) The charge wilt is shared by eight cubes if it has to be enclosed. Therefore, the flux through the cube will be one-eighth of the total flux. $\Phi = q/8\varepsilon_0$
(b) The charge will be shared by four cubes if it has to be enclosed. Therefore, the flux</td><td>3</td></tr>
</table>

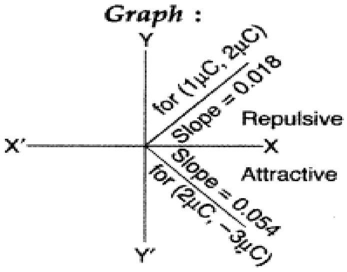
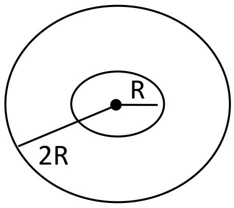
	through the cube will be one-fourth of the total flux. $\Phi = q/4\varepsilon_0$ (c) The charge will be shared by two cubes if it has to be enclosed. Therefore, the flux through the cube will be one-half of the total flux. $\Phi = q/2\varepsilon_0$ (d) The charge will be shared by two cubes if it has to be enclosed. Therefore, the flux through the cube will be one-half of the total flux. $\Phi = q/2\varepsilon_0$	
6	Figure shows three-point charges, +2q, -q and + 3q. Two charges +2q and -q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'?  According to *Gauss's law*, $\phi = \oint_S \vec{E}.\vec{dS} = \frac{q_1}{\varepsilon_0}$ **where q_1 is the total charge enclosed by the surface S** $\phi = \frac{2q-q}{\varepsilon_0} = \frac{q}{\varepsilon_0}$ $\therefore$ **Electric flux,** $\phi = \frac{q}{\varepsilon_0}$	2
7	A metallic sphere is placed in a uniform electric field. Which one of the path a, b,c and d shown in figure will be followed by the electric field lines and why?  Ans. Path 'd' is followed by electric field lines because there is no electric field lines within a metallic sphere and field lines are normal at each point of the surface	2
8	Figure shows the point charge +Q is located at a distance R/2 from the centre of the spherical metal shell. Draw the electric field lines  Ans. Electric field lines for a given system is shown:	2

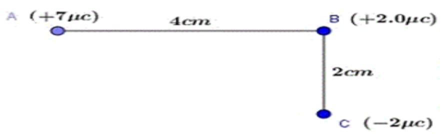
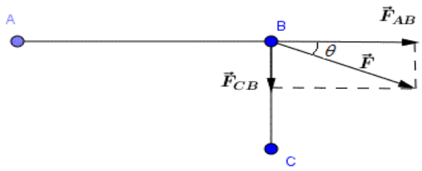
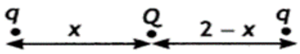
	 	
9	Which among the curves cannot possibly represent electrostatic field lines?  Ans : (a) Field lines are wrongly drawn because electric field lines must be normal to the surface of the conductor at each point. (b) Field lines are wrongly drawn because electric field lines cannot start from a negative charge. (c) Field lines are correctly drawn because they are originating from negative charge. (d) Field lines are wrongly drawn because electric field lines cannot intersect.	2
10	In the figure shown, calculate the total flux of the electrostatic field through the spheres S1 and S2. The wire AB shown here has a linear charge density ƛ given by ƛ=kx where x is measured along the wire from end A.  $Q_{AB} = \int_0^l \lambda dx = \int_0^l kx dx = kl^2/2$ By Gauss Theorem S1= Q/ ε_0 Total flux through S2 = $\frac{Q+Q_{AB}}{\varepsilon_0} = \frac{Q+kl^2/2}{\varepsilon_0}$	2
11	The given figure shows electric field lines around three-point charges A, B and C  (a) Which charges are positive? (b) Which charges has the largest magnitude? Why? Ans. (a) Charges A and C are positive since lines of forces emanate from them. (b) Charge C has the largest magnitude since maximum no. of field lines are associated with it	2

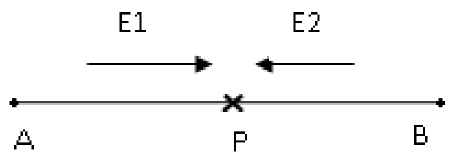
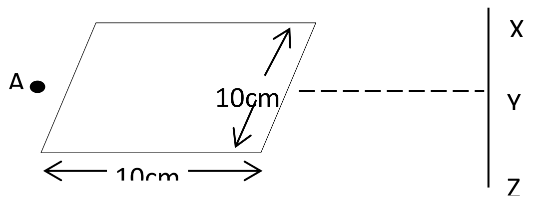
12	A simple pendulum consists of a small sphere of mass m and positive charge q is suspended by the string of length L. The pendulum is placed in the electric field of strength E directed vertically downwards. (i) What will be the time period of simple pendulum? (ii) What will be the tension of the string when pendulum will be in the rest state.? Ans (i) Time period of oscillation=$T=2\pi\sqrt{L/(g + qE/m)}$ (ii) Tension in the string when the pendulum is at rest $=mg + qE$	2
13	(a) An infinitely long positively charged straight wire has a linear charge density λ cm^{-1}.An electron is revolving around the wire as its centre with a constant velocity in a circular plane perpendicular to the wire. Deduce the expression the kinetic energy. (b) Plot the graph of kinetic energy as a function of charge density λ. Ans. Electric field due to straight wire $E= \lambda/2\pi\varepsilon_0 r$  $eE= mv^2/r$ $KE=\frac{1}{2} mv^2= e\lambda/4\pi\varepsilon_0$ b) 	3

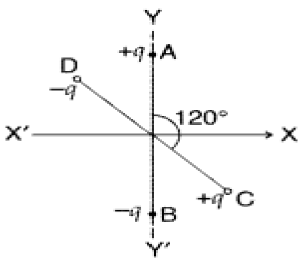
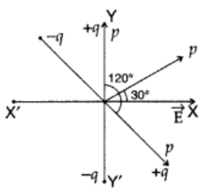
NUMERICALS

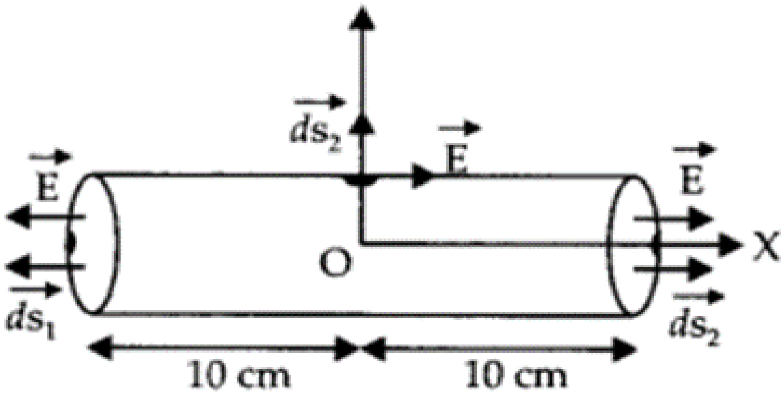
S NO	NUMERICALS	MARKS
1	If a body gives out 10^9 electrons every second, how much time is required to get out total charge of 1C from it.? Ans. Time $T= 1/(10^9 x\ 1.6x10^{-19})$ s = $6.25x10^9$s = 198.18 years	2
2	Plot a graph showing the variation of coulomb force (F) versus (1r2), where r is the distance between the two charges of each pair of charges: (1μC, 2μC) and (2μC, –3μC). Interpret the graphs obtained. Answer:	3

	For (1 μC, 2 μC) $$F_1 = \frac{9 \times 10^9 (1 \times 10^{-6})(2 \times 10^{-6})}{r^2} = \frac{0.018}{r^2}$$ and for (2 μC, –3 μC) $$F_2 = \frac{9 \times 10^9 (2 \times 10^{-6})(-3 \times 10^{-6})}{r^2} = \frac{-0.054}{r^2}$$ *Graph :*  Here positive slope depicts that force is repulsive in nature and negative slope depicts that the force is attractive in nature.	
3	Two concentric metallic spherical shells of radii R and 2R are given charges Q1 and Q2 respectively. The surface charge densities on the outer surfaces of the shells are equal. Determine the ratio Q1:Q2 Ans: Surface charge density $\sigma = constant$ $Q1 = 4\pi R^2 \sigma$ $Q2 = 4\pi (2R)^2 \sigma$ $\therefore \frac{Q1}{Q2} = \frac{1}{4}$  	2
4	Two identical metallic spheres, having unequal opposite charges are placed at a distance of 0.5m apart in air. After bringing them in contact with each other they are again placed at the same distance apart. Now the force of repulsion between them is 0.108 N. Calculate the final charge on each of them. Ans. When identical spheres come in contact then let us suppose that charge on both of them becomes equal to q then force between them is $F = (\frac{1}{4\pi\,\varepsilon 0}) qxq/r^2$ $q^2 = (0.108x(0.5)^2)/(9x10^9)$ q = 1.732μC	2
5	Three charges +Q, q, +Q are placed respectively, at distance 0, d/2 and d from the origin, on the x-axis. If the net force experienced by +Q placed at x = 0 is zero, then find value of q . QQ/d2 + Qq/(d/2)2 =0 Q + 4q = 0 or q = -Q/4	2
6	What is the net force and its direction that the charges at the vertices A and C of the	3

	right triangle ABC exert on the charge in vertex B?  HINT $\|F\| = \sqrt{(\|F_{AB}\|^2 + \|F_{CB}\|^2)} =$ $k \times 10^{-8} \sqrt{(0.875^2 + 1^2)} =$ $9.00 \times 10^9 \times 10^{-8} \sqrt{(0.875^2 + 1^2)} = 1.20 \times 10^2$ N $\theta = \arctan(\|F_{CB}\|/\|F_{AB}\|) = \arctan(k \times 10^{-8} / 0.875\ k \times 10^{-8}) = 48.8°$  	
7	Two identical point charges, q each, are kept 2 m apart in the air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q Answer: - The third charge Q. wilt is in equilibrium if it experiences zero net force. Let it be placed at a distance x meter from the charge q.  $k\frac{qQ}{x^2} = k\frac{qQ}{(2-x)^2}$ or $x^2 = (2-x)^2$ Solving for x, we have x= 1 m For the equilibrium of charges "q", the nature of charge Q must be opposite to the nature of charge q and should be placed at the centre of two charges.	2
8	The bob of a simple pendulum has a mass of 2 g and a charge of 5.0 C. It is at rest in a uniform horizontal electric field of intensity 2000 V m^{-1}. At equilibrium, find the angle that the pendulum makes with the vertical (take g = 10 m s^{-2}) At equilibrium, $T\cos\theta = mg$ ———(1) $T\sin\theta = qE$ ———(2) Dividing (2) by (1) $\tan\theta = qE/mg$ $\theta = \tan^{-1}((5 \times 10^{-6} \times 2 \times 10^3) / (2 \times 10^{-3} \times 10)) = \tan^{-1}(0.5)$	2

9	A charge of 17.7 × 10^{-4} C is distributed uniformly over a large sheet of area 200 m^2. Calculate the electric field intensity at a distance of 20 cm from it in the air. Answer: Given q = 17.7 × 10^{-4}C, A = 200 m^2, r = 20cm = 0.2 m Using the relation $E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} = \frac{17.7 \times 10^{-4}}{200 \times 8.854 \times 10^{-12}} = 9.9 \times 10^5\ NC^{-1}$	2
10	Two point charges of $+5 \times 10^{-19}C$ and $+20 \times 10^{-19}C$ are separated by a distance of 2m. Find the point on the line joining them at which electric field intensity is zero.  Ans: $\frac{1}{4\pi\epsilon o}\frac{q1}{x^2} = \frac{1}{4\pi\epsilon o}\frac{q2}{(2-x)^2}$ On solving, $\therefore x = \frac{2}{3}$ m	2
11	Given a uniformly charged plane/sheet of surface charge density $\sigma = 2 \times 10^{17} C/m^2$  (1) Find the electric field intensity at a point A, 5mm away from the sheet on the left side. (2) Given a straight line with three points X, Y and Z placed 50cm away from the charged sheet on the right side. At which of these points, the field due to the sheet remain the same as that of point A and why? Ans: (1) At A, $E = \frac{\sigma}{2\epsilon o} = 1.1 \times 10^{28}$N/C Directed away from sheet (2) Point Y Because at 50cm, the charge sheet acts as a finite sheet and thus the magnitude remains same towards the middle region of the planar sheet.	3
12	Calculate the field due to an electric dipole of length 10 cm and consisting of charges of ±100 μC at a point 20 cm from each charge. (Ans. 1.125 ×10^7 NC^{-1})	2
13	A sample of HCl gas is placed in a uniform electric field of magnitude 3 × 10^4 N C^{-1}. The dipole moment of each HCl molecule is 3.4 × 10^{-30} Cm. Calculate the maximum	2

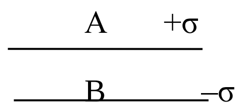
	torque experienced by each HCl molecule. Ans The maximum torque experienced by the dipole is when it is aligned perpendicular to the applied field. $\tau = pE \sin 90 = 3.4\times10^{-30} \times 3 \times10^{4}$ N m $\tau = 10.2 \times10^{-26}$ N m	
14	A dipole consisting of an electron and a proton separated by a distance of 4×10^{-10}m is situated in an electric field of intensity 3×10^{-5} NC^{-1} at an angle of 30° with the field. Calculate the dipole moment and the torque acting on it. Charge on an electron = 1.602×10^{-19} C. (Ans. 6.41×10^{-29} C m, 9.615×10^{-24} Nm)	2
15	Two small identical electrical dipoles AB and CD, each of dipole moment 'p' are kept at an angle of 120° as shown in the figure. What X' is the resultant dipole moment of this combination? If this system is subjected to electric field (E) directed along + X direction, what will be the magnitude and direction of the torque acting on this?  Answer: Resultant dipole moment of both dipoles is $= \sqrt{p^2 + p^2 + 2p^2 \cos\theta}$ $= \sqrt{2p^2 + 2p^2 \cos 120°}$ $= \sqrt{2p^2 + 2p^2\left(-\frac{1}{2}\right)}$ $= \sqrt{p^2} = p$  Resultant dipole moment (p) makes an angle of 60° with each dipole and 30° with x-axis as shown in the figure. Now $\tau = pE \sin 30° = pE\left(\frac{1}{2}\right) \Rightarrow \boxed{\tau = \frac{pE}{2}}$	3
16	An electric field along the x-axis is given by $\vec{E}$ = 100 îN/C for x > 0 and $\vec{E}$ = -100 îN/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm lies parallel to the x-axis with its centre at the origin and one face at x = +10 cm, the other face at x = -10 cm. Calculate the net outward flux through the cylinder	3

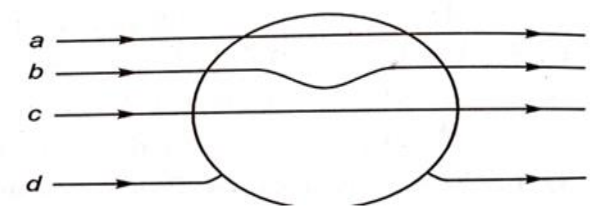
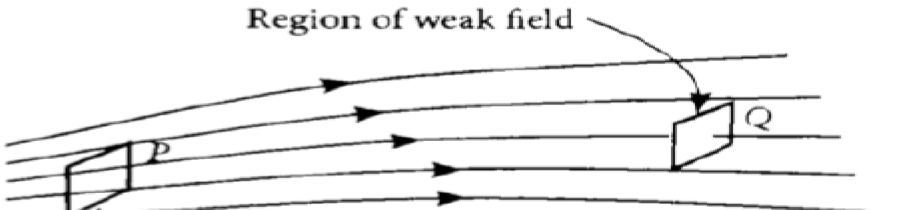
	Here $E_x = 100\,\hat{i}\,NC^{-1}$ for $x > 0$ $E_x = -100\,\hat{i}\,NC^{-1}$ for $x < 0$ $l = 20$ cm $= 0.2$ m  r = 5 cm = 0.05 m , $\Phi = ?$ Net outward flux through the cylinder $\Phi = \Phi_1 + \Phi_2 + \Phi_3$ $= \vec{E}\cdot\vec{ds}_1 + \vec{E}\cdot\vec{ds}_2 + \vec{E}\cdot\vec{ds}_3$ $= Eds_1 \cos 180° + Eds_2 \cos 90° + Eds3 \cos 0°$ $= -Eds_1 + Eds_2\,(0) + Eds \cos 0°$ $= -(-100)\,ds + 100\,ds$ $= (100 + 100)\,ds$ $= 200 \times \pi r^2 = 200 \times 3.14 \times (0.05)^2$ $= 1.57\ Nm^2\,C^{-1}$	
17	A uniformly charged conducting sphere of 2.4m diameter has a surface charge density of 80 $\mu c/m^2$. (a) Find the charge on the sphere (b) What is the total electric flux leaving the surface of the sphere? (a) $q = \sigma A = \sigma \times 4\pi R \ = 80 \times 10^{-6} \times 4 \times 3.14 \times 1.2^2 \ = 1446.9\mu C$ (b) $\phi = \frac{q}{\varepsilon_0} = \frac{1446.9 \times 10^{-6}}{8.854 \times 10^{-12}} = 163 \times 10^6\ Nm^2C^{-1}$	2
18	Two charges of magnitudes – 2Q and + Q are located at points (a, 0) and (4a,0) respectively. What is the electric flux due to these charges through a sphere of radius ‘3a’ with its centre at the origin? Answer:	2

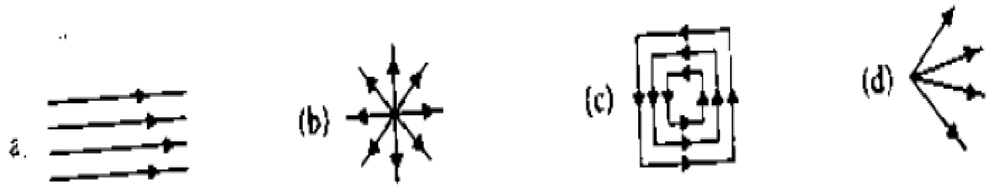
	$\text{Flux} = \frac{\text{Charge Enclosed}}{\varepsilon_0} = \frac{-2Q}{\varepsilon_0}$	
19	Given a uniform electric field E = 2 × 103 i^ N/ C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x-axis? Answer: Given : E =5×103i^N/C $A = 10 \times 10 \times 10^{-4} m^2$, Flux (ϕ) = EA cos θ (i) For first case, θ = 0, cos 0 = 1 ∴ Flux = $(5 \times 10^3) \times (10 \times 10 \times 10^{-4})$ (ii) Angle of square plane with x-axis = 30° Hence the 0 will be 90° – 30° = 60° EA cos θ = $(5 \times 10^3) \times (10 \times 10 \times 10^{-4}) \times \cos 60$ = 50 × 12 = $25\ Nm^2C^{-1}$	3
20	What is the flux due to electric field E=3×103i^ N/C through a square of side 10 cm, when it is held normal to if? **Given :** $E = 3 \times 10^3 \hat{i}$ N/C $A = 10 \times 10\ cm^2 = \frac{10}{100} \times \frac{10}{100}\ m^2$ $\phi = \vec{E} \times \vec{A} = EA \cos\theta$ $\because \theta = 0$ and $\cos\theta =$ $= EA$ $= (3 \times 10^3) \times \left(\frac{10}{100} \times \frac{10}{100}\right)$ $= \mathbf{30\ Nm^2\ C^{-1}}$	2

SELF-EVALUATION TEST

MAX.MARKS: -35 **DURATION: -90Min**

NO	QUESTIONS	MARKS
1	Two-point charges + Q and + q is separated by a certain distance. If + Q > + q then in between the charges the electric field is zero at a point (a) closer to + Q (b) exactly at the mid-point of line segment joining + Q and + q. (c) closer to + q (d) nowhere on the line segment joining + Q and + q.	1
2	Electric lines of force about a negative point charge are (a) circular anticlockwise (b) circular clockwise (c) radial, inwards (d) radial, outwards	1
3	The electric field at a point on equatorial line of a dipole and direction of dipole moment (a) will be parallel (b) will be in opposite direction (c) will be perpendicular (d) are not related	1
4	Dielectric constant for a metal is (a) zero (b) infinite (c) 1 (d) 10	1
5	Which of the following statements is false for a perfect conductor? (a) The surface of the conductor is an equipotential surface. (b) The electric field just outside the surface of a conductor is perpendicular to the surface. (c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor. (d) None of these	1
6	**Assertion:** A metallic shield in the form of a hollow shell may be built to block an electric field. **Reason**: In a hollow spherical shield, the electric field inside it is zero at every point. a) Both assertion and reason are correct and the reason is the correct explanation of assertion. b) Both assertion and reason are correct and reason is not a correct explanation of assertion. c) Assertion is correct but the reason is incorrect d) Assertion is incorrect but the reason is correct	1
7	a) What is the angle between the directions of electric field and dipole moment at any (i) axial point and (ii) Equatorial point due to an electric dipole? b) The force between two-point charges kept at a distance r apart in air is F. If the same charges are kept in water of dielectric constant 81 at the same distance, how does the force between them change	2
8	Define electric dipole moment. Is it scalar or a vector quantity? What is its SI unit?	2
9	Define electric flux. Write its SI unit. Scalar or vector	2
10	Two plane sheet of charge densities +σ and –σ are kept as shown in figure. What are the electric field intensities at points A & B.? 	2

11	Derive an expression for the electric field intensity at a point on the equatorial line of an electric dipole of dipole moment p and length 2a.	3
12	State Gauss theorem. Derive an expression of electric field due to infinitely long line charge of uniform linear charge density.	3
13	a) Sketch the electric field lines for two-point charges q_1 and q_2 for $q_1q_2>0$ and $0>q_1q_2$ separated by a distance d. b) Plot Between E & r	3
14	a) A simple pendulum consists of a small sphere of mass m and positive charge q is suspended by the string of length L. The pendulum is placed in the electric field of strength E directed vertically downwards. What will be the time period of simple pendulum? b) A metallic sphere is placed in a uniform electric field. Which one of the path a,b,c and d shown in figure will be followed by the electric field lines and why?  	3
15	**Case Study :** Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in given figure, the electric field at P is stronger than at Q.  (i) Electric lines of force about a positive point charge are (a) radially outwards (b) circular clockwise (c) radially inwards (d) parallel straight lines (ii) Which of the following is false for electric lines of force? (a) They always start from positive charge and terminate on negative charges. (b) They are always perpendicular to the surface of a charged conductor. (c) They always form closed loops. (d) They are parallel and equally spaced in a region of uniform electric field.	4

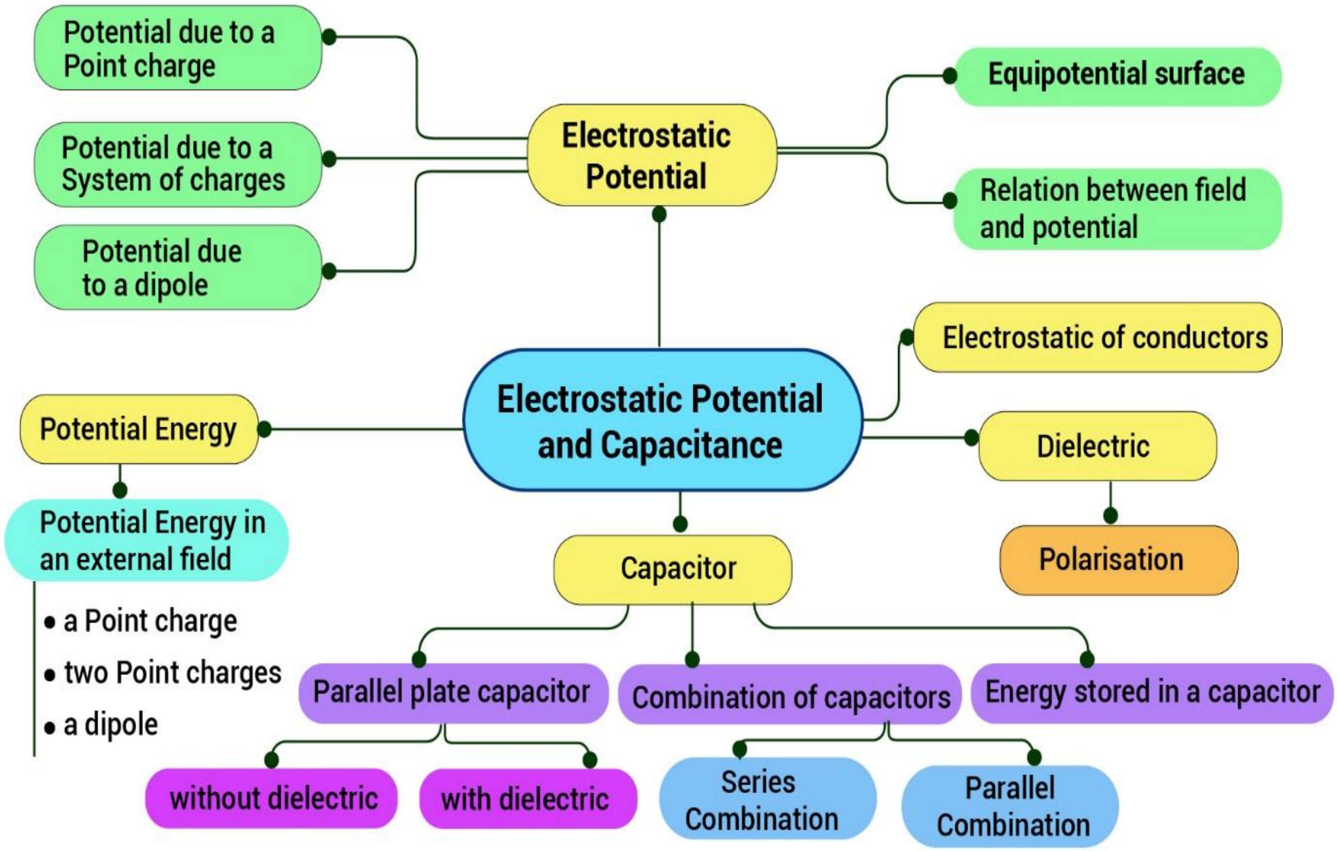
	(iii) Which one of the following patterns of electric line of force is not possible in field due to stationary charges?  (iv) Electric field lines are curved (a) in the field of a single positive or negative charge (b) in the field of two equal and opposite charges. (c) in the field of two like charges. (d) both (b) and (c)	
16	(a) A point charge (+Q) is kept in the vicinity of uncharged conducting plate. Sketch electric field lines between the charge and the plate. (b) Two infinitely large plane thin parallel sheets having surface charge densities σ1 and σ2 (σ1> σ2) . Write the magnitudes and directions of the net fields in the regions I, II and III.	5

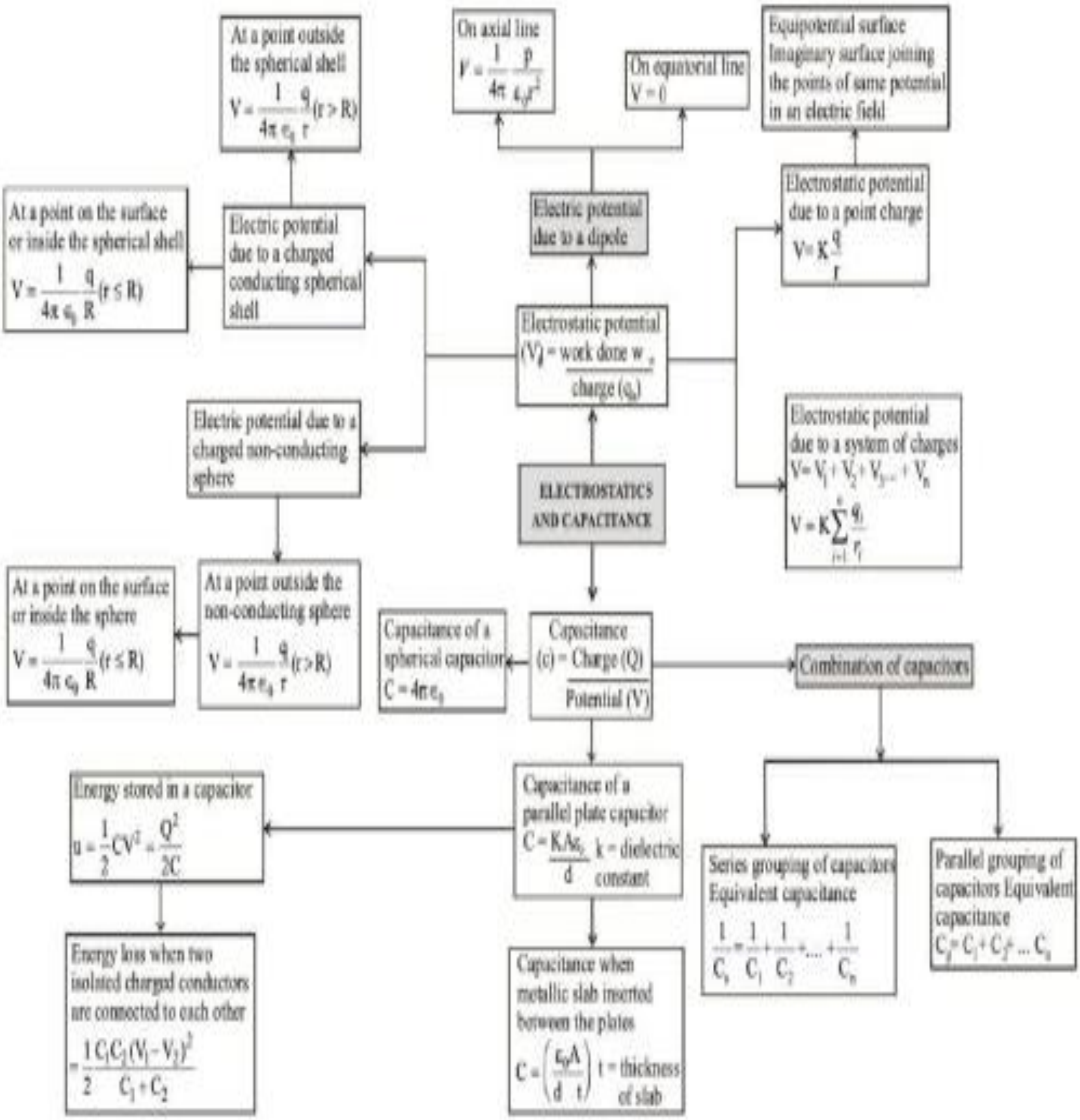
CHAPTER - 2
ELECTROSTATIC POTENTIAL AND CAPACITANCE

1.GIST OF THE CHAPTER

Chapter–2: Electrostatic Potential and Capacitance: Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field. Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor (no derivation, formulae only).

2. MIND MAP




At a point outside the spherical shell $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r} (r > R)$
On axial line $V = \frac{1}{4\pi\epsilon_0}\frac{p}{r^2}$
On equatorial line V = 0
Equipotential surface Imaginary surface joining the points of same potential in an electric field
At a point on the surface or inside the spherical shell $V = \frac{1}{4\pi\epsilon_0}\frac{q}{R} (r \le R)$
Electric potential due to a charged conducting spherical shell
Electric potential due to a dipole
Electrostatic potential due to a point charge $V = K\frac{q}{r}$
Electrostatic potential $(V) = \frac{\text{work done } w}{\text{charge } (q_0)}$
Electric potential due to a charged non-conducting sphere
Electrostatic potential due to a system of charges $V = V_1 + V_2 + V_3 ... + V_n$ $V = K\sum_{i=1}^{n}\frac{q_i}{r_i}$
ELECTROSTATICS AND CAPACITANCE
At a point on the surface or inside the sphere $V = \frac{1}{4\pi\epsilon_0}\frac{q}{R} (r \le R)$
At a point outside the non-conducting sphere $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r} (r > R)$
Capacitance of a spherical capacitor $C = 4\pi\epsilon_0$
Capacitance $(c) = \frac{\text{Charge (Q)}}{\text{Potential (V)}}$
Combination of capacitors
Energy stored in a capacitor $u = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$
Capacitance of a parallel plate capacitor $C = \frac{KA\epsilon_0}{d}$ k = dielectric constant
Series grouping of capacitors Equivalent capacitance $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}$
Parallel grouping of capacitors Equivalent capacitance $C_p = C_1 + C_2 + ... C_n$
Energy loss when two isolated charged conductors are connected to each other $= \frac{1}{2}\frac{C_1C_2(V_1 - V_2)^2}{C_1 + C_2}$
Capacitance when metallic slab inserted between the plates $C = \left(\frac{\epsilon_0 A}{d - t}\right)$ t = thickness of slab

Electrostatic Potential & Capacitance

Electric Potential

$V_p = Q/4\pi\varepsilon_0 r$ ← Electric Potential due to a point charge

Work done perunit test charge by an external agent in moving the test charge from reference point to the charge from reference point to the desired point S.I. unit J/C
V_0 = Work done/ charge

Potential due to a system charge: $V = \frac{1}{4\pi\varepsilon_0} \sum \frac{Q_i}{r_i}$

Potential due to a Dipole: $V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$

Where p = qd

$\theta = \angle AON$

At $\theta = 0$, $V = \frac{1}{4\pi\varepsilon_0} P$[Axial position]

At, $\theta = 90°$, V = 0[equitorial position]

Conductors	Insulators
Such a materail which when placed in an electric field, the free electrons move in a direction opposite to the field	Such a materail in which electrons are tightly bound, & when exposed in an electric field, Electrons does not move i.e. having no free electrons.

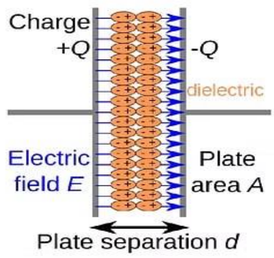
· Electric field inside a conductor is zero · Electric field is always perpendicular to the charged surface.
· In static state, there will be no additional charge in a conductor.

In 1774, AlessandroVolta worte Treatise" on the forces of attraction of electric fire"

Dielectric

· $F = \frac{q_1 q_2}{4\pi k\varepsilon_0 r^2}$, K = Dielectric constant of medium

· A dielectric is an electric insulator that can be polarized by an applied electric field.



Equipotential Surface

At $\theta = 0$, $V = \frac{1}{4\pi\varepsilon_0} p$ [axial position]
At $\theta = 90°$, $V = 1$ p [axial position]

· Potential is same at all the points of the surface
· Componenets of electric field parallel to an equipotential surface is zero.

Electric Potential Energy

Its the negative work done by electric force as the configuration of the sytem changes.

$Ur_2 - Ur_1 = -W = \frac{q_1 . q_2}{4\pi\varepsilon_0} \left(\frac{1}{R1} - \frac{1}{R2}\right)$

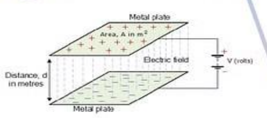
If the seperation between charges is 'r' then $U(r) = \frac{q1 . q2}{4\pi\varepsilon_0 r}$

Potential Difference,
$V_B - V_A = \frac{U_B - U_A}{q}$

$U_B - U_A$ = change in Potential Energy
q = test Charge

Potential Energy of a Dipole

dU =pEsinθd
If we choose P.E. of Dipole to be zero when θ= 90°then
$U_\theta - U_{90} = pE \sin_\theta d$
$U_\theta = -pE \cos_\theta = -p \times E$ If it is rotated through angle Against the troque



Capacitance, C = Q/V

Capacitance of a parellel plate capacitor $C = K_\varepsilon 0$ A/d, K = dielectric constant
K = dielectric constant

Capacitance when material slab inserted between them
C= kε0 A/[Kd -x(k-1)]
where x = thichness of the slab inserted

Capacitance when Spherical capacitor
$C = 4\pi\varepsilon_0 / \frac{1}{R1} - \frac{1}{R2}$

For isolated sphere
$C = 4\pi\varepsilon_0 R$

Parallel grouping of capacitors
$C = C_1 + C_2 + C_3 + C_4 + C_5 + ... + C_n$
For two, C=C1+C2

Series Grouping of Capacitors
$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ------ + \frac{1}{C_n}$

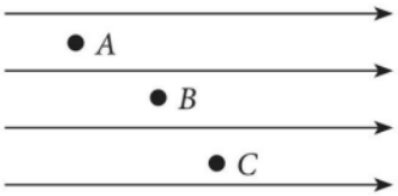
Energy stored in a capacitor
$U = \frac{1}{2} CV^2 = \frac{Q^2}{2C}$

3.MULTIPLE CHOICE QUESTIONS

1	Three charges +Q, q, +Q are placed respectively, at distance 0, d/2 and d from the origin, on the x-axis. If the net force experienced by +Q placed at x = 0 is zero, then value of q is (a) +Q/4 (b) –Q/2 (c) +Q/2 (d) –Q/4
2	An electric field of 1000 V/m is applied to an electric dipole at an angle of 45°. The value of the electric dipole moment is 10^{-29} Cm. What is the potential energy of the electric dipole? (a) -10×10^{-29} J (b) -7×10^{-27} J (c) -20×10^{-18} J (d) -9×10^{-20} J
3	Voltage rating of a parallel plate capacitor is 500 V. Its dielectric can withstand a maximum electric field of 106 V m^{-1}. The plate area is 10^{-4} m^2. What is the dielectric constant if the capacitance is 15 pF? (given $\varepsilon_0 = 8.86 \times 10^{-12}$ C^2 N^{-1} m^{-2}) (a) 3.8 (b) 8.5 (c) 6.2 (d) 4.5
4	The bob of a simple pendulum has a mass of 2 g and a charge of 5.0 C. It is at rest in a uniform horizontal electric field of intensity 2000 V m^{-1}. At equilibrium, the angle that the pendulum makes with the vertical is (take g = 10 m s^{-2}) (a) $\tan^{-1}$ (0.2) (b) $\tan^{-1}$ (0.5) (c) $\tan^{-1}$ (2.0) (d) $\tan^{-1}$ (5.0)
5	A parallel plate capacitor has 1 μF capacitance. One of its two plates is given + 2 μC charge and the other plate, +4 μC charge. The potential difference developed across the capacitor is (a) 3 V (b) 2 V (c) 5 V (d) 1 V

6	Two identical conducting spheres A and B, carry equal charge. They are separated by a distance much larger than their diameters, and the force between them is F. A third identical conducting sphere, C, is uncharged. Sphere C is first touched to A, then to B, and then removed. As a result, the force between A and B would be equal to (a) 3F/8 (b) F/2 (c) 3F/4 (d) F
7	Two capacitors C_1 and C_2 are charged to 120 V and 200 V, respectively. It is found that by connecting them together the potential on each one can be made zero. Then (a) $9C_1 = 4C_2$ (b) $5C_1 = 3C_2$ (c) $3C_1 = 5C_2$ (d) $3C_1 + 5C_2 = 0$
8	An electric dipole is placed at an angle of 30º to a non-uniform electric field. The dipole will experience (a) a torque only (b) a translational force only in the direction of the field (c) a translational force only in a direction normal to the direction of the field (d) a torque as well as a translational force
9	The magnitude of electric field intensity E is such that, an electron placed in it would experience an electrical force equal to its weight is given by (a) mge (b) mg/e (c) e/mg (d) e^2g/m^2
10	Four-point charges -Q, -q, 2q and 2Q are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of square is zero is: (a) Q = -q (b) Q = - 1/q (c) Q = q (d) Q = 1/q

11	What is the flux through the cube of side 'a' if a point charge of q is at one corner? (a) $2q/\varepsilon_0$ (b) $q/8\ \varepsilon_0$ (c) $q/\ \varepsilon_0$ (d) $q\ 6a^2/\ \varepsilon_0$
12	The electric potential V at any point (x, y,z), all in metres in space is given by $V = 4x^2$ volt. The electric field at the point (1,0,2) in volt/metre, is (a) 8 along positive X -axis (b) 16 along negative X -axis (c) 16 along positive X - axis (d) 8 along negative X - axis
13	The presence of an uncharged conductor near a charged one increases the (a) the potential of the charged conductor (b) the capacity of the charged conductor (c) charge of the charged conductor (d) No effect
14	What is the value of capacitance that must be connected in parallel with 50 pF condenser to make an equivalent capacitance of 150 pF? (a) 200pF (b) 100pF (c) 50pF (d) 150pF
15	The relation between electric polarization and susceptibility indicates that electric polarization is (a) proportional to square root of susceptibility. (b) proportional to susceptibility. (c) inversely proportional to susceptibility. (d) independent of susceptibility.
16	If a third equal and similar charge is placed between two equal and similar charges, then this third charge will (a) move out of the field of influence of the two charges (b) not be in equilibrium (c) Will be in stable equilibrium (d) be in unstable equilibrium
17	The electric potential at a point in free space due to a charge Q coulomb is $Qx10^{11}$ V. The electric field at that point is (a) $4\pi\varepsilon_0 Qx10^{22}$ V/m (b) $12\pi\varepsilon_0 Qx10^{20}$ V/m (c) $4\pi\varepsilon_0 Qx10^{20}$ V/m (d) $12\pi\varepsilon_0 Qx10^{22}$ V/m
18	Two points P and Q are maintained at the potentials of 10 V and – 4 V,

	respectively. The work done in moving 100 electrons from P to Q is a) 2.24×10^{-16} J b) -2.24×10^{-16} J c) 2.0×10^{-16} J d) 1.24×10^{-16} J
19	A parallel plate air capacitor is charged and then isolated. When a dielectric material is inserted between the plates of the capacitor, then which of the following does not change a) Electric field between the plates b) Potential difference across the plates c) Charge on the plates d) Energy stored in the capacitor
20	Figure shows three points A, B and C in an uniform electric field. Arrange the potential at these points in the descending order.  a) VA, VB, VC b) VB, VA, VC c) VA, VC, VB d) VC, VA, VB
21	Which of the following statements is not true for a perfect conductor? a) The surface of the conductor is an equipotential surface. b) The electric field just outside the surface of a conductor is perpendicular to the surface. c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor. d) None of these
22	On moving a charge of 20 C by 2 cm, 2 J of work is done. Then the potential difference between the points is (a) 0.1 V (b) 8 V (c) 2 V (d) 0.5 V
23	In brining an electron towards another electron, the electrostatic potential energy of the system (a) increases (b) decreases (c) remains unchanged (d) becomes zero

24	Electric potential of earth is taken to be zero, because earth is a good (a) insulator (b) conductor (c) semi-conductor (d) dielectric
25	Equipotential surface associated with an electric field, which is increasing in magnitude along the X-direction, are (a) Planes parallel to YZ-plane. (b) Planes parallel to XZ-plane. (c) Planes parallel to XY-plane. (d) Coaxial cylinder of increasing radii around the X-axis.
26	What is angle between electric field and equipotential surface? (a) 90° always (b) 0° always (c) 0° to 90° (d) 0° to 180°

Qn.No	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans	**d**	**b**	**b**	**b**	**d**	**a**	**c**	**d**	**b**	**a**	**b**	**d**	**b**
Qn.No	14	15	16	17	18	19	20	21	22	23	24	25	26
Ans	**b**	**d**	**c**	**a**	**a**	**c**	**a**	**d**	**a**	**a**	**b**	**c**	**a**

4.ASSERTION REASON TYPE QUESTIONS

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) **Both A and R are true and R is the correct explanation of A**
b) **Both A and R are true but R is NOT the correct explanation of A**
c) **A is true but R is false**
d) **A is false and R is also false**

Q.1. Assertion: If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.
Reason: Capacity of the capacitor does not depend upon the nature of the material.
Q.2. Assertion: A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant K is introduced between the plates. The energy which is stored becomes K times.
Reason: The surface density of charge on the plate remains constant or unchanged.
Q.3. Assertion: The total charge stored in a capacitor is zero.
Reason: The field just outside the capacitor is σ/ε_0. (σ is the charge density).
Q.4. Assertion: The electrostatic force between the plates of a charged isolated capacitor decreases when dielectric fills whole space between plates.
Reason: The electric field between the plates of a charged isolated capacitance increases when dielectric fills whole space between plates.
Q.5. **Assertion:** One may have zero potential but non-zero electric field at a point in space.
Reason: Potential is a scalar quantity.
Q.6. **Assertion:** Two equipotential surfaces cannot cut each other.
Reason: Two equipotential surfaces are parallel to each other.

Q.7. **Assertion:** A dielectric is inserted between the plates of a battery connected capacitor. The energy of the capacitor increases.
Reason: Energy of the capacitor, $U=CV^2/2$
Q.8. **Assertion:** Sensitive instruments can protect from outside electrical influence by enclosing them in a hollow conductor.
Reason: Potential inside the cavity is zero.
Q.9**. Assertion:** Polar molecules have permanent dipole moment.
Reason: In polar molecules, the centres of positive and negative charges coincide even when there is no external field.
Q.10. **Assertion:** Work done by the electrostatic force in bringing the unit positive Charge form infinity to the point P is positive.
Reason: The force on a unit positive test charge is attractive, so that the electrostatic force and the displacement (from infinity to P) are in the same direction.

ANSWER

1	2	3	4	5	6	7	8	9	10
c	c	c	d	b	c	a	c	c	a

5. NUMERICAL PROBLEMS

1. An electric field of 1000 V/m is applied to an electric dipole at an angle of 45°. The value of the electric dipole moment is 10^{-29} Cm. What is the potential energy of the electric dipole?

$E = 1000$ V/m , $p = 10^{-29}$ Cm, $\theta = 45^0$

Potential energy stored in the dipole,

$U = -p.E\cos\theta = -10^{29-} \times 1000 \times \cos 45^0$

$U = -12\times10^{-26}$

$U = -0.707 \times 10^{-26}$ J $= -7 \times 10^{-27}$ J

2. There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between the limits 589.0 V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field?

$\Delta V = E.d$

$\Delta V = Ed\cos\theta = 0.8 \times \cos 60^0$

$\Delta V = 0.4$

Hence the new potential at the point on the sphere is

589.0 + 0.4 = 589.4 V

3. Two capacitors of capacitance 6μf and 12μf are connected in series with a battery. The voltage across the 6μf capacitor is 2V. Compute the total battery voltage.

Ans: - In series combination, Q is same in both capacitors

Q1= Q2, C1V1 = C2V2, 6μf x 2V = 12μf x V2

V2 = 6x2 / 12 = 1 volt

V=V1 + V2 = 2V+1V = 3V

4. Net capacitance of three identical capacitors in series is 1μF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations

$$C_s = \frac{C}{3} = 1\mu F$$

$$C = 3\mu F$$

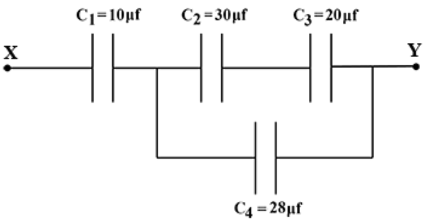
$$C_p = 3C = 9\mu F$$

$$\frac{U_s}{U_p} = \frac{\frac{1}{2} C_s V^2}{\frac{1}{2} C_p V^2}$$

$$= \frac{C_s}{C_p} = \frac{1}{9} = 1:9$$

($1/C_S = 1/C_1 + 1/C_2 + 1/C_3$ $\quad$ $C_P = C_1 + C_2 + C_3$)

5.Four capacitors, C1,C2,C3 and C4 are connected as shown in figure below. Calculate equivalent capacitance of the circuit between points X and Y.



The given arrangement of capacitors can be analysed as below. The combination of capacitors C2 and C3 of capacity 30 μF and 20 μF are in series, their combined capacity is given by

C' = [30 × 20]/50 = 12μF

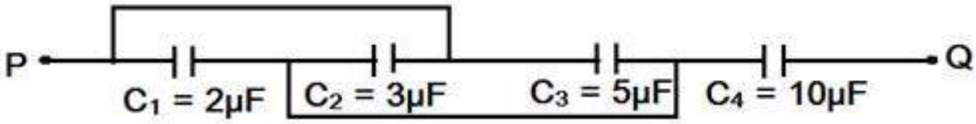
The capacitor C' is in parallel with C4, their combined capacity C" is given by

C" = 12 + 28 = 40μF

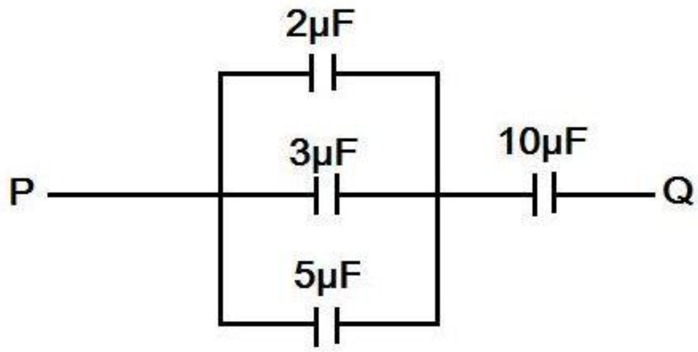
Now, C1 and C" are in series. ∴ Net capacity of the combination is given by

C = [40 × 10]/ 50= 400/ 50 = 8μF

6.For circuit the equivalent capacitance between points P and Q is (A) 6 if C1 = 2μF, C2 = 3μF, C3 = 5μF C4 = 10μF.

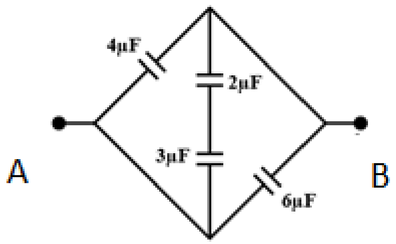


one of the plates of capacitor C1, C2, C3 is connected to one common point. Hence C1, C2, C3 are effectively connected in parallel. and C4 is in series with this combination



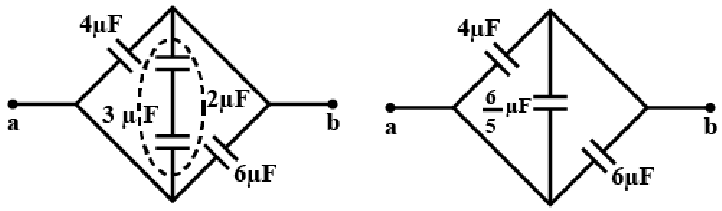
C_T=5 Mf

7.. From the given figure, find the equivalent capacitance between the points A and B.



Ans:- In series combination C = (C1C2) / (C1+C2) = 3μFx 2μF / 5μF = 6/5 μF

In parallel combination C_{AB}=C1+C2+C3 = 4μF+ 6/5μF + 6μF = 56/5μF = 11.2μF



8.The equivalent capacitance of the combination between *A* and *B* in the given figure is 4 μF.

(i) Calculate capacitance of the capacitor C.

(ii) Calculate charge on each capacitor if a 12 V battery is connected across terminals A and B.

(iii)What will be the potential drop across each capacitor?

(i) Given $C_{AB} = 4\,\mu F$

Capacitance 20 μF and C (μF) are in series

$$\therefore \qquad C_{AB} = \frac{C \times 20}{C + 20}$$

$$\Rightarrow \qquad 4\,\mu F = \frac{20\,C}{C + 20} \quad \text{or} \quad 4C + 80 = 20\,C$$

$$\Rightarrow \qquad 16C = 80 \quad \text{or} \quad C = 5\,\mu F$$

(ii) Charge on each capacitor, $Q = C_{AB}V$

$$= (4\,\mu F) \times (12\,V) = 48\,\mu C$$

(iii) Potential drop across 20 μF capacitor

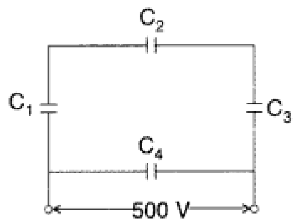
$$V_1 = \frac{Q}{20\,\mu F} = \frac{48\,\mu C}{20\,\mu F} = 2 \cdot 4\,V$$

Potential drop across C, $V_2 = \frac{Q}{C} = \frac{48\,\mu C}{5\,\mu F} = 9 \cdot 6\,V$

9.A network of four capacitors each of 12μF capacitance is connected to a 500 V supply as shown in the figure. Determine

(a) equivalent capacitance of the network and

(b) charge on each capacitor.



Equivalent capacitance of the network,

$$C_{123} = \frac{12\mu F}{3} = 4\,\mu F (\because \text{ being in series}) \ldots (i)$$

$$C_{eq} = C_{123} + C_4 = (4 + 12)\,\mu F = \mathbf{16\,\mu F}$$

...**[From (*i*)**

(*b*) (*i*) $Q = CV, \qquad Q_1 = C_4V$

$\therefore \quad Q_1 = 500 \times 12 \times 10^{-6}$

$= 6000 \times 10^{-6} = 6 \times 10^{-3}$ C

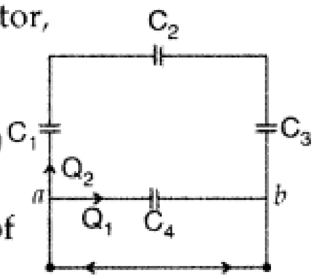
$\therefore$ Charge on capacitor, $C_4 = \mathbf{6 \times 10^{-3}\,C}$

(*ii*) $Q_2 = C_{123}\,V$

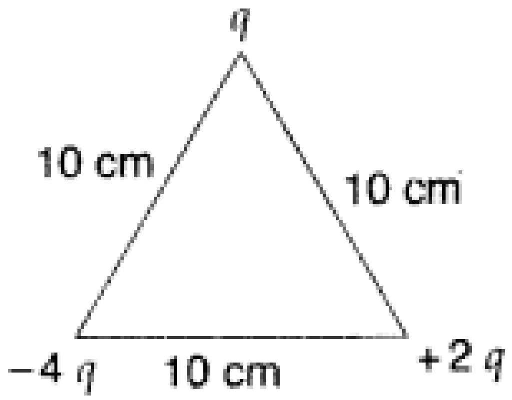
$= (4 \times 10^{-6}) \times 500$

$= 2 \times 10^{-3}$ C

$\therefore$ Charge on each of the capacitors C_1, C_2 and C_3 $= \mathbf{2 \times 10^{-3}}$ C



10.Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown. (Delhi 2008)



Answer:

Initial P.E. of the three charges

$$u_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r} + \frac{q_2q_3}{r} + \frac{q_1q_3}{r}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q(-4q)}{r} + \frac{(-4q)\times 2q}{r} + \frac{q\times 2q}{r}\right]$$

$$= -\frac{1}{4\pi\varepsilon_0}.\frac{10q^2}{r} = \frac{-9\times 10^9 \times 10\times(1.6\times 10^{-10})^2\,\text{J}}{0.10}$$

$$= \frac{-9\times 10^9 \times 10\times 2.56\times 10^{-20}\times 100}{10}$$

$$= -23.04 \times 10^{-9} = -2.304 \times 10^{-8}\ \text{J}$$

Final P.E, $U_f = 0$

∴ Work required to dissociate the system of three charges,

$W = U_f – U_i = -2.304 \times 10^{-8}$J

11.A parallel plate capacitor, of capacitance 20pF, is conneted to a 100 V supply. After sometime the battery is disconnected, and the space, between the plates of the capacitor is filled with a dielectric, of dielectric constant 5. Calculate the energy stored in the capacitor

(i) before

(ii) after the dielectric has been put in between its plates.

Answer:

Given : $C = 20\ \mu F = 20 \times 10^{-6}$ F, $V = 100$ V

$K = 5 \quad E_1 = ? \quad E_2 = ?$

Charge stored, $Q = CV = (20 \times 10^{-6}) \times (100)$

$= 2000\ \mu C$

New value of capacitance $(C') = 5 \times 20\ \mu F = 100\ \mu F$

Energy stored in a capacitor, **(E)** = $\frac{1}{2}\frac{Q^2}{C}$

(*i*) ∴ Energy stored *before* dielectric is introduced

$$E_1 = \frac{1}{2} \times \frac{(2000 \times 10^{-6}) \times (2000 \times 10^{-6})}{(20 \times 10^{-6})} = \mathbf{0.1\ J}$$

(*ii*) Energy stored *after* the dielectric is introduced

(∴ there is no change in the value of Q)

$$E_2 = \frac{1}{2} \times \frac{(2000 \times 10^{-6}) \times (2000 \times 10^{-6})}{(100 \times 10^{-6})} = \mathbf{0.02\ J}$$

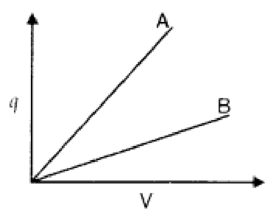
12.Suppose you wish to construct a parallel-plate capacitor with a capacitance of 1.0 F. What area must you use for each plate if the plates are separated by 1.0 mm?

Solution

$$A = \frac{Cd}{\varepsilon_0} = \frac{(1.0\ \text{F})(1.0 \times 10^{-3}\ \text{m})}{8.85 \times 10^{-12}\ \text{F/m}} = 1.1 \times 10^8\ \text{m}^2.$$

6.GRAPH BASED QUESTIONS

Q1. The given graph shows variation of charge ‘q’ versus potential difference ‘V’ for two capacitors C1 and C2. Both the capacitors have same plate seperation but plate area of C2 is greater than that of C1. Which line (A or B) corresponds to C1 and why?



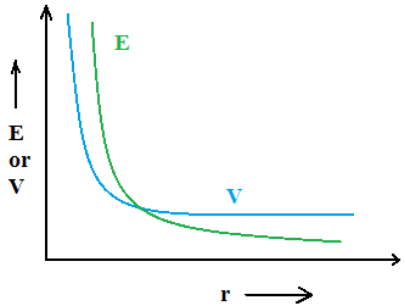
ANSWER

Line B corresponds to C1

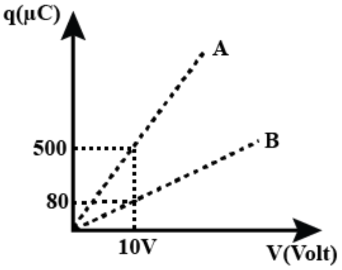
Reason: Since slope (q/V) of ‘B’ is less than that of ‘A’

Q2. Show on a plot the nature of variation of the (i)Electric field (E) and (ii) potential (V), of a point charge with the distance (r) of the field point from the centre of the charge.

ANSWER



Q3. Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors. Identify which one the capacitors.

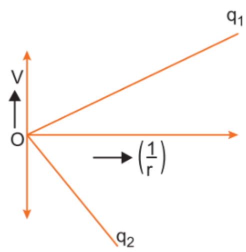


ANSWER

As C=q/V Hence slope of graph will give capacitance.

Slope will be more in parallel combination. Hence capacitance in parallel should be 50μF & capacitance in series must be 8μF

Q4. The two graphs are drawn below, show the variations of electrostatic potential (V) with 1/r (r being the distance of field point from the point charge) for two-point charges q_1 and q_2. (i) What are the signs of the two charges? (ii) Which of the two charges has the larger magnitude and why? [HOTS]

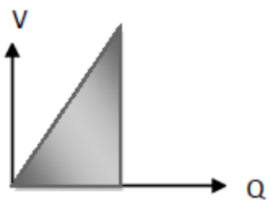


Answer.

(*i*) The potential due to positive charge is positive and due to negative charge, it is negative, so, q_1 is **positive** and q_2 is **negative**.

(*ii*) $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

The graph between V and 1/ r is a straight line passing through the origin with slope $\frac{q}{4\pi\varepsilon_0}$. As the magnitude of slope of the line due to charge q_2 is greater than that due to q_1, q_2 has larger magnitude.

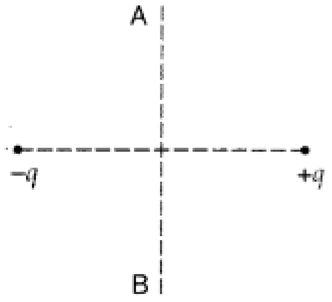


Q5.What does the area of the shaded portion indicates?

Electrostatic potential energy of a capacitor. $U= \frac{1}{2}QV$

7. DIAGRAM BASED QUESTIONS

Q1.A charge ‘q’ is moved from a point A above a dipole of dipole movement ‘p’ to a point B below the dipole in equatorial plane without acceleration. Find the work done in the process. (All India 2016)

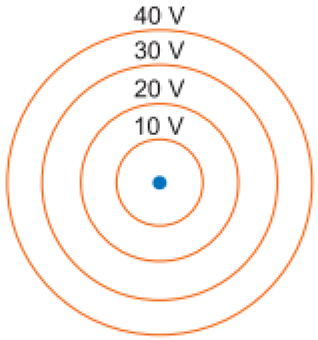


Answer:

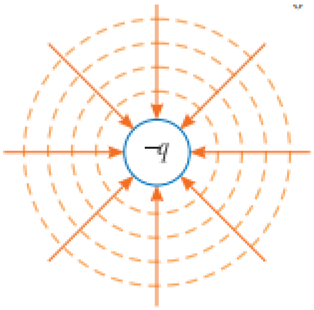
No work is done

[W = q V_{AB} = q × 0 = 0, since potential remains constant]

Q2. Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it



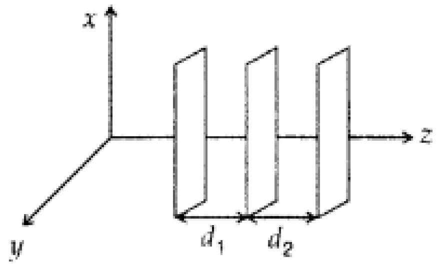
For a single charge the potential is given by $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$



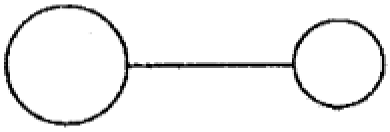
This shows that V is constant if r is constant. Greater the radius smaller will be the potential. In the given figure, potential is increasing. This shows that the polarity of charge is negative (– q). The direction of electric field will be radially inward. The field lines are directed from higher to lower potential

Q3. Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction?

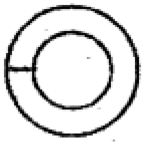
$d_2 < d_1$ for increasing field
and $d_2 = d_1$ for uniform field.



Q4.Two hollow conductors are charged positively. The smaller is at 50V and the bigger is at 100V potential.
a) What will happen if these conductors are connected externally as shown?

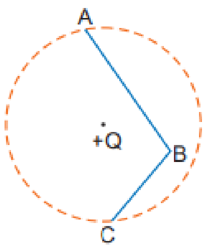


b) What will happen if these conductors are connected as shown below? Why?



Answer:
a) Here positive changes flows from bigger conductor (higher potential) to lower one (lower potential)
b) Now charges flow from the inner conductor to the outer conductor. This is because charges tend to resides on the outer surface of the hollow conductor.

Q5. In the given figure, charge +Q is placed at the centre of a dotted circle. Work done in taking another charge +q from A to B is W1 and from B to C is W2. Which one of the following is?
correct: W1 > W

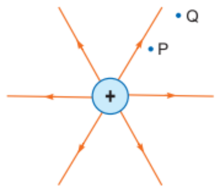


The points A and C are at same distance from the charge +Q at the centre, so
$V_A = V_C$
Therefore, $V_A - V_B = V_C - V_B$

Hence, the magnitude of work done in taking charge +q from A to B or from B to C will be the same i.e., $W_1 = W_2$.

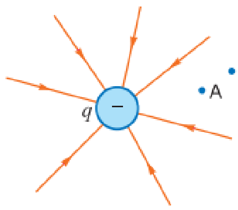
6.A-point charge Q is placed at point O as shown in the figure. Is the potential difference *VA* – *VB* positive, negative, or zero, if Q is (*i*) positive (*ii*) negative?

The potential due to a point charge decreases with increase of distance.
So, in case (*i*) $V_A - V_B$ is positive. For case (*ii*) $V_A - V_B$ is negative.

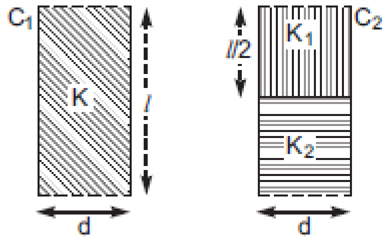


Q.7. Figure shows the field lines on a positive charge. Is the work done by the field in moving a small positive charge from Q to P positive or negative? Give reason.
Ans. The work done by the field is negative. This is because the charge is moved against the force exerted by the field.

Q. 8. The field lines of a negative point charge are as shown in the figure. Does the kinetic energy of a small negative charge increase or decrease in going from B to A?
Ans. The kinetic energy of a negative charge decreases while going from point B to point A, against the movement of force of repulsion.



Q 9. Two identical parallel plate (air) capacitors C_1 and C_2 have capacitances C each. The space between their plates is now filled with dielectrics as shown. If the two capacitors still have equal capacitance, obtain the relation between dielectric constants K, K_1 and K_2.



$$\text{Let initially } C_1 = C = \frac{\epsilon_0 A}{d} = C_2$$

After inserting respective dielectric slabs:

$$C_1' = KC \qquad \ldots(i)$$

and $$C_2' = K_1 \frac{\epsilon_0 (A/2)}{d} + \frac{K_2 \epsilon_0 (A/2)}{d}$$

$$= \frac{\epsilon_0 A}{2d}(K_1 + K_2)$$

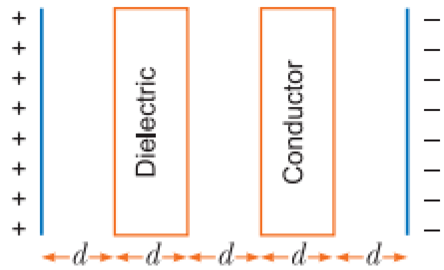
$$C_2' = \frac{C}{2}(K_1 + K_2) \qquad \ldots(ii)$$

From (i) and (ii)

$$C_1' = C_2'$$

$$KC = \frac{C}{2}(K_1 + K_2)$$

K = 1/2(K1 + K2)



10.Given two parallel conducting plates of area A and charge densities +σ and –σ. A dielectric slab of constant K and a conducting slab of thickness d each are inserted in between them as shown.

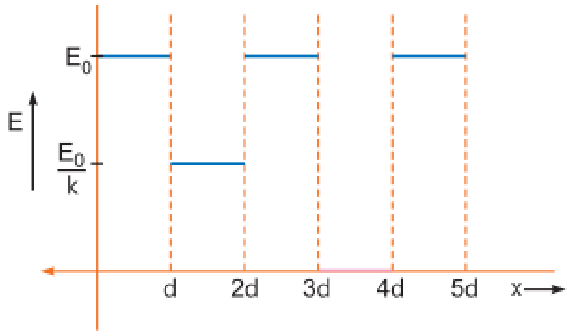
(a) Find the potential difference between the plates.

(b) Plot E versus x graph, taking x = 0 at positive plate and x = 5d at negative plate.

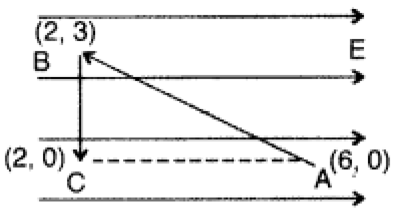
(*a*) The potential difference between the plates is given by

$$V = E_0 d + \frac{E_0}{K} d + E_0 d + 0 + E_0 d \quad \Rightarrow \quad V = 3E_0 d + \frac{E_0}{K} d$$

(*b*) *E* versus *x* graph



11.. A test charge 'q' is moved without acceleration from A to C along the path from A to B and then from B to C in electric field E as shown in the figure.



(i) Calculate the potential difference between A and C.
(ii) At which point (of the two) is the electric potential more and why?
P.D does not depend upon the path along which the test charge q moves

$$\therefore \; E = \frac{-dV}{dr} = -\left(\frac{V_C - V_A}{d}\right) = \frac{V_A - V_C}{d}$$

$$\because \; d_{AC} = 4 \quad \text{So } V_A - V_C = E \times 4 = 4E$$

(ii) At point C, electric potential will be more as potential decreases in the direction of electric field.

8. CCT [1mark]

Q1. Why does a dielectric's internal electric field weaken when exposed to an external electric field?
Ans. The polarisation causes an internal electric field that is opposite to the external electric field inside a dielectric, which causes the net electric field to decrease when the dielectric is exposed to an external electric field.

Q2. A 10 cm square with a 500 C charge in the centre. Find the amount of effort required to move a charge of 10C between two square spots that are diagonally opposed.
Ans. Since these two spots on the square will be equipotential, the work required to move a charge of 10C between them will be zero.

