KENDRIYA VIDYALAYA SANGATHAN

REGIONAL OFFICE BHOPAL

तत् त्वं पूषन् अपावृणु
केन्द्रीय विद्यालय संगठन

<u>STUDENT SUPPORT MATERIAL</u>

SESSION: 2024-25

CLASS - XII

PHYSICS

तत् त्वं पूषन् अपावृणु
केन्द्रीय विद्यालय संगठन

ADVISORS

Dr. R Senthil Kumar
Deputy Commissioner
KVS RO Bhopal

Smt. Nirmala Budania
Assistant Commissioner
KVS RO Bhopal

Sh. Vijay Veer Singh
Assistant Commissioner
KVS RO Bhopal

Sh Gaurav Kumar Dwivedi
Principal
K. V. SULTANPUR

Sh Manish Tilak
Principal
PM SHRI KV-5, GWALIOR

CONTENT MAKING TEAM:

SNO	Name of KV	Name of PGT PHY	D.O.J as PGT	WhatsApp No.	Class/Chapter No.
1	GWALIOR NO. 2	AJAY KUMAR SINGH	10.10.2002	9977124863	XII Chapter 1
2	GWALIOR NO.1(S1)	DEVENDRA PRASAD SHARMA	01.09.2003	9425787621	XII Chapter 1
3	GWALIOR NO.1(S1)	VIKAS GIRI	31.10.2008	8319788106	XII Chapter 2
4	GWALIOR NO.3	DEVENDRA NATH SAMADHIYA	04.11.2008	9864693963	XII Chapter 2
5	GWALIOR NO.5	AJAY SAGAR	30.07.2009	9927420387	XII Chapter 3
6	GWALIOR NO.1(S2)	MUKESH KUMAR	24.10.2017	9783146877	XII Chapter 3
7	GWALIOR NO.3	BALMAKUND AHIRWAR	11.02.2019	7985531012	XII Chapter 4
8	GWALIOR NO. 2	MAYANK YADAV	18.03.2019	8923200824	XII Chapter 4
9	TEKANPUR, BSF	RATAN	26.03.2019	8077064181	XII Chapter 5
10	GWALIOR NO.4	SEEMA	09.12.2019	7027661833	XII Chapter 5
11	UJJAIN	M.L. CHOURASIYA	03.03.1998	9826698759	XII Chapter 6
12	MHOW	SAPAN KUMAR VAISHY	17.08.2001	9425034189	XII Chapter 6
13	INDORE NO.1(S1)	B. K. VERMA	02.01.2003	9926350494	XII Chapter 7
14	INDORE NO.2	VIPUL SINHA	04.09.2003	8989448631	XII Chapter 7
15	MHOW	YOGINDER SUNANIA	10/11/2010	9755467665	XII Chapter 8
16	INDORE NO.1(S1)	DEEPAK KUMAR DUBEY	21.02.2019	9407806073	XII Chapter 8
17	INDORE NO.2	INDERSINGH KUSHWAH	12-03-2019	9479483962	XII Chapter 9
18	DEWAS	PREM KUMAR	18.03.2019	9896979855	XII Chapter 9
19	SHAJAPUR	SARVESH GOATEM	19.03.2019	9414261291	XII Chapter 10
20	IIT INDORE	AZAD SARKAR	19.03.2019	8572089277	XII Chapter 10
21	DHAR	DEEPA MALVIYA	20.03.2019	9907644623	XII Chapter 11
22	INDORE NO.1(S2)	DEEPA	26.03.2019	9999604338	XII Chapter 11
23	DEWAS	GEETA JOG	31.01.2000	9009808582	XII Chapter 12
24	UJJAIN	MRS. PARUL	18.10.2023	8433089494	XII Chapter 12
25	BETUL	SURESH PUROHIT	25.01.2000	9926550148	XII Chapter 13
26	AMLA	K K SAHU	07.02.2019	9407494595	XII Chapter 13
27	HOSHANGABAD	SNEH LATA	25.03.2019	8279361981	XII Chapter 14
28	SARNI	RANU CHAUKIKAR	06.10.2023	7354249444	XII Chapter 14

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 between multiple 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 a dipole, 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 straight wire, 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 electric dipole inan 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).

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 relation with 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 Periods

Chapter–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 loopas 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 due to 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), magnetic field lines.

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

Unit IV: Electromagnetic Induction and Alternating Currents 24 Periods

Chapter–6: Electromagnetic Induction

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

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 reflection and 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 their magnifying 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'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 treatmentonly).

Unit VII: Dual Nature of Radiation and Matter **08 Periods**

Chapter–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 of particles, 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; nuclear fission, 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 extrinsic semiconductors- p and n type, p-n junction

Semiconductor diode - I-V characteristics in forward and reversebias, application of junction diode -diode as a rectifier.

PRACTICALS

Total Periods 60

The record to be submitted by the students at the time of their annual examination has toinclude:

- Record of at least 8 Experiments [with 4 from each section], to be performed bythe students.
- Record of at least 6 Activities [with 3 each from section A and section B], to be performed by the students.
- The Report of the project carried out by the students.

Evaluation Scheme

Max. Marks: 30

Time 3 hours

Two experiments one from each section	7+7 Marks
Practical record [experiments and activities]	5 Marks
One activity from any section	3 Marks
Investigatory Project	3 Marks
Viva on experiments, activities and project	5 Marks
Total	**30 marks**

Experiments **SECTION–A**

1. To determine resistivity of two / three wires by plotting a graph for potential difference versus current.
2. To find resistance of a given wire / standard resistor using metre bridge.
3. To verify the laws of combination (series) of resistances using a metre bridge.

OR

To verify the laws of combination (parallel) of resistances using a metre bridge.

4. To determine resistance of a galvanometer by half-deflection method and to find itsfigure of merit.

5. To convert the given galvanometer (of known resistance and figure of merit) into a voltmeter of desired range and to verify the same.

OR

To convert the given galvanometer (of known resistance and figure of merit) into an ammeter of desired range and to verify the same.

6. To find the frequency of AC mains with a sonometer.

Activities

1. To measure the resistance and impedance of an inductor with or without iron core.

2. To measure resistance, voltage (AC/DC), current (AC) and check continuityof a given circuit using multimeter.

3. To assemble a household circuit comprising three bulbs, three (on/off) switches, afuse and a power source.

4. To assemble the components of a given electrical circuit.

5. To study the variation in potential drop with length of a wire for a steady current.

6. To draw the diagram of a given open circuit comprising at least a battery, resistor/rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order and correct the circuit and also the circuit diagram.

SECTION-B

Experiments

1. To find the value of *v* for different values of *u* in case of a concave mirror and to findthe focal length.
2. To find the focal length of a convex mirror, using a convex lens.
3. To find the focal length of a convex lens by plotting graphs between *u* and *v* or between *1/u* and *1/v*.
4. To find the focal length of a concave lens, using a convex lens.
5. To determine angle of minimum deviation for a given prism by plotting a graph

between angle of incidence and angle of deviation.

6. To determine refractive index of a glass slab using a travelling microscope.
7. To find the refractive index of a liquid using convex lens and plane mirror.
8. To find the refractive index of a liquid using a concave mirror and a plane mirror.
9. To draw the I-V characteristic curve for a p-n junction diode in forward and reverse bias.

Activities

1. To identify a diode, an LED, a resistor and a capacitor from a mixed collection of such items.
2. Use of multimeter to see the unidirectional flow of current in case of a diode and an LED and check whether a given electronic component (e.g., diode) is in working order.
3. To study effect of intensity of light (by varying distance of the source) on an LDR.
4. To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab.
5. To observe diffraction of light due to a thin slit.
6. To study the nature and size of the image formed by a (i) convex lens, or (ii) concave mirror, on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).
7. To obtain a lens combination with the specified focal length by using two lenses from the given set of lenses.

Suggested Investigatory Projects

1. To study various factors on which the internal resistance/EMF of a cell depends.
2. To study the variations in current flowing in a circuit containing an LDR because of a variation in
   (a) the power of the incandescent lamp, used to 'illuminate' the LDR (keeping all the lamps at a fixed distance).

(b) the distance of a incandescent lamp (of fixed power) used to 'illuminate'the LDR.

3. To find the refractive indices of (a) water (b) oil (transparent) using a plane mirror, an equiconvex lens (made from a glass of known refractive index) and an adjustable object needle.

4. To investigate the relation between the ratio of (i) output and input voltage and (ii) number of turns in the secondary coil and primary coil of a self-designed transformer.

5. To investigate the dependence of the angle of deviation on the angle of incidence using a hollow prism filled one by one, with different transparent fluids.

6. To estimate the charge induced on each one of the two identical Styrofoam (or pith) balls suspended in a vertical plane by making use of Coulomb's law.

7. To study the factor on which the self-inductance of a coil depends by observing the effect of this coil, when put in series with a resistor/(bulb) in a circuit fed up by an A.C. source of adjustable frequency.

8. To study the earth's magnetic field using a compass needle -bar magnet by plotting magnetic field lines and tangent galvanometer.

Class XII

A. Items for Identification/ familiarity with the apparatus for assessment in practicals (All experiments)

Meter scale, general shape of the voltmeter/ammeter, battery/power supply, connecting wires, standard resistances, connecting wires, voltmeter/ammeter, meter bridge, screw gauge, jockey Galvanometer, Resistance Box, standard Resistance, connecting wires, Potentiometer, jockey, Galvanometer, Lechlanche cell, Daniell cell [simple distinction between the two vis-à-vis their outer (glass and copper) containers], rheostat connecting wires, Galvanometer, resistance box, Plug-in and tapping keys, connecting wires battery/power supply, Diode, Resistor (Wire-wound or carbon ones with two wires connected to two ends), capacitors (one or two types), Inductors, Simple electric/electronic bell, battery/power supply, Plug- in and tapping keys, Convex lens, concave lens, convex mirror, concave mirror, Core/hollow wooden cylinder, insulated wire, ferromagnetic rod, Transformer core, insulated wire.

B. List of Practical's

1. To determine the resistance per cm of a given wire by plotting a graph between voltage and current.
2. To verify the laws of combination (series/parallel combination) of resistances byOhm's law.
3. To find the resistance of a given wire / standard resistor using a meter bridge.
4. To determine the resistance of a galvanometer by half deflection method.
5. To identify a resistor, capacitor, inductor and diode from a mixed collection ofsuch items.
6. To observe the difference between
   (i) a convex lens and a concave lens
   (ii) a convex mirror and a concave mirror and to estimate the likely difference between the power of two given convex /concave lenses.
7. To design an inductor coil and to know the effect of
   (i) change in the number of turns

(ii) Introduction of ferromagnetic material as its core material on the inductance of the coil.

8. To design a (i) step up (ii) step down transformer on a given core and know the relation between its input and output voltages.

Note: The above practical's may be carried out in an experiential manner rather than recording observations.

Prescribed Books:

1. Physics, Class XI, Part -I and II, Published by NCERT.
2. Physics, Class XII, Part -I and II, Published by NCERT.
3. Laboratory Manual of Physics for class XII Published by NCERT.
4. The list of other related books and manuals brought out by NCERT (consider multimedia also).

Note:

The content indicated in NCERT textbooks as excluded for the year 2023-24 is not to be tested by schools and will not be assessed in the Board examinations 2023-24.

QUESTION PAPER
DESIGN

Theory (Class: XI/XII)

Maximum Marks: 70 **Duration: 3 hrs.**

S No.	Typology of Questions	Total Marks	Approximate Percentage
1	**Remembering**: Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers. **Understanding**: Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas	27	38 %
2	**Applying**: Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	22	32%
3	**Analysing :** Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations **Evaluating:** Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria. **Creating**: Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.	21	30%
	Total Marks	70	100
	Practical	30	
	Gross Total	100	

Note:

CHAPTER 1 – ELECTRIC CHARGES AND FIELDS

MCQ's:

1. A charged oil drop is to be held stationary between two plates separated by a distance of 25mm. If the mass of drop is 5 x 10^{-15} kg and the charge on it is 10^{-18} C, the potential applied between two plate is (g = 10m/s^2).

   A.125V B.1250V C.2500V D.450 V

2. A cube of side 'b' has a charge q at each of its vertices. The electric field due to charge distribution at the centre of cube will be

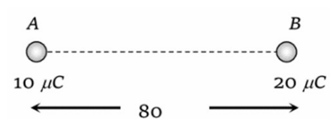
   A. q/b^2 B. $q/2b^2$ C. $32q/b^2$ D. zero

3. Inside a uniformly charged spherical shell of radius r, electric field is
   A. zero B. non-zero constant
   C. varies with r D. inversely varies with r

4. When 10^{19} electrons are removed from a neutral metal plate, the electric charge on it is
   A. – 1.6 C B. +1.6 C C. 10^{+19}C D. 10^{-19}C

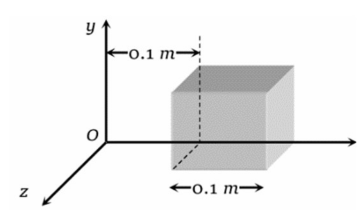
5. Two point charges of the same polarities are hung with the help of two threads and kept close. The angle between the threads will be _________ if the system is taken to space.
   A. 180 degree B. 90 degree
   C. 45 degree D. 60 degree

6. In the figure two charges 80cm apart distance of the point from A, where the electric field is zero



   A. 20cm B. 10cm C. 33cm D. None

7. What will be the charge present inside a cube which produces electric field
   $E_x = 600x^{1/2}$, Ey = 0, $E_z = 0$



   A. 600μC B. 60 μC C. 7 μC D. 6μC

8. Electric field intensity at a point in between two parallel sheets with like charges of same surface charge densities (σ) is

A. $\sigma/2\varepsilon_o$ B. zero C. σ/ε_o D. $2\sigma/\varepsilon_o$

9. Two point charges q_1 and q_2 are situated at a distance d. There is no such point in between them where the electric field is zero. What can we deduce?

A. no such point B. charges are of the same polarity
C. charges are of opposite polarity D. charges must be unequal

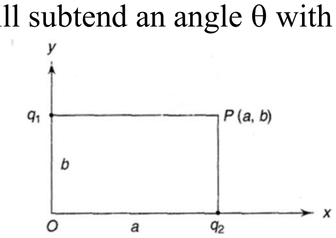
10. When an electric dipole **P** is placed in a uniform electric field **E** then at what angle between **P** and **E** the value of torque will be maximum

A. 90° B. 0° C. 180° D. 45°

11. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2 the electric charge inside the surface will be

A. $(\phi_1 + \phi_2)\,\varepsilon_o$ B. $(\phi_2 - \phi_1)\,\varepsilon_o$ C. $(\phi_1 + \phi_2)/\varepsilon_o$ D. $(\phi_2 - \phi_1)/\varepsilon_o$

12. Two-point charges q1 = 2 μC and q2 = 1 μC are placed at distances b = 1 cm and a = 2 cm from the origin on the y and x axes as shown in Fig. The electric field vector at point P (a, b) will subtend an angle θ with the x-axis given by

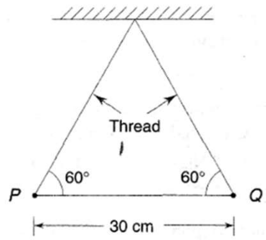


A. tan θ = 1 B. tan θ=2 C. tan θ = 3 D. tan θ = 4

13. A charge having magnitude Q is divided into two parts q and (Q - q) which are held a certain distance r apart. The force of repulsion between the two parts will be maximum if the ratio q/Q is

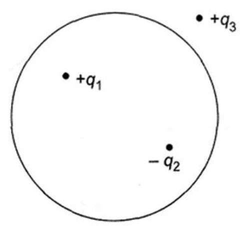
A. 1/2 B. 1/3 C. 1/4 D. 1/5

14. Two small identical balls P and Q, each of mass √3/10 gram, carry identical charges and are suspended by threads of equal lengths. At equilibrium, they position themselves as shown in Fig. What is the charge on each ball? Given $1/4\pi\varepsilon_0 = 9 \times 10^9 Nm^2C^{-2}$ and take $g = 10\ ms^{-2}$.



A. 10^{-3} C B. 10^{-5} C C. 10^{-7} C D. 10^{-9} C

15. Figure shows a spherical Gaussian surface and a charge distribution. When calculating the flux of electric field through the Gaussian surface, the electric field will be due to



A. +q3 B. + q1 and + q3
C. +q1, +q3 and -q2 D. +q1 and -q2

16. An electric dipole placed in a non-uniform electric field experience
A. a force but no torque B. a torque but no force
C. a force as well as a torque D. neither a force nor a torque.

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Assertion And Reasoning Based Question

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) 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, Reason is incorrect

(d) Both Assertion and Reason are correct.

Q.1. Assertion: Electron move away from a region of lower potential to a region of higher potential.
Reason: An electron has a negative charge.

Q.2. Assertion: A metallic shield in 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.

Q.3. Assertion: Electric lines of force never cross each other.
Reason: Electric field at a point superimpose to give one resultant electric field.

Q.4. Assertion: The Coulomb force is the dominating force in the universe.
Reason: The Coulomb force is weaker than the gravitational force.

Q.5. Assertion: When bodies are charged through friction, there is a transfer of electric charge from one body to another, but no creation or destruction of charge
Reason: This follows from conservation of electric charges.

Very Short Answer Type (2 Marks each)

1. Sketch the electric field lines for two-point charges q_1 and q_2 for $q_1 = q_2$ and $q_1 > q_2$ separated by a distance d.

2. Why do the electrostatic field lines not form closed loops?

3. What orientation of an electric dipole in a uniform electric field corresponds to its (i) stable and (ii) unstable equilibrium?

4. An arbitrary surface encloses a dipole. What is the electric flux through this surface?

5. The distance of the field point on the axis of a small dipole is doubled. By what factor will the electric field, due to the dipole change?

6. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased?

7. A charge q is placed at the centre of a cube of side l. What is the electric flux passing through two opposite faces of the cube?

8. What is the nature of electrostatic force between two point electric charges q1 and q2 if
   (a) $q1 + q2 > 0$?
   (b) $q1 + q2 < 0$?

9. The dimensions of an atom are of the order of an Angstrom. Thus, there must be large electric fields between the protons and electrons. Why, then is the electrostatic field inside a conductor zero?

10. A small plane area is rotated in an electric field. In which orientation of the area is the flux of the electric field through the area maximum? In which orientation is it zero?

Short Answer Type

1. A spherical conducting shell of inner radius r1 and outer radius r_2 has a charge 'Q'. A charge 'q' is placed at the centre of the shell.

(a) What is the surface charge density on the (i) inner surface, (ii) outer surface of the shell?

(b) Write the expression for the electric field at a point $x > r_2$ from the centre of the shell.

2. (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 for its kinetic energy.

(b) Plot a graph of the kinetic energy as a function of charge density λ.

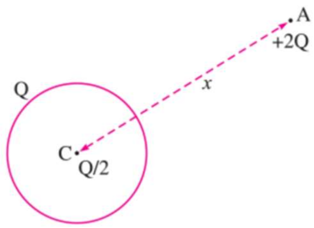
3. Two small identical electrical dipoles AB and CD, each of dipole moment 'p' are kept at an angle of 120° as shown in the figure. What is the resultant dipole moment of this combination? If this system is subjected to electric field directed along + X direction, what will be the magnitude and direction of the torque acting on this?