Q.3. When a 10C charge is present in the square's centre, how much work is required to move a 2C point shift from corner A to corner B?
Ans. Points A and B are equally distant from point O. Hence the work done is equal to zero. $V_A = V_B$
Therefore, the work done=0

Q4. What physical effort is expended when an electric dipole's equatorial axis is traversed by a test charge q over a distance of 1 cm?
Ans. Given that the equatorial axis potential is V = 0
∴W = qV = 0,

Q.5. A voltmeter connects the plates of a charged capacitor. What will happen when the capacitor's plates are separated further by voltmeter reading?
Ans. Capacitance, area, distance, and dielectric constant are all related.
C=A0dC∝1d
Hence, the capacitance will decrease if the distance increases.
Since V=QC and there is a constant charge on the capacitor,
Therefore, the voltmeter reading will increase.

Q.6. A hollow metal sphere with a 10 cm radius is charged to a surface potential of 5 V. What potential exists in the sphere's centre?
Ans. The potential in the centre of a hollow metal sphere will be 5 V because it functions as an equipotential surface.

Q.7. Why must every point of an empty charged conductor's electrostatic potential be the same?
Ans. Since there is no electric field within the hollow-charged conductor, there is no effort expended in moving the test charge. The electrostatic potential is hence constant throughout a hollow-charged conductor.

Q.8. When is the potential energy of a dipole kept in uniform electric field is minimum and maximum?

Ans:- PE (U) = -PE cosθ

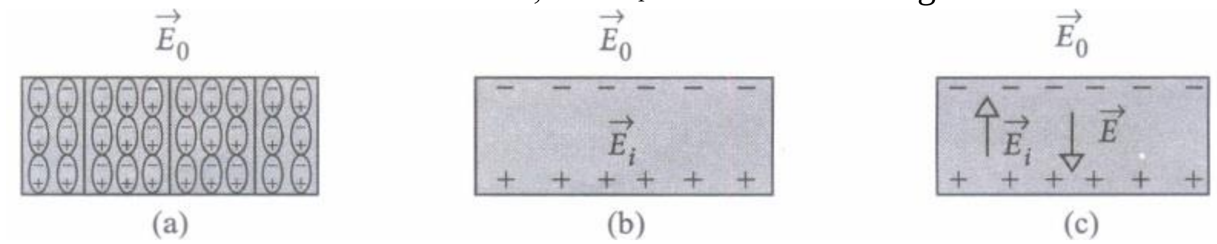
(i) When θ=0º, U = -PE= minimum

(ii) When θ = 180º, U = PE = maximum

9.CASE STUDY-BASED QUESTIONS

I.ELECTRIC POLARIZATION

When an insulator is placed in an external field, the dipoles become aligned. Induced surface charges on the insulator establish a polarization field $\bar{E}_i$ in its interior. The net field $\bar{E}$ in the insulator is the vector sum of $\bar{E}$, and $\bar{E}_i$ as shown in the figure.



On the application of external electric field, the effect of aligning the electric dipoles in the insulator is called polarisation and the field $\bar{E}$; is known as the polarisation field.
The dipole moment per unit volume of the dielectric is known as *polarisation* (***P***). For linear isotropic dielectrics, ***P*** $=\chi$***E***, where χ = electrical susceptibility of the dielectric medium.

(i) Which among the following is an example of polar molecule?

(2) O_2
(b) H
(c) N_2
(d) HCI

(ii) When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance

(a) increases K times
(b) remains unchanged
(c) decreases K times
(d) increases 2K times.

(iii) Which of the following is a dielectric?

(a) Copper
(b) Glass
(c) Antimony (Sb)
(d) None of these

(iv) For a polar molecule, which of the following statements is true ?

(a) The centre of gravity of electrons and protons coincide.
(b) The centre of gravity of electrons and protons do not coincide.
(c) The charge distribution is always symmetrical.
(d) The dipole moment is always zero.

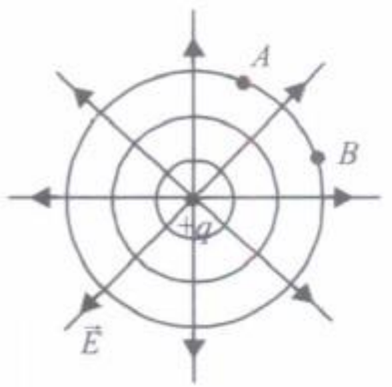
(v)When a comb rubbed with dry hair attracts pieces of paper. This is because the

(a) comb polarizes the piece of paper
(b) comb induces a net dipole moment opposite to the direction of field
(c) electric field due to the comb is uniform
(d) comb induces a net dipole moment perpendicular to the direction of field

Answers: (i) (d)
Explanation: In polar molecules the centre of positive and negative charges are separated even when there is no external field. Such molecule is having a permanent dipole moment. Ionic molecule like HCl is an example of polar molecule.
(ii) (c)
Explanation: As F’=F/K, Therefore the maximum force decreases by K times.
(iii) (b)
(iv)(b)
Explanation: A polar molecule is one in which the centre of gravity for positive and negative charges are separated.
(v) (a)

II. EQUIPOTENTIAL SURFACES

For the various charge systems, we represent equipotential surfaces by curves and line of force by full line curves. Between any two adjacent equipotential surfaces, we assume a constant potential difference the equipotential surfaces of a single point charge are concentric spherical shells with their centres at the point charge. As the lines of force point radially outwards, so they are perpendicular to the equipotential surfaces at all points.



1.What is the work done in moving a charge of 50nC between two points on an equipotential surface?
2.An infinite charged sheet has a surface charge density of $10^{-8}C/m^2$. In this situation the what is the separation between two equipotential surfaces which are having a potential difference of 5volt
3.Two equipotential surfaces of 40 V and 50 V potential are separated by 2 cm. If the electric field present between them is uniform, then what will be its strength?
4.Depict the equipotential surfaces for a sytem of two identical positive point charges placed a distance 'd' apart.
5.List a few properties of the equipotential surface.

Answer

1. The potential difference between two points on the equipotential surface is zero. i.e, dV=0   The work done =qdV=0

2. $E=\sigma/2\varepsilon_0$ and $E=V/d$

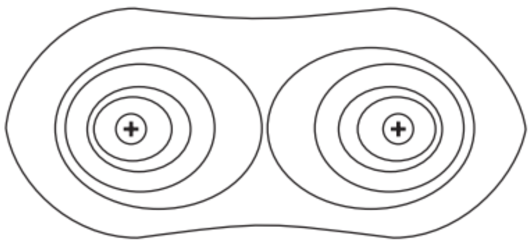
given the potential difference between two equipotential surfaces =5V

$E\Delta d=\Delta V$

$\Delta d=8.85\times10^{-3}$m

3. $E=\Delta V/d=500$ V/m.

4.



5. An equipotential surface has an electric field that is constantly perpendicular to it.
- The intersection of two equipotential surfaces is impossible.
- Equipotential surfaces for a point charge are concentric spherical shells.
- Equipotential surfaces are planes normal to the x-axis, given a homogeneous electric field.
- The equipotential surface is directed from high potential to low potential.

III.CAPACITOR AND CAPACITANCE

A capacitor contains two oppositely charged metallic conductors at a finite separation. It is a device by which capacity of storing charge may be varied simply by changing separation and/or medium between the conductors. The capacitance of a capacitor is defined as the ratio of magnitude of charge (Q) on either plate and potential difference (V) across the plate, i.e., $C = Q/V$. The unit of capacitance is coulomb/volt or farad (F)

1. What is a capacitor?
2. What is main purpose of using a capacitor?
3. Can we increase the capacitance by increasing potential applied across it?

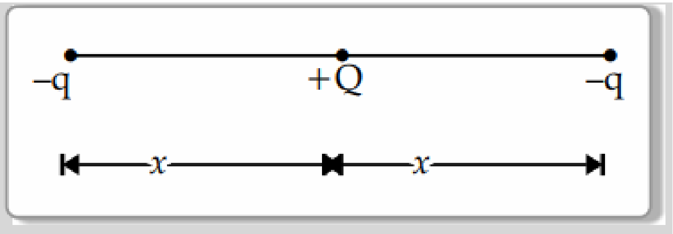
   [OR]

4. What will be the effect on capacitance by inserting a dielectric in between the plates?

10. HOTS

Q1. Three charges –q, Q and –q are placed at equal distances on a straight line. If the potential energy of the system of these charges is zero, then what is the ratio Q: q?

Diagram



$$\frac{K(-q)Q}{x} + \frac{kQ(-q)}{x} + \frac{k(-q)(-q)}{2x} = 0$$

$$\frac{-2kqQ}{x} + \frac{kq^2}{2x} = 0$$

or $$\frac{kq^2}{2x} = \frac{2kqQ}{x}$$

$$q = 4Q \text{ or } \frac{Q}{q} = \frac{1}{4}$$

Q2.Net capacitance of three identical capacitors in series is 1 pF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source.

Let C be the capacitance of a capacitor

Given: C1 = C2 = C3 = C When connected in series:

When connected in series:

$$C_S = \frac{C}{3} = 1\ \mu F \qquad \therefore\ C = 3\ \mu F$$

When connected in parallel:

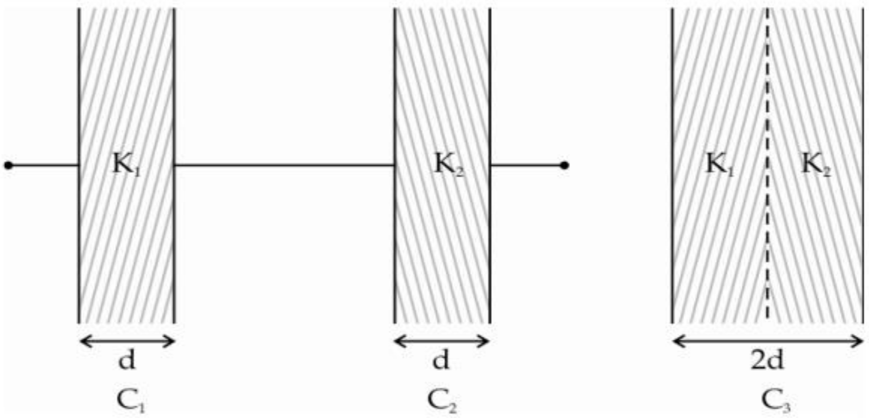
$$C_p = C + C + C = 3 + 3 + 3 = 9\ \mu F$$

Energy stored in capacitor

$$E = \frac{1}{2} CV^2$$

$$\therefore \quad \frac{E_s}{E_p} = \frac{\frac{1}{2}C_sV^2}{\frac{1}{2}C_pV^2} = \frac{C_s}{C_p} = \frac{1}{9} = \mathbf{1:9}$$

Q3.The capacitors C1, and C2, having plates of area A each, are connected in series,as shown. Compare the capacitance of this combination with the capacitor C3, again having plates of area “A” each, but ‘made up’ as shown in the figure.



Answer

We have $C_1 = \frac{\varepsilon_0 K_1 A}{d}$

and $C_2 = \frac{\varepsilon_0 K_2 A}{d}$

$C_{eq} = = \frac{C_1 \ C_2}{C_1 + C_2}$

Now, capacitor C_3 can be considered asmade up of two capacitors C_1 and C_2, each of plate area A and separation d, connected in series.

We have : $C_1' = \frac{\varepsilon_0 K_1 A}{d}$

and $C_2' = \frac{\varepsilon_0 K_2 A}{d}$

$C_3 = = \frac{C_1' \ C_2'}{C_1' + C_2'}$

$\frac{C_{eq}}{C_3} = 1$

11.STATEMENT BASED QUESTIONS

1.Define one volt.
Electric potential at a point is one volt if one joule of work is done in moving one coulomb charge from infinity to that point in the electric field.

2. Write electric potential as line integral of electric field.

$V = -\int_{\infty}^{r} E.\,dr$

3. Work done electrostatic field is conservative, why?
Work done by electrostatic force is independent of the path, and depends only on initial and final point.

4.. Write a relation between electric field and potential
Electric field intensity = negative gradient of potential.
E= -(dV/dr)

5.What is an equipotential surface?
A surface passing through the points at the same potential in an electric field is called an equipotential surface.

6.What are the characteristics of equipotential surface?
a. No work is done in moving a charge over an equipotential surface.
b. Equipotential surface is always perpendicular to the electric field.
c. Equipotential surfaces never intersect.

7.Define Dielectric Constant (K)
It is defined as the ratio of the external polarizing field 'E_0' to the net internal field 'E' = ($E_0 - E_p$) inside the substance when placed in the external electric field 'E_0'

$$K = \frac{E_0}{E} = \frac{E_0}{E_0 - E_p} = \frac{\sigma}{\sigma - \sigma_p}$$

Other definitions for K are

(1) $K = \frac{E}{E_0}$ (2) $K = \frac{C}{C_0}$ (3) $K = \frac{V_0}{V_1}$ (4) $K = \frac{F_{air}}{F_{medium}}$

8.What is meant by dielectric strength of a material?
The maximum electric field that a dielectric medium can withstand without break-down (of its insulating property) is called its dielectric strength.

9.What is the work done in moving a test charge q through a distance of 1 cm along the equatorial axis of an electric dipole?
Zero(Potential Difference is Zero)

10.Name the physical quantity whose S.I. unit is J/C. Is it a scalar or a vector quantity? Potential Difference and Scalar Quantity

11.Why should electrostatic field be zero inside a conductor?
Charge inside the conductor is Zero. Hence E=0($E=-\frac{dV}{dx}$,dV=0,E=0)

12.Show that at a point where the electric field intensity is zero, electric potential need not be zero.
Ans: E=- dV/dr when E=0, then V= constant

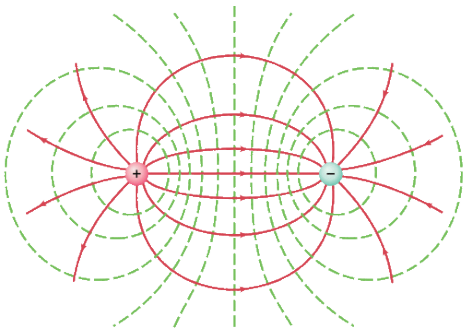
12. ONE MARK QUESTIONS

1. What is the work done in moving a charge of +5 micro coulomb once around a charged sphere of radius 10 cm.
Ans: Zero

2. Write a relation for polarisation of a dielectric material in the presence of an external electric field .
Ans:$\boldsymbol{P} = \boldsymbol{\chi e E}$

3. Why is there no work done in moving a charge from one point to another on an equipotential surface
Ans:Potential difference between two points of equipotential surface is zero.

4. Draw equipotential surface corresponding to an electric dipole.
Ans:

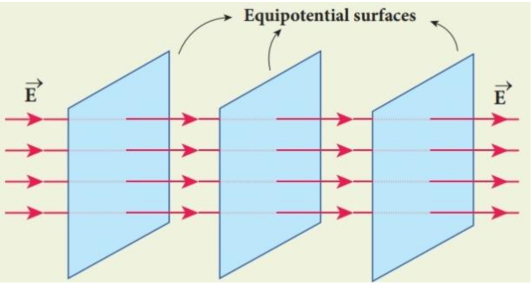


5. What is the work done in moving a charge over an equatorial plane of a dipole?
Ans:Zero

6. A hollow metallic sphere of 5cm is charged such that the potential on its surface is 10V.What is the potential at the centre of the sphere?
Ans: Potential at the centre= 10V

7. Name the physical quantity whose unit is J/C . Is it a scalar quantity or vector quantity?
Ans: Electric potential, scalar.

8. Draw the equipotential surfaces for uniform electric field.
Ans:



9. Why does the separation between successive equipotential surfaces get wider as the distance from the charges increases ?
Ans: E= (dV/dr) Electric field intensity decreases.

10. Why do the equipotential surface due to a uniform electric field not intersect each other?
Ans: If they intersect it would mean that at the point of intersection the electric field could be two directions, which is impossible.

11. A metal plate is introduced between the plates of a capacitor. What is the effect on the capacitance of the capacitor?
Ans: Capacitance increases.

12. Why does the electric field inside a dielectric slab decrease when it is placed in an external electric field?
Ans:Due to polarization field, electric field decreases.

13. Find the electric field between two metal plates 3mm apart, connected to 12V battery.

Ans: $E = V/d = 12 / 0.003 = 4 \times 10^3$ V/m

13.Three /Five –MARK QUESTIONS

Q1. Write down the relation between electric field and electric potential at a point. Write the SI unit of potential gradient. A spherical conductor of radius 12cm has a charge of 1.6×10^{-7}C distributed uniformly on its surface. What is the electric field

(i) Inside the sphere?

(ii) (Just outside) On the sphere?

(iii) at a point 18cm from the centre of the sphere

Electric field at any point is equal to the negative of the potential gradient at that point.

$E = -dV/dr$ SI unit of potential gradient =V/m

(*i*) *Inside the sphere,* $E = \mathbf{0}$. This is because the charge resides on the outer surface of the spherical conductor.

(*ii*) *Just outside the sphere,* $r = R = 0.12$ m. Here the charge may be assumed to be concentrated at the centre of the sphere.

$$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{R^2}$$

$$= \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{(0.12)^2} = \mathbf{10^5\ NC^{-1}}$$

Q.2.A parallel plate capacitor is charged by a battery which is then disconnected A dielectric slab is then inserted in the space between the plates. Explain what changes, if any occur in the value of

a) Capacitance

b) Potential difference between the plates

c) Electric field between the plates

d) Energy stored in the capacitor.

(iii) *At a point 18 cm from the centre,*

$$r = 18 \text{ cm} = 0.18 \text{ m}.$$

$$\therefore \quad E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{(0.18)^2}$$

$$= \mathbf{4.44 \times 10^4 \ NC^{-1}}$$

a) The capacitance of the capacitor increases to K times. (C= $K\epsilon_0 A/d$)
b) The potential difference between the plates becomes 1/K times (V=$Q/$)
Q is same, C increases to K times. Therefore, V'=V/K
c) As E=V/t, V decreases. Therefore, electric field decreases to 1/K times.
d) The energy stored will be decreased by 1/K times.
($U=\frac{Q_0^2}{2C}=\frac{Q_0^2}{2KC}=\frac{U_0}{K}$)

Q.3(a) Draw equipotential surfaces for (i) an electric dipole and (ii) two identical positive charges placed near each other.
(b) In a parallel plate capacitor with air between the plates, each plate has an area of 6×10^{-3} m^2 and the separation between the plates is 3 mm.
(i) Calculate the capacitance of the capacitor.
(ii) If the capacitor is connected to 100V supply, what would be the the charge on each plate?
(iii) How would charge on the plate be affected if a 3 mm thick mica sheet of k = 6 is inserted between the plates while the voltage supply remains connected? 5

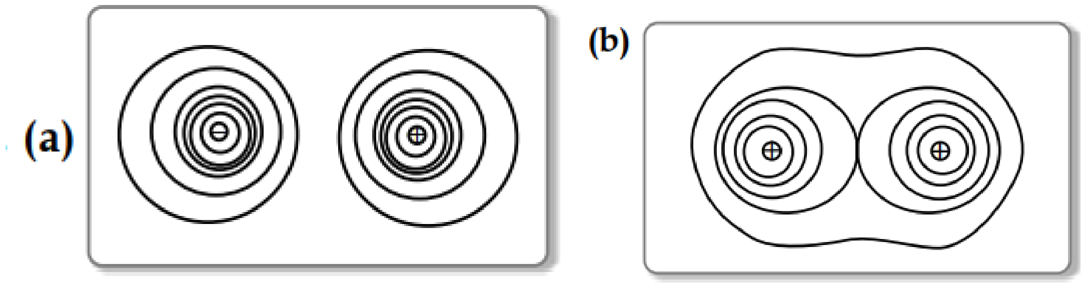
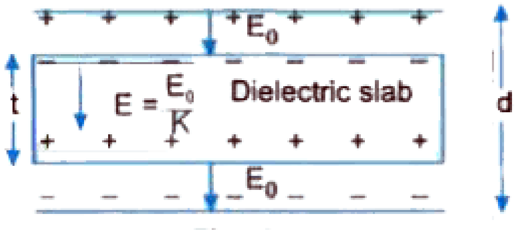


FIGURE: Some equipotential surface for
(a) a dipole
(b) two identical positive charge.
Here, A = 6×10^{-3} m^2
, d =3 mm = 3×10^{-3} m
(b) (i) Capacitance, C = $\varepsilon_0 A/d$
= $(8.85 \times 10^{-12} \times 6 \times 10^{-3}/3 \times 10^{-3})$
= 17.7×10^{-12} F
(ii) Charge, Q = CV
=$17.7 \times 10^{-12} \times 100$
= 17.7×10^{-10} C
(iii) New charge Q'= KQ
= $6 \times 17.7 \times 10^{-10}$
=1.062×10^{-8} C

Q.4.A dielectric slab of thickness t is kept in between the plates, each of area A of a parallel plate capacitor separated by a distance d. Derive an expression for the capacitance of this capacitor for t<<d.
On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved, and a dielectric medium of ε r = 10 is introduced between the plates, without disconnecting the d.c. source. Explain, using suitable expressions, how the
(i) capacitance
(ii) electric field and
(iii)energy density of the capacitor change.
Consider parallel plate capacitor of area A and separation between the plates is d. A dielectric slab of thickness t and dielectric constant K is introduced between the plates of the capacitor. Let E0 be the electric field intensity inside air and E be the net electric field intensity inside the dielectric slab. Capacitance of a parallel plate capacitor is given by,



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

$Q=\sigma A$

$V= E_0 (d-t) + Et$

$E_0 = \frac{\sigma}{\varepsilon_0}$ $\quad$ $E = \frac{\sigma}{\varepsilon_0 K}$

$V= \frac{\sigma}{\varepsilon_0}(d-t) + \frac{\sigma}{\varepsilon_0 K}t$

$V= \frac{\sigma}{\varepsilon_0}[(d-t) + \frac{t}{K}]$

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

$C= \frac{\varepsilon_0 A}{d-t+\frac{t}{K}}$

This equation shows that capacitance of a parallel plate capacitor increases, when a dielectric slab is inserted between its plates.

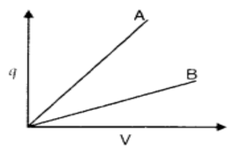
i) C =KA ε_0/ d (capacitance become K times)
ii) E=V/d (Electric field remains same, since V remains constant
iii) $\mathcal{U}$ = 1/2 CV^2 (energy becomes K times)

14. DERIVATION BASED QUESTIONS

1. Derive an expression for electric potential at a point due to an electric dipole.

2. Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.
3. Derive an expression for the potential energy of an electric dipole of dipole movement **p** in the electric field **E**
4. Derive the expression for the electric potential at any point along the axial line of an electric dipole
5. Find the equivalent capacitance of three capacitors connected in (i)series (ii) parallel with a battery.
6. Derive the expression for the electric potential at any point along the axial line of an electric dipole(ii) What is its potential at a point on the equatorial line? [At a point on the equatorial line V=0]
7. Find the Capacitance of parallel plate capacitor with a dielectric medium between the plates

ASSIGNMENT- 1 (Descriptive questions)

Q. No	Question	Mark
1	How does the electric flux, electric field enclosing a given charge vary when the area enclosed by the charge is doubled?	1
2	Name the physical quantities whose SI units are Vm, Vm^{-1}. Which of these are vectors?	1
3	How much work is done in moving a 500 µC charge between two points separated by a distance of 2cm on an equiotential surface?	1
4	Two capacitors of 0.1 µF and 0.2 µF are raised to the same potential of 50V.Calculate the ratio of the energy stored in each.	1
5	Consider three charged bodies P, Q and R. If P and Q repel each other and P attracts R, what will be the nature of the force between Q and R?	1
6	What is the work done in moving a test charge q through a distance of 1 cm along the equatorial axis of an electric dipole?	1
7	Two capacitors of capacitances 6µF and 12 µF are connected in series with a battery. The voltage across 6µF capacitor is 2 V. Compute the total battery voltage.	1
8	A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is the potential at the centre of the sphere?	1
9	Two equal balls having equal positive charge 'q' coulumbs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two?	1
10	The given graph shows variation of charge 'q' versus potential difference 'V' for two capacitors C_1 and C_2. Both the capacitors have same plate seperation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C_1 and why? 	- 2
11	two identical metallic spheres A and B of exactly equal masses are taken. Sphere A is given positive charge of Q coulomb and B is given an equal negative charge. So initially before the charge is given $M_A=M_B=M$	2
12	Electric field inside a dielectric decrease when it is placed in an external field. Give reason to support this statement.	2
13	An electric dipole of moment p is aligned parallel to the external electric field. How much work has to be done in rotating the dipole through (a) 90^0 (b) 180^0	2
14	Derive the expression for the electric field intensity dur to an infinitely long straight charged wire.	2
15	Derive the expression for the electric field intensity due to a thin infinite plane sheet of charge,	3
16	When two charged capacitors having different capacities and different potentials are joined together, show that there is always some loss of energy.	3

MARKING KEY to ASSIGNMENT- 1

Q.no	Marks
1	**∅=constant 1/2** **E is halved** ½ (1) mark
2	Electric flux ∅-scalar ½ Electric field intensity E-Vector ½ (1) mark
3	Zero (1) mark
4	U_1/U_2 = $1/2C_1V^2/1/2C_2V^2$ – ½ = 2----1/2 (1) mark
5	Q attracts R---(1) mark
6	Since potential for equatorial axis V = 0 1/2 ∴ W = qV = 0 -- ½ (1) mark
7	Charge on both capacitors are same 6x2 =12x V_2 ---1/2 V_2= 1V, battery voltage=3V ½ (1) mark
8	Inside the sphere E =0----1/2 V= constant = 10V—1/2 (1) mark
9	force would be reduced by a factor 'K' (equal to the value of dielectric constant of plastic sheet)—1/2 $F_K = \frac{F_{Air}}{K}$ --1/2 (1) mark
10	line B corresponds to C_1--1 slope (q/v) of 'B' is less than that of 'A' ---1 (2) marks
11	The process of giving positive charge involves removal of electrons and that of negative charge involves addition of electrons. ---1 Hence the mass of the positively charged sphere will be less than that of negatively charged sphere$M_A < M_B$—1 (2) marks
12	An electric field E_P is induced inside the dielectric in a direction opposite to the direction of external electric field E_0. Thus, net field becomes E=E0−E (2) marks
13	W = pE($\cos\Theta_1$-$\cos\Theta_2$)

	(a) $W = pE$---1 (b) $W = 2pE$ ---1 (2) marks
14	Diagram----1/2 Derivation $E = \lambda/2\pi\varepsilon_0 r$ —11/2 (2)marks
15	Diagram --1/2 Derivation $E = \sigma/2\ \varepsilon_0$ –2 ½ (3)marks
16	Derivation $U_1 - U_2 = (V_1 - V_2)^2/2(C_1 + C_2)$ (3) marks

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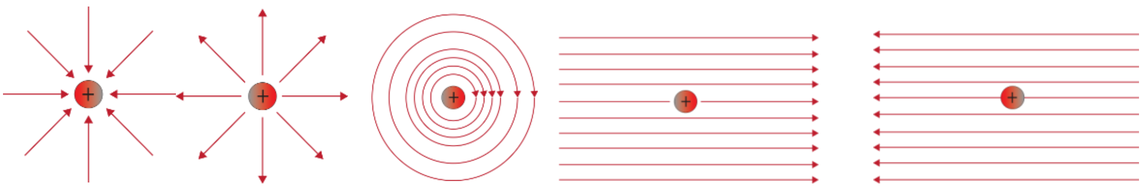
ASSIGNMENT- 2

CLASS TEST Max marks:20

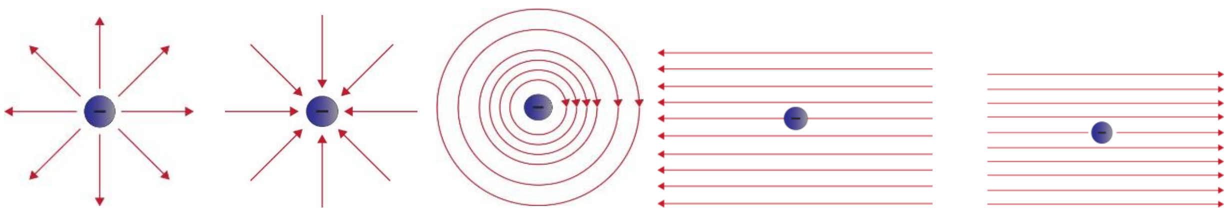
Multiple Choice Questions

1.Which of the following represents the electric field map due to a single positive charge?



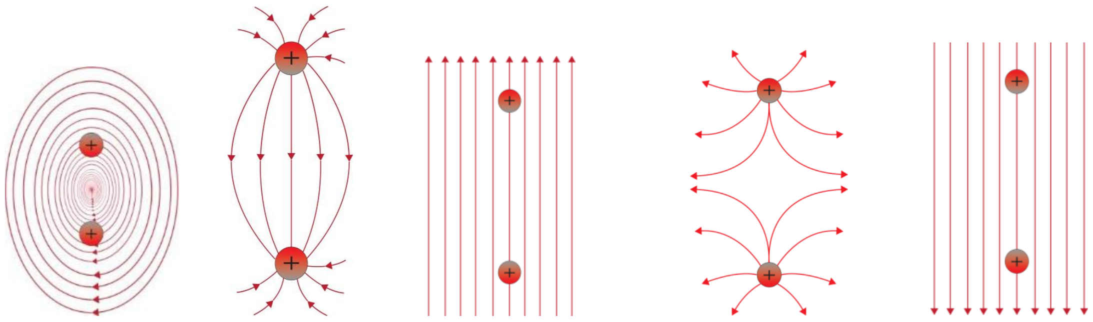
A) B) C) D) E)

2.Which of the following represents the electric field map due to a single negative charge?



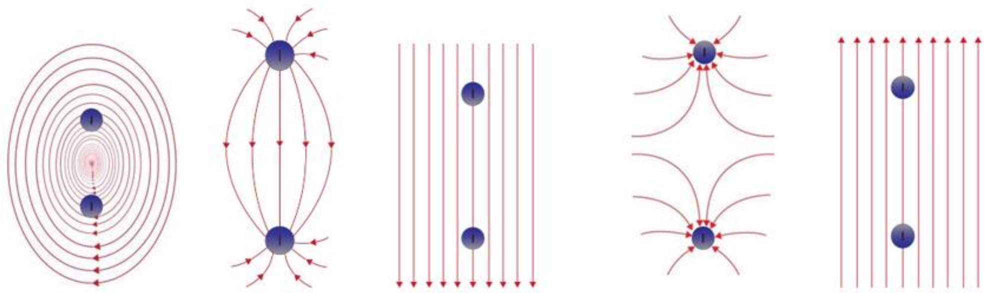
A) B) C) D) E)

3.Which of the following represents the electric field map due to a combination of two positive charges?



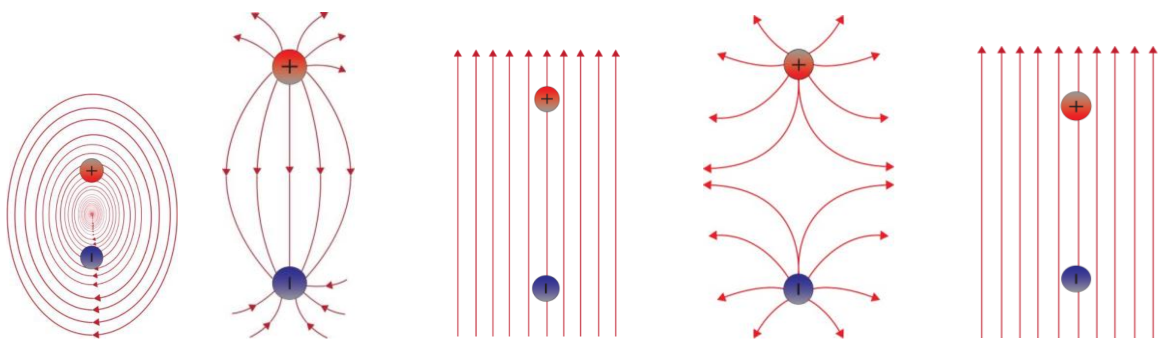
A) B) C) D) E)

4. Which of the following represents the electric field map due to a combination of two negative charges?



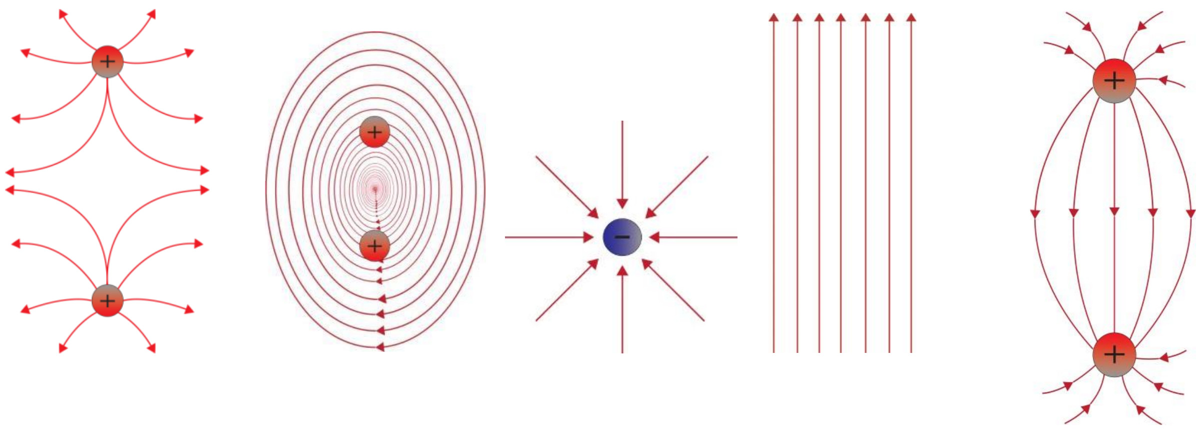
A) B) C) D) E)

5. Which of the following represents the electric field map due to a combination of one positive and one negative charge?



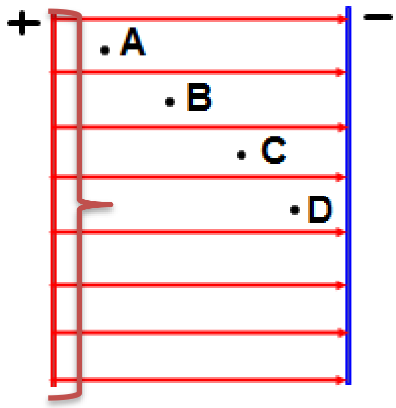
A) B) C) D) E)

6.Which of the following is a uniform electric field?



A) B) C) D) E)

7. An electric field is created by two parallel plates. At which ofthe following points is the electric field the strongest?



A. A B. B C.C D.D

E. The electric field is the same at all points

8. An electric field is created by two parallel plates. Which of thefollowing points corresponds to the higher electric potential?

A.A B. B C.C D.D

E. The electric potential is the same at all points

9.Compare the Gravitational Field and the Electric Field produced by a proton.

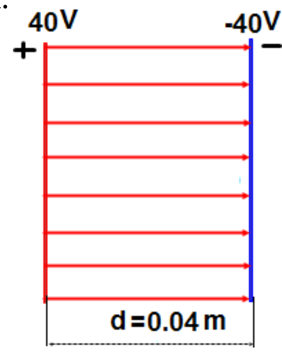
A) The Gravitational Field is the same strength as the Electric Field.

B) The Electric Field is stronger and is in the same direction as the Gravitational Field.

C) The Electric Field is stronger and in the opposite direction of the Gravitational Field.

D) The Gravitational Field is stronger and is in the same direction as the Electric Field.

10.A uniform electric field is created by two parallel plates separated by a distance of 0.04 m. What is the magnitude ofthe electric field established between the plates?



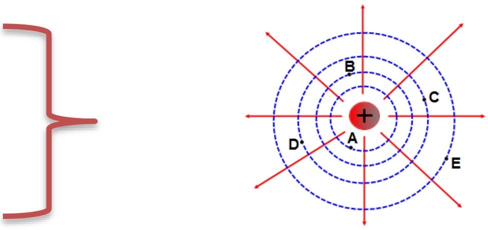
A.20 V/m B.200 V/m C. 2,000 V/m D. 20,000 V/m E. 0 V/m

11.An electric field due to a positive charge is represented by the diagram. Which of thefollowing points has higher potential?

A)A B)B C)C D)D E)E

12.An electric field due to a positive charge is represented by the diagram. At which of the following points is the electric field strongest inmagnitude?

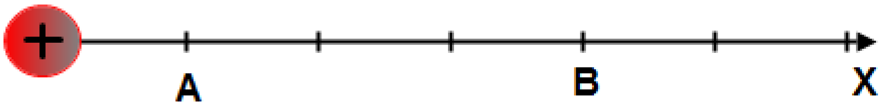
A)A B)B C)C D)D E)E



13.An electric field due to a positive charge is represented bythe diagram. Between which of the following two points does the electric field do zero work on a moving charge?

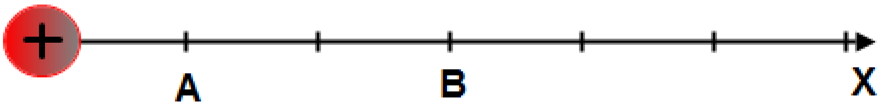
(A) A and B (B) B and C (C) C and D (D) D and E (E)E and A

14.In the given below diagram, the electric potential at point A is V. What is the electric potential at point B in terms of V?



A)2V B)4V C)V D)V/2 E)V/4

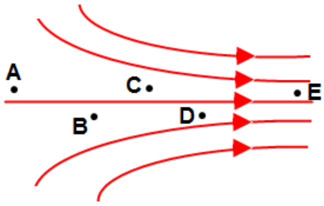
15.In the given below diagram, the magnitude of the electric field at point A is E. What is the electric field atpoint B in terms of E?



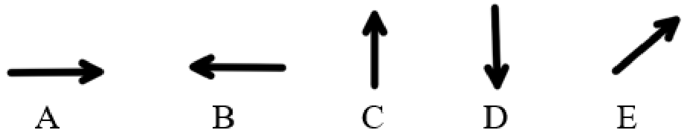
A)3E B)9E C)E D)E/9 E)E/3

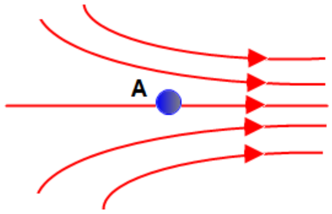
16.A non-uniform electric field is represented by the diagram. At which of the following points is the electric field greatest in magnitude?

A)A B)B C)C D)D E)E



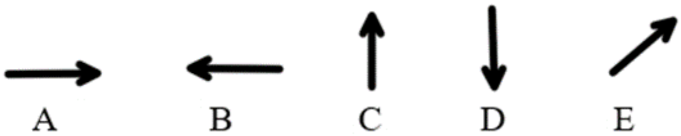
17.A small conducting sphere is placed in a region of a non-uniform electric field. What is the direction of theelectric force on the sphere applied by the field?

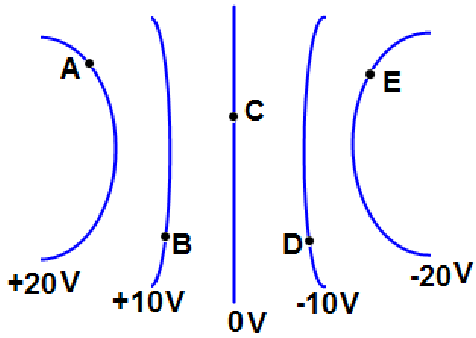




A non-uniform electric field is represented byequipotential lines. [Qn-18,19 & 20]

18. What is the direction of the electric field at point A?





19. How much work is done by the electric field when a positive charge of magnitude 1 μC moves from point A to point E

A)0 μJ B)20 μJ C)40 μJ D)60 μJ E)80 μJ

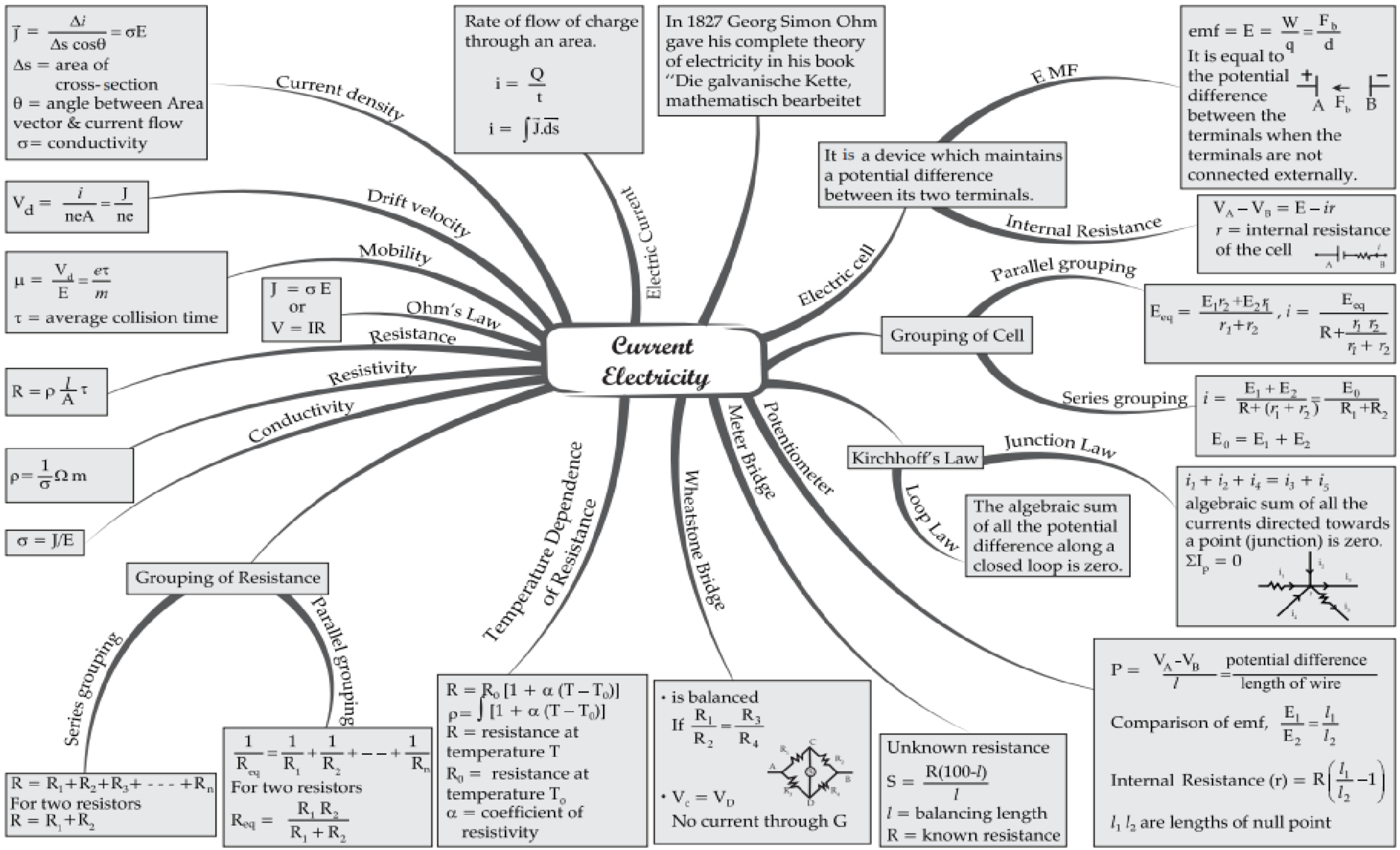
20. A positive charge with a magnitude of 1 μC moves in the following path: A→B→C→D→E→A. How much work is done by the electric field?

A)0 μJ B)20 μJ C)40 μJ D)60 μJ E)80 μJ

Answer:-

Qn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans	**B**	**B**	**D**	**D**	**B**	**D**	**E**	**A**	**C**	**C**	**A**	**A**	**C**	**E**	**D**	**E**	**A**	**E**	**C**	**A**

MIND MAP : LEARNING MADE SIMPLE CHAPTER - 3



UNIT- II CURRENT ELECTRICITY

Electric current - Electric current across an area held perpendicular to the direction of flow of charge is defined as the amount of charge flowing across that area per unit time.

For a steady flow of charge, $I = \frac{q}{t}$

If the rate of flow of charge varies with time, then $I = \frac{dq}{dt}$

Electric current is a scalar quantity. Electric currents do not obey the laws of vector addition.

Ohm's law - The potential difference across two ends of a conductor is directly proportional to the current flowing through it, provided the temperature and other physical conditions remain unchanged.

$V \alpha I$ or $V = RI$

Resistance – It is the opposition offered by a conductor to flow of charges through it It depends on the length *I*, area of cross-section *A*, nature of material of the conductor and temperature.

$$R = \rho \frac{l}{A} = \frac{m}{ne^2\tau} \frac{l}{A}$$

SI unit of resistance is ohm (Ω). The resistance of a conductor is 1 ohm if a current of I ampere flows through it on applying a potential difference of I volt across its ends.

Resistivity or specific resistance - It is the resistance offered by a unit cube of the material of a conductor. It depends on the nature of the material of the conductor and the temperature.

$$\rho = \frac{m}{ne^2\tau} \quad \text{and} \quad \rho = \frac{1}{en\mu_e}$$

Current density - It is the amount of charge flowing per second per unit area normal to the flow of charge. It is a vector quantity having the same direction as that of the motion of the positive charge. SI unit - Am.

$$I = \vec{j} \cdot \vec{A} \text{ and } \quad j = nev_d = ne\mu E = \sigma E$$

Conductance -It is the reciprocal of resistance. SI unit - mho or siemen.

Conductivity - It is the reciprocal of resistivity. SI unit – mho/ m. $\sigma = ne\mu = \frac{ne^2}{m}\tau$

Carriers of current – Metal - free electrons, Ionized gases - electrons and positive ions Electrolyte - both positive and negative ions, Semiconductor - electrons and holes.

Drift velocity - The average velocity acquired by the free electrons of a conductor in the opposite direction of the applied electric field is called drift velocity. $v_d = \frac{eE}{m}\tau = \frac{eV}{ml}\tau$

Relaxation time - The average time interval between the two successive collisions of an electron is called relaxation time (τ).

Temperature coefficient of resistivity - It is defined as the change in resistivity per unit original resistivity per degree rise in temperature. $\alpha = \frac{\rho_t - \rho_0}{\rho_0 (T - T_0)} \Rightarrow \rho_T = \rho_0 [1 + \alpha (T - T_0)]$

Effect of temperature on resistivity - For metals α is positive i.e., resistivity of metals increases with the increase in temperature.For semiconductors and insulators, α is negative i.e., their resistivity decreases with the increase in temperature.For alloys like constantan and manganin, α is very small. So they are used for making standard resistors.

Mobility of a charge carrier - The mobility of a charge carrier is the drift velocity acquired by it per unit electric field. $\mu = \frac{v_d}{E} = \frac{e}{m}\tau$

Ohmic conductors - The conductors which obey Ohm's law are called Ohmic conductors. For these conductors, V-I graph is a straight line passing through the origin. For example, a metallic conductor for small currents is an Ohmic conductor.

Non-ohmic conductors - The conductors which do not obey Ohm's law are called non-ohmic conductors. The Non-ohmic situations –

(i) The straight-line V-I graph does not pass through the origin.
(ii) V-I relationship is non-linear.
(iii) V-I relationship depends on the sign of V.
(iv) V-I relationship is non-unique.
Examples - water voltameter, thyristor, a *p-n* junction, etc.

Electromotive force (emf) - It is the energy supplied by the source in taking a unit positive charge once round the complete circuit. It is equal to the terminal p.d. measured in open circuit

Terminal potential difference (V) -The potential drop across the terminals of a cell when a current is drawn from it is called its terminal potential difference. It is less than the emf of the cell in a closed circuit.
$V=E-Ir$
Terminal p.d. of a cell when it is being charged is $V=E + Ir$

Internal resistance -The resistance offered by the electrolyte of a cell to the flow of current between its electrodes is called internal resistance of the cell. It depends on

i) Nature of the electrolyte,
ii) concentration of the electrolyte,
iii) distance between the electrodes, common area of the electrodes dipped in the electrolyte and
iv) temperature of the electrolyte.

$$r = \frac{E-V}{I} = \frac{E-V}{V} R = \left(\frac{E}{V} - 1\right) R$$

Cells in series - If n cells of emf E and internal resistance r each are connected in series, then current flowing through external resistance R is $I = \frac{nE}{R+nr}$

Cells in parallel - If m cells are connected in parallel, then current drawn through external resistance R is $I = \frac{mE}{mR+r}$

Cells in mixed grouping - If n cells are connected in series in each row and m such rows are connected in parallel, then current drawn through an external resistance R is

$$I = \frac{mnE}{mR+nr}.$$

For maximum current, the external resistance must be equal to the total internal resistance, *i.e.*,

$$R= \frac{nr}{m} \Rightarrow mR = nr.$$

Heating effect of current - The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating.

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

Electric power - It is the rate at which an electric appliance converts electric energy into other forms of energy. Or, it is the rate at which work is done by a source of emf in maintaining an electric current through a circuit. $P = VI = I^2 R = \frac{V^2}{R}$

Electric energy - It is the total work done in maintaining an electric current in an electric circuit for a given time.

$W = Pt = VI\,t = I^2 Rt$ joule

Kirchhoff's Laws

(i) Junction Rule

The algebraic sum of all currents meeting at a junction in a closed circuit is zero, i.e., $\Sigma I = O$.

This law follows law of conservation of charge.

(ii) Loop Rule

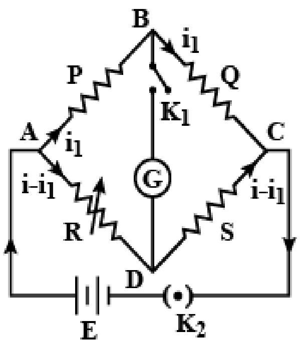
The algebraic sum of all the potential differences in any closed circuit is zero, i.e.,

$\Sigma V = 0 \Rightarrow \Sigma E = \Sigma IR$

This law follows law of conservation of energy

.

Wheatstone bridge (balanced) – Let i be the current from battery E .At point A , current i1 flows through resistance P and current $i - i_1$ flows through R. In balanced state , no current flows through BD , hence point B and D are at same potential .Therefore current i_1 flows through resistance Q also and current $i - i_1$ flows through S.



Applying Kirchhoff's loop rule in closed mesh ABDA ,

$I_1 P - (i - i_1)R = 0$

or $i_1 P = (i - i_1)R$..................eq1

In closed mesh BCDB ,

$i_1 Q - (i - i_1)S = 0$

Or $i_1 Q = (i - i_1)S$ eq2

Dividing eq1 from eq2 , we get

P/Q=R/S

This is the condition for balance in a Wheatstone's bridge .

MULTIPLE CHOICE QUESTIONS

1. Among the following dependences of drift velocity v on electric field E, Ohm's law is obeyed when

a) v α E b) v α 1/E c) v α E2 d) v= constant

2. When electric field is applied on the ends of a conductor, the free electrons acquire a small velocity in a direction

a) Along the electric field b) Opposite to the electric field

c) Perpendicular to electric field d) at an angle to the electric field

3. If the electron in Hydrogen atom makes 6.25 x 10^{15} revolutions in one second, the current is

a) 1.12mA b) 1mA c) 1.25mA d) 1.5mA

4. From the following quantities, the term analogous to temperature is

a) Potential b) Resistance c) Current d) Charge

5. The flow of electric current through a metallic conductor is

a) Only due to electrons b) only due to positive charges

c) Due to both positive charges and electrons d) neither electrons or positive

6. For making standard resistor, which of following material is used?

a) Carbon b) Copper c) Silver d)Manganin

7. A piece of silver and another of silicon are heated from room temperature. The resistance of

a) Both increases b) both decreases c) Silver increases and silicon decreases

d)Silver decreases and silicon increases

8. A certain piece of copper is to be shaped into a conductor of minimum resistance.

Its length and cross-sectional area should be

a) L and A b) 2L and A/2 c)L/2 and 2A d)3L and A/3

9. With the increase in temperature, the ratio of conductivity to resistivity of a metallic conductor

a) Decreases b) Remains same c) Increases d) Depends on the metal

10. When a piece of aluminium wire of finite length is drawn to reduce its diameter to

half its original value, its resistance become

a)Two times b)Four times c) Eight times d)Sixteen times

11. Consider a rectangular slab of length L, area of cross section A. A current I is passed through it.If the length is doubled, then the potential drop across the end faces for the same current

a) Becomes half of the initial value b) Becomes one-fourth of the initial value

c) Becomes double the initial value d) Remains same

12. A metallic block has no potential difference applied across it, and then the mean velocity of free electrons is

a) Proportional to absolute temperature
b) Proportional to square root of absolute temperature
c) Zero
d) Finite but independent of absolute temperature

13. The resistance of a metal increases with increasing temperature because

a) The collisions of the conducting electrons with the electrons increase

b) The collisions of the conducting electrons with the lattice consisting of the ions of the metal increases

c) The number of conduction electrons decreases

d) The number of conduction electrons increases

14. In the absence of applied potential, order of random velocity of the free electron is

a) mm/s b) cm/s c) m/s d) km/s

15. A wire has resistance 12Ω. It is bent in the form of a circle. The effective resistance between two points across its diameter is

a) 3Ω b) 6Ω c) 12Ω d) 24Ω

16. The resistance of a wire of 100cm length is 10Ω. Now, it is cut into 10 equal parts and all of them are twisted to form a single bundle. Its resistance is

a) 1 ohm b) 0.5 ohm c) 5 ohm d) 0.1 ohm

17. A piece of wire of resistance 4 ohm is bent through 180^0 at its midpoint and the two halves are twisted together. Then the resistance is

a) 8 ohm b)1 ohm c) 2 ohm d) 5 ohm

18. Two lamps have resistance r and R, R > r. If they are connected in parallel in an electric circuit, then

a) The lamp with resistance R will shine more brightly
b) The lamp with resistance r will shine more brightly
c) The two lamps will shine equal brightly
d) The lamp with resistance R will not shine at all

19. The direction of current inside a cell is
a) Negative pole to positive pole during discharging
(b) Positive pole to negative pole during discharging
c) Always negative pole to positive pole
(d) Always flows from positive pole to negative pole

20. The terminal voltage of a cell is greater than its emf when it is
a) Being charged
b) An open circuit
c) Being discharged
d) It never happens

21. What is constant in a battery (also called a source of emf?
a) Current supplied by it
b) Terminal potential difference

c) Internal resistance d) Emf

22. In a circuit two or more cells of the same emf are connected in parallel in order
    a) Increase the potential difference across a resistance in the circuit
    b) Decreases potential difference across a resistance in the circuit
    c) Facilitate drawing more current from the battery system
    d) Change the emf across the system of batteries

23. The resistance of an open circuit is
    a) Infinity b) Zero c) Negative d) Positive

24. Internal resistance of a cell depends on
    a) Concentration of electrolyte b) Distance between electrodes
    c) Area of electrode d) All the above

25. The terminal potential difference of a cell is equal to its emf if
    a) External resistance is infinity b) Internal resistance is zero
    c) Both a) and b) d) Neither a) nor b)

26. Kirchhoff's law of junctions is also called the law of conservation of
    a) Energy b) Charge c) Momentum d) Angular momentum

27. If galvanometer and battery are interchanged in balanced Wheatstone's bridge, then
    a) The battery discharges b) The bridge still balances
    c) The balance point is changed d) The galvanometer is damaged due to flow of high current

28. A p.d. V is applied across a conductor of length L and diameter D. How are electric field E and resistance R affected if the p.d. V is halved?
    a) E and R become double b) E doubles and R is halved
    c) E and R become half d) E is halved and R remains same

ANSWERS:

1	2	3	4	5	6	7	8	9	10
A	B	b	A	A	d	c	C	a	d
11	12	13	14	15	16	17	18	19	20
C	C	b	C	A	d	b	B	a	a
21	22	23	24	25	26	27	28		
D	C	a	D	C	B	b	D		

II Assertion and Reason questions

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

Q.1. Assertion: In a simple battery circuit, the point of the lowest potential is positive terminal of the battery.
Reason: The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal.

Q.2. Assertion: A larger dry cell has higher emf.
Reason: The emf of a dry cell is proportional to its size.

Q.3. Assertion: The resistivity of a substance is a characteristic property of the material.
Reason: The resistivity of a substance does not depend on the nature of the substance and temperature.

Q.4. Assertion: Voltmeter is connected in parallel with the circuit.
Reason: Resistance of a voltmeter is very large.

Q.5. Assertion: Ohm's law is applicable for all conducting elements.
Reason: Ohm's law is a fundamental law.

Q.6. Assertion: An electric bulb becomes dim, when the electric heater in parallel circuit is switched on.
Reason Dimness decreases after sometime.

Q.7. **Assertion:** Voltmeter always gives e.m.f of a cell if it is connected across the terminals of a cell.
Reason Terminal potential of a cell is given by V = E-Ir

Q.8. Assertion: Bending a wire does not affect electrical resistance.

Reason: Resistance of wire is proportional to resistivity of material.

Q.9. Assertion: Kirchhoff's junction rule can be applied to a junction of several lines or a point in a line.

Reason: when steady current is flowing, there is no accumulation of charges at any junction or at any point in a line.

10. **Assertion: -** Direction of electronic current cannot be from negative potential to positive terminal.
Reason: - Direction of current is in the direction of flow of electron.

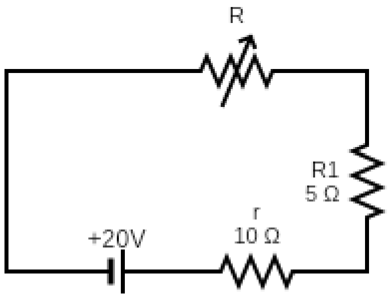
11. **Assertion: -** Insulators do not allow flow of current through them.
Reason: - Insulators have no free charge carrier.

12. **Assertion: -** If there is no current in a wire, potential drop has to be there.
Reason: - If potential drop is zero, the resistance may be zero

13. **Assertion: -** Constant potential difference is applied across a conductor. If the temperature of conductor is increased, the drift speed of electron will decrease.

Reason: - Resistivity increases with increase in temperature.

14. Assertion: - For zero value of R in circuit, power transfer in external resistance will be maximum.



Reason:- Since $R_1 < r$ in the given circuit, so power transfer in external resistance will be maximum when R=0.

15. Assertion :- A voltmeter is an inherently inaccurate instrument.

Reason:- A voltmeter is always connected in parallel in a circuit.

16. Assertion :- If potential difference between two points is zero and resistance between two those points is zero, current may flow between the points

Reason: - Kirchoff's 1st law is based on conservation of charge.

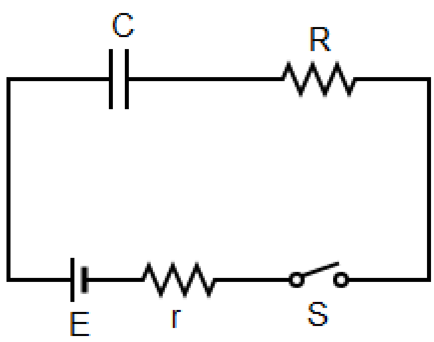
17. Assertion: - Electrical appliances with metallic body have three pin connections whereas electric bulb has two pin connections.

Reason: - Three pin connections reduce the heating of connecting wires.

18. Assertion: - Higher the range of an ammeter, greater is the resistance of ammeter.

Reason:- To increase the range of ammeter, additional shunt resistance is used.

19. **Assertion :-** The switch S shown in the figure is closed at t=0, initial current flowing through battery is $\frac{E}{R+r}$



Reason:- Initially capacitor was unchanged, so resistance offered by capacitor at t=0 is zero

20. **Assertion :-** When current through bulb is increased by 2% power increases by 4%

Reason:- Current passing through the bulb is inversely proportional to its resistance.

ANSWERS:

1	2	3	4	5	6	7	8	9	10
D	D	c	b	c	B	d	A	A	a
11	12	13	14	15	16	17	18	19	20
A	D	B	C	B	B	C	D	A	B

II. Short answer type (Each question carries 2 marks)

1. Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1: 2. They are connected
(i) in series and
(ii) in parallel.

Compare the drift velocities of electrons in the two wires in both the cases (i) and (ii).

Given : $l_1 = l_2 = l$

$A_1 : A_2 = 1 : 2$ or $\frac{A_1}{A_2} = \frac{1}{2}$

As $R = \rho \frac{l}{A}$, as $\rho_1 = \rho_2$

We have $\frac{R_1}{R_2} = \frac{2}{1}$

(*i*) In series current is same so from

$v_d = \frac{I}{neA}$ So, $I_1 = I_2$, $\frac{A_1}{A_2} = \frac{1}{2}$

We get $\frac{v_{d_1}}{v_{d_2}} = \frac{2}{1}$ $\therefore$ $v_{d_1} : v_{d_2} = \mathbf{2 : 1}$

(*ii*) In parallel current gets divided in inverse ratio of resistances

$\therefore$ $\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{1}{2}$

As $v_{d_1} = \frac{I_1}{enA_1}$, $v_{d_2} = \frac{I_2}{enA_2}$

We have $\frac{v_{d_1}}{v_{d_2}} = \frac{I_1}{I_2} \times \frac{A_2}{A_1} = \frac{1}{2} \times \frac{2}{1} = \frac{1}{1}$

$\therefore$ $\mathbf{v_{d_1} : v_{d_2} = 1 : 1}$

2. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons.
Answer:
Drift speed gained by an electron under the effect of electric field **E** in a conductor is

$$v_d = \frac{eE}{m}\tau$$

$$v_d = \frac{eV}{ml}\tau \qquad \ldots\left(\because E = \frac{V}{l}\right)$$

We have relation, $I = neAv_d$

$$I = neA\left(\frac{eV}{ml}\tau\right), \quad R = \frac{V}{I} = \frac{ml}{ne^2\tau A} \Rightarrow R = \rho\frac{l}{A}$$

$$\frac{ml}{ne^2\tau A} = \rho\frac{l}{A}$$

$\rho = m/ne^2\tau$ between resistivity and relaxation time of electrons.

3. Using the mathematical expression for the conductivity of a material, explain how it varies with temperature for

(i) semiconductors,

(ii) good conductors.

Answer:

Conductivity $\sigma = ne^2\tau/ m$

(i) Semiconductors: With increase in temperature, conductivity of semiconductor increases. It is due to increase in V. It dominates the effect caused by decrease in 'x'.

(ii) Good conductors: With increase in temperature, conductivity of good conductors decreases. It is due to decrease in the value of relaxation time. The effect of increased value of V is negligible.

4. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time.

Answer:

In the absence of electric field the electrons motion is random and the net velocity is zero. In the presence of electric field, they tend to flow opposite to that of the electric field in the conduction. If an electric field 'E' is applied across a length l of the conductor, the electrons will experience an acceleration, a =eE/m.

If the average time for the acceleration is x, the velocity required is

$$\vec{v}_d = \vec{u} + \vec{a}\,\tau = \vec{a}\,\tau. \therefore v_d = -\frac{e\vec{E}}{m}\tau, \ \left|\vec{v}_d\right| = \frac{eE}{m}\tau$$

5.. A battery of emf 10 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5 A, find

(i) the resistance of the resistor;

(ii) the terminal voltage of the battery.

Answer:

(i) Since $I = \frac{V}{r+R}$ $\therefore \frac{10}{r+R} = 0.5$

or $\frac{10}{3+R} = 0.5$ or $\frac{100}{5} = 3 + R$

$\therefore$ $R = 20 - 3 = \mathbf{17\Omega}$

(ii) Since $V = IR$ $\therefore$ $V = \frac{5}{10} \times 17 = \frac{85}{10} = \mathbf{8.5V}$

6. A battery of emf 6 V and internal resistance 2Ω is connected to a resistor. If the current in the circuit is 0.25 A, find
(i) the resistance of the resistors;
(ii) the terminal voltage of the battery.
Answer:

(i) **Given :** Current, $I = 0.25$ A, emf, $\varepsilon = 6V$,
internal resistance, $r = 2\ \Omega$

As $I = \frac{\varepsilon}{r+R}$ $\Rightarrow 0.25 = \frac{6}{2+R}$

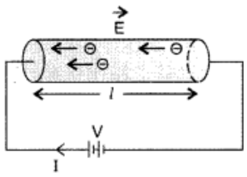
$\Rightarrow 2 + R = \frac{600}{25} = 24$

$\therefore$ *Resistance,* $R = 24 - 2 = \mathbf{22\ \Omega}$

(ii) As $V = IR$ $\therefore$ $V = \frac{25 \times 22}{100} = \frac{22}{4} = 5.5$ V

$\therefore$ *Terminal voltage,* $V = \mathbf{5.5\ V}$

7. Explain the term ‘drift velocity’ of electrons in a conductor. Hence obtain the expression for the current through a conductor in terms of ‘drift velocity’
Answer:
Definition: Drift velocity is defined as the velocity with which free electrons in a conductor get drifted in a direction opposite to the direction of the applied field. Its unit is m/s.



Expression: The magnitude of electric field set up across the conductor is given by
$E = V/l$
Let n be the number of free electrons per unit volume of the conductor.
Then, total number of free electrons in the conductor
= n × Volume of the conductor

Hence, Q = (nAl)e
Time taken by the charge to cross the conductor length l is given by

$$t = \frac{1}{v_d} \quad \text{where } [v_d \text{ is drift velocity of electrons}$$

$$\therefore \quad I = \frac{Q}{t} = \frac{nAle}{\frac{l}{v_d}} = neAv_d \quad \therefore \boxed{I = neAv_d}$$

8. Derive the expression for the current in a conductor of cross-sectional area A in terms of drift velocity.
Expression: Consider a conductor of length l and of uniform cross-section area A.
∴ Volume of the conductor = Al
If n is the number of the conductors, then total number of free electrons in the conductor = Aln
If e is the charge on ” each electron, then
total charge on all A the free electrons in the conductor, q = Alne
The electric field set up across the conductor of potential difference V is given by,

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

Due to this field, the free electrons present in the conductor will begin to move with a drift velocity vd towards the positive terminal of the battery
∴ Time taken by free electrons to cross the conductor,

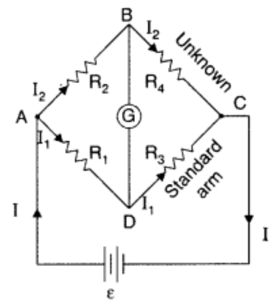
$$t = \frac{l}{v_d}$$

$$\text{Hence, Current } I = \frac{l}{v_d}\frac{q}{t} = \frac{Alne}{l / v_d} \quad \Rightarrow I = Anev_d$$

SinceA, n and e are constants,
Hence $I \propto v_d$, Therefore, the current flowing through a conductor is directly proportional to the drift velocity.

9. State Kirchhoff’s rules. Explain briefly how these rules are justified.
Kirchhoff’s junction rule: At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

1.**Kirchhoff’s loop rule**: The algebraic sum of changes in potential in any closed loop involving resistors and cells is zero.
These two laws are justified on the basis of law of conservation of charge and the law of conservation of energy respectively.



10. Use Kirchhoff’s rules to obtain conditions for the balance condition in

a Wheatstone bridge.

Answer:

Conditions for the balance condition in a Wheatstone bridge:

Applying Kirchhoff's loop rule to closed loop ADBA,

$$-I_1R_1 + 0 + I_2R_2 = 0 \quad (I_g = 0) \quad \ldots(i)$$

For loop CBDC,

$$-I_2R_4 + 0 + I_1R_3 = 0 \quad (I_g = 0) \quad \ldots(ii)$$

From equation, (*i*)

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

From equation, (*ii*)

$$\frac{I_1}{I_2} = \frac{R_4}{R_3} \quad \therefore \frac{R_2}{R_1} = \frac{R_4}{R_3} \quad \text{or} \quad \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

This is the required balance condition in a Wheatstone bridge arrangement.

III. Short answer type (3 marks)

1. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

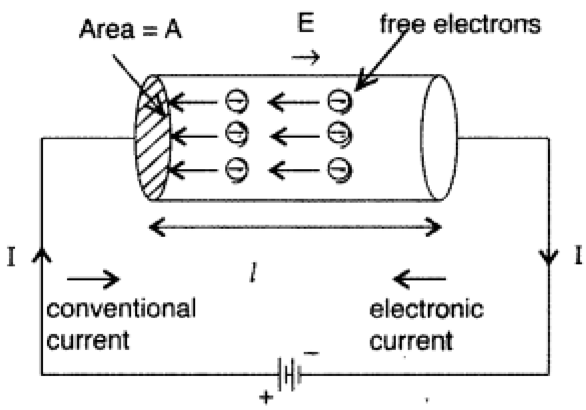
   Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by

   E = V/ l

   under the influence of field **E**, the free electrons begin to drift in the opposite direction **E** with an average drift velocity v_d.

   Let the number of electrons per unit volume or electron density = n

   Charge on an electron = e



No. of electrons in length l of the conductor = n x volume of the conductor = n × Al

Total charge contained in length l of the conductor is q = enAl … (i)

All the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d} \quad \ldots (ii)$$

Using equations (i) and (ii), we get

$$\text{Current } I = \frac{q}{t} = \frac{l\,ne\,A}{l/v_d} = neAv_d$$

Current density 'J' is given by

$$J = \frac{I}{A} = \frac{neAv_d}{A} = nev_d \qquad \therefore J \propto v_d$$

Hence the current density of a metallic conductor is directly proportional to the drift speed of electrons.

2.Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material?

Answer:

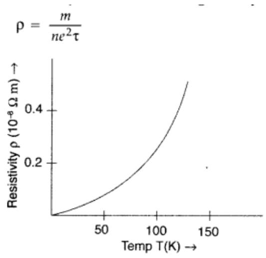
(i) Resistivity of conductor: It is the resistance of a conductor of unit length and unit area of cross-section.

The S.I. unit of resistivity is Ω m (ohm-metre)

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

(ii) Variation of resistivity with temperature:

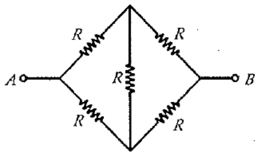
The resistivity of a material is given by



On increasing temperature, average speed of drifting electrons increases. As a result, collisions are more frequent. Average relaxation time τ decreases, hence 'ρ' increases.

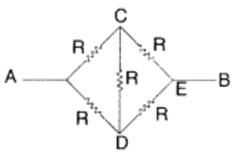
3. (i) Calculate the equivalent resistance of the given electrical network between points A and B.

(ii) Also caculate the current through CD and ACB, if a 10 V d.c. source is connected between A and B, and the value of R is assumed as 2 Ω.



(i) Equivalent circuit of the given problem is shown in the given diagram. The simplified circuit is equivalent to a balanced wheatstone bridge.

Hence there will be no current in arm CD,



(ii) Being a balanced wheatstone bridge

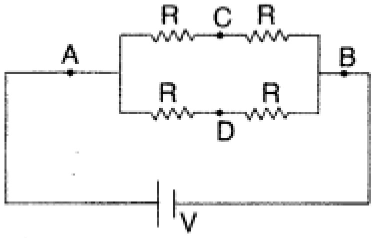
$I_{CD} = 0$

$V = 10$ volt

$R = 2\Omega$

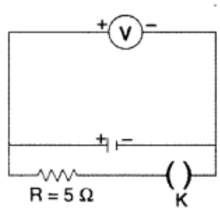
$V_{AB} = 10$ volt

$R_{ACB} = 4\Omega$



$\therefore\ I_{ACB} = \frac{10}{4} = \mathbf{2.5A}$

4. Write any two factors on which internal resistance of a cell depends. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5 Ω as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.



(a) Internal resistance of a cell depends upon:

(i) nature of electrolyte of the cell

(ii) separation between the electrodes.

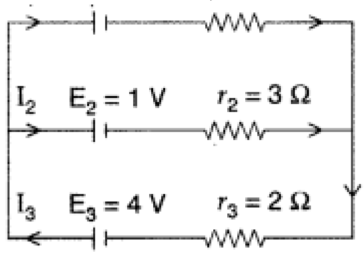
(b) Given: emf of cell, e = 2.2 V, R = 5 Ω, V = 1.8 V

$$r = \left(\frac{\varepsilon}{V} - 1\right) R$$

$$\Rightarrow r = \left(\frac{2.2}{1.8} - 1\right) \times 5 = \left(\frac{2.2 - 1.8}{1.8}\right) \times 5$$

$$\therefore r = \frac{0.4}{1.8} \times 5 = \frac{2}{1.8} = \mathbf{1.1\ \Omega}$$

5. State Kirchhoff's rules. Use these rules to write the expressions for the current I_1, I_2 and I_3 in the circuit diagram shown.



Answer: (i)

Kirchhoff's junction rule: At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction. (ii)

Kirchhoff's loop rule : The algebraic sum of changes in potential-in any closed loop involving resistors and cells is zero. (b)

According to Kirchhoff's junction rule,

$I_3 = I_1 + I_2$ ...(*i*)

Considering loop FCDEF

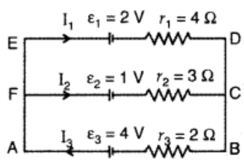
$3I_2 - 4I_1 = 1$ ...(*ii*)

Considering loop FCBAF

$3I_2 + 2I_3 = 3$ ...(*iii*)

$3I_2 + 2(I_1 + I_2) = 3$

$5I_2 + 2I_1 = 3$ ...(*iv*)



On solving equations (*i*), (*ii*) and (*iv*), we get

$I_1 = \frac{2}{13}$ A; $I_2 = \frac{7}{13}$ A; $I_3 = \frac{9}{13}$ A

6. Define the terms
(i) drift velocity,
(ii) relaxation time.
A conductor of length L is connected to a dc source of emf e. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3L, how will the drift velocity change?
Answer:
(i) Drift velocity: It may be defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied field.
(ii) Relaxation time: The average time that elapses between two successive collisions of an electron is called relaxation time.

$$V'_d = \frac{eV}{m3L} = \frac{1}{3}V_d \quad \because \; V_d = \frac{eV}{mL}$$

When length is tripled (3L), drift velocity becomes one-third of the original.
For details :
(i) Drift velocity. Drift velocity is defined as the velocity of the free electrons with which they get drifted towards the positive terminal under the influence of the external electric field. The drift velocity of electron is of the order of 10~5 m/ sec.
Derivation. Let 'm' be the mass of an electron and 'e' be the charge on it. When an external electric field 'E is applied, the acceleration
acquired by an electron is given by

$$F = ma \quad \Rightarrow a = \frac{F}{m} \quad \Rightarrow a = \frac{eE}{m}$$

Let v1 v2, v3 … vn be final velocities of electrons then average velocity of the electrons is given by

Let $v_1, v_2, v_3 \dots v_n$ be final velocities of electrons then average velocity of the electrons is given by

$$v_d = \frac{v_1 + v_2 + v_3 \dots v_n}{n} \quad \dots(i)$$

$$v_d = \frac{v_1 + v_2 + v_3 \dots v_n}{n} = \frac{(u_1 + at_1) + (u_2 + at_2) + \dots (u_n + at_n)}{n}$$

$$[\because v = u + at]$$

$$v_d = \frac{(u_1 + u_2 + \dots u_n)}{n} + \frac{a(t_1 + t_2 + \dots t_n)}{n}$$

$$v_d = 0 + a\tau \quad \Rightarrow v_d = a\tau$$

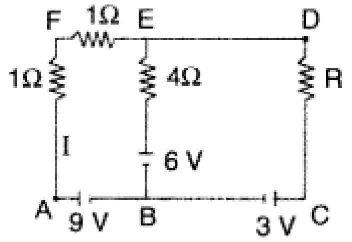
$$\therefore \; v_d = \frac{eE}{n}\tau \quad \dots[\text{From}(i)]$$

where $\tau = \frac{t_1 + t_2 + \dots t_n}{n}$ is the average time between two successive collisions and called **relaxation time**.

(ii) We know that $v_D = \frac{e}{m}\left(\frac{E}{L}\right)\tau \; \therefore \; v_D \propto \frac{1}{L}$

Therefore, when length is tripled, the drift velocity becomes one-third.

7. Using Kirchoff's rules determine the value of unknown resistance R into circuit so that no current flows through 4Ω resistance. Also find the potential difference between A and D.



Answer: Current flows from A TO E, E to D to C to B to A.

Putting the value of current I from (*i*), we have

$$\frac{3}{2} \times R = 3 \qquad \therefore\ R = 3 \times \frac{2}{3} = 2\Omega \ldots(ii)$$

Potential difference between A and D through path ABCD

$$+9V - 3V - IR = V_{AD}$$

$$\Rightarrow \quad +9V - 3V - \frac{3}{2} \times 2 = V_{AD}$$

[Alternatively through path AFD]

$$\therefore \quad V_{AD} = 3V$$

8. A cell of emf 'E' and internal resistance V is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus

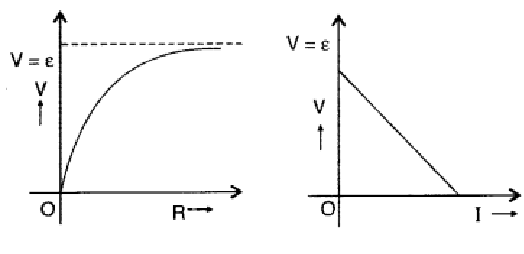
(i) R and

(ii) the current I.

It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r.

Answer:

(*a*) **Graph between V and I** (*b*) **Graph between V and R**



(*c*) $I = \frac{E}{R+r}$ $I = \frac{E}{4+r}$ $\Rightarrow E = 4 + r$ ...(*i*)

Also $0.5 = \frac{E}{9+r}$ $\Rightarrow E = 4.5 + 0.5r$ ...(*ii*)

From equations (*i*) and (*ii*)

$4 + r = 4.5 + 0.5r \ \therefore\ r = \mathbf{1\Omega}$

Using this value of *r*, in equation (*i*) we get

E = 5V

9. Derive the expression for the current density of a conductor in terms of the conductivity and applied electric field. Explain, with reason how the mobility of electrons in a conductor changes when the potential difference applied is doubled, keeping the temperature of the conductor constant.
Answer:
(i) Derivation of expression for current density—
Using Ohm's law,

$$V = IR = \frac{I\rho l}{A} = I\left(\frac{\rho l}{A}\right) \qquad \ldots(i)$$

Potential difference (V), across the ends of a conductor of length 'l' where field 'E' is applied, is given by

$$V = El \qquad \ldots(ii)$$

From equations (*i*) and (*ii*),

$$\therefore \quad El = I\left(\frac{\rho l}{A}\right)$$

But current density $J = \frac{I}{A}$

$$El = J\rho l = \frac{Jl}{\sigma} \qquad \left[\because \rho \frac{1}{\sigma}\right]$$

$$\Rightarrow \quad J = \sigma E$$

(*ii*) Mobility, $\mu = \frac{v_d}{E} = \frac{v_d}{\frac{V}{l}}$

So, as potential is doubled, drift velocity also gets doubled, therefore, there will be no change in mobility.

10. Potential difference V is applied across the ends of copper wire of length (l) and diameter D. What is the effect on drift velocity of electrons if
(1) V is doubled
(2) l is doubled
(3) D is doubled
Ans.
(1) Since V_d

$$= V_d = \frac{I}{neA} = \frac{V}{R(neA)}$$

$$= \frac{V}{\left(P\frac{\ell}{A}\right)(neA)} = \frac{V}{nep\ell}$$

V is doubled, drift velocity gets doubled.
(2) If l is doubled, drift velocity gets halved.
(3) Since V of is independent of D, drift velocity remains unchanged.

Long answer type (5 marks)

1. (a) Derive the relation between current density '**J**' and potential difference 'V' across a current carrying conductor of length area of cross-section 'A' and the number density of free electrons.
(b) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0 × 10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9 × 10^{28} m^{-3}]

(a)

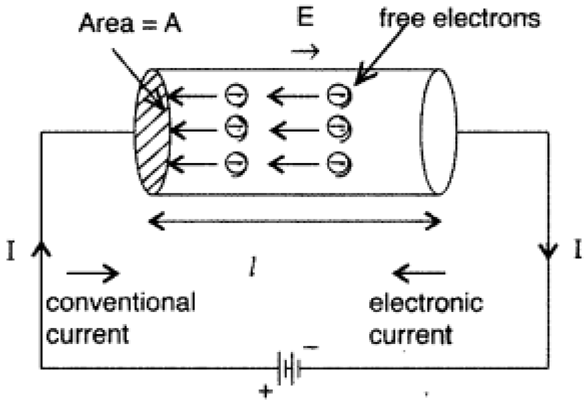
Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by

E = V/l

Under the influence of field **E** the free electrons begin to drift in the opposite direction **E** with an average drift velocity v_d.

Let the number of electrons per unit volume or electron density = n

Charge on an electron = e



No. of electrons in length l of the conductor = n x volume of the conductor = n × Al

Total charge contained in length l of the conductor is

q = enAl … (i)

All the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d} \quad \dots (ii)$$

Using equations (*i*) and (*ii*), we get

$$\text{Current I} = \frac{q}{t} = \frac{l\,ne\,A}{l/v_d} = neAv_d$$

Current density 'J' is given by

$$J = \frac{I}{A} = \frac{neAv_d}{A} = nev_d \qquad \therefore J \propto v_d$$

Hence the current density of a metallic conductor is directly proportional to the drift speed of electrons.

(b) Since $I = neAv_d \Rightarrow v_d = \frac{1}{neA}$

$$\therefore \quad v_d = \frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$$

$$= \frac{1.5}{9\times1.6}\times10^{-28+26}$$

$$= \frac{0.5}{4.8}\times10^{-2} = \mathbf{1.04\times10^{-3}\ m/s}$$

2. (i) Define the term drift velocity.
(ii) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?
(iii) Why alloys like constantan and manganin are used for making standard resistors?
Answer:
(i) Drift velocity may be defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied field.
(ii)
Relaxation time : The average time that elapses between two successive collisions of an electron is called relaxation time.

$$\vec{V}_d = \vec{a}\,\tau = -e\frac{\vec{E}}{m}\tau$$

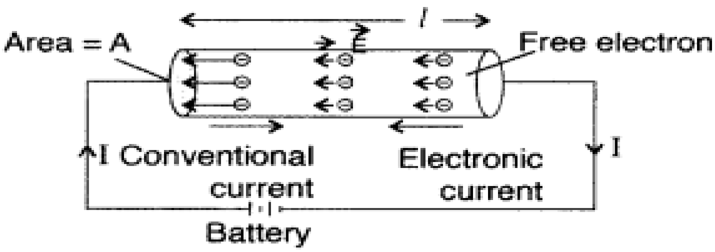
where [$\vec{V}_d$ is called drift velocity of electrons.]

Suppose a potential difference V is applied across a conductor of length T and of uniform cross-section A, then

Electric field E set up inside the conductor is given by

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

Under the influence of field E→, the free electrons begin to drift in the opposite direction E→ with an average drift velocity vd.



Let the number of electrons per unit volume or electron density = n

Charge on an electron = e

Number of electrons in length l of the conductor = n × volume of the conductor = nAl

Total charge contained in length l of the conductor, q = enAl

According to the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d},$$

$$\text{Current, } I = \frac{q}{t} = \frac{enAl}{l / v_d} = enAv_d$$

$$I = enAv_d \quad . \qquad v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

$$I = enAv_d = enA.\frac{eV\tau}{ml}$$

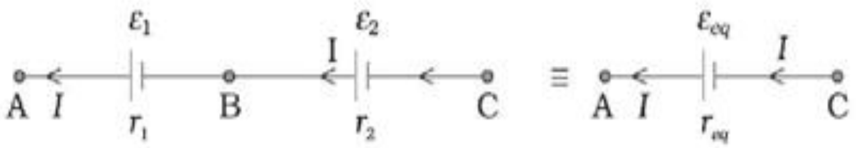
$$\frac{v}{I} = \frac{ml}{ne^2\tau A} \qquad \therefore\ R = \frac{ml}{ne^2\tau A}$$

where [R is electrical resistivity]

$$R = \rho\frac{l}{A},\ \text{or}\ \rho = \frac{AR}{l} \quad \therefore\ \rho = \frac{Aml}{ne^2\tau Al} = \frac{m}{ne^2\tau}$$

(iii) Because constantan and manganin show very weak dependence of resistivity on temperature. .

3. Two cells of different emfs and different internal resistances are connected in series. Find the equivalent emf and equivalent internal resistance of the combination.



Let V (A), V (B), V (C) be the potentials at points A, B and C shown in Fig. Then V (A) – V (B) is the potential difference between the positive and negative terminals of the first cell.

$V_{AB} = V(A) - V(B) = \varepsilon - I r$

Similarly, $V_{BC} = V(B) - V(C) = \varepsilon - I r$

Hence, the potential difference between the terminals A and C of the combination is

$$V_{AC} = V(A) - V(C) = [V(A) - V(B)] + [V(B) - V(C)]$$
$$V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$$
$$or, V_{AC} = \varepsilon_{eq} - I r_{eq}$$
$$where, \varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$$
$$\text{and, } r_{eq} = r_1 + r_2$$

If we connect the two negatives of the cell, we get

$$\varepsilon_{eq} = \varepsilon_1 - \varepsilon_2 \ (\varepsilon_1 > \varepsilon_2)$$

Note: For ***n*** cells of EMF $\boldsymbol{\varepsilon}$ and internal resistance ***r***

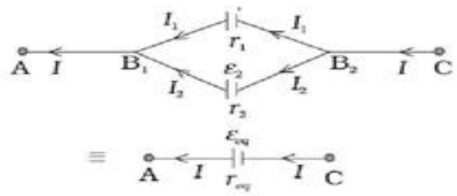
The total emf = n ε

The total resistance = nr + R and

Current $I = \frac{n\varepsilon}{R + nr}$

If out of ***n*** cells, ***m*** cells are grouped in reverse order then, **net emf =** ***n ε – (2m) ε***

4. Two cells of different emfs and different internal resistances are connected in parallel. Find the equivalent emf and equivalent internal resistance of the combination.



Consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flow out. Since as much charge flows in as out, we have

$$I = I_1 + I_2$$

Let V (B_1) and V (B_2) be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is V (B_1) – V (B_2). Hence,

$$V = V(B_1) - V(B_2) = \varepsilon_1 - I_1 r_2$$
$$\Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$$

For the second cell

$$V = V(B_1) - V(B_2) = \varepsilon_2 - I_2 r_2$$
$$\Rightarrow I_2 = \frac{\varepsilon_2 - V}{r_2}$$
$$Now, I = I_1 + I_2$$
$$I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$
$$or\ V = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$$
$$or, V = \varepsilon_{eq} - I r_{eq}$$
$$where\ \varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$
$$and\ r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$
$$or, in\ simpler\ way \boxed{\frac{I}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}} \qquad and, \boxed{\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}}$$

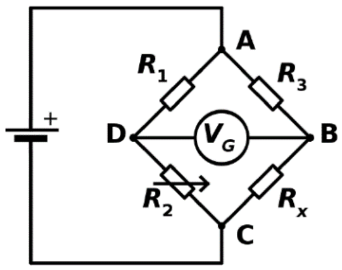
Note: For $\boldsymbol{m}$ rows of cells of emf $\boldsymbol{\varepsilon}$ and internal resistance $\boldsymbol{r}$.

The total resistance $= \frac{r}{m} + R$

$$And\ current\ = I = \frac{m\varepsilon}{mR + r}, \quad If\ r \ll R, \quad I = \frac{\varepsilon}{R}$$

CASE STUDY QUESTIONS

Q1. A **Wheatstone bridge** is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. The primary benefit of the circuit is its ability to provide extremely accurate measurements. The resistance is adjusted until the bridge is "balanced" and no current flows through the galvanometer At this point, the voltage between the two midpoints (**B** and **D**) will be zero. Therefore, the ratio of the two resistances in the known leg is equal to the ratio of the two resistances in the unknown leg



1. In balanced Wheat Stone Bridge, what is the potential difference between B and D?

Potential at points B and D remain same, so potential difference is zero.

2. What is the use of the Wheat Bridge?

It is used to measure unknown resistance, compare the resistances and find temperature coefficient of resistance or resistivity of the material.

3. Name the devise using in the laboratory to use Wheatstone condition to find unknown resistance?

Meter Bridge

4. Write the Condition for balanced Wheat stone bridge.

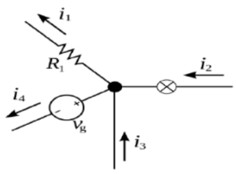
R1 / R2 = R3/ Rx

Q2. Voltage is the difference in charge between two points. **Current** is the rate at which charge is flowing. **Resistance** is a material's tendency to resist the flow of charge (current). So, when we talk about these values, we're really describing the movement of charge, and thus, the behaviour of electrons. A circuit is a closed loop that allows charge to move from one place to another. Components in the circuit allow us to control this charge and use it to do work. Ohm was a Bavarian scientist who studied electricity. Ohm starts by describing a unit of resistance that is defined by current and voltage.

1. Write the relationship gave by Ohm in the above passage.
Voltage and Current
Voltage across the ends of a conductor is directly proportional to the current through it at constant physical condition.

2. Write SI unit of resistance.
Ohm

3. What condition the flow of positive charge takes place?
The flow of positive charge takes place when potential difference maintained.
That if from Higher to Lower Potential



4. Name the device measures Voltage.
   Voltmeter

Q3. Kirchhoff's circuit laws are two equalities that deal with the current and potential difference in the lumped element model of electrical circuits. They were first described in 1845 by German physicist Gustav Kirchhoff.

Kirchoff' Current Law This law states that, for any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node **Kirchoff's Voltage Law** The directed sum of the potential differences (voltages) around any closed loop is zero.

1. Name the quantity conserved in Kirchhoff current law.
   Charge.

2. How will you write Kirchhoff current law in mathematical form?
   $\Sigma I = 0$

3. Name the physical quantity conserved in Kirchhoff's Voltage Law.
   Energy

4. Which circuit Kirchhoff's Voltage Law is applied?
   Any Closed-Circuit loop .

SELF ASSESSMENT PAPER M.M:25

I. Multiple Choice Questions (1 × 2 =2)

Q1. If the flow of current increases inside a conductor, value of drift velocity……

(A) Increases **(B)** Decreases **(C)** Zero **(D)** Infinite

Q2. Wheatstone bridge is not suitable for measurement of

(A) Very high value resistors **(B)** very low value resistances

(C) Both (A) and (B) **(D)** medium value resistances

II. Assertion & Reasoning (1 × 2 =2)
Instructions

These questions consist of two statements each, as Assertion and Reason. While answering these Questions you are required to choose one of the following four responses.

A. If both Assertion & Reason are True & the Reason is the correct explanation of the Assertion.
B. If both Assertion & Reason are True but the Reason is not the correct explanation of the Assertion.
C. If Assertion is True but the Reason is False.
D. If Assertion is False but Reason is true.

Q1. **Assertion: -** Fuse wire has low resistance and high melting point.

Reason: - Fuse wire has different ratings for different current flow.

(1) A (2) B (3) C (4) D

Q2. **Assertion: -** Kirchhoff's junction rule is applicable for any number of lines meeting at a point of an electrical circuit.

Reason: - When there is a steady flow of current, then there is accumulation of charges at the junction.

(1) A (2) B (3) C (4) D

III. Competency based (1 × 4 =4)

Read the following text and answer any four of the following questions on the basis of the same.

Electric Toaster: Small Industries Service Institute Takyelpat Industrial Estate Imphal has designed an Electric toaster which is operated at 220 volts A.C., single phase and available in four different rated capacity such as 600W, 750 W, 1000 W and 1250 W. The heating element is made of nichrome 80/20 (80% nickel, 20% chromium), since Nichrome does not get oxidize readily at high temperature and have higher resistivity, so it produces more heat The element is wound separately on Mica sheets and fitted with body of toaster with the help of ceramic terminals.

Q1. Heating element of the toaster is made of:

(A) Copper **(B)** Nichrome

(C) Chromium **(D)** Nickel

Q2. What is meant by 80/20 Nichrome?

(A) 80% Chromium and 20% Nickel **(B)** 80% Nickel and 20% Chromium

(C) Purity 80%, Impurity 20% **(D)** It is a mixture of Chromium and Nickel

Q3. Which one will consume more electricity?

(A) 600W (**B)** 750W

(C) 1000W **(D)** 1200W

Q4. Operating voltage of the device is:

(A) 220 V AC, single phase **(B)** 220 V AC, three phase

(C) 220 V DC **(D)** 220 V AC/DC

Q5. Insulating materials used in the device are:

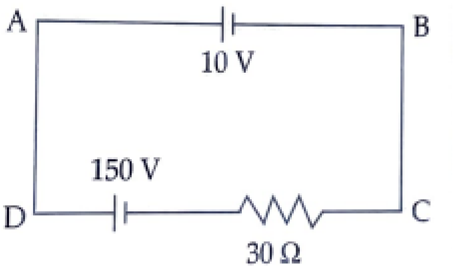
(A) Mica **(B)** Ceramic

(C) Mica, Ceramic, Nichrome **(D)** Mica, Ceramic

IV.Short Answer Type Questions – I (2× 3 =6)

Q1. Two electric bulbs P and Q have their resistances in the ratio of 2:4. They are connected in series across battery. Find the ratio of the power dissipation in these bulbs.

Q2. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 150 V and internal resistance of 30 Ω as shown in the figure. Find the value of current in the circuit.



Q3. A cell of emf 4 V and internal resistance 1 Ω is connected to a d.c. source of 10 V through a resistor of 5 Ω. Calculate the terminal voltage across the cell during charging.

IV.Short Answer Type Questions – II (3 × 2 =6)

Q1. A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27.0 °C and the temperature coefficient of resistance of nichrome is 1.70×10^{-4} °C^{-1}?

Q2. (a) Define the term “conductivity” of a metallic wire. Write its S.I. unit.

(b) Using the concept of free electrons is a conductor; derive the expression for the conductivity of a wire in term of current density and relaxation time. Hence obtain the relation between current density and the applied electric field E.

V.Long Answer Type Questions (5 ×1 =5)

Q1. (i) State Kirchhoff's rules for an electric network.

(ii) Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheatstone bridge.

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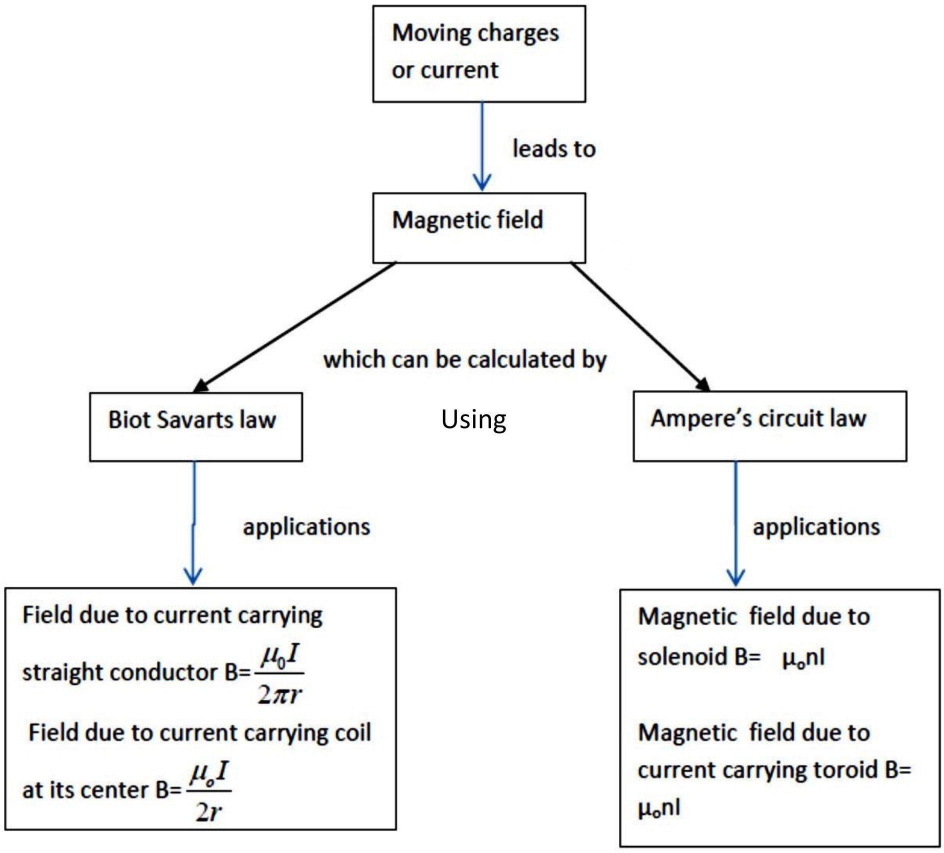
CHAPTER 4

MOVING CHARGES AND MAGNETISM

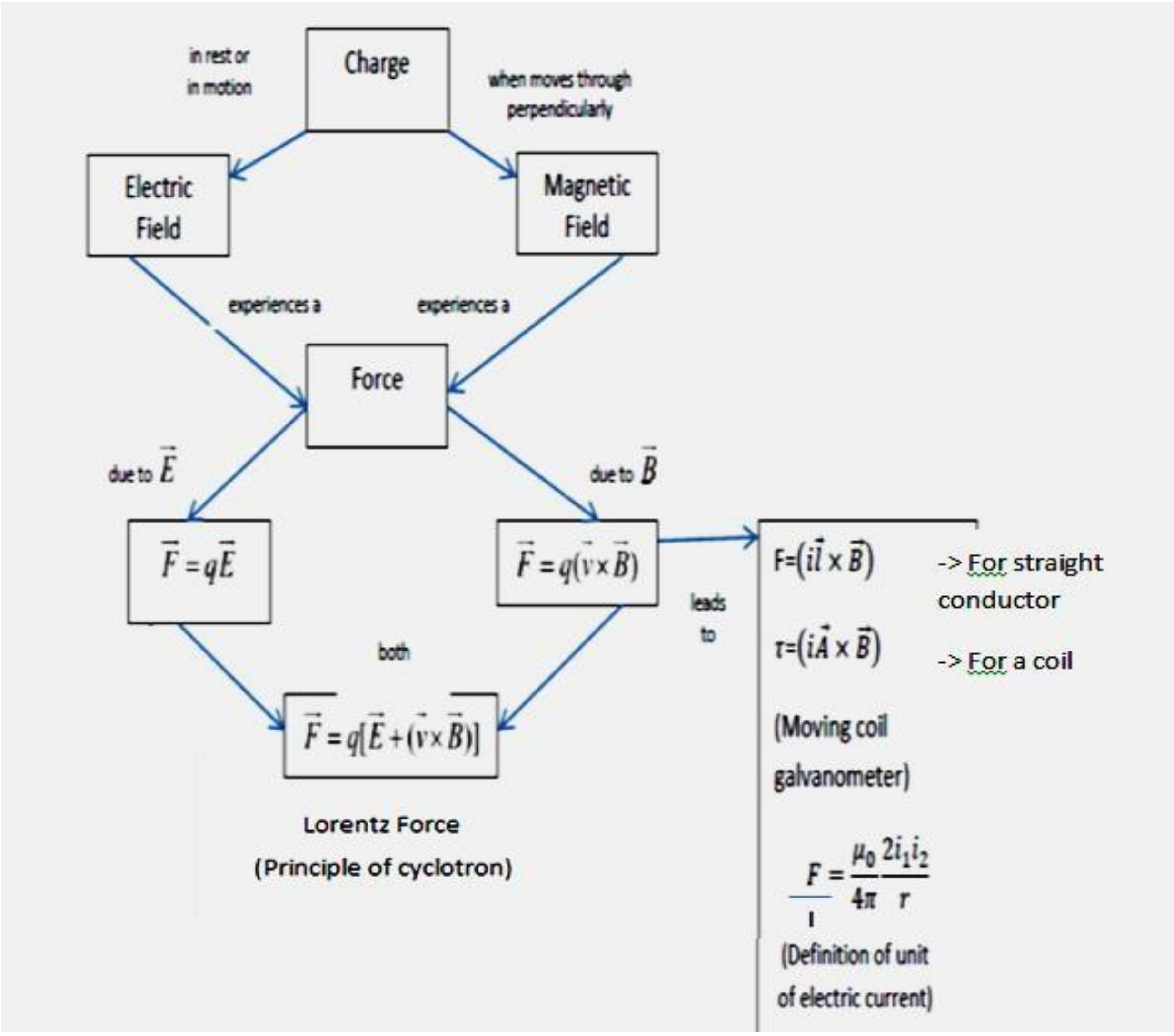
CONCEPT_MAP

Moving Charges



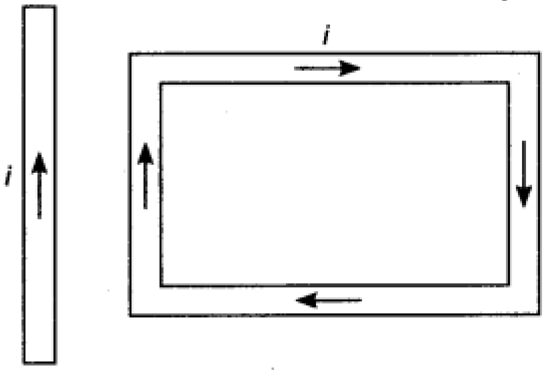
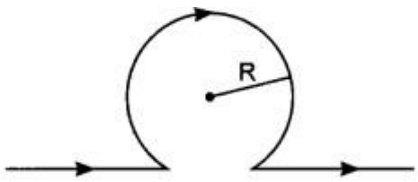
CONCEPT_MAP

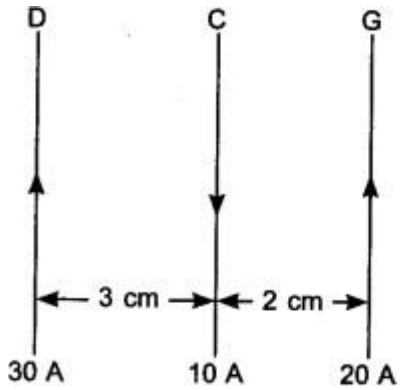
Moving Charge and Force

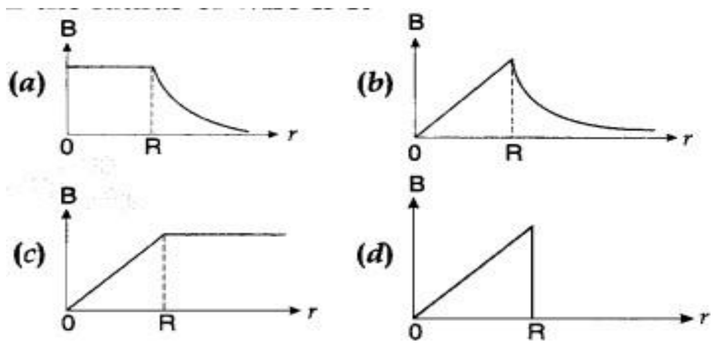


MULTIPLE CHOICE QUESTIONS

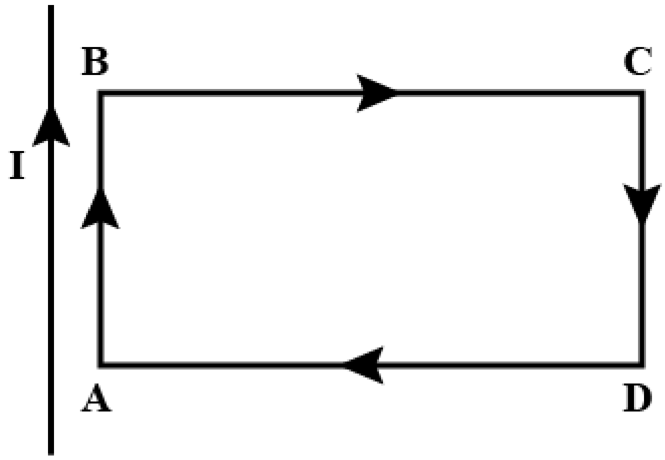
SECTION A (MCQ)		
1	Oersted's experiment demonstrated that: a) Electric currents produce magnetic fields b) Magnetic fields can generate electric currents c) Electric fields can produce magnetic forces d) Magnetic fields can produce electric forces	1
2	In a current-carrying loop, the magnetic field is strongest: a) At the center of the loop b) Along the edges of the loop c) Inside the loop d) Outside the loop	1
3	The magnetic field inside a current-carrying conductor_________. (a) increases with the increase in current (b) decreases with the increase in current (c) remains constant with the increase in current (d) is zero	1
4	The direction of the magnetic field at the center of a current-carrying circular loop is: (a) Along the axis of the loop (b) Parallel to the plane of the loop (c) Radially inward (d) Tangential to the loop	1
5	Which of the following statements is correct regarding the magnetic field around astraight current-carrying conductor? a) The magnetic field lines form concentric circles centered on the conductor.b) The magnetic field lines form straight lines parallel to the conductor. c) The magnetic field lines form radial lines away from the conductor. d) The magnetic field lines form hyperbolic curves around the conductor.	1
6	A circular coil of radius 4 cm and of 20 turns carries a current of 3 amperes. It is placed in a magnetic field of intensity of 0.5 weber/m². The magnetic dipole momentof the coil is a) 0.15 ampere-m² b) 0.3 ampere-m² c) 0.45 ampere-m² d) 0.6 ampere-m²	1
7	A flat circular coil of 100 turns and radius 10 cm carries a current of 1 A. Then the magneticdipole moment of the coil isA. a) π A·m^2 b) π/2 A·m^2 c) 2π A·m^2 d) π/4 A·m^2	1
8	If a charged particle moves through a magnetic field perpendicular to it a) Both momentum and energy of particle change. b) Momentum as well as energy is constant.	1

	c) Energy is constant but momentum changes. d) momentum is constant but energy changes	
9	A rectangular loop carrying a current i is situated near a long straight wire such thatthe wire is parallel to the one of the sides of the loop and is in the plane of the loop. If a steady current I is established in wire as shown in figure, the loop will  a) Rotate about an axis parallel to the wire. b) Move away from the wire or towards right. c) Move towards the wire. d) remain stationary	1
10	The maximum current that can be measured by a galvanometer of resistance 40 Ωis 10 mA. It is converted into voltmeter that can read up to 50 V. The resistance to be connected in the series with the galvanometer is a) 2010 Ω b) 4050 Ω c) 5040 Ω d) 4960 Ω	1
11	The strength of magnetic field at the Centre of circular coil is  (a) $\frac{\mu_0 I}{R}\left(1-\frac{1}{\pi}\right)$ (b) $\frac{\mu_0 I}{\pi R}$ (c) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$ (d) $\frac{\mu_0 I}{2R}\left(1+\frac{1}{\pi}\right)$	1
12	A current carrying closed loop of an irregular shape lying in more than one plane wheplaced in uniform magnetic field, the force acting on it (a) Will be more in the plane where its larger position is covered. (b) Is zero. (c) Is infinite. (d) May or may not be zero.	1

13	If the beams of electrons and protons move parallel to each other in the same direction, then they a) Attract each other. b) Repel each other. c) No relation. d) Neither attracts nor repel.	1
14	An electron is projected along the axis of a circular conductor carrying the samecurrent. Electron will experience a) a force along the axis. b) a force perpendicular to the axis. c) a force at an angle of 4° with axis. d) no force experienced.	1
15	Three long, straight parallel wires, carrying current are arranged as shown in thefigure. The force experienced by a 25 cm length of wire C is  a)10^{-3} N b) 2.5×10^{-3} N c) zero d) $1.5 \times ^{3}$ N	1
16	A strong magnetic field is applied on a stationary electron. Then the electron a) Moves in the direction of the field. b) Remained stationary. c) moves perpendicular to the direction of the field d) moves opposite to the direction of the field	1
17	A charged particle is moving on circular path with velocity v in a uniform magnetic field B, if the velocity of the charged particle is doubled and strength of magnetic fieldis halved, then radius becomes a) 8 times b) 4 times c) 2 times d)16 times	1

18	Two α-particles have the ratio of their velocities as 3: 2 on entering the field. If theymove in different circular paths, then the ratio of the radii of their paths is a) 2 : 3 b) 3 : 2 c) 9 : 4 d) 4 : 9	1
19	The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R 	1
20	In a moving coil galvanometer the deflection (Φ) on the scale by a pointer attached tothe spring is (a) $\left(\frac{NA}{kB}\right)I$ (b) $\left(\frac{N}{kAB}\right)I$ (c) $\left(\frac{NAB}{k}\right)I$ (d) $\left(\frac{NAB}{kI}\right)$	1

MARKING SCHEME

1	a) Electric currents produce magnetic fields
2	a) At the center of the loop
3	(c) zero
4.	(a) Along the axis of the loop
5	a) The magnetic field lines form concentric circles centered on the conductor.
6	0.3 ampere-m² The magnetic dipole moment (μ) of a coil can be calculated using theformula: Magnetic dipole moment (μ) = current (I) × area (A) × number of turns (N) In this case, the current is given as 3 amperes, the coil has 20 turns, and the radius is 4 cm. The area of coil is Area (A) = π × radius^2 Substituting the values given: Area (A) = π × (0.04 m)^2 = 0.0016π m^2 Now, we can calculate the magnetic dipole moment: Magnetic dipole moment (μ) = 3 A × 0.0016π m^2 × 20 = 3 × 0.0016π × 20 A·m^2 Magnetic dipole moment (μ) = 3 × 0.0016π × 20 A·m^2 = 0.096π A·m^2=0.3 A·m^2
7	No. of turns N = 100 Radius r = 10 cm = 0.1 m Current I = 1 A Magnetic moment M = NIA Now area of the circular coil A = πr2 Therfore, M = NIπr2 = 100×1×3.14×0.1×0.1 = 3.14 a) π A·m^2
8	c) Since the direction of velocity of a particle varies so momentum changesbut direction of magnetic force is always perpendicular to direction of charged particle. So no work is done, i.e. energy remains the same.
9	move towards the wire.  The long straight wire and side AB carry current in the same direction, hence willattract each other. The long straight wire and side CD carry current in the opposite direction, hence will

	repel each other. Force on side BC will be equal and opposite to force on side DA. Since CD is farther from the wire than AB, the force of attraction on AB willexceed the force of repulsion on CD. Hence, there will be a net force of attraction on the loop ABCD and it will movetowards the wire.
10	(d) $R = \frac{V}{I_g} - G = \frac{50}{10 \times 10^{-3}} - 40 = 4960\ \Omega$
11	(c) B = Field to circular portion – Field due to straight portion $= \left(\frac{\mu_0 I}{2R} - \frac{\mu_0 I}{2\pi R}\right) = \frac{\mu_0 I}{2R}\left(1 - \frac{1}{\pi}\right)$
12	b) is zero A current carrying closed loop of any shape when placed in a uniformmagnetic field does not experience any force.
13	b) repel each other As current carried by electrons and protons are in opposite direction
14	d) no force experienced Since electron is moving parallel to direction of magnetic field of the conductor Force (F) = qvB sin 0 = 0
15	c) zero Force of repulsion by wire D and G on wire C is equal and opposite
16	b) remained stationary
17	b) 4 times To perform circular motion required centripetal force would be provided by themagnetic force on the moving charge. So, Bqv=mv^2 / r or r=Bq / mv According to the question, v′=2v andB′ = B/2/////// ∴r’=B′q / mv ′ = (B/2)q / m(2v) = Bq/4mv=4r
18	b) 3 : 2 R=mv / qB Let the velocity of the first α particle be v1and that of the second one be v2 v1:v2=3:2 v1/ v2=3/2 let the radii of the circular paths of the first and second α - particlesbe R1 and R2 respectively R1=mv1 / qBR2=mv2 / qB R1/R2=mv1/qB/mv2/qB=v1/v2 R1/R2=3/2=3:2
19	b)
20	c)

ASSERTION AND REASONING TYPE QUESTIONS

Instructions: Two statements are given-one labelled Assertion (A) andthe other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

S.NO	QUESTIONS
1	**Assertion (A):** An electron projected parallel to the direction ofmagnetic force will experience maximum force. **Reason (R):** Magnetic force on a charge particle is given byF = (IL x B).
2	**Assertion (A):** A proton is placed in a uniform electric field, ittends to move along the direction of electric field. **Reason(R):** A proton is placed in a uniform electric field it experiences a force in the direction opposite to electric field.
3	**Assertion (A):** If an electron and proton enter a magnetic fieldwith equal momentum, then thepaths of both of them will be equally curved. **Reason (R):** The magnitude of charge on an electron is same as thaton a proton.
4	**Assertion (A):** If a proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed, the time period of revolution of α-particle is double than that of proton. **Reason (R):** In a magnetic field, the period of revolution of a charged particle is directly proportional to the mass of the particle and inversely proportional to the charge of the particle.
5	**Assertion (A):** The magnetic field at the ends of a very long current carrying solenoid is half of that at the center. **Reason (R):** If the solenoid is sufficiently long, the field within it is uniform.
6	**Assertion (A):** Magnetic field due to an infinite straightconductor varies inversely as the distance from it. **Reason (R):** The magnetic field due to a straight conductor is in theform of concentric circles.
7	**Assertion (A):** The torque acting on square and circular current carrying coils having equal areas, placed in uniform magnetic field,will be same. **Reason (R):** Torque acting on a current carrying coil placed inuniform magnetic field does not depend on the shape of the coil, ifthe areas of the coils are same.

8	**Assertion (A):** The magnetic field produced by a current carrying long solenoid is independent of its length and cross-sectional area. **Reason(R) :** The magnetic field inside the solenoid is uniform.
9	**Assertion (A):** The voltage sensitivity may not necessarily increaseon increasing the current sensitivity **Reason (**R): Current sensitivity decreases on increasing the number of turns of the coil
10	**Assertion(A):** Torque on the coil is maximum when the coil issuspended in a radial magnetic field **Reason(R) :** If the coil is set with its plane parallel to the direction of the magnetic field, then torque on it is maximum
11	**Assertion (A):** Electron enters into a magnetic field at an angle of 60 degree.Its path will be Parabola. **Reason (R) :** Force on electron moving perpendicular to magneticfield is zero.
12	**Assertion (A):** Two parallel conducting wires carrying currents insame direction come close to each other. **Reason (R) :** Parallel currents attract and antiparallel currents repel.
13	**Assertion(A):** When radius of circular loop carrying current isdoubled, its magnetic moment becomes four times **Reason (R) :** Magnetic moment depends on area of the loop
14	**Assertion(A):** Galvanometer cannot as such be used as an ammeter to measure the value of current in a given circuit **Reason (R) :** It gives full scale deflection for a current of the orderof micro ampere**.**
15	**Assertion(A):** A galvanometer can be converted to voltmeter byconnecting a very small resistance in series to it**.** **Reason (R) :** Voltmeter is to be connected in series with the circuit
16	**Assertion (A):** An electron projected parallel to the direction of magnetic force will experience maximum force. **Reason (R):** Magnetic force on a charge particle is given by F = (IL x B).

1(d)	**2(c)**	**3(a)**	**4(a)**	**5(b)**	**6(b)**	**7(a)**	**8(b)**	**9(c)**	**10(a)**
11(d)	**12(a)**	**13(b)**	**14(a)**	**15(d)**	**16(d)**				

TWO MARK QUESTIONS

S.NO	QUESTION AND SOLUTION
1	Write the expression for the force acting on a charged particle of charge q moving with velocity is in the presence of magnetic field B. Show that in the presence of this force. Ans: (a) The K.E. of the particle does not change. (b) Its instantaneous power is zero. Ans. Since F = q ($\vec{v} \times \vec{B}$) (a) Since direction of force is perpendicular to the plane containing ($\vec{v} \times \vec{B}$) => w = Fs cos θ $(=90^0)$ w = Fs $cos 90^0$ = 0 => KE = 0 $\therefore$ KE will not – change (b) since p = Fvcos θ = Fv $cos 90^0$ = 0 => Instantaneous power is also zero.
2	. An electron of kinetic energy 25KeV moves perpendicular to the direction of a uniform magnetic field of 0.2 millitesla calculate the time period of rotation of the electron in the magnetic field? Ans. B = 0.2 T = 0.2 $\times$ 10^{-3}T Time Period T = $\frac{2\pi M}{QB}$ T = $\frac{2\times3.14\times9.1\times10^{-31}}{1.6\times10^{-17}\times0.2\times10^{-3}}$ T = 1.787 $\times$ 10^{-7} second
3	It is desired to pass only 10% of the current through a galvanometer of resistance 90 Ω. How much shunt resistance be connected across the galvanometer? Ans. IG = 10% of I = $\frac{10I}{100}$ G= 90Ω S = $\frac{IgG}{I-Ig} = \frac{\frac{10I}{100}\times 90}{I - \frac{10I}{100}}$

	S = $\frac{9I}{\frac{10I-I}{10}}$ S = $\frac{90\cancel{I}}{90\cancel{I}} = 10$ => $s = 10\Omega$
4	A long straight telephone cable contains six wires each carrying a Current of 0.5 A. The distance between wires can be neglected what is the magnitude of magnetic field at a distance 10 am from the cable (a) is the comments in all Dip wires an in the same direction and the other two in the opposite direction. a) I = 0.5x6=3A B= $\frac{\mu_0 2I}{4\pi r} = \frac{10^{-7}x2x3}{1} = 6x10^{-6}T$ **b) I 0.5X4 -0.5X2 = 1A** **B=** $\frac{\mu_0 2I^1}{4\pi r} = \frac{2x1}{0.1}x10^{-7} = 2x10^{-6}T$
5	A galvanometer having 39 division has a current sensitivity of 20μA/division. It has a résistance of 25 ohms. How will you connect it into an ammeter into voltmeter upto 1 volt. Current sensitivity = 20μA/div. Ig = $20X10^{-6}X30 = 6X10^{-4}$A. **a-> ammeter** $S = \frac{Ig}{I-Ig}a = \frac{6x10^{-4}x25}{(1-6x10^{-4})} = 0.1050$ **ohms** $a^1 = \frac{as}{a+s} = \frac{0.015x25}{25+0.015} = 0.015$ **ohms** Conversion of a into voltmeter $R = \frac{V}{Ig} - a = \frac{1}{1} - 0.015 = 0.985$ **ohms**

Unit-3 Magnetic effect of Current and Magnetism

(Moving charge and Magnetism, Magnetism and Matter)

1. Using Biot-Savart's law, derive the expression for the magnetic field due to a current carrying loop of radius '*R*', at a point which is at a distance '*x*' from its centre along the axis of the loop.

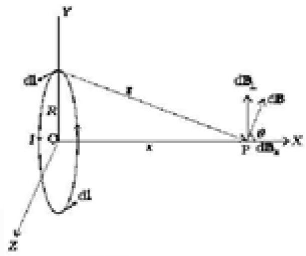


Figure depicts a circular loop carrying a steady current I. The loop is placed in the y-z plane with its centre at the origin O and has a radius R. The x-axis is the axis of the loop. Let x be the distance of P from the centre O of the loop.

Consider a conducting element dl of the loop. This is shown in Fig. The magnitude dB of the magnetic field due to dl is given by the Biot-Savart law,

$$dB = \frac{\mu_0}{4\pi}\frac{I|d\vec{l}\ x\ \vec{r}|}{r^3}$$

Now $r^2 = x^2 + R^2$. Further, any element of the loop will be perpendicular to the displacement vector from the element to the axial point.

Hence $|d\vec{l}\ x\ \vec{r}| = rdl$. Thus $dB = \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}$

The direction of $d\vec{B}$ is shown in Fig. It is perpendicular to the plane formed by $d\vec{l}$ *and* $\vec{r}$. It has an x-component $d\vec{B}_x$ and a component perpendicular to x-axis, $d\vec{B}_\perp$. When the components perpendicular to the x-axis are summed over, they cancel out and we obtain a null result. The net contribution along x-direction can be obtained by integrating $dB_x = dB\cos\theta$ over the loop.

Now from above fig,

$$\cos\theta = \frac{R}{(x^2+R^2)^{\frac{1}{2}}}$$

From above two equations

$$dB_x = \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}\frac{R}{(x^2+R^2)^{\frac{1}{2}}}$$

$$= \frac{\mu_0 Idl}{4\pi}\frac{R}{(x^2+R^2)^{\frac{3}{2}}}$$

The summation of elements dl over the loop yields 2πR, the circumference of the loop. Thus, the magnetic field at P due to entire circular loop is

$$\boxed{\vec{B} = B_x\hat{\imath} = \frac{\mu_0 IR^2}{2(x^2+R^2)^{\frac{3}{2}}}\hat{\imath}} \quad or\ for\ coil\ having\ N\ turns, B = \frac{\mu_0 NIR^2}{2(x^2+R^2)^{\frac{3}{2}}}$$

Special cases

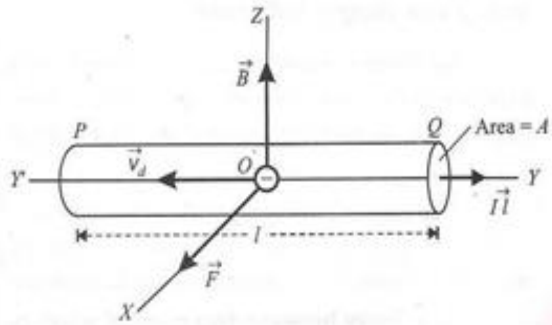
At the centre of the current loop, $x = 0$

$$\therefore B = \frac{\mu_o NIA}{2\pi R^3}, \qquad where\ A = \pi R^2, area\ of\ circular\ current\ loop$$

At the axial points lying far away from the coil, $x \gg R$, $B = \frac{\mu_o NIR^2}{2x^3} = \frac{\mu_o NIA}{2\pi x^3}$

At an axial point at a distance equal to the radius of the coil i.e. $x = R$, we get $B = \frac{\mu_o NIR^2}{2(R^2+R^2)^{3/2}} = \frac{\mu_o NI}{2^{5/2}R}$

2. Derive a mathematical expression for the force acting on a current carrying straight conductor kept in a magnetic field. Under what condition is this force (i) zero and (ii) maximum?



Consider a conductor PQ of length l, area of cross section A, carrying current I, along +ve Y-direction. The field $\vec{B}$ acts along +ve Z-direction. The electrons drift towards left with velocity $\vec{v}_d$. Each electron experiences a magnetic Lorentz force along +ve X-axis, which is given by

$$\vec{f} = -e(\vec{v}_d \times \vec{B})$$

If n is the number of free electrons per unit volume, then total number of electrons in the conductor is $N = n \times volume = nAl$

The total force on the conductor is

$$\vec{F} = N\vec{f} = nAl[-e(\vec{v}_d \times \vec{B})] = enA[-l\vec{v}_d \times \vec{B}]$$

If $I\vec{l}$ represents a current element vector in the direction of current, then vectors $\vec{l}\ and\ \vec{v}_d$ will have opposite directions and we can take

$$-l\vec{v_d} = v_d\vec{l}$$

$$\therefore \vec{F} = enAv_d(\vec{l} \times \vec{B})$$

$$or, \vec{F} = I(\vec{l} \times \vec{B}) \quad magnitude\ of\ force, F = IlBsin\,\theta$$

where θ is the angle between the direction of the magnetic field and the direction of flow of current.

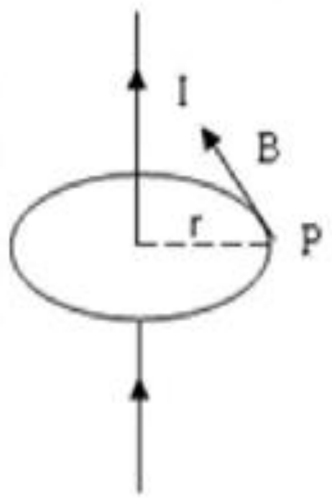
(i) If θ = 0° or 180°, then $F = IlB\,(0) = 0$

Thus, a current carrying conductor placed parallel to the direction of the magnetic field does not experience any force.

(ii) If θ = 90°, then $F = Ilb \sin 90° = IlB = F_{max}$

Thus, a current carrying conductor placed perpendicular to the direction of the magnetic field does not experience a maximum force.

3. State Ampere's circuital law. Derive an expression for the magnetic intensity at a point due to a current carrying straight wire of infinite length.



Ampere's law states that the line integral of the magnetic field around any closed path in free space is equal to μ_o times the total current passing through the surface. i.e. $\boxed{\oint \vec{B}.d\vec{l} = \mu_o I}$

Let a long straight conductor of infinite length carry current *I*.

Now, to find the magnetic intensity at a point 'P' due to this current carrying straight wire let us consider a circular amperian loop of radius '*r*' through point 'P'.

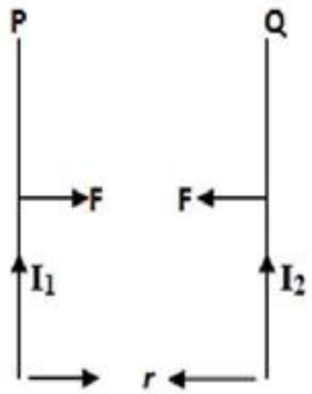
Applying Ampere's circuital law for this closed circular surface we get

$$\oint \vec{B}.d\vec{l} = \mu_o I$$

$$B \oint dl = \mu_o I or B.2\pi r = \mu_o I$$

$$\Rightarrow \boxed{B = \frac{\mu_o I}{2\pi r}}$$

4. Derive an expression for the force acting per unit length between two long straight parallel metallic conductors, carrying current in the same direction and kept near each other. Hence define an ampere.



(a) Consider two long straight conductors P and Q, placed parallel to each other, at a distance r apart. The currents through the two conductors are I_1 and I_2 respectively in the same direction.

The magnitude of the magnetic field due to current I_1 in P, at any point of Q, is given by

$$B = \frac{\mu_o I_1}{2\pi r} \quad \ldots\ldots(1)$$

The direction of magnetic field is into the plane of the paper. The current carrying conductor Q is placed in the magnetic field B. Since Q is placed perpendicular to the magnetic field B, the force acting per unit length l of Q is given by

$$F = BI_2 l,$$

directed towards P. Using eq (1), we get

$$F = \frac{\mu_o}{2\pi}\frac{I_1}{r} I_2 l = \frac{\mu_o}{2\pi}\frac{I_1 I_2}{r}\, l$$

$$or, \boxed{f = \frac{F}{l} = \frac{\mu_o}{2\pi}\frac{I_1 I_2}{r}}$$

When $I_1 = I_2 = 1\,A\ and\ r = 1m$, we get

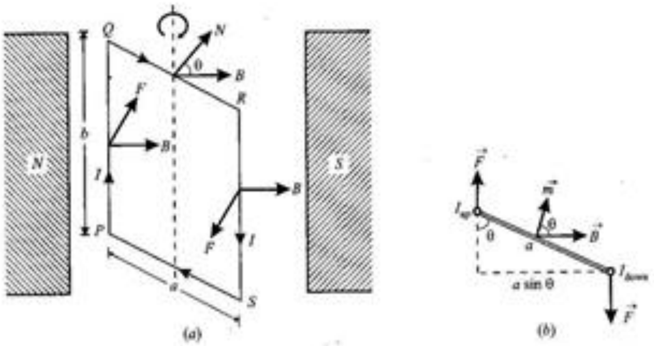
$$f = \frac{\mu_o}{2\pi} = 2 \times 10^{-7} Nm^{-1}$$

One ampere is that value of steady current, which on flowing in each of the two parallel infinitely long conductors of negligible cross-section placed in vacuum at a distance of 1m from each other, produces between them a force of $2 \times 10^{-7} Nm^{-1}$ *of their length.*

Note : For information only- The standard definition of one ampere is now modified

The ampere is defined by taking the fixed numerical value of the elementary charge e to be $1.602\ 176\ 634 \times 10^{-19}$ *when expressed in the unit C, which is equal to As, where the second is defined in terms of* $\Delta\nu_{Cs}$*. (2019)*

5. **Derive an expression for the torque on a rectangular coil of area *A*, carrying a current *I* and placed in a magnetic field *B*. The angle between the direction of *B* and vector perpendicular to the plane of the coil is *θ*.**



As shown in the figure, consider a rectangular coil PQRS suspended in a uniform magnetic field $\vec{B}$, with its axis perpendicular to the field.

Let I =current flowing through the coil, a, b = sides of the coil PQRS, $A = ab$=area of the coil and θ =angle between the direction of $\vec{B}$ and normal to the plane of the coil.

According to the Fleming's left hand rule, the magnetic forces on sides PS and QR are equal, opposite and collinear (along the axis of the loop), so their resultant is zero.

The sides PQ experiences a normal inward force equal to *IbB* while the side RS experiences an equal normal outward force. These two forces from a couple which exerts a torque given by

$$\tau = Force \times perpendicular\ distance = IbB\ x\ a\sin\theta = IBA\sin\theta$$

If the rectangular loop has N turns, the torque increases N times, i.e.

$$\tau = NIBA\sin\theta$$

But $NIA = m$, the magnetic moment of the loop, so

$$\tau = mB\sin\theta\ \ or\ in\ vector\ notation\ \boxed{\vec{\tau} = \vec{m} \times \vec{B}}$$

The direction of the torque is such that it rotates the loop clockwise about the axis of suspension.

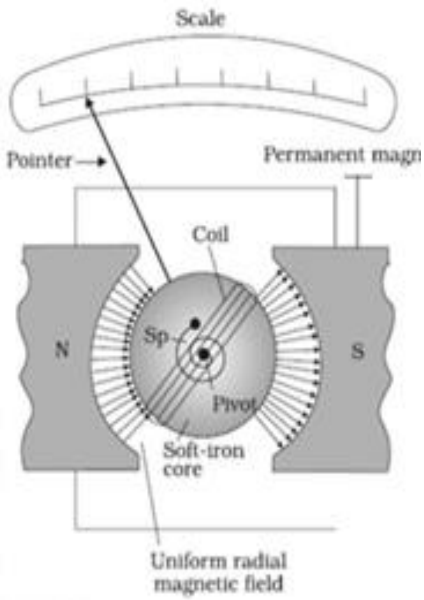
Special cases:

When θ = 0°, τ =0, i.e. the torque is minimum when the plane of the loop is perpendicular to the magnetic field.

When θ =90°, $\tau = NIBA$, i.e. the torque is maximum when the plane of the loop is parallel to the magnetic field.

6. Describe the principle, construction and working of a moving coil galvanometer. Define its figure of merit, current sensitivity and voltage sensitivity.

A galvanometer is a device to detect the presence of current in a circuit.



Principle: A Weston type moving coil galvanometer is based on the fact that when a current carrying loop or coil is placed in the uniform magnetic field, it experiences a torque.

Construction: A Weston type moving coil galvanometer is shown in the figure. It consists of a coil wound on a non metallic frame. The coil is suspended between two poles of a permanent cylindrical magnet. The motion of the coil is controlled by a pair of hair springs (usually of phosphor- bronze). The inner ends of the springs are soldered to the ends of the coil and the outer ends are connected to the binding screws. The spring provides the restoring torque and also serves as current leads. A light aluminum pointer attached to the coil measures its deflection. There is a cylindrical soft iron core which not only makes the field radial but also increases the strength of the magnetic field.

Working: Let $B = Intensity\ of\ magnetic\ field, I = current\ flowing\ through\ the\ coil, A = area\ of\ the\ coil\ and\ N = number\ of\ turns\ in\ the\ coil.$

When current flows through the coil, it experiences a torque, which is given by

$$\tau = NIAB\sin\theta = NIAB \quad (\because \sin\theta = 1)$$

This torque is called ***deflecting torque***.

As the coil is deflected, the spring gets twisted and a restoring torque is developed, which is given by $= \boldsymbol{k\phi}, where\ k = restoring\ torque\ per\ unit\ twist\ and\ \phi = deflection.$

For equilibrium of the coil, ***Deflecting torque = Restoring torque***

$$i.e. NIAB = k\phi$$

$$or, I = \left(\frac{k}{NAB}\right)\phi = G\phi$$

$$where\ G = \frac{k}{NAB}\ is\ called\ Galvanometer\ constant.$$

$$or\ I\ \alpha\ \phi$$

Thus, deflection of the coil is directly proportional to the current flowing through it. Hence a linear scale in the galvanometer can be used to detect the current in the circuit.

+

Figure of merit: It is defined as the current which produces a unit deflection in the galvanometer. It is given by

$$G = \frac{I}{\phi} = \frac{k}{NAB}$$

This is equal to the galvanometer constant.

Current Sensitivity: It is defined as the deflection produced in the galvanometer, when a unit current flows through it. It is given by

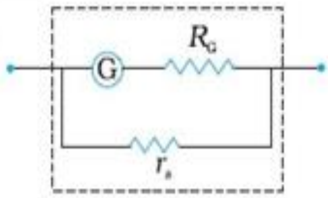
$$I_s = \frac{\phi}{I} = \frac{NAB}{k}$$

Voltage sensitivity: It is defined as the deflection produced in the galvanometer, when a unit potential difference is applied across its ends. It is given by,

$$V_s = \frac{\phi}{V} = \frac{\phi}{IR} = \frac{NAB}{IR} = \frac{I_s}{R} \quad i.e.\, voltage\ sensitivity = \frac{current\ sensitivity}{R}$$

7. Explain how a galvanometer can be converted into an ammeter of given range.

An ammeter is an instrument used to measure electric current in an electric current. An ideal ammeter should have zero resistance.



Ammeter

A galvanometer can be converted into an ammeter by connecting a low resistance called shunt parallel to the galvanometer. The value of shunt resistance depends on the range of the current required to be measured.

$let\ G = galvanometer\ resistance,$

$I_g = current\ for\ which\ galvanometer\ gives\ full\ scale\ deflection$

$0\ to\ I = required\ range\ of\ current,\qquad S = shunt\ resistance$

As $G\ and\ S\ are\ connected\ parallel$

$$potential\ difference\ across\ the\ galvanometer$$
$$= potential\ diff.\ across\ the\ shunt$$

$$I_g G = (I - I_g)S$$

$$or, S = \frac{I_g}{I - I_g} G \qquad also\ I_g = \frac{S}{G + S} I$$

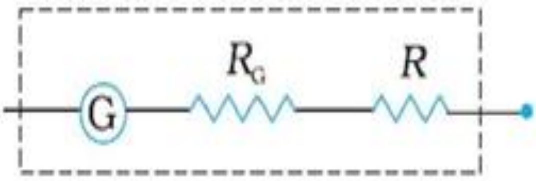
An ammeter is a shunted or low resistance galvanometer. Its effective resistance is

$$R = \frac{GS}{G + S}\ \ which\ is < S$$

8. Explain how a galvanometer can be converted into a voltmeter of given range.

Voltmeter is a device for measuring potential difference across any two points in a circuit.

Ideal voltmeter should have infinite resistance.



Voltmeter

A galvanometer can be converted into a voltmeter by connecting a high resistance in series with it.

$let\ G = galvanometer\ resistance,$
$I_g = current\ for\ which\ galvanometer\ gives\ full\ scale\ deflection$
$0\ to\ V = required\ range\ of\ voltage, \quad R = High\ resistance$

Total resistance of the circuit = $R + R_G$

By ohm's law

$$I_g = \frac{V}{R + R_G}$$

$$or, R = \frac{V}{I_g} - R_G$$

A voltmeter is a high resistance galvanometer. Its effective resistance is $R_V = R + R_G \gg R_G$

9. Show that a current carrying circular loop behaves as a magnetic dipole. Hence derive an expression for the magnetic dipole moment of the loop.