4. Two parallel uniformly charged infinite plane sheets, '1' and '2', have charge densities + σ and -2σ respectively. Give the magnitude and direction of the net electric field at a point.

(i) In between the two sheets and

(ii) Outside near the sheet '1'.

5. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at the centre C and another charge +2Q is placed outside the shell at A at a distance x from the centre as shown in the figure.



(i) Find the electric flux through the shell.
State the law used.

(ii) Find the force on the charges at the centre C of the shell and at the point A.

6. Two charges q and –3q are placed fixed on x-axis separated by distance 'd'. Where should a third charge 2q be placed such that, it will not experience any force?

7. Plot a graph showing the variation of coulomb force (F) versus $(1/r^2)$, where r is the distance between the two charges of each pair of charges: (1 μC, 2 μC) and (2 μC, – 3 μC). Interpret the graphs obtained.

8. Calculate the amount of work done in rotating a dipole, of dipole moment 3×10^{-8} Cm, from its position of stable equilibrium to the position of unstable equilibrium, in a uniform electric field of intensity 10^4 N/C

9. Given a uniform electric field $\mathbf{E} = 5\times10^3\,\mathbf{i}$ N/C, find the flux of this field through a square of 10 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square if the plane makes a 30° angle with the X-axis?

10. Represent graphically the variation of electric field with distance, for a uniformly charged plane sheet.

Long Answer Type

1. Find an expression for the electric field strength at a distant point situated
(i) on the axis and
(ii) along the equatorial line of an electric dipole.

2. State and Prove Gauss theorem in electrostatics.

3. Using Gauss's law obtain the expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for r > R and r < R.

4. A uniform electric field N/C for x > 0 and N/C for x < 0 are given. A right circular cylinder of length l cm and radius r cm has its centre at the origin and its axis along the X-axis. Find out the net outward flux. Using Gauss's law, write the expression for the net charge within the cylinder.

5. A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for point's at large distances from the ring, it behaves like a point charge.

<u>**Case Study Based**</u>

1. **Read the following paragraph and answer the questions that follow.**
If you rub a glass rod with silk, a positive charge appears on the rod. Measurement shows that a negative charge of equal magnitude appears on the silk. This suggests that rubbing does not create charge but only transfers it from one body to another, upsetting the electrical neutrality of each body during the process. This hypothesis of conservation of charge, first put forward by Benjamin Franklin, has stood up under close examination, both for large-scale charged bodies and for atoms, nuclei, and elementary particles. No exceptions have ever been found. Thus, we add electric charge to our list of quantities—including energy and both linear momentum and angular momentum—that obey a conservation law.

(i) When an electron e^- (charge -e) and its antiparticle, the positron e^+(charge +e), undergo an annihilation process, transforming into gamma rays (high-energy light):
(a) $e^- + e^+ \rightarrow \gamma$
(b) $e^- + e^+ \rightarrow \gamma + \gamma$
(c) $\gamma \rightarrow e^- + e^+$
(d) $\gamma + \gamma \rightarrow e^- + e^+$

(ii) Identify X in the following nuclear reaction: $^{1}H + {}^{9}Be \rightarrow X + n$ (neutron)
(a) ^{9}B
(b) ^{10}B
(c) $_{9}F$
(d) $_{10}Ne$

(iii) Electrons and positrons are produced by the nuclear transformations of protons and neutrons known as beta decay. If a proton transforms into a neutron, and a neutron transforms into a proton,
(a) an electron and a positron are produced respectively.
(b) electrons are produced in both.

(c) a positron and an electron are produced respectively.
(d) positrons are produced in both.

(iv)
(A) A polythene piece rubbed with wool is found to have a negative charge of 3.2 ×
10-7 C. The number of electrons transferred (from which to which) is
(a) 2×10^{12} from polythene to wool
(b) 2×10^{12} from wool to polythene
(c) 3×10^{23} from polythene to wool
(d) 3×10^{23} from wool to polythene

OR

(B) Objects A, B, and C are three identical, insulated, spherical conductors. Originally A and B both have charges of + 3 mC, while C has a charge of -6 mC. Objects A and C are allowed to touch, then they are moved apart. Then objects B and C are allowed to touch, and they are moved apart.
If objects A and C are held near each other, they will

(a) attract.
(b) repel.
(c) have no effect on each other.
(d) more information is needed to answer.

2. **Read the following paragraph and answer the questions that follow.**
   Food can be warmed and cooked in a microwave oven if the food contains water because water molecules are electric dipoles. When you turn on the oven, the microwave source sets up a rapidly oscillating electric field E within the oven and thus also within the food. The electric field E produces a torque on an electric dipole moment p to align p with E. Because the oven's E oscillates, the water molecules continuously flip-flop in a frustrated attempt to align with E. Energy is transferred from the electric field to the thermal energy of the water (and thus of the food) where three water molecules happened to have bonded together to form a group. The flip-flop breaks some of the bonds. When the molecules reform the bonds, energy is transferred to the random motion of the group and then to the surrounding molecules. Soon, the thermal energy of the water is enough to cook the food.

(i) A neutral water molecule (H2O) in its vapor state has an electric dipole moment of magnitude 6.2 x 10 -30 C. m. How far apart are the molecule's centers of positive and negative charge?
(A) 3.9 pm
(B) 39 pm
(C) 3.9 μm
(D) 39 μm

(ii) If the molecule is placed in an electric field of 1.5 x 104 N/C, what maximum torque can the field exert on it?

(A) 9.3×10^{-34} N. m.

(B) 9.3×10^{-26} N. m.

(C) 4.65×10^{-26} N. m.

(D) 4.65×10^{-34} N. m.

(iii) How much work must an external agent do to rotate this molecule by 180°on this field, starting from its fully aligned position, for which θ = 0° ?

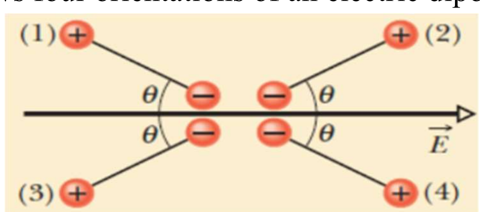
(A) 9.3×10^{-26} J

(B) 9.3×10^{-25} J

(C) 1.9×10^{-26} J

(D) 1.9×10^{-25} J

(iv) The figure shows four orientations of an electric dipole in an external electric field.



(a) Rank the orientations according to the magnitude of the torque on the dipole greatest first.

(A) τ 1 > τ 2 > τ 3 > τ 4

(B) τ 4 > τ 3 > τ 2 > τ 1

(C) τ 1 = τ 2 = τ 3 = τ 4

(D) τ 1 = τ 3 > τ 2 = τ 4

OR

(b) Rank the potential energy of the dipole, greatest first.

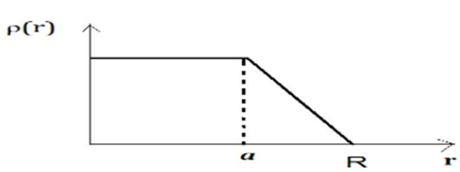
(A) U1 = U3 > U2 = U4

(B) U4 > U3 > U2 > U1

(C) U1 = U2 = U3 = U4

(D) U1 > U2 > U3 >U4

3. **Read the following paragraph and answer the questions that follow.**
   The nuclear charge (Z e) is non-uniformly distributed within a nucleus of radius R. The charge density ρ(r) (charge per unit volume) is dependent only on the radial distance r from the center of the nucleus as shown in the figure. The electric field is only along the radial direction.



(i) The electric field at r = R is
(A) independent of a.
(B) directly proportional to a.
(C) directly proportional to a 2.
(D) inversely proportional to a.

(ii) For a = 0, the value of d (maximum value of ρ as shown in the figure) is

(A) 3Ze/4πR 3
(B) 3Ze/πR 3
(C) 4Ze/3πR 3
(D) Ze/3πR 3

(iii) The electric field within the nucleus is generally observed to be linearly dependent on r. This implies,

(A) a = 0
(B) a = R/2
(C) a = R
(D) a = 2R/3

(iv) (a) A non-conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere, at a distance r from its center.

(A) increases as r increases for r < R.
(B) decreases as r increases for 0 < r < ∞.
(C) increases as r increases for R < r < ∞.
(D) is discontinuous at r = R.

OR

(b)A thin spherical shell of radius R is uniformly charged. The magnitude of the electric field due to the shell, at a distance r from its center.

(A) increases as r increases for r < R.
(B) decreases as r increases for 0 < r < ∞.
(C) increases as r increases for R < r < ∞.
(D) is discontinuous at r = R.

4. **Read the following paragraph and answer the questions that follow**.

The visible portion of a lightning strike is preceded by an invisible stage in which a column of electrons is extended from a cloud to the ground. These electrons come from the cloud and from air molecules that are ionized within the column. The linear charge density λ along the column is typically -1×10^{-3} C/m. Once the column reaches the ground, electrons within it are rapidly dumped to the ground. During the dumping, collisions between the electrons and the air within the column result in a brilliant flash of light. Although the column is not straight or infinitely long, we can approximate it as being a line of charge as in Figure.

(i) The electric field due to the column of charge points

(a) radially outward

(b) radially inward

(c) towards ground along axis of the column

(d) towards cloud along axis of the column

(ii) The electric field magnitude due to the column of charge varies with distance from the axis of the column as

(a) $1/r$

(b) $1/r^2$

(c) $1/r^3$

(d) $1/r^0$

(iii) (A) If air molecules break down (ionize) in an electric field exceeding 3×10^6 N/C, what is the radius of the column of charge?

(a) 3 m

(b) 9 m

(c) 6 m

(d) 1.5 m

OR

(B) You are not safe if you are a somewhat greater distance than the radius of the column from the strike point because

(a) the electrons dumped by the strike travel along the ground and these ground currents are lethal.

(b) the electrons dumped by the strike travel along the ground but these ground currents are not lethal.

(c) the electrons dumped by the strike travel perpendicular to the ground and these currents are lethal.

(d) the electrons dumped by the strike travel perpendicular to the ground but these currents are not lethal.

(iv) Let us enclose a section of the column of charge with a concentric cylinder (Gaussian surface) of radius r and height h. Let E be the magnitude of the electric field at any point on the cylinder's curved surface. Electric flux through the cylinder's curved surface and each end cap (cylinder's flat surface) are respectively

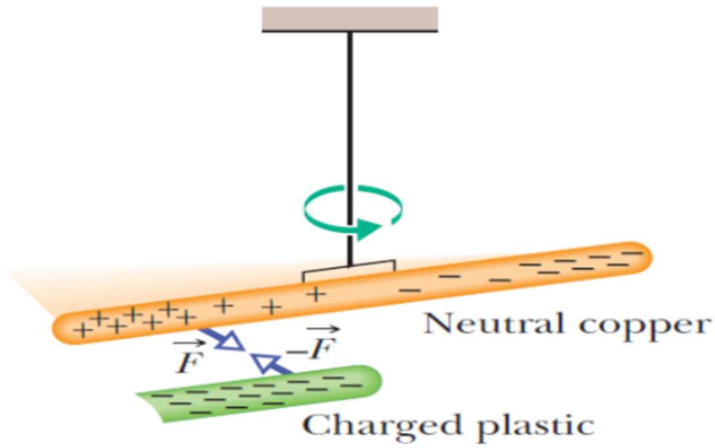
(a) $2\pi rhE$, 0

(b) $-2\pi rhE$, 0

(c) $2\pi rhE$, $\pi r^2 E$

(d) $-2\pi rhE$, $\pi r^2 E$

5. **Read the following paragraph and answer the questions that follow**.



The experiment of Figure demonstrates the mobility of charge in a conductor. A negatively charged plastic rod will attract either end of an isolated neutral copper rod. What happens is that many of the conduction electrons in the closer end of the copper rod are repelled by the negative charge on the plastic rod. Some of the conduction electrons move to the far end of the copper rod, leaving the near end depleted in electrons and thus with an unbalanced positive charge. This positive charge is attracted to the negative charge in the plastic rod. Although the copper rod is still neutral, it is said to have an induced charge, which means that some of its positive and negative charges have been separated due to the presence of a nearby charge.

(i) If an object made of substance A rubs an object made of substance B, then A becomes positively charged and B becomes negatively charged. If, however, an object made of substance A is rubbed against an object made of substance C, then A becomes negatively charged. What will happen if an object made of substance B is rubbed against an object made of substance C?

(a) B becomes positively charged and C becomes positively charged.

(b) B becomes positively charged and C becomes negatively charged.

(c) B becomes negatively charged and C becomes positively charged.

(d) B becomes negatively charged and C becomes negatively charged

(ii) (A) If a body is charged, its mass

(a) remains precisely constant

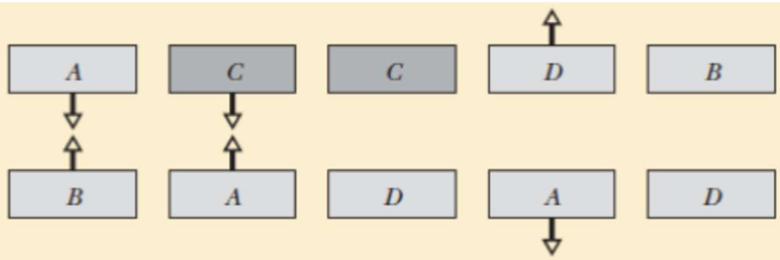
(b) increases slightly

(c) decreases slightly
(d) may increase slightly or may decrease slightly

OR

(B) An object becomes positively charged
(a) only through the removal of negative charges
(b) only through the gain of positive charges
(c) through the removal of negative charges and gain of positive charges both
(d) through the removal of negative charges or gain of positive charges

(iii) The figure shows five pairs of plates: *A*, *B*, and *D* are charged plastic plates and *C* is an electrically neutral copper plate. The electrostatic forces between the pairs of plates are shown for three of the pairs. For the remaining two pairs, do the plates repel or attract each other?



(a) Plates C and D attract but plates B and D repel each other.
(b) Plates C and D attract and plates B and D also attract each other.
(c) Plates C and D repel but plates B and D attract each other.
(d) Plates C and D repel and plates B and D also repel each other.

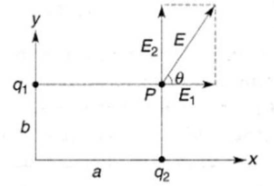
(iv) A positively charged rod is held near a neutral conducting sphere suspended by an insulating thread. The sphere will
(a) be unaffected, because it is neutral.
(b) remain neutral, but be repelled from the rod.
(c) remain neutral, but be attracted to the rod.
(d) acquire a negative charge and be attracted to the rod.

Solutions

MCQ:

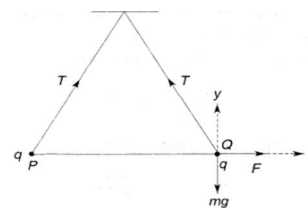
1. B. 1250 V, Using qe = mg
2. D. zero
3. A. zero
4. B. +1.6 C
5. A. 180 degree
6. C. 33cm
7. C. 7 μC, using gauss law
8. B. Zero

9. C. charges are of opposite polarity
10. A. 90°
11. B. $(\phi_2 - \phi_1)\ \varepsilon_o$, using gauss law
12.



13. A. 1/2, because d F / d q = 0
14. C. 10^{-7} C

These equations give $F = mg \cot 60° = \frac{\sqrt{3}}{10} \times 10^{-3} \times 10 \times \frac{1}{\sqrt{3}}$



15. D. +q1 and -q2
16. C. a force as well as a torque

Assertion and Reasoning

1. Because electrons have negative charges. both, Assertion and Reason are true and the Reason is correct explanation of the Assertion.

2. (a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

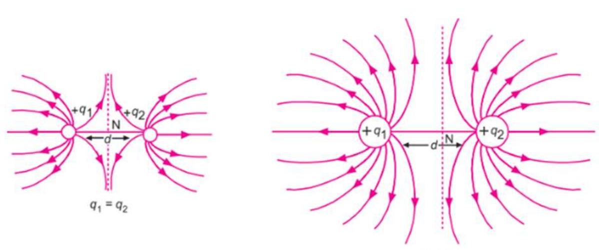
3. (b) Both statements are true but reason does not give proper reasoning for the assertion. Two field lines do not cross each other at any point, because if they do so then there will be two possible directions of the electric field at the point of crossing, which is impossible.

4. (d) If both assertion and reason are false statements.

5. (a) Conservation of electric charges states that the total charge of an isolate system remains uncharged with time.

Very Short Answer type

1.



2. Electric field lines start from positive charge and terminate at negative charge. If there is a single positive charge, the field lines start from the charge and terminate at infinity. So, the electric field lines do not form closed loops.

3. $\theta = 0$ (stable)
$\theta = \pi$ (unstable)

4. Net charge on a dipole is $-q + q = 0$, hence according to gauss law, flux will be 0.

5. For a small dipole,
$$E_{\text{axis}} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3} \propto \frac{1}{r^3}$$
When the distance r is doubled, the electric field strength becomes 1/8 times the original field.

6. Electric flux through a Gaussian surface, enclosing the charge q is $\varphi E = q/\varepsilon_0$. This is independent of radius of Gaussian surface, so if radius is increased, the electric flux through the surface will remain unchanged.

7. By symmetry, the flux through each of the six faces of the cube will be same when charge q is placed at its centre.
$\varphi E = q/6\varepsilon_0$
hence, two opposite faces = $q/3\varepsilon_0$

8. (a) If both q1 and q2 are positive, the electrostatic force between these will be repulsive. However, if one of these charges is positive and is greater than the other negative charge, the electrostatic force between them will be attractive.
(b) If both q1 and q2 are –ve, the force between these will be repulsive. However, if one of them is –ve and it is greater in magnitude than the second +ve charge, the force between them will be attractive.

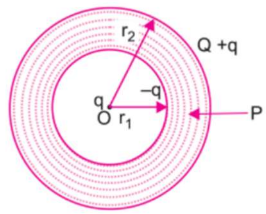
9. The electric fields bind the atoms to neutral entity. Fields are caused by excess charges. There can be no excess charge on the inner surface of an isolated conductor. So, the electrostatic field inside a conductor is zero.

10. The flux of electric field through an area is defined as the number of field lines that pass through that area in the direction of the electric field.
Flux, $\varphi = \int \mathbf{E}.ds$
$E.ds = |E||ds|\cos\theta$
maximum when $\cos\theta = 0$ or 180°,
since cos 0 or cos 180° = +1 or -1
minimum when cos 90°, since cos 90° = 0.
$\Phi = |E||ds| \cos 90° = 0$

Thus, when the unit normal vector perpendicular to the direction of the electric field the flux is ZERO.

Short Answer Type

1.



(a) Charge Q resides on outer surface of spherical conducting shell. Due to charge q placed at centre, charge induced on inner surface is –q and on outer surface it is +q. So, total charge on inner surface –q and on outer surface it is Q + q.