The magnetic field due to a circular current loop of radius *r* at a distance *x* from its centre is given by

$$B = \frac{\mu_0 I r^2}{2(r^2 + x^2)^{\frac{3}{2}}}$$

$$Or, B = \frac{\mu_o}{4\pi} \frac{2\pi I r^2}{(r^2 + x^2)^{\frac{3}{2}}}$$

πr^2 is the area of the plane of the loop, say *A*.

$$\therefore B = \frac{\mu_o}{4\pi} \frac{2IA}{(r^2 + x^2)^{\frac{3}{2}}}$$

$for\ x \gg r,$

$$B = \frac{\mu_o}{4\pi} \frac{2IA}{(x)^3}$$

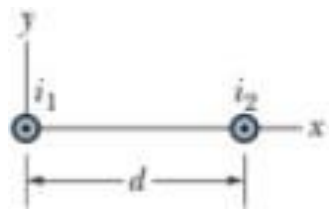
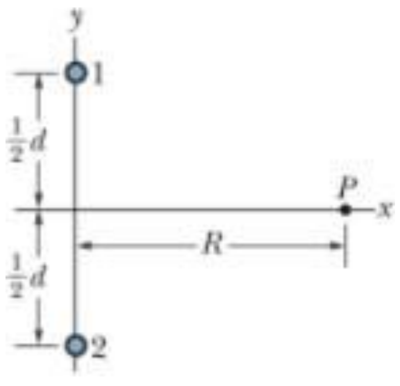
Now, the electric field due to an electric dipole along the dipole axis, at a distance *x* from the centre of the dipole is given by

$$E = \frac{1}{4\pi\varepsilon_0} \frac{2p}{x^3}$$

Comparing the two equations, we conclude that a current loop behaves like a magnetic dipole whose magnetic dipole moment is equal to the product of the current and the area of plane of coil. It is denoted by *M*. Thus,

$$\boxed{M = IA}$$

NUMERICALS

<table>
<tr><th>S.NO</th><th>QUESTIONS</th></tr>
<tr><td>1</td><td>A circular coil of 200 turns and radius 10 cm is placed in a uniform magnetic field of 0.5 T, normal to the plane of the coil. If the current in inthe coil is 3.0 A, calculate the
(a) total torque on the coil
(b) total force on the coil
(c) Average force on each electron in the coil, due to the magnetic field.</td></tr>
<tr><td>2</td><td>A long, straight wire of radius 'a' carries a current distributed uniformlyover its cross section. What is the ratio of the magnetic fields due to the wire at distance a/3 and 2a, respectively, from the axis of wire?</td></tr>
<tr><td>3</td><td>In the figure, two long straight wires at separation d=16.0 cm carry currents i1=3.61mA and i2=3.00 i1 out of the page. (a) Where on the x- axis is the net magnetic field equal to zero? (b) If the two currents aredoubled, is the zero-field point shifted toward wire 1, shifted toward wire 2 or unchanged?

</td></tr>
<tr><td>4</td><td>Figure shows, in cross section, two long parallel wires that are separated by distance d=18.6cm. Each carries 4.23A, out of the page in wire 1 and into the page in wire 2. In unit-vector notation, what is thenet magnetic field at point P at distance R=34.2cm, due to the two currents?

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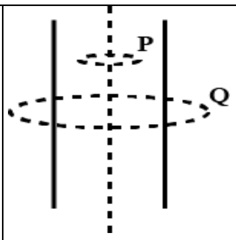
5	The force per unit length is 10^{-3} N on the two current-carrying wires of equal length that are separated by a distance of 2 m and placed parallel to each other. If the current in both the wires is doubled and the distance between the wires is halved, then what will be the force per unit length on the wire?
6	A galvanometer of resistance 90ohms is shunted by a resistance of 10ohms. What Fraction of the main current passes through the galvanometer through the shunt?
7	Calculate the magnetic field inside a solenoid, when (a) the length of the solenoid becomes twice and fixed number of turns (b) both the length of the solenoid and number of turns are double (c) the number of turns becomes twice for the fixed length of thesolenoid Compare the results.
8	Two long parallel wires separated by 0.1 m carry currents of 1A and 2A respectively in opposite directions. A third current-carrying wire parallelto both of them is placed in the same plane such that it feels no net magnetic force. Find the distance of the third wire.
9	Wire P carrying current 6 A upward and wire Q is 1m apart from it. If μ_0 = $4\pi\times10^{-7}$ wb A^{-1} m^{-1} and there is a repulsive force between wire P and Q 1.2×10^{-5} $N.m^{-1}$. Determine the magnitude and direction of electric current on wire Q.
10	A long straight conductor PQ, carrying a current of 60 A, is fixed horizontally. Another long conductor XY is kept parallel to PQ at a distance of 4 mm, in air. Conductor XY is free to move and carries a current 'I' . Calculate the magnitude and direction of current 'I' for which the magnetic repulsion just balances the weight of the conductor XY. .

SOLUTION

S.NO	ANSWER
1	(a) As $\vec{B}$ is parallel to the dipole moment $\vec{M}$ $\therefore r = \mathrm{BM}\sin 0 \quad = 0$ (b) As the force on different parts of the coil appears in pairs, equal in Magnitude, and opposite in direction, net force on coil is zero. (c) $\mathrm{F} = \mathrm{B}e\mathrm{V_d}$ $= 1.5 \times 10^{-24}\mathrm{N}$

2	 Let current density= σ $R_P=a/3$ $R_Q=2a$
	At P, From Ampere's law, $\Rightarrow\int B_p.dl = \mu_0 I_{in}$ $\Rightarrow\int B_P\, dl\cos\theta = \mu_0 \sigma\pi (\frac{a}{3})^2$ $\Rightarrow B_P \times 2\times\pi\frac{a}{3} = \mu_0\sigma\pi(\frac{a}{3})^2$ $\Rightarrow B_p = \frac{\mu_0\sigma a}{6}$ At Q, $\Rightarrow\int B_Q.dl = \mu_0 I_{in}$ $\Rightarrow\int B_Q\, dl\cos\theta = r\sigma\times\pi a^2$ $\Rightarrow B_Q 2\pi(2a) = \mu_0\sigma\pi a^2$ $\Rightarrow B_Q = \frac{\mu_0\sigma a}{4}$ Ratio=$\frac{B_p}{B_9} = \frac{\frac{\mu_0\sigma a}{6}}{\frac{\mu_0\sigma a}{4}}$ = 4/6 = 2:3
3	(a)Since they carry current in the same direction, then (by the righthand rule) the only region in which their fields might cancel is between them. Thus, if the point at which we are evaluating their field is r away from the wire carrying current i and (d−r)away fromthe wire carrying current 3.00i, then the cancelling of their fields leads to $\mu_0 i/2\pi r = \mu_0(3i)/2\pi(d-r)r$ = d/4 = 16/4 =4.0 cm (b) Doubling the currents does not change the location where themagnetic field is zero.

4	with $r=\sqrt{R^2+(d/2)^2}$ (by the Pythagorean theorem). The vertical components of the fields cancel, and the two (identical) horizontalcomponents add to yield the final result $B==1.25\times10^{-6}T$, where $(d/2)/r$ is a trigonometric factor to select the horizontal component. It is clear that this is equivalent to the expression in theproblem statement. Using the right-hand rule, we find both horizontal components point in the +x direction. Thus, in unit-vectornotation, we have $B=(1.25\times10-6T)\hat{i}$.

5	Force per unit length on both wires $f_{ab} = f_{ba} = f = 10^{-3}$ N distance (d) = 2m The force per unit length on wires is given as, **$f_{ab} = f_{ba} = f = \mu_0 I_a I_b / 2\pi d$** —(1) when the current in both wires is doubled, $I'_a = 2I_a$ $I'_b = 2I_b$ Distance between the wires is halved, d' = d/2 equation (1) can be written as, $f'_{ab} = f'_{ba} = f' = \mu_0 I'_a I'_b / 2\pi d'$ $f' = 2 \times (\mu_0 \times 2I_a \times 2I_b / 2\pi d)$ $f' = 8 \times (\mu_0 \times I_a \times I_b / 2\pi d)$ f' = 8f $f' = 8 \times 10^{-3}$ N

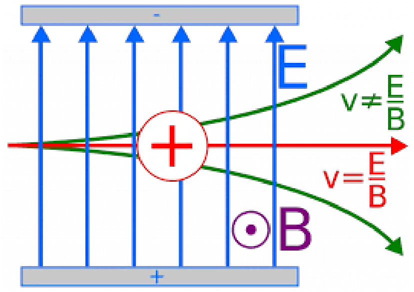
6	$\frac{Ig}{I} = \frac{S}{G+S} = \frac{10}{90+10} = \frac{1}{10} = 0.1$ A

7	The magnetic field of a solenoid (inside) is $$B_{L,N} = \mu_o \frac{NI}{L}$$ (a) length of the solenoid becomes twice and fixed number of turnsL→2L (length becomes twice) N→N (number of turns are fixed)The magnetic field is B2L , N = μ NI/2L = 1/2 BL ,N (b) both the length of the solenoid and number of turns are double
8	We know that the magnetic field due to long straight wire, $B = \mu_0 I / 2\pi x$ Therefore, $B_1 = B_2$ $(\mu d / 2\pi x) = \mu d_2 / 2\pi(0.1 + x)$ Here, $i_1 = 1A$ $i_2 = 2A$ $\mu_0 \times 1 / 2\pi x = \mu_0 \times 2 / 2\pi(0.1 +$ $x)$ $2x = (0.1 + x)$ $x = 0.1$ m
9	Current (I_p) = 6 A $\mu_0 = 4\pi \times 10^{-7}$ wb A^{-1} m^{-1} Repulsive force (F) = 1.2×10^{-5} N m^{-1} L = 1 m Electric current on wire is given by, $F = (\mu_0/2\pi)$ $(I_p$ $I_q/L)$ $1.2 \times 10^{-5} = (4\pi\times10^{-7}/2\pi)$ $(6\times I_q/1)$ $1.2 \times 10^{-5} = (2\times10^{-7})$ $(6\times I_q)$ $1.2 \times 10^{-5} = (12\times10^{-7})$ (I_q) $1.2 = (12\times10^{-2})$ (I_q) $1.2 = 0.12(I_q)$ $I_q = 1.2 / 0.12$ $I_q = 10$ A
10	Ans: I = 32. 67 A, The current in XY must flow opposite to that in PQ, because only thenthe force will be repulsive.

CASE STUDY BASED QUESTIONS

Read the following case/passage and answer the following questions:

1. A charge q moving with a velocity v in presence of both electric and magnetic fields experience a force F = q [E + v x B]. If electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle, the electric and magnetic forces are in opposite directions. If we adjust the value of electric and magnetic field such that magnitude of the two forces is equal. The total force on the charge is zero and the charge will move in the fields UN deflected.



1. What will be the value of velocity of the charge particle, when it moves un deflected in a regionwhere the electric field is perpendicular to the magnetic field and the charge particle enters at right angles to the fields.

(a) v = E/B (b) v = B/E (c) v = EB (d) v = EB/q

2. Proton, neutron, alpha particle and electron enter a region of uniform magnetic field with samevelocities. The magnetic field is perpendicular to the velocity. Which particle will experience maximum force?

(a) Proton (b) Electron (c) Alpha particle (d) Neutron

3. A charge particle moving with a constant velocity passing through a space without any changein the velocity. Which can be true about the region?

(a) E = 0, B = 0 (b) E ≠ 0, B ≠ 0 (c) E = 0, B ≠ 0 (d) All of these

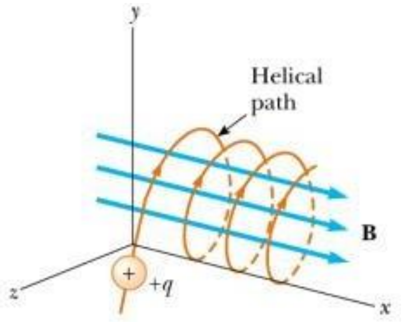
4. Proton, electron and deuteron enter a region of uniform magnetic field with same electricpotential-difference at right angles to the field. Which one has a more curved trajectory?

(a) Electron (b) Proton (c) Deuteron (d) All will have same radius of circular path

CASE STUDY-BASED QUESTION: ANSWER:

1. (a)	**2. (c)**	**3. (d)**	**4. (a)**

2. If velocity has a component along B, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a planeperpendicular to magnetic field is a circular one, thereby producing a helical motion.



1. The radius of the charge particle, (when v is perpendicular to B) placed in a Uniform magneticfield is given by

(a) R = mv/qB (b) R = qB/mv (c) R = Bqm/v (d) R = vq/Mb

2. An electron, proton, He+ and Li++ are projected with the same velocity perpendicular to auniform magnetic field. Which one will experience maximum Magnetic force?

(a) Electron (b) Proton (c) He+ (d) Li++

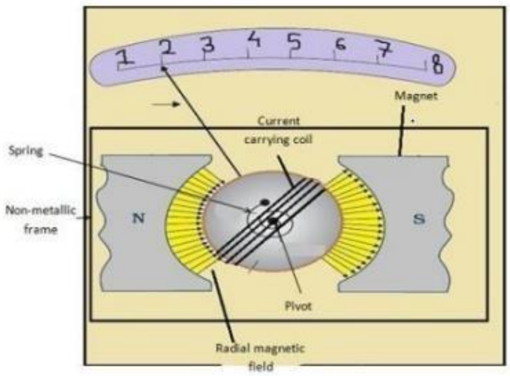
3. The work done by the magnetic field on the charge particle moving perpendicular to a uniformmagnetic field is

(a) Zero (b) q (v x B). S (c) Maximum (d) qBS/v

CASE STUDY-BASED QUESTION: ANSWER:

1. (a)	**2. (d)**	**3. (a)**

3. The galvanometer is a device used to detect the current flowing in a circuit or a small potential difference applied to it. It consists of a coil with many turns, free to rotate abouta fixed axis, in a uniform radial magnetic field formed by using concave pole pieces of a magnet. When a current flows through the coil, a torque acts on it.



1. What is the principle of moving coil galvanometer?
(a) Torque acting on a current carrying coil placed in a uniform magnetic field.
(b) Torque acting on a current carrying coil placed in a non-uniform magnetic field.
(c) Potential difference developed in the current carrying coil.
(d) None of these.

2. Why pole pieces are made concave in the moving coil galvanometer?
(a) To make the magnetic field radial.
(b) To make the magnetic field uniform.
(c) To make the magnetic field non-uniform.
(d) None of these.
3. What is the function of radial field in the moving coil galvanometer?
(a) To make the torque acting on the coil maximum.
(b) To make the magnetic field strong.
(c) To make the current scale linear.
(d) All the above.
4. If the rectangular coil used in the moving coil galvanometer is made circular, then what will bethe effect on the maximum torque acting on the coil in magnetic field for the same area of the coil?
(a) Remains the same
(b) Becomes less in circular coil
(C) becomes greater in circular coil

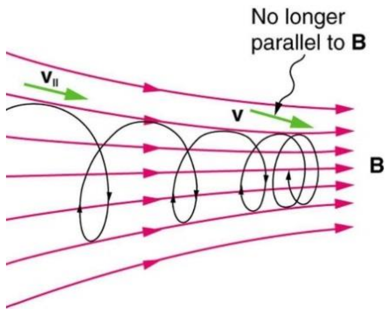
(d) Depends on the orientation of the coil

CASE STUDY-BASED QUESTION: ANSWER:

1.(a)	2.(d)	3.(a)	4.(d)	5.(a)

4. A point charge q (moving with a velocity v and located at r at a given time t) in the presence of both the electric field E and magnetic field B. The force on an electric charge qdue to both of them can be written as

F = q [E + v x B] = F_{el} + F_{mag} It is called the '**Lorentz force'**.



1. If the charge q is moving under a field, the force acting on the charge depends on the magnitude of field as well as the velocity of the charge particle, what kind of field is the chargemoving in?
(a) Electric field
(b) Magnetic field
(c) Both electric and magnetic field perpendicular to each other
(d) None of these

2. The magnetic force acting on the charge 'q' placed in a magnetic field will vanish if
(a) if v is small
(b) If v is perpendicular to B
(c) If v is parallel to B
(d) None of these

3. If an electron of charge -e is moving along + X direction and magnetic field is along + Z direction,then the magnetic force acting on the electron will be along
(a) + X axis (b) - X axis (c) - Y axis (d) + Y axis

4. The vectors which are perpendicular to each other in the relation for magnetic force acting on acharge particle are
(a) F and v (b) F and B (c) v and B (d) All of these

5. A particle moves in a region having a uniform magnetic field and a parallel, uniform electric field. At some instant, the velocity of the particle is perpendicular to the field direction. The pathof the particle will be
(a) A straight line (b) A circle
(c) A helix with uniform pitch (d) A helix with non-uniform pitch

CASE STUDY-BASED QUESTION: ANSWER:

1.(b)	2.(c)	3.(d)	4.(d)	5.(d)

ASSIGNMENT

S.NO	QUESTIONS
1	Derive the expression for force on a moving charge in a magnetic field and hence define magnetic field induction and its unit.
2	State Biot Savart's law. Derive the expression for the magnetic induction at a point on the axial line of a current carrying circular coil.
3	State Ampere's Circuital Law. Derive an expression for the magnetic field at a point due to straight current carrying conductor
4	Derive an expression for the magnetic field at a point along the axis of an air cored solenoid using a Ampere's circuital law..
5	For a circular coil of radius R and N turns carrying current I , deduce the magnitude of magnetic field at a point on its axis at a distance n from its centre. $B=\frac{\mu_0 IR^2 N}{2(R^2+x^2)^{3/2}}$ a) What will be the magnetic field at the centre of the coil? b) Consider two parallel coaxial coil of equal radius R and number of turns N, carry equal currents I in the same direction separated by a distance R. show that the field on the axis around the mid-point between the coils is given by $B=0.72\frac{\mu_0 NI}{R}$
6	A100 turn closely wound circular coil of radius 10 c.m. carries a current of 3.2 A. a) What is the field at the centre of the coil? b) What is the magnetic moment of this arrangement? A coil is placed in a vertical plane and free to rotate about a horizontal axis which coincides with its diameter. A uniform magnetic field of 2T in the horizontal direction exists such that initially the axis of the coil is in the samedirection of the field. The coil rotates through an angle of 90^0 under the influence of magnetic field i) What are the magnitudes of torques on the coil in the initial andfinal position? ii) What angular speed is acquired by the coil when it is rotated by 90^0?The moment of inertia of the coil is $0.1kgm^2$.
7	A helium nucleus is completing one round of a circle of radius 0.8m in 2 seconds. Find the magnetic field induction at the centre of circle.
8	A long straight telephone cable contains six wires each carrying a Current of 0.5 A. The distance between wires can be neglected what is the magnitude of magnetic field at a distance 10 am from the cable (a) is the comments in all Dip wires an in the same direction and the other two in the opposite direction
9	Give the expression for current sensitivity and voltage sensitivity of galvanometer. Increase in current sensitivity may not necessarily increase thevoltage sensitivity of galvanometer. Justify.

10	A galvanometer having 39 divisions has a current sensitivity of 20μA/division. It hasa résistance of 25 ohms. How will you connect it into an ammeter into voltmeter up to 1 volt?
11	Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed around an orbit of radius in hydrogen atom..
12	Derive an expression for the force acting on a current carrying conductor in a magnetic field. Under what conditions this force is maximum and minimum?
13	Obtain the force per unit length experienced by two parallel conductors of infinite lengthcarrying current in the same direction. Hence define one ampere.
14	Derive an expression for torque acting on a rectangular current carrying loop kept in auniform magnetic field B. Indicate the direction of torque acting on the loop.
15	With neat diagram, describe the principle, construction and working of a moving coil galvanometer. Explain the importance of radial field.

PART II

CHAPTER 5

MAGNETISM AND MATTER

Concepts:

- Magnetic field of a bar magnet of length $2l$ and dipole moment **m** at a distance **r** from the centre of the dipole(r>> *l*)

$$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$$, along the direction of dipole moment.

$$B_{equtorial} = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3}$$, opposite to the direction of dipole moment.

- Magnetic dipole in a uniform magnetic field experiences a torque

$$\vec{\tau} = \vec{m} \times \vec{B} = mBsin\theta$$

- The electrostatic analogue: $\vec{E} \rightarrow \vec{B}, \ \vec{p} \rightarrow \vec{m} \quad , \frac{1}{4\pi\varepsilon_0} \rightarrow \frac{\mu_0}{4\pi}$

- Magnetic properties of materials

  Diamagnetic material move from stronger to weaker part of external magnetic field.

  $$-1 \leq \chi < 0 \quad ,0 \leq \mu_r < 1 \quad ,\mu < \mu_0$$

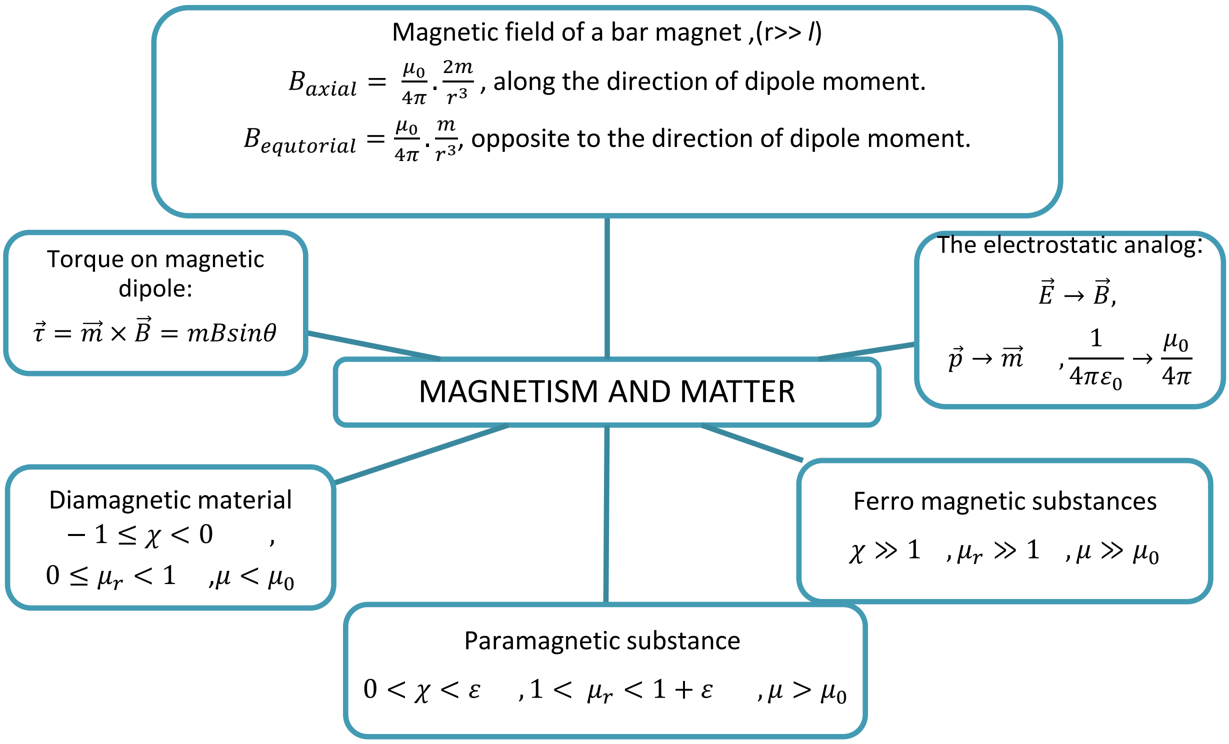
  Paramagnetic substance is those which get weakly magnetised when placed in an external magnetic field.

  $0 < \chi < \varepsilon \quad ,1 < \mu_r < 1 + \varepsilon \quad ,\mu > \mu_0$

  Ferromagnetic substances are those which get strongly magnetised when placed in an external magnetic field

$\chi \gg 1 \quad , \mu_r \gg 1 \quad , \mu \gg \mu_0$

CONCEPT MAP



Topics: Bar magnet, bar magnet as an equivalent solenoid, (qualitative treatment only), magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis(qualitative treatment only)

OBJECTIVE TYPE QUESTIONS (MCQ- Each carries 1 Mark)

1. When a bar magnet is immersed in a heap of iron filings and is taken out, it is observed that iron filings sticks to the surface of the bar magnet .which of the following will be most appropriate :
   (A) stick uniformly throughout the surface of bar magnet
   (B)stick randomly on the surface of bar magnet
   (C) have maximum concentration at the two ends of bar magnet
   (D) have maximum concentration at the centre of the bar magnet
2. A bar magnet is cut into two equal halves by a plane parallel to the magnetic axis. Of the following physical quantities, the one which remains unchanged is:
   (A) Pole strength
   (B) magnetic moment
   (C) Intensity of magnetisation
   (D) none of these
3. A bar magnet of length 3 cm has points A and B along its axis at a distance of 24 cm and 48 cm on the opposite sides. The ratio of magnetic fields at these points will be**:**
   (A) 8 (B) $\frac{1}{2\sqrt{2}}$ (C) 3 (D) 4
4. A bar magnet of magnetic moment M is cut in to two parts of equal length. The magnetic moment and pole strength m of either part is:
   (A) $\frac{M}{2}, \frac{m}{2}$ (B) M, $\frac{m}{2}$ (C) $\frac{M}{2}$,m (D) M,m
5. At a point on the equatorial line of a magnetic dipole:
   (A) potential varies as $\frac{1}{r^2}$ (B)potential is zero at all points on the equatorial line
   (C) Field varies r^3 (D) field is perpendicular to the axis of magnetic dipole

ASSERTION REASON QUESTIONS:

6. **Assertion**: The poles of magnet cannot be separated by breaking into two pieces. **Reason:** The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
   b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
   c) Assertion is correct but Reason is incorrect.
   d) Assertion and Reason are incorrect
7. **Assertion:** An arrangement of two equal and opposite magnetic poles separated by a small distance is called magnetic dipole.
   Reason: The direction of magnetic dipole moment is from north pole to south pole
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
c) Assertion is correct but Reason is incorrect.
d) Assertion and Reason are incorrect.

ANSWER KEY

MCQ: 1. **(C)** 2. **(C)** 3**. (A**) 4. **(C)** 5**. (B)**
ASSERTION REASON QUESTIONS: 6. **b)** 7. C**)**

2 Marks Questions

8. A closely wound solenoid of 800 turns and area of cross section 2.5×10^{-4} m^2 carries a current 3.0 A . Explain the sense in which the solenoid acts like a bar magnet.

ANSWER

A current carrying solenoid behaves as a bar magnet. A magnetic field develops along its axis. The magnetic moment associated with the solenoid M= n I A=0.6 J/T.

……………………………………………………………………………………

TOPICS: Torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative idea only), magnetic field lines

OBJECTIVE TYPE QUESTIONS (MCQ- Each carries 1 Mark)

1. A bar magnet is placed inside a uniform magnetic field. It experience:
   (A) a force and torque (B) a force but no torque
   (C) a torque but no force (D) neither force nor torque
2. The direction of magnetic field lines of a bar magnet is :
   (A) from south pole to north pole
   (B) From North Pole to South Pole
   (C) Across the bar magnet
   (D) from South Pole to North Pole inside the magnet and from North Pole to South Pole outside the magnet.
3. A bar magnet is held perpendicular to a uniform magnetic field. If the torque acting on the magnet to be reduced to be zero, by rotating it, the angle by which it is to be rotated is :
   (A) 30^0 (B) 60^0 (C) 45^0 (D) 90^0
4. Which of the following statements is not correct about magnetic field?
   (A) Magnetic lines of force do not cut each other
   (B) Inside the magnet, the lines go from south to North Pole and outside from north to South Pole
   (C) magnetic field lines do not form closed loop
   (D) tangent to the field lines give the direction of magnetic field
5. For protecting a sensitive equipment from external magnetic field, it should be :

(A) Surrounded with fine copper gauge
(B) placed inside aluminium can
(C) Placed inside an iron can
(D) keep inside a current carrying coil.

ASSERTION REASON QUESTIONS:

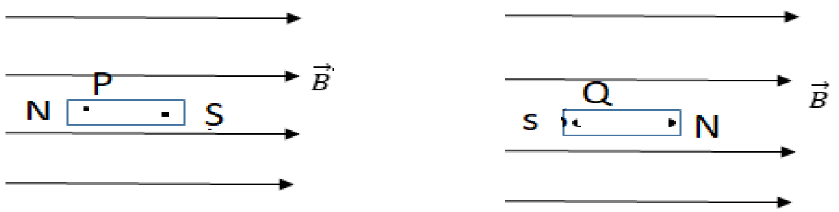
6. **Assertion**: unlike poles attract each other and like poles repel.
   Reason: The lines of force have a tendency to contract lengthwise and expand sidewise.
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
   b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
   c) Assertion is correct but Reason is incorrect.
   d) Assertion and Reason are incorrect.
7. **Assertion**: A freely suspended magnet always aligns in north-south direction.
   Reason: The earth has its own magnetic field which exerts a torque on the magnet tending to align it along the external field
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
   b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
   c) Assertion is correct but Reason is incorrect.
   d) Assertion and Reason are incorrect.

ANSWER KEY

MCQ: 1. **(C)** 2. **(D)** 3. **(D)** 4. **(C)** 5. **(C)**
ASSERTION REASON QUESTIONS: 6. **a)** 7. **a)**

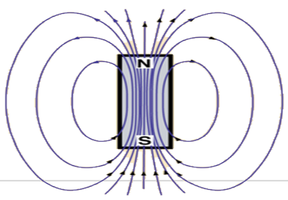
2 Marks Questions

8. Distinguish between electric and magnetic field lines. Sketch the field lines of a bar magnet.
9. Two identical bar magnets P and Q are placed in two identical uniform magnetic as shown in fig. Justify that both the magnets are in equilibrium. Which one of this is in stable equilibrium? Give reason for your answer



ANSWER:
Q.8
a) Electric field lines do not form closed loop. Magnetic field lines form closed loop.
b) Electric field lines emanate from positive charge and terminate at negative charge. Inside the magnet, the magnetic lines go from south to north pole and outside from north to south pole.

Magnetic field lines of a bar magnet:

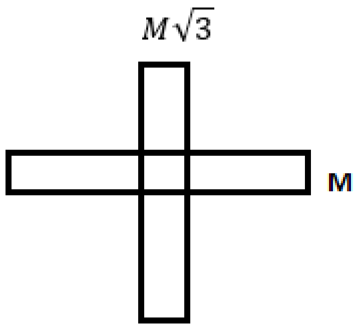


Q.9

$\tau = m\,B\sin\theta$. In both cases torque acting is zero.in case of Q dipole moment is along the direction of magnet field. Hence the potential energy is minimum = -mB, is in stable equilibrium. In case of P dipole moment is opposite to the direction of magnetic field. Hence potential energy is maximum = + mB. Hence in unstable equilibrium

3 Marks Questions

10. A short bar magnet placed with its axis at 30º with a uniform external magnetic field of 0.50T experiences a torque of magnitude equal to $9.0\text{x}10^{-2}$ J. What is the magnetic moment of the magnet?
11. Two magnets of magnetic moments M and M√3 are joined to form a cross. The combination is suspended in a uniform magnetic field B. The magnetic moment M now makes an angle θ with the field direction. Find the value of angle θ.



ANSWERS:

Q.10. m=τ/Bsinθ =9.0x10-2 /0.5xsin30 =0.36J/T)

Q11. (ans) In the position of equilibrium (ans. MBsinθ= √3 MBsin(90-θ) =√3 MBcosθ)

5 Marks Questions

12. Derive an expression for the torque experienced by a magnetic dipole in a uniform magnetic field. Hence obtain the expression for potential energy of the dipole.

ANSWER:

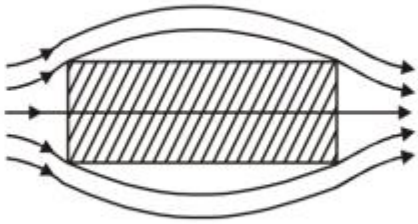
Q.12. Derive $\tau = m\,B\sin\theta$ & $U = mB\,(\cos\theta_1 - \cos\theta_2)$

Topics: Magnetic properties of materials-para-dia-and ferro magnetic substance with examples, magnetisation of materials effect on temperature on magnetic properties

1. The domain formation is a necessary feature of
   (A) Diamagnetism (B) Para magnetism
   (C) Ferromagnetism (D) all of these
2. All magnetic materials loss their magnetic properties when :
   (A) Dipped in water (B) dipped in oil
   (C) Brought near a piece of iron (D) strongly heated
3. Relative permittivity and permeability of a material are ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material?

   (A) ε_r=1.5, μ_r=0.5 (B) ε_r=0.5, μ_r=0.5 (C) ε_r=1.5, μ_r=1.5 (D) ε_r=0.5, μ_r=1.5

4. Consider the given statements with respect to the figure showing a bar of diamagnetic material placed in an external magnetic field.



I. The field lines are repelled or expelled and the field inside the material is reduced.

II. When placed in a non–uniform magnetic field, the bar will tend to move from high to low field.

III. Reduction in the field inside the material is slight, being one part in 10^5. Which of the above statements are correct?

(A) I and II (B) I and III

(C II and III **(**D) I, II and II

5. Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet when brought close to them will
   (A) attract N1 and N2 strongly but repel N3
   (B) attract N1 strongly, N2 weakly and repel N3 weakly
   (C) attract N1 strongly, but repel N2 and N3 weakly
   (D) attract all three of them

ASSERTION REASON QUESTIONS

6. **Assertion:** A paramagnetic sample display greater magnetisation (for the same magnetic field) when cooled.
   Reason: The magnetisation does not depend on temperature.
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
   b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
   c) Assertion is correct but Reason is incorrect.
   d) Assertion and Reason are incorrect.
7. **Assertion**: Diamagnetic materials can exhibit magnetism.
   Reason: Diamagnetic materials have permanent magnetic dipole moment.
   a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
   b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
   c) Assertion is correct but Reason is incorrect.
   d) Assertion and Reason are incorrect

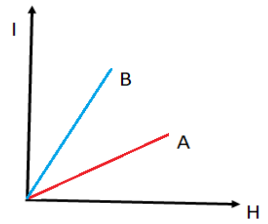
ANSWER KEY

MCQ: 1. **(C)** 2. **(D)** 3**. (A**) 4. **(D)** 5**. (B)**

ASSERTION REASON QUESTIONS: 6. (C**)** 7.**C)**

2 marks Questions:

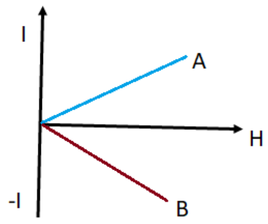
8. The following figure shows the variation of intensity of magnetization versus the applied magnetic field intensity, H, for two magnetic materials A and B.



(a) Identify the materials A and B

(b) For the material A, plot the variation of intensity of magnetisation versus temperature.

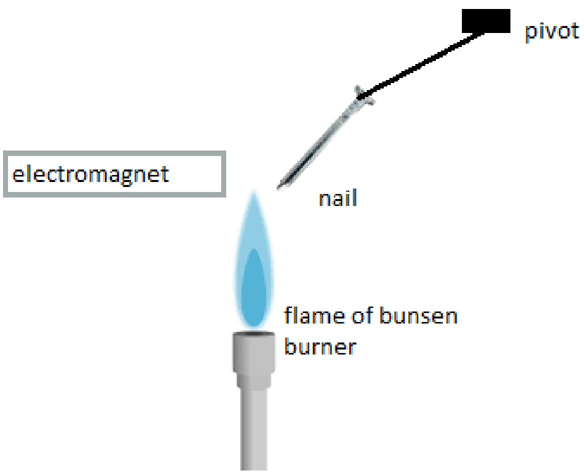
9. The following figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B.



a) Identify the material A and B

b) Draw the variation of susceptibility with temperature for B.

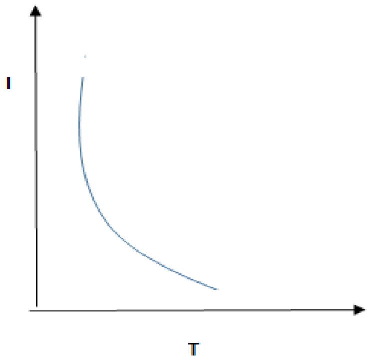
10. A small thin iron nail is suspended from a light fire proof thread. A strong electromagnet is placed near the nail and a flame from a gas burner is placed between the nail and the electromagnet as in fig.



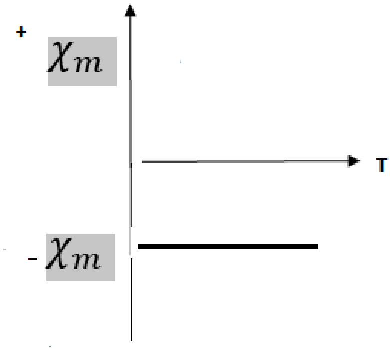
The flame engulfs the nail, when it is attracted by the magnet. As the current through the solenoid of the electromagnet is switched on, the nail will be at once deflected in to the flame and will then get out of the flame to assume its original position. After a lapse of time, the nail will again draw to magnet. Explain, what causes the periodic oscillations.

ANSWERS:

Q.8 The slop of the graph gives susceptibility of the material. Material A is paramagnetic and material B is ferromagnetic.



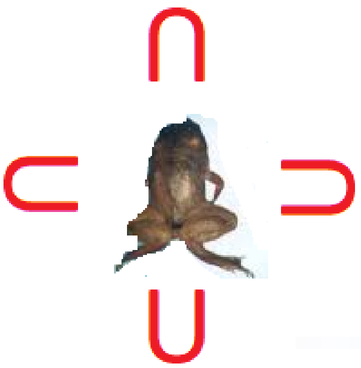
Q.9 . For material A, the susceptibility is small and positive, so it is paramagnetic. For material B the susceptibility is small and negative, so it is diamagnetic.



Q.10. On heating the iron nail loses its ferromagnetism. As a result the interaction between the nail and the electromagnet decreases and it returns to its original position. When the nail cools it regains its ferromagnetism and again gets attracted toward the magnet and is drawn in to the flame. This process repeats and the nail undergoes oscillation.

Case study Questions (4 Marks)

11. A frog can be levitated in a magnetic field produced by a current in a vertical solenoid placed below the frog. C.Maan, a physicist at the University of Nijmegen in the Netherlands. So he and colleagues employed a very strong magnet (chiefly used for crystallography experiments) to float the frog. It took 16 teslas--a very powerful field indeed--to lift the confused amphibian off the ground. Also levitating trains like those in Japan can fly over the tracks.



Choose the correct options for the following questions

I. The frog levitated in the magnet field indicates that, the body of frog behaves as:
(A) Paramagnetic (B) dia magnetic (C) ferromagnetic (D) antiferromagnetic

II. Universal property among all substance is :
(A) diamagnetism (B) paramagnetism
(C) Ferromagnetism (D) non-magnetism

III. In which type of material magnetic susceptibility does not depend on temperature.
(A) Dia magnetic (B) paramagnetic (C) ferromagnetic (D) ferrite

IV. Hysteresis is exhibited by a -------substance.
(A) paramagnetic (B)ferromagnetic (C)diamagnetic (D) all of the above

12. There exists a perfect diamagnetic, namely, a superconductor. This is a metal at very low temperatures. In this case $\chi = -1$, $\mu r = 0$, $\mu = 0$. The external magnetic field is totally expelled. Interestingly, this material is also a perfect conductor. However, there exists no classical theory which ties these two properties together. A quantum-mechanical theory by Bardeen, Cooper, and Schrieffer (BCS theory) explains these effects. The BCS theory was proposed in1957 and was eventually recognised by a Nobel Prize in physics in 1970.

I. The value of magnetic susceptibility for a superconductor is
(A) Zero (B) Infinity (C) +1 (D) -1

II. Superconductors are:
(A) Insulators (B) Semiconductors (C) Conductors (D) Perfect conductors.

III. Resistance of a superconductor is
(A) Infinite (B) Zero (C) Maximum (D) Minimum

IV. Which of the following is a property of superconductors?
(A) Meissner Effect (B) Hall Effect (C) Photoelectric effect (D) Doppler effect

ANSWERS

Q.11 case study: I. **B)** II. **A)** III**. A)** IV**.B)**

Q.12. case study I. **D)** II**. D)** III**. B)** IV**.A)**

SELF-ASSESSMENT TEST

1. An electromagnet is made of a coil of wire with an iron core in the centre of the coil. When there is an electric current in the wire, the electromagnet becomes magnetised. State the effect on the magnetic field of each of the following

(a) increasing the current (b) removing the iron core (c) switching off the current.

2. A permanent magnet:

(a) Attract all substances (b) attract only ferromagnetic substances (c) attract ferromagnetic substance and repel all others (d) attract some substances and repel others

(1)

3. The susceptibly of a magnetic material is 1.9 x10 $^{-5}$. Name the type of magnetic material it represents

(1)

4. Depict the behaviour of magnet field lines in the presence of a

(i) Diamagnetic (ii) ferromagnetic material

(2)

5. A uniform conducting wire of length 12 a and resistance R is wound up as a current carrying coil in the shape of equilateral triangle of side a. Find the magnetic moment of the coil.

(3)

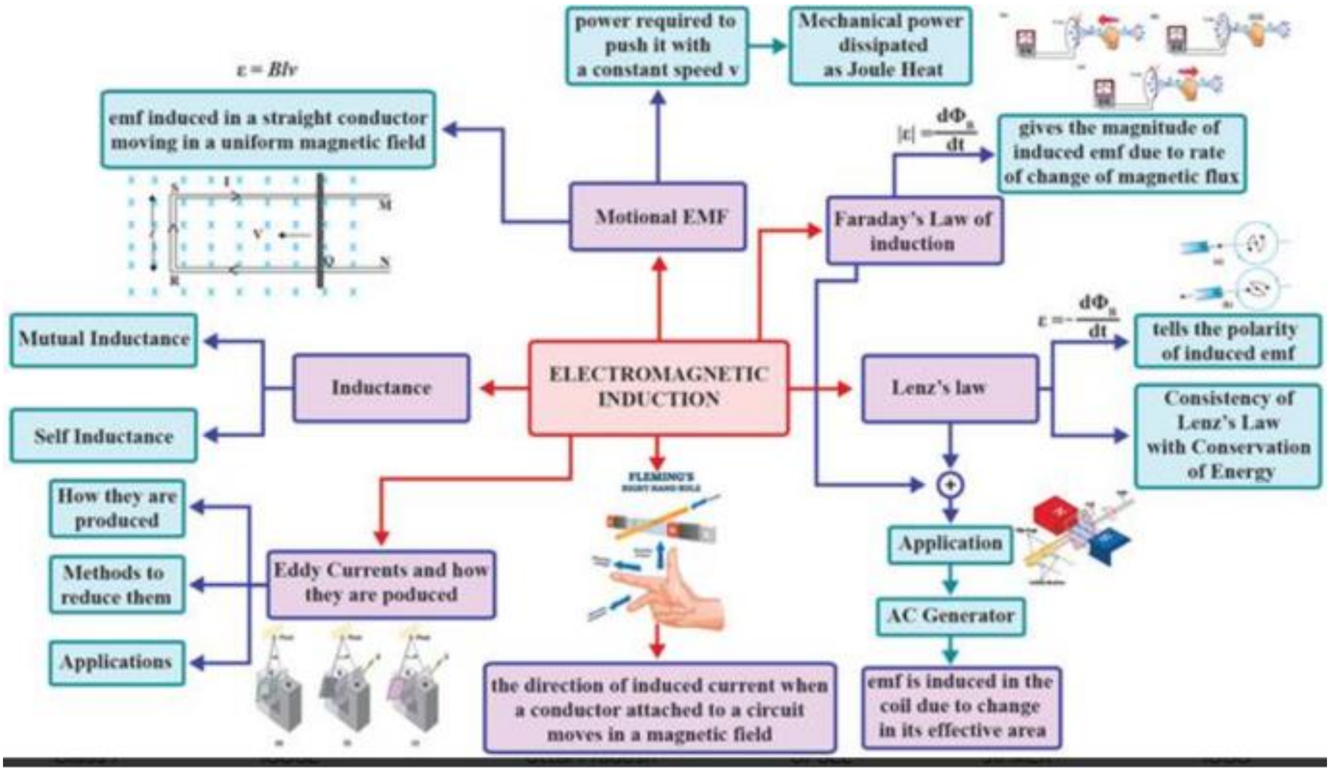
6. Explain the following :
   a. Why do magnetic lines of force form closed loops
   b. Why are the field lines repelled when a diamagnetic material placed in an external uniform magnetic field?
   c. Magnetic field lines do not cross each other

   (3)

7. Derive the expression for magnetic field line at the axial point of a magnetic dipole (5)

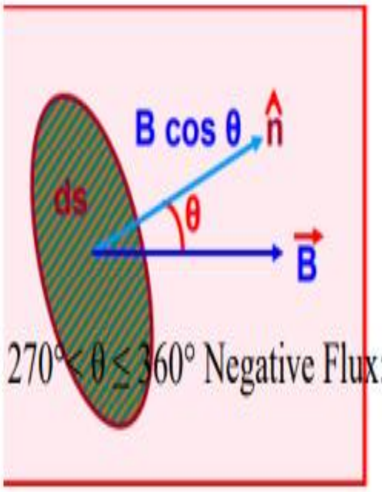
CHAPTER 6

ELECTROMAGNETIC INDUCTION



Magnetic Flux (Φ): Magnetic Flux through any surface is the number of magnetic lines of force passing normally through that surface.

It can also be defined as the product of the area of the surface and the component of the magnetic field normal to that surface.



$d\Phi = \mathbf{B} \cdot \mathbf{ds} = B\, d s\, n$

$\Phi = \mathbf{B} \cdot \mathbf{A} = B\, A\, n$ or $\Phi = B\ A \cos\theta$

Positive Flux: Magnetic Flux is positive for $0° \le \theta < 90°$ & $270° < \theta \le 360°$ Negative Flux: Magnetic Flux is negative for $90° < \theta < 270$

Magnetic Flux is zero for $\theta = 90°$ & $\theta = 270°$ Flux is maximum when $\theta = 0°$ and $\Phi = BA$

Magnetic Flux across a coil can be changed by changing :

1) the strength of the magnetic field B
2) the area of cross section of the coil A
3) the orientation of the coil with magnetic field θ or
4) any of the combination of the above

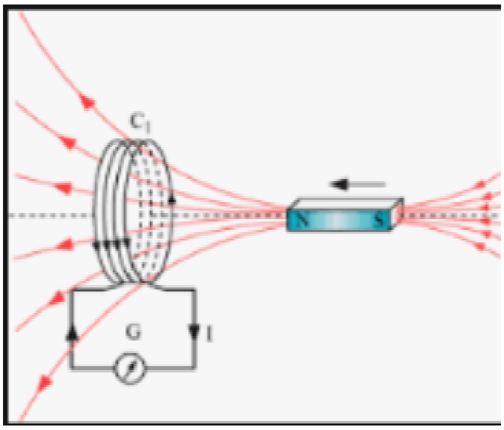
Magnetic flux is a scalar quantity.

* SI unit of magnetic flux is weber or tesla-metre^2 or (wb or Tm^2).

* cgs unit of magnetic flux is maxwell.

* 1 maxwell = 10^{-8} weber

Faraday's Experiment - 1:



If North-pole of a bar magnet is pushed towards the coil, the pointer in the galvanometer deflects, indicating the presence of electric current in the coil. This deflection lasts as long as the bar magnet remains in motion.

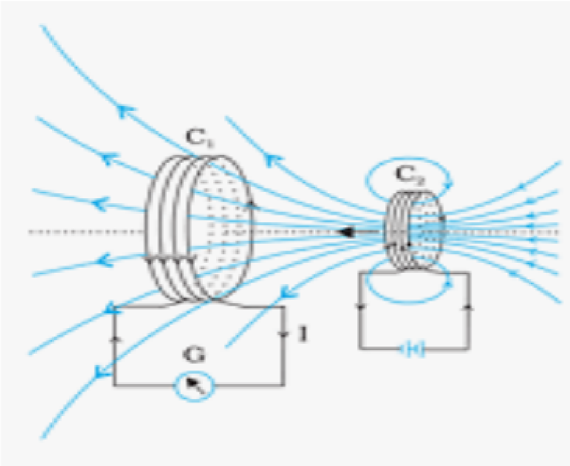
The galvanometer doesn't show any deflection when the magnet is held at rest.

When the magnet is pulled away from the coil, the galvanometer shows deflection in the opposite direction, which indicates reversal of the current's direction.

This shows that the relative motion between the magnet and the coil is responsible for generation (induction) of electric current in the coil.

Faraday's Experiment - 2:

If the bar magnet is replaced by a second coil C2 (as shown in figure given above) connected to a battery. The steady current in the coil C2 produces a steady magnetic field.

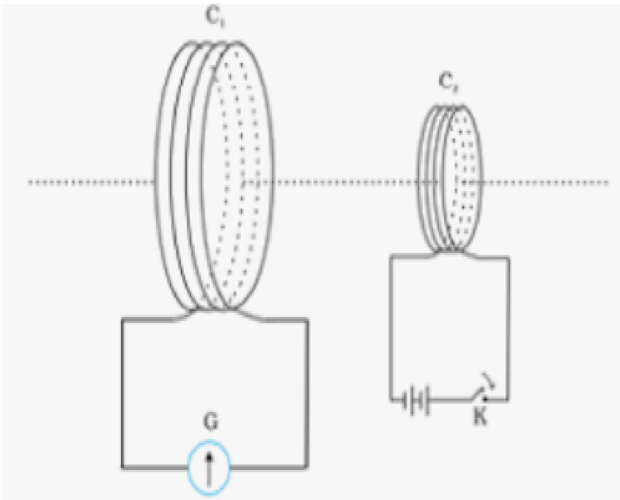


If coil C2 is moved towards the coil C1, then the galvanometer shows a deflection. This indicates that electric current is induced in coil C1.

When C2 is moved away, the galvanometer shows a deflection again, but this time in the opposite directio The deflection will be observed as long as coil C2 is in motion.

Faraday's Experiment - 3:

When the coil C2 is held fixed and C1 is moved, the same effects are observed. Again, it is the relative motion between the coils that induces the electric current. The galvanometer shows a momentary deflection when the tapping key K is pressed. The pointer in the galvanometer returns to zero immediately. If the key is held pressed continuously, there is no deflection in the galvanometer.



When the key is released, a momentary deflection is observed again, but in the opposite direction. It is also observed that the deflection increases when an iron rod is inserted into the coils along their axis.

Faraday's Laws of Electromagnetic Induction:

I Law: Whenever there is a change in the magnetic flux linked with a circuit, an emf and hence a current is induced in the circuit. However, it lasts only so long as the magnetic flux is changing.

II Law: The magnitude of the induced emf is directly proportional to the rate of change of magnetic flux linked with a circuit.

$E \alpha \, d\Phi / dt$

$E = k \, d\Phi / dt$ (where k is a constant and units are chosen such that k = 1)

$E = d\Phi / dt$

$E = (\Phi 2 - \Phi 1) / t$

Lenz's Law: The direction of the induced emf or induced current is such that it opposes the change that is producing it.

i.e. If the current is induced due to motion of the magnet, then the induced current in the coil sets itself to stop the motion of the magnet. If the current is induced due to change in current in the primary coil, then induced current is such that it tends to stop the change.

Lenz's Law and Law of Conservation of Energy:

According to Lenz's law, the induced emf opposes the change that produces it. It is this opposition against which we perform mechanical work in causing the change in magnetic flux. Therefore, mechanical energy is converted into electrical energy. Thus, Lenz's law is in accordance with the law of conservation of energy.

Expression for Induced emf based on both the laws:

$E = - d\Phi / dt$

$E = - (\Phi_2 - \Phi_1) / t$

Methods of producing Induced emf:

1. **By changing Magnetic Field B**: Magnetic flux Φ can be changed by changing the magnetic field B and hence emf can be induced in the circuit (as done in Faraday's Experiments).
2. **By changing the area of the coil A available in Magnetic Field**(MOTIONAL EMF)

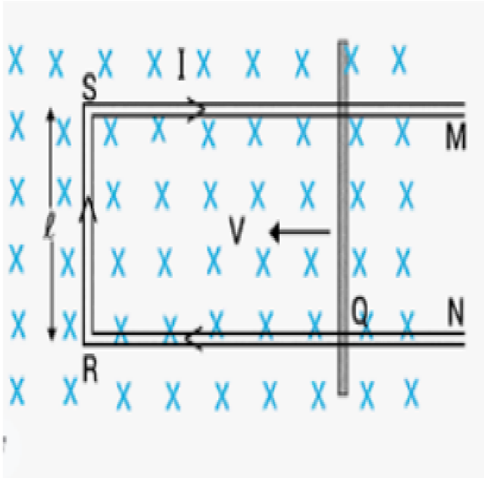
   Magnetic flux Φ can be changed by changing the area of the loop A which is acted upon by the magnetic field B and hence emf can be induced in the circuit.

   (A=Lx is the area of the loop)

   $E = - d\Phi / dt$

   $E = - \frac{d(BLx)}{dt}$

   $d\Phi = B.A = BA\ COS0 = BA = BL\ x$

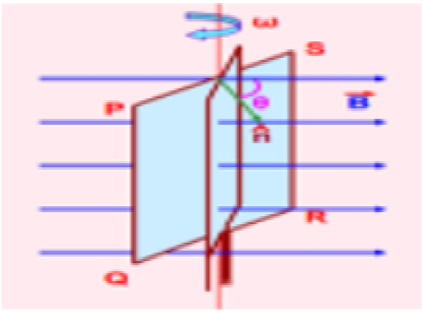


$= - B\,L\,\frac{dx}{dt} = BLv \quad$ where $v = -\frac{dx}{dt}$

The induced emf is due to motion of the loop and so it is called 'motional emf'.
The direction of induced current is clockwise in the loop by Fleming's Right Hand Rule or Lenz's Rule.

Fleming's Right Hand Rule: If the central finger, fore finger and thumb of right hand are stretched mutually perpendicular to each other and the fore finger points to magnetic field, thumb points in the direction of motion (force), then central finger points to the direction of induced current in the conductor.

3. **By changing the orientation of the coil (θ) in Magnetic Field**:
Magnetic flux Φ can be changed by changing the relative orientation of the loop (θ) with the magnetic field B and hence emf can be induced in the circuit.
$\Phi = N B A \cos\theta$
At time t, with angular velocity ω, $\theta = \omega t$
(at $t = 0$, loop is assumed to be perpendicular to the magnetic field and $\theta = 0°$)
$\Phi = N B A \cos \omega t$
Differentiating w.r.t. t,
$d\Phi / dt = - NBA\, \omega \sin \omega t$
$E = - d\Phi / dt$
$E = NBA\, \omega \sin \omega t$



$E = E_0 \sin \omega t$ (where $E_0 = NBA\, \omega$ is the maximum emf)

Self Induction: Self Induction is the phenomenon by which any growth or decay of current in the coil is opposed by the production of self induced emf (back emf) due to change in current and hence the change in magnetic flux in the coil.
The induced emf opposes the growth or decay of current in the coil and hence delays the current to acquire the maximum value.
Self induction is also called inertia of electricity as it opposes the growth or decay of current.

Factors on which Self Inductance depends

Self-inductance of the coil depends on its geometry and on the permeability of the medium. The self-induced emf is also called the back emf as it opposes any change in the current in a circuit

Energy stored in Inductor:

Small work done dW in establishing a current I in the coil in time dt is

$dW = - EI\,dt$

$dW = LI\,dI$

(since $E = -L\,(dI / dt)$)

$W = \int L\,I\,dI = \frac{1}{2} L I_0^2$

Mutual Induction:

Mutual Induction is the phenomenon of inducing emf in the secondary coil due to change in current in the primary coil and hence the change in magnetic flux in the secondary coil.

Self Inductance:

$\Phi \propto I$ or $\Phi = LI$

If $I = 1$, then $L = \Phi$ (where L is the constant of proportionality and is known as Self Inductance or co-efficient of self induction)

Thus, self inductance is defined as the magnetic flux linked with a coil when unit current flows through it.

Also, $E = - d\Phi / dt$ or

$E = - L\,(dI / dt)$

If $dI / dt = 1$, then $L = E$

Thus, self inductance is defined as the induced emf set up in the coil through which the rate of change of current is unity.

SI unit of self inductance is henry (H).

Self inductance is said to be 1 henry when 1 A current in a coil links magnetic flux of 1 weber.

or

Self inductance is said to be 1 henry when unit rate of change of current (1 A / s) induces emf of 1 volt in the coil.

Inductance is a scalar quantity. It has the dimensions of $[M L^2 T^{-2} A^{-2}]$

Self inductance of a solenoid:

Magnetic Field due to the solenoid is $B = \mu_0 nI$

Magnetic Flux linked across one turn of the coil is

$\Phi = BA = \mu_0 nIA = \frac{\mu_0 NIA}{l}$ $\qquad (n = \frac{N}{l})$

Magnetic Flux linked across N turns of the coil is

$N\Phi = \frac{\mu_0 N \times N IA}{l} = \frac{\mu_0 N^2 IA}{l}$ ……(1)

But, $N\Phi = LI$ …… (2)

So,

$$L = \frac{\mu_0 N^2 A}{l}$$

Note: If we fill the inside of the solenoid with a material of relative permeability μ_r (for example soft iron, which has a high value of relative permiability),

$\Phi_{21} \propto I_1$ or $\Phi_{21} = M_{21} I_1$

If $I_1 = 1$, then $M_{21} = \Phi_{21}$ (where M_{21} is the constant of proportionality and is known as Mutual Inductance or co-efficient of mutual induction)

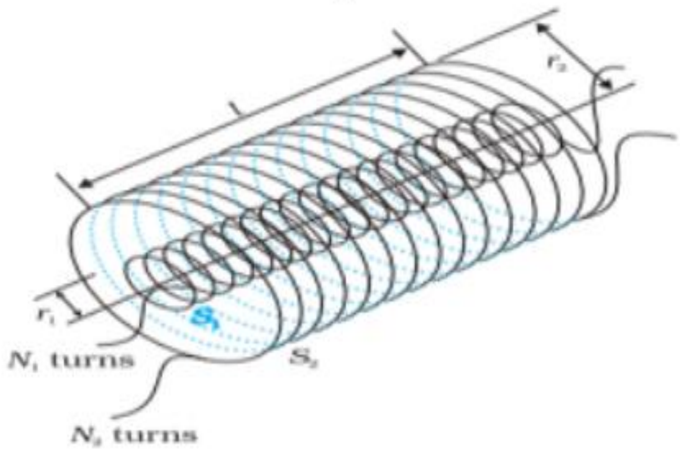
Thus, **mutual inductance** is defined as the magnetic flux linked with the secondary coil when unit current flows through the primary coil.

Thus, **mututal inductance** is defined as the induced emf set up in the secondary coil when the rate of change of current in primary coil is unity.

SI unit of mututal inductance is henry (H). Mutual inductance is said to be 1 henry when 1 A current in the primary coil links magnetic flux of 1 weber across the secondary coil.

or Mutual inductance is said to be 1 henry when unit rate of change of current (1 A / s) in primary coil induces emf of 1 volt in the secondary coil.

Mutual inductance of two long co-axial solenoids:



Magnetic Field due to primary solenoid is

$\mathbf{B_1 = \mu_0 n_1 I_1}$

Magnetic Flux linked across one turn of the secondary solenoid is

Φ_{21} per turn $= B_1 A = \mu_0 n_1 I_1 A = \mu_0 N_1 I_1 / L$ | (where $n_1 = N_1/L$)

Magnetic Flux linked across N_2 turns of the secondary solenoid is

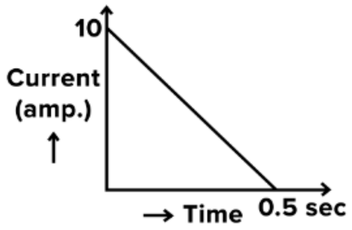
$N_2 \Phi_{21} = \mu_0 N_1 N_2 I_1 A / L$

But, $N_2 \Phi_{21} = M_{21} I_1$

$\mathbf{M_{21} = \mu_0 N_1 N_2 A / L = \mu_0 n_1 n_2 A L}$

<u>MULTIPLE CHOICE QUESTIONS</u> (15X1=15 marks)

1. A small circular loop of wire is placed inside a long solenoid carrying a current. The plane of the loop contains the axis of the solenoid. If the current in the solenoid is varied, the current induced in the loop is
   (a) Anticlockwise
   (b) Clockwise
   (c) Zero
   (d) Direction depends on the resistance
2. A conducting circular loop is placed in a uniform magnetic field 0.04T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm is
   (a) $3.2\pi\mu V$
   (b) $4.8\pi\mu V$
   (c) $0.8\pi\ \mu V$
   (d) $1.6\pi\mu V$
3. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\Phi$ in time Δt. The quantity of charge which passes through this time is
   (a) $Q = \Delta\Phi/\Delta t$
   (b) $Q = -(\Delta\Phi/\Delta t)$
   (c) $Q = \{-\Delta\Phi/\Delta t\} R$
   (d) $Q = \Delta\Phi/R$
4. In a coil of resistance 100Ω a current is induced by changing the magnetic flux through it. The variation of current with time is as shown in figure. The magnitude of change in flux through the coil is

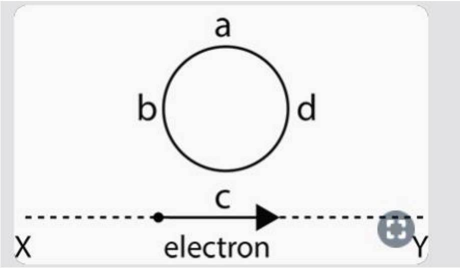


   (a) 200 weber
   (b) 275 weber

(c) 225 weber

(d) 250 weber

5. A Cylindrical bar magnet is kept along the axis of a Circular coil. If the magnet is rotated about its axis, then,
   (a) A current will be induced in the coil
   (b) No current will be induced in the coil
   (c) Only an emf will be induced in the coil
   (d) An emf and a current both will be induced in the coil.
6. A magnet is brought towards a coil (i)Quickly (ii)slowly then the Induced emf and induced charge will be respectively
   (a) More in first case / More in first case
   (b) More in first case / Equal in both case
   (c) Less in first case / More in second case
   (d) Less in first case / Equal in both cases.
7. The flux linked with a circuit is given by $\mathbf{\Phi} = t^3 + 3t - 7$. The graph between time (x-axis) and induced emf (y-axis) will be
   (a) Straight line through the origin.
   (b) Straight line with positive slope and positive intercept.
   (c) Parabola through the origin
   (d) Parabola not through the origin
8. A long conductor AB lies along the axis of a circular loop of radius R. If the current in the conductor AB varies at the rate of 1 A/s the induced emf in the loop is
   (a) $\frac{\mu_o I R}{2}$
   (b) $\frac{\mu_o I R}{4}$
   (c) $\frac{\mu_o \pi I R}{2}$
   (d) Zero
9. An electron is moving in a straight-line path XY as shown in figure. A coil placed adjacent to the path of the electron. What will be the direction of current, if any induced in the coil



(a) No current is induced

(b) Current is induced in the direction adcb

(c) Current is induced in the direction abcd

(d) Current will reverse direction as the electron goes past the coil

10. Two solenoids of equal number of turns have their lengths and radii in the same ratio 1:2. The ratio of their self-inductances will be

    (a) 1:2

    (b) 2:1

    (c) 1:1

    (d) 1:4

11. A coil and a bulb are connected in series with a d.c source, a soft iron is then inserted in the coil. Then

    (a) Intensity of the bulb decreases

    (b) Intensity of the bulb increases

    (c) Intensity remains the same

    (d) The bulb ceases to glow.

12. Two Similar Circular loops carry equal currents in the same direction. On moving the coils further apart, the electric current will

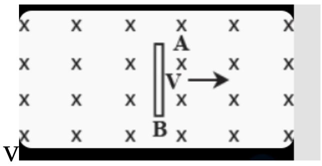
    (a) Remain unaltered

    (b) Increases in one decreases in the second

    (c) Increase in both

(d) Decrease in both

13. A conducting rod AB moves with a uniform velocity V in a constant magnetic field as shown in figure.



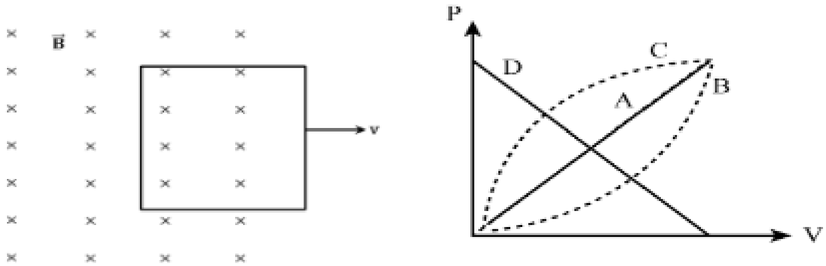
(a) The rod becomes hot because of Joule heating

(b) The end A becomes positively charged

(c) The end B becomes positively charged

(d) The rod becomes electrically charged

14. Figure shows a conducting loop pulled out of a magnetic field with constant speed which of the 4 plots shown in figure may represent the power delivered by the pulling agent as a function of constant speed V.



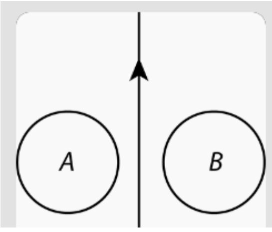
(a) A

(b) B

(c) C

(d) D

15. A and B are two metallic rings placed at opposite sides of an infinitely long straight conducting wire. If the current in the wire is slowly decreased, the direction of the induced current will be



(a) Clockwise in A anticlockwise in B

(b) Anticlockwise in A and clockwise in B

(c) Clockwise in both

(d) Anticlockwise in both

Assertion – Reason type questions_ (8x1=8 marks)

Read the statement marked as Assertion and Reason and mark the option out of the 5 given below.

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true and the reason is not the correct explanation of the assertion.

(c) If assertion is true and reason is false

(d) If assertion and reason are false

(e) If assertion is false but reason is true.

16. Assertion: Self-inductance is called the intertia of electricity.

Reason: Self-inductance is the phenomenon in which an opposing induced emf is produced in a coil as a result of change in current or magnetic flux linked with the coil.

17. Assertion: Two identical loops of copper and aluminium when rotated with same speed in the same magnetic field, the induced emf and current will be same in both.

    Reason: Induced emf is proportional to rate change of flux while induced current depends on resistance of the wire.

18. Assertion: A spark occurs between the poles of a switch when the switch is opened.

    Reason: Current flowing in the conductor produces magnetic field.

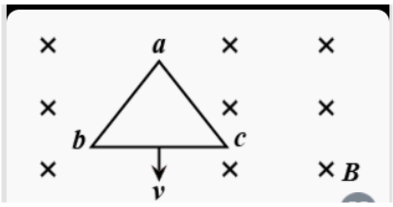
19. Assertion: A square loop is placed in x-y plane. Magnetic field is in the negative z direction. The induced current in the loop is anticlockwise.

    Reason: If inward magnetic field from such a loop increases, then current should be anticlockwise.

20. Assertion: Electric field produced by a variable magnetic field cannot exert a force on a charged particle.

    Reason: This electric field is non-conservative in nature.

21. Assertion: A conducting equilateral loop abc is moved with constant speed V in uniform inward magnetic field as shown in figure.Then $V_a - V_b = V_b - V_c$



    Reason: Point **a** is at a higher potential than **b**

22. Motional emf e = Blv is obtained from Faraday's law.

    Reason: Lenz's law is a consequence of law of conservation of energy

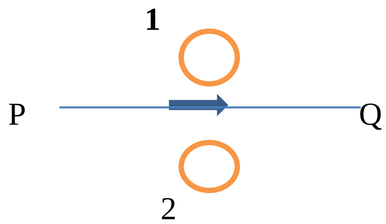
23. Assertion: If ferromagnetic substance is filled inside a solenoid coefficient of self induction L will increase.

    Reason: By increasing current in a coil its coefficient of self induction can be increased

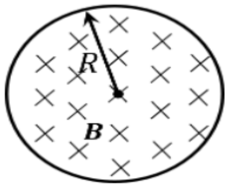
ANSWER KEY TO MCQ	
Q NO.	ANSWER
1	**c**
2	**a (d/dt(BA)= B dA/dt= B d/dt (πr^2)= 2πBr dr/dt)**
3	**D (dq=$\Delta\Phi$/R)**
4	**D (Hint: dq= area of triangle)**
5	**b**
6	**b**
7	**d**
8	**d**
9	**d**
10	**a**
11	**c**
12	**c**
13	**b**
14	**b**
15	**b**
	Answers (Assertion-Reason)
16	**b**
17	**e**
18	**b**
19	**d**
20	**a**
21	**e**
22	**b**
23	**c**

TWO MARK QUESTIONS

1. The current through the wire PQ is increasing. In which direction does the induced current flow in the closed loops 1 and 2. (2)

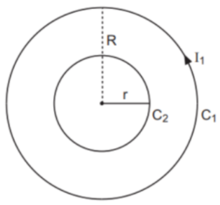


2. A cylindrical space of radius R is filled with a uniform magnetic induction B parallel to the axis of the cylinder. If B changes at a constant rate draw the graph showing the variation of induced electric field with distance ‘r’ from the axis of the cylinder. (2)



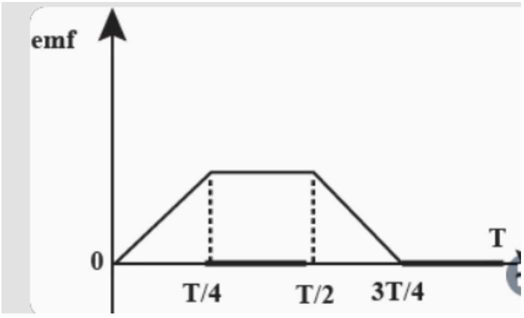
3. A rectangular loop and a circular loop are moving out of a magnetic field to a field free region with a constant velocity. It is given that the field is normal to the plane of both loops. Draw the expected shape of the graphs showing the variation of flux with time in both the cases. What is the cause of difference in shape of the two graphs. (2)

4. Two coplanar concentric circular loop of radius R are r(r<<R) are arranged co-axially. Obtain the expression for their mutual inductance (2)

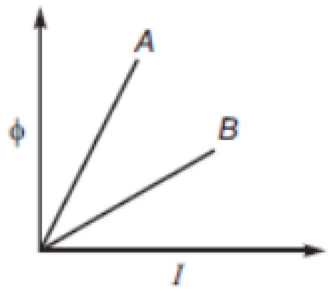


5. Variation of magnetic flux associated with a coil with time is shown below. Draw the corresponding graph shown variation of induced emf with time

(2)



6. Two inductors A and B shows variation of flux with current as shown in figure. Which of the two has larger value of self-inductance and why? (2)

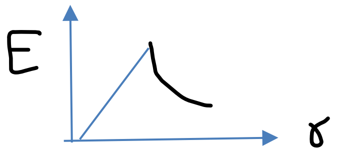


7. What is the magnetic flux through one turn of a solenoid of self-inductance?
8.0×10^{-5} H when a current of 3 A flows through it? Assume that the solenoid has 1000 turns and is wound from wire of diameter 1.0 mm (2)
8. A long solenoid with 20 turns per cm has a small loop area $4 cm^2$ placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 4A to 6A in 0.2 seconds, what is the average induced emf in the loop while the current is changing (2)

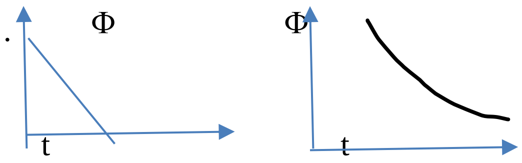
Answers to Questions from 1 to 6 (2 mark questions)

1. According Lenz's law in coil 1 -cloclwise, coil 2- anticlockwise

2.



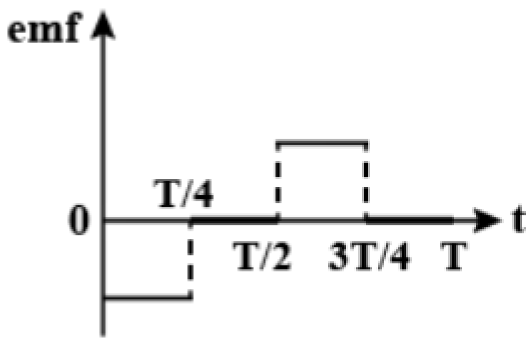
3.



difference in shape is due to rate of change of area

4. $M12 = \mu 0 \pi r^2 / 2R$

5.



6. A has more slope and hence more self inductance

7. N Φ= Li On substitution $\Phi = 2.4 X 10^{-7}$ Wb

$\Phi = BA = \mu 0 ni\ A$

n =N/l l=N x diameter

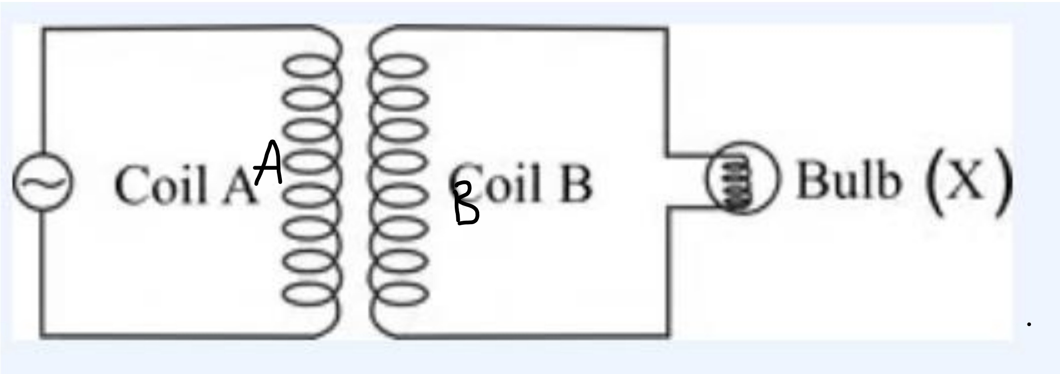
On substitution and rearrangement $A = \Phi d / \mu 0 i = 6.3 x 10^{-5} m^2$

8. $e = \mu 0 nAdI/dt = 50.24 x 10^{-5}$ V

THREE MARK QUESTIONS

9. The magnetic flux through a coil perpendicular to the plane is varying according to the relation $\Phi = (5t^3+4t^2+2t-5)$ weber .Find the current through the coil at t= 2 seconds if the resistance of the coil is 5Ω (3)

10. Figures shows an arrangement by which alternatively current flows through coil A and B is placed near A and connected to a bulb X. Now explain the observations with reason (3)

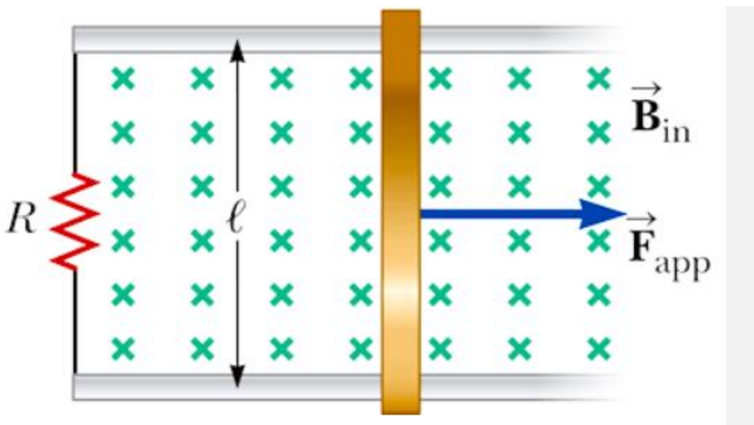


(i) When the switch S is closed the bulb lights up. Why?

(ii) What happens to the brightness if an iron rod is in coil A.

(iii) What happens to the brightness if a copper plate is inserted in the gap between the coils?

11. Figure shows the top view of a rod that can slide without friction. The resistor is 6.0hm and a 2.5 T magnetic field is directed perpendicularly downward into the paper. (Given length = 1.2 m) (3)

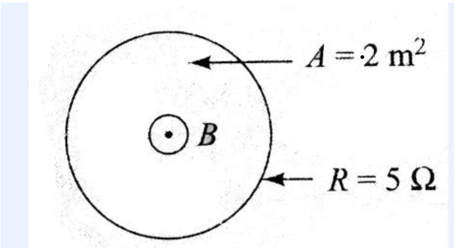


(a) Calculate current in the circuit if rod is moving with 2 m/s

(b) Magnitude of force to move the rod at a constant speed of 2m/s

(c) Rate at which energy is delivered to the resistor

12. Figure shows a coil placed in a decreasing magnetic field applied perpendicular to the plane of the coil.The magnetic field is decreasing at the rate 10T /s. Find out current in magnitude and direction (3)



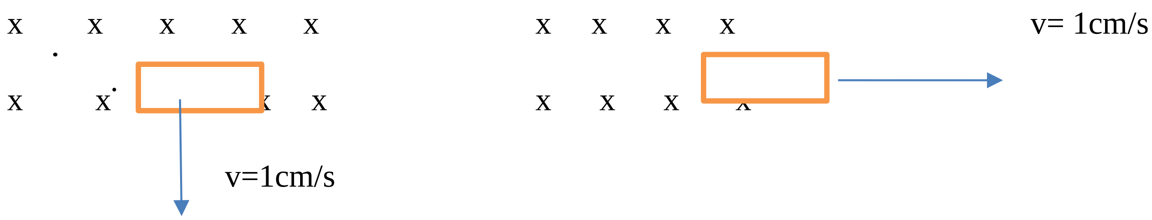
13. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of 0.3 T directed normal to the loop.

(i) What is the emf developed across the cut if the velocity of the loop is 1 cms^{-1} in a direction normal to the

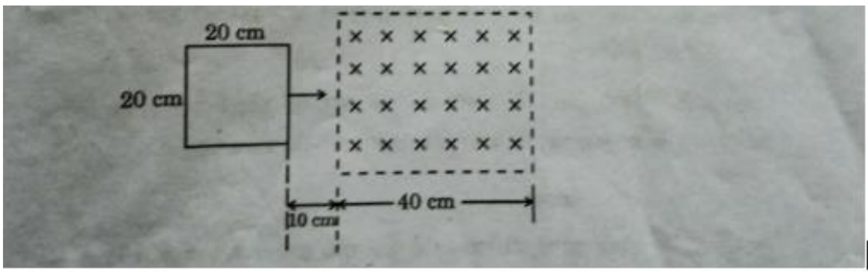
(a) Longer side

(b) Shorter side of the loop?

(ii)For how long does the induced voltage last in each case. (3)



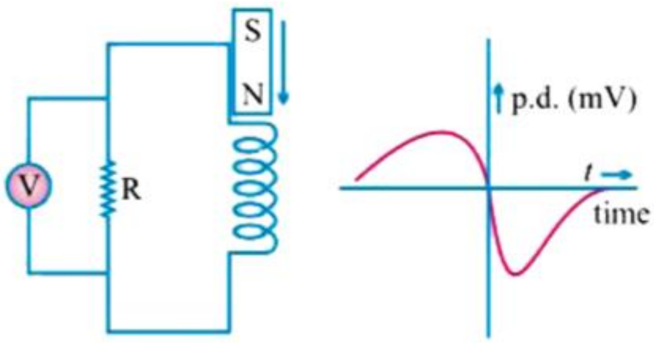
14. A square loop of side 20cm starts moving at t=0 with a velocity of 10cm/s towards a region of uniform magnetic field as shown in the figure. Specify the time intervals during the which the induced emf is produced in the loop (3)



15. A bar magnet is dropped vertically through a coil. The graph obtained for variation of voltage produced in the coil vs time is shown in figure.

1. Explain the shape of the graph

2. Why is negative peak longer than the positive peak (3)



Answers to Q.no. 9 to Qno. 38(three-mark questions)

9. e=d Φ/dt= $15t^2+8t+2$

At t=2 seconds e=78 V

I = e/R = 15.6A

10. (i) Due to mutual induction (ii) Brightness decreases as the induced current decreases

(iii) Brightness decreases due to production of induced current set up in the copper plate which opposes passageof magnetic flux

11. e= Blv= 6V i= e/R= 1A

F=Bil = 3N

P= i^2 R = 6W

12. Φ=BA e= A dB/dt = 20V

I= e/R= 4A

13. (a) longer side

e = Blv = 2.4X 10^{-4} V

T=b/v= 2seconds

(b (shorter side

E = 0.6X 10^{-4} V

T= l/v = 8seconds

14. t= l/v

Induced emf exists, during time intervals,

Time = 10/5= 2 seconds to 30/5= 6 seconds during inward motion

Time= 50/5= 10 seconds to 14 seconds during motion out of magnetic field induced emf exists during time interval between 2seconds and 6 seconds and between 10 seconds and 14 seconds

15(a) As the bar magnet falls through the coil the magnetic flux linked with the coil increases so the induced emf also increases across the coil. Intially rate of increase in flux inceases then it becomes maximum, later on it decreases and becomes zero. When the magnet exits the coil the emf decreases as well as induced polarity reverses. The rate of decreases of emf increases initially becomes maximum and when the magnet is sufficiently far from the coil the flux becomes zero and induced emf becomes zero.

(b)The negative peak is longer than positive peak as the magnet moves faster than it moves into the coil.As it enters the coil the back emf of the coil resists the the fall of the magnet.However when it is inside the coil thereis no back emf to resist the fall Hence gravity pulls the magnet faster.

I CASE STUD BASED QUESTION

Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators. An inductor is a passive component that is used in most power electronic circuits to store energy in the form of magnetic energy when electricity is applied to it. When a current begins to flow through a coil of wire, it undergoes an opposition to its flow in addition to the resistance of the metal wire. On the other hand, when an electric circuit carrying a steady current and containing a coil is suddenly opened, the collapsing, and hence diminishing, magnetic field causes an induced electromotive force that tends to maintain the current and the magnetic field and may cause a spark between the contacts of the switch.

16. How to increase the energy stored in an inductor by four times?

(a) By doubling the current

(b) This is not possible

(c) By doubling the inductance

(d) By making current $\sqrt{2}$ times

17. Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?

(a) 9 times

(b) 3 times

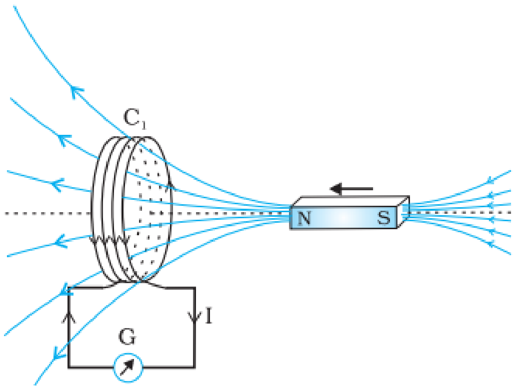
(c) 27 times

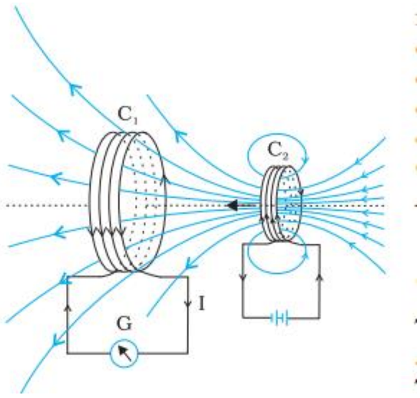
(d) 13 times

18. What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?
    (a) It depends on the diameter of the ring and the length of the magnet
    (b) It is equal to acceleration due to gravity
    (c) It is less than acceleration due to gravity
    (d) It is more than acceleration due to gravity

19. Which of the following statements is correct for a current carrying infinitely long wire kept along the diameter of a circular wire loop without touching it.
    (a) The emf induced in the loop is zero if the current is constant
    (b) The emf induced in the loop is finite if the current is constant
    (c) The emf induced in the loop is finite if the current decreases at a steady rate
    (d) The emf induced in the loop is finite if the current increases at a steady rate.

II CASE STUDY BASED QUESTION





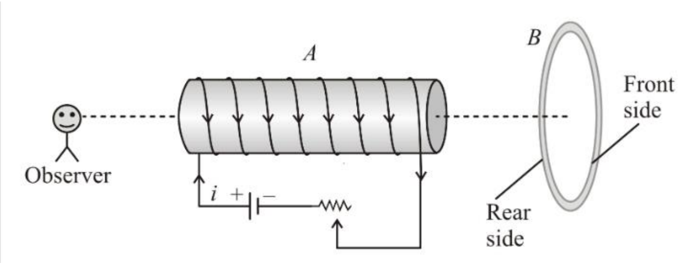
A coil C1 connected to a galvanometer G. When the North-pole of a bar magnet is pushed towards the coil, the pointer in the galvanometer deflects, indicating the presence of electric current in the coil. The deflection lasts as long as the bar magnet is in motion. The galvanometer does not show any deflection when the magnet is held stationary. When the magnet is pulled away from the coil, the galvanometer shows deflection in the opposite direction

In fig II the bar magnet is replaced by a second coil C2 connected to a battery. The steady current in the coil C2 produces a steady magnetic field. As coil C2 is moved towards the coil C1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C1. When C2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction.

The deflection lasts as long as coil C2 is in motion. When the coil C2 is held fixed and C1 is moved, the same effects are observed.

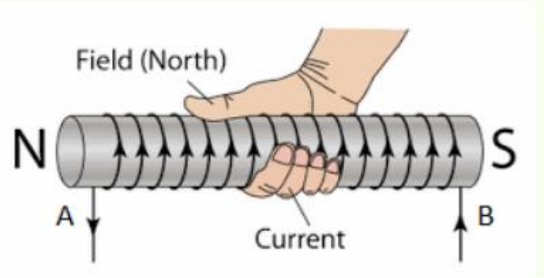
20. An iron rod is inserted in coil C1 .What change is observed in deflection of the galvanometer
    (a) Deflection increases due to increase in current
    (b) Deflection decreases due to increase of back emf
    (c) Deflection decreases due to decrease in induced current
    (d) Deflection increases due to increase in back emf
21. The current induced in the coil is given by $I= 3t^2 + 2t$ If the inductance of the coil is 10mH the value of induced emf at t=2 seconds will be
    (a) 0.14V
    (b) 0.12V
    (c) 0.11V
    (d) 0.13V

22. An aluminium ring B faces an electromagnet. If current through A is altered



(a) B will not experience any force
(b) If I decreases A will repel B
(c) If I increases A will attract B
(d) If I increases A will repel B

23. An insulated copper wire is wound on a soft iron core. Current is passed through the coil such that at end A the current flows anti-clockwise and a magnetic compass needle is placed at other end B of the coil.The magnetic compass will point towards



(a) With its North towards A

(b) With its South towards A
(c) With its North away from A
(d) Data insufficient

Answers to Case study-based questions	
Q NO	ANSWER
16	a
17	b
18	c
19	a
20	c
21	a
22	d
23	a

24. (a) State Faraday's Law of electromagnetic induction
(b) Give three possible ways of producing an induced emf in a coil.
(c) Deduce an expression induced emf in a coil of N turns each of area A rotated with a constant angular velocity w in a magnetic field

25. A metallic rod of length 'l' and resistance 'R' is rotated with a frequency ν with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius 'r' about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis present everywhere.
(i) Derive expression for induced emf and current in the rod
(ii) Find the expression for magnitude and direction of force acting on the rod
(iii) Obtain power required to rotate the rod

Answers to Long answer type questions of 5marks

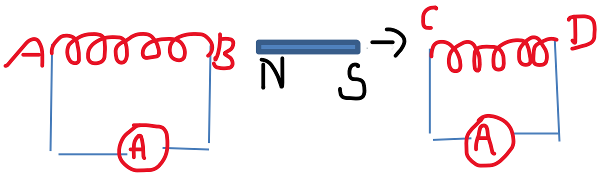
.24. (i) Statement of the law (ii) by changing area, by changing magnetic field, by changing the orientation of the coil with explanation (iii) $e= NBA\,\omega\,\sin\omega t$ (derivation)

25. (i) $e= \frac{1}{2} Bl^2 \omega$ $i= e/R = B l^2 \omega/2R$ (derivation)

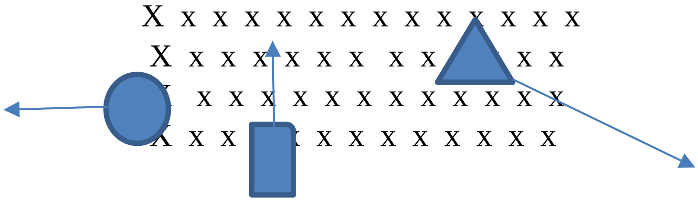
(ii) $P= EI= B^2 l^4 \omega^2 / 4R$ (derivation)

SELF EVALUATION TEST (MM:20)

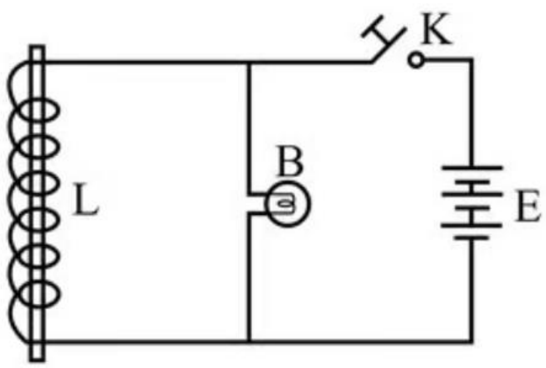
1. When is the magnetic flux crossing a given surface area held in a magnetic field maximum (1)
2. State Lenz's law On which conservation law it is based upon (1)
3. A metallic rod is held horizontally along east-west direction. When it is allowed to fall freely ,will an emf be induced across its ends.Give reason (1)
4. A magnet is moved in a direction as indicated between two coils AB and CD Suggest the direction of current in each coil (2)



5. Figure shows planar loops of different shapes moving out of or in to a region of magnetic field which is directed normal to the plane of the loop away from the reader Determine the direction of induced current using Lenz's law (3)



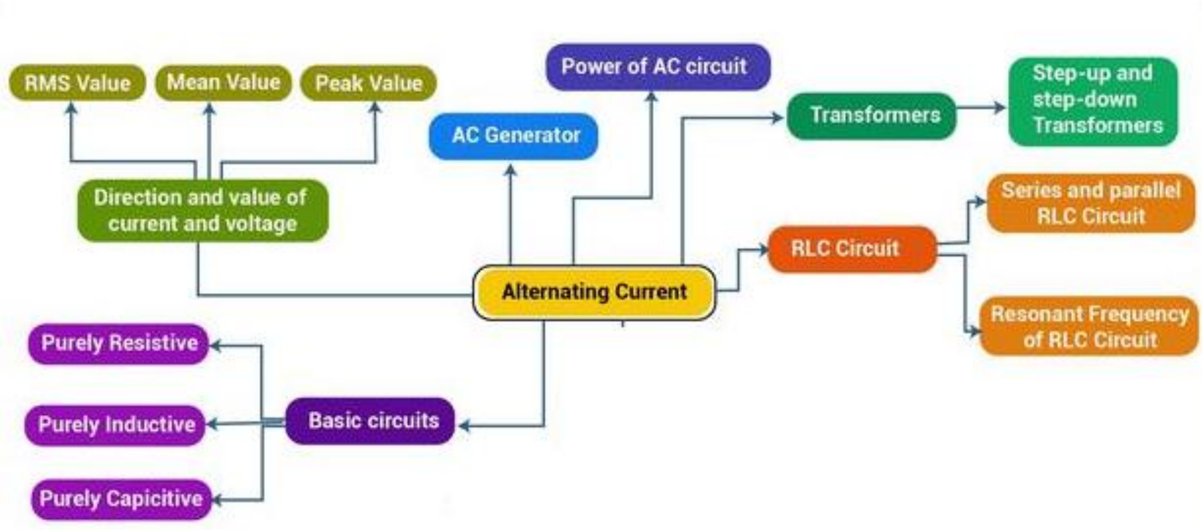
6. Define self inductance What is its SI unit Derive expression for self inductance of a long solenoid (3)
7. How does mutual inductance of apair of coils change when (i) the distance between the coils is increased (ii) the number of turns in each coil is increased (iii) a thin iron sheet is placed between the two coils (3)
8. Lenz's law is in accordance with law of conservation of energy Explain the statement with necessary diagrams (3)
9. A copper coil L is wound on a soft iron core and a lamp are connected to a battery through a tapping key. What observations can be recorded (i) when the key is closed (ii) Key is suddenly opened Explain (3)



CHAPTER 7

TOPIC: ALTERNATING CURRENT

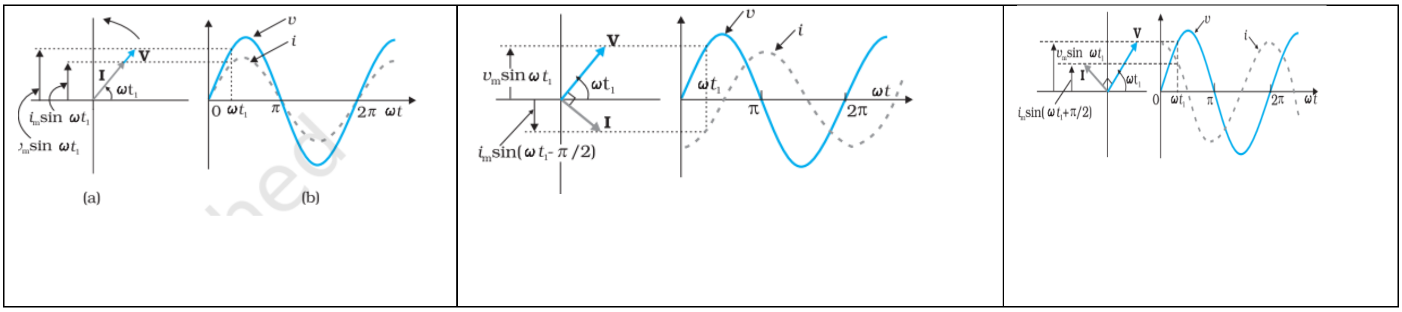
MIND MAP



GIST OF LESSON

- Alternating voltage and current and its mathematical formula.
  $V = V_0 \sin \omega t$
- Average value of alternating voltage and alternating current in a cycle is zero.
- Average value of alternating voltage and alternating current over a half cycle are $2V_0/\pi$ and $2I_0/\pi$.
- RMS value of alternating voltage is $V_{rms} = V_0 / \sqrt{2}$
- RMS value of alternating current is $I_{rms} = I_0 / \sqrt{2}$
- A C circuits

CONTAINIG **R** ONLY	CONTAINIG **L** ONLY	CONTAINIG **C** ONLY
$V = V_0 \sin \omega t$ $I = I_0 \sin \omega t$ V and I are in same phase Resistance R Average power = $V_{rms}I_{rms}$	$V = V_0 \sin \omega t$ $I = I_0 \sin (\omega t - \pi/2)$ Current lags behind the voltage by a phase of 90^0 Inductive reactance = $L\omega$ Average power = 0	$V = V_0 \sin \omega t$ $I = I_0 \sin (\omega t + \pi/2)$ Current leads the voltage by a phase of 90^0 Capacitive reactance = $1/C\omega$ Average power = 0



- For a series RLC circuit driven by voltage v = vm sin wt, the current is given by

  I = Im sin (ωt + Φ)

  Where Im = Vm / Z, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

  tan Φ= (X_L- X_C) / R

  The average power loss over a complete cycle is given by

  P = V I cos Φ

  The term cos Φ is called the power factor

- In a purely inductive or capacitive circuit, cosf = 0 and no power is dissipated even though a current is flowing in the circuit. In such cases, current is referred to as a wattless current.
- A transformer consists of an iron core on which are bound a primary coil of Np turns and a secondary coil of Ns turns. If the primary coil is connected to an ac source, the primary and secondary voltages are related by $\frac{Ns}{Np} = \frac{Vs}{Vp}$

  and the currents are related by

  $$\frac{Is}{Ip} = \frac{Np}{Ns}$$

  If the secondary coil has a greater number of turns than the primary, the voltage is stepped-up (Vs >Vp). This type of arrangement is called a stepup transformer. If the secondary coil has turns less than the primary, we have a step-down transformer

Practice Questions

MCQ

1. Average value of A.C voltage for positive half cycle is [If V_0 is its peak voltage]

   (A) V_0 (B) $\frac{2V_0}{\pi}$ (C) O (D) $\frac{V_0}{\sqrt{2}}$

2. An alternating current in a circuit is given by $I = 20\sin(100\pi t + 10.05\pi)A$. The r.m.s value and frequency of current respectively are

   (A) 10A & 100 Hz (B) 10 A & 50 Hz

   (C) $10\sqrt{2}A$ & 50Hz (D) $20\sqrt{2}$ & 100Hz

3. In A.C circuit having only capacitor, the current

(A) lags behind the voltage by $\frac{\pi}{2}$ in phase

(B) leads the voltage by $\frac{\pi}{2}$ in phase

(C) leads the voltage by π in phase

(D) is in phase with voltage

04. An alternating voltage $E = 200\sqrt{2}\sin(100t)$ is connected to a $1\mu F$ capacitor through an A.C ammeter. The reading of the ammeter shall be

(A) 10 mA (B) 20 mA (C) 40 mA (D) 80 mA

05. A coil of self-inductance L is connected in series with a bulb B and an AC source. Brightness of the bulb decreases when

(A) an iron rod is inserted in the coil

(B) frequency of A.C source is decreases

(C) number of turns in the coil is reduced

(D) a capacitance of reactance $X_C = X_L$ is included in the same circuit.

06. At resonance frequency in an A.C circuit containing L, C and R in series

(A) The voltage and current will be in same phase

(B) The voltage will lead the current

(C) The voltage will lag behind the current

(D) Phase difference depends on peak voltage of source

07. An inductance of 1 mH, a condenser of $10\mu F$ and a resistance of 50Ω are connected in series. The reactances of inductor and condenser are same. The reactance of either of them will be

(A) 100Ω (B) 30Ω (C) 3.2Ω (D) 10Ω

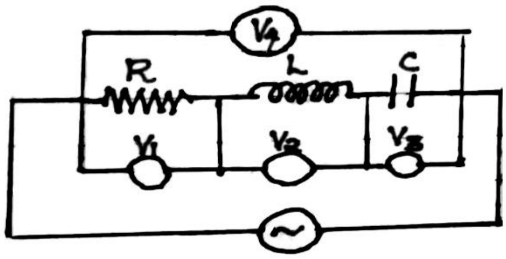
08. An ideal resistance R, ideal inductance L, ideal capacitance C and A.C volt meters, V_1, V_2, V_3 and V_4 are connected to an A. C source as shown. At resonance

(A) Reading in V_3 = Reading in V_1

(B) Reading in V_1 = Reading in V_2

(C) Reading in V_2 = Reading in V_4

(D) Reading in V_3 = Reading in V_3



09. In an LCR circuit the voltage across L, C and R is 10V each. If the inductor is short circuited, the effective voltage becomes

(A) 10 V (B) $10\sqrt{2}$V (C) $20\sqrt{2}$V (D) 20 V

10. A circuit has a resistance of 11Ω, an inductive reactance of 25Ω and a capacitive reactance of 18Ω. It is connected to an ac source of 260V and 50 Hz. The current through the circuit (in A) is

(A) 11 (B) 15 (C) 18 (D) 20 V

11. In an AC circuit, V and I are given by V = 150 sin (150t) volt and

$I = 150 \sin\left(150t + \frac{\pi}{3}\right)$ amp. The power dissipated in the circuit is

(A) Zero (B) 5625 W (C) 150 W (D) 106 W

12. In an AC circuit the emf (e) and the current (i) at any instant are given respectively by

$E = E_0 \sin \omega t$

$I = I_0 \sin(\omega t - \phi)$

The average power in the circuit over one cycle of AC is

(A) $\frac{E_0 I_0}{2}$ (B) $\frac{E_0 I_0}{2} \sin \phi$ (C) $\frac{E_0 I_0}{2} \cos \phi$ (D) $E_0 I_0$

13. In an AC circuit the voltage applied is $E = E_0 \sin \omega t$. The resulting current in the circuit is $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The power consumption in the circuit given by

(A) $P = \frac{E_0 I_0}{\sqrt{2}}$ (B) P = Zero (C) $P = \frac{E_0 I_0}{2}$ (D) $P = \sqrt{2}\, E_0 I_0$

14. The current i passed in any instrument in an AC circuit is $i = 2 \sin \omega t$ A and potential difference applied is given by $V = 5 \cos \omega t$ V. Power loss in the instrument is

(A) 10 W (B) 5 W (C) Zero W (D) 20 W

15. In an AC circuit the instantaneous values of emf and current are e = 200 sin 300 t volt and $i = 2 \sin\left(300t + \frac{\pi}{3}\right)$ amp the average power consumed in watt is

(A) 200 (B) 100 (C) 50 (D) 400

ANSWERS MCQ

01. Option: B

Average value of voltage over +ve half cycle = $\frac{\int_0^{T/2} V_0 \sin \omega t.dt}{\int_0^{T/2} dt}$

$$= \frac{V_0\left[\frac{-\cos\omega t}{\omega}\right]_0^{\pi/2}}{[t]_0^{T/2}} \qquad = \frac{V_0}{\omega.\frac{T}{2}}\left[-\cos\left(\frac{\omega T}{2}\right) - \cos 0\right] = \frac{2V_0}{2\pi}\times 2 = \frac{2V_0}{\pi}$$

02. Option: C

$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{20}{\sqrt{2}} = 10\sqrt{2}A \qquad \omega = 100\pi \qquad 2\pi f = 100\pi \quad \Rightarrow f = 50$ Hz

03. Option: B

04. Option: B

Reading of ammeter = $I_{rms} = \frac{V_{rms}}{X_C} = \frac{V_0}{\sqrt{2}X_C} = \frac{V_0.C\omega}{\sqrt{2}} = \frac{200\times\sqrt{2}\times 10^{-6}\times 100}{\sqrt{2}} = 20mA$

05. Option: A

06. Option: A

07. Option: D

Given $L\omega = \frac{1}{C\omega} \qquad \Rightarrow \omega = \frac{1}{\sqrt{LC}} \qquad \omega = \frac{1}{\sqrt{10^{-3}\times 10\times 10^{-6}}} = \frac{1}{\sqrt{10^{-8}}} = 10^4$

$X_L = L\omega = 10^4\times 10^{-3} = 10\Omega$

08. Option : D

At resonance $V_L = V_C$

09. Option : B

If the inductor is short circuited, $V_{eff} = \sqrt{V_R^2 + V_C^2} = \sqrt{10^2 + 10^2} = 10\sqrt{2}V$

10. Option : D

$Z = \sqrt{R^2 + (X_L - X_C)^2} \qquad = \sqrt{11^2 + (25-18)^2} = \sqrt{170} \approx 13\Omega$

$\therefore I = \frac{V}{Z} = \frac{260}{13} = 20A$

11. Option : B

12. Option : C

13. Option : B

14. Option : A

15. Option : B

ASSERTION – REASON

Two statement are given – one labelled **Assertion** (A) and other labelled **Reason** (R). Select the correct codes (a), (b), (c) and (d) as given below

(a) Both **Assertion** and **Reason** are true and **Reason** is the correct explanation of **Assertion**

(b) Both **Assertion** and **Reason** are true, but **Reason** is not the correct explanation of **Assertion**

(c) **Assertion** is true, but **Reason** is false

(d) **Assertion** is false and **Reason** is also false

01. **Assertion** : The alternating current lags behind the emf by a phase angle of $\frac{\pi}{2}$, when ac flows through an inductor

Reason : The inductive reactance increases as the frequency of ac source decreases

02. **Assertion** : Capacitor servers as a block for dc and offers an easy path to ac

Reason : Capacitive reactance is inversely proportional to frequency

03. **Assertion** : The average value of alternating current and rms value are same

Reason : R.M.S value of alternating current is always greater than peak value

04. **Assertion** : Inductors are used in a.c. circuits for controlling current

Reason : Inductive reactance, $X_L = L\omega$

05. **Assertion** : For an electric lamp connected in series with a variable capacitor and ac source, its brightness increases with increase in capacitance

Reason : Capacitive reactance decreases with increase in capacitance of capacitor

06. **Assertion** : When capacitance reactance is smaller than the inductive reactance in LCR circuit, e.m.f leads the current

Reason : The phase angle is the angle between the alternating e.m.f and alternating current of the circuit

07. **Assertion** : A.C is more dangerous than D. C

Reason :frequency of A.C is dangerous for human body.

08. **Assertion** : Average power in an A.C circuit having L only is Zero.

Reason : Power factor of A.C circuit having L only is zero.

09. **Assertion** : Winding the Primary coil and secondary coils one over the other reduces flux leakage

Reason : Magnetic flux is directly propossional to number of terms f coil

10. **Assertion** : As the number of turns of secondary increases, the voltage across secondary decreases for a transformer

Reason: Current in secondary is more if the number of turns is more than that of number of terms of primary .

ANSWERS

01 Option (C)

02. Option (A)

03. Option (D)

04. Option (B)

05. Option (A)

06. Option (B)

07. Option : (A)

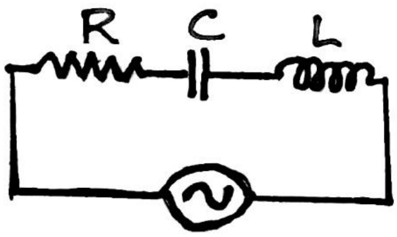
08. Option : (A)

09. Option : (B)

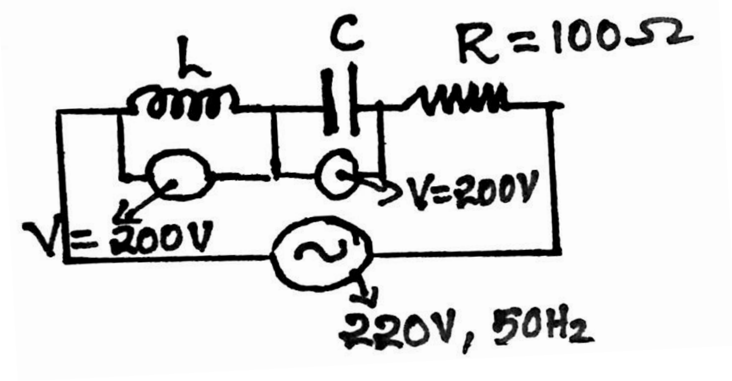
10. Option : (D)

DIAGRAM BASED QUESTIONS

01. In the circuit shown, R represents an electric bulb. If the frequency of the supply is doubled, how should the values of C and L be changed so that the glow in the bulb remains unchanged?



02. Find the average power consumed in the circuit?



ANSWERS

01. For the same current value, the total impedence must remain same. $\therefore\ \omega L - \frac{1}{C\omega}$ must remain same. Thus L and C both must be halved simultaneously.

02. Here $V_L = 200$

$V_C = 200$

$\therefore$ The circuit is at resonance $\therefore\ V = V_R$

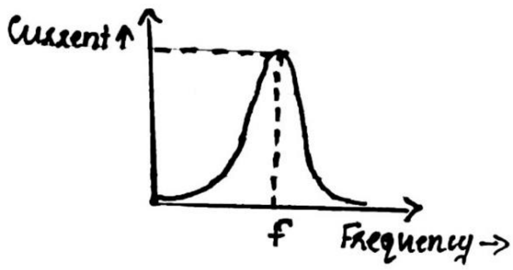
$$\text{Power} = \frac{V_{rms}^2}{R} = \frac{22\not{0} \times 22\not{0}}{1\not{0}\not{0}} = 484W$$

GRAPH BASED QUESTIONS

2 Mark Questions

01. Sketch a graph to show how the reactance of a capacitor and inductor varies as a function of frequency

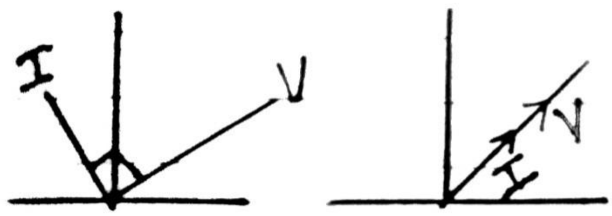
02. The graph showing the variation of current with frequency of ac source in a series LCR circuit



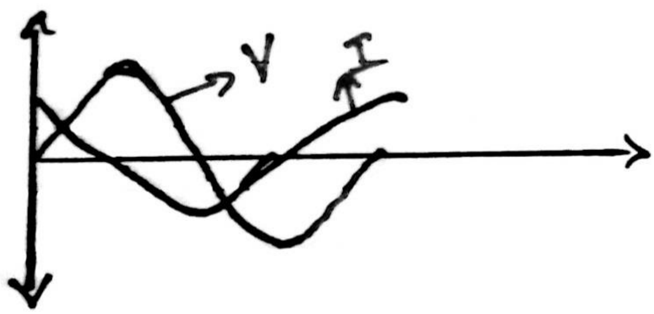
(i) Write down the name of frequency ‘f’ in graph

(ii) Write down an expression for finding out ‘f’

03. Observe the following graph an find out the power factor in each case



04. The voltage and current with respect to time is shown in the graph. Find the power factor



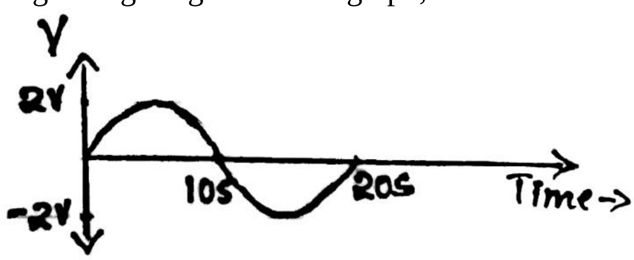
3 Mark Questions

05. V – t graph of an alternating voltage is given in the graph, find

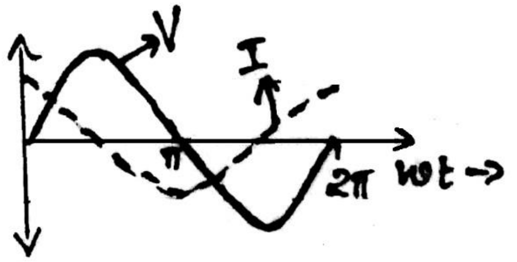
(i) Peak voltage

(ii) V_{rms}

(iii) Frequency



06. Observe the graph and answer the following questions



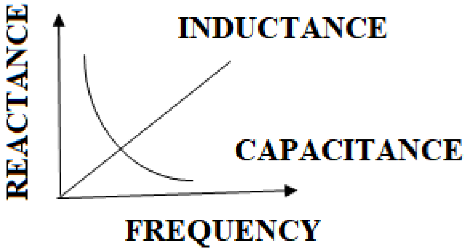
(i) Identify the A.C circuit?

(ii) Write down phase difference between V & I

(iii) Write down an expression for reactance of this circuit

ANSWERS

01.



02. (i) Threshold frequency

(ii) $F = \dfrac{1}{2\pi\sqrt{LC}}$

03. (i) Phase difference between V and I is, $\phi = \dfrac{\pi}{2}$

$\therefore$ Power factor = $\cos\phi = \cos\dfrac{\pi}{2} = 0$

(ii) Phase difference between V & I is $\phi = 0$

$\therefore$ Power factor = $\cos\phi = \cos 0 = 1$

04. Phase difference between V & I is $\phi = \dfrac{\pi}{2}$

$\therefore$ Power factor = $\cos\phi = \cos\frac{\pi}{2} = 0$

05. (i) 2V

(ii) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}V$

(iii) T = 20S

$\therefore$ Frequency, $f = \frac{1}{T} = \frac{1}{20S} = 0.05\,Hz$

06. (i) A.C circuit having capacitance only

(ii) $\phi = \frac{\pi}{2}$, current leads the voltage by a phase of $\frac{\pi}{2}$.

(iii) The reactance of this circuit the capacitive reactance $X_C = \frac{1}{C\omega} = \frac{1}{2\pi fc}$

NUMERICAL BASED

2 Mark Questions

01. A pure inductor of 25 mH is connected to a source of 220V. Find the inductive reactance and rms current in the circuit if frequency of a.c. source is 50Hz

02. An ac voltage of 100V, 50 Hz is connected across a 20Ω resistor and 2 mH inductor in series. Calculate

i. impedence of circuit

ii. rms current in the circuit

03. If effective current in a 50 cycle per second a.c circuit is 50A, what is

(A) The peak value of current?

(B) The value of current 1/300 second after it was zero?

04. In an ideal transformer, the number of turns of primary and secondary are 100 and 2000 respectively. If maximum voltage in primary is 120V, what is the maximum voltage in secondary?

3 Marks Questions

05. A series CR circuit with $R = 200\Omega$ and $C = \frac{50}{\pi}\mu F$ is connected across an a.c source of peak voltage $\epsilon_0 = 100V$ and frequency $\upsilon = 50Hz$. Calculate

a. Impedence of the circuit (Z)

b. Phase angle (ϕ)

c. Voltage across resistor

06. A series LCR circuit with $R = 20\Omega$, L = 2H and $C = 50\mu F$ is connected to a 200V a.c source of variable frequency

(i) what is the amplitude of the current and

(ii) the average power transferred to the circuit in one complete cycle at resonance

(iii) Calculate the potential drop across the capacitor?

07. An inductor 20 mH, a capacitor $50\mu F$ and a resistor 40Ω are connected in series across a source of emf V = 10 sin (340 t). Find out the power loss in ac circuit

08. A 60V, 10 W lamp is to be run on 100 V, 60 Hz ac mains.

(i) Calculate the inductance of a choke coil required

(ii) If a resistance is used instead of choke, what will be its value?

ANSWERS

01. The inductive reactance, $X_L = 2\pi\upsilon L = 2\times3.14\times50\times25\times10^{-3}\Omega = 7.85\Omega$

The r.m.s current in the circuit is $I = \frac{V}{X_L} = \frac{220}{7.85} = 28A$

02. (i)Impedence, $Z = \sqrt{R^2 + \omega^2 L^2} = \sqrt{R^2 + 4\pi^2\upsilon^2 L^2}$

$= \sqrt{400 + 4\times10\times2500\times(2\times10^{-3})^2} = 20\Omega$

(ii) Current I = $\frac{V}{2} = \frac{100}{20} = 5A$

03. (a) I_{rms} = 5A, I_0= ?, $\upsilon = 50Hz$, t = 1/300

$I_{rms} = \frac{I_0}{\sqrt{2}} \Rightarrow I_0 = \sqrt{2}I_{rms}$

$I_0 = \sqrt{2}\times5 = 5\sqrt{2}A = 7.07A$

(b) Now, $I = I_0\sin(\omega t) = I_0\sin(2\pi\upsilon t)$ = $7.07\sin\left(2\pi\times50\times\frac{1}{300}\right)$

$= \quad 7.07\sin\left(\frac{\pi}{3}\right) = 6.12A$

04. $\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{2000}{100} = 20$;

$V_s = 20\ V_P = 20 \times 120V = 2400\,V$

05. (a) $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\frac{1}{2\pi\upsilon C}\right)^2}$

$X_C = \frac{1}{2\pi\upsilon C} = \frac{1}{2\pi \times 50 \times \frac{50}{\pi} \times 10^{-6}} = 200\Omega$

$R = 200\Omega \quad = \qquad Z = \sqrt{200^2 + 200^2} = 200\sqrt{2}\Omega$

(b) $\tan\phi = \frac{X_C}{R} = \frac{200}{200} = 1$

$\phi = 45^o \text{ or } \frac{\pi}{4} \text{ rad}$

(c) $V_{rms} = I_{rms}R = \frac{V_{rms}}{Z}.R = \frac{100}{\sqrt{2} \times 200 \times \sqrt{2}} \times 200 = 50V$

06. (i) At resonance Z = R

$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_{rms}}{R} = \frac{200}{20} = 10A$

Amplitude of current $I_0 = \sqrt{2}I_{rms} = 10\sqrt{2}A$

(ii) Average power, $P = I_{rms}^2 R = 10^2 \times 20 = 2000W$

(iii) Resonant frequency, $\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2 \times 50 \times 10^{-6}}} = 100\text{rad/s}$

$X_C = \frac{1}{C\omega} = \frac{1}{100 \times 50 \times 10^{-6}}$; $\quad V_C = I_{rms}X_c = \frac{T}{C\omega} = 10 \times \frac{1}{100 \times 50 \times 10^{-6}} = 2000V$

07. L = 20 mH, V_0 = 10V

$C = 50\mu F \ \&\ R = 40\Omega, \omega = 340\text{rad/sec}$

$X_C = \frac{1}{C\omega} = \frac{1}{340 \times 50 \times 10^{-6}} = 58.8\Omega$; $\qquad X_L = L\omega = 20 \times 10^{-3} \times 340 = 6.8\Omega$

$Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{40^2 + (58.8 - 6.8)^2} = \sqrt{4304}\Omega$

$$P = I_{rms}^2 R = \left(\frac{V_{rms}}{Z}\right)^2 \times R = \frac{(10/\sqrt{2})^2}{(\sqrt{4304})^2} \times 40 = \frac{50 \times 40}{4304} = 0.47W$$

08. $P = VI \Rightarrow I = \frac{P}{V} = \frac{10W}{60V} = \frac{1}{6}A$

Resistance of lamp, $R = \frac{V}{I} = \frac{60V}{\frac{1}{6}A} = 360\Omega$

Now, I = $\frac{V}{Z} = \frac{V}{\sqrt{R^2 + \omega^2 L^2}}$; $\frac{1}{6} = \frac{100}{\sqrt{360^2 + L^2 + (2 \times 3.14 \times 60)^2}}$

On simplification, L = 1.274 H

Total resistance in the circuit = $\frac{V}{I} = \frac{100}{\frac{1}{6}} = 600\Omega$

Required resistance = 600 – 360 = 240Ω

CASE STUDY QUESTIONS

01. At an airport, a person is made to walk through the doorway of a metal detector, for security reasons if she / he is carrying anything made of metal, the metal detector emits a sound.

i. Identify the circuit through which the person is walking?
ii. On what principle does this work?
iii. How impendence of this circuit changes when a person with metal piece is entering o a metal detector?

OR

With the help of an equation explain how inductance of a coil changes with the introduction of metal piece.

02. The antenna of a radio accepts signals from many broadcasting stations. The signal picked up in the antenna act as a source in the tuning circuit of radio, so the circuit can be driven at many frequencies. But o hear one particular radio station, we tune the radio:

i. Which circuit is used in radio receivers?
ii. Write down the principle behind the working of radio receivers.
iii. Is the above phenomenon is applicable for RL circuit? Why?

OR

Is this happens for an RC circuit? Why?

03. The large scale transmission and distribution of electrical energy over long distance is done with the use of transformers. The voltage output of the generator is step- up. It is then transmitted to substations nearer to consumers. There the voltage stepped down.

i. Which transformer is used at power stations for energy distribution?
ii. Write down the relation connecting between number of tunes and voltages across primary and secondary coils.

iii. What is the advantage of A.C. over D. C for long transmission?

OR

How energy is lost in transformers.

ANSWERS OF CASE STUDY

01. i. LCR circuit

ii. Resonance of LCR circuit

iv. When a person with metal peace is walking through the circuit, due to magnetic induction, inductance of the coil changes and hence the reactance and impendence of circuit changes.

OR

Self inductance of the coil

$$L = \mu 0\ N^2 Al$$

When metal piece introduced μ0 changes to μr μ0 and hence inductance reactance and impendence changes.

02. i. LCR circuit

ii. Resonance of LCR circuit

iv. No. resonance is exhibited by circuit only if both L and C are present in the circuit. Only then do the voltage across L and C cancel each other and current amplitude become maximum.

OR

No. Explanation is same as above.

03. (i) Step- up transformer.

(ii) $\frac{Ns}{Np} = \frac{Vs}{Vp}$

(iii) A.C can be transmitted with high voltage and low current. Hence it reduces heat lost due to I^2Rt

OR

Energy lost in transformers may be due to

i. Flux leakage.
ii. Resistance of windings.
iii. Eddy currents.
iv. Hysteresis loss.

HOTS QUESTIONS

01. Inductive resistance 25 Ωand capacitive resistance 75Ω are connected in series across 250V mains in series. Find he rms potential difference across inductor and capacitor. How can you reconcile this in terms of main voltage?

02. An inductor (L = 20mH) is connected to an A.C source of peak emf 210 V and frequency 50 Hz calculate the peak current. What is the instantaneous voltage of the source when the current is at its peak value?

03. A transformer has 50 tunes in the primary and 100 in the secondary. If primary is connected to 220 V DC supply, what will he the voltage across the secondary?

04. Power factor can often he improved by the use of a capacitor if appropriate capacitance in the circuit. It is Correct?

ANSWER OF HOTS

01. $Z = X_c - X_l = 75 - 25 = 50\Omega$

$I = 250 \text{ V} / 50\ \Omega = 5 \text{ A}$

$V_L = 5*25 = 125 \text{ V}$

$V_C = 5*75 = 375 \text{ V}$

$V_{mains} = I(X_C - X_L) = 5*50 = 250 \text{ V}$

Again $V_{mains} = V_C - V_L = 375-125 = 250\text{V}$

02. $X_L = L\omega = 62.8\ \Omega$

$I_m = V_m / X_L = 3.3 \text{ A}$

Since the current lags behind he voltage by $\pi/2$ therefor the voltage is zero when the current has its peak value.

03. Zero. Transforms will works only on a AC. Because its principle is mutual induction. It will work only if there is change in flux.

04. Power factor, $\cos\Phi = R/Z$
Many device have inductive reactance. A capacitance f appropriate valude reduce the net reactance so that 2 approcher R.

DERIVAATION BSED QUESTIONS

01. Drive an expression for the impendence of LCR circuit using phasor diagram.

02. Drive an expression for current in an AC circuit containing inductor (L) only.

03. Derive an expression for current in an Ac circuit containing capacitor (C) only.

04. Derive an expression for average power in A.C circuit containing R only.

05. Derive the relation connectiong between Vs, Vp and Ns, Np.

ANSWERS OF DERIVAION BASED QUESTIONS

01. Refer NCERT (Rationalised 23 -24) Page No. 187
02. Refer NCERT (Rationalised 23 -24) Page No. 181-182
03. Refer NCERT (Rationalised 23 -24) Page No. 184
04. Refer NCERT Rationalised 2023 -24, Page No. 179,180
05. Refer NCERT Rationalised 2023 -24, Page No. 194,195

SELF EVALUATION TEST

TIME : 30 MINUTES **MAX.MARKS:15**

01. An AC voltage source of variable angular frequency ω and fixed amplitude V_0 is connected in series with a capacitance C and an electric bulb of resistance R (inductance zero). When ω is increased
(A) The bulb glows dimmer
(B) The bulb glows brighter
(C) Total impedance of the circuit is unchanged
(D) Total impedance of the circuit increases 1 mark

02. A capacitor and an inductance coil are connected in separate AC circuits with a bulb glowing in both the circuits. The bulb glows more brightly when
(A) An iron rod is introduced into the inductance coil
(B) The number of turns in the inductance coil is increased
(C) Separation between the plates of the capacitor is increased
(D) A dielectric is introduced into the gap between the plates of the capacitor

1 mark

03. A 100 W resistor is connected to a 220 V, 50 Hz ac supply.
(a) What is the rms value of current in the circuit?
(b) What is the net power consumed over a full cycle? 2 marks

04. How does the resistance differ from impedance ? With the help of a suitable phasor diagram, obtain an expression for impedance of a series LCR circuit, connected to a source V= Vm sin ωt. 3 marks

05. An ac source V = Vm sin ωt is connected across an ideal capacitor. Derive the expression for the (i) current flowing in the circuit, and (ii) reactance of the capacitor. Plot a graph of current i versus t. 3 marks

06. (i) Derive an expression for the average consumed by an ac circuit containing R only.
(ii) A light bulb is rated at 100W for a 220 V supply.
Find (a) the resistance of the bulb;
(b) the peak voltage of the source 5 marks

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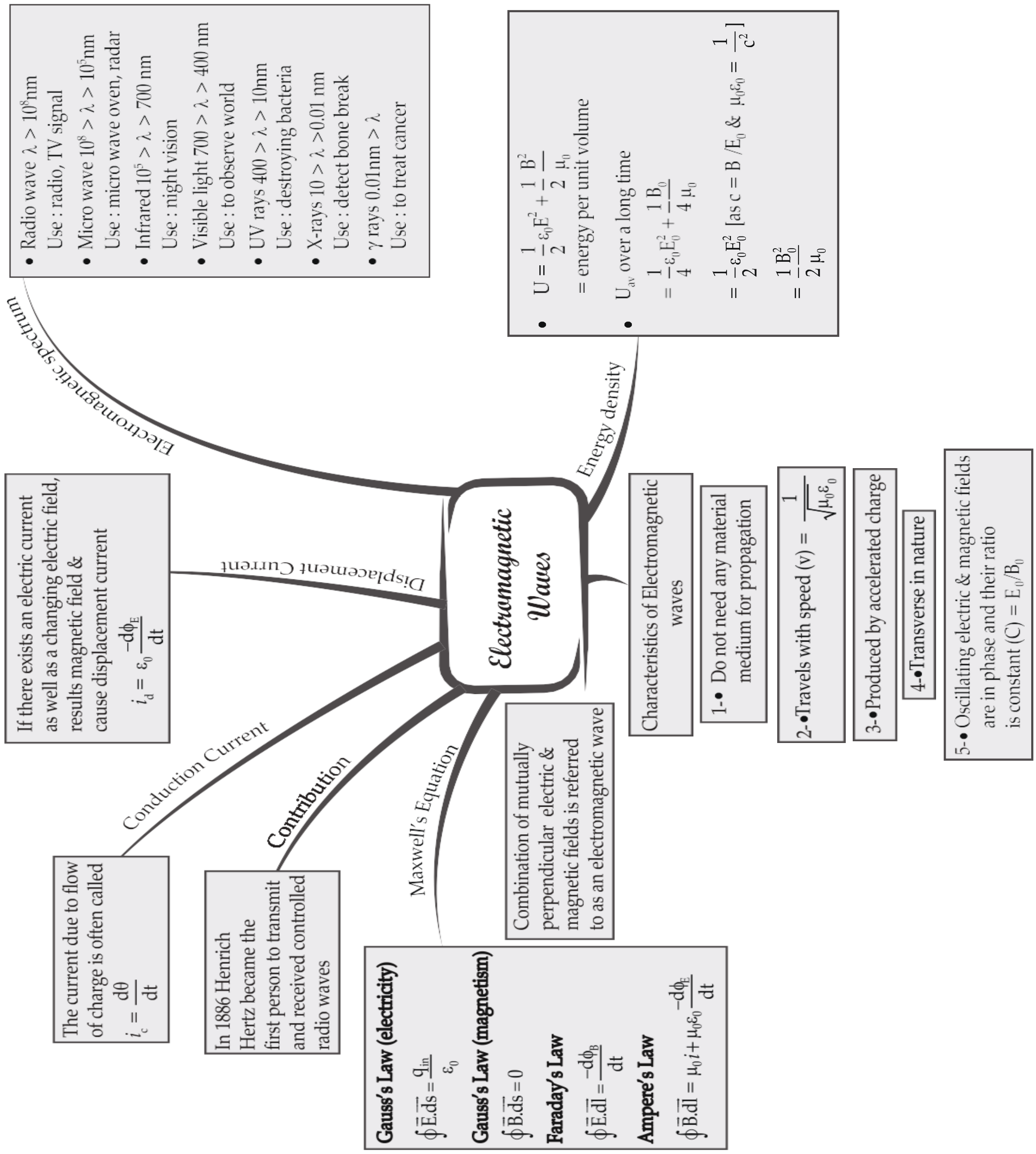
CHAPTER 8

ELECTROMAGNETIC WAVES

Gist of the unit

- Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea only). Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

MIND MAP : ELECTROMAGNETIC WAVES



Introduction

In this chapter, we will study the basic idea regarding displacement current, electromagnetic waves, its transverse nature and its various parts and their uses.

History of electromagnetic waves

Maxwell: was the first to predict the presence of electromagnetic waves.

Hertz: produced and detected electromagnetic waves of wavelength 6 m experimentally.

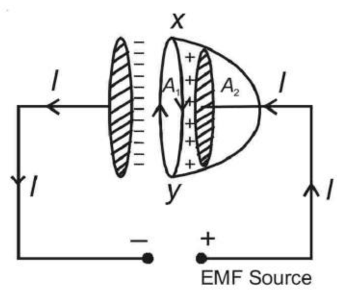
J.C. Bose: the produced electromagnetic wave of wavelength ranging from 5 mm to 25 mm.

Marconi: successfully transmitted the EM waves up to a few kilometers. Marconi discovered that if one of the spark gap terminals is connected to an antenna and the other terminal is earthed, the EM waves radiated could go up to several kilometers.

BASIC CONCEPTS OF DISPLACEMENT CURRENT

Current in capacitors

consider a capacitive circuit, we can see there is current flowing through the circuit. But if you look at the capacitor plates, there is a small empty region in between them. Then how the circuit is completed?



The circuit is completed despite the small space because there is displacement in that region which is developed as a consequence of the varying electric field in between the plates.

So, Ampere's circuital law for conduction current during "charging of a capacitor was found inconsistent.

ie according to Ampere's circuital law

$$\oint \vec{B}.d\vec{l} = \mu_0 I_{enclosed}$$ here $I_{enclosed} = I_c$ (Conduction current)

Maxwell suggested that the above inconsistency of Ampere's circuital law is because of some missing term. The term is related to varying electric field called displacement current

$$\oint \vec{B}.d\vec{l} = \mu_0(I_c + I_d)$$

Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea only). Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.: Dispalcement current arise due to electric flux changing with time.

$$I_d = \varepsilon_0 \frac{d\phi_E}{dt}$$

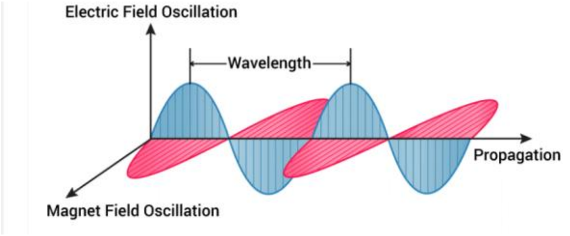
MAXWELL'S EQUATIONS

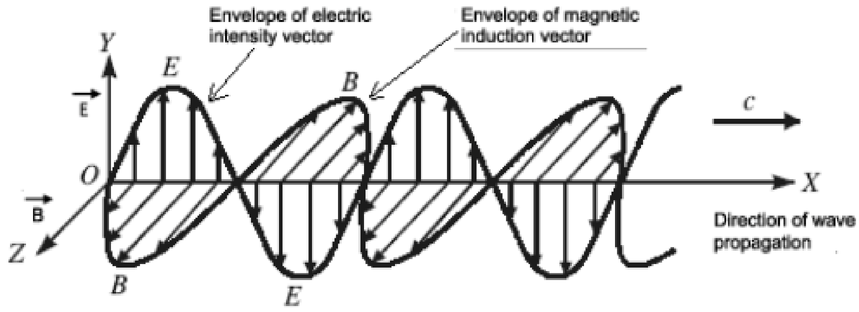
Maxwell's equations relate electric field E and magnetic field B and their sources which are electric charges and current. In free space, Maxwell's equations are as follows.

1. Gauss's Law in Electrostatics : $\oint \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$
2. Gauss's Law in Magnetism: $\oint \vec{B}.d\vec{S} = 0$
3. Faraday's- Lenz's law of Electromagnetic Induction: $\oint \vec{E}.d\vec{l} = \frac{d\phi}{dt}$
4. Ampere's- Maxwell law : $\oint \vec{B}.d\vec{l} = \mu_0(I_c + I_d)$

ELECTROMAGNETIC WAVES:

These waves propagates through spaceas coupled electric and magnetic fields, oscillating perpendicular to each other and to the direction of propagation of the wave.





$E_y = E_0 \sin(kx - \omega t)$

$E = E_y(t) = E_0 \sin(kx - \omega t)$

$B = B_z(t) = B_0 \sin(kx - \omega t)$

PROPERTIES OF EM WAVES:

- They are produced by oscillating or accelerating charges.
- They do not require any medium for their propagation.
- They are transverse in nature.
- The amplitudes of electric and magnetic fields are related by $C = \frac{E}{B}$
- All EM waves travels through space or vaccum with the speed of 3 x 10^8m/s and it is given by the relation. $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$
- EM waves carry energy, which is shared equally between electrc and magnetic field vectors.
- EM waves carry momentum and exert a radiation pressure.

  Momentum, $p = U/c$
- The velocity of EM waves depends entirely on electric and magnetic properties of the medium in which they travel and is independent of the amplitude of field vectors.

  $$C = \frac{1}{\sqrt{\mu\varepsilon}}$$

ELECTROMAGNETIC SPECTRUM :

The orderly arrangement of electromagnetic radiations according to its frequqency or wavelengthis called electromagnetic spectrum.

S.No.	Type	Wavelength range(λ)	Visible Spectrum		Decreasing Order of wavelength OR Increasing order of frequency
1	Radiowaves	>0.1m		Red	
2	Microwaves	0.1m to 1mm		Orange	
3	Infra -red rays	1mm to 700nm		Yellow	
4	Visible light	700nm to 400nm		Green	
5	Ultra-Voilet rays	400nm to 1nm		Blue	
6	X-rays	1nm to 10^{-3}nm		Indigo	
7	Gamma(γ) rays	<10^{-3}nm		Violet	

EM SPECTRUM, ITS PRODUCTION, DETECTION AND USE

Type of wave	Wavelength range Frequency Range	Production	Detection	Uses
Radio Waves	> 0.1 m 10^9 Hz to 10^5Hz	Rapid acceleration and deceleration of electrons in aerials	Receiver's aerials	➢ Used in radio & TV Communication. ➢ Cellular phones used radio waves to transmit voice communication.in the UHF band.
Microwave	0.1m to 1 mm 10^{11}Hz to 10^9Hz	Klystron valve or Magnetron valve	Point contact diodes	➢ Used in radar system for aircraft navigation. ➢ Used in long distance communication. ➢ Used in microwave oven. ➢ Used in detecting the speed of cricket ball, tennis ball, speed of vehicle etc. ➢ Used in study of atomic & molecular structure.
Infrared	1 mm to 700 nm 10^{11}Hz to 10^{14}Hz	Vibration of atoms or molecules	Thermophiles Bolometer, Infrared photographic film	➢ Greenhouse effect ➢ Used in haze photography. ➢ IR lamps are used in Physical therapy. ➢ IR detectors are used in Earth satellites, both for military purposes and to observe growth of crops. ➢ Used in remote control of TV & VCD. ➢ Used in weather forecasting through IR photography.
Visible Light	700 nm to 400 nm 4 x 10^{14}Hz to 8 x	Electron in atom during transition	The eye, Photocells	➢ It produced the sense of vision. ➢ Used in photography. ➢ Used in optical instruments.

	10^{14}Hz		Photographic film	
Ultra violet	400 nm to 1 nm 8 x 10^{14}Hz to 10^{16}Hz	Inner shell electron in atom moving from one energy level to a lower energy level	Photocell & Photographic film	➢ UV lamps are used to kill germs in water purifier. ➢ Used in LASIK eye surgery. ➢ Used in burglar alarms. ➢ Used to check forged documents in the forensic labs.
X –rays	1 nm to 10^{-3}nm 10^{16} Hz to 10^{21}Hz	X- ray tube or inner shell electrons	Photographic film, Geiger tubes Ionisation chamber	➢ Used as diagnostic tool in medicine to take the picture of internal organ of human body for the detection of fracture. ➢ Used to study the crystal structure. ➢ Used to detect the faults, cracks & holes in metal sheets. ➢ Used in treatment of certain form of cancer.
Gamma rays	< 10^{-3}nm 10^{19}Hz to 10^{23}Hz	Radioactive decay of the nucleus	Photographic film, Geiger tube Ionisation chamber	➢ Used in treatment of cancer & tumour ➢ Used to study the structure of atomic nuclei ➢ Used for detecting flaws in metal castings.

MUTIPLE CHOICE QUESTIONS

1. An electromagnetic wave going through vacuum is described by $E=E_o \sin(kx - \omega t)$. Which of the following is/are independent of the wave length?

   (a) k (b) ω (c) k/ω (d) k ω

2. An electromagnetic wave going through vacuum is described by $E=E_o \sin(kx - \omega t)$; $B=B_o \sin(kx - \omega t)$. Then

   (a) $E_o k=B_o \omega$ (b) $E_oB_o=\omega k$ (c) $E_o \omega=B_o k$ (d) none of these

3. A plane electromagnetic wave is incident on a material surface. The wave delivers momentum p and energy E.

   (a)p=0, E=0 (c) p≠0 E=0 (c) p≠0, E≠0 (d)p=0, E=0

Answer

1. C
2. a
3. c

ASSERTION –REASON TYPE QUESTIONS

In the following questions, mark the correct choice as:

(a) Both assertion and reason are true and the reason is a correct explanation of the assertion.