Surface charge density on inner surface = $-q/4\Pi r_1^2$

Surface charge density on outer surface = $Q+q/4\Pi r_2^2$

(b) For external points, whole charge acts at centre, so electric field at distance x > r2,

$$E(x) = \frac{1}{4\pi\varepsilon_0}\frac{Q+q}{x^2}.$$

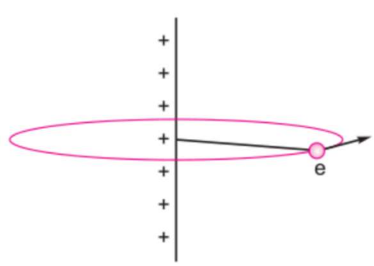
2.

(a) infinitely long charged wire produces a radical electric field.

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \quad \text{... (1)}$$

The revolving electron experiences an electrostatic force and provides necessarily centripetal force.

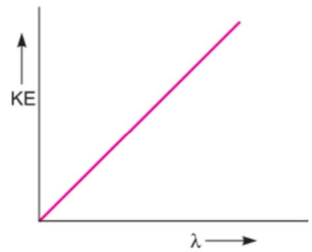
$$\mathrm{eE} = \frac{\mathrm{mv}^2}{r} \quad \text{... (2)}$$



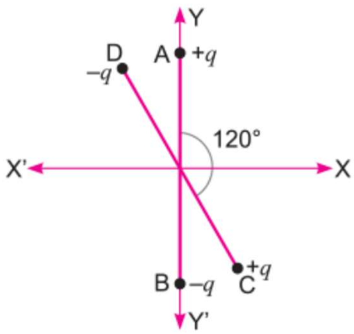
$$\frac{e.\lambda}{2\pi\varepsilon_0 r} = \frac{\mathrm{mv}^2}{r} \Rightarrow \mathrm{mv}^2 = \frac{e\lambda}{2\pi\varepsilon_0}$$

Kinetic energy of the electron, $K = \frac{1}{2}\mathrm{mv}^2 = \frac{e\lambda}{4\pi\varepsilon_0}$

(b)



3.



Resultant dipole moment

$$\vec{p}_r = \sqrt{p^2 + p^2 + 2\,\text{pp}\cos 120^\circ}$$

$$= \sqrt{2p^2 + 2p^2 \cos 120^\circ}$$

$$= \sqrt{2p^2 + (2p^2) \times \left(-\tfrac{1}{2}\right)} = \sqrt{2p^2 - p^2} = p,$$

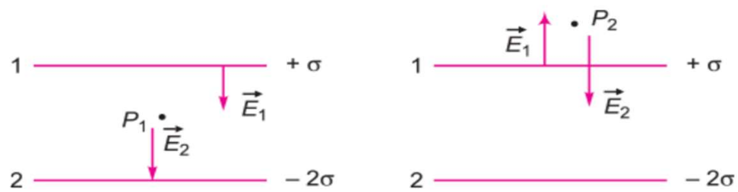
Using law of addition of vectors, we can see that the resultant dipole makes an angle of 60° with the y axis or 30° with x - axis.

Torque, $\vec{\tau} = \vec{p} \times \vec{E}$ ($\vec{\tau}$ is perpendicular to both $\vec{p}$ and $\vec{E}$

$$= \text{pE}\sin 30^\circ = \tfrac{1}{2}\text{pE}.$$

Direction of torque is along positive Z-direction.

4.



(i) Let $\overrightarrow{E_1}$ and $\vec{E}_2$ be the electric field intensity at the point P_1, between the plates. So,

$|E_{P_1}| = |E_1| + |E_2|$

$= \frac{\sigma}{\varepsilon_0} + \frac{2\sigma}{\varepsilon_0}$

$= \frac{3\sigma}{\varepsilon_0}$ (directed towards sheet 2)

$\vec{E}_{P_1} = \frac{3\sigma}{\varepsilon_0}(-\hat{j}) = -\frac{3\sigma}{\varepsilon_0}\hat{j}$

(*ii*) Outside near the sheet '1', $|\vec{E}_{P_2}| = \vec{E}_2 - \vec{E}_1$

$= \frac{2\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{2\varepsilon_0}$ (directed towards sheet 2)

$\vec{E}_{P_2} = \frac{\sigma}{2\varepsilon_0}(-\hat{j}) = -\frac{\sigma}{\varepsilon_0}\hat{j}$

5.

(*i*) Electric flux through a Gaussian surface, $\varphi = \frac{\text{Total enclosed charge}}{\varepsilon_0}$

Net charge enclosed inside the shell, $q = 0$

∴ Electric flux through the shell $\frac{q}{\varepsilon_0} = 0$

(*ii*) **Gauss's Law:** Electric flux through a Gaussian surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed within it.

Mathematically, $\oint \vec{E} \cdot \vec{ds} = \frac{1}{\varepsilon_0} \times q$

(ii) We know that electric field or net charge inside the spherical conducting shell is zero. Hence, the force on charge Q/2 is zero.

$$\text{Force on charge at } A,\ F_A = \frac{1}{4\pi\varepsilon_0}\frac{2Q\left(Q+\frac{Q}{2}\right)}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{x^2}$$

6.

Let the charge 2q be placed at point P as shown. The force due to q is to the left and that due to –3q is to the right.

$$\therefore \quad \frac{2q^2}{4\pi\varepsilon_0 x^2} = \frac{6q^2}{4\pi\varepsilon_0 (d+x)^2} \quad \Rightarrow \quad (d+x)^2 = 3x^2$$

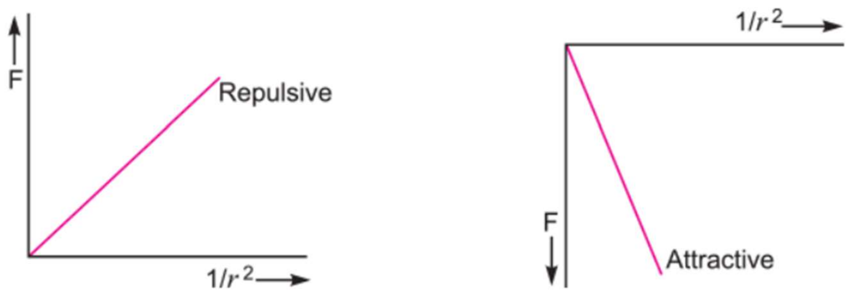
$$\therefore \quad 2x^2 - 2\,dx - d^2 = 0 \quad \Rightarrow \quad x = \frac{d}{2} \pm \frac{\sqrt{3}\,d}{2}$$

(–ve sign would be between q and $-3q$ and hence is unacceptable.)

$$\Rightarrow \quad x = \frac{d}{2} + \frac{\sqrt{3}\,d}{2} = \frac{d}{2}(1+\sqrt{3}) \text{ to the left of } q.$$

7.

The graph between F and $1/r^2$ is a straight line of slope $q_1q_2/4\Pi\varepsilon_0$ passing through origin in both the cases.



Since, magnitude of the slope is more for attraction, therefore, attractive force is greater than repulsive force.

8.

P= 3×10^{-8} Cm

E= 10^4 N/C

At stable equilibrium (θ_1) = 0°

At unstable equilibrium (θ_2) =180°

Work done in a rotating dipole is given by:

W = PE ($\cos\theta_1 - \cos\theta_2$) = 3×10^{-8} (10^4) [cos 0° - cos 180°] = 3×10^{-4} [1 - (-1)]

W= 6×10^{-4} J.

9. **E** = 5×10^3 **i** N/C, positive direction of X-axis.

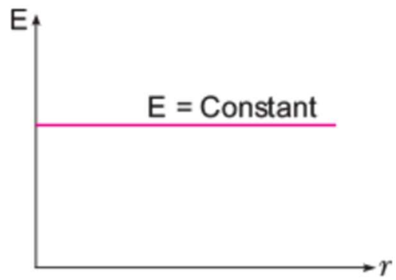
A = 10^{-2} m^2

(i) When plane is parallel to Y-Z plane, the normal to plane is along X-axis. Hence

y = EAcos θ =$5 \times 10^3 \times 10^{-2}$ cos 0° =50 Nm^2/C.

(ii) When the plane makes a 30° angle with the X-axis, the normal to its plane makes 60° angle with X-axis. Hence θ = 60°, y = EAcos θ = $5 \times 10^3 \times 10^{-2}$ cos 60° = 25Nm^2/C.

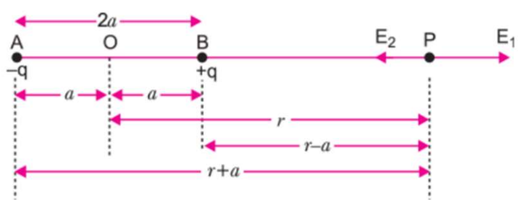
10.



Electric field due to a uniformly charged plane sheet. Which is independent of distance
$E = \sigma/2\varepsilon_o$.

Long Answer Type

1.



∴ The resultant electric field due to electric dipole has magnitude equal to the difference of E_1 and E_2 direction from B to P i.e.

$$E = E_1 - E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

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

$$= \frac{q}{4\pi\varepsilon_0}\frac{4\,ra}{(r^2-a^2)^2} = \frac{1}{4\pi\varepsilon_0}\frac{2(q2a)r}{(r^2-a^2)^2}$$

But $q.2l = p$ (electric dipole moment)

$$\therefore \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{2\,pr}{(r^2-a^2)^2} \qquad ...(i)$$

$r >> l$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2\,pr}{r^4} \quad \text{or} \quad E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3} \qquad ..(ii)$$

At a point of equatorial line: Consider a point P on broad side on the position of dipole formed of charges +q and –q at separation 2a. The distance of point P from mid-point (O) of electric dipole is r. Let **E_1** and **E_2** be the electric field strengths due to charges +q and –q of electric dipole.

From fig. $AP = BP = \sqrt{r^2 + a^2}$

$\therefore \quad \vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2}$ along B to P

$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2}$ along P to A

Clearly $\vec{E}_1$ and $\vec{E}_2$ are equal in magnitude *i.e.* $|\vec{E}_1| = |\vec{E}_2|$ or $E_1 = E_2$

To find the resultant of $\vec{E}_1$ and $\vec{E}_2$, , we resolve them into rectangular components.

Component of $\vec{E}_1$ parallel to $AB = E_1 \cos\theta$, in the direction to $\overrightarrow{BA}$

Component of $\vec{E}_1$ perpendicular to $AB = E_1 \sin\theta$ along OP

Component of $\vec{E}_2$ parallel to $AB = E_2 \cos\theta$ in the direction $\overrightarrow{BA}$

Component of $\vec{E}_2$ perpendicular to $AB = E_2 \sin\theta$ along PO

Clearly, components of $\vec{E}_1$ and $\vec{E}_2$ perpendicular to AB: $E_1 \sin\theta$ and $E_2 \sin\theta$ being equal and opposite cancel each other, while the components of $\vec{E}_1$ and $\vec{E}_2$ parallel to AB : $E_1 \cos\theta$ and $E_2 \cos\theta$, being in the same direction add up and give the resultant electric field whose direction is parallel to $\overrightarrow{BA}$.

$\therefore$ Resultant electric field at P is $E = E_1 \cos\theta + E_2 \cos\theta$

But $E_1 = E_2 = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2+a^2)}$

From the figure, $\cos\theta = \frac{OB}{PB} = \frac{l}{\sqrt{r^2+a^2}} = \frac{l}{(r^2+a^2)^{1/2}}$

$$E = 2E_1 \cos\theta = 2 \times \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2+a^2)} \cdot \frac{l}{(r^2+a^2)^{1/2}} = \frac{1}{4\pi\varepsilon_0} \frac{2ql}{(r^2+a^2)^{3/2}}$$

But $q.2l = p$ = electric dipole moment ...(*iii*)

$\therefore \qquad E = \frac{1}{4\pi\varepsilon_0} \frac{p}{(r^2+a^2)^{3/2}}$

If dipole is infinitesimal and point P is far away, we have a << r, so l^2 may be neglected as compared to r^2 and so equation (iii) gives

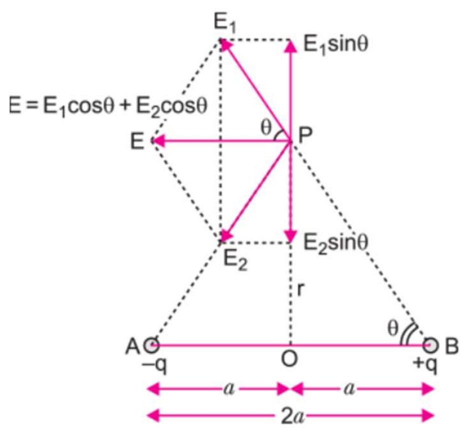
$$E = \frac{1}{4\pi\,\varepsilon_0} \frac{p}{(r^2)^{3/2}} = \frac{1}{4\pi\,\varepsilon_0} \frac{p}{r^3}$$

i.e., electric field strength due to a short dipole at broadside on position

$$E = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^3} \text{ in the direction parallel to } \overrightarrow{BA} \qquad ...(iv)$$

Its direction is parallel to the axis of dipole from positive to negative charge. It may be noted clearly from equations (ii) and (iv) that electric field strength due to a short dipole at any point is inversely proportional to the cube of its distance from the dipole and the electric field strength at axial position is twice that at broad-side on position for the same distance.

Important: Note the important point that the electric field due to a dipole at large distance falls off as $1/r^3$ and not as $1/r^2$ as in the case of a point charge.

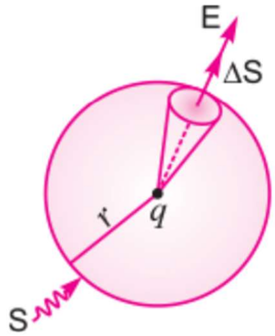


2. The net-outward normal electric flux through any closed surface of any shape is equal to $1/\varepsilon_0$ times the total charge contained within that surface, $1/\varepsilon_0$ i.e.,

$$\oint S\ \vec{E} \bullet d\vec{S} = \frac{1}{\varepsilon_0} \sum q$$

Proof: Let a point charge +q be placed at centre O of a sphere S. Then S is a Gaussian surface. Electric field at any point on S is given by

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



The electric field and area element points radially outwards, so θ = 0°.

Flux through area $\overrightarrow{dS}$ is

$$d\varphi = \overrightarrow{E} \ . \text{dS} = E \ \text{dS} \cos 0^\circ = E \ \text{dS}$$

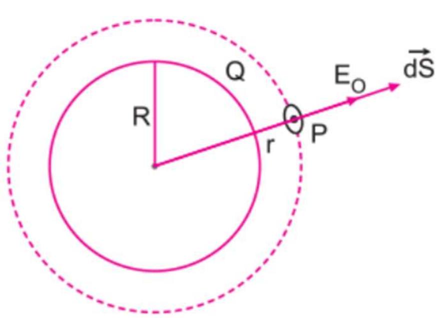
Total flux through surface S is

$$\varphi = \oint_S d\varphi = \oint_S E\text{dS} = E \oint_S dS = E \times \text{Area of Sphere}$$

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} .4\pi r^2$$

or, $\varphi = \frac{q}{\varepsilon_0}$ which proves Gauss's theorem.

3.



(i) Electric field intensity at a point outside a uniformly charged thin spherical shell: Consider a uniformly charged thin spherical shell of radius R carrying charge Q. To find the electric field outside the shell, we consider a spherical Gaussian surface of radius r (>R), concentric with given shell. If **E** is electric field outside the shell, then by symmetry electric field strength has same magnitude E_0 on the Gaussian surface and is directed radially outward. Also, the directions of normal at each point is radially outward, so angle between **E** and ds is zero at each point. Hence, electric flux through Gaussian surface.

$$\oint S = \overrightarrow{E}_0 \bullet \overrightarrow{dS}.$$

$$\oint = E_0 \ \mathrm{dS} \cos 0 = E_0 \ . \ 4\pi r^2$$

Now, Gaussian surface is outside the given charged shell, so charge enclosed by Gaussian surface is Q.

Hence, by Gauss's theorem

$$\oint s = \overrightarrow{E}_0 \bullet \overrightarrow{dS} = \frac{1}{\varepsilon_0} \times \text{ charged enclosed}$$

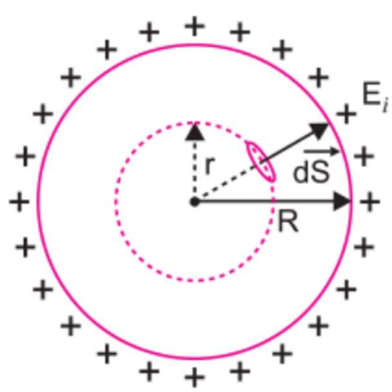
$$\Rightarrow \qquad E_0 \ . \ 4\pi r^2 = \frac{1}{\varepsilon_0} \times Q \ \Rightarrow \ E_0 = \frac{1}{4\pi\varepsilon_0} \ \frac{Q}{r^2}$$

Thus, electric field outside a charged thin spherical shell is the same as if the whole charge Q is concentrated at the centre.

If σ is the surface charge density of the spherical shell, then

$$Q = 4\pi R^2 \sigma \text{ coulomb}$$

$$\therefore \qquad E_0 = \frac{1}{4\pi\varepsilon_0} \ \frac{4\pi R^2 \sigma}{r^2} = \frac{R^2 \sigma}{\varepsilon_0 r^2}$$



(ii) Electric field inside the shell (hollow charged conducting sphere): The charge resides on the surface of a conductor. Thus, a hollow charged conductor is equivalent to a charged spherical shell. To find the electric field inside the shell, we consider a spherical Gaussian surface of radius r (< R) concentric with the given shell. If **E** is the electric field inside the shell, then by symmetry electric field strength has the same magnitude E_i on the Gaussian surface and is directed radially outward. Also, the directions of normal at each point is radially outward, so angle between **E** and ds is zero at each point. Hence, electric flux through Gaussian surface

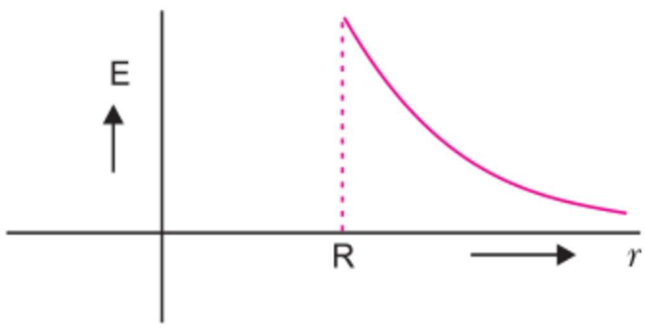
$$= \int_S \overrightarrow{E}_i \,.\, \overrightarrow{dS} = \int E_i \; \mathrm{dS} \cos 0 = E_i \;.\; 4\pi r^2$$

Now, Gaussian surface is inside the given charged shell, so charge enclosed by Gaussian surface is zero.

Hence, by Gauss's theorem

$$\int_S \overrightarrow{E}_i \,.\, \overrightarrow{dS} = \frac{1}{\varepsilon_0} \times \text{ charge enclosed}$$

$$\Rightarrow \qquad E_i \; 4\pi r^2 = \frac{1}{\varepsilon_0} \times 0 \quad \Rightarrow \quad E_i = 0$$



Thus, electric field at each point inside a charged thin spherical shell is zero. The graph is shown in fig.

4.

Electric flux through flat surface S1:

$$\varphi_1 = \oint_{S_1} \overrightarrow{E}_1 \,.\, \overrightarrow{dS}_1 = \oint_{S_1} (E_x \hat{i}) \,.\, (\,\mathrm{dS}_1 \,\hat{i}\,) = E_x S_1$$

Electric flux through flat surface S2:

$$\varphi_2 = \int_{S_2} \overrightarrow{E}_2 \,.\, \overrightarrow{dS}_2 = \int_{S_2} (-E_x \hat{i}) \,.\, (-\mathrm{dS}_2 \,\hat{i}\,) = \int_{S_2} E_x \, \mathrm{dS}_2 = E_x S_2$$

Electric flux through flat surface S3:

$\varphi_3 = \int_{S_3} (\vec{E}_3 . \overrightarrow{dS_3}) = \int_{S_3} E_3 \, dS_3 \cos 90^\circ = 0$

$\therefore$ Net electric flux, $\varphi = \varphi_1 + \varphi_2 = E_x(S_1 + S_2)$

But $S_1 = S_2 = \pi \left(r \times 10^{-2}\right)^2 \text{ m}^2 = \pi r^2 \times 10^{-4} \text{ m}^2$

$\therefore \varphi = E_x . 2 \left(\pi r^2 \times 10^{-4}\right)$ units

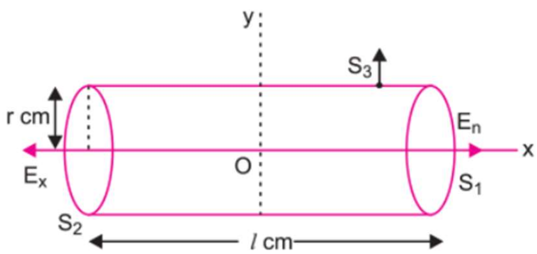
By Gauss's law, $\varphi = \frac{1}{\varepsilon_0} q$

$q = \varepsilon_0 \varphi = \varepsilon_0 E_x \left(2 \pi r^2 \times 10^{-4}\right)$

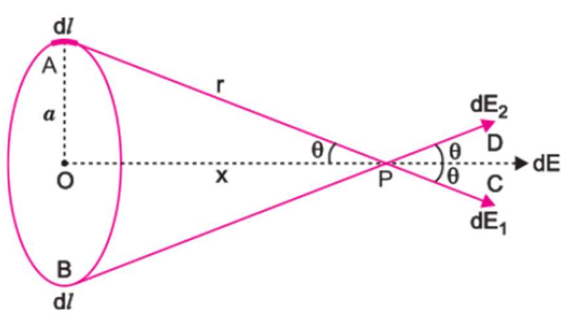
$= 2\pi\varepsilon_0 E_x r^2 \times 10^{-4} = 4\pi\varepsilon_0 \left(\frac{E_x r^2 \times 10^{-4}}{2}\right)$

$= \frac{1}{9\times10^9} \left[\frac{E_x r^2 \times 10^{-4}}{2}\right]$

$= 5.56 E_x r^2 \times 10^{-11}$ coulomb.



5.



Consider a point P on the axis of uniformly charged ring at a distance x from its centre O. Point P is at distance r = $\sqrt{a^2+x^2}$ from each element dl of ring. If q is total charge on ring, then, charge per metre length, $\lambda = \frac{q}{2\pi a}$.

The ring may be supposed to be formed of a large number of ring elements.

Consider an element of length dl situated at A.

The charge on element, dq = λ dl

∴ The electric field at P due to this element

$$\mathrm{dE_1} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{dq}}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\ \mathrm{dl}}{r^2},\ \text{along}\ \overrightarrow{\mathrm{PC}}$$

The electric field strength due to opposite symmetrical element of length *dl* at *B* is

$$\overrightarrow{dE_2} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{dq}}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\ \mathrm{dl}}{r^2},\ \text{along}\ \overrightarrow{\mathrm{PD}}$$

If we resolve $\mathbf{E_1}$ and $\mathbf{E_2}$ along the axis and perpendicular to axis, we note that the components perpendicular to axis are oppositely directed and so get cancelled, while those along the axis are added up. Hence, due to symmetry of the ring, the electric field strength is directed along the axis. The electric field strength due to charge element of length dl, situated at A, along the axis will be

$$\mathrm{dE} = \mathrm{dE_1}\cos\theta = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\ \mathrm{dl}}{r^2}\cos\theta$$

But, $\cos\theta = \frac{x}{r}$

$$\therefore \qquad \mathrm{dE} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\ \mathrm{dl}\ x}{r^3} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda x}{r^3}\ \mathrm{dl}$$

The resultant electric field along the axis will be obtained by adding fields due to all elements of the ring, i.e.,

$$\therefore \qquad E = \int \frac{1}{4\pi\varepsilon_0}\frac{\lambda x}{r^3}\mathrm{dl} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda x}{r^3}\int \mathrm{dl}$$

But, $\int \mathrm{dl}$ = whole length of ring = $2\pi a$ and $r = \left(a^2+x^2\right)^{1/2}$

$$\therefore \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{\lambda x}{(a^2+x^2)^{3/2}}2\pi a$$

As, $\lambda = \frac{q}{2\pi a}$, we have $E = \frac{1}{4\pi\varepsilon_0} \frac{\left(\frac{q}{2\pi a}\right)x}{(a^2+x^2)^{3/2}} 2\pi a$ $E = \frac{1}{4\pi\varepsilon_0} \frac{qx}{(a^2+x^2)^{3/2}}$

or, $E = \frac{1}{4\pi\varepsilon_0} \frac{qx}{(a^2+x^2)^{3/2}}$, along the axis

At large distances i.e., $x >> a$, $E = \frac{1}{4\pi\varepsilon_0} \frac{q}{x^2}$

i.e., the electric field due to a point charge at a distance x. For points on the axis at distances much larger than the radius of ring, the ring behaves like a point charge

<u>Case Study:</u>

1.

(i) $e^- + e^+ \rightarrow \gamma + \gamma$ Because of momentum conservation

(ii) (a) 9B Because of conservation of charge

(iii) (c) a positron and an electron are produced respectively. Because of conservation of charge

(iv) (A) 2×10^{12} from wool to polythene

OR

(B) (a) attract, As C has positive charge and A has negative charge.

2.

(i) (A) 3.9 pm

(ii) (B) 9.3×10^{-26} N. m.

(iii) (D) 1.9×10^{-25} J

(iv) (a) (C) $\tau 1 = \tau 2 = \tau 3 = \tau 4$

OR

(b) (A) U1 = U3 > U2 = U4

3.

(i) (A) independent of a.

(ii) (B) 3Ze/πR 3

(iii) (C) a = R

(iv) (a) (A) increases as r increases for r < R.

OR

(b) (D) is discontinuous at r = R.

4.

(i) (b) radially inward

Because the column has negative charge density.

(ii) (a) 1/r

(iii) (A) (c) 6 m

Substituting Values, r = 6 m

OR

(B) (a) the electrons dumped by the strike travel along the ground and these ground currents are lethal.

(iv) (b) -2πrhE, 0

Electric field is perpendicular and inward at each point on cylinder's curved surface, hence flux through cylinder's curved surface is - 2πrhE.

5.

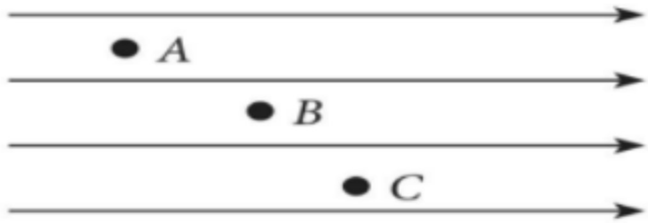
(i) (c) B becomes negatively charged and C becomes positively charged.
Electron affinity of B is greater than that of A and electron affinity of A is greater than that of C.
(ii) (A) (d) may increase slightly or may decrease slightly
If a body is charged, it either loses or gains electrons and electron has its own mass.
OR
(B) (a) only through the removal of negative charges.
(iii) (b) Plates C and D attract and plates B and D also attract each other.
A neutral conductor always attracts a nearby charged object because of induced charges in the conductor and B and D plates have opposite charges.
(iv) (c) remain neutral, but be attracted to the rod.
Because when a charged rod is held near a neutral conducting sphere, negative and positive charges are induced in the neutral conducting sphere.

CHAPTER–2: ELECTROSTATIC POTENTIAL AND CAPACITANCE

MCQ type Questions

1. 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) $4\pi\varepsilon_0 Q \times 10^{22}$ V/m
   (b) $12\pi\varepsilon_0 Q \times 10^{20}$ V/m
   (c) $4\pi\varepsilon_0 Q \times 10^{20}$ V/m
   (d) $12\pi\varepsilon_0 Q \times 10^{22}$ V/m

2. Figure shows three points A, B and C in an uniform electric field. Arrange the potential at these points in the descending order.



(a) V_A, V_B, V_C b) V_B, V_A, V_C
(c) V_A, V_C, V_B d) V_C, V_A, V_B

3. 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
4. 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

5. What is angle between electric field and equipotential surface?
   (a) 90° always
   (b) 0° always
   (c) 0° to 90°
   (d) 0° to 180°

6. 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) (b) $5C_1 = 3C_2$

(c) (c) $3C_1 = 5C_2$

(d) (d) $3C_1 + 5C_2 = 0$

7. The capacitance of a parallel plate capacitor is 5 μF . When a glass slab of thickness equal to the separation between the plates is introduced between the plates, the potential difference reduces to 1/8 of the original value. The dielectric constant of glass is

a) 1

b) 1/8

c) 8

d) 40

8. In series combination of capacitors, potential drops across the individual capacitors is

a) inverse ratio of charges stored

b) direct ratio of capacitors

c) none of these

d) inverse ratio of capacitors

9. In bringing an electron towards another electron, the electrostatic potential energy of the system

a) decreases

b) become zero

c) remains same

d) increases

10. An electric dipole consisting of charges + q and - q separated by a distance L is in stable equilibrium in a uniform electric field . The electrostatic potential energy of the dipole is

a) zero

b) - qLE

c) - 2 qEL

d) qLE

11. For a charged conductor of arbitrary shape, inside the conductor

a) V= 0 and $E \neq 0$

b) E and V are zero

c) E = 0, but V is same as on the surface and non-zero

d) E is non-uniform but V is zero everywhere

12. An electron of mass m and charge e is accelerated from rest through a potential difference V in vacuum. Its final speed will be

a) $\sqrt{\frac{2eV}{m}}$

b) $\sqrt{\frac{eV}{m}}$
c) $eV/2m$
d) eV/m

13. 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.

14. An electric dipole is placed at an angle of 30^0 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

15. Electric potential at any point is $V = -5x + 3y + \sqrt{15}z$, then the magnitude of the electric field is
(a) $3\sqrt{2}$
(b) $4\sqrt{2}$
(c) $5\sqrt{2}$
(d) 7

16. Two capacitors of capacitance 2 μF and 3 μF are joined in series. Outer plate of first capacitor is at 1000 V and outer plate of second capacitor is earthed (grounded). Now the potential on inner plate of each capacitor will be
(a) 700 V
(b) (b) 200 V
(c) (c) 600 V
(d) (d) 400 V

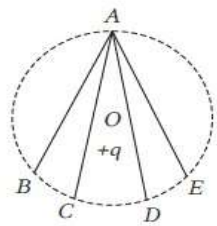
17. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface becomes 80V. The potential at the centre of the sphere is
(a) 80 V
(b) (b) 800 V
(c) (c) 8 V
(d) (d) zero

18. Two unilike charges of magnitude q are separated by a distance 2d. The potential at a point midway between them is
a) Zero
b) $1/4\pi\varepsilon_0$

c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{d}$

d) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{d}$

19. In the electric field of a point charge q, a certain charge is carried from point A to B, C, D and E. Then, the work done

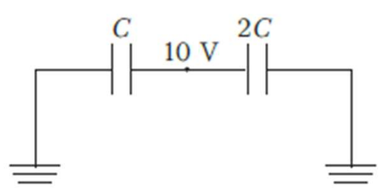


(a) is least along the path AB
(b) is least along the path AD
(c) is zero along all the paths AB, AC, AD and AE
(d) is least along AE

20. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at $x = 0$ and positive plate is at $x = 3d$. The slab is equidistant from the plates. The capacitor is given some charge. As one goes from 0 to $3d$

(a) the magnitude of the electric field remains the same
(b) the direction of the electric field remains the same
(c) the electric potential decrease continuously
(d) the electric potential increases at first, then decreases and again increases

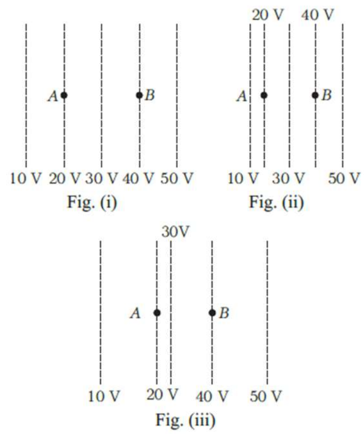
21. In the circuit shown in figure $C = 6$ μF. The charge stored in the capacitor of capacity C



is

(a) zero
(b) 90 μC
(c) 40 μC
(d) 60 μC

22. Figure shows some equipotential lines distributed in space. A charged object is moved from point *A* to



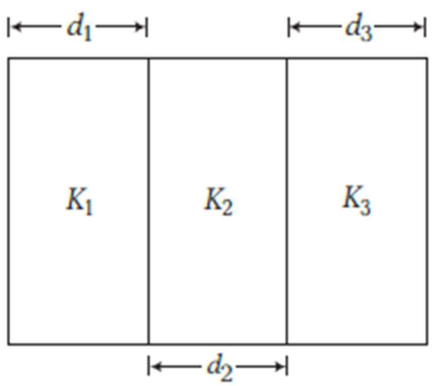
point *B*.

(a) The work done in Fig. (i) is the greatest
(b) The work done in Fig. (ii) is least
(c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii)
(d) The work done in Fig. (iii) is greater than Fig. (ii) but equal to that in Fig.(i)

23. The distance between the circular plates of a parallel plate condenser 40 mm in diameter, in order to have same capacity as a sphere of radius 1 m is

(a) 0.01 mm
(b) (b) 0.1 mm
(c) (c) 1.0 mm
(d) (d) 10 mm

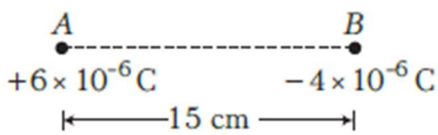
24. The expression for the capacity of the capacitor formed by compound dielectric placed between the plates of a parallel plate capacitor as shown in figure, will be (area of plate = *A*)



(a) $\dfrac{\varepsilon_0 A}{\left(\dfrac{d_1}{K_1}+\dfrac{d_2}{K_2}+\dfrac{d_3}{K_3}\right)}$ (b) $\dfrac{\varepsilon_0 A}{\left(\dfrac{d_1+d_2+d_3}{K_1+K_2+K_3}\right)}$

(c) $\dfrac{\varepsilon_0 A(K_1K_2K_3)}{d_1d_2d_3}$ (d) $\varepsilon_0\left(\dfrac{AK_1}{d_1}+\dfrac{AK_2}{d_2}+\dfrac{AK_3}{d_3}\right)$

25. Two charges + 6 μC and − 4 μC are placed 15 cm apart as shown. At what distances from *A* to its right, the electrostatic potential is zero (distances in cm)?



(a) 4, 9, 60
(b) 9, 45, infinity
(c) 20, 45, infinity
(d) 9, 15, 45

ASSERTION AND REASON TYPE QUESTIONS

For two statements are given-one labeled **Assertion** (A) and the other labeled **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.

1. **Assertion:** The potential at a point is characteristic of the electric field at a point only whereas electric potential energy at a point is characteristic of the charge–field system.

Reason: The potential is independent of a charged test charge placed in the field and the electric potential energy is due to an interaction between the electric field at the point and the charged particle placed in the field at that point.

Select the correct option.

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

2. **Assertion:** The electric potential is constant everywhere inside a charged conductor and is equal to its value at the surface.
Reason: A constant work has to be done to move a test charge from the interior of a charged conductor to its surface.
Select the correct option.
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
3. **Assertion:** A thin uncharged metallic plate placed in between the two charged plates of a capacitor results in an arrangement equivalent to two capacitors in a series combination. The equivalent capacitance of this combination stays the same irrespective of the position of the metallic plate in between the plates of the capacitor.
Reason: The change in the position of the central metallic plate, results in the decrease in plate separation of one capacitor that is compensated by the increase in plate separation for the other.
Select the correct option.
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
4. Assertion: An electric field is preferred in comparison to magnetic field for detecting the electron beam in a television picture tube.
Reason : Electric field requires low voltage.
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.
5. Assertion: An applied electric field will polarize the polar dielectric material.
Reason : In polar dielectrics, each molecule has a permanent dipole moment but these are randomly oriented in the absence of an externally applied electric field.
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.
6. **Assertion :** Conductor having equal positive charge and volume, must also have same potential.
Reason : Potential depends on charge and geometry of conductor.
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.
7.Assertion When two positive point charges move away from each other, then their electrostatic potential energy decreases.

Reason Change in potential energy between two points is equal to the work done by electrostatic forces.
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.

8. Assertion A charged capacitor is disconnected from a battery. Now, if its plates are separated further, the potential energy will fall.
Reason Energy stored in a capacitor is equal to the work done in charging it
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.

9. Assertion When a capacitor is charged by a battery, half of the energy supplied by the battery is stored in the capacitor and rest half is lost.
Reason If resistance in the circuit is zero, then there will be no loss of nergy.
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.

10. 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
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.

<u>Very short Answer type questions</u>

Q.1 What is an equipotential surface ? Give an example.

Q,2 Define electron volt. How is it related to joule ?

Q.3 How much work is done in moving a 500 pC charge between two points on an equipotential surface?

Q.4 Write a relation for polarisation $\vec{P}$ of a dielectric material in the presence of an external electric field $\vec{E}$.

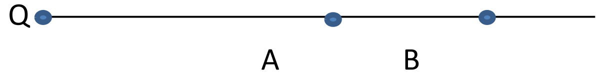
Q.5 In which orientation, a dipole placed in a uniform electric field is in (i) stable, (ii) unstable equilibrium ?

Q.6 Where is the knowledge of dielectric strength helpful ?

Q.7 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 ?

Q.8 A metal plate is introduced between the plates of a charged parallel plate capacitor. What is its effect on the capacitance of the capacitor ?

Q.9 A point charge Q is placed at point O as shown in the figure . The potential difference $V_A - V_B$ is positive. Is the charge Q negative or positive?



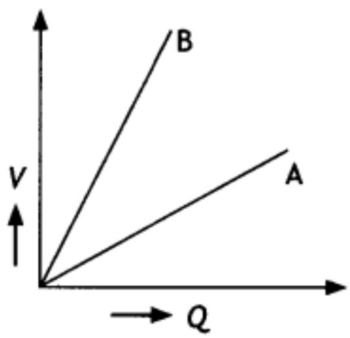
Q.10 State the SI unit of electric polarization vector P.