(b) Both assertion and reason are true but the reason is not a correct explanation of the assertion.

(c) Assertion is true but the reason is false.

(d) Both assertion and reason are false.

1. Assertion – A charge moving in a circular orbit can produce electromagnetic wave.
   Reason – The source of electromagnetic wave should be in accelerated motion.
2. Assertion – In electromagnetic waves electric field and magnetic field lines are perpendicular to each other.
   Reason – Electric field and magnetic field are self-sustaining.

Answer

1. (a)
2. (b)

NUMERICAL

1. Let an electromagnetic wave propagate along the x direction, the magnetic field oscillates at a frequency of 10^{10} Hz and has an amplitude of 10^{-5}T, acting along the y - direction. Then, compute the wavelength of the wave. Also write down the expression for electric field in this case.
   Hint: $\lambda = c/\upsilon$ $C = E_0 / B_0$ $K = \frac{2\pi\upsilon}{c}$
   Answer: $\lambda = 3 \times 10^{-2}$m and $E(x,t) = 3 \times 10^3 \sin(2.09 \times 10^2 x - 6.28 \times 10^{10} t)\hat{i}$ N C−1

2. A magnetron in a microwave oven emits electromagnetic waves (em waves) with frequency f = 2450 MHz. What magnetic field strength is required for electrons to move in circular paths with this frequency?
   Hint: $\omega = 2\pi f$ the magnetic field $B = m_e\omega / |q|$ $B = 0.0887$ T
   This magnetic field can be easily produced with a permanent magnet. So, electromagnetic waves of frequency 2450 MHz can be used for heating and cooking food because they are strongly absorbed by water molecules.

3. In a plane em wave, the electric field oscillates sinusoidally at a frequency of 2×10^{10} Hz and amplitude 48 V/m. What is the wavelength of the wave? What is the amplitude of the oscillating magnetic field?

   Ans: $\lambda = c/\nu = 1.5 \times 10^{-2}$ m $B_0 = E_0/c = 48/3 \times 10^{8} = 1.6 \times 10^{-7}$ T

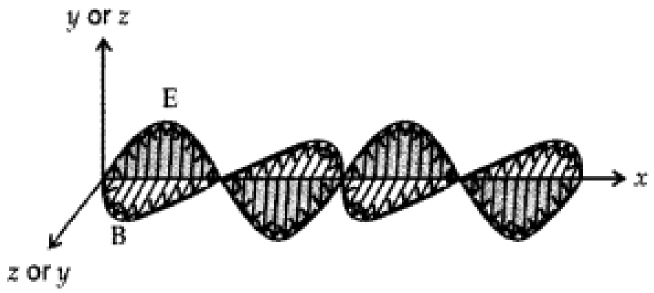
GRAPH BASED QUESTION

1. How is electromagnetic wave produced? Draw a sketch of a plane e.m. wave propagating along X-axis depicting the directions of the oscillating electric and magnetic fields.

   Answer:

   Electromagnetic waves are produced due to oscillating/accelerating charged particles.

(a)

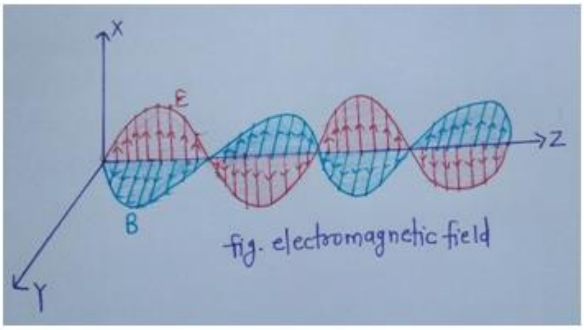


(b) $\frac{E_0}{B_0} = c$

CASE STUDY QUESTIONS

I. According to Maxwell's electromagnetic equations it has been proved that electric and magnetic field vectors are perpendicular to each other and also perpendicular to the direction of propagation as shown in the figure below. If E_X is the electric field along X axis, then B_Y will be the direction of magnetic field along Y axis and both which are perpendicular to the Z axis showing direction of propagation. The light waves are also the electromagnetic waves and may travel through vacuum also. So, we can find the velocity of a light traveling through the material medium having permittivity 'ε' and magnetic permeability 'μ' as $v = 1/\sqrt{\varepsilon\mu}$.

In this way, we proved that velocity of light also depends on the electrical and magnetic properties of that medium through which it is traveling. The velocity of light which is a constant, having value as 3 x 10^8 m/s. The most technological importance of EM waves is that they are having strong capacity to take energy from one place to another place. The best examples are radio waves, TV signals which also carry energy from their broadcasting stations. Also, life is possible on the earth only because of the sunlight coming from the sun to the earth which also carry energy and it is nothing but the EM waves. Due to which EM waves are considered as the transverse waves.



(i) The ratio of permittivity of the medium to the permittivity of vacuum is called as _____.

- (a) Permeability
- (b) Permittivity of free space
- (c) Dielectric constant of the medium
- (d) Electric intensity

(ii) Who showed that electromagnetic waves can be produced?

- (a) Maxwell
- (b) Hertz
- (c) Ampere
- (d) Michelson and Morley

(iii) The pressure exerted by the electromagnetic wave is called as

- (a) Light pressure
- (b) Electric pressure
- (c) Magnetic pressure
- (d) Radiation pressure

(iv) What is the relationship between magnitude of magnetic field and electric field in case of electromagnetic waves from Maxwell's equations?

OR

(v) What is meant by permittivity and permeability of the medium?

Answer

(i). (c) dielectric constant of the medium

(ii). (b) Hertz

(iii). (d) radiation pressure

(iv). From Maxwells equqtions,the relationship between magnitude of electric field and magnetic field is given as $B_\circ = E_\circ / c$

(v). Permittivity of the medium is the ability of that medium to store electric potential energy in that medium.While permeability of the medium is the ability of the medium to allow the number of field lines through it

HOTS

1. **An EM wave from the air enters a medium. The electric fields are $\vec{E_1} = E_{01}\hat{x}cos[2\pi f(\frac{z}{c} - t)]$ in air and $\vec{E_2} = E_{02}\text{x}\cos[k(2z - ct)]$ in medium, where the wavenumber k and frequency f refer to their values in air. The medium is non-magnetic. If ε_{r1} and ε_{r2} refer to relative permittivity of air and medium respectively, which of the following options is correct?**

a) $\varepsilon_{r1} / \varepsilon_{r2} = 4$

(b) $\varepsilon_{r1} / \varepsilon_{r2} = 2$

(c) $\varepsilon_{r1} / \varepsilon_{r2} = 1/4$

(d) $\varepsilon_{r1} / \varepsilon_{r2} = ½$

Answer

In the air, the EM wave is

$\vec{E_1} = E_{01}\hat{x}cos[2\pi f(\frac{z}{c} - t)]$ $\vec{E_2} = E_{02}\ x\ \cos[k(z - ct)]$

In the medium, the EM wave is

$\vec{E_2} = E_{02}\ x\ \cos[k(2z - ct)]$ $\vec{E_2} = E_{02}\ x\ \cos[2k(z - ct/2)]$

During refraction, frequency remains unchanged, whereas the wavelength gets changed

k' = 2k (From equations)

$2\pi/\lambda' = 2(2\pi/\lambda_0) = \lambda' = \lambda_0/2$

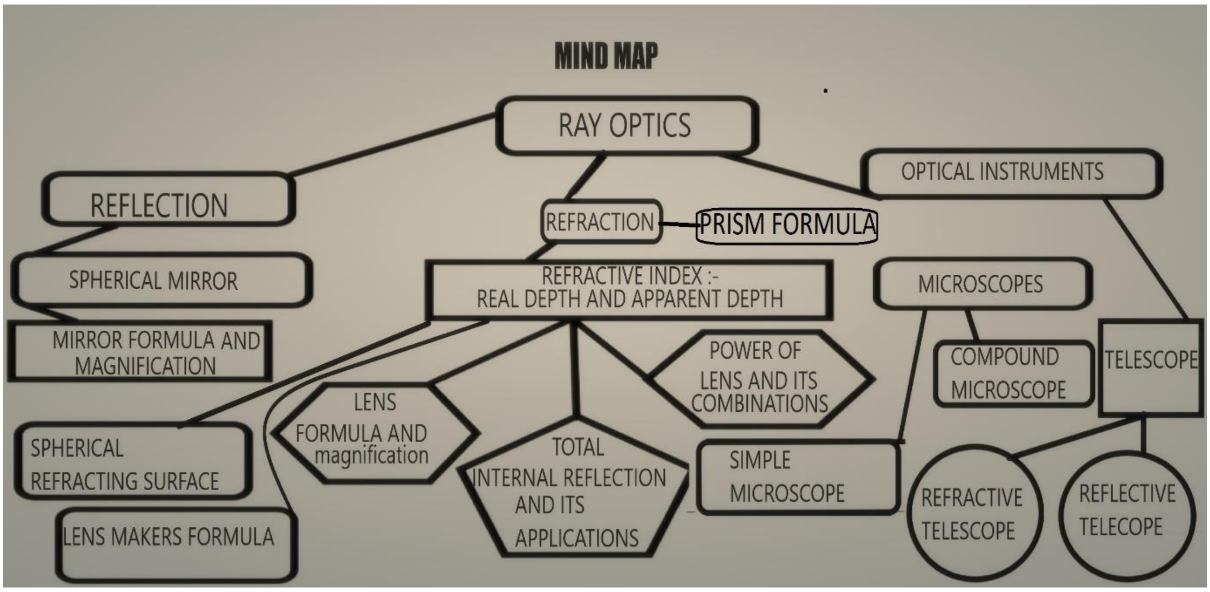
Since, v = c/2 $\frac{1}{\sqrt{\mu_0 \epsilon_{r2}}} = \frac{1}{2} \times \frac{1}{\sqrt{\mu_0 \epsilon_{r1}}}$ $\varepsilon_{r1}/\varepsilon_{r2} = 1/4$

SHORT ANSWER QUESTIONS (2 MARKS EACH)

1. Draw a sketch of electromagnetic spectrum, showing the relative positions of UV, IR, X rays, and microwaves with respect to visible light. State approximate wavelength of any two.
2. What is meant by transverse nature of EM waves? Draw a diagram showing the propagation of an EM wave along the X direction, indicating clearly the directions of oscillating electric and magnetic fields associated with it.
3. Write expressions for (i) linear momentum and (ii) pressure exerted by an em wave on a surface.

CHAPTER 9

RAY OPTICS AND OPTICAL INSTRUMENTS



CONCEPTS

Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism. Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

Reflection.

When light travelling in a medium strikes a reflecting surface, it goes back into the same medium obeying certain laws. This phenomenon is known as reflection of light.

Laws of reflection. 1. The incident ray, the normal to the reflecting surface at the point of incidence and the reflected ray all lie in the same plane.

2. The angle of incidence (i) is always equal to the angle of reflection (r).

mirror.

Relation between f and R: f =R/2 According to new cartesian sign conventions, both f and R, are taken as negative for a concave mirror and positive for a convex mirror.

Mirror formula $\mathbf{1/v} + \mathbf{1/u} = \mathbf{1/f}$ where u and v denote the object and image distances from the pole of the mirror.

Linear magnification. The ratio of the size of the image (formed by the mirror) to the size of the object is called linear magnification produced by the mirror. Mathematically- m = $\boldsymbol{I/O} = -\boldsymbol{v/u} = \boldsymbol{f/f-u} = \boldsymbol{f-v/f}$

Refraction.

The phenomenon of change in the path of light as it goes from one medium to another is called refraction.

Laws of refraction.

1. The incident ray, the normal to the refracting surface at the point of incidence and the refracted ray all lie in the same plane.

2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for any two- given media. It is called Snell's law.

Mathematically- $\boldsymbol{\sin i / \sin r} = n_{21}$

Absolute retractive index (n).

The absolute refractive index of a medium is defined as the ratio of the velocity of light in vacuum (c) to the velocity of light in that medium (v).

Refractive index in terms of real depth and apparent depth

When an object is placed in an optically denser medium, the apparent depth of the object is always less than its real depth.

$\boldsymbol{Real\ depth / Apparent\ depth} = n_{21}$

Total internal reflection.

The phenomenon of reflection of light that takes place when a ray of light travelling in a denser medium gets incident at the interface of the two media at an angle greater than the critical angle for that pair of media.

$\boldsymbol{1/\sin} i_c = n_{21}$ is refractive index of the denser medium 2 w.r.t. the rarer medium 1 and i_c is the critical angle.

Refraction at a Spherical refracting surface.

The portion of a refracting medium, whose curved surface forms the part of a sphere, is called spherical refracting surface.

When object is situated in the rarer medium, the relation is

$- n_1/\boldsymbol{u} + n_2/\boldsymbol{v} = (n_2 - n_1)/R$

When the object is situated in denser medium, the relation is

$- n_2/u + n_1/v = (n_1 - n_2)/R$

Lens maker's formula.

The relation connecting the focal length of the lens with the radii of curvature of its two surfaces and the refractive index of the material of the lens is called lens maker's formula.

$1/f = (n - 1)(1/R_1 - 1/R_2)$ where n is n_2/n_1

Thin Lens formula.

The relation between the focal length, the object and image distances is called lens formula. $1/v - 1/u = 1/f$

Linear magnification.

The ratio of the size of the image (formed by the lens) to the size of the object is called linear magnification produced by the lens.

$m = I/O = -v/u = f/(f+u) = (f-v)/f$

Power of a lens.

It is defined as the reciprocal of the focal length of the lens in metre.

$P = 1/f = (n - 1)(1/R_1 - 1/R_2)$

Combination of thin lenses in contact.

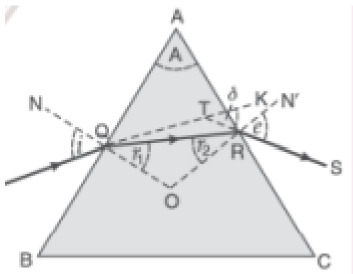
When two lenses of focal lengths f_1 and f_2 are placed in contact

the focal length of the combination is given by $1/f = 1/f_1 + 1/f_2$

Power of the equivalent lens: $P = P_1 + P_2$

Magnification produced by equivalent lens: $m = m_1 m_2$

Refraction through a prism.



A prism is the portion of a transparent refracting medium bound by two plane surfaces meeting each other along a straight edge. When a ray of light is incident on one face of a prism having angle of prism equal to A at an angle of incidence i, it suffers successive refractions at the two surfaces (angles of refraction at the two surfaces are r_1, and r_2 respectively) and then emerges out of it making an angle of emergence equal to e. Due to refraction at the two surfaces, the incident ray deviates from its path through an angle δ, called angle of deviation.

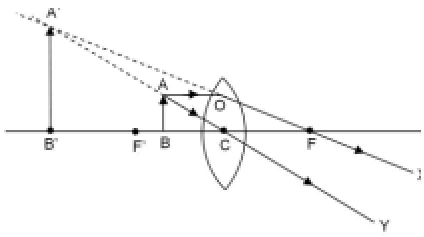
1. $A = \boldsymbol{r1} + \boldsymbol{r2}$

2. $A + \delta = I + e$

3. $n = \frac{\sin\{(A+Dm)/2\}}{\sin A/2}$ (when the prism is placed in minimum deviation position)

4. $\boldsymbol{\delta} = A(n-1)$ (when angle of prism is small)

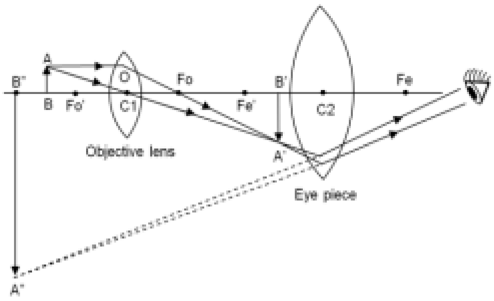
<u>Simple microscope</u>.



A convex lens of small focal length is called a simple microscope or a magnifying glass. The magnifying power of a microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object seen directly, when both lie at the least distance of distinct vision. $m = 1 + D/f$

When the image is formed at infinity ,$m=D/f$

<u>Compound microscope</u>.



A compound microscope is a two-lens system (object lens and eye lens of focal lengths f, and f,). Its magnifying power is very large, as compared to the simple microscope.

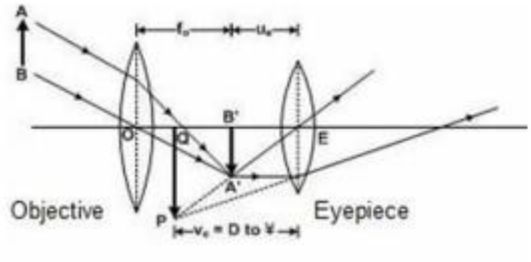
When the image is formed at the least distance of distinct vision, the magnifying power is given by m $=m_o m_e= \frac{vo}{uo}(\boldsymbol{1} + \boldsymbol{D}/\boldsymbol{fe}) = \frac{L}{fo}(\boldsymbol{1} + \boldsymbol{D}/\boldsymbol{fe})$

When the image is formed at infinity, the magnifying power is given by

$m = m_o m_e = \frac{L}{fo}(\boldsymbol{D/\,fe})$

Astronomical telescope.

Refracting Telescope



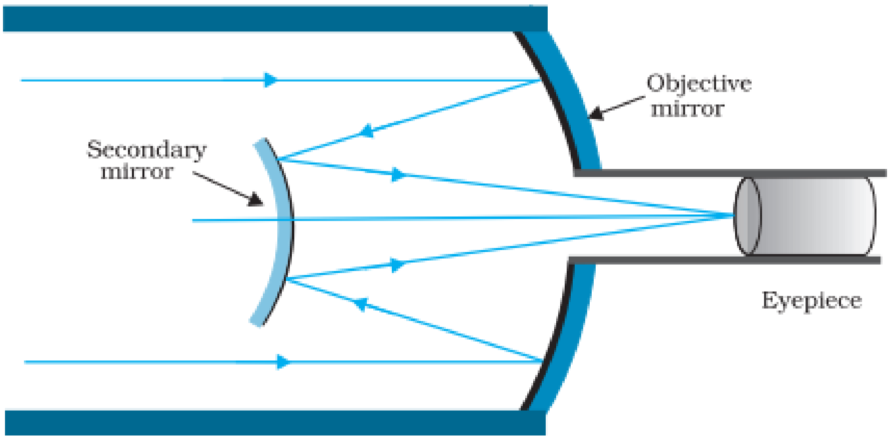
It is a two-lens system and is used to observe distant heavenly objects. It is called refracting type astronomical telescope. When the final image is formed at infinity, the telescope is said to be in normal adjustment.

Magnifying power $m = -f_o/f_e$

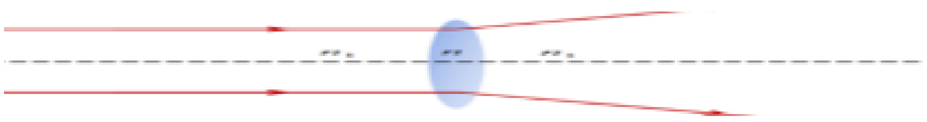
Length of the telescope tube is fo+fe

Reflecting Telescope

The telescopes with mirror objectives are called reflecting telescopes. There is no chromatic aberration in a mirror. Mechanical support is much less of a problem as it weighs much less than a lens of equivalent optical quality.



REFLECTION OF LIGHT BY SPHERICAL MIRRORS AND REFRACTION OF LIGHT BY LENSES

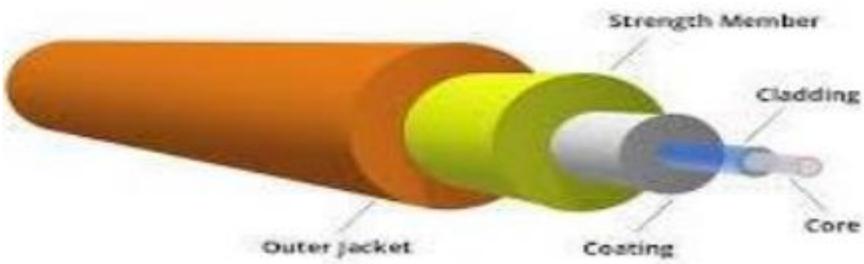
Q.No.	Multiple Choice Questions	MARKS
1	The wavelength of light in air is 6000 A^0 and in medium its value is 4000 A^0. It means that the refractive index of that medium with respect to air is (a) 1.2 (b) 2.4 (c) 0.66 (d) 1.5	1
2	Which of the following is not due to total internal reflection? (a) Working of optical fibre (b) Difference between apparent and real depth of a pond (c) Mirage on hot summer days (d) Brilliance of diamond	1
3.	A screen is placed 90 cm from an object. The image of the object on the screen is formed by a convex lens at two different locations separated by 20 cm, then the focal length of the lens is (a) 21.4 cm (b) 15 cm (c) 10 cm (d) None of these	1
4	A double convex air bubble in water behaves as (a) Convergent lens (b) divergent lens (c) plane slab (d) concave mirror	1
5	If two thin lenses are kept coaxially together, then their power is proportional (R1, R2 radii of curved surfaces) to (a) R1 + R2 (b) (R1 R2)/ R1 + R2 (c) (R1 + R2)/R1 R2 (d) None of these	1
6.	Refractive index of water and glass are 4/3 and 5/3. A light ray is going to water from glass. Then, its critical angle will be: (a) $\sin^{-1}$ (4/5) (b) $\sin^{-1}$(5/6) (c) $\sin^{-1}$ (½) (d) $\sin^{-1}$ (2/1)	1
7.	A convergent lens will become less convergent in : (a) oil (b) water (c) both of (a) and (b) (d) none of these	1
8	What is the correct relation between the refractive indices n and n_1 if the behavior of light rays is as shown in the figure given below? 	1

	(a) $n_1 < n$ (b) $n1 > n$ (c) $n_1 = n$ (d) None of these	
9.	You are given four sources of light each one providing alight of a single colour- red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°.Which of the following statements is correct if the source of yellow light is replaced with that of other lights without changing the angle of incidence? (a) The beam of red light would undergo total internal reflection. (b) The beam of red light would bend towards normal while it gets refracted through the second medium. (c) The beam of blue light would undergo total internal reflection (d) The beam of green light would bend away from the normal as it gets refracted through the second medium.	1
10	The radius of curvature of the curved surface of a plano-convex lens is 20cm .If the refractive index of the material of the lens be 1.5, it will (a) Act as a convex lens only for the objects that lie on its curved side. (b) Act as a concave lens for the objects that lie on its curved side. (c) Act as a convex lens irrespective of the side on which the objects lies. (d) Act as a concave lens irrespective of the side on which the object lies.	1
	ASSERTION AND REASON QUESTIONS **For questions 6 and 7, there are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate Answer from the options given below:** **(a) Assertion is true, reason is true; reason is a correct explanation for assertion. (b) Assertion is true, reason is true; reason is not a correct explanation for assertion (c) Assertion is true, reason is false** **(d) Assertion is false, reason is true.**	
11	Assertion: When a convex lens (µg= 3/2) of focal length f is dipped in water, its focal length becomes (4/3)f . Reason: The focal length of convex lens in water becomes 4f.	1
12	Assertion: Light travels faster in glass than in air Reason: Glass is denser than air	1
13.	Assertion: Rear view mirror in vehicles is a convex mirror Reason: A convex mirror has much larger field of view than a plane mirror.	1
14	Assertion: The edges of the images of white object formed by a concave mirror on the screen appear white. Reason: Concave mirror does not suffer from chromatic aberration.	1
15.	Assertion: In optical fibre, the diameter of the core is kept small.	1

	Reason: The smaller diameter of the core ensures that the fibre should have incident angle more than the critical required for total internal reflection	
	NUMERICAL BASED QUESTIONS	
16.	Find the radius of curvature of the convex surface of a plano-convex lens, whose focal length is 0.3 m and the refractive index of the material of the lens is 1.5.	2
17.	What is the focal length of a combination of a convex lens of focal length 30 cm and a concave lens of focal length 20 cm in contact? Is the system a converging or a diverging lens? Ignore thickness of lenses.?	3
18.	Two lenses of powers 10 D and − 5 D are placed in contact. (i) Calculate the power of the new lens. (ii) Where should an object be held from the lens, so as to obtain a virtual image of magnification 2?	3
	GRAPH BASED QUESTIONS	
19.	A mirror forms a real image of an object. The distance of the object to the mirror is u cm and the distance of the image from the mirror is v cm. Draw a graph showing the variation of v with u .What is the nature of the mirror and explain how you use the u-v graph to find the focal length of the mirror.	3
20.	The following data was recorded for values of object distance and the corresponding values of image distance in the experiment on study of real image formation by a convex lens of power +5D. Draw u-v graph. Also identify the incorrect observation in the given data and justify it.	3

Sl.No.	1	2	3	4	5	6
Object Distance (u) cm	25	30	35	45	50	55
Image Distance(v)cm	97	61	37	35	32	30

	DIAGRAM BASED QUESTIONS	
21.	Draw a ray diagram to show how a right isosceles prism made of crown glass can be used to obtain the inverted image .	2
	CASE STUDY BASED QUESTIONS	
22.	A lens is a portion of transparent refracting medium bound by two spherical refracting surfaces or one spherical surface and the other plane surface. A lens behaves according to the medium in which it is present. The lens maker‘s formula is the relation between radii of curvature of bounding surfaces and the refractive index of the material of the lens . In an activity picture is stuck on the exterior curved surface of the transparent glass jar such that the side of the paper with picture is facing the interior of the jar. The picture is observed from the diametrically opposite end. According to different conditions following observations are noted and concluded that a convex lens (or concave lens) made up of material with refractive index n_2 behaves as a converging lens (or	3

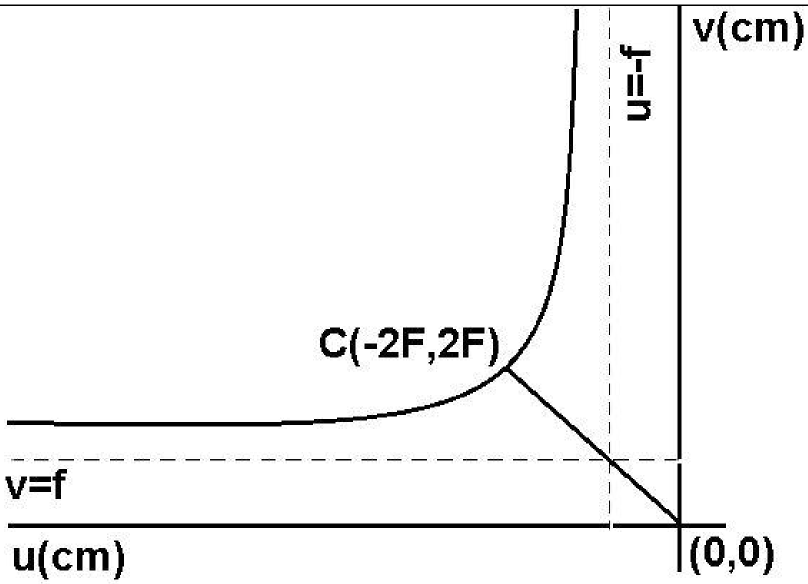
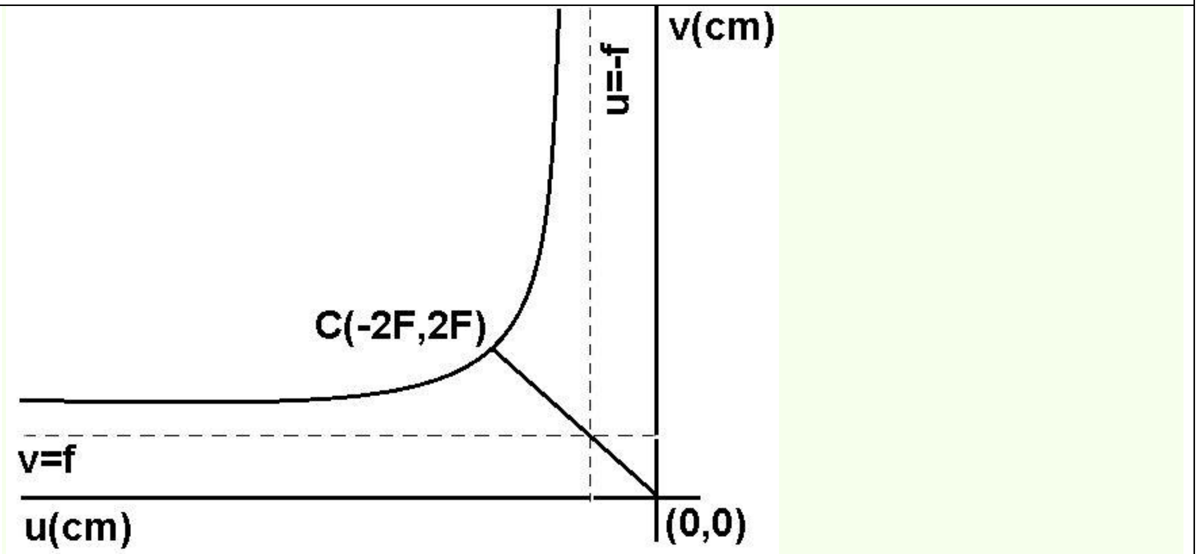
	diverging lens) when placed in a medium of refractive index n_1 if $n_2>n_1$and vice-versa. (i) What is the focal length of a double convex lens(n=3/2) if radius of curvature of its surfaces is 15cm? (ii) A glass lens is immersed in water. What will be the effect on the power of lens? *(iii)* A convex lens made of a material of refractive index n_1 is kept in a medium of refractive index n_2 .Parallel rays of light are incident on the lens. Complete the path of rays of light emerging from the convex lens if (i) $n1 > n2 (ii) n1 < n2 (iii) n1 = n2$	
23.	 An optical fibre is a structure comprising of thin rod of high-quality glass of refractive index n1 surrounded by a medium of refractive index n_2. Very little light is absorbed by the glass. Light getting in at one end undergoes repeated total internal reflection, even when the fibre is bent, and emerges at the other end. All rays with angle of incidence θi less than critical angle θc are confined inside optical fibre. (i). What should be the refractive index of core and cladding of optical fibre? (ii). What are the uses of optical fibres? (Any two) (iii) Calculate the speed of light in a medium whose critical angle is 45°	2
	HOTS QUESTIONS	
24.	A beam of light converges at a point P. Now a convex lens is placed in the path of the convergent beam at 15 cm from P. At what point does a beam converge if the convex lens has a focal length 10cm	2
25.	(a) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2.Find the location of the image also. (b) Using mirror formula, explain why a convex mirror always produces a virtual image independent of the location of the object.	3
	STATEMENT QUESTIONS	
26.	State Snell's law of refraction and define absolute refractive index of a medium .	2

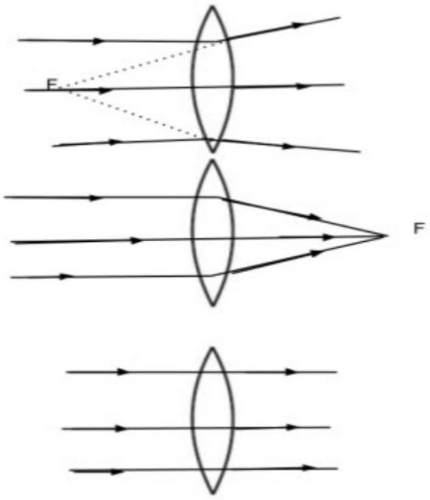
27.	State the conditions under which total internal reflection takes place? Define critical angle and establish its relationship with refractive index.	3
	DERIVATION QUESTIONS	
28.	Trace the rays of light showing the formation of an image due to a point object placed on the axis of a spherical surface separating the two media of refractive indices n1 and n2. Establish the relation between the distances of the object, the image and the radius of curvature from the central point of the spherical surface. Hence derive the expression of the lens maker's formula.	5
29.	Derive the relation between object distance u, image distance v and focal length f for a concave mirror ,when it forms a real image of an object of finite size.	5

ANSWERS

QUESTION NUMBER	ANSWER	QUESTION NUMBER	ANSWER
1	**d**	**9**	**c**
2	**b**	**10**	**c**
3	**a**	**11**	**d**
4	**b**	**12**	**d**
5	**c**	**13**	**a**
6	**b**	**14**	**a**
7	**b**	**15**	**c**
8	**a**		

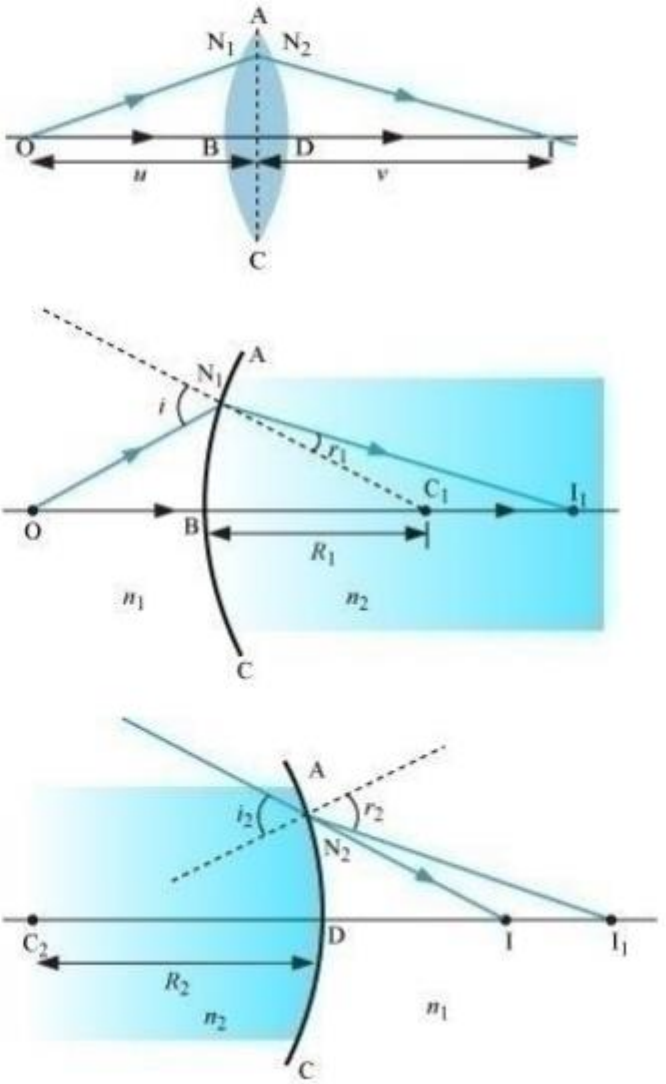
Q.NO	VALUE POINTS
16	The focal length of a combined lens can be determined by the formula $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ Here, $R_2=\infty$ and $f=0.3$ m $\frac{1}{0.3}=(\mu-1)\times\frac{1}{R_1}$ $R_1=0.3(\mu-1)$ $=0.3(1.5-1)$ $=0.3\times0.5$ $=0.15$ m $=15$ cm
17	Given f1 = + 30 cm, f2 = – 20 cm The focal length (F) of combination of given by $1/F = 1/f1 + 1/f2$ F = $f1f2\ f1+f2 = 30\ x-20\ 30+(-20)$ = -60cm That is, the focal length of combination is 60 cm and it acts like a diverging lens
18	(i) Power of new lens, P = P1 + P2 ∴P = 10 − 5 = + 5 D (ii) Here, u =? (ii) Here, u =? $f=\frac{1}{P}=\frac{1}{5}m=\frac{100}{5}$ cm = 20 cm $m=2$ i.e., $\frac{-v}{-u}=2$ or $v=2u$ Using lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ $\frac{1}{20}=\frac{1}{2u}-\frac{1}{u}$ $\frac{1}{20}=\frac{1-2}{2u}\Rightarrow\frac{1}{20}=-\frac{1}{2u}\therefore u=-110$ cm

	∴ Object distance = 10 cm
19	 The mirror is a concave mirror as it forms a real image. The u and v values corresponding to point C gives 2f , half of which gives the value of focal length of the mirror
20	 Power of the lens =+5D. Focal length of the lens=$\frac{1}{p}$ =$\frac{1}{5}$=0.20m=20cm The observations at serial No.3 is incorrect because if the object is placed at a distance between fand 2f its image will be formed beyond 2f ,but in this observation , the object and image distances are between f and 2f.
21	Refer FIGURE 9.13 (b) of Page No.231 of NCERT TEXTBOOK
22	

	(i) The focal length of the lens is 15cm by using Lens maker's formula. (ii) The power decreases as it is proportional to the rrefractive index. (iii) The diagrams corresponding to the three different cases ; n2<n1 n2>n1 n1=n2 are given below respectively, 
23	(i) The refractive index of core should be greater than that of cladding. (ii) Endoscopy, Communication (iii) Critical Angle, i_c =45°, Refractive index, μ=$\frac{1}{sin\mathrm{c}} = \frac{1}{sin45} = \sqrt{2}$, μ=c/v, So v=c/μ=$3*10^8/\sqrt{2}=2.1*10^8$ ms^{-1}
24	f = +10cm u = +15cm lens equation 1/ f = 1/ v – 1/ u 1/10 = 1/ v – 1/ +15 1/ v = 1 /10 + 1 /15 = 3+ 2 /30 1 /v = 5 /30 v = **6cm**
25	Concave mirror f=−10cm and m=−2 height of object=h Since m=-v/u = 2 =hi/h v=−2u So, from mirror formula u/v=u/f-1 m=-v/u=f/f-u

	-2= f/f-u Solving above equation we will get u= -15 cm Substituting in magnification formula v= -30 cm
26	Refer Page No.228 of NCERT TEXTBOOK for the statement of Snell's Law. Absolute refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in the medium.
27	The conditions for the total internal reflection to take place: 1.The ray of light should travel from denser medium to rarer medium. 2.The angle of incidence must be greater than the critical angle. Refer Page No.230 for the relation between critical angle and refractive index.

28



In the given figure, image is I and object is denoted as O. The centre of curvature is C. The rays are incident from a medium of refractive index to another of refractive index . We consider NM to be perpendicular to the principal axis

$$\tan \angle NOM = \frac{MN}{OM}$$

$$\tan \angle NCM = \frac{MN}{MC}$$

$$\tan \angle NIM = \frac{MN}{MI}$$

For ΔNOC, i is the exterior

Therefore, $i = \angle NOM + \angle N$

$$i = \frac{MN}{OM} + \frac{MN}{MC}$$

Similarly,

$r = \angle NCM - \angle NIM$

i.e., $r = \frac{MN}{MC} - \frac{MN}{MI}$

According to Snell's law, For small angles

$n_1 i = n_2 r$

$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

Where, OM, MI, and MC are the distances

$OM = -u$

$MC = +R$

$MI = v$

Substituting these, we obtain Applying equation (i) to lens ABCD

we obtain for surface ABC

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1} \qquad ...(ii)$$

For surface ADC, we obtain

$$\frac{-n_2}{DI_1} + \frac{n_1}{DI} = \frac{n_2 n_1}{DC_2} \qquad ...(iii)$$

For a thin lens,

$BI_1 = DI_1$

Adding (ii) and (iii), we obtain

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

Suppose object is at infinity and $DI = f$, then

$$\frac{n_1}{f} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

Using sign convention,

$$BC_1 = +R_1$$
$$DC_2 = -R_2$$

We obtain:

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$n_{21} = \frac{n_2}{n_1}$$

n_{21} → Refractive index of medium 2 with respect to medium 1

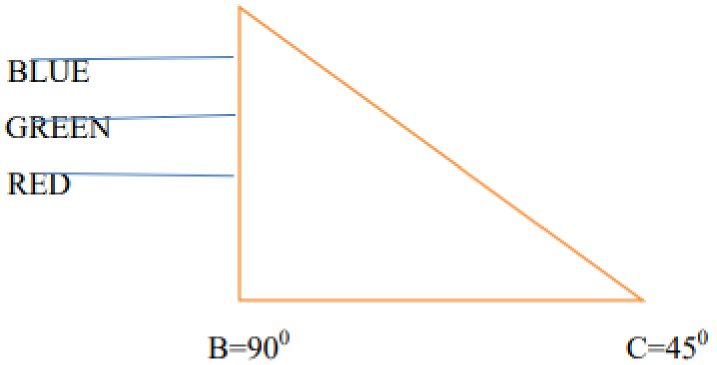
This is known as lens maker's formula.

29	Refer Page No .224 of NCERT TEXTBOOK

REFRACTION THROUGH A PRISM AND OPTICAL INSTRUMENTS

<table>
<tr><th>Q.No.</th><th>Multiple Choice Questions</th><th>MARKS</th></tr>
<tr><td>1</td><td>The refractive index of water and glass are 4/3 and 5/3. A light ray is going to water from glass. Then, its critical angle will be:

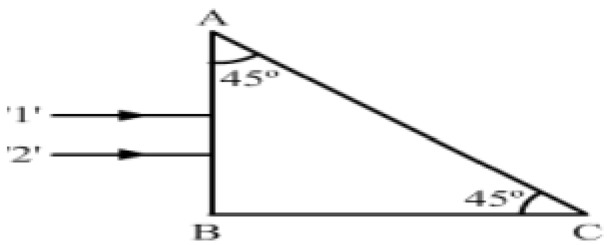
(a) $\sin^{-1}$ (4/5) (b) $\sin^{-1}$ (5/6) (c) $\sin^{-1}$ (1/2)(d) $\sin^{-1}$ (2/1)</td><td>1</td></tr>
<tr><td>2</td><td>A beam of light consisting of red, green, and blue colours is incident on a right-angled prism. The refractive index of the material of the prism for the above red, green, and blue wavelengths are 1.39,1.44 and 1.47 respectively (II

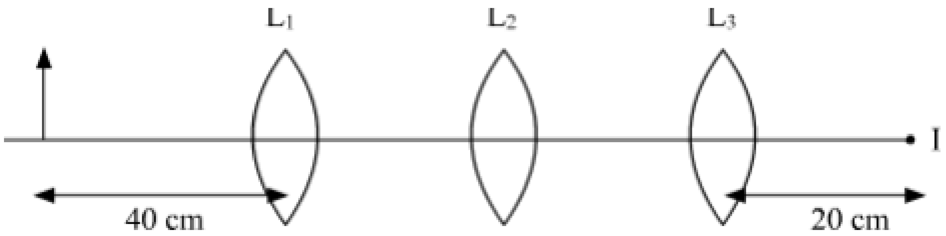


The prism will
(a) Separate part of the red colour from the green and blue colours
(b) Separate part of the blue colour from the red and green colours
(c) Separate all the three colours from each other
(d) Not separate even partially any colour from the other two colours</td><td>1</td></tr>
<tr><td>3.</td><td>The magnifying power of an astronomical telescope in normal adjustment is 100. The distance between the objective and the eyepiece is 101 cm. The focal length of the objectives and eyepiece is
(a) 10 cm and 1 cm respectively
(b) 100 cm and 1 cm respectively
(c) 1 cm and 100 cm respectively
(d) 1 cm and 10 cm respectively</td><td>1</td></tr>
<tr><td>4</td><td>You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope?

<table><tr><td>Lenses</td><td>Power (D)</td><td>Aperture (cm)</td></tr><tr><td>L_1</td><td>3</td><td>8</td></tr><tr><td>L_2</td><td>6</td><td>1</td></tr><tr><td>L_3</td><td>10</td><td>1</td></tr></table></td><td>1</td></tr>
</table>

	(a) Objective-L_1 & Eyepiece-L_3 (b) Objective-L_2 & Eyepiece-L_3 (c) Objective-L_3 & Eyepiece-L_2 (d) Objective-L_3 & Eyepiece-L_1	
5	You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct a compound microscope? Lenses / Power (D) / Aperture (cm): L_1 / 6 / 2 L_2 / 3 / 8 L_3 / 10 / 1 a) Objective-L_1 & Eyepiece-L_3 (b) Objective-L_2 & Eyepiece-L_3 (c) Objective-L_3 & Eyepiece-L_2 (d) Objective-L_3 & Eyepiece-L_1	1
	ASSERTION AND REASON QUESTIONS **For questions 6 and 7, there are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate Answer from the options given below:** **(a) Assertion is true, reason is true; reason is a correct explanation for assertion. (b) Assertion is true, reason is true; reason is not a correct explanation for assertion (c) Assertion is true, reason is false** **(d) Assertion is false, reason is true.**	
6	Assertion (A): If objective and eye lenses of a microscope are interchanged, then it can work as telescope. Reason(R) : The objective of telescope has small focal length.	1
7	Assertion (A): A total reflecting prism is used to erect the inverted image without deviation. Reason (R): Rays of light incident parallel to base of the prism emerge out as parallel rays.	1
	NUMERICAL BASED QUESTIONS	
8.	A ray of light incident on an equilateral glass prism shows minimum deviation of 30°. Calculate the speed of light through the glass prism.	2
9.	A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope.	3

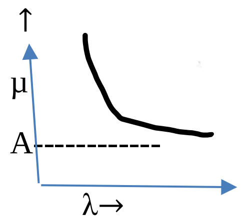
10	A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope. If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.42×10^6 m, and the radius of the lunar orbit is 3.8×10^8 m.	3
	GRAPH BASED QUESTIONS	
11.	Draw a graph showing the variation of angle of deviation with angle of incidence for a triangular prism. Explain why any given value of angle of deviation, corresponds to two values of angle of deviation.	2
12.	It is known that the refractive index ,μ of the material of a prism depends on the wavelength λ of the incident radiation as per the relation $\mu = A + B/\lambda^2$ where A and B are constants. Plot a graph showing the dependence of μ on λ and identify the pair of variables that can be used here to get a straight-line graph	2
	DIAGRAM BASED QUESTIONS	
13	Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering the prism.  	3
14	Draw a labeled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope.	3
	CASE STUDY BASED QUESTIONS	
15	A prism is a transparent medium enclosed by two plane refracting surfaces. When a monochromatic ray of light incidents on one of the faces , it gets refracted and falls on the second refracting face. It undergoes refraction once again and emerges out. This ray is called emergent ray and it deviates from the incident ray. As the angle of incidence increases the angle of deviation decreases , reaches a minimum value and then increases. (i) Write the relation between angle of prism, angle of deviation ,angle of incidence and angle of emergence. (ii) When the prism is in the minimum deviation position, what is the relation between angle of incidence and angle of emergence? (iii) A prism is made of glass of unknown refractive index. A parallel beam of light is incident on the face of a prism. The angle of minimum deviation is measured to be 40°.What is the refractive index of the	3

	material of the prism? The refracting angle of the prism is 60°.	
16.	An astronomical refracting telescope consists of two coaxial cylindrical tubes ,out of which one tube is long and wide, while the other tube is small and narrow . The narrow tube may be moved in and out of the wide tube by rack and pinion arrangement . At one end of the wide tube an achromatic convex lens is placed which faces the object and is called objective .The narrow tube is towards eye and carries an achromatic convex lens of small focal length and small aperture on its outer end. This is called eyepiece. (i) What is the length of the telescope in its normal adjustment position? (ii) State two limitations of refracting telescope . (iii) A small telescope has an objective lens of focal length 140cm and an eyepiece of focal length 5cm. If this telescope is used to view a 100m tall tower 3km away ,what is the height of the image of the tower formed by the objective lens?	3
	HOTS QUESTIONS	
17.	At what angle should a ray of light be incident on the face of a prism of refracting angle 60° so that it just suffers total internal reflection at the other face? The refractive index of the prism is 1.524	3
18.	You are given three lenses L1, L2 and L3 each of focal length 20 cm. A object is kept at 40 cm in front of L1, as shown. The final real image is formed at the focus _I' of L3. Find the separation between L1, L2 and L3.  	3
	STATEMENT QUESTIONS	
19.	What is the angle of deviation produced by a prism when a ray of light undergoes refraction through a prism? State the factors on which the angle of deviation depends .	3
20	Define magnifying power of a refracting telescope and write the two important factors to be considered to increase the magnifying power.	2
	DERIVATION QUESTIONS	
21	Obtain the relation between the refractive index of the material of the prism, angle of prism and angle of minimum deviation.	5
22.	Draw a ray diagram for a compound microscope. Derive an expression for the magnifying power when the final image is formed at the least distance of distinct vision. Write the equation for the magnifying power when the final image is formed at infinity.	5

ANSWERS

QUESTION NUMBER	ANSWER	QUESTION NUMBER	ANSWER
1	b	5	d
2	a	6	d
3	b	7	a
4	a		

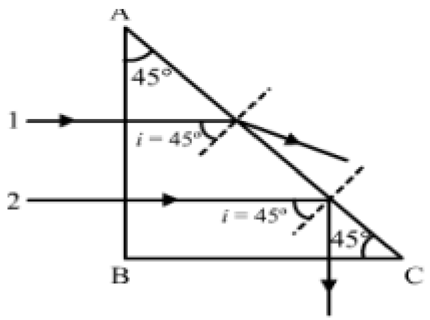
Q No.	Value points
8.	n=c/v ,v=c/n, n=$\frac{sin45}{sin30} = \frac{1/\sqrt{2}}{\frac{1}{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}$ (By using prism formula) v=$\frac{c}{\sqrt{2}}$ ms^{-1}
9.	$\frac{1}{fo} = \frac{1}{vo} - \frac{1}{uo}$,f_o=4cm,u_o=-6cm,substitutingin the equation ,we get v_o=12 cm. Magnification of the microscope is $m=m_om_e = \frac{vo}{uo}(1+\frac{D}{fe}) = \frac{12}{-6}(1+\frac{25}{10}) = -7$, negative sign indicates that the image is inverted. The length of the microscope is vo+ u, u=$\lvert u_e \rvert$ is the object distance for the eyepiece. And u_e can be found using, $\frac{1}{fe} = \frac{1}{D} - \frac{1}{ue}$ as D is the image distance for the eyepiece. Substituting f_e as 10cm and D as -25cm,we get u_e=-7.14cm Length of the microscope=12+7.14=19.14cm
10.	Refer the answer for exercise question 9.14 of NCERT TEXTBOOK
11.	Refer i-d graph from NCERT TEXTBOOK Any given value of deviation corresponds to two values of angle of incidence except for angle of minimum deviation. This is as per the equation, δ=i+e-A , angle of deviation remains the same if i and e are interchanged.
12.	$\mu=A+B/\lambda^2$,hence μ is inversely proportional to λ^2. Also, as $\lambda \to \infty, \mu \to A$. So the graph between $\mu$and λ is a parabola as shown below.



To get a straight-line graph, the pair of variables that can be used here are

μ and $1/\lambda^2$

13. Critical angle of ray 1: $\sin(c_1)=1.35 \Rightarrow c_1=\sin-1(1.35)=47.73°$ Similarly, critical angle of ray 2: $\sin(c_2)= 1.45 \Rightarrow c2=\sin-1(1.45)=43.6°$ Both the rays will fall on the side AC with angle of incidence (i) equal to 45°. The critical angle of ray 1 is greater than that of i. Hence, it will emerge from the prism, as shown in the figure. The critical angle of ray 2 is less than that of i. Hence, it will be internally reflected, as shown in the figure.



14. Refer Page No.245 and 246 NCERT TEXTBOOK for the correct answer and ray diagram.

15. (i) $A+\delta=i+e$

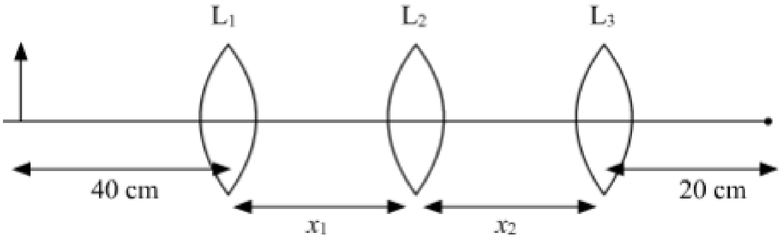
(ii) When the prism is in the minimum deviation position, i=e

(iii)Refer the answer for exercise question 9.6 on Page No. 249 of NCERT TEXTBOOK

16. (i)Length of the telescope $L=f_0 + f_e$

(ii) The limitations are:

It suffers from chromatic aberration.

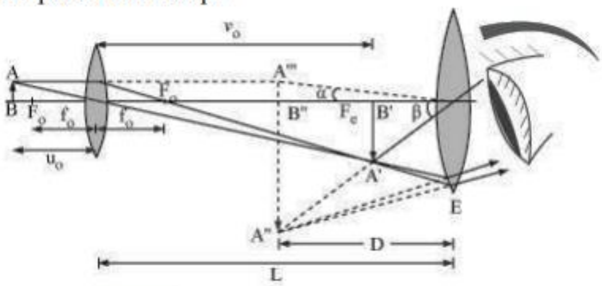
	It suffers from spherical aberration. (iii)Angle subtended by 100 m tower at 3km away is α=tan α=100/3000=$\frac{1}{30}$ Let h be the height of image of tower formed by objective. The angle subtended by image produced by objective will also be equal to α. α=$\frac{h}{fo}$ = $\frac{h}{140}$ = $\frac{1}{30}$ .So h=$\frac{140}{3}$ =4.67 cm
17.	Refer the answer for exercise question 9.21 on page No. 251 of NCERT TEXTBOOK
18.	 Here f1 = f2 = f3 = 20 cm Now, u1 = −40 cm from lens makers formula $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$ $\frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1}$ $= \frac{1}{20} + \frac{1}{-40}$ $= \frac{2-1}{20} = \frac{1}{40}$ $v_1 = 40 \text{cm}$ Here, image by L3 is formed at focus. So the object should lie at infinity for L3. Hence, L2 will produce image at infinity. So, we can conclude that object for L2 should be at its focus. But, we have seen above that image by L1 is formed at 40 cm right of L1 which is at 20 cm left of L2(focus of L2). So X1 = distance between L1 and L2 = (40 + 20) cm = 60 cm Again distance between L2 and L3 does not matter as the image by L2 is formed at infinity so X2can take any value.
19	Refer Page No.239 of NCERT TEXTBOOK for the defintion of angle of deviation . Factors on which angle of deviation depends: Angle of incidence, the wavelength of the light used, the material of the prism and angle of prism.
20	Refer Page No.244 of NCERT TEXTBOOK for the defintion of magnifying power of refracting telescope.

The factors to be considered to increase the magnifying power:

The focal length and aperture of the objective have to be increased.

21 Refer Page No.239 of NCERT TEXTBOOK .

22 Ray diagram for a compound microscope



Total angular magnification, β → Angle subtended by the image α → Angle subtended by the object Since α and β are small

$\tan\alpha \approx \alpha$ and $\tan\beta \approx \beta$

$$m = \frac{\tan\beta}{\tan\alpha}$$

$$\tan\alpha = \frac{AB}{D}$$

And

$$\tan\beta = \frac{A''B''}{D}$$

$$m = \frac{\tan\beta}{\tan\alpha} = \frac{A''B''}{D} \times \frac{D}{AB} = \frac{A''B''}{AB}$$

On multiplying the numerator and the denominator with A′B′, we obtain

$$m = \frac{A''B'' \times A'B'}{A'B' \times AB}$$

Now, magnification produced by objective, $m_0 = \frac{A'B'}{AB}$

Magnification produced by eyepiece, $m_e = \frac{A''B''}{AB}$

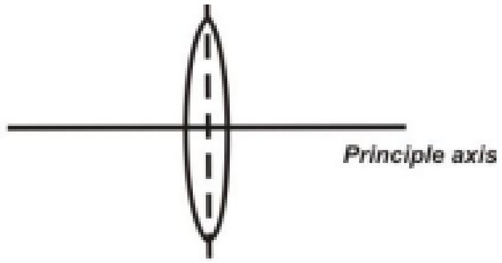
Magnification produced by eyepiece,

Therefore, Total magnification, (m) = m0 me

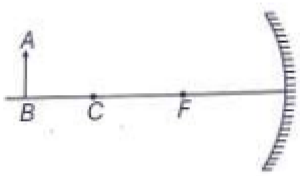
	$m_0 = \frac{v_0}{u_0} = \frac{\text{(Image distance for image produced by objective lens)}}{\text{(Object distance for the objective lens)}}$ $m_e = \left(1 + \frac{D}{f_e}\right)$ $_e \rightarrow$ Focal length of eyepiece $m = m_0 m_e$ $= \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ $v_0 \approx \mathrm{L}$ (Separation between the lenses) $u_0 \approx -f_0$ $\therefore m = \frac{-\mathrm{L}}{f_0}\left(1 + \frac{D}{f_e}\right)$

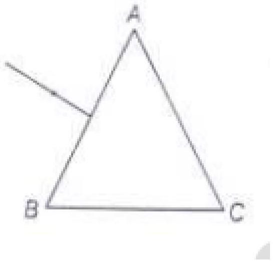
SELF EVALUATION TEST

MAX.MARKS :70 **TIME:3Hrs.**

Q.No.	**SECTION A**	MARKS
1.	What is the magnification and focal length of a plane mirror. (a) +1, ∞ (b) +1, 0 (c) −1, ∞ (d) −1, 0	1
2.	An equiconvex lens of focal length 15 cm is cut into two halves as shown in figure. Find the focal length of each part?  (a) -30cm (b) -20cm (c) 30cm (d) -15cm	1
3.	A glass lens is immersed in water. What will be the effect on the power of lens? (a) increase (b) decrease (c) constant (d) no effect	1
4.	Two lenses of focal lengths 20 cm and - 40cm are held in contact. If an object lies at infinity, image formed by the lens combination will be at (a) infinity (b) 20cm (c) 40cm (d) 60cm	1
5.	The characteristic feature of light which remains unaffected on refraction is (a) speed (b) frequency (c) wavelength (d) velocity of light	1
6.	If two thin lenses of power P_1 and P_2 are held in contact, then the power of the combination will be (a) $P_1 P_2$ (b) $P_1 - P_2$ (c) $P_1 + P_2$ (d) P_1 / P_2	1
7.	Optical fibres are based on the phenomenon of (a) reflection (b) refraction (c) dispersion (d) total internal reflection	1
8.	How does the magnifying power of a telescope change on increasing the linear diameter of its objective? (a) Power increases on increases diameter (b) Power decreases on decreases diameter (c) Power remains constant on increases diameter (d) Power doesn't depend on diameter	1
9.	How does the focal length of a convex lens change if mono chromatic red	1

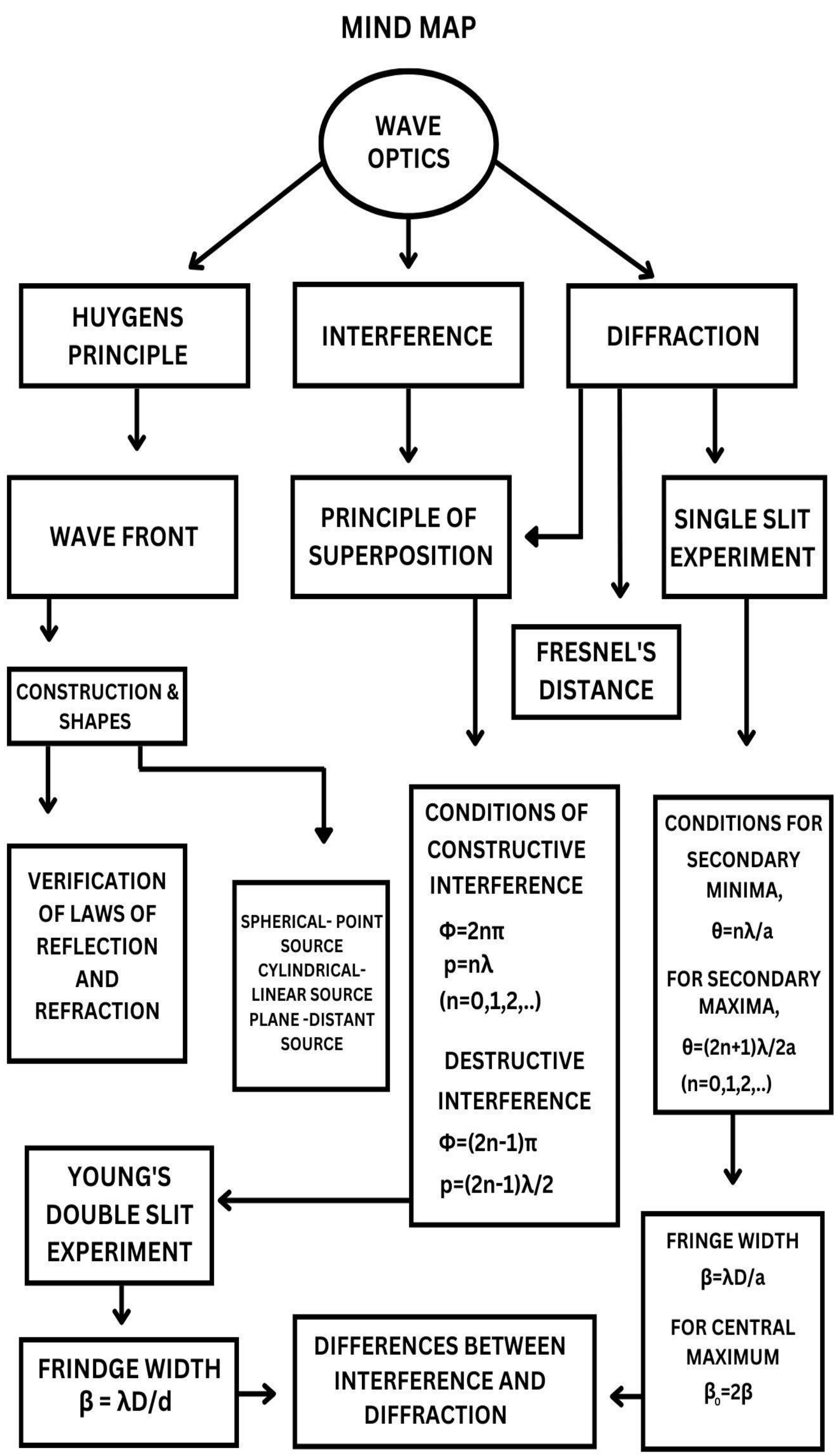
	light is used instead of violet light? (a) Focal length is increased when red light is used (b) Focal length is decreased when red light is used (c) Focal length is remained same when red light is used (d) Not depends on color of light.	
10.	An object approaches a convergent lens from the left of the lens with a uniform speed of 5 m/s and stops at the focus. The image (a) moves away from the lens with a uniform speed of 5 m/s. (b) moves away from the lens with uniform acceleration. (c) moves away from the lens with a non-uniform acceleration. (d) moves towards the lens with a non-uniform acceleration	1
11.	When the plane surface of a planoconvex lens of refractive index 1.5 is silvered ,it behaves like a concave mirror of focal length 30 cm. When its convex surface is silvered, it will behave like a concave mirror of focal length (a) 10 cm (b) 20 cm (c) 30 cm (d) 45 cm	1
12.	For the same angle of incidence, the angles of refraction in three different medium A, B and C are 15°, 25°and 35°respectively. The velocity of light will be minimum in medium. (a) A (b) B (c) C (d) None of these **ASSERTION AND REASON QUESTIONS** **For questions 12 to 16, there are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate Answer from the options given below:** **(a) Assertion is true, reason is true; reason is a correct explanation for assertion. (b) Assertion is true, reason is true; reason is not a correct explanation for assertion (c) Assertion is true, reason is false (d) Assertion is** false**, reason is true.**	1
13.	Assertion**(A):** When a convex lens (µg= 3/2) of focal length f is dipped in water, its focal length becomes (4/3)f . Reason**(R) :**: The focal length of convex lens in water becomes 4f	1
14.	Assertion **(A):**Mirror formula is valid only for mirrors whose sizes are very small compared to their radii of curvature. Reason **(R) :** The laws of reflection are strictly valid for plane surfaces but not for large spherical surfaces.	1
15.	. Assertion **(A):** A pencil placed in a beaker filled with water appears to be tilted/ bent. Reason **(R):** A ray of light coming from denser medium to rarer medium bends away from the normal.	1
16.	Assertion**(A):** A ray of light entering from glass to air suffers change in	1

	frequency. Reason**(R):** Velocity of light in glass is more than that in air.	
	SECTION B	
17.	Use the mirror equation to show that an object placed between f and 2f of a concave mirror produces a real image beyond 2f.	2
18.	Draw a ray diagram to show the image formation when the concave mirror produces a real, inverted and magnified image of the object.	2
19.	The refractive index of diamond is much higher than that of glass. How does a diamond cutter make use of this fact?	2
20.	Light from a point source in air falls on a spherical glass surface (n = 1.5 and radius of curvature 20 cm). The distance of the light source from the glass surface is 100 cm. At what position the image is formed?	2
21.	A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.	2
	SECTION C	
23.	An object AB is kept in front of a concave mirror as shown in the figure.  (i) Complete the ray diagram showing e image formation of the object. (ii) How will the position and intensity or image be affected, if the lower half of the mirror's reflecting surface is painted black?	3
24.	A ray of light suffers minimum deviation, while passing through a prism of refractive index 1.5 and refractive angle 600. Calculate the angle of deviation and angle of incidence. (Given, $\sin^{-1}(0.75) = 48.60$)	3
25.	When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons. (i) Is the frequency of reflected and refracted light the same as the frequency of incident light? (ii) (ii) Does the decrease in speed imply reduction in the energy carried by the light wave?	3
26.	The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index 3/2, placed in water of refractive index 4/3. Will this ray suffer total internal reflection on striking the face AC? Justify your answer.	3

		
27.	Define power of a lens. Write its units. Deduce the relation for effective power of two thin lenses kept in contact coaxially.	3
28.	Draw a labelled ray diagram showing the formation of a final image by a compound microscope at infinity and write its magnifying power	3
29.	Draw a labelled ray diagram of a reflecting telescope. Write two important advantages of a reflecting telescope over a refracting type telescope.	3
	SECTION D	
30.	**Real and apparent depth** The object appears to be raised from its real position to apparent position (ie from O to I) . The distance through which the position of the object appears to be raised is called normal shift . The normal shift in the position of the objects depends upon the real depth of the object and the refractive index of the refracting medium. (i) Write the equation for refractive index of the denser medium with respect to the rarer medium. (ii) What is the apparent depth of a tank 3 m deep when viewed outside (refractive index of water is 4/3). (iii) .A mark at the bottom of a liquid appears to rise by 0.1m . The depth of the liquid is 1m. Calculate the refractive index of the liquid.	4
31.	The lens maker's formula relates the focal length of a lens to the refractive index of its material and the radii of curvature of its two surfaces . This formula is used to manufacture a lens of particular focal length from the glass of a given refractive index. For this reason , it is called the lens maker's formula. (i) Two thin lenses of focal lengths 60 cm and -20 cm are kept in contact. What is the focal length of the combination? (ii) .For a plano-convex lens of radius of curvature 10 cm the focal length is 30 cm . Find the refractive index of the material of the lens . (iii) In the case of thin lens of focal length f ,an object is placed at a distance X_1 from first focus and its image is formed at a distance X_2 from the second focus . Find X_1 and X_2	4

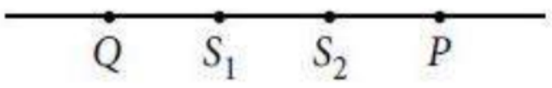
	SECTION E	
32.	With the help of a suitable ray diagram, derive the mirror formula for a concave mirror. Also write the equation for its linear magnification	5
33.	Draw a ray diagram to show the formation of the image of an object placed on the axis of a convex refracting surface, of radius of curvature 'R', separating the two media of refractive indices "n1 and 'n2' (n2 > n1). Use this diagram to deduce the relation n2/v−n1/u=n2−n1/R, where u and v represent respectively the distance of the object and the image formed.	5

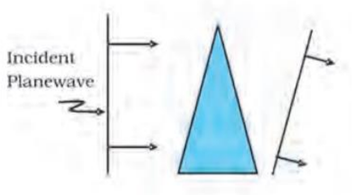
CHAPTER 10
WAVE OPTICS

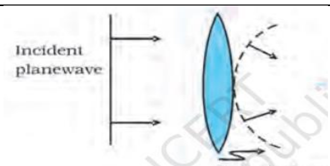
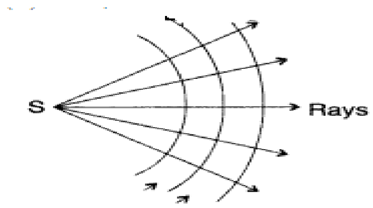
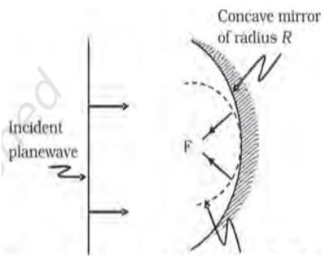


	WAVE OPTICS -1	
	GIST	
	Wave front and Huygens principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygens's principle.	
	MCQ	
1	The initial shape of the wavefront of the beam is (a) planar (b) convex (c) concave (d) convex near the axis and concave near the periphery	1
2	The speed of light in the medium is (a) maximum on the axis of the beam. (b) minimum on the axis of the beam. (c) the same everywhere in the beam (d) directly proportional to the intensity I.	1
3	As the beam enters the medium, it will (a) travel as a cylindrical beam. (b) diverge (c) converge (d) diverge near the axis and converge near the periphery.	1
4	Which one of the following phenomena is not explain by Huygens construction of wave front? (a) refraction (b) reflection (c) diffraction (d) origin of Spectra	1
5	Which one of the following statements is true? (a) both light and sound waves can travel in vacuum. (b) both the light and sound waves in air are transverse (c) the sound waves in air are longitudinal and while the light waves are transverse (d) both light and sound waves in air are longitudinal	1

6	The frequency of light wave in a material is 2×10^{14} Hz and wavelength are 5000 A °. The refractive index of material will be (a) 1.50 (b) 3 (c) 1.33 (d) 1.4	1
7	The wavefront due to a source situated at infinity is (a) Spherical (b) cylindrical (c) planar (d) circular	1
8	When a wave undergoes reflection at a denser medium, what happens to its phase? (a) 0 (b) π/3 (c) π/2 (d) π	1
9	If a wave undergoes refraction, what will be the phase change? (a) 0 (b) π/3 (c) π/2 (d) π	1
10	The phase difference between any two points of a wavefront is: (a) 0 (b) π/3 (c) π/2 (d) π	1
	ASSERTION - REASON	1
	For Questions 11 to 15, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below. **a)** If both Assertion and Reason are true and Reason is correct explanation ofAssertion. **b)** If both Assertion and Reason are true but Reason is not the correctexplanation of Assertion. **c)** If Assertion is true but Reason is false. **d)** If both Assertion and Reason are false.	