Short Answer Type Questions

Q.1 Draw a plot showing the variation of (i) electric field (E) and (ii) electric potential (V) with distance r due to a point charge Q.

Q.2 Two identical capacitors of 10 pF each are connected in turn (i) in series and (ii) in parallel across a 20 V battery. Calculate the potential difference across each capacitor in the first case and the charge acquired by each capacitor in the second case.

Q.3 The graph shows the variation of voltage V across the plates of two capacitors A and B versus charge Q stored on them. Which of the two capacitors has higher

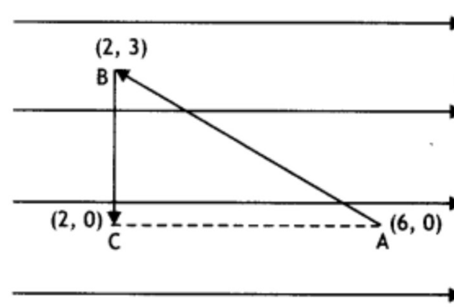


capacitance? Give a reason for your answer.

Q.4 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

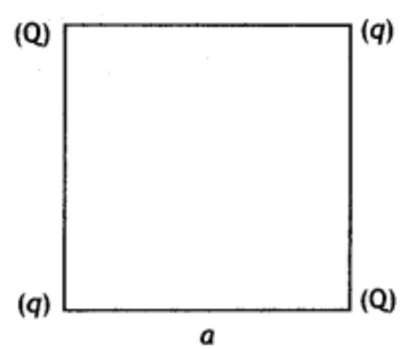
(ii) At which point (of the two) is the electric potential more and why?



Q.5 A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

Q.6 Two-point charges q and -2q are kept 'd' distance apart. Find the location of the point relative to charge 'q' at which potential due to this system of charges is zero.

Q.7 Four-point charges Q, q, Q., and q are placed at the corners of a square of side 'a' as shown in the figure. Find the potential energy of this system.



Q.8 A capacitor is connected across a battery. ii) Why does each plate receive a charge of exactly the

same magnitude ? {ii) Is this true even if the plates are of different sizes ?

Q.9 Justify that the electrostatic potential is constant throughout the volume of a charged conductor

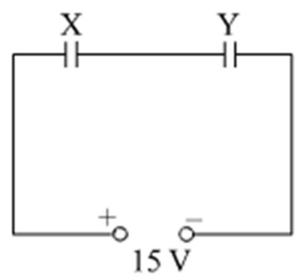
and has the same value on its surface as inside it.

Q.10 Why electric potential in the field of a negative charge is lower at near points and higher at

distant points ?

{Long Type Questions) (Each Carry 5 Marks)

1. Two parallel plate capacitors X and Y have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric of $\varepsilon_r = 4$.



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

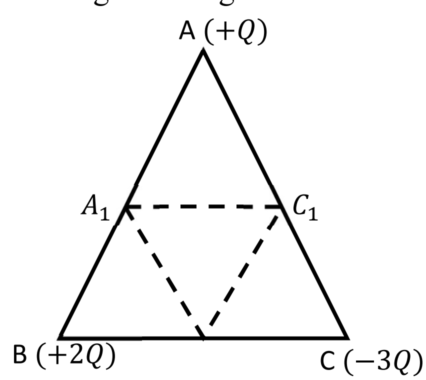
(iii) Estimate the ratio of electrostatic energy stored in X and Y.

2. A potential difference is set up between the plates of a parallel plate capacitor by a battery and then the battery is removed. If the distance between the plates is decreased, then how the (a) charge (b) potential difference, (c) electric field (d) energy and (e) energy store & capacitance parallel plate capacitor?

3. If n similar small drops of mercury, each of capacity C, surface charge density σ, energy E and potential V, combine to form a big drop, then calculate the capacity, surface charge density, energy and potential of the big drop.

4. (a) Deduce the expression for the potential energy of a system of two charges q_1 and q_2 located at $\vec{r_1}$ and $\vec{r_2}$ respectively in an external electric field.

(b) Three-point charges, $+Q, +2Q$ and $-3Q$ are placed at the vertices of an equilateral triangle ABC of side l. If these charges are displaced to the mid-points A_1, B_1 and C_1 respectively, find the amount of the work done in shifting the charges to the new locations.

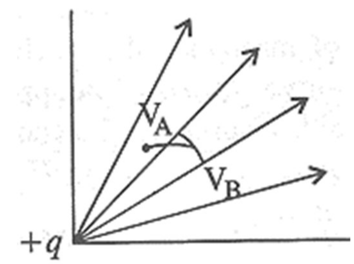


5. . Two capacitors of capacitances 10 μF and 20 μF are connected in series with a 6V battery. If E is the energy stored in 20 μF capacitor, what will be the total energy supplied by the battery in terms of E?

Section: - F (Case Study Based Questions)

Read the following paragraphs and answers the question that follows: -

1. Electrostatic potential energy of a system of point charges is defined as the total amount of work done in bringing the different charges to their respective positions from infinitely charge mutual separations. The work is stored in the system of two point charges in the form of electrostatic potential energy U of the system. Electric potential difference between any points A and B in an electric field is the amount of work done in moving a unit positive test charge from A to B along any path agents the electrostatic force



$$V_B - V_A = \frac{W_{AB}}{q_o} = \int \vec{E}.\overrightarrow{dl}$$

(i) A test charge is moved from lower potential point to a higher potential point. The potential energy of test charge will

(a) remain the same (b) increase

(c) decrease (d) become zero

(ii) Which of the following statement is not true?

(a) Electrostatic force is a conservative force.

(b) Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity.

(c) Spring force and gravitational force are conservative force.

(d) Both (a) and (c).

(iii) Work done in moving a charge from one point to another inside a uniformly charged conducting sphere is

(a) always zero (b) non-zero (c) may be zero (d) none of these

(iv) The work done in bringing a unit positive charge from infinite distance to a point at distance x from a positive charge Q is W. Then the potential ϕ at that point is

(a) $\frac{WQ}{x}$ (b) W (c) $\frac{W}{x}$ (d) WQ

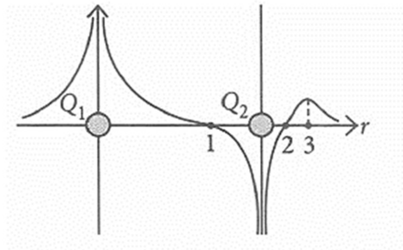
Or

If 1 μC charge is shifted from A to B and it is found that work done by an external force is 40 μJ In doing so against electrostatics force, the potential difference $V_A - V_B$ is

(a) 40 V (b) $-40\ V$ (c) 20 V (d) $-60\ V$

2. The potential at any observation point P of a static electric. field is defined as the work done by the external agent (or negative of work done by electrostatic field) in slowly

bringing a unit positive point charge from infinity to the observation point. Figure shows the potential variation along the line of charges. Two point charges Q_1 and Q_2 lie along a line at a distance from each other.



(i) At which of the points 1, 2 and 3 is the electric field is zero?
(a) 1 (b) 2 (c) 3 (d) Both (a) and (b)

(ii) The signs of charges Q_1 and Q_2 respectively are
(a) positive and negative (b) negative and positive
(c) positive and positive (d) negative and negative

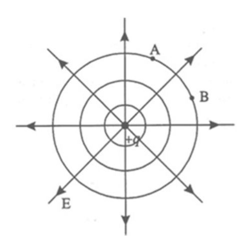
(iii) Which of the two charges Q, and Q_2 is greater in magnitude?
(a) Q_2 (b) Q_1 (c) same (d) Can't determined

Or

Which of the following statement is not true?
(a) Electrostatic force is a conservative force.
(b) Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity.
(c) When two like charges lie infinite distance apart, their potential energy is zero.
(d) Both (a) and (c).

(iv) Positive and negative point charges of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, \frac{-a}{2}\right)$ The work done by the electric field when another positive point charge is moved from $(-a, 0, 0)$ to $(0, a, 0)$ is
(a) positive (b) negative
(c) zero (d) depends on the path connecting the initial and final positions

3. 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.



(i) Identify the wrong statement.
(a) Equipotential surface due to a single point charge is spherical.
(b) Equipotential surface can be constructed for dipoles too.
(c) the electric field is normal to the equipotential surface through the point.
(d) The work done to move a test charge on the equipotential surface is positive.

(ii) Nature of equipotential surface for a point charge is
(a) Ellipsoid with charge at foci
(b) Sphere with charge at the centre of the sphere
(c) Sphere with charge on the surface of the sphere
(d) Plane with charge on the surface.

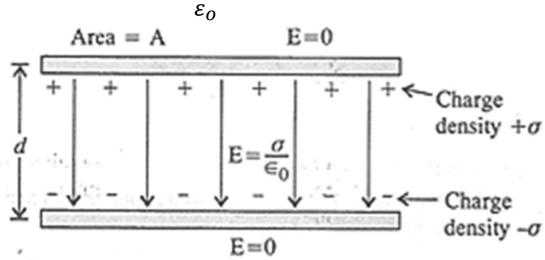
(iii) A spherical equipotential surface is not possible
(a) inside a uniformly charged sphere (b) for a dipole
(c) inside a spherical condenser (d) for a point charge

(iv) The work done in carrying a charge q once round a circle of radius a with a charge Q at its centre is
(a) $\frac{qQ}{4\pi\varepsilon_o a}$ (b) $\frac{qQ}{4\pi\varepsilon_o a^2}$ (c) $\frac{q}{4\pi\varepsilon_o a}$ (d) zero

Or

The work done to move a unit charge along an equipotential surface from P to Q
(a) must be defined as $\int_P^Q \vec{E}.d\vec{l}$ (b) is zero
(c) can have a non-zero value (d) both (a) and (b) are correct.

4. The simplest and the most widely used capacitor is the parallel plate capacitor. It consists of two large plane parallel conducting plates, separated by a small distance.
In the outer regions above the upper plate and below the lower plate, the electric fields due to the two charged plates cancel out. The net field is zero.
In the inner region between the two capacitor plates, the electric fields due to the two charged plates add up. The net field is $\frac{\sigma}{\varepsilon_o}$.



(i) A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential and capacitance respectively are
(a) Charge remains constant, potential decreases & capacitance increases
(b) Charge remains constant, potential increases & Capacitance decreases
(c) Charge increases, potential increases & Capacitance decreases
(d) Charge decreases, potential decreases & Capacitance increases

(ii) In a parallel plate capacitor, the capacity increases if
(a) area of the plate is decreases (b) distance between the plates increases
(c) area of the plate is increases (d) dielectric constant decreases.

(iii) A parallel plate capacitor has two square plates with equal and opposite charges. The surface charge densities on the plates are + and -σ respectively. In the region between the plates the magnitude of the electric field is

(a) $\frac{\sigma}{2\varepsilon_o}$ (b) $\frac{\sigma}{\varepsilon_o}$ (c) 0 (d) none of these

(iv) If a parallel plate air capacitor consists of two circular plates of diameter 8 cm. At what distance should the plates be held so as to have the same capacitance as that of sphere of diameter 20 cm?

(a) 9 mm (b) 4 mm (c) 8 mm (d) 2 mm

Or

If a charge of $+2.0 \times 10^{-8}$ C is placed on the positive plate and a charge of -1.0×10^{-8} C on the negative plate of a parallel plate capacitor of capacitance 1.2×10^{-3} μF, then the potential difference developed between the plates is

(a) 6.25 V (b) 3.0 V (c) 12.5 V (d) 25 V

5. This energy possessed by a system of charges by virtue of their positions. When two like charges lie Infinite distance apart, their potential energy is zero because no work has to be done in moving one charge at infinite distance from the other.
In carrying a charge q from point A to point B, work done $W = q(V_A - V_B)$. This work may appear as change in KE/PE of the charge. The potential energy of two charges q_1 and q_2 at a distance r in air is $\frac{q_1 q_2}{4\pi\varepsilon_o r}$ It is measured in joule. It may be positive, negative or zero depending on the signs of q_1 and q_2.

(i) Calculate work done in separating two electrons form a distance of 1 m to 2 m in air, where e is electric charge and k is electrostatic force constant.

(a) ke^2 (b) $\frac{e^2}{2}$ (c) $-ke^2/2$ (d) zero

(ii) Four equal charges q each are placed at four corners of a square of side a each. Work done in carrying a charge $-q$ from its centre to infinity is

(a) zero (b) $\frac{\sqrt{2}q^2}{\pi\varepsilon_o a}$ (c) $\frac{\sqrt{2}q}{\pi\varepsilon_o a}$

(d) $\frac{q^2}{\pi\varepsilon_o a}$

(iii) Two points A and B are located in diametrically opposite directions of a point charge of +2 μC at distances 2 m and 1 m respectively from it. The potential difference between A and B is

(a) $3 \times 10^3\ V$ (b) $6 \times 10^4\ V$ (c) $-9 \times 10^3\ V$ (d) $-3 \times 10^3\ V$

Or

Two-point charges $A = +3$ nC and $B = 1$ nC are placed 5 cm apart in air. The work done to move charge B towards A by 1 cm is

(a) $2.0 \times 10^{-7} J$ (b) $1.35 \times 10^{-7}\ J$ (c) $2.7 \times 10^{-7} J$ (d) $12.1 \times 10^{-7} J$

(iv) A charge Q is placed at the origin. The electric potential due to this charge at a given point in space is V. The work done by an external force in bringing another charge q from infinity up to the point is

(a) $\frac{V}{q}$ (b) Vq (c) $V + q$ (d) V

SOLUTIONS

Chapter: -2

ELECTROSTATIC POTENTIAL AND CAPACITANCE

Answer key of MCQ type questions

S.NO.	ANS
1	D
2	A
3	D
4	A
5	A
6	D
7	C
8	D
9	D
10	A
11	C
12	A
13	C
14	D
15	D
16	D
17	A
18	A
19	C
20	B
21	D
22	C
23	B
24	A
25	B

ASSERTION AND REASON TYPE QUESTIONS

ANSWER-KEY

1-A

2-C

3-A

4-D

5-B Explanation:

If a material contains polar molecules, they will generally be in random orientations when no electric field is applied. An applied electric field will polarize the material by orienting the dipole moment of polar molecules.

6-D

(*d*) Electric potential of a charged conductor depends not only on the amount of charge and volume but also on the shape of the conductor. Hence, if their shapes are different, they may have different electric potential.

7-B

7-b (*b*) Potential energy of a system of two charges,

$$U = K\frac{q_1 q_2}{r}.$$

8-D Battery is disconnected from the capacitor. So,

Q= Const.

$$\text{Energy} = \frac{Q^2}{2C} = \frac{Q^2 d}{2\varepsilon_0 A}$$

$$\text{Energy} \propto d$$

9-C

4 (*c*) Energy supplied by battery $= qV = (CV)V = CV^2$

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

$\therefore$ Energy lost $= CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$

Therefore, half energy is lost.

10-A

Very short Answer type questions

Answer key

Ans.1 Any surface which has same electric potential at every point is called an equipotential surface. The surface of a charged conductor is an equipotential surface.

Ans.2 Electron volt is the potential energy gained or lost by an electron in moving through a potential difference of one volt.

1 electron volt = leV =1.6×10^{-19} J

Ans.3 Zero. W = qΔV=500pCxO = 0.

Ans.4 $\vec{P} = \epsilon_0 \chi_e \vec{E}$

Ansa.5 (i) When the dipole moment p is parallel to the the electric field

$\vec{E}(\theta = 90°)$ the dipole is in stable equilibrium,

(ii) When the dipole moment p is antiparallel to the electric field

$\vec{E}(\theta = 180)$, the dipole is in unstable

Ans.6 The knowledge of dielectric strength helps in designing a capacitor by determining the maximum potential that can be applied across the capacitor without causing its electrical breakdown.

Ans.7 Potential at the center = Potential at the surface= 10V.

Ans.8 The introduction of a metal sheet of thickness t in a parallel plate capacitor increases its capacitance by a factor of $\frac{d}{d-t}$, where d is the plate separation of the capacitor.

Ans.9 $V_A - V_B = \frac{Q}{4\pi\epsilon_0}\left[\frac{1}{OA} - \frac{1}{OB}\right]$

$V_A - V_B > 0 \; and \; \left[\frac{1}{OA} - \frac{1}{OB}\right] > 0,$

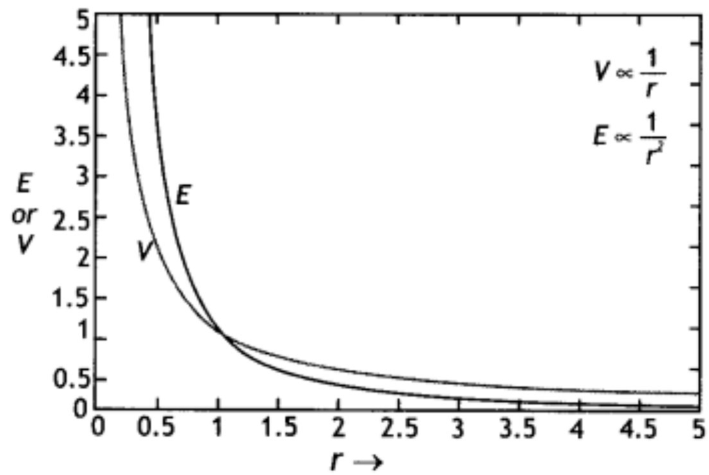
So the charge Q is positive.

Ans.10 Cm^{-2}.

Short Answer type questions

Answer key

Ans.1 The plot is as shown.



Ans.2 (i) Since the two capacitors have the same capacitance, therefore, the potential will be divided amongst them. Hence V = 10 V each

(ii) Since the capacitors are connected in parallel, therefore, potential difference =20 V
Hence charge Q = CV = 10 × 20 = 200 pC

Ans.3 Capacitor A has higher capacitance. We know that capacitance C = Q/V.

For capacitor A

$c_A = \frac{Q}{V_A}$

For capacitor B

$c_B = \frac{Q}{V_B}$

As $V_B > V_A$

∴ $C_B < C_A$

Thus, capacitance of A is higher.

Ans.4 (i) dV = - E dr = - E (6 - 2) = - 4E

(ii) Electric potential is more at point C as dV = - Edr, i.e. the electric potential decreases in the direction of the electric field.

Ans.5 Given t = d/2, C = ?

We know that when a dielectric of thickness 't' is inserted between the plates of a capacitor, its capacitance is given by

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

Hence we have

$$C = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}} = \frac{2K\varepsilon_0 A}{d(1+K)}$$

Ans.6 Let the potential be zero at point P at a distance x from charge q as shown

Now potential at point P is

$$V = \frac{kq}{x} + \frac{k(-2q)}{d+x} = 0$$

Solving for x we have

x = d

Ans.7 The potential energy of the system

$$U = \frac{1}{4\pi\varepsilon_0}\left(4\frac{qQ}{a} + \frac{q^2}{a\sqrt{2}} + \frac{Q^2}{a\sqrt{2}}\right)$$

$$U = \frac{1}{4\pi\varepsilon_0 a}\left(4qQ + \frac{q^2}{\sqrt{2}} + \frac{Q^2}{\sqrt{2}}\right)$$

Ans.8 (i) This is because of conservation of charge. If q_1 and q_2, are the charges taken by the two plates,

Then q_1+q_2 must be zero because the charge on the battery is simply redistributed and not

created or destroyed.

{ii) Yes, the charges will be of equal magnitude even if the two plates have different sizes.

Ans.9 Since electric field inside the conductor is zero and has no tangential component on the surface,

No work is done in moving a small test charge within the conductor or on its surface.

Tlnis means that, there is no potential difference between any two points inside or on the surface

of the conductor. Hence the potential is constant throughout the volume of the conductor and

has the same value on its surface.

Ans.10 For a negative charge the electric potential is V = $\frac{1}{4\pi\epsilon_0}\frac{q}{r}$

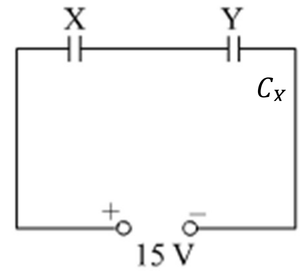
For near points, r is less and V is more negative (lower). For distant points, r is more and V is less

negative (higher).

(Each Carry 5 Marks) {Long Type Questions}

1. Here, $C_X = \frac{\varepsilon_o A}{d}$

$$C_y = \frac{\varepsilon_o \varepsilon_r A}{d} = \varepsilon_r C_X = 4C_X$$



C_X C_Y

(i) C_X and C_y are in series, so equivalent capacitance is given by

$$C = \frac{C_X \times C_Y}{C_X + C_Y}$$

$$\Rightarrow 4 = \frac{C_X \times 4C_X}{C_X + 4C_X} \qquad (\therefore C = 4\mu F)$$

$$\Rightarrow 4 = \frac{4C_X}{5} \qquad \therefore C_X = 5\mu F \text{ and } C_Y = 4C_X = 20\mu F$$

(ii) charge on each capacitor $Q = CV$

$$Q = 4 \times 10^{-6} \times 15 = 60 \times 10^{-6} C$$

Potential difference between the plates of X,

$$V_X = \frac{Q}{C_X} = \frac{60 \times 10^{-6}}{5 \times 10^{-6}} = 12V$$

Potential difference between the plates of Y,

$$V_y = V - V_X = 15 - 12 = 3\ V$$

(iii) Ratio of electrostatic energy stored,

$$\frac{U_X}{U_Y} = \frac{\frac{Q^2}{2C_X}}{\frac{Q^2}{2C_y}} = \frac{C_Y}{C_X} = \frac{4C_X}{C_X} = 4$$

2. As the battery is removed, therefore, the charge will remain conserved. But the capacitance, i.e $C = \frac{A\varepsilon_o}{d}$ will increased as d decrease.

(a) The charge remains constant.

(b) As $V = \frac{Q}{C} \propto \frac{1}{C}$; so potential difference decreases.

(c) Since, the electric field, $E = \frac{Q}{A\varepsilon_o}$ is independent of d. Hence, it remains constant.

(d) Energy, $U = \frac{Q^2}{2C} \propto \frac{1}{C}$; hence, it decrease.

(e) Capacitance increases because $C \propto \frac{1}{D}$

3. If R be the radius of big drop and r be the radius of small drop.

$\therefore$ Volume remains same.

$$V = nV_1$$

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

$$R = n^{1/3} r$$

$\therefore$ capacity of each droplet,

$$C = 4\pi\varepsilon_o r$$

∴ capacity of big drop

$$C' = 4\pi\varepsilon_o R = 4\pi\varepsilon_o n^{1/3} r = n^{1/3} C$$

If the surface charge density of small drop, $\sigma = \frac{Q}{4\pi r^2}$ and change remains conserved.

$$Q' = nQ$$

Then surface charge density.

$$\sigma' = \frac{Q'}{4\pi R^2} = \frac{nQ}{4\pi\left(n^{\frac{1}{3}} r\right)^2} = n^{1/3}\sigma$$

If electrostatic energy of a small drop, $U = \frac{Q^2}{2C}$

$U' =$ energy of a big drop

$$= \frac{(nQ)^2}{2C}$$

$$= \frac{n^2 Q^2}{2n^{\frac{1}{3}} C} = n^{5/3} U$$

If potential of a small drop,

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

Then potential of a big drop,

$$V' = \frac{nQ}{n^{\frac{1}{3}} C} = n^{2/3} V$$

4. (a) Work done in bringing the charge q_1 from infinity to $\vec{r_1}$ against the external electric field, $W_1 = q_1 V(r_1)$ Work done in bringing the charge q_2 from infinity to $\vec{r_1}$ $W_2 = q_2 V(r_2)$

Work done on q_2 against the field due q_1

$$W_3 = \frac{q_1 q_2}{4\pi\varepsilon_o r_{12}}$$

As work done is stored in the form of potential energy, therefore

Potential energy of the system $= W_1 + W_2 + W_3$

$$= U_1 + U_2 + U_3$$

Potential energy of the system

$$= q_1 V(r_1) + q_2 V(r_2) + \frac{q_1 q_2}{4\pi\varepsilon_o r_{12}}$$

(b) Electrostatic potential energy of the systems of charges corresponding to initial configuration is

$$U_i = \frac{2kQ^2}{l} - \frac{3kQ^2}{l} - \frac{6kQ^2}{l} = -\frac{7kQ^2}{l}$$

Electrostatic potential energy of the system of charges corresponding to final configuration is

$$U_f = \frac{4kQ^2}{l} - \frac{6kQ^2}{l} - \frac{12kQ^2}{l} = -\frac{14kQ^2}{l}$$

The amount of work done in shifting the charges to new locations is

$$W = U_f - U_i$$

$$= -\frac{14kQ^2}{l} - \left(-\frac{7kQ^2}{l}\right) = -\frac{7kQ^2}{l}$$

5. In series, the electric charge remains same. Therefore, Q is constant electric charge on each capacitor

   Given: $C_1 = 10 \times 10^{-6}F,\ C_2 = 20 \times 10^{-6}F$

   $\therefore$ C_1 and C_2 are in series.

$$C_{eq} = \frac{C_1C_2}{C_1 + C_2} = \frac{10 \times 10^{-6} \times 20 \times 10^{-6}}{(10 + 20) \times 10^{-6}}$$

$$= \frac{20}{3} \times 10^{-6}F$$

   $\therefore$ energy stored by

$$C_2 = E = \frac{Q^2}{2C_2}$$

   Total energy stored by the series combination,

$$E_{total} = \frac{Q^2}{2C_{eq}}$$

$$\frac{E_{total}}{E} = \frac{C_2}{C_{eq}}$$

$$E_{total} = \frac{20 \times 10^{-6}}{\frac{20}{3} \times 10^{-6}} \times E = 3E$$

Section: - F (Case Study Based Questions)

1.
   (i) (c)
   (ii) (b)
   (iii) (a)
   (iv) (b)
   Or
   (b)

2.
   (i) (c)
   (ii) (a)
   (iii) (b)
   Or
   (b)
   (iv) (c)

3.
   (i) (d)
   (ii) (b)
   (iii) (b)
   (iv) (d)
   Or

(d)

4.

(i) (b)

(ii) (c)

(iii) (b)

(iv) (b)

Or

(c)

5.

(i) (c)

(ii) (b)

(iii)(c)

Or

(b)

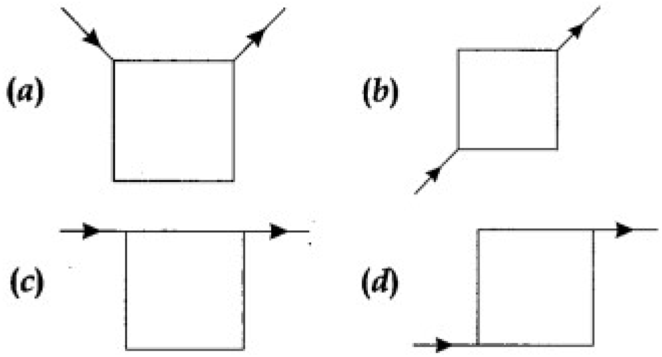
(iv)(b)

UNIT-III CHAPTER 4 & 5: MAGNETIC EFFECT OF ELECTRIC CURRENT AND MAGNETISM

MCQ

1. If an electron is moving with velocity v produces a magnetic field B, then
(a) the direction of field B will be same as the direction of velocity v.
(b) the direction of field B will be opposite to the direction of velocity v .
(c) the direction of field B will be perpendicular to the direction of velocity v .
(d) the direction of field B does not depend upon the direction of velocity v .

2. Current flows through uniform, square frames as shown in the figure. In which case is the magnetic field at the centre of the frame not zero?



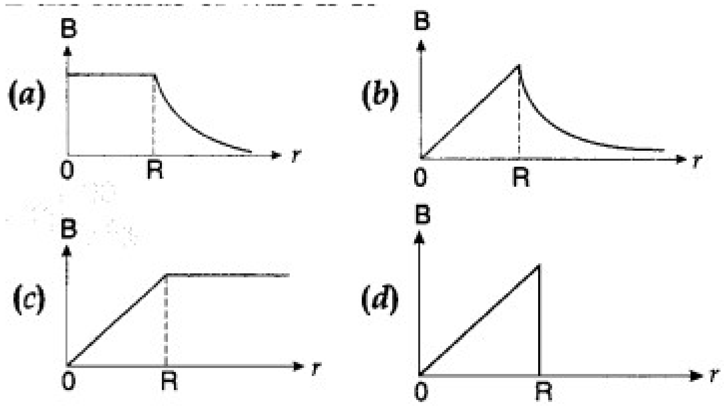
3. Ampere's circuital law is given by

(a) $\oint \vec{H}.\vec{dl} = \mu_0 I_{enc}$ (b) $\oint \vec{B}.\vec{dl} = \mu_0 I_{enc}$
(c) $\oint \vec{B}.\vec{dl} = \mu_0 J$ (d) $\oint \vec{H}.\vec{dl} = \mu_0 J$

4. Two identical current carrying coaxial loops, carry current I in opposite sense. A simple amperian loop passes through both of them once. Calling the loop as C, then which statement is correct?

(a) $\oint_c \vec{B}.\vec{dl} = \pm 2\mu_0 I$
(b) the value of $\oint_c \vec{B}.\vec{dl}$ is independent of sense of C.
(c) there may be a point on C where B and dl are
parallel.
(d) none of these

5. The correct plot of the magnitude of magnetic field vs distance r from centre of the wire is, if the radius of wire is R



6. The nature of parallel and anti-parallel currents are
(a) parallel currents repel and ant parallel currents attract.
(b) Parallel currents attract and ant parallel currents repel.
(c) both currents attract. ’
(d) both currents repel.
7. The magnetic moment of a current I carrying circular coil of radius r and number of turns N varies as
(a) $1/r^2$
(b) $1/r$
(c) r
(d) r^2
8. A short bar magnet has a magnetic moment of 0. 65 J T^{-1}, then the magnitude and direction of the magnetic field produced by the magnet at a distance 8 cm from the centre of magnet on the axis is
(a) 2.5×10^{-4} T, along NS direction
(b) 2.5×10^{-4} T along SN direction
(c) 4.5×10^{-4} T, along NS direction
(d) 4.5×10^{-4} T, along SN direction
9. A current carrying loop is placed in a uniform magnetic field. The torqe acting on it does not depend upon
(a) area of loop
(b) value of current
(c) magnetic field
(d) None of these

10. In a moving coil galvanometer, the deflection (Φ) on the scale by a pointer attached to the spring is

(a) $\left(\frac{NA}{kB}\right) I$ (b) $\left(\frac{N}{kAB}\right) I$

(c) $\left(\frac{NAB}{k}\right) I$ (d) $\left(\frac{NAB}{kI}\right)$

11. A moving coil galvanometer can be converted into an ammeter by
(a) introducing a shunt resistance of large value in series.
(b) introducing a shunt resistance of small value in parallel.
(c) introducing a resistance of small value in series.
(d) introducing a resistance of large value in parallel.

12. The conversion of a moving coil galvanometer into a voltmeter is done by
(a) introducing a resistance of large value in series. (b) introducing a resistance of small value in parallel.
(c) introducing a resistance of large value in parallel.
(d) introducing a resistance of small value in series.

13. When a magnetic compass needle is carried nearby to a straight wire carrying current, then
(I) the straight wire cause a noticeable deflection in the compass needle.
(II) the alignment of the needle is tangential to an imaginary circle with straight wire as its centre and has a plane perpendicular to the wire
(a) (I) is correct
(b) (II) is correct
(c) both (I) and (II) are correct
(d) neither (I) nor (II) is correct

14. 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.

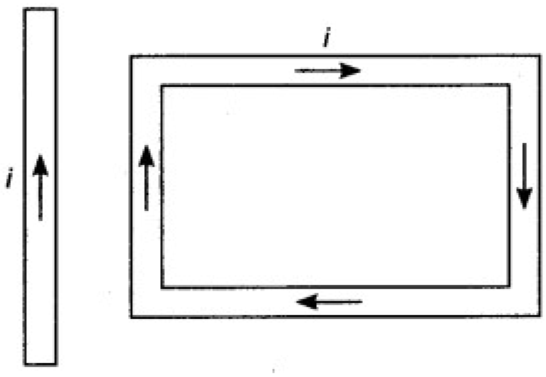
15. In an inertial frame of reference, the magnetic force on a moving charged particle is F. Its value in another inertial frame of reference will be
(a) remained same
(b) changed due to change in the amount of charge
(c) changed due to change in velocity of charged particle
(d) changed due to change in field direction

16. Which one of the following is correct statement about magnetic forces?
(a) Magnetic forces always obey Newton's third law.
(b) Magnetic forces do not obey Newton's third law.
(c) For very high current, magnetic forces obey Newton's third law.
(d) Inside low magnetic field, magnetic forces obey Newton's third law

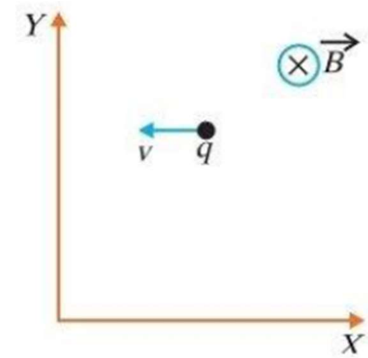
17. A charged particle is moving on circular path with velocity v in a uniform magnetic field B, if the velocity of the charged particle is doubled and strength of magnetic field is halved, then radius becomes
(a) 8 times
(b) 4 times
(c) 2 times
(d) 16 times

18. Two a-particles have the ratio of their velocities as 3 : 2 on entering the field. If they move 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

19. A rectangular loop carrying a current i is situated near a long straight wire such that the 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.



20. The maximum current that can be measured by a galvanometer of resistance 40 Ω is 10 mA. It is converted into voltmeter that can read upto 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

<u>Very Short Answer Type Questions – Two marks questions.</u>

Q1. State two reasons why a galvanometer can not be used as such to measure current in electric circuit. Or Can a galvanometer as such be used to measuring the current? Explain.

Q2. Two long straight parallel wires A and B are 2.5 cm apart in air. They carry 5.0A and 2.5A current in opposite direction. Calculate the magnitude of force exerted by the wire A on 10cm length of wire B.

Q3. A closely wound solenoid 80cm long has 5 layers of winding of 400 turns each. The diameter of solenoid is 1.8cm. if the current carried 8.0A, Estimate the value of B inside the solenoid near its center.

Q4. What can be the cause of helical motion of charged particle.

Q5. A narrow beam of protons and deuterons, each having same momentum, enter a region of uniform magnetic field directed perpendicular to their momentum. What would be the ratio of circular paths describe by them.

Q6. Is the source of magnetic field analogue to the source of electric field?

Q7. Does a current carrying circular coil produce uniform magnetic field?

Q8. What kind of magnetic field is produced by an infinitely long current carrying conductor?

Q9. Does a stationary charge experience a force in an electric field?

Q10. Does the torque on a planar current loop in magnetic field change, when its shape is changed without changing its geometrical area?

Short Answer Type Questions – Three marks questions.

Q11. Write two important point of similarities and differences each between coulomb's law for electrostatics and Bio- Savart's law for the magnetic field.

Q12. (a) A circular coil of 30 turns and radius of 8.0cm carrying a current of 6.0A is suspended in uniform horizontal magnetic field of magnetic field intensity 1.0T. The field lines makes an angle of 60 degree with the normal of the coil. Calculate the magnitude of counter torque that must be applied to prevent the coil from turning.
(b) Would your answer change if the circular coil in (a) were replaced by a planer coil of irregular shape that encloses the same area?

Q13. An alpha particle, deuteron and proton are accelerated through a same potential and subject to a uniform magnetic field, perpendicular to the direction of their motions. Compare (i) their kinetic energies (ii) if the radius of circular path described by the proton is 5cm, determine the radius of the circular paths described by the deuteron and alpha particle.

Q14. (i) A point charge q moving with speed v enters a uniform magnetic field B that is acting in to the plane of paper as shown in the fig. What is the path followed by the charge q and in which plane does it move?
(ii) How does the path followed by the charge particle get affected if it's velocity has a component parallel to the magnetic field?
(iii) If an electric field E is applied such that the particle continues moving along the original straight path, what would be the magnitude and direction of the electric field?

Q15. A circular coil of 'N' turns and diameter 'd' carries a current 'I'. it is unwound and rewound to make another coil of diameter '2d' and current 'I' remaining the same. Calculate the ratio of the magnetic moment of the new coil and old coil.

Q16. (i) What is the effect of increasing the number of turns on magnetic field produced due to a circular coil? (ii) Looking at a circular coil, the current is found to be flowing in anticlockwise direction. Predict the direction of magnetic field produced at a point on the axis of the coil on the same side as the observer.
(iii) What kind of magnetic field is produced by an infinitely long current carrying conductor?

Q17. (i) An electric charge enters in electric field at right angles to the direction of electric field. What is the nature of the path followed?
(ii) What is the magnitude of transverse acceleration produced in the motion of the electric charge, when it passes through the electric field?
(iii) Under what condition is the force acting on a charge moving through a uniform magnetic field minimum?

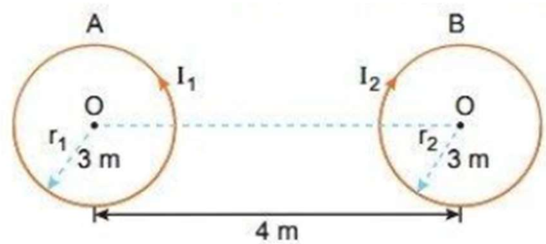
Q18. (i) An electron is projected in the direction of magnetic field. How will its motion be affected by the action of magnetic field?
(ii) What will be the path of a charged particle moving perpendicular to the direction of a uniform magnetic field?
(iii) Does a stationary charge experience a force in an electric field?