11	ASSERTION: According to Huygens's principle, no backward wave-front is possible. REASON: Amplitude of secondary wavelet is proportional to (1 + cos θ) where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.	1
12	ASSERTION: When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave. REASON: The energy of a wave is proportional to velocity of wave	1
13	ASSERTION: Two-point coherent sources of light S1 and S2 are placed on a line as shown. P and Q are two points on that line. If at point P maximum intensity is observed then maximum intensity should also be observed at Q.  REASON: In the figure of assertion the distance |S1P-S2P| is equal to distance |S2Q-S1Q|	1
14	ASSERTION: Wavefront emitted by a point source of light in an isotropic medium is spherical. REASON: Isotropic medium has the same refractive index in all directions.	1
15	ASSERTION: When a light wave travels from rarer to denser medium, its speed decreases. Due to this reduction of speed, the energy carried by the light wave reduces. REASON: Energy of the wave is proportional to the frequency.	1

	ANSWERS	
	1. (a) planar 2. (b) minimum on the axis of the beam. V= C/μ as refractive index of the medium,μ is maximum at the axis . 3. (c) converge . 4. .(d) origin of Spectra 5. (c) the sound waves in air are longitudinal and while the light waves are transverse 6. (b) 3 Vmedium = $\nu\lambda = 2x10^{14}$ x $5000x10^{-10} = 10^{8}$ m/s μ = C / V med = 3x $10^{8} / 10^{8}$ =3 7. (c) planar 8. (d) π 9. (a) 0 10. (a) 0 11. (b) 12. (d) 13.(b) 14. (a) 15. (d)	
	2 MARKS QUESTIONS	
16	Draw the diagram to show the shape of plane wave front as they pass through (i) a thin prism and (ii) a thin convex lens. State the nature of refracted wave front. Ans. (i)  The refracted wave front is a plane wave front. (ii)	2

	 The refracted wave front is spherical.	
17	Draw the geometrical shape of the wave front when (i) light diverges from a point source (ii) plane wave is reflected by a concave mirror. Ans. (i)  (ii) 	2
	3 MARKS QUESTIONS	
18	State Huygens principle. Using Huygens's construction of secondary wavelets draw a diagram showing the passage of a plane wavefront from a denser to a rarer medium. Using it verify Snell'slaw. Ans. According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later	3

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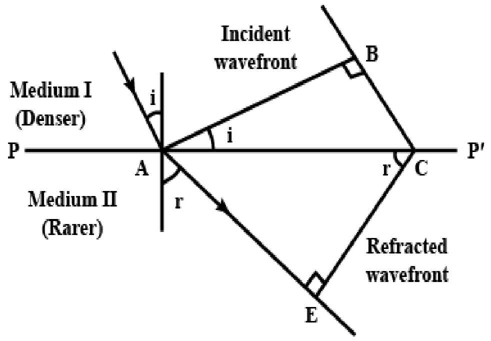
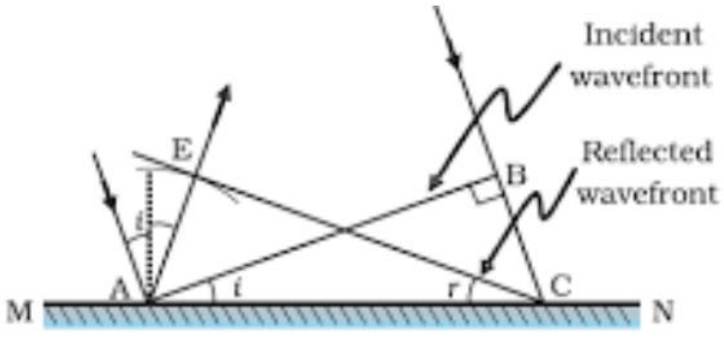
<tr><td></td><td>
time.
AB: Incident Plane Wave Front & CE is Refracted Wave front
Sin i =BC/AC & Sin r = AE /AC
Sin i / Sinr = BC /AE = v_1 /v_2 = constant



</td><td></td></tr>
<tr><td>19</td><td>
State Huygens principle. Using Huygens's construction of secondary wavelets, draw a diagram showing the reflection of a plane wave by a reflecting surface. Using it verify the law of reflection.
Ans. . According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.

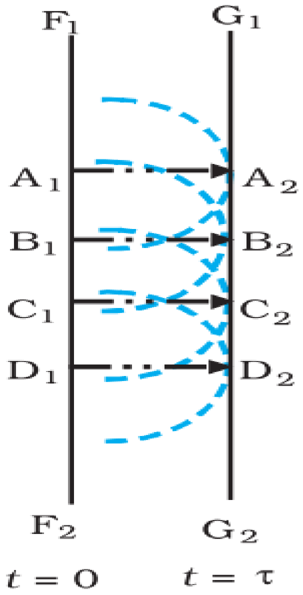


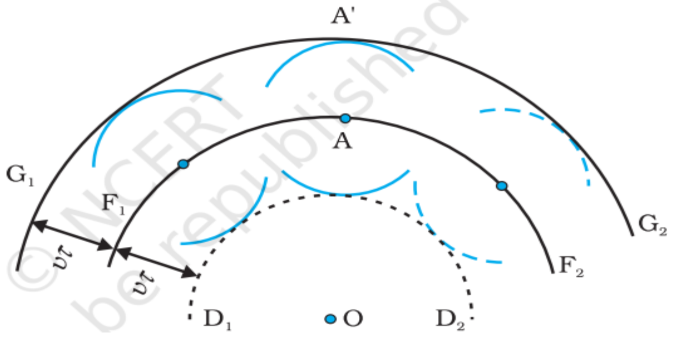
Reflection of a plane wave AB by the reflecting surface MN. AB and CE represent incident and reflected wavefronts.

If *v* represents the speed of the wave in the medium and if τ represents the time taken by the wavefront to advance from the point B to *C* then the distance
BC = vτ
In order to construct the reflected wavefront we draw a sphere of radius *v*τ from the point A . Let CE represent the tangent plane drawn from the point C to this sphere. Obviously
AE = BC = vτ
</td><td>3</td></tr>
</table>

<table>
<tr><td></td><td>If we consider the triangles EAC and BAC we will find that they are congruent and therefore, the angles i and r would be equal. This is the law of reflection.</td><td></td></tr>
<tr><td></td><td>4 MARKS QUESTIONS</td><td></td></tr>
<tr><td>20</td><td>Read the following paragraph and answer the questions that follow.

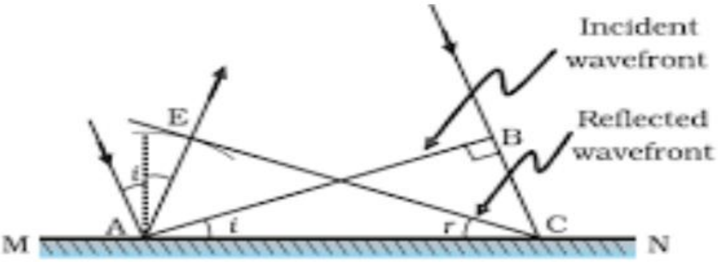
According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wave front at a later time.



(a) Huygens geometrical construction for a plane wave propagating to the right


(b) Huygens geometrical construction for a spherical wave.</td><td>4</td></tr>
</table>

	i.) According to Huygens Principle, the surface of constant phase is (a) called an optical ray (b) called a wave front (c) called a wave (d) always linear in shape. ii) Two plane wave fronts of light, one incident on a thin convex lens and another on the refracting face of a thin prism. After refraction at them, the emerging wave fronts respectively become (a) Plane wave front and plane wave front. (b) Plane wave front and spherical wave front. (c) Spherical wave front and plane wave front. (d) Spherical wave front and spherical wave front. iii) Which of the following phenomena support the wave theory of light. 1. Scattering. 2. Interference. 3. Diffraction. 4. Velocity of light in a denser medium is less than the velocity of light in the rarer medium. (a) 1,2,3 (b) 1,2,4 (c) 2,3,4 (d) 1,3,4 iv) The rectilinear propagation of light in a medium is due to (a) Its short wavelength (b) Its high frequency. (c) Its high velocity. (d) The refractive index of medium. OR The wave front due to a source situated at infinity is (a) Spherical (b) cylindrical (c) planar (d) none of the above.	
21	REFLECTION OF PLANE WAVES USING HUYGENS PRINCIPLE According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wave front at a later time.	4



Reflection of a plane wave AB by the reflecting surface MN. AB and CE represent incident and reflected wavefronts.

(i) Which of following remain constant in reflection of light
(a) Frequency
(b) Wavelength
(c) Speed
(d) All

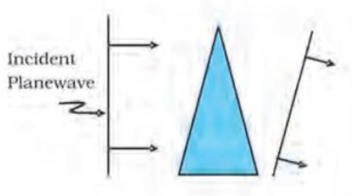
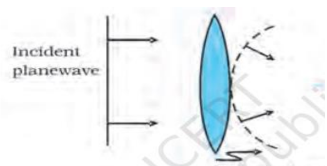
(ii) Huygen's concept of secondary wave
(a) allows us to find the focal length of a thick lens
(b) is a geometrical method to find a wavefront
(c) is used to determine the velocity of light
(d) is used to explain polarization

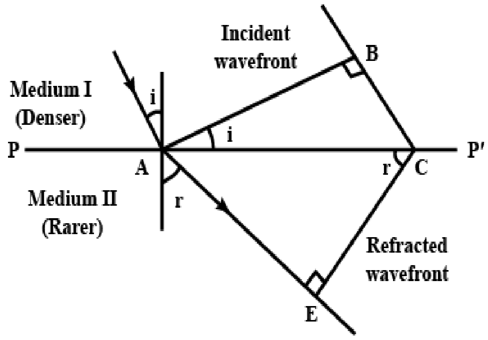
(iii) Spherical wavefronts, emanating from a point source, strike a plane reflecting surface. What will happen to these wave fronts, immediately after reflection?
(a) They will remain spherical with the same curvature, both in magnitude and sign.
(b) They will become plane wave fronts.
(c) They will remain spherical, with the same curvature, but sign of curvature reversed.
(d) They will remain spherical, but with different curvature, both in magnitude and sign.

(iv) When light suffers reflection at the interface between water and glass, the change of phase in the reflected wave is
(a) zero
(b) π
(c) $\pi/2$
(d) 2π

OR

Which of the following describes Huygen's Principle
(a) Every point on a wavefront acts as a source of lots of secondary spherical wavelets, which can therefore interfere with each other.
(b) A wave can produce an interference pattern.

	(c) The angle of incidence is equal to the angle of reflection. (d) All	
	ANSWERS OF 4 MARKS QUESTION	
	20. (i) b (ii) c (iii) c (iv) b or c 21. (i) d (ii) b (iii) c (iv) b or d	
	5 MARKS QUESTIONS	
22	(a) Define a wave front. (b) Draw the diagram to show the shape of plane wave front as they pass through (i) a thin prism and (ii) a thin convex lens. State the nature of refracted wave front. (c) Verify Snell's law of refraction using Huygens principle. Ans. (a) A wavefront is defined as the continuous locus of all such particles of the medium which are vibrating in the same phase at any instant. (b) (i)  The refracted wave front is a plane wave front. (ii)  The refracted wave front is spherical. (c) AB: Incident Plane Wave Front & CE is Refracted Wave front Sin i =BC/AC & Sin r = AE /AC	5

	Sin i / Sinr = BC /AE = v1 /v2 = constant  	
	ASSIGNMENTS	
1.	State Huygens principle. Sketch the wavefront that corresponds to a beam of light (i) coming from a very far away souece (ii) diverging radially from a point source.	2
2.	State Huygens principle. Use it to show that a plane wavefront advances as a plane wavefront in a homogenous medium.	2
3.	Draw the sketches to differentiate between plane wavefront and spherical wavefront.	2

WAVE OPTICS -1

ASSIGNMENT QUESTIONS

ASSIGNMENTS (2 marks)

1. Use Huygens principle to show how a plane wavefront advances in a homogenous medium.
2. Use Huygens principle to show how a spherical wavefront advances in a homogenous medium.
3. Deine a wavefront. How is it different from awave?
4. (i) Sketch the wave front that will emerge from a distance source of light like a star.
   (ii) Sketch the shape of wave front emerging/diverging from a point source of light and also mark the rays.
   (iii) Sketch the wave front that will emerge from a linear source of light like a slit.
5. Derive Snell's law on the basis of Huygens wave theory when light is travelling from a *rarer to a denser* medium.
6. Using Huygens's construction draw a figure showing the propagation of a plane wave front reflecting at a plane surface. Show that the angle of incidence is equal to the angle of reflection.
7. When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Explain why.
8. When light travels from a rarer to a denser medium, it loses some speed. Does the reduction in speed imply a reduction in the energy carried by the light wave ?
9. Is it necessary that the amplitude be constant over a given wavefront ?
10. When a wave undergoes reflection at a denser medium, what happens to its phase?
11. If a wave undergoes refraction,what will be the phase change?
12. Monochromatic light of wavelength 600nm is incident from air on a glass surface. What are the wavelength, frequency and speed of refracted light. Refrac tive index of glass is 1.5.
13. Calculate the time which light will take to travel normally through a glass plate of thickness 1mm. Refrac tive index of glass is 1,5 and velocity of light is 3x 10^6 m/s.
14. The refractive index of glass is 1.5 and that of water is 1.3, the speed of light in water is 2.25 x 10^8 m/s. What is the speed of light in glass?

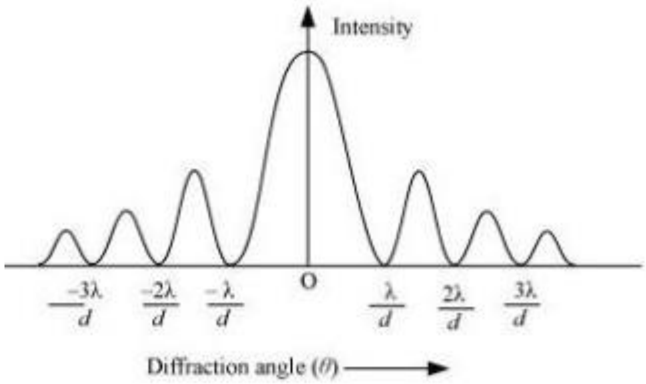
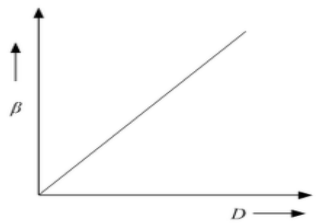
	GIST	
	Interference, Young's double slit experiment and expression for fringe width (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only).	
	1 MARK QUESTIONS	
1	In a Young's double slit experiment, the path difference at a certain point on the screen between two interfering waves is **1**/ **8** th of the wavelength. The ratio of intensity at this point to that at the centre of a bright fringe is close to (a) 0.80 (b) 0.74 (c) 0.94 (d) 0.85	1
2	The shape of the interference fringes in Young's double slit experiment when D (distance between slit and screen) is very large as compared to fringe width is nearly (a) straight line (b) parabolic (c) circular (d) hyperbolic	1
3	In Young's double slit experiment, the separation between the slits is halved and distance between the slits and screen is doubled. The fringe width is (a) unchanged (b) halved (c) doubled (d) quadrupled	1
4	In Young's double slit experiment using a monochromatic light of wavelength λ, the path difference corresponding to any point having half the peak intensity is (a) (2n+1) λ/2 (b) (2n+1) λ/4 (c) (2n+1) λ/8 (d) (2n+1) λ/16	1
5	In a Young's Young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen, when light of wavelength 600nm is used. If the wavelength of light of light is changed to 400nm, number of fringes observed in the same segment of the screen is given by (a) 12 (b) 18 (c) 24 (d) 30	1

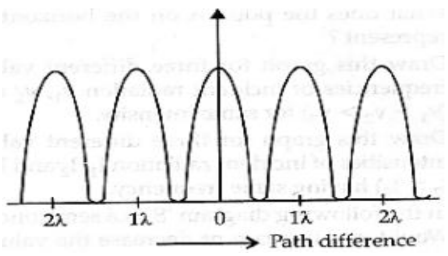
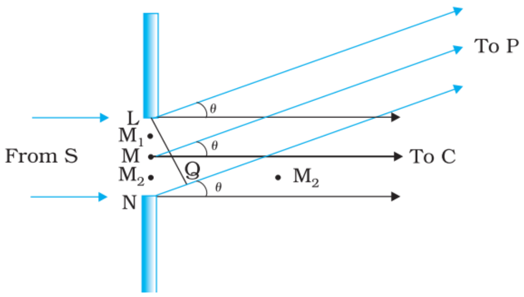
6	Yellow light is used in a single slit diffraction experiment with slit with of 0.6 mm. If yellow light is replaced by x-rays, then the observed pattern will reveal (a) that the central maximum is narrower. (b) more number of fringes. (c) less number of fringes. (d) no diffraction patterns	1
7	A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on the screen is (a) Hyperbola (b) Circle (c) straight line (d) parabola	1
8	If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled? (a) 2 I_0 (b) 4 I_0 (c) I_0 (d) $I_0/2$	1
9	The intensity at a point on a screen in Young's double slit experiment where the interfering waves have a path difference of $\lambda/6$ is (a) I_0 (b) $2I_0$ (c) 3 I_0 (d) 4 I_0	1
10	In the phenomena of interference, energy is (a) destroyed at dark.fringe (b) created at bright fringe (c) conserved but redistributed (d)same at all points.	1
	ASSERTION - REASON	1
	For Questions 11 to 15, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the	

	options as given below. **e)** If both Assertion and Reason are true and Reason is correct explanation ofAssertion. **f)** If both Assertion and Reason are true but Reason is not the correctexplanation of Assertion. **g)** If Assertion is true but Reason is false. **h)** If both Assertion and Reason are false.	
11	ASSERTION: In an interference pattern observed in Young's double slit experiment, if the separation (d) between coherent sources as well as the distance (D) of the screen from the coherent sources both are reduced to 1/3rd, then new fringe width remains the same. REASON: Fringe width is proportional to (d/D)	1
12	ASSERTION: Static crashes are heard on radio, when lightning flash occurs in the sky. REASON: Electromagnetic waves having frequency of radiowave range, interefere with radiowaves.	1
13	ASSERTION: To observe diffraction of light, the size of obstacle/aperture should be of the order of 10^{-7} m. REASON: 10^{-7} m is the order of wavelength of visible light.	1
14	ASSERTION: It is not possible to have interference between the waves produced by two violins. REASON: For interference of two waves the phase difference between the waves must remain constant.	1
15	ASSERTION: No interference pattern is detected when two coherent sources are infinitely close to each.	1

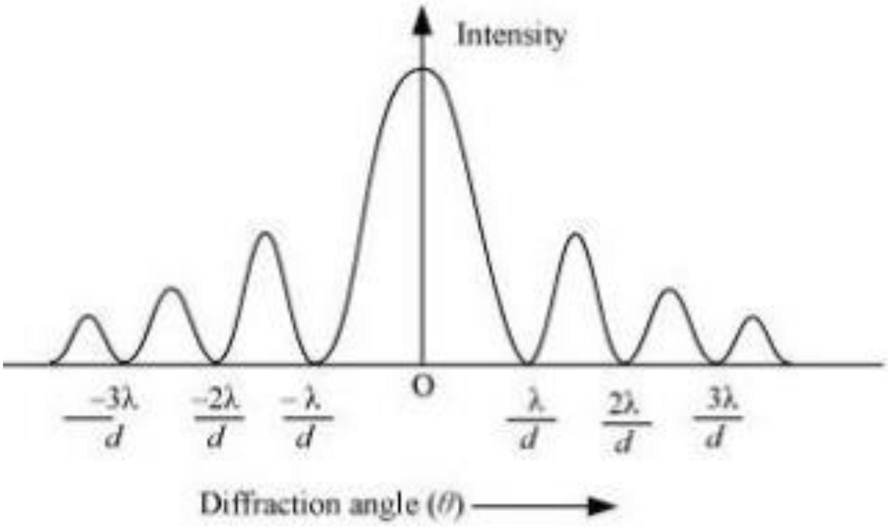
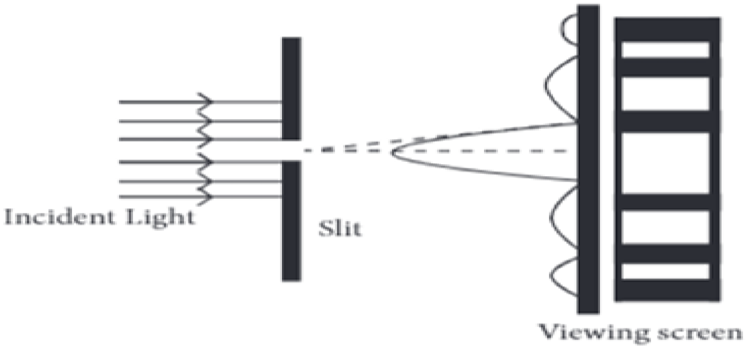
	REASON: Fringe width is inversely proportional to the distance between two slits.	
	ANSWERS	
	1.(d) 0.85 Phase difference, $\Delta \varphi = (2\pi /\lambda)\, \Delta x = \pi /4$ $I = I_{max} Cos^2(\Delta \varphi/2)$ $I / I_{max} = (0.9238)^2 = 0.85$ 2. (a) straight line 3. (d) quadrupled $\beta = \lambda D/d$, $\beta' = (\lambda x 2D)/(d/2) = 4\beta$ 4. (b) $(2n+1)\, \lambda/4$ 5. (b) 18 $n_1 \times \lambda_1 = n_2 \times \lambda_2$ $12 \times 600 = n_2 \times 400$ $n_2 = 18$ 6. d) no diffraction pattern For diffraction do be pronounced, the size of the slit should be comparable to the wavelength of the waves. X-rays have very small wavelength as compare to yellow light. There for no diffraction is observed when yellow light is replaced by x-rays. 7. (a) Hyperbola 8. (c) I_0 The intensity of principal maximum in the single slit diffraction does not depend upon the slit width. 9. (c) 3 I_0 Phase difference , $\varphi = (2\pi/\lambda)$ path difference $=(2\pi/\lambda) \times \lambda/6 = \pi/3$ $I = 4I_0 \cos^2(\varphi/2) = 3 I_0$ 10. (c) conserved but redistributed 11. c	

	12. a 13. a 14. a 15. b	
	2 MARK QUESTIONS	
16	In a double slit experiment, the distance between the slits is 3 mm and the slits are 2 m away from the screen. Two interference patterns can be seen on the screen one due to light with wavelength 480 nm, and the other due to light with wavelength 600 nm. What is the separation on the screen between the fifth order bright fringes of the two interference patterns? Ans. $\beta = \lambda D / d$ 5^{th} bright = $5\beta_1 = 5\lambda_1 D/d = 5 \times 480 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 16 \times 10^{-4}$m 5^{th} bright = $5\beta_2 = 5\lambda_2 D/d = 5 \times 600 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 20 \times 10^{-4}$ m distance between two 5^{th} bright fringes = $(20 - 16) \times 10^{-4} = 4 \times 10^{-4}$ m	2
17	What should be the width of each slit to obtain n maxima of double slit pattern within the central maxima of single slit pattern ? Ans. $n\lambda/d = 2\lambda/a$ $n = 2 d/a$.	2
18	Determine angular separation between the central maximum and first order maximum of diffraction pattern due to a single slit of width 0.25 mm, when light of wavelength 5890 A˚ is incident normally on it. Ans. d = 0.25mm = 0.25×10^{-3} m λ = 5890 A˚ = 5890×10^{-10} m . Angular position of first minimum $\theta = 3\lambda/2d = (3 \times 5890 \times 10^{-10})/ (2 \times 0.25 \times 10^{-3}$ $= 3.5 \times 10^{-3}$ rad	2
19	In a double slit experiment using light of wavelength 600nm and the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits. Ans.	2

	$\theta = \lambda/a$ i.e. $a = \frac{\lambda}{\theta} = \frac{6\times10^{-7}}{0.1\times\frac{\pi}{180}} = 3.4\times10^{-4}\,m$	
20	In Young's double slit experiment, while using a source of light of wavelength 5000A˚, the fringe width obtained is 0.6 cm. If the distance between slits and screen is reduced to half, calculate new fringe width. $\beta = D\lambda/d$ $\beta' = 1/2\ D\lambda/d$ since $D' = D/2$ $\beta' = 0.6/2 = 0.3$ cm	2
21	Draw the graph showing intensity distribution of fringes with phase angle due to diffraction through a single slit. What is the width of the central maximum in comparison to that of a secondary maximum?  Width of central maximum is twice that of secondary maximum.	2
22	In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. What information can one obtain from the slope of the graph ? Ans.  The slope of the graph gives $\beta/D = \lambda/d$ is a constant.	2

23	Draw the intensity pattern for double slit interference pattern . Hence state one difference between interference and diffraction pattern.  The interference pattern has a number of equally spaced bright and dark bands. The intensity is constant.The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side.	2
	3 MARK QUESTIONS	
24	The ratio of intensities of maxima and minima in an interference pattern is found to be 25:9. Calculate ratio of light intensities of the sources producing the pattern. Ans. $I_{max} / I_{min} = 25/9$ $I_{max} / I_{min} = (a_1+a_2)^2/(a_1-a_2)^2 = 25/9$ $a_1 / a_2 = 1/4$ $I_1/I_2 = a_1^2 / a_2^2 = (1/4)^2 = 1/16$	3
25	Describe briefly how a diffraction pattern is obtained on a screen due to a single slit illuminated by a monochromatic source of light. Ans.  	3

	The path difference NP – LP = NQ = a sin θ□□□a θ□(for smaller angles) At the central point C on the screen, the angle θ□is zero. All path differences are zero and hence all the parts of the slit contribute in phase. This gives maximum intensity at C. The maxima are at θ= (n + 1/2) λ/a and minima at θ= nλ/a	
26	In a Young's double slit experiment, slits are separated by 0.5 mm and the screen is placed 150 cm away a beam of light consisting of two wavelength, 615 nm and 520 nm is used to obtain indifference fringes on the screen. What is the least distance from the common central maximum to the point where the bright fringes due to both the wavelength coincide? Ans. The two bright finches will coincide at the least distance x from the central maximum if $x = n \lambda_1 D/d = (n+1) \lambda D/d$ n X 650 = (n+1) X 520 n=4 $x = 4 D\lambda_1/d = 4X1.5 X 650X 10^{-9} = 7.8X 10^{-3 m}$	3
27	How does Huygen’s principle used to obtain the diffraction pattern due to a single slit? Show the plot of variation of intensity with the angle and state the reason for reduction in intensity of secondary maxima compare to centre maximum. Ans. When a plane wavefront is incident on a single slit, all the point sources of light constituting the wavefronts are in the same phase. The wavelets coming out from the wavefront might meet over the screen with some path difference i.e., a phase. difference is introduced between them .The brightness at a point on the screen depends on the phase difference between the wavelets meeting at the point. We imagine that the slit is divided into smaller parts and the wavelets coming out from these portions meet and superpose on the screen with proper phase difference. The wavelets from different parts of the wavefront incident on the slit meet with zero phase difference to constitute a central maximum. In case of secondary maxima there are some wavelets meeting the screen out of phase, thus, reducing intensity of secondary maxima	3

		
	4 MARK QUESTIONS	
28	DIFFRACTION AT A SINGLE SLIT When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on a screen called diffraction pattern of single slit. In diffraction pattern of single slit, it is found that (i) the central bright fringe is of maximum intensity and the intensity of any secondary, bright fringe decreases with increase in its order. (ii) central bright fringe is twice as wide as any other secondary, bright or dark fringe.  (i) To observe diffraction, the size of the obstacle (a) should be λ/2 where λis the wavelength (b) should be of the order of wavelength. (c) has no relation to wavelength. (d) should be much larger than the wavelength. (ii) Light of wavelength 600 nm is incident normally on a slit of width 0.2	4

mm. The angular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

(a) 6 x 10 $^{-3}$ rad
(b) 4 x 10 $^{-3}$ rad
(c) 2.4 x 10 $^{-3}$ rad
(d) 4.5 x 10 $^{-3}$ rad

(iii) A diffraction pattern is obtained by using a beam of red light. What will happen if the red light is replaced by blue light?

(a) bands disappear
(b) bands become boarder and farther apart
(c) no change will take place
(d) diffraction bands become narrower and crowded together.

(iv) A single slit of it 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 A° and diffraction bands are observed on a screen is 0.5 away from the slit. The distance of the third dark band from the central bright band is

(a) 3 mm
(b) 1.5 mm
(c) 9 mm
(d) 4.5 mm

OR

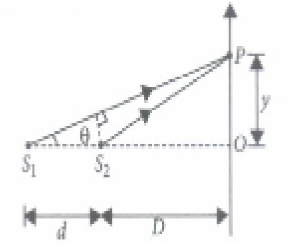
In diffraction at a single slit, the slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000 A°, then the distance between the first minimum on either side of the central maximum is

(a) 10 $^{-1}$ m
(b) 10 $^{-2}$ m
(c) 2x 10 $^{-2}$ m
(d) 2x 10 $^{-1}$ m

29 | 4

YOUNG’S DOUBLE SLIT EXPERIMENT

In Young's double slit experiment, the width of the central bright fringe is equal to the distance between the first dark fringes on the two sides of the central bright fringe.
In given figure below a screen is placed normal to the line joining the two point coherent source SI and S2' The interference pattern consists of concentric circles.



(i) The phenomenon of interference is shown by

(a) longitudinal mechanical waves only
(b) transverse mechanical waves only
(c) electromagnetic waves only
(d) all of these

(ii) The coherence of two light sources means that the light waves emitted will have

(a) Same velocity

(b) Same intensity

(c) Constant phase difference.

(d) Same amplitude

(iii) In Young's double slit experiment, the fringe width is 0.4 mm. If the whole apparatus is immersed in water of refractive index 4 /3 without changing its geometry, then the new fringe width will be

(a) 0.53 mm

(b) 0.4 mm

(c) 0.3 mm

(d) 540 µm

(iv) Which nature of light is exposed by interference of light.

(a) Quantum nature of light

(b) Longitudinal nature of light

(c) Wave nature of light

(d) Nature of light is electromagnetic

OR

In Young's double slit experiment., the slit separation is 1mm and the

	screen is 1 m from the slit. For a monochromatic light of wavelength. 500 nm, the distance of third minima from the central maximum is (a) 0.5 mm (b) 1.25 mm (c) 1.50mm (d) 1.75 mm	
	ANSWERS	
28	(i) b (ii) (a) 6x x 10 $^{-3}$ rad $\theta = \frac{2\lambda}{a} = \frac{2\times6\times10^{-7}}{2\times10^{-4}} = 6\times10^{-3}$ rad (iii) (d) diffraction bands become narrower and crowded together. (iv) (c) 9 mm $d\sin\theta = 3\lambda$; $\sin\theta = \frac{3\lambda}{d} = \frac{y}{D}$ $y = \frac{3D\lambda}{d} = \frac{3\times0.5\times6\times10^{-7}}{0.1\times10^{-3}} = 9\times10^{-3}$ m = 9 mm OR (b) 10 $^{-2}$ m $x = \frac{2\lambda D}{d} = \frac{2\times5\times10^{-7}\times2}{0.2\times10^{-3}} \Rightarrow x = 10^{-2}$ m	
29	. (i) (d) (ii) c (iii) c (iv) c OR b	
	5 MARKS QUESTIONS	
30	(a) Define interference. (b) Why is no interference pattern observed when two coherent sources are	5

	(i) Infinitely close to each other ? (ii) Far apart for each other ? (c) In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1^o. What is the spacing between the two slits? Ans. (a) The phenomenon of redistribution of light energy due to superposition of light waves from two coherent sources is called interference. (b)Fringe width $\beta = \lambda D/d$ (i) When the slits are infinitely close to each other, the fringe width becomes so large that the fringe pattern will vanish. (ii) When the slits are far apart for each other, d is large , the fringe width becomes so small to be detected. (c) Wavelength of light used, λ = 6000 nm = 600×10^{-9} m Angular width of fringe, θ = 0.1° = 0.1 x ¶/180 = 3.14/1800 rad Angular width of a fringe is related to slit spacing (d) as: $d = \lambda/\theta = 600 \times 10^{-9}/3.14/1800 = 3.44 \times 10^{-4}$ m	
31	(i) Define a wavefront. How is it different from a ray? (ii) Using Huygens's construction of secondary wavelets draw a diagram showing the passage of a plane wavefront from a denser to a rarer medium. Using it verify Snell'slaw. (iii)In a double slit experiment using light of wavelength 600nm and the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits. Write two differences between interference pattern and diffraction pattern. Ans. (i) A wavefront is defined as a surface of constant phase. (a) The ray indicates the direction of propagation of wave while the wavefront is the surface of constant phase. (b) The ray at each point of a wavefront is normal to the wavefront at that point. (ii) AB: Incident Plane Wave Front & CE is Refracted Wave front. Sin i =BC/AC & Sin r = AE /AC	5

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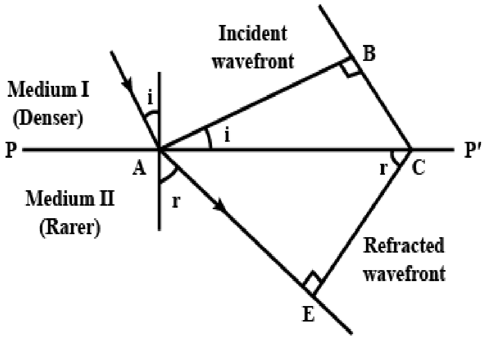
Sin i / Sinr = BC /AE = v1 /v2 = constant



(iii) $\theta = \lambda / a$ i.e. $a = \dfrac{\lambda}{\theta} = \dfrac{6 \times 10^{-7}}{0.1 \times \dfrac{\pi}{180}} = 3.4 \times 10^{-4}\,m$

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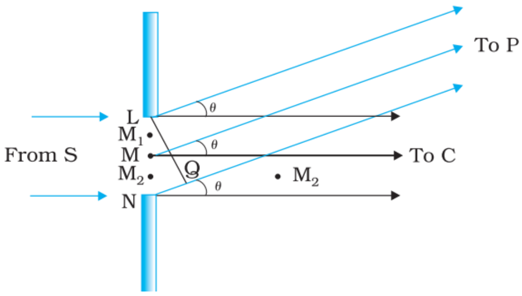
(a) Explain two features to distinguish between the interference pattern in Young's double slit experiment with the diffraction pattern obtained due to a single slit.
(b) Explain diffraction of light due to a narrow single slit..
(c) If the width of the slit is made double te original width , how does it affect the size and intensity of the central band ?

Ans.(a)

The interference pattern has a number of equally spaced bright and dark bands. The intensity is constant. The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side.

(b)



The path difference NP – LP = NQ = a sin θ□□□a θ□(for smaller angles)

At the central point C on the screen, the angle θ□is zero. All path differences are zero and hence all the parts of the slit contribute in phase. This gives maximum intensity at C.

The maxima are at θ= (n + 1/2) λ/a and minima at θ= nλ/a

(c) When the width of the slit is doubled, width of the central maximum is halved.

Its area becomes ¼ times and hence intensity becomes 4 times.

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	ASSIGNMENTS	
1	(i) the width of the source slit is increased? (ii) the monochromatic source is replaced by another monochromatic source of shorter wavelength.? (iii) Thre monochromatic source is replaced by a source of white light?	3
2	What is the effect on the interference pattern observed in a Young's double slit experiment in the following cases. (i) screen is moved away from the plane of the slits. (ii) the separation between the slits is increased. (iii) Width of the slits is doubled ?	3
3	What is the effect on the interference fringes in Young's double slit experiment. if (i) the separation between the slits is halved? (ii) The source slit is moved closesr to the double slit.? Justify your answer.	2
4	Why is no interference pattern observed when two coherent sources are? (i) infinitely close to each other? (ii) far apart from each other ?	2
5	What changes in the interference pattern in Young's double slit experiment will be observed. when (i) light of smaller frequency is used (ii) the apparatus is immersed in water?	2

WAVE OPTICS -2

ASSIGNMENT QUESTIONS

1. What is the effect on the interference pattern observed in a Young's double slit experiment in the following cases.
   i. the width of the source slit is increased?
   ii. the monochromatic source is replaced by another monochromatic source of shorter wavelength.?
   iii. the monochromatic source is replaced by a source of white light?
2. What is the effect on the interference pattern observed in a Young's double slit experiment in the following cases.

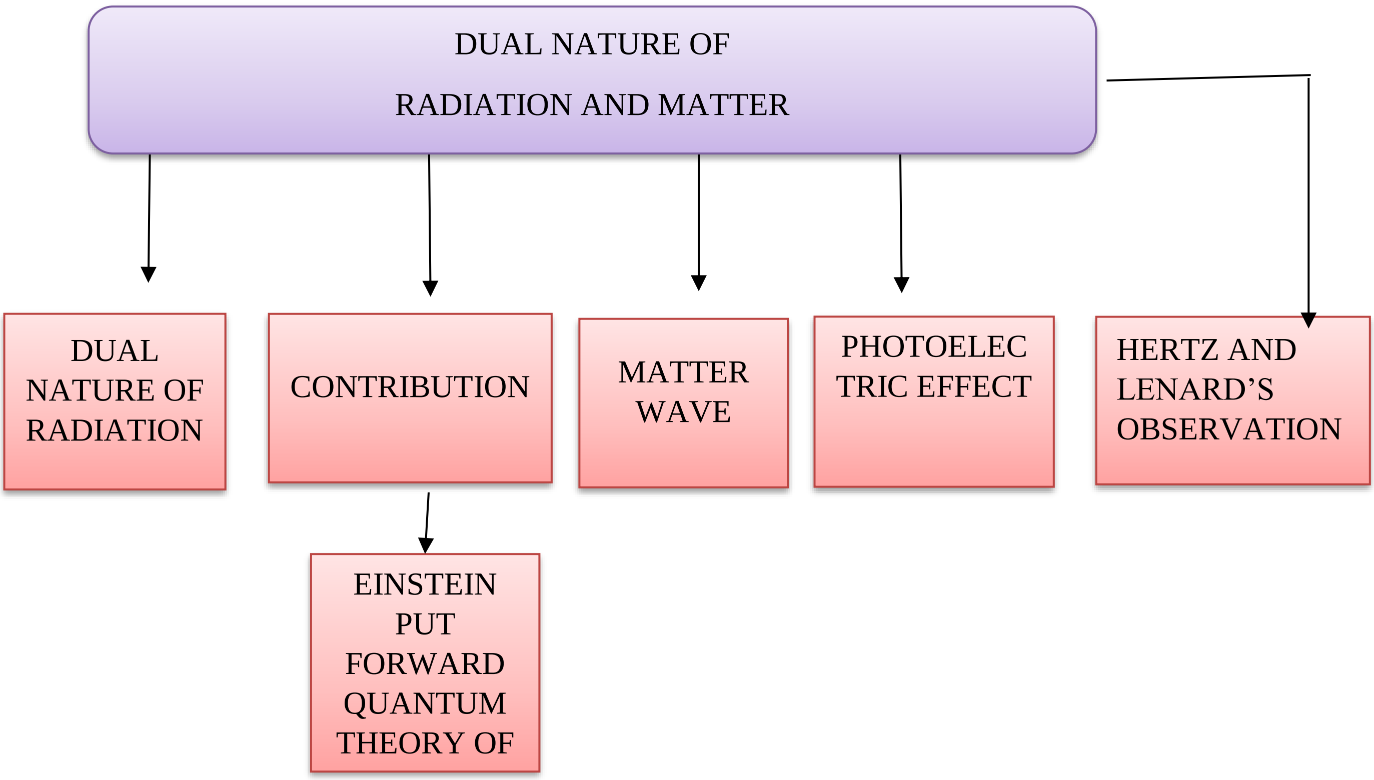
(iv) screen is moved away from the plane of the slits.
(v) the separation between the slits is increased.
(vi) width of the slits is doubled ?

3. What is the effect on the interference fringes in Young's double slit experiment, if
   i. the separation between the slits is halved?
   ii. The source slit is moved closer to the double slit.?
   Justify your answer.
4. Why is no interference pattern observed when two coherent sources are?
   (i) infinitely close to each other?
   (ii) far apart from each other?
5. State two differences between interference and diffraction patterns.
6. What is sustained interference pattern? Write the necessary conditions to obtain sustained interference fringes.
7. (a) There are two sets of apparatus of Young's double slit experiment. In set A, the phase difference between the two waves emanating from the slits does not change with time, whereas in set B, the phase difference between the two waves from the slits changes rapidly with time. What difference will be observed in the pattern obtained on the screen in the two setups?
   (b) Deduce the expression for the resultant intensity in both the above-mentioned set ups (A and B), assuming that the waves emanating from the two slits have the same amplitude A and same wavelength λ.
8. A monochromatic light of wavelength λ is incident normally on a narrow slit of width a to produce a diffraction pattern on the screen placed at a distance D from the slit. With the help of a relevant diagram, deduce te conditions for obtaining maxima and minima. Use these conditions to show that angular width of central maximum is twice the angular width of secondary maximum.
9. How does the fringe width of interference fringes change, when the whole apparatus of Young's experiment is kept in a liquid of refractive index 1.3?
10. Why are coherent sources required to create interference of light?
11. What should be the approximate slit size to observe diffraction with it?
12. A parallel beam of light of 600nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2m away. It is observed that the first minimum is at a distance of 3mm from the centre of the screen. Calculate the width of the slit.
13. Microwaves of frequency 24,000 MHz are incident normally on a rectangular slit of width 5 cm. Calculate the angular spread of the central maximum of the diffraction pattern of the slit.
14. A screen is placed 50 cm from a single slit which is illuminated with light of wavelength 6000 A°. If the distance between the first and the third minima in the diffraction pattern is 3mm, what is the width of the slit?
15. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 mm. The screen is 1 m away from the slits. Find the distance of the second (i) bright fringe and (ii) the dark fringe from the maximum.

CHAPTER 11

DUAL NATURE OF RADIATION AND MATTER

CONCEPT MAP / MIND MAP



GIST OF THE CHAPTER

- **Dual nature of radiation.**
- **Photoelectric effect.**
- **Hertz and Lenard's observations.**
- **Einstein's photoelectric equation particle nature of light.**
- **Experimental Study on photoelectric effect.**
- **Matter waves – wave nature of particles.**
- **De- Broglie relation.**

DUAL NATURE OF MATTER & RADIATIONS

A. MCQ BASED

1. Which of the following statements is true regarding the photoelectric experiment?
   a. The stopping potential increases with the increase in the intensity of incident light.
   b. The photocurrent increases with the intensity of light.
   c. The photocurrent increases with the increase in frequency
   d. All of the above
2. De-Broglie equation states the:
   a. dual nature b. particle nature
   c. wave nature d. none of these
3. A metal’s work function is:
   a. The minimum current needed to remove an electron from a metal surface
   b. The highest frequency needed to remove an electron from a metal surface
   c. None of the mentioned
   d. The least amount of energy required to remove an electron from a metal surface

4. Only when the incident light exceeds a particular threshold……… does photoelectric emission occur.
a. Power b. wavelength c. Intensity d. Frequency

5. The photoelectric effect may be described using the following theories:
a. wave theory of light b. Bohr’s theory
c. quantum theory of light d. corpuscular theory of light.

6. Which of the following phenomena explain the wave nature of light?
a) Interference b) Diffraction c) polarization d) all of them

7. Wave –particle duality is shown by
a) Light only b) matter only c) both light and matter d) None of them

8. The experiment to explain the wave nature of light i.e electromagnetic wave theory is given by
a) Hertz b) Einstein c) Lenard d) Huygen

9. The concept of photoelectric effect given by Einstein explains that the light is a
a) Photon b) Wave c) Particle d) Both

10. The practical application of the phenomenon of photoelectric effect and the concept of ‘matter waves’ is
a) Photocells b) Automatic doors at shops and malls
c) Automatic light switches d) All of them

11. The photoelectric current is unaffected by
a) Incident light frequency b) Metal work function
c) Stopping potential d) Incident light intensity

12. Which of the following will emit photoelectrons when it collides with a metal?
a) UV radiations b) Infrared radiation c) Radio waves d) Microwaves

13. What will be the de-Broglie wavelength of an electron accelerated from rest through a potential difference of 100 volts?
a) 12.3 Å b) 1.23 Å c) 0.123 Å d) None of these

14. Two beams, one of red light and the other of blue light having the same intensity are incident on a metallic surface to emit photoelectrons. Which emits electrons of greater frequency?

a) Both　　b) Red light　　c) Blue light　　d) None

15. The work function for a metal surface is 4.14 eV. The threshold wavelength for this metal surface is:

(a) 4125 Å　　(b) 2062.5 Å　　(c) 3000 Å　　(d) 6000 Å

ANSWERS MCQ

1	b	6	iv	11	i
2	c	7	iii	12	a
3	d	8	i	13	b
4	d	9	iii	14	c
5	c	10	i	15	c

B. ASSERSATION & REASONING

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Q.1 **Assertion (A):** The photoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.

Reason(R): The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal.

Q.2 **Assertion:** The photon behaves like a particle.

Reason: If E and P are the energy and momentum of the photon, then $p = E / c$.

Q.3 **Assertion: -** Photoelectric effect demonstrates the wave nature of light.

Reason: - The number of photoelectrons is proportional to the frequency of light

Q.4 Assertion: In process of photoelectric emission, all emitted electrons do not have same kinetic energy.

Reason: If radiation falling on photosensitive surface of a metal consists of different wavelength then energy acquired by electrons absorbing photons of different wavelengths shall be different.

Q.5 **Assertion:** The kinetic energy of photoelectrons emitted from metal surface does not depend on the intensity of incident photon.

Reason: The ejection of electrons from metallic surface is not possible with frequency of incident photons below the threshold frequency.

Q.6. **Assertion:** Photoelectric saturation current increases with the increase in frequency of incident light.

Reason: Energy of incident photons increases with increase in frequency and as a result photoelectric current increase.

Q7. **Assertion: -** When the speed of an electron increases its specific charge decreases.

Reason: -: Specific charge is the ratio of the charge to mass.

Q8. **Assertion: -** Photosensitivity of a metal is high if its work function is small.

Reason: -Work function =hf_0, where f_0 is the threshold frequency.

Q9. **Assertion:** Though light of a single frequency (monochromatic) is incident on a metal, the energies of
emitted photoelectrons are different.

Reason: The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal.

ANSWERS ASSERSATION & REASONING

1	B	4	B	7	B
2	A	5	B	8	B
3	D	6	D	9	B

C. NUMERICAL BASED

1. The momentum of photon of electromagnetic radiation is 3.3 10^{-29} kg-m/s. Find out the frequency and wavelength of the wave associated with it.

2. Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W Calculate the (i) energy of a photon in the light beam and (ii) number of photons emitted on an average by the source.

3. The Kinetic Energy (K.E.), of a beam of electrons, accelerated through a potential V, equals the energy of a photon of wavelength 5460 nm. Find the de Broglie wavelength associated with this beam of electrons.

4. Explain giving reasons for the following:

(a) photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.

(b) The stopping potential (V_0) varies linearly with the frequency (v) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.

(c) Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation

5. The wavelength of a photon is 4000 Å calculates its energy.

6. Light of wavelength 5000 Å falls on a sensitive surface. If the surface has received 10^{-7} joule of energy, then what is the number of photons falling on the surface?

ANSWERS NUMRICAL BASED

Ans 1. Given, h = 6.63 10-34 J/s, c= 3 x10^8 m/s and p = 3.3 x 10^{-29} - kg m/s

Momentum, p= $h\nu/c$ or ν = pc/h = 3.3 x 10^{-29} x3 x 10^8 /6.63 x 10^{-34} = 1.5 x 10^{13} Hz

$\lambda = c/\nu$

= 3 x10^8 /1.5 x 10^{13} = 2 x 10^{-5} m

Ans 2. Calculating (i) Energy of a photon = hν= 6.63 × 10^{-34} × 6.0 × 10^{14} J = 3.978 × 10^{-19} J

(ii) Number of photons emitted per second = Power x Energy of photon

= 2 $x10^{-3}$ x 3.978 x 10^{-19}

= 7.956 × 10^{-22} photons/second

Ans 3.

Given : $\lambda = 5460 \text{ nm} = 5460 \times 10^{-9} \text{ m}$ $\quad \lambda_B = ?$

Energy of the photon (K) $= \frac{hc}{\lambda}$ ...(i)

de-Broglie wavelength, $(\lambda_B) = \frac{h}{p} = \frac{h}{\sqrt{2mk}}$ ...(ii)

$$\therefore \quad \lambda_B = \frac{h}{\sqrt{2m.\frac{hc}{\lambda}}} = \sqrt{\frac{h\lambda}{2mc}}$$

$$= \left[\frac{(6.63 \times 10^{-34}) \times (5460 \times 10^{-9})}{2 \times (9.1 \times 10^{-31}) \times (3 \times 10^8)}\right]^{\frac{1}{2}}$$

$$= \mathbf{25.75 \times 10^{-10} \text{ m}}$$

Ans 4.

(a) The collision of a photon can cause emission of a photoelectron (above the threshold frequency). As the intensity increases, number of photons increases. Hence, the current increases.

(b) We have, $eV_s = h(v - v_0)$

$\therefore \quad V_s = \frac{h}{e}(v) + \left(-\frac{hv_0}{e}\right)$

$\therefore$ Graph of V_s with v is a straight line and slope $\left(\frac{h}{e}\right)$ is a constant.

(c) Since maximum kinetic energy for different surfaces is given by $(K.E.)_{max} = h(v - v_0)$,

Hence, it depends on the frequency and not on the intensity of the incident radiation.

Ans 5. The wavelength of a photon is 4000 Å, Energy

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{4000\times10^{-10}}$$

$$= 4.95 \text{ X } 10^{-19}$$

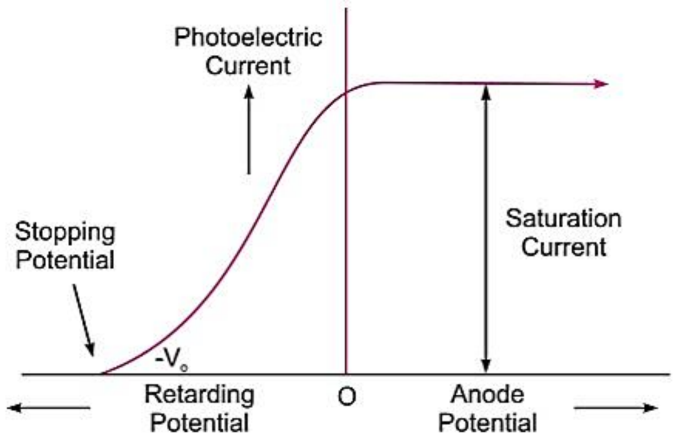
Ans 6. Energy = $\frac{nhc}{\lambda}$

n= $\frac{E\lambda}{hc}$ N=$\frac{10^{-7}\times5000\times10^{10}}{(6.6\times10^{-34})(3\times108)}$ =2.5 x 10^{11}

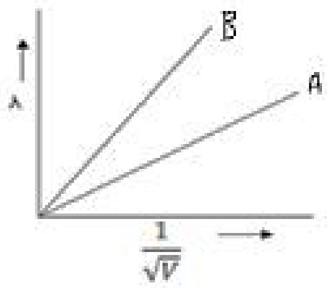
D. GRAPH BASED

1. Draw a graph showing variation of photocurrent with anode potential for a particular intensity of incident radiation. Mark saturation current and stopping potential.
2. (i) Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles and carrying same charge but of masses m_1 and m_2 (where $m_1 > m2$).
   (ii) Which one of the two graphs represents particle of smaller mass and why?

Ans1.



Ans2. (i)



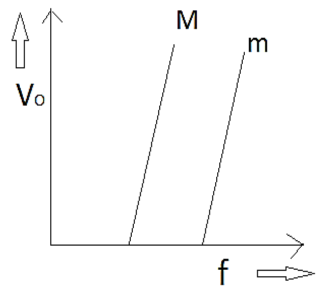
(ii) B represents smaller mass (m_2) because its slope is more **Slope $\alpha \frac{1}{\sqrt{m}}$**

E. DIAGRAM BASED

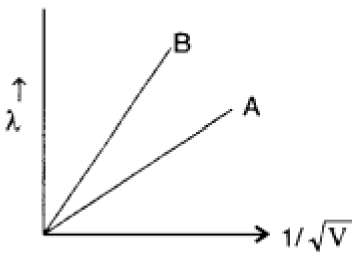
1. The figure shows variation of stopping potential (V_0) With the frequency (f) for the two photosensitive materials M and m

   i) Why is the slope same for both the lines

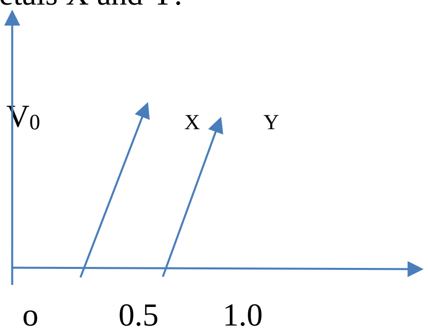
   ii) For which material will emitted electron have greater K.E. For the incident radiation of same frequency? Justify your answer.



2. Two lines, A and B, in the plot given below show the variation of de-Broglie wavelength, λ versus 1V√, Where V is the accelerating potential difference, for two particles carrying the same charge. Which one of two represents a particle of smaller mass? (All India 2008)



3.The graph in figure, shows the variation of stopping potential with frequency v of the incident radiation for two photosensitive metals X and Y.



(i) Which of the metals has large threshold wavelength? Give reason.

(ii) Explain giving reason, which metal gives out electrons, having large K.E. for the same wavelength of the incident radiation

(iii) If the distance between the light source and metal X is doubled, how will the K.E of electrons emitted from it change? Give reason.

4.(i) Plot a graph showing the variation of photocurrent versus collector potential for three different intensities $I_1 > I_2 > i_3$, two of which ([I_1 and I_2) have the same frequency V and the third has frequency $V_1 > V$.
(ii) Explain the nature of curves on the basis of Einstein's equation.

5. If light of wavelength 412.5 nm is incident on each of the metal given below, which ones will show photoelectric emission and why?

S.NO.	Metal	Work Function (eV)
1.	Na	1.92
2.	K	2.15
3.	Ca	3.2
4.	Mo	4.17

ANSWERS GRAPH BASED

Ans 1: (i) Both graphs have same slope = h/e
(ii) Work function of M<m, hence KE (M) > KE (m)

Ans 2: The de -Broglie wavelength of a particle is given by λ = 12.27/ V Å where, V is the accelerating potential of the particle.

It is given that

$\lambda_{proton} = \lambda_{alpha}$

12.27 / proton = 12.27 / alpha

$V_{proton} / V_{alpha} = 1$

(ii) The de – Broglie wavelength (λ) of a particle is also given by

λ = h /mv

λ_{proton} = h m proton v proton

λ alpha = h m_{alpha} v_{alpha}

We known $m_{alpha} = 4m_{proton}$

$\lambda_{alpha} = h / 4m_{proton} v_{alpha}$

$\lambda_{proton} = \lambda_{alpha}$

$h / m_{proton} v_{proton} = h / 4 m_{proton} v_{alpha}$

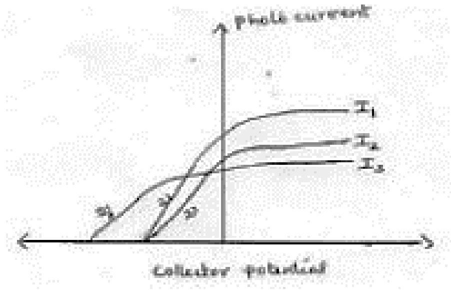
$v_{proton} / v_{alpha} = 4$

Ans 3: (i) The threshold frequency for metal X is less and hence threshold wavelength of metal X will be larger.

(ii) As threshold frequency for X is less than that of Y and work function $\phi_0 = h\nu_0$, hence work function for X is less than that of Y. Lesser the work function, more will be its K.E. $(K.E.)_{max} = h\nu - \phi_0$, K.E. of X will be more.

(iii)If the distance between the light source and metal X is halved, intensity of incident light becomes four times its previous value but frequency of light remains unchanged. Therefore, the K.E. of ejected electron remains unchanged.

Ans 4. (i) graph is shown



(ii) as per the Einstein's equation $eV_0 = h(V - V_0)$ which concludes (a) the stopping potential is same for I_1 and I_2 as they have the same frequency. (b) the saturation currents are as shown12.27, because $I_1 > I_2 > I_3$

Ans 5. E = hc / λ

= 1240 / 412.5 = 3eV

So, only Na and K will show photoelectric emission.

F. CCT BASED

Wave–particle duality

Q1. Dual nature of matter is an important concept in physics and is basically the study of different nature that a matter possesses or exhibits. A matter can either display or have a particle nature or waves nature. Various experiments have further been conducted to prove this theory.

Initially, the properties of matter or light were explained in terms of its particle nature. Corpuscular theory of light, etc. were some of the primitive steps that influenced this. Later on, it was experimentally found out that matter does possess the properties of a wave. Hence, the matter is said to possess dual nature, i.e., it has both the properties of a particle and as well as awave.

1. If we consider electrons and photons of same wavelength, then they will have same

(a) Momentum (b) angular momentum (c) energy (d) velocity.

2. Wave nature of light was not established through

(a) Maxwell's equations (b) photo electric effect

(c) Hertz experiment (d) Davisson - Germer Experiment

3. Corpuscular theory of light tells about the

(a) dual nature of light (b) wave nature of light (c) particle nature of light (d) none

4. Wave –particle duality is first confirmed for

(a) Radiation (b) Simultaneously confirmed for both radiation and matter
(c) Matter (d) till now only confirmed for matter

THE PHOTO-ELECTRIC EFFECT

Q2. When a photon is incident on a metallic surface, it interacts with an atom in the metal and transfers all its energy to one of the atom's electrons. This electron may then escape through the electric field at the surface, which keeps less energetic electrons inside the metal. The emerging electron then has energy equal to the energy of the photon minus the energy W lost inescaping the metal. W, the work function of the surface, is a material-dependent constant. Since electrons also lose energy in collisions with other electrons before emerging, we may only specify the maximum possible energy for an electron liberated by light of frequency f from a
metal. If the material work function is W, this maximum energy is Emax = hf -W

1. At stopping potential, the kinetic energy of emitted photo electron is
   (a) Minimum (b) maximum (c) zero (d) cannot be predicted

2. Photo electric effect experiment
   (a) Confirm Quantum nature of light (b) help to measure work function
   (c) help to measure planck's contant (d) All of the above

3. Kinetic energy of electrons emitted in photoelectric effect is
   (a) directly proportional to the intensity of incident light.
   (b) inversely proportional to the intensity of incident light.
   (c) independent of the intensity of incident light.
   (d) independent of the frequency of light.

4. What is true about emitted photo electron from the metal surface?
   (a) $hf - W < 0$ (b) $hf - W \geq 0$ (c) f > threshold frequency (d) both b & c

5. How does the maximum kinetic energy of electrons emitted vary with the increase in work function of the metal?
   (a)Increase (b) decrease (c) remain same (d) no effect

ANSWERS CCT

Q1.		Q2.	
1	Momentum	1	zero
2	photo electric effect	2	independent of the intensity
3	particle nature of light	3	both b & c
4	Radiation	4	b

G. HOTS

1. A blue lamp mainly emits light of wavelength 4500 A^0 .The lamp is rated as 150 watt and 8% of
   the energy is emitted as visible light how many photons are emitted by lamp per second?

2. If the frequency of incident light on a metal surface is doubled will the kinetic energy of photoelectrons be doubled? Give reason.

3. A particle of mass M at rest decays into two particles of mass m_1 and m_2 having non zero velocities. What is the ratio of the de Broglie wavelength of the two particles?

ANSWER HOTS

1. $N = \frac{8\% \text{ of P}}{E}$
   $N = \frac{8\,P\,\lambda}{100\,hC}$ on substituting the values
   $N = 2.71 \times 10^{29}$ photons / sec

2. Let W_0 = work function of metal,
   E1 = KE corresponding to frequency υ
   E2 = KE corresponding to frequency 2υ

   $h\upsilon = E1 + W_0$ and
   $2h\upsilon = E2 + W_0$
   On dividing and solving
   $E2 = 2\,E1 + W_0$, ie KE of Photon increase more than the doubled.

3. By conservation of linear momentum

   $m_1 v_1 + m_2 v_2 = M \times 0$
   on solving $P_1 = P_2$
   $P_2/P_1 = \lambda 1/\lambda 2 = 1$

H. STATEMENT BASED

1. The photoelectric emission is possible only if the incident light is in the form of packets of energy, each having a definite value, more than the work function of the metal. This shows that light is not of wave nature but of particle nature. It is due to this reason that photoelectric emission was accounted by quantum theory of light.

1. Packet of energy are called ____________________ quanta
2. One quantum of radiation is called ______________
3. Energy associated with each photon _______________
4. Which of the waves produce photo electric effect ____________
5. Work function of alkali metals is ________________

Q2. According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle or a wave is associated with moving material particle which controls the particle in every respect. The wave associated with moving material particle is called matter wave or de-Broglie wave whose wavelength called de-Broglie wavelength, is given by $\lambda = h/mv$.

1.The dual nature of light is exhibited by _________________ .

2. If the momentum of a particle is doubled, then its de-Broglie wavelength will become ______________

3. If an electron and proton are propagating in the form of waves having the same λ , it implies that they have the same ______________

4. Velocity of a body of mass m, having de-Broglie wavelength λ , is _______________

5. Moving with the same velocity, which of the following has the longest de Broglie wavelength?

(a) β particle (b) α -particle (c) proton (d) neutron

Ans 1:

1. Quanta 2. Photon 3. hv 4. UV radiation 5. quite less than other metals

Ans 2.

1. Diffraction & Photo electric effect 2. Half 3. Momentum 4. $v = h/\lambda m$ 5. β particle

I. DERIVATION BASED

1. What are matter waves? Derive an expression for De Broglie wavelength associated with an electron accelerated through a potential difference of V volts. (b) Draw a graph showing the variation of De Broglie wavelength of a particle of charge q, mass m with accelerating voltage V.
2. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photoelectrons emitted from this surface have the de-Broglie wavelength λ_1, prove that $\lambda = (2mc/h)\lambda_1^{\ 2}$

ANSWER DERIVATION

Ans 1. When the charge particle is accelerated by a potential V, the kinetic energy is equal to electrostatic potential

energy. Thus

$$\frac{1}{2} mv^2 = qV$$

$$v = (2qV/m)^{1/2}$$

$$\lambda = h/p$$

$$= h/mv$$

$$= h/(2mqV)^{1/2}$$

Ans 2. KE of electron = energy of Photon on em wave

$$= \frac{hc}{\lambda}$$

de Broglie wavelength, $\lambda_1 = \frac{h}{\sqrt{2mE_k}}$ or $\lambda_1^2 = \frac{h^2}{2mE_k}$

Using (1), we get

$$\lambda_1^2 = \frac{h^2}{2m\left(\frac{hc}{\lambda}\right)} \Rightarrow \lambda = \left(\frac{2mc}{h}\right)\lambda_1^2$$

DUAL NATURE OF RADIATION AND MATTER

IMPORTANT CONCEPT

Photon. It is a packet of energy. A photon of frequency v possesses energy hν. The rest mass of a photon iszero.

Work function of a metal. The minimum energy, which must be supplied to the electron so that it can just come out of a metal surface, is called the work function of the metal. It is denoted by W

Photoelectric effect. The phenomenon of ejection of electrons from a metal surface, when light of sufficientlyhigh frequency falls on it, is known as photoelectric effect.

The electrons so emitted are called photoelectrons.

Threshold frequency. The minimum frequency (ν_O)), which the incident light must possess so as to ejectphotoelectrons from a metal surface, is called threshold frequency of the metal.

Mathematically- W = hν_O Laws of photoelectric fect.

Photoelectric emission takes place from a metal surface, when the frequency of incident light is above itsthreshold frequency.

1. The photoelectric emission starts as soon as the light is incident on the metal surface.
2. The maximum kinetic energy with which an electron is emitted from a metal surface is independent of theintensity of light and depends upon its frequency.
3. The number of photoelectrons emitted is independent of the frequency of the incident light and depends onlyupon its intensity.

Cut off potential. It is that minimum value of the negative potential ( ), which should be applied to theanode in a photo cell so that the photoelectric current becomes zero.

de-Broglie hypothesis :. Both radiation and matter have dual nature.A particle of momentum p is associated with de-Broglie wave of wavelength.

The above relation is called de-Broglie relation and the wavelength of the wave associated is called de-Brogliewavelength of the particle. $\Lambda = h/p$ de-Broglie wavelength of electron. An electron of kinetic energy E possesses de-Broglie wavelength, If electron is accelerated through a potential difference V, so as to acquire kinetic energy E (=e V), then

$$\lambda = \frac{h}{\sqrt{mev}} = \frac{12 \cdot 3}{\sqrt{v}} A^0$$

IMPORTANT QUESTIONS (TEST YOUR SELF)

Q.1 How does the intensity affect the photoelectric current?

Q.2 Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Q.3 Define the term 'stopping potential' in relation to photoelectric effect.

Q.4 Define the term 'threshold frequency' in relations to photoelectric effects.

Q.5 In photoelectric effect, why should the photoelectric current increase as the intensity of incident radiation increases.

Q.6 Do all the electrons that absorb a photon come out as photoelectrons?

Q.7 Light of wavelength 3500 Å is incident on two metals A and B. Which metal will yield morephotoelectrons if their work functions are 5 eV and 2 eV respectively?