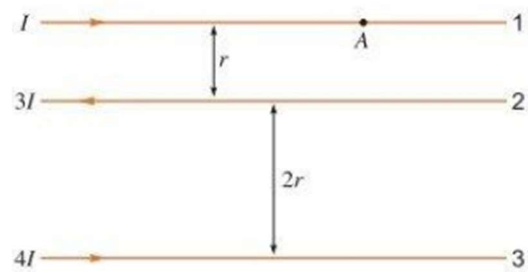
Q19. Two circular loops A and B, each of radius 3cm, are placed coaxially at a distance of 4m. They carry current of 3A and 2A in opposite directions respectively. Find the magnetic field at the center of circular loop A.

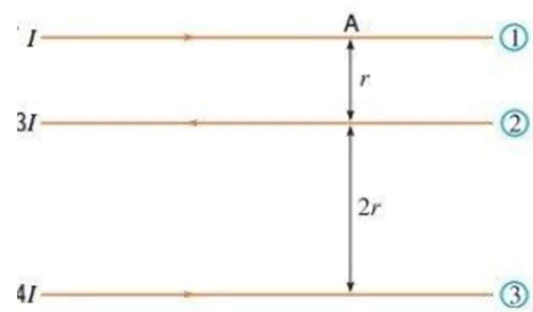
Q20. The figures show three infinitely long straight parallel current carrying conductor. Find the

(a) magnitude and direction of net magnetic field at point A lying on conductor -1.

(b) magnetic force on conductor -2.





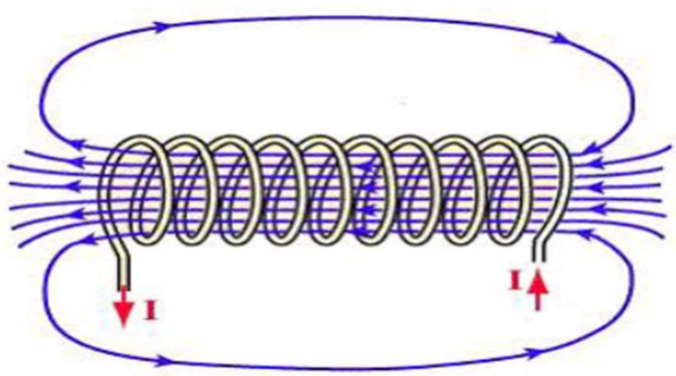


CASE STUDY BASED QUESTIONS-

NO. OF QUESTIONS – 5 (EACH HAVING 5 QUESTIONS)

Q1. As shown in figure a solenoid where the wire is coiled around a cylinder, each wire loop in this coil acts as if it was a separate circular wire carrying the same current I, the current in the coiled wire and the dense enough array of such loops may be approximated by a cylindrical current sheet with the current density K = I × (N/L) = I × L(loops) /solenoid length.

For simplicity, let's assume a long solenoid (length ≫ diameter) which we approximate as infinitely long. For a long solenoid (compared to its diameter), the magnetic field inside the solenoid is approximately uniform and approximately parallel to the axis, except near the ends of the solenoid. Outside the solenoid, the magnetic field looks like the field of a physical dipole, with the North pole at one end of the solenoid and the South pole at the other end and is approximately negligible.



1. Which of the following material can be used to make loops around the cylinder?
   (a) Plastic (b) Glass
   (c) Quartz (d) copper
2. The magnetic field inside the solenoid is
   (a) Non-Uniform and parallel to the axis
   (b) Uniform and parallel to the axis
   (c) Non-uniform and perpendicular to the axis

(d) Uniform and perpendicular to the axis

3. A proton is moving from left to right direction and outside the solenoid, then what is the direction of force on the proton?

(a) upwards (b) downwards

(c) proton will not deflect (d) inwards

4. How the magnetic field inside the solenoid depends upon the number of turns?

(a) inversely proportional (b) directly proportional

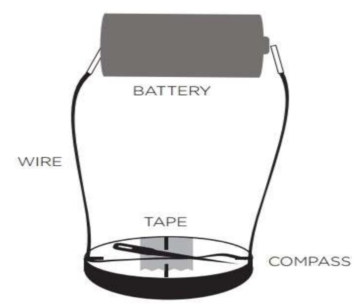
(c) proportional to the number of turns (d) none of these

5. Direction of magnetic field due to ma solenoid can be determined by

(a) Ohm's Law (b) Fleming's left-hand rule

(c) Ampere's Right-hand rule (d) Biot-savart's Law

Q2. In 1820, a Danish physicist, Hans Christian Oersted, discovered that there was a relationship between electricity and magnetism. By setting up a compass through a wire carrying an electric current, Oersted showed that moving electrons can create a magnetic field. Oersted found that, for a straight wire carrying a steady (DC) current: The magnetic field lines encircle the current-carrying wire. The magnetic field lines lie in a plane perpendicular to the wire. If the direction of the current is reversed, the direction of the magnetic force reverses. The strength of the field is directly proportional to the magnitude of the current. The strength of the field at any point is inversely proportional to the distance of the point from the wire.



1. First who discovered the relation between electric and magnetic field is-

(a) Hans Christian Oersted (b) Charles William Oersted

(c) Charles Maxwell (d) Andre Marie Ampere

2. If magnitude of the current in the wire increases, strength of magnetic field-

(a) Increases (b) Decreases (c) remains unchanged (d) none of these

3. Which of the following statements is true?

(a) There is no relationship between electricity and magnetism.

(b) An electrical current produces a magnetic field.

(c) A compass is not affected by electricity.

(d) A compass is not affected by a magnet.

4. A compass needle is placed below a straight conducting wire. If current is passing through the conducting wire from North to South. Then the deflection of the compass is ___.

(a) Towards West. (b) Towards East.

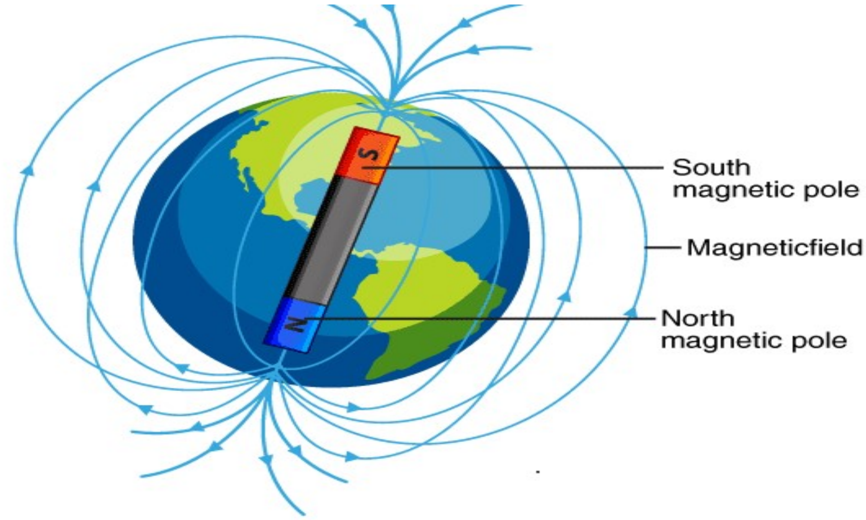
(c) keeps oscillating in East-West direction (d) No deflection

5. Charges at rest can produces-

(a) Static electric field (b) Magnetic field

(c) Induced current (d) Conventional current

Q3. The earth's magnetic field extends millions of kilometres into outer space and looks very much like a bar magnet. The earth's south magnetic pole is actually near the North Pole and the magnetic north pole is in Antarctica! This is why a compass magnet's north pole actually points north (north and south poles attract). The Earth's magnetic field extends far and wide but is very weak in terms of field strength.



There are three components that are responsible for the magnitude as well as the direction of the earth's magnetic field:

Magnetic Declination- The magnetic declination is defined as the angle between the true north and the magnetic north. On the horizontal plane, the true north is never at a constant position and keeps varying depending upon the position on the earth's surface and time.

Magnetic Inclination- The magnetic inclination is also known as the angle of dip. It is the angle made the horizontal plane on the earth's surface. At the magnetic equator, the angle of dip is 0° and at the magnetic poles, the angle of dip is 90°.

Horizontal Component of the Earth's Magnetic Field- There are two components to explain the intensity of the earth's magnetic field: Horizontal component (H) and vertical component (v)

$$\tan\delta = B_V / B_H$$

1. The vertical component of the earth's magnetic field is at a place is $\sqrt{3}$ times the horizontal component. What is the value of angle of dip at this place?

(a) 60^0 (b) 45^0 (c) 90^0 (d) 30^0

2. A bar magnet is placed with its north pole pointing earth's north. The points of zero magnetic field will be in which direction from the centre of the magnet?

(a) north and south (b) east and west

(c) north-east and south-west (d) north-west and south-east

3. Which of the following statements is true about magnetic lines of force?

(a) Magnetic lines of force are always closed.

(b) Magnetic lines of force always intersect each other.

(c) Magnetic lines of force tend to crowd far away from the poles of the magnet

(d) Magnetic lines of force do not pass through the vacuum.

4. A long magnet is cut into two parts such that the ratio of their lengths is 2:1. What is the ratio pole strength of both the section?

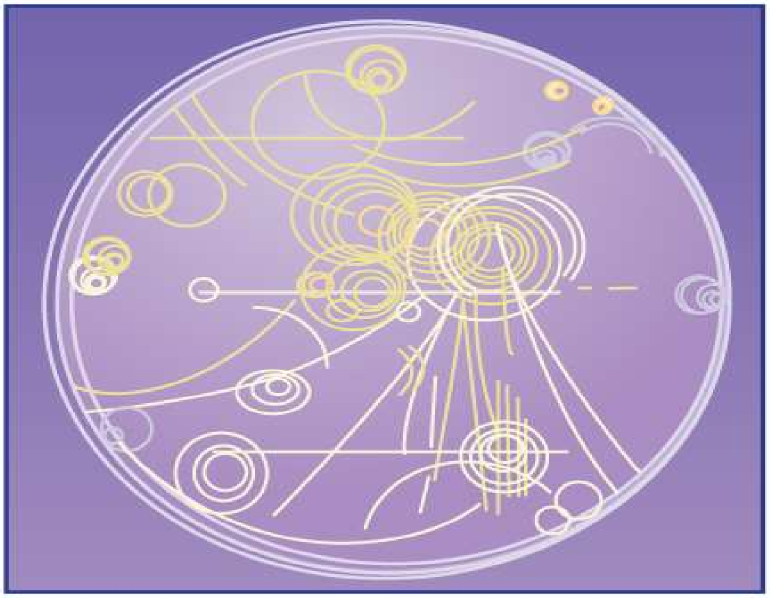
(a) 1:2 (b) 2:1 (c) 4:1 (d) Equal

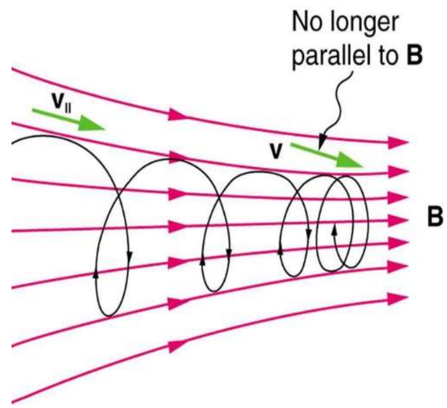
5. If a man is in Antarctica, then what is the angle of dip for the man is

(a) 60^0 (b) 45^0 (c) 90^0 (d) 30^0

Q.4 **Bubble Chamber:** Trails of bubbles are produced by high-energy charged particles moving through the superheated liquid hydrogen in this artist's rendition of a bubble chamber. There is a strong magnetic field perpendicular to the page that causes the curved paths of the particles. The radius of the path can be used to find the mass, charge, and energy of the particle.

Magnetic forces can cause charged particles to move in circular or spiral paths. Particle





accelerators keep protons following circular paths with magnetic force. Cosmic rays will follow spiral paths when encountering the magnetic field of astrophysical objects or planets (one example being Earth's magnetic field). The bubble chamber photograph in the figure below shows charged particles moving in such curved paths. The curved paths of charged particles in magnetic fields are the basis of a number of phenomena and can even be used analytically, such as in a mass spectrometer. shows the path traced by particles in a bubble chamber.

1. When a charged particle moves perpendicular to a uniform electric field, it follows-

(a) circular path (b) parabolic path

(c) translational path (d) helical path

2. A charged particle moving with velocity v in X direction is subjected to a magnetic field B in negative X direction. As a result, the charge will

(a) retard along X-axis

(b) start moving in a circular path in YZ plane

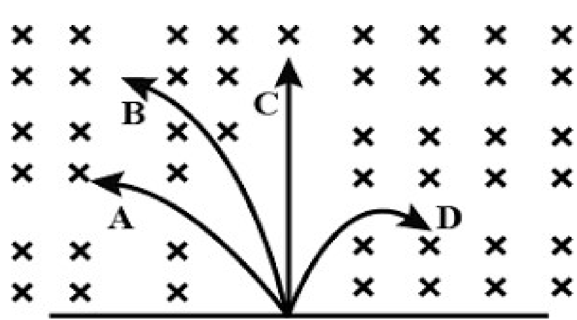
(c) remains unaffected

(d) move in a helical path around X-axis

3. An α- particle and proton having same momentum enter into a region of uniform magnetic field and move in a circular path. The ratio of the radii of curvature of their paths

(a) 1 (b) ¼ (c) ½ (d) 4

4. A neutron, a proton, an electron and an α- particle enter in a region of uniform magnetic field with equal velocities. The magnetic field is perpendicular and directed into the paper. The tracks



of the particles are shown in figure. The electron will follow the track-

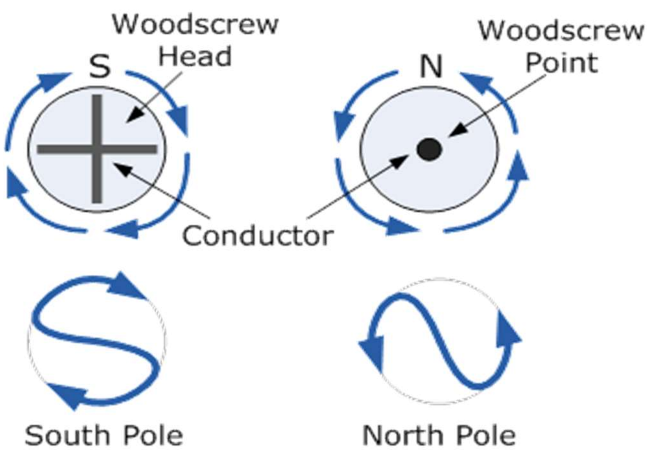
(a) A (b) B (c) C (d) D

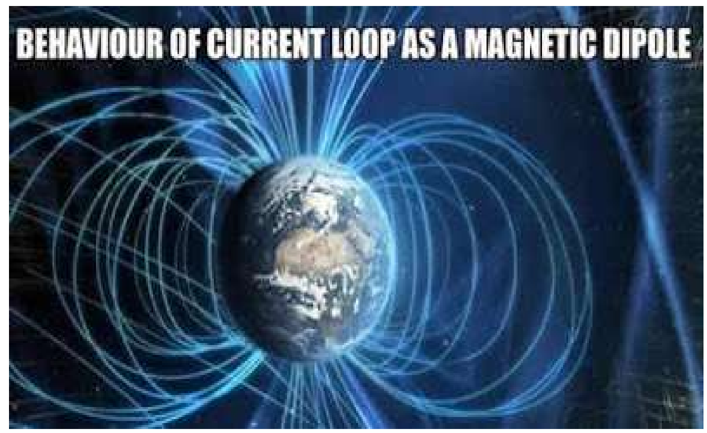
5. If magnetic force experienced by the charged particle is perpendicular to the velocity of the particle, then work done is-

(a) zero (b) maximum (c) minimum (d) none of these

Q5. Current loop behaves likes a magnetic dipole and has a magnetic field. They behave just like a magnet. Interesting part is, it depends upon the direction of current in loop which decides whether magnetic field line is in outward or inward direction. With the help of this outward and inward direction of magnetic field, North and South poles get decided.

Anticlockwise direction of current creates north pole (outward direction magnetic field) and





clockwise direction of current creates a south pole (inward direction magnetic field). Magnetic dipole moment M with the circular current loop carrying a current I and of area A. The magnitude of m is given by

$$|m| = I \times A$$

Current in the circular coil produces magnetic field and amperes found out that magnetic field created due to circular coil is similar to the magnetic field due to a bar magnet. Wood screw head sign shows that direction of screw is inward because we are not able to see pointed part of screw and so direction is inward. This inward direction of screw denotes the direction of the magnetic field.

1. A thin circular wire carrying a current I, has a magnetic moment M. The shape of a wire is changed to a square and it carries the same current. It will have a magnetic moment-

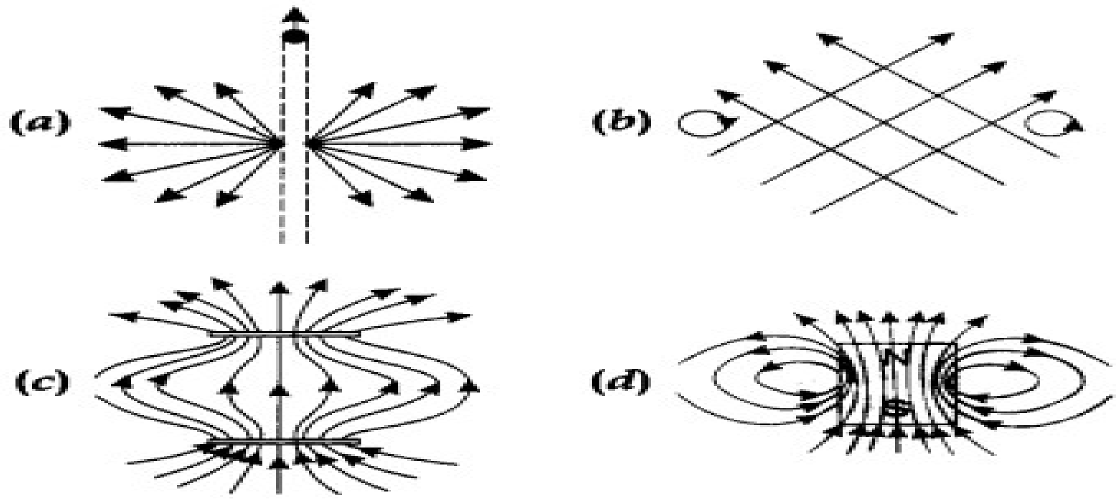
(a) $4M/\pi^2$ (b) M (c) $4\pi \times M$ (d) $4M/\pi$

2. A current carrying loop is placed in a uniform magnetic field in four different orientations as shown in figure. Arrange them in the decreasing order of potential energy.