Q.8 The momentum of photon of electromagnetic radiation is 3.3 10^{-29} kg-m/s. Find out thefrequency and wavelength of the wave associated with it. (Ans 2 x 10^{-5})

Q.9 Monochromatic light of frequency 6.0 × 10^{14} Hz is produced by a laser. The power emitted is 2.0 × 10^{-3}Watt Calculate the

(i) energy of a photon in the light beam and (Ans 3.978 × 10^{-19} J)

(ii) number of photons emitted on an average by the source. (Ans 5.03 x 10^{15} photons / second)

Q.10 (a) Define the term 'intensity of radiation' in photon picture.

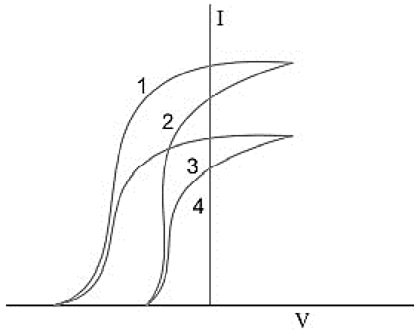
(b) Plot a graph showing the variation of photo current vs collector potential for three different intensities $I_1 > I_2 > I_3$, two of which (I_1 and I_2) have the same frequency v andthe third has frequency $v_1 > v$.

Q.11 Show the variation of photocurrent with collector plate potential for different frequenciesbut same intensity of incident radiation.

Q.12 Write Einstein's photoelectric equation and point out any two characteristic properties ofphotons on which this equation is based.

Q.13 What is meant by work function of a metal? How does the value of work function influencethe kinetic energy of electrons liberated during photoelectron emission?

Q.14 The given graph shows the variation of photo-electric current (I) with the applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify and explain using Einstein's photo electricequation for the pair of curves that correspond to



(i) different materials but same intensity of incident radiation,

(ii) different intensities but same materials.

Q.15 Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$). On what factorsdoes the (i) slope and (ii) intercept of the lines depend?

Q.16 A proton and an alpha particle are accelerated through the same potential. Which one of thetwo has (i) greater value of de Broglie wavelength associated with it and (ii) less kinetic energy? Give reasons to justify your answer.

Q.17 A proton and a deuteron are accelerated through the same accelerating potential. Which oneof the two has (i) greater value of de-Broglie wavelength associated with it, and (ii) less momentum? Give reasons to justify your answer

Q.18 An α-particle and a proton are accelerated from rest by the same potential. Find the ratio oftheir de- Broglie wavelengths.

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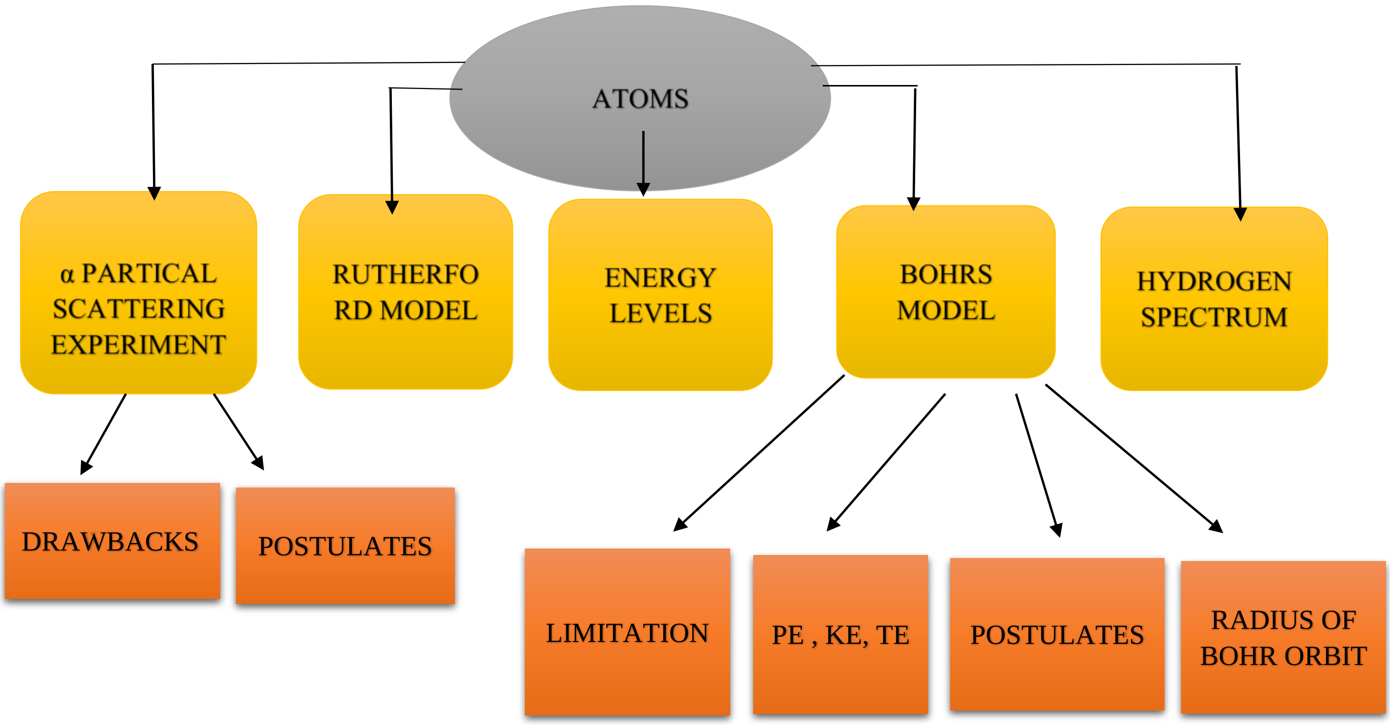
CHAPTER 12

ATOMS



CONCEPT MAPS / MIND MAPS

GIST OF THE CHAPTER

- **Alpha – particle scattering experiment.**
- **Rutherford's model of an atom.**
- **Bohr model of hydrogen atom.**
- **Expression for radius of nth possible orbit.**
- **Velocity and Energy of electron in the orbit.**
- **Hydrogen line spectra(qualitative treatment)**

A. MCQ BASED

1. According to Bohr's theory, the angular momentum of an electron revolving in second orbit of hydrogen atom will be

(a) $2h/\pi$ (b) h/π (c) $2\pi rh$ (d) πh

2. The energy of the electron revolving in the orbit of Bohr radius is

(a) 13.6 MeV (b) -13.6 eV (c) -13.6 MeV (d) 13.6 eV

3. If an electron jumps from 1st orbit to 3rd orbit, then it will

(a) Absorb energy (b) Release energy (c) Remains same (d) None of these

4. In Bohr model of hydrogen atom which of the following is quantized?

(a) linear velocity of electron (b) angular velocity of electron

(c) Linear momentum of electron (d) Angular momentum of electron

5. The number of waves contained in unit length of the medium is called

(a) elastic wave (b) Wave number (c) Wave pulse (d) None of these

6. According to Bohr theory , the relation between principle quantum number n and the radius of the orbit r is

(a) $r \propto n$ (b) $r\ \alpha\ \frac{1}{n}$ (c) $r\ \alpha\ n^2$ (d) $r\ \alpha\ \frac{1}{n^2}$

7. In Bohr's model the atomic radius of the first orbit is r_0. Then the radius of the third orbit is

(a) $\frac{r_0}{9}$ (b) $6r_0$ (c) $9r_0$ (d) $3r_0$

8. An electron orbiting in H-atom has energy level -3.4eV. Its angular momentum will be

(a) $2.1 x 10^{-34}$ Js (b) $2.1 x 10^{-20}$ Js (c) $4 x 10^{-20}$ Js (d) $4 x 10^{-34}$ Js

9. The ground state energy of hydrogen atom is -13.6eV. What is the potential energy of electron in this state?

(a) 0 eV (b) -27.2 eV (c) 1 eV (d) 2 eV

10. According to Rutherford's atomic model the electrons inside an atom are

(a) Stationary (b) centralized (c) Non-stationary (d) None of these

11. $h/2\pi$ has the dimension of

(a) velocity (b) momentum (c) energy (d) angular momentum

12. In terms of Rydberg constant the wave number of first Balmer line is

(a) R (b) 3R (c) 5R/36 (d) 8R/9

13. The ratios between Bohr radii are

(a) 1:2:3 (b) 2:4:6 (c) 1:4:9 (d) None of these

14. What is the angle of scattering for zero impact parameter?

(a) 0 (b) 90 (c) 180 (d) None of these

15. A classical atom based on which model is doomed to collapse

(a) Rutherford's model (b) Bohr's model (c) None of these d) Thomson model

Answers MCQ

1	b	4	d	7	c	10	c	13	c
2	b	5	b	8	a	11	d	14	c
3	a	6	c	9	b	12	c	15	a

B. ASSERSATION & REASONING

Read the assertion and reason carefully to mark the correct option out of the options given below:

(A) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(B) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(C) If assertion is true but reason is false.

(D) If the assertion and reason both are false.

1. **Assertion:** The force of repulsion between atomic nucleus and alpha particle varies with distance according to inverse square law.

   Reason: Rutherford did alpha particle scattering experiment.

2. **Assertion:** The positively charged nucleus of an atom has a radius of almost 10^{-15} m

   Reason: In alpha-particle scattering experiment, the distance of closest approach for alpha particles is approximately 10^{-15} m.

3. **Assertion: For** the scattering of alpha-particles at a large angle, only the nucleus of the atom is responsible.

   Reason: Nucleus is very heavy in comparison to electrons.

4. **Assertion:** Electrons in the atom are held due to coulomb forces.

   Reason: The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

5. **Assertion:** Hydrogen atom consists of only one electron but its emission spectrum has many lines.

   Reason: Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

6. Assertion: Total energy of revolving electron in any stationary orbit is negative

Reason: Energy is a scalar quantity. It can have only positive value.

7. Assertion: The isotopes of an element exhibit similar chemical properties.

   Reason: Isotopes of an element have same atomic number.

8. Assertion: Bohr postulated that the electrons in stationary orbits around the nucleus do not radiate.

   Reason: According to classical physics all moving electrons radiate.

ANSWERS ASSERSATION & REASONING

1	B	4	C	7	B
2	A	5	B	8	C
3	A	6	B		

C. NUMERICAL BASED

1. The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What is the radius of orbit in the second excited state?
2. The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of electron in this state?
3. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?

Answer Numerical Based

Ans 1.

$r = n^2 \times 5.3 \times 10^{-11}$ m

$\therefore$ Radius of second excited state ($n = 3$) is :

$r = (3)^2 \times 5.3 \times 10^{-11}$ m $= 9 \times 5.3 \times 10^{-11}$ m

$= \mathbf{4.77 \times 10^{-10}}$ **m**

Ans 2.

Kinetic energy, K_e = + T.E. = 13.6 eV

Potential energy, P_e = 2 T.E. = 2 (-13.6) = – 27.2 eV

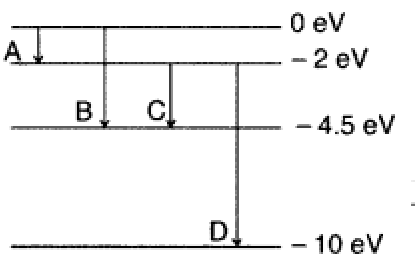
Ans 3.

Radius of Bohr's stationary orbi

Clearly, $r \propto n^2$ and in ground

For 1^{st} excited state, $n = 2$

$\therefore$ Ratio of radii of the orbits

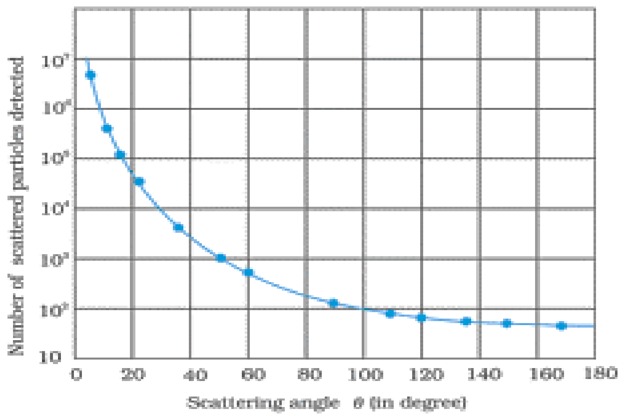


D. GRAPH BASED

1. Draw graph showing total number of alpha particles scattered at different angle θ in Rutherford alpha particle scattering experiment.
2. Draw graph showing de Broglie wave and hydrogen atom.

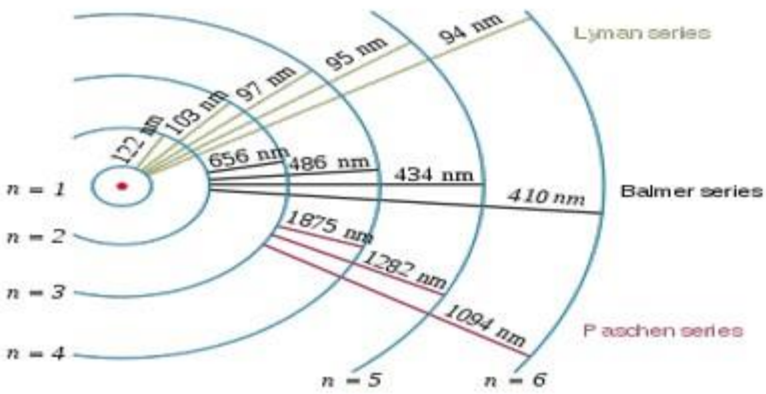
ANSWERS GRAPH BASED

Ans 1.



Courtesy Central Institute of educational Technology.

Ans 2.



Courtesy Assignment Point.

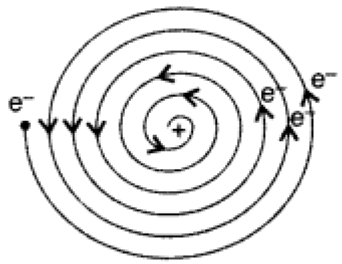
E. DIAGRAM BASED

1. Why is the classical (Rutherford) model for an atom—of electron orbiting around the nucleus—not able to explain the atomic structure?
2. In Rutherford scattering experiment, draw the trajectory traced by a-particles in the coulomb field of target nucleus and explain how this led to estimate the size of the nucleus.
3. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions

correspond to emission of radiation of (i) maximum and (ii) minimum wavelength?

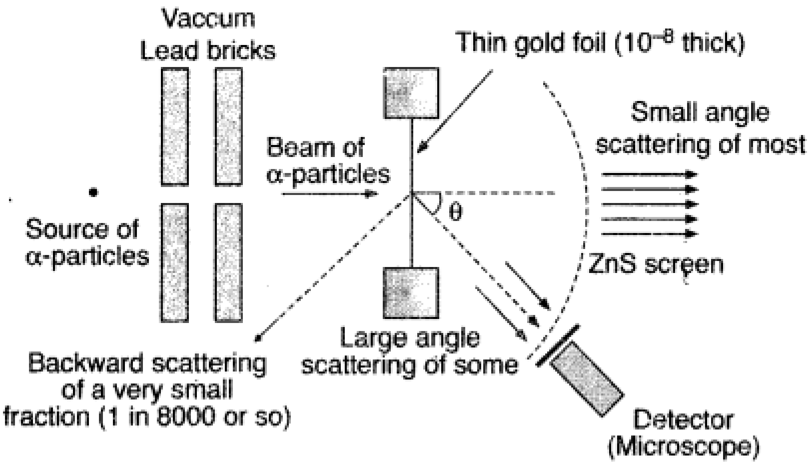
ANSWERS DIAGRAM BASED

Ans 1. As the revolving electron loses energy continuously, it must spiral inwards and eventually fall into the nucleus. So it was not able to explain the atomic structure.



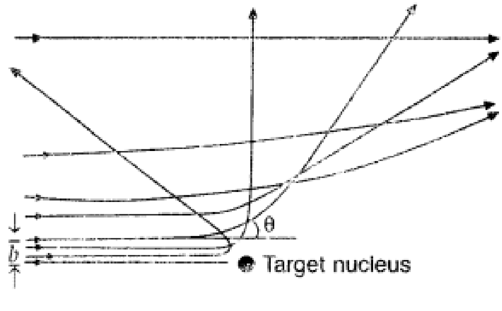
Ans 2.

(*a*) (*i*) **Geiger-Marsden experiment**



(ii) For most of the α-particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go right through the foil.

(iii) Trajectory of α-particles



It gives an estimate of the size of nucleus, that it relatively very very small as compared to the size of atom.

Ans 3.

Energy of photon wavelength 275 nm

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{275\times10^{-9}\times1.6\times10^{-19}}.eV = 4.5 \text{ eV}$$

This componds to transition 'B'.

(*i*) *Element A* has radiation of maximum wavelength *621 nm*.

(*ii*) *Element D* has radiation of minimum wavelength *155 nm*.

F. CCT BASED

Q1. Teacher taught the Rutherford alpha scattering experiment in class. His teacher explained that in alpha scattering experiment Rutherford concluded that most of the space within the atom is empty. The entire positive charge and most of the mass of the atom is concentrated in its central core. Trajectory of alpha particle depends on impact parameter which is the perpendicular distance of the initial velocity vector of the alpha particle from the Centre of the nucleus The extent of scattering is inversely proportional to the impact parameter.

1. The least distance at which an alpha particle stops before reaching the nucleus is called:

(a) Distance of scattering (b) Distance of rebounding (c) Distance of closest approach (d) Nuclear radius.

2. The alpha particles are emitted in this experiment by:

(a) Charged helium (b) Electric cell (c) Gold foil of 0.01µm thickness (d) Radioactive source

3. The perpendicular distance of velocity vector of approaching alpha particle from center of target nucleus is

(a) Scattering distance (b) impact parameter (c) trajectory (d) distance of closest approach

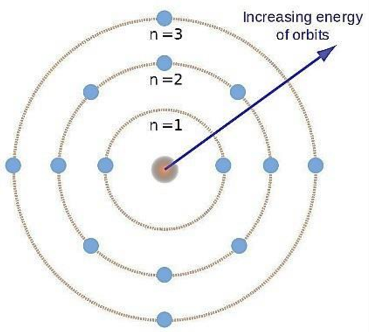
4. The electrons revolve around the nucleus in

(a) Orbit (b) Form the electron clouds (c) Both (a) & (b) (d) None of these

5. Most of the space inside the atom is

(a) Filled (b) Empty (c) Neutral (d) positively charged.

Q2. The Bohr model of the atom was proposed by Neil Bohr in 1915. It came into existence with the modification of Rutherford's model of an atom. Rutherford's model introduced the nuclear model of an atom, in which he explained that a nucleus (positively charged) is surrounded by negatively charged electrons.



1. Which of the following statements does not form a part of Bohr's model of a hydrogen atom?
   a. The energy of the electrons in the orbit is quantized
   b. The electron in the orbit nearest the nucleus has the lowest energy
   c. Electrons revolve in different orbits around the nucleus
   d. The position and velocity of the electrons in the orbit cannot be determined simultaneously
2. What is in the center of the Rutherford model?
   a. Single proton b. multiple electrons c. A nucleus d. Neutrons
3. When an electron jumps from its orbit to another orbit, energy is:
   a. emitted only b. absorbed only c. both (a) and (b) d. none of these
4. What were the limitations of the Rutherford model which could not explain the observed features of atomic spectra explained in Bohr's model of a hydrogen atom?
   a. It must emit a continuous spectrum b. It loses its energy
   b. Gaining its energy d. A discrete spectrum
5. When an electron remains between orbits its momentum is:
   a. Quantized b. emitted c. dequantized d. none of the above

Q3. In 1938, the German chemist Otto Hahn, a student of Rutherford, directed neutrons onto uranium atoms expecting to get transuranium elements. Instead, his chemical experiments showed barium as a product. A year later, Lise Meitner and her nephew Otto Frisch verified that Hahn's result were the first experimental nuclear fission. In 1944, Hahn received the Nobel Prize in Chemistry. Despite Hahn's efforts, the contributions of Meitner and Frisch were not recognized.

In the 1950s, the development of improved particle accelerators and particle detectors allowed scientists to study the impacts of atoms moving at high energies. Neutrons and protons were found to be hadrons, or composites of smaller particles called quarks. The standard model of particle physics was developed that so far has successfully explained the properties of the nucleus in terms of these sub-atomic particles and the forces that govern their interactions.

1. Who performed first experimental nuclear fission?
2. What product Otto Hahn expected by directing neutrons to uranium atom?
3. What product Otto Hahn obtain by directing neutrons to uranium atom?
4. What made the scientists to study the impacts of atoms moving at high energies?
5. Neutrons and Protons are composite smaller particles called ____________.

ANSWER CCT BASED

Question	Q1	Q2	Q3
1.	c	d	Otto Hahn
2.	a	c	Transuranium elements
3.	b	c	barium
4.	a	d	development of improved particle accelerators and particle detectors
5.	b	a	quarks

G. HOTS

1. The wavelength of second line of Balmer series in the hydrogen spectrum is $4861A^{0.}$ Calculate the wavelength of first line.
2. The photon emitted during de-excitation from the first excited level to the ground state of the hydrogen atom is used to irradiate a photocell, in which stopping potential of 5V is used. Calculate the work function of the cathode used.
3. Using Bohr's postulate, derive the expression for the orbital period of the electron in the nth orbit.

ANSWERS HOTS

1. The wavelength λ_1 and λ_2 of the first and second lines of the Balmer series is given by:

   $\frac{1}{\lambda 1} = R[\frac{1}{4} - \frac{1}{9}] = 5\ R/36$

   $\frac{1}{\lambda 2} = R[\frac{1}{4} - \frac{1}{16}] = 3\ R/16$

   $\frac{\lambda 1}{\lambda 2} = 27/20$

   $\lambda_1 = 27 \times 4861/20 = 6562\ A^0$

2. Energy of incident photon = E2 – E1 = - 3.4 – (13.6) = 10.2 eV

   KE of photo electron = eV_0 = 5eV

   Energy of incident photon = KE + Work function

   10.2 eV = 5 eV + W_0

   W_0 = 5.2eV

3. Centripetal force = Electrostatic attraction

   $Mv^2/r = ke^2/r^2$

   $Mv^2r = ke2$ ------------- (1)

   Bohr's quantization condition

   $Mvr = nh/2\pi$ -------------(2)

   Dividing 1 by 2, $v = 2\pi ke^2 / nh$

   $T = 2\pi r / v$

   $= n^3h^3 / 4\pi^2mk^2e^4$

H. STATEMENT BASED

Q1. At the suggestion of Earnest Rutherford in 1911, H Geiger and E. Marsden performed an experiment. They directed a beam of 5.5 MeV Alpha particles emitted from $_{83}Bi^{214}$ radioactive source at a thin metal foil made of gold. The beam was allowed to fall on thin gold foil. The scattered Alpha particles were observed through a rotatable detector consisting of zinc sulphide screen and a microscope. The scattered Alpha particles on striking the screen produced brief light flashes or scintillations. These may be viewed through a microscope and the distribution of number of scattered particles maybe studied as function of angle of scattering only about 0.14% of incident Alpha particles scatter by more than 1 degree and about one in 8000 deflect by more than 90 degrees. Rutherford argued that to deflect the Alpha particle backwards, it must experience in large repulsive force. This force could be provided if the greater part of mass of the atom and its positive charge were concentrated tightly at its center.

1. Which Alpha particle source was used by H Geiger and E. Marsden?

2. Why gold foil was used for the experiment?
3. How much percentage of incident Alpha particles scatter by more than 1 degree?
4. Rotatable detector consists of screen made up of ______________.

Q2. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons because when we derive the formula of radius / energy levels etc. we make the assumption that centripetal force is provided only by electrostatic force of attraction by the nucleus so that this will only work for single electron system in multi electrons there will also be repulsion due to other electrons the simple Bohr model cannot be directly applied to calculate the energy levels of an atom with multi electrons system.

1. Simple Bohr model of an atom can be applied to ____________.
2. Simple Bohr model of an atom cannot be applied to _________.
3. Centripetal force for revolution of electron is provided by ______.
4. Give example of multi electron atom.

ANSWER STATEMENT BASED

Ans 1.

1. 5.5 MeV Alpha particles emitted from $_{83}Bi^{214}$.
2. As Gold is malleable it is possible to make thin films.
3. About 0.14% of incident Alpha particles scatter by more than 1 degree.
4. Zinc Sulphide.

Ans 2.

1. Single electron atom.
2. Multi electron atom.
3. Electrostatic force.
4. Na, Al, Ca etc.

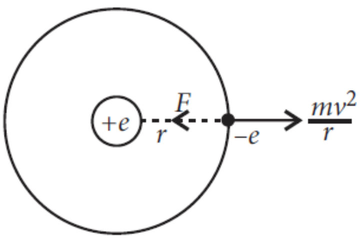
I. DERIVATION BASED

1. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.
2. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$. Identify the spectral series to which the emission lines belong.

ANSWER DERIVATION BASED

Answer 1.

Radius of nth orbit of hydrogen atom: In H-atom, an electron having charge –e revolves around the nucleus of charge +e in a circular orbit of radius r, such that necessary centripetal force is provided



by the electrostatic force of attraction between the electron and nucleus.

$\frac{mv^2}{r} = \frac{kZe^2}{r^2}$ And $mvr = \frac{nh}{2\pi}$

Putting value of v from second equation to first we get

$$r = \frac{n^2h^2 \in_0}{\pi me^2}$$

$r \propto n^2$

Answer 2.

$$\frac{mv^2}{r} = \frac{kZe^2}{r^2}$$

$$mvr = \frac{nh}{2\pi}$$

Solving these

$$r_n = \frac{\epsilon_0 n^2 h^2}{\Pi me^2}$$

Total energy = Kinetic energy + Potential energy = $\frac{1}{2}mv^2 + (-)\frac{ke^2}{r}$

$E = -\frac{Rhc}{n^2}$where, R = Rydberg constant

Energy emitted ΔE = $E_i - E_f$

And ΔE = hv

$$v = Rc\left[\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right]$$

When electron in hydrogen atom jumps from energy state n_i = 4 to n_f = 3, 2, 1, the Paschen, Balmer and Lyman spectral series are found.

IMPORTANT QUESTIONS (TEST YOUR SELF)

1. The mass of a H-atom is less than the sum of the masses of a proton and electron. Why is this?
2. When an electron falls from a higher energy to a lower energy level, the difference in the energies appears in the form of electromagnetic radiation. Why cannot it be emitted as other forms of energy?
3. Consider two different hydrogen atoms. The electron in each atom is in an excited state. Is it possible for the electrons to have different energies but the same orbital angular momentum according to the Bohr model?
4. The first four spectral lines in the Lyman series of a H-atom are λ = 1218 Å, 1028Å, 974.3 Å and 951.4Å. If instead of Hydrogen, we consider Deuterium, calculate the shift in the wavelength of these lines.
5. What is the main feature of Rutherford's nuclear atom model?
6. State Bohr's postulate of quantisation of angular momentum of the election in hydrogen atom.
7. What is Bohr's radius? What is its value?

8. Define ionisation energy. What is its value for a hydrogen atom?
9. What is the significance of negative energy of the orbiting electron in an atom?
10. How does atomic spectrum differ from a continuous spectrum?

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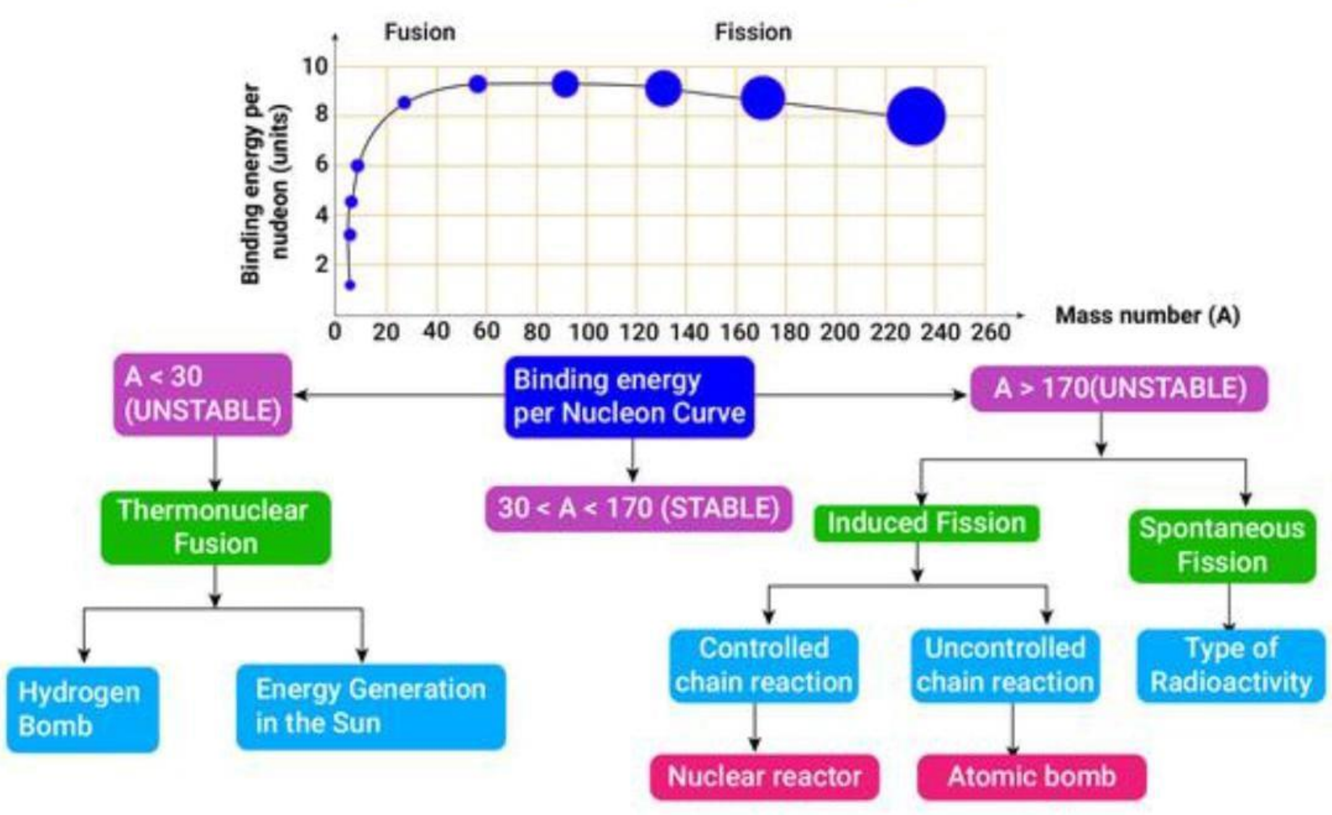
CHAPTER 13

NUCLEI



CONCEPTS

Composition and size of nucleus, nuclear force Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

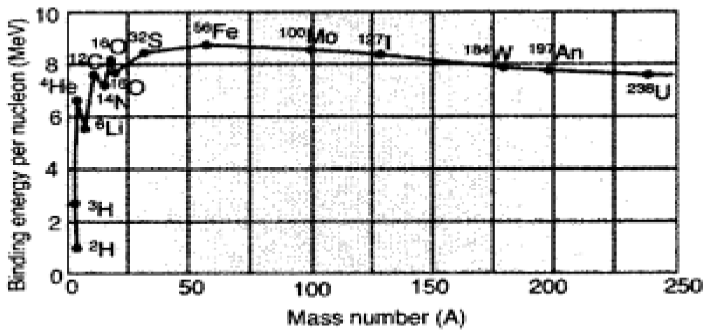
NUCLEI

Q.No.	Multiple Choice Questions	MARKS
1	Which of the following quantities is not conserved in a nuclear reaction? (a) Mass (b) Charge (c) Momentum (d) None of the above Answer : (a) Mass	1
2	An electron emitted in beta radiation originates from (a) free electrons existing in the nuclei (b) inner orbits of an atom (c) photon escaping from the nucleus (d) decay of a neutron in a nuclei **Answer:** (c) photon escaping from the nucleus	1
3.	Heavy stable nuclei have more neutrons than protons. This is because of the fact that (a) neutrons are heavier than protons. (b) electrostatic force between protons are repulsive (c) neutrons decay into protons through beta decay (d) nuclear forces between neutrons are weaker than that between protons. Answer: (b) electrostatic force between protons are repulsive	1
4	The light energy emitted by a star is due to (a) Joining of nuclei (b) Burning of nuclei (c)Breaking of nuclei (d)Reflection of solar light **Answer:** (a) Joining of nuclei	1
5	Sun's radiant energy is due to (a) Nuclear Fusion (b)Nuclear Fission (c)Photoelectric Effect (d)Radioactive Decay **Answer:** (a) Nuclear Fusion	1
6.	Complete the series $6He \rightarrow e^- + 6Li +$ (a) Neutrino (b) antineutrino (c) proton (d) neutron Answer: (b) antineutrino	1
7.	Ratio of the radii of the nuclei with mass numbers 8 and 27 would be (a) 27/8 (b) 8/27 (c) 2/3 (d) 3/2 Answer: (c) 2/3	1
8	Binding energy per nucleon of a stable nucleus is (a) 8 eV (b) 8 KeV (c) MeV (d) 8 BeV	1

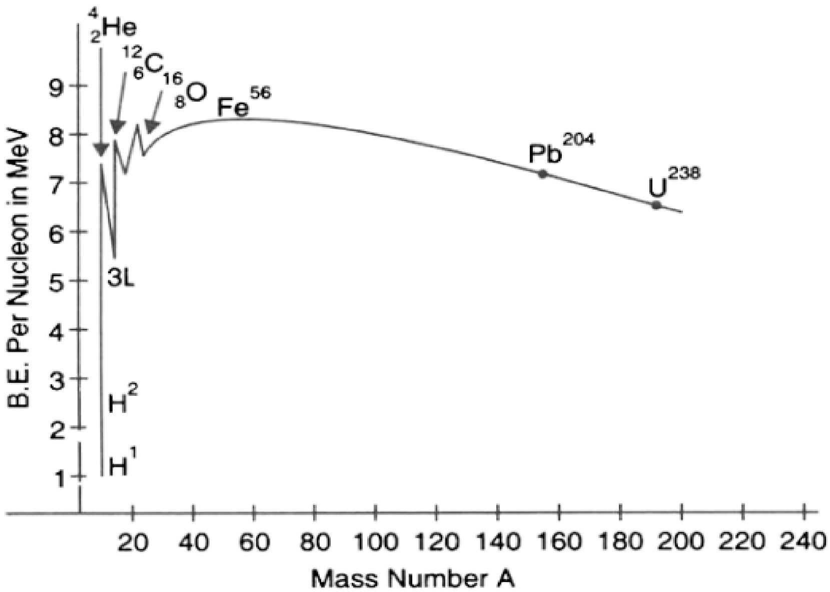
	Answer: (c) 8 MeV	
9.	Average binding energy is maximum for (a) C^{12} (b) Fe^{56} (c) U^{235} (d) Po^{210} Answer: (b) Fe^{56}	1
10	The atomic number of an atom indicates (a) Number of electrons (b) Number of protons (c)Number neutrons (d) Both number of protons and neutrons Answer: (b) number of protons	1
	ASSERTION AND REASON QUESTIONS **For questions 11 and 15, there are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate Answer from the options given below:** **(a) Assertion is true, reason is true; reason is a correct explanation for assertion. (b) Assertion is true, reason is true; reason is not a correct explanation for assertion (c) Assertion is true, reason is false** **(d) Assertion is false, reason is true.**	
11	**Assertion :** Density of all the nuclei is same. **Reason :** Radius of nucleus is directly proportional to the cube root of mass number.	1
12	**Assertion :** Neutrons penetrate matter more readily as compared to protons. **Reason :** Neutrons are slightly more massive than protons.	1
13.	**Assertion :** The mass number of a nucleus is always less than its atomic number. **Reason :** Mass number of a nucleus may be equal to its atomic number.	1
14	**Assertion :** The binding energy per nucleon, for nuclei with atomic mass number $A > 100$, decrease with A. **Reason :** The forces are weak for heavier nuclei.	1
15.	**Assertion:** Naturally , thermonuclear fusion reaction is not possible on earth. **Reason :** For thermonuclear fusion to take place, extreme condition of temperature and pressure are required	1
	NUMERICAL BASED QUESTIONS	
16.	Two nuclei have mass numbers in the ratio 1: 2. What is the ratio of their nuclear densities? Answer:	2

	Nuclear density, $f = \frac{\text{Mass of Nucleus}}{\text{Volume of Nucleus}}$ But, $R = R_0 A^{1/3}$ $\therefore \quad f = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$ ...where [m is mass of proton or neutron and A is number of nucleons $\therefore \quad f = \frac{m}{\frac{4}{3}\pi R_0^3}$ Thus, f is independent of A (mass number) $\therefore$ The ratio of density will be **1 : 1**.	
17.	Two nuclei have mass numbers in the ratio 8:125. What is the ratio of their nuclear radii? Answer: $A_1 : A_2 = 8 : 125 \Rightarrow \frac{A_1}{A_2} = \frac{8}{125}$ Since $R = R_0 A^{1/3} \quad \therefore \quad \frac{R_1}{R_2} = \frac{A_1^{1/3}}{A_2^{1/3}} = \frac{8^{1/3}}{125^{1/3}} = \frac{2}{5}$	3
18.	**A nucleus with mass number A = 240 and $\frac{BE}{A}$ = 7.6 MeV breaks into two fragments each of A = 120 with $\frac{BE}{A}$ = 8.5 MeV. Calculate the released energy.** Answer: Binding energy of nucleus with mass number 240, $(E_{BN})_1 = 240 \times 7.6$ MeV ...(*i*) Binding energy of two fragments $(E_{BN})_2 = 2 \times 120 \times 8.5$ MeV ...(*ii*) Energy released $= (E_{BN})_2 - (E_{BN})_1$ $= (2 \times 120 \times 8.5) - (240 \times 7.6)$ $= 240(8.5 - 7.6) = 240 \times 0.9$ $= 216$ MeV	3
	GRAPH BASED QUESTIONS	
19.	Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release of energy in the processes of nuclear fission and nuclear fusion can be explained. Answer: 1. Nuclear fission : Binding energy per nucleon is smaller for heavier nuclei than the middle ones i.e. heavier nuclei are less stable. When a	3

<table>
<tr><td></td><td>heavier nucleus splits into the lighter nuclei, the B.E./nucleon changes (increases) from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.


</td><td></td></tr>
<tr><td>20.</td><td>Draw a curve between mass number and binding energy per nucleon. Give two salient features of the curve. Hence define binding energy.

Ans: The total energy required to disintegrate the nucleus into its constituent particles is called binding energy of the nucleus.



Salient features of the curve

(i) The intermediate nuclei have a large value of binding energy per nucleon, so they are most stable. (For $30 < A > 63$)

(ii) The binding energy per nucleon has low value for both the light and heavy nuclei. So, they are unstable nuclei.</td><td>3</td></tr>
<tr><td></td><td>DIAGRAM BASED QUESTIONS</td><td></td></tr>
<tr><td>21.</td><td>Draw a diagram of Binding Energy Curve
Answer:</td><td>2</td></tr>
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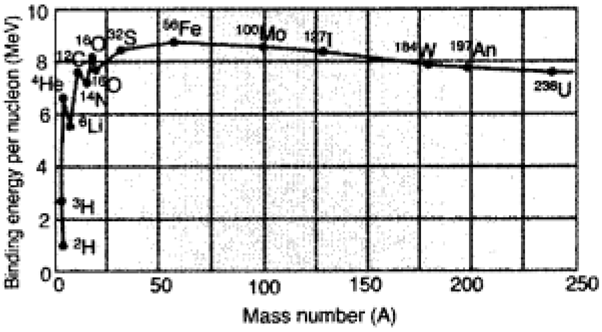


CCT QUESTIONS

22. ***Read the passage given below and answer the following questions:*** 5

Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadrupole moment and spin of nucleus depends on even and odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.

(i) The correct statements about the nuclear force is/are

(a) charge independent
(b) short range force
(c) non-conservative force
(d) all of these.

(ii) The range of nuclear force is the order of

(a) 2×10^{-10} m
(b) 1.5×10^{-20} m
(c) 1.2×10^{-4} m
(d) 1.4×10^{-15} m

(iii) A force between two protons is same as the force between proton and neutron. The nature of the force is

(a) electrical force
(b) weak nuclear force
(c) gravitational force
(d) strong nuclear force

(iv) two protons are kept at a separation of 40 A^0. F_n is the nuclear force and F_e is the electrostatic force between them. Then

(a) $F_n << F_e$
(b) $F_n = F_e$
(c) $F_n >> F_e$
(d) $F_n \approx F_e$

(iv) **All the nucleons in an atom are held by**

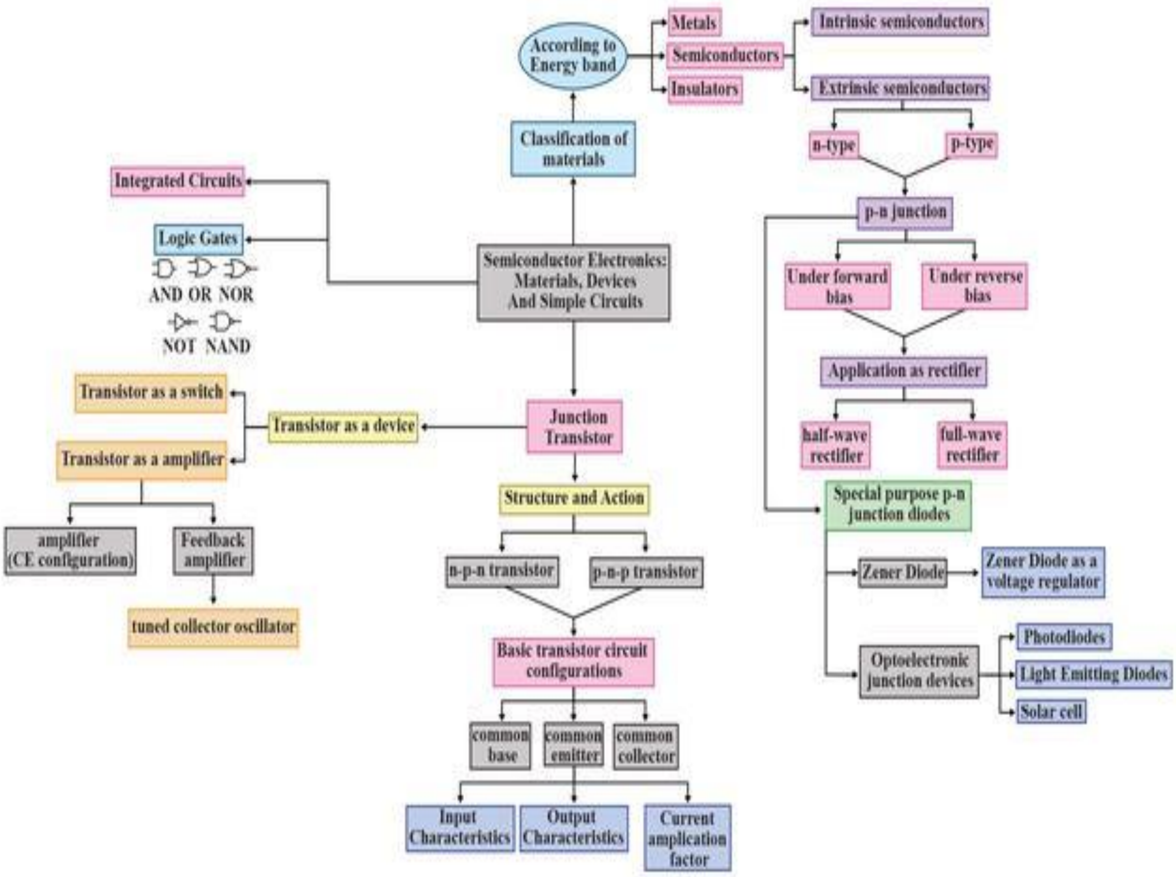
(a) nuclear forces
(b) vander waal's forces
(c) tensor forces
(d) coulomb forces

	HOTS QUESTIONS	
23	**Why do stable nuclei never have more protons than neutrons?** **Answer:** A stable nuclei never have more protons than neutrons because protons are charged particles and they repel each other. The repulsion is so much that excess neutrons only produce attractive forces and this is sufficient enough to build stability.	2
24.	$He2^3$ and $He1^3$ **Nuclei have the same mass number. Do they have the same binding energy?** **Answer:** $He2^3$ and $He1^3$ have the same mass number but the binding energy of these two nuclei is different. The binding energy of the $He1^3$ is greater than the $He2^3$ because the number of protons and neutrons present in both the nuclei are different. $He1^3$ has one proton and two neutrons while $He2^3$ has two protons and one neutron.	2
25.	**Nuclei with magic no. of proton Z = 2, 8, 20, 28, 50, 52 and magic no. of neutrons N = 2, 8, 20, 28, 50, 82 and 126 are found to be very stable** **(i) Verify this by calculating the proton separation energy Sp for Sn120 (Z = 50) and Sb121 = (Z = 51). The proton separation energy for a nuclide is the minimum energy required to separate the least tightly bound proton from a nucleus of that nuclide. It is given by Sp = (M_{Z-1}, N + M_H – $M_{Z,N}$) c^2. Given In^{119} = 118.9058u, Sn^{120} = 119.902199u, Sb^{121} = 120.903824u, H^1 = 1.0078252u** **(ii) What does the existence of magic number indicate?** **Answer:** i) The proton separation energy is SpSn = (M119.70 + Mh – M120.70)c^2 = 0.0114362 c^2 Similarly SpSp = (M120.70 + Mh – M121.70)c^2 = 0.0059912 c^2 Since SpSn > SpSp, Sn nucleus is more stable than Sb nucleus. iii) The magic numbers indicate that the shell structure of	3

	the nucleus is similar to the shell structure of the atom. This explains the peaks in the binding energy.	
	STATEMENT QUESTIONS	
26.	Write the difference between Fission & Fusion?	2
27.	Difference between Binding energy and ionization energy?	3
	DERIVATION QUESTIONS	
28.	Derive the expression for the radius of the Nuclei.	3
29.	Derive Fusion reaction in Sun	2

CHAPTER 14

SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS



CONCEPTS

Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diode as a rectifier.

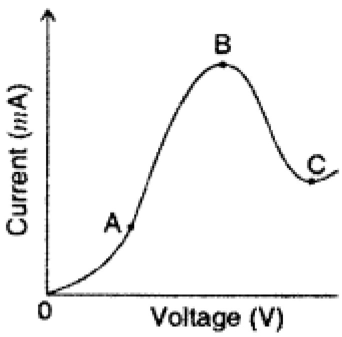
SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

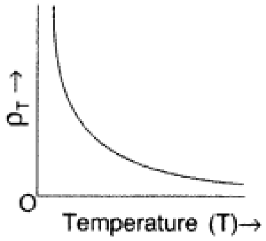
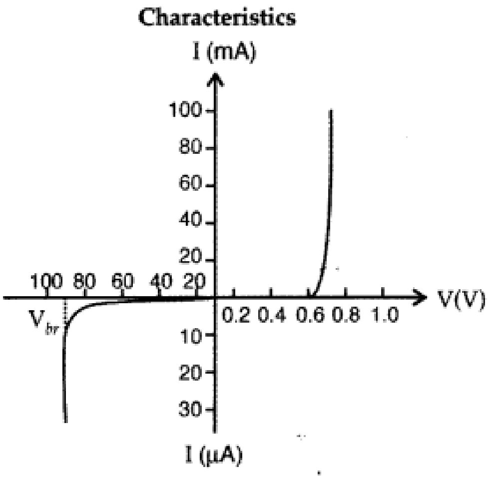
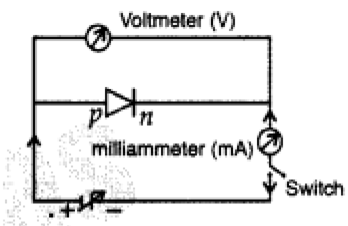
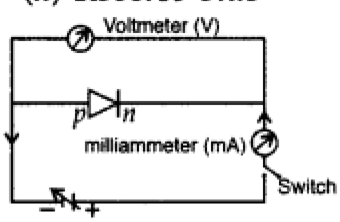
Q.No.	Multiple Choice Questions	MARKS
1	What bonds are present in a semiconductor? a. Monovalent b. Bivalent c. Trivalent d. Covalent **Answer:** (d) Covalent	1
2	A p-type semiconductor is a. Positively charged, b. Negatively charged c.Uncharged, d None of the above **Answer:** (c) Uncharged	1
3.	What happens to the forbidden energy gap of a semiconductor with the fall of temperature? a. Decreases, b. Increases, c. Unchanged, d. Sometimes decreases and sometimes increases **Answer:** (b) Increases	1
4	In a p-type semiconductor, the current conduction is due to a. Holes, b. Atoms, c. Electrons, d. Protons **Answer:** (a) Holes	1
5	In intrinsic semiconductors at room temperature, the number of electrons and holes are a. Unequal, b. Equal, c. Infinite, d. Zero **Answer:** (b) Equal	1
6	In a semiconductor, what is responsible for conduction? a. Electrons only, b. Holes only	1

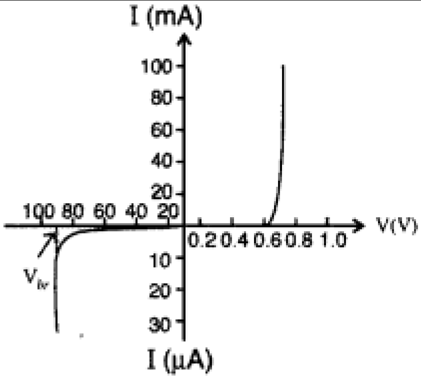
	c.Both electrons and holes, d. Neither electrons nor holes **Answer:** (c) Both electrons and holes	
7	What happens to the resistance of semiconductors on heating? a. Increases, b. Decreases, c. Remains the same d. First increases later decrease **Answer:** (b) decreases	1
8	Energy bands in solids are a consequence of a. Ohm's law, b. Paul's exclusion principle, b. c. Bohr's theory, d. Heisenberg's uncertainty principle Answer: b. Paul's exclusion principle	1
9	In semiconductor which are responsible for conduction a. Only electron, b. electron and hole both, c. only hole, d. None of these Answer: b electron and hole both	1
10	The SI unit of resistivity is a) Ohm, b) Ohm m, c) Ohm m-1, d) Mho Ans: b) ohm m	1
11	The range of conductivity 105 – 10-6 Sm-1 is for a) Insulators, b) Semiconductor, c) Metals, d) Conductors Ans: b) semiconductors	1
12	**The solids having high resistivity or low conductivity are called as** a) Insulators, b) Semiconductors, c) Conductors, d) Superconductors Ans: a) insulators	1
13	**The deliberate addition of a desirable impurity is called as** a) Imputation, b) Doping, c) Adding, d) None	1

	Ans: b) doping	
14	**The current flowing in case of forward bias is in** a) Ampere's, b) Milliamp, c) Microamp, d) None Ans: b) milliamp	1
15	**When an external voltage is applied such that n side is positive and p side is negative then diode is said to be in** a) Forward bias mode, b) Reverse bias mode, c) Both a and b d) None Ans: b) reverse bias mode	1
	ASSERTION AND REASON QUESTIONS **For questions 16 and 23, there are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate Answer from the options given below:** **(a) Assertion is true, reason is true; reason is a correct explanation for assertion. (b) Assertion is true, reason is true; reason is not a correct explanation for assertion (c) Assertion is true, reason is false** **(d) Assertion is false, reason is true.**	
16	**Assertion :** A pure semiconductor has negative temperature coefficient of resistance. **Reason :** In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.	1
17	**Assertion :** If the temperature of a semiconductor is increased then its resistance decreases. **Reason :** The energy gap between conduction band and valence band is very small.	1
18	**Assertion :** In semiconductors, thermal collisions are responsible for taking a valence electron to the conduction band. **Reason :** The number of conduction electrons go on increasing with time as thermal collisions continuously take place.	1
19	**Assertion :** A p-type semiconductors is a positive type crystal. **Reason :** A p- type semiconductor is an uncharged crystal.	1
20	**Assertion :** Silicon is preferred over germanium for making semiconductor devices. **Reason :** The energy gap in germanium is more than the energy gap in silicon.	1
21	**Assertion :** When two semiconductor of p and n type are brought in contact, they form p-n junction which act like a rectifier. **Reason :** A rectifier is used to convent alternating current into direct current	1
22	**Assertion :** The diffusion current in a p-n junction is from the p-side to the n-side. **Reason :** The diffusion current in a p-n junction is greater than the drift current	1

	when the junction is in forward biased.	
23	**Assertion :** A p-n junction with reverse bias can be used as a photo-diode to measure light intensity. **Reason :** In a reverse bias condition the current is small but it is more sensitive to changes in incident light intensity.	1
	NUMERICAL BASED QUESTIONS	
24.	**In half-wave rectification, what is the output frequency if the input frequency is 50 Hz? What is the output frequency of a full-wave rectifier for the same input frequency?** **Ans:** For a half-wave rectifier, the output frequency is equal to the input frequency. In this case, the input frequency of the half-wave rectifier is 50 Hz. On the other hand, the output frequency for a full-wave rectifier is twice the input frequency. Therefore, the output frequency is 2 × 50 = 100 Hz.	2
25.	**A p-n photodiode is fabricated from a semiconductor with a bandgap of 2.8 eV. Can it detect a wavelength of 6000 nm?** **Ans:** No, the photodiode cannot detect the wavelength of 6000 nm because of the following reason: The energy bandgap of the given photodiode, $E_g = 2.8$ eV The wavelength is given by $\lambda = 6000$ nm $= 6000 \times 10^{-9}$ m We can find the energy of the signal from the following relation: $E = hc/\lambda$ In the equation, h is Planck's constant $= 6.626 \times 10^{-34}$ J and c is the speed of light $= 3 \times 10^{8}$ m/s Substituting the values in the equation, we get $E = (6.626 \times 10^{-34} \times 3 \times 10^{8}) / 6000 \times 10^{-9} = 3.313 \times 10^{-20}$ J But, 1.6×10^{-19} J = 1 eV Therefore, $E = 3.313 \times 10^{-20}$ J $= 3.313 \times 10^{-20} / 1.6 \times 10^{-19} = 0.207$ eV The energy of a signal of wavelength 6000 nm is 0.207 eV, which is less than 2.8 eV − the energy band gap of a photodiode. Hence, the photodiode cannot detect the signal.	3
26.	**The number of silicon atoms per m^3 is 5×10^{28}. This is doped simultaneously with 5×10^{22} atoms per m^3 of Arsenic and 5×10^{20} per m^3 atoms of Indium. Calculate the number of electrons and holes. Given that $n_I = 1.5 \times 10^{16} m^{-3}$. Is the material n-type or p-type?**	3

	Ans: The following values are given in the question: Number of silicon atoms, $N = 5 \times 10^{28}$ atoms/m^3 Number of arsenic atoms, $n_{AS} = 5\times10^{22}$atoms/m^3 Number of indium atoms, $n_{In}=5\times10^{22}$atoms/m^3 $n_i=1.5\times10^{16}$electrons/m^3 $n_e=5\times10^{22}-1.5\times10^{16}=4.99\times10^{22}$ Let us consider the number of holes to be n_h In the thermal equilibrium, $n_e n_h = n_i^2$ Calculating, we get $n_h=4.51\times10^9$ Here, $n_e>n_h$, therefore, the material is an n-type semiconductor.	
	GRAPH BASED QUESTIONS	
27.	The graph shown in the figure represents a plot of current versus voltage for a given semi-conductor. Identify the region, if any, over which the semi-conductor has a negative resistance.  Answer: Between the region B and C, the semiconductor has a negative resistance	2
28.	Show variation of resistivity of Si with temperature in a graph. Answer:	2

	 	
29	Draw V-I characteristics of a p-n junction diode. Answer:  	3
30	(a) Draw the circuit arrangement for studying . the V- I characteristics of a p-n junction diode in (i) forward and (ii) reverse bias. Briefly explain how the typical V-I characteristics of a diode are obtained and draw these characteristics. (b) With the help of necessary circuit diagram explain the working of a photo diode used for detecting optical signals. Answer: ***(a) (i) Forward bias*** ***(ii) Reverse bias***   The battery is connected to the silicon diode through a potentiometer (or rheostat), so that the applied voltage can be changed for different values of voltages, the corresponding values of current are noted.	3



Using the circuit arrangements shown in fig. (i) and fig (ii), we study the variation of current with applied voltage to obtain the V-I characteristics.
From the V-I characteristics of a junction diode, it is clear that it allows the current to pass only when it is forward biased. So when an alternatively voltage is applied across the diode, current flows only during that part of the cycle when it is forward biased.

(b) Photo diodes. Photo diode is a special type of photo-detector. Simplest photo-diode is a reverse biased as shown in Figure (i).

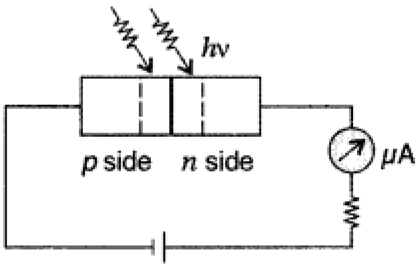


Fig. (i)

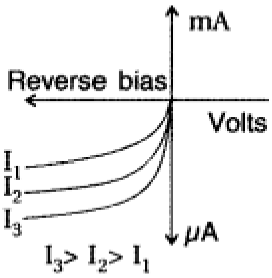


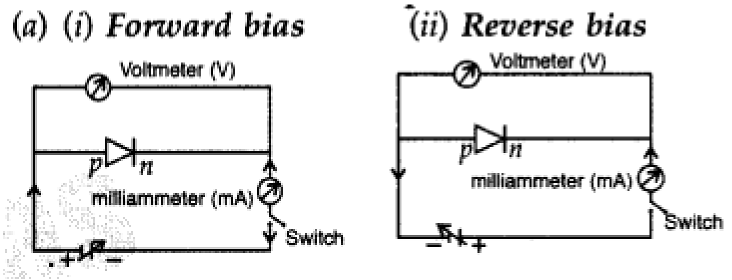
Fig. (ii)

When a p-n diode is illuminated with light photons having energy /xv > and intensities Iv I2, I3 etc. the electron and hole pairs generating in the depletion layer will be separated by the junction field and made to flow across the junction.
Graph showing variation in reverse bias currents for different intensities are shown in Figure (ii).

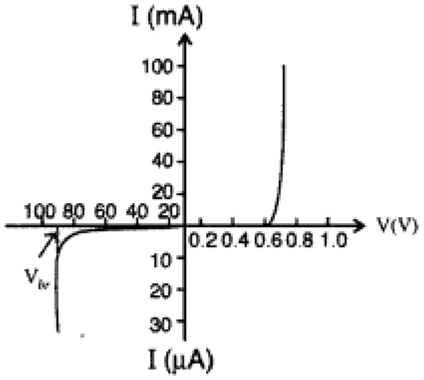
DIAGRAM BASED QUESTIONS

31 Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases. 2

Answer:

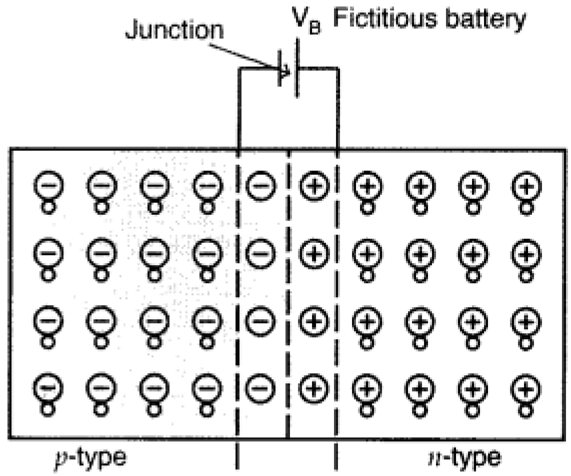


The battery is connected to the silicon diode through a potentiometer (or rheostat), so that the applied voltage can be changed for different values of voltages, the corresponding values of current are noted.



Using the circuit arrangements shown in fig. (i) and fig (ii), we study the variation of current with applied voltage to obtain the V-I characteristics.

From the V-I characteristics of a junction diode, it is clear that it allows the current to pass only when it is forward biased. So when an alternatively voltage is applied across the diode, current flows only during that part of the cycle when it is forward biased.

32	Explain how a depletion region is formed in a junction diode. Answer: As soon as a p-n junction is formed, the majority charge carriers begin to diffuse from the regions of higher concentration to the regions of lower concentrations. Thus the electrons from the n-region diffuse into the p-region and where they combine with the holes and get neutralised. Similarly, the holes from the p-region diffuse into the n-region where they combine with the electrons and get neutralised. This process is called electron-hole recombination.  The p-region near the junction is left with immobile -ve ions and n-region near the junction is left with +ve ions as shown in the figure. The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer. In the depletion region, a potential difference VB is created, called potential barrier as it creates an electric field which opposes the further diffusion of electrons and holes. (i) In forward biased, the width of depletion region is decreased. (ii) In reverse biased, the width of depletion region is increased..	2
33	Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier. Answer: Rectifier. A rectifier is a circuit which converts an alternating current into direct current. p-n diode as a half wave rectifier. A half wave rectifier consists of a single diode as shown in the circuit diagram. The secondary of the transformer gives the desired a.c. voltage across A and B. In the positive half cycle of a.c., the voltage at A is positive, the diode is forward biased and it conducts current.	2

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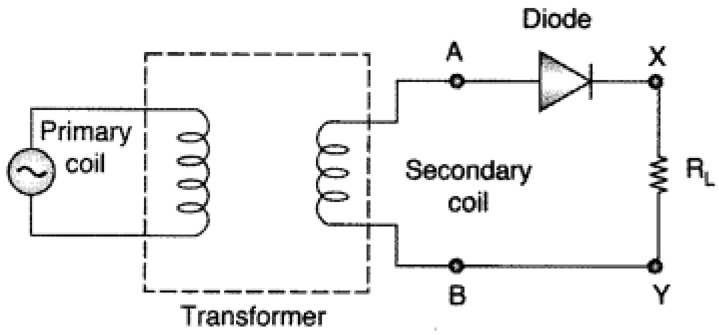

Fig. (a)

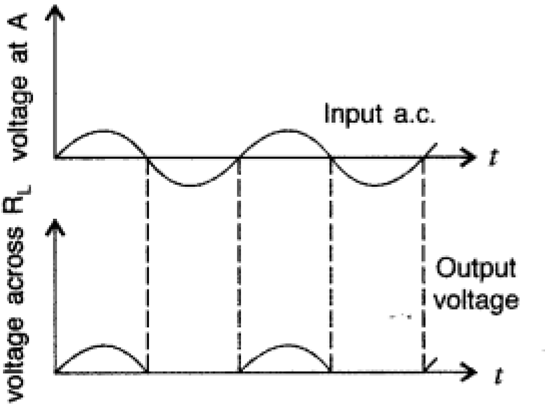

Fig. (b)

In the negative half cycle of a.c., the voltage at A is negative, the diode is reversed biased and it does not conduct current.
Thus, we get output across R_L during positive half cycles only. The output is unidirectional but varying
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<td>Materials are classified on the basis of their conductivity as metals, semiconductors and insulators. Metals are having low resistivity and high conductivity. While semiconductors are having resistivity and conductivity in between metals and insulators. And finally insulators are those which are having high resistivity or very low conductivity. Semiconductors may exist as elemental semiconductors and also compound semiconductors. Si and Ge are elemental semiconductor and CdS, GaAs, CdSe, anthracene, polypyrrole etc. are the compound semiconductors. Each electron in an atom has different energy level and such different energy levels continuing forms the band of energy called as energy bands. Those energy band which has energy levels of Valence electrons is called as Valence band. And the energy band which is present above the Valence band is called as conduction band. On the basis of energy bands materials are also defined as metals, semiconductors and insulators. In case of metals, conduction band and Valence band overlaps with each other due to which electrons are easily available for conduction. In case of insulators, there is some energy gap between conduction band and Valence band due to which no free electrons are easily available for conduction. And in semiconductors, there is a small energy gap between conduction band and Valence</td>
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band and if we give some external energy then electron from Valence band goes to conduction band due to which conduction will be possible. These semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors also. Intrinsic semiconductors are those semiconductors which exist in pure form. And intrinsic semiconductors has number of free electron is equal to number of holes. The semiconductors doped with some impurity in order to increase its conductivity are called as extrinsic semiconductors. Two types of dopants are used they are trivalent impurity and pentavalent impurity also. The extrinsic semiconductors doped with pentavalent impurity like Arsenic, Antimony, Phosphorus etc are called as n – type semiconductors. In n type semiconductors electrons are the majority charge carriers and holes are the minority charge carriers. When trivalent impurity is like Indium, Boron, Aluminium etc are added to extrinsic semiconductors then p type semiconductors will be formed. In p type semiconductors holes are majority charge carriers and electrons are the minority charge carriers.

Questions:

Q 1.) In case of p-type semiconductors___

a) $n_h << n_e$

b) $n_h = n_e$

c) $n_h >> n_e$

d) $n_h = n_e = 0$

Q 2.) An intrinsic semiconductor behaves like _____ at T = 0K.

a) conductor

b) metal

c) non metal

d) insulator

Q 3.) If the energy band gap Eg> 3 eV then such materials are called as

a) conductors

b) semiconductors

c) insulators

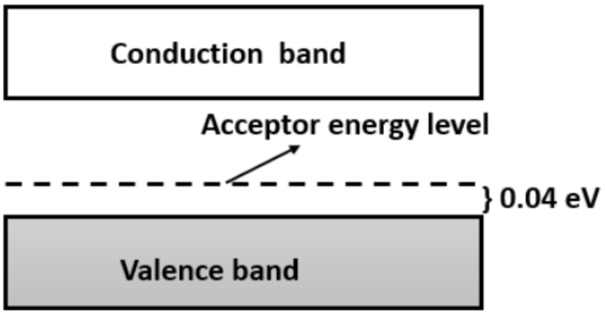
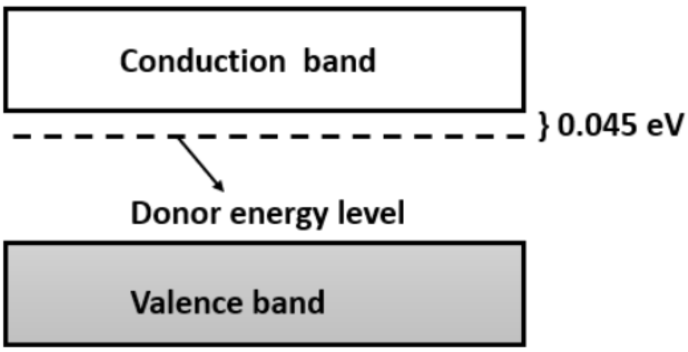
d) superconductors

Q 4.) What is energy band gap in case of materials?

Q 5.) How p-type and n-type semiconductors are formed?

Answer key:

Q 1.) c) $n_h >> n_e$

	Q 2.) d) insulator Q 3.) c) insulators Q 4.) The energy difference between top of the Valence band and bottom of the conduction band is called as energy band gap. On the basis of energy band gap materials are also classified. Metals are having nearly zero energy band gap. Semiconductors are having 0.2 eV to 3 eV energy band gap. And insulators are having energy band gap more than 3eV. Q 5.) When trivalent impurity like B, Al, In are added to extrinsic semiconductor like Ge or Si then p-type Ge or Si semiconductor is formed. And when pentavalent impurity like As, Sb, P are added to extrinsic semiconductors like Ge or Si then n-type Ge or Si semiconductor is formed.	
	HOTS QUESTIONS	
35.	**For an extrinsic semiconductor, indicate on the energy band diagram the donor and acceptor levels.** **Ans:** There are two types of extrinsic semiconductors: n-type extrinsic semiconductor and p-type extrinsic semiconductor. The energy band diagrams with the donor and acceptor levels are shown below:   	3
	STATEMENT QUESTIONS	
36.	Differentiate between forward biasing and reverse biasing	3
37	Distinguish between half wave rectifier and full wave rectifier.	2