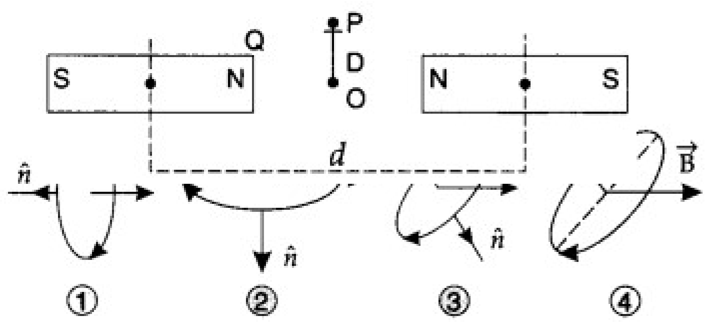
(a) 4, 2, 3,1 (b) 1, 4, 2, 3

(c) 4, 3, 2,1 (d) 1, 2, 3, 4

3. Point out the correct direction of magnetic field in the given figures.



4. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figure. The force on the charge Q is
(a) zero



(b) directed along OP
(c) directed along PO
(d) directed perpendicular to the plane of paper
5. In a bar magnet, magnetic lines of force-
(a) are produced only at north pole like rays of light from a bulb
(b) starts from north pole and ends at the south pole
(c) emerge in circular paths from the middle of the bar
(d) run continuously through the bar and outside

Long Answer Type Questions – Five mark questions.

Q21. (a) Explain and State Bio- Savart law. Use it to derive the expression for the magnetic field produced at a point near a long current carrying wire.
(b) Using this law, find an expression for the magnetic field at the center of circular coil of N- turns, radius R, current carrying I. Sketch the magnetic field lines due to circular current loop. Clearly indicating the direction of field.

Q22. Using Ampere's circuital law find an expression for the magnetic field at a point on the long solenoid with closely wound turns.

Q23. Derive the expression for the force per unit length between two long straight parallel current carrying conductors. Hence define SI unit of current.

Q24. Derive an expression for torque acting on a rectangular current carrying loop kept in a uniform magnetic B. Indicating the direction of torque acting on the loop.

Q25. (i) Draw the labelled diagram of moving coil galvanometer. Briefly explain the principle and working of it. (ii) Answer the following: (a) Why is it necessary to introduce a soft iron core in to coil of galvanometer. (b) Increasing the current sensitivity of a galvanometer may not necessarily increases the voltage sensitivity. Explain giving reason.

Answers of the Questions bank:

MCQ

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

Very Short Answer (Answers of 2 marks questions)

Ans-1:- A galvanometer can not be used as such to measure current due to the following reasons:

1. A galvanometer has finite large resistance and is connected in series in the circuit so it will increase the resistance of the circuit and hence change the value of current in the circuit.
2. A galvanometer is sensitive device. It gives full scale deflection for the current of order of microampere. If connected to as such it will not measure the current of order of ampere.

Ans-2: Given: d= 2.5cm =2.5×10^{-2}m

I_1= 5.0A and I_2= 2.5A

L= 10cm = 10^{-1}m

We know that the force exerted by one wire to the other is given by

$$F = \frac{\mu 0}{2\pi}\frac{I1I2L}{d}$$

$$F = \frac{2 X 10^{-7} X 5 X 2.5 X 10^{-1}}{2.5 X 10^{-2}}$$

F= 10^{-5} N.

Ans-3: Given:

L = 80cm = 0.8m

Total no. of turns= 5 x 400 = 2000 turns.

Current, I = 8A

Diameter of Solenoid, d=1.8cm=1.8×10^{-2}

We know that The Magnetic field B inside a solenoid is give by

$$B= \frac{\mu 0NI}{l} = \frac{4\pi X 10^{-7} X 2000 X 8}{0.8} = 2.5 \times 10^{-2} T$$

Ans-4: Charged particle moves inclined to the magnetic field. When there is an angle between the velocity and magnetic field, then vertical component of velocity rotates the particle in circular path but the horizontal component of velocity moves the particle in straight path. Hence the path of the particle become helical.

Ans-5: We know that

Charge on deuterons (q_d) = Charge on protons (q_p)

And the radius of orbit $\propto \frac{1}{q}$

So r_p: r_d =1:1

Ans-6: No. It is because, the source of magnetic field is not a magnetic charge. In case of electric field, the source of electric field is electric charge.

Ans-7: No, magnetic field produced due to a current carrying circular coil is not uniform. However, it may be considered as uniform at the centre of the circular coil.

Ans-8: Magnetic field lines are concentric circular loops in a plane perpendicular to the straight conductor. The centres of the circular magnetic field lines lie on the conductor.

Ans-9: The force due to electric field does not depend, whether the charge is at rest or is in motion. A stationary charge experiences force in an electric field, which is given by F = qE.

Ans-10: The torque on a planar current loop in a magnetic field does not change, when its shape is changed without changing the area of the loop

Short Answers (Answers of 3 marks questions)

Ans-11: **Similarities:**

1. Bothe electrostatic field and magnetic field follows the principle of superpositions.
2. Bothe electrostatic field and magnetic field depends on the square of distance from source to the point of interest.

Differences:

1. Electrostatic field produce by a scalar source and magnetic field produce by a vector source.
2. Electrostatic field is along the displacement vector between the source and point of interest while the magnetic field is perpendicular to the plane containing source vector and displacement vector.
3. Electrostatic field is angle independent while the magnetic field is dependent on the angle between source vector and displacement vector.

Ans-12: (a) Given:

No. of turns, N=30

Radius of coil, r= 8.0cm = 0.8m, Area (A) = πr^2 = 3.14 x $(0.8)^2$

Current, I = 6.0A

Magnetic field, B=1.0 T

Angle between the B and normal of coil, $\Theta = 60^0$

We know that

The torque required to prevent the coil form turning = The torque required to turn the coil

So τ = NIAB SinΘ = 30 x 6 x 3.14 x $(0.8)^2$ x 1.0 x Sin60^0

= 3.13 Nm

(b) As the Expression for the toque contains area not the shape of the coil, so torque on the planner loop remain the same provided magnitude of the area is same.

Ans-13: (i) Since $qV=\frac{1}{2}mv^2$

For proton, $qV = \frac{1}{2}m_p v_p^2$

For deuteron, $qV = \frac{1}{2}m_d v_d^2$

For alpha, $2qV = \frac{1}{2}m_\alpha v_\alpha^2$

So it is clear from the above equations

$(K.E.)_p : (K.E.)_d : (K.E.)_\alpha = 1: 1: 2$

(ii) We have

$Bqv = \frac{mv^2}{r}$ so $r_p= \frac{mv}{Bq} = 5cm$

So $r_p : r_d : r_\alpha = v_p : v_d : v_\alpha = 1 : \sqrt{2} : \sqrt{2}$

Hence, $r_d = 5\sqrt{2}cm,$ and $r_\alpha = 5\sqrt{2}cm.$

Ans-14: (i) The force experienced by the charge is given by ***F= q (V x B)*** when **V** is perpendicular to **B**, the force on the charge particle acts as centripetal force and makes it move along a circular path. Path followed by the charge is anticlockwise in X-Y plane. The point charge moves in the plane perpendicular to the both **V** and **B**.

(ii) The component of velocity of charge particle is parallel to the B, the force experienced by the particle due to this component is zero because the angle between V and B is Zero so $\sin 0^0 = 0$. Thus, the particle moves in straight line.

(iii) Magnetic force on the charge ***F= q (V x B) = q(V(i) x B(k)) = qVB(j)***

Hence, for charge q moving in original paths.

$\mathbf{F_E + F_M = 0}$

$\mathbf{F_E = - F_M = -} \boldsymbol{qVB(j)}$

We know that $F_E = qE = -qVB$

So $\mathbf{E = VB}$

And the direction of E should be in negative J-axis.

Ans-15: We know that

Magnetic moment, m=NIA

Then the length of wire remains same so

$$N \times 2\pi \times \frac{d}{2} = N' \times 2\pi \times \frac{2d}{2}$$

$$N' = \frac{N}{2}$$

Now $m_A = NIA = N \times I \times \pi r^2 = \frac{1}{4} \times NId^2$ ....equ. (i)

$m_B = N'IA' = N' \times I \times \pi r'^2 = \frac{1}{2} \times NId^2$ ....equ. (ii)

hence $m_A : m_B = 2:1$

Ans-16(i): The magnetic field produced by a coil of m turns is n times the magnetic field produced by a

coil of single turn. B= $\underline{\mu 0\ Ni}$

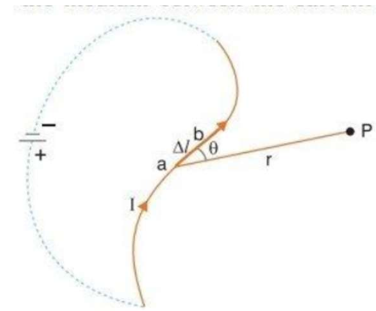
$2r$

Ans-16 (ii): The direction of magnetic field is perpendicular to the plane of the coil and directed towards the observer.

Ans-16(iii): Magnetic field lines are concentric circular loops in a plane perpendicular to the straight conductor. The centers of the circular magnetic field lines lie on the conductor.

Ans-17(i): The electric charge will move along a parabolic path.

Ans-17(ii): If a charge q having mass m passes transversely through an electric field E, then acceleration, a = qE/m.



Ans-17(iii): A charge moving through a magnetic field, experiences no force (minimum), when it moves along the direction of magnetic field.

Ans-18(i): No force acts on the electron due to the magnetic field, when it is projected in the direction of magnetic field. Hence, its motion will not be affected.

Ans-18(ii): When the charged particle moves perpendicular to the direction of a uniform magnetic field, it experiences a force perpendicular to its direction of motion. As such, it moves alone a circular path.

Ans-18(iii): The force due to electric field does not depend, whether the charge is at rest or is in motion. A stationary charge experiences force in an electric field, which is given by F = qE

Ans-19: Given:-

$I_1 = 3A,\ I_2 = 2A,\ X = 4m,\ r_1 = r_2 = 3cm = 0.3m$

Magnetic field at center of A due to A

$$\mathbf{B_1} = \frac{\mu 0\ I1}{2r} = \frac{4\pi\ X\ 10^{-7}\ X\ 3}{2\ X\ 0.3} = \mathbf{2\pi\ X\ 10^{-7}\ T\ (out\ ward)}$$

Magnetic field at center of A due to B

$$\mathbf{B_2} = \frac{\mu 0\ I2\ r^2}{2(x^2+r^2)^3/2} = \frac{4\pi\ X\ 10^{-7}\ X\ 2\ X\ 9}{2(9+16)^3/2} = \frac{4\pi\ X\ 10^{-7}\ X\ 9}{125}\ \mathbf{T\ (inward)}$$

Now, net magnetic field at the center of A

$$\mathbf{B = B_1 - B_2}$$

$$\mathbf{= 2\pi\ x\ 10^{-7}\ (1 - \frac{18}{125}) = 5.4\ x\ 10^{-7}\ T(outward)}$$

Ans-20:- (i) Magnetic field

$B_2 = \frac{\mu 0}{4\pi}\frac{2(3I)}{r} = \frac{\mu 0\ 6I}{4\pi r}$ in to the plane of paper

$B_3 = \frac{\mu 0}{4\pi}\frac{2(4I)}{3r} = \frac{\mu 0\ 8I}{12\pi r}$ out of the plane of paper

$B_A = B_2 - B_3$

$= \frac{\mu 0}{4\pi}\frac{10\ I}{43r}$ in to the plane of paper.

(ii) Magnetic force per unit length of wire 2

$F = \frac{\mu 0}{2\pi r}.3I^2 + \frac{\mu 0}{2\pi}.\frac{12I^2}{2r}$

$= \frac{-3\mu 0\ I^2}{2\pi r}$ N in the direction of wire -1

<u>Answers of Case Base Questions</u>

Q-1	1	d	2	b	3	c	4	b	5	c
Q-2	1	a	2	a	3	b	4	b	5	a

Q-3	1	a	2	b	3	a	4	d	5	c
Q-4	1	b	2	c	3	c	4	d	5	a
Q-5	1	c	2	b	3	d	4	a	5	b

Answers of Long questions (Answers of 5 marks questions)

Ans-21(a) : **Bio-Savart Law:** Two French physicist Jean Baptistic Biot and Felix Savart in 1820, deduced an expression for the magnetic field of a current element which is known as Bio-Savart Law. According to this law, the magnitude of the magnetic field **dB** is:

I. It is directly proportional to the current flowing through the conductor.

$$dB \propto I$$

II. It is directly proportional to the length of current element.

$$dB \propto dl$$

III. It is directly proportional to the Sine of angle between current element and position vector between current element and point at which magnetic field is to be calculated.

$$dB \propto Sin\theta$$

IV. It is inversely proportional to the square of distance between current element and position vector between current element and point at which magnetic field is to be calculated.

$$dB \propto \frac{1}{r^2}$$

From all the equations it can be written as:

$$dB = \frac{\mu 0\ IdL\ sin\theta}{4\pi\ r^2}.$$

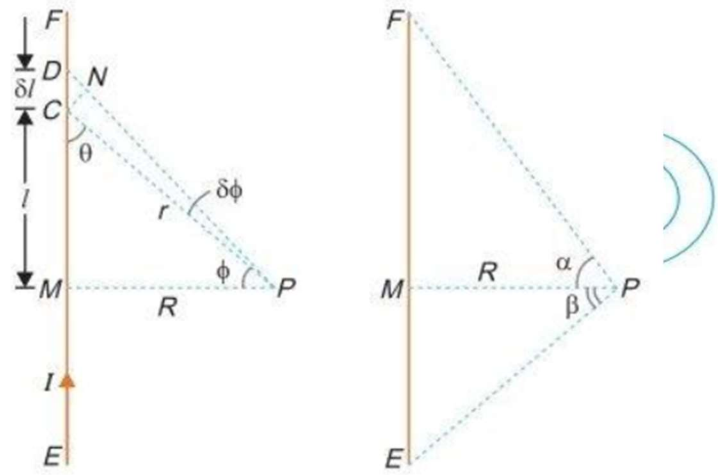
Expression for the magnetic field produced at a point near a long current carrying wire:

Consider a wire EF carrying current I in the upward direction. The point of observation is P at a infinite distance R from the wire. If PM is perpendicular dropped from P on the wire. Then PM = R. The wire may be supposed to be formed of a large number of small currents elements. Consider a small elements of length δl at a distance l from the M.

Let <CPM = ϕ, <CPD = $d\phi$ and <PDM = θ.

The length δl is very small so that <PCM is taken equal to θ.

The perpendicular dropped form C on PD is CN. The angle formed between the current element and position vector is π-θ. Therefore, according to Biot-Savart law, the magnetic field produced due to the current elements at P is:



(a) (b)

$$dB = \frac{\mu 0}{4\pi}\frac{I\,\delta l \sin(\pi-\theta)}{r^2} = \frac{\mu 0}{4\pi}\frac{I\,\delta l \sin\theta}{r^2}$$
……………………(i)

but in △CND, $\sin\theta = \sin(<CND) = \frac{CN}{CD} = \frac{r\,\delta\phi}{\delta l}$

or $\delta l \sin\theta = r\,\delta\phi$

∴ from equation (i)

$$dB = \frac{\mu 0}{4\pi}\frac{I\,r\,\delta\phi}{r^2} = \frac{\mu 0}{4\pi}\frac{I\,\delta\phi}{r}$$
………………………………………(ii)

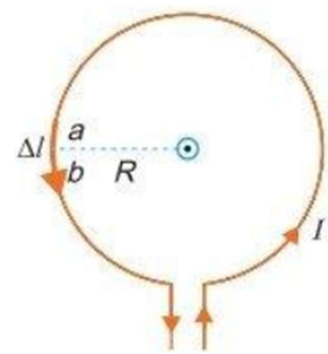
Again from fig.

$$\cos\phi = \frac{R}{r} \Rightarrow r = \frac{R}{\cos\phi}$$

From equation (ii),

We have $dB = \frac{\mu 0}{4\pi}\frac{I\cos\phi\,\delta\phi}{R}$

If the wire is of finite length and its end make angle α and β with line MP, then the magnetic field B at point P is obtained by summing over magnetic field due to all current elements i.e.



$$B = \int dB = \int_{-\beta}^{\alpha}\frac{\mu 0}{4\pi}\frac{I\cos\phi\,\delta\phi}{R} = \frac{\mu 0}{4\pi}\frac{I}{R}\int_{-\beta}^{\alpha}\cos\phi\,\delta\phi$$

$$B = \frac{\mu 0}{4\pi}\frac{I}{R}[\sin\phi]^{\alpha}_{-\beta} = \frac{\mu 0}{4\pi}\frac{I}{R}[\sin\alpha - \sin(-\beta)]$$

i.e. $B = \frac{\mu 0}{4\pi}\frac{I}{R}[\sin\alpha + \sin\beta]$.

This is the expression for the magnetic field produced at a point near a long current carrying wire.

Ans-21: (b) **Expression for the magnetic field at the center of circular loop:**

Consider a circular coil of radius R carrying current I in the anticlockwise direction. Say O is the centre of coil, at which magnetic field is to be calculated. The coil is supposed to be made of large number of small currents elements. Consider a small current element ‘ab’ of length δl. According to Bior- Savart law the magnetic field at centre O due to current elements is

$$\triangle B = \frac{\mu 0}{4\pi}\frac{I\,\delta l\sin\theta}{R^2}$$

Where θ is the angle between the current elements and position vector between current elements and center of circular coil. As the current elements is along the tangent of circular coil and position vector is along the radius so the θ will be 90^0. Therefore, the magnetic field produced at center of circular coil due to small currents elements

$$\triangle B = \frac{\mu 0}{4\pi}\frac{I\,\delta l}{R^2}$$

The Net magnetic field at the center due to all such current elements at the center of circular coil will be the sum of individual magnetic field of all current elements at the centers. So the net magnetic field is

$$B = \sum\triangle B = \sum\frac{\mu 0}{4\pi}\frac{I\,\delta l}{R^2} \qquad \text{since } \sum\delta l = 2\pi R$$

$$B = \frac{\mu 0}{4\pi}\frac{I\,2\pi R}{R^2} = \frac{\mu 0\, I}{2R}$$

$$B = \frac{\mu 0\, I}{2R}$$

If the coil contains N no. of turns then magnetic field produced at the center is

$$B = \frac{N\,\mu 0\, I}{2R}.$$

(ii)

Ans-22: **Magnetic field inside a long straight solenoid:-**

Consider a long straight solenoid having number of turns per unit length equal to 'n'. Let I be the currents flowing in the solenoid, then by the right hand rule, magnetic field is parallel to the axis of solenoid.

Field outside the solenoid: Consider a closed path *abcd*. Applying Ampere's law to this path

$\oint B.dl = \mu_0$ x 0 (since the net current enclosed by the loop)

As dl ≠ 0, ∴ B = 0

This means the magnetic field is outside the solenoid is zero.

Field inside the solenoid: Consider a closed path *pqrs*. The line integral of magnetic field B along the paths *pqrs* is

$$\oint_{pqrs} B.dl = \int_{pq} B.dl + \int_{qr} B.dl + \int_{rs} B.dl + \int_{ps} B.dl \quad ....(i)$$

For path pq, **B** and **dl** are along the same direction,

∴ $\int_{pq} B.dl$ = B.dl =Bl because pq= l.

For path qr and sp, **B** and **dl** are mutually perpendicular.

∴ $\int_{qr} B.dl = \int_{sp} B.dl = \int_{sp} Bdl\, cos90^0$ =0

because $cos90^0$ =0.

For the path rs, B =0 because field outside the solenoid is zero.

∴ $\int_{rs} B.dl = \mathbf{0}$

In view of these, equation (i) gives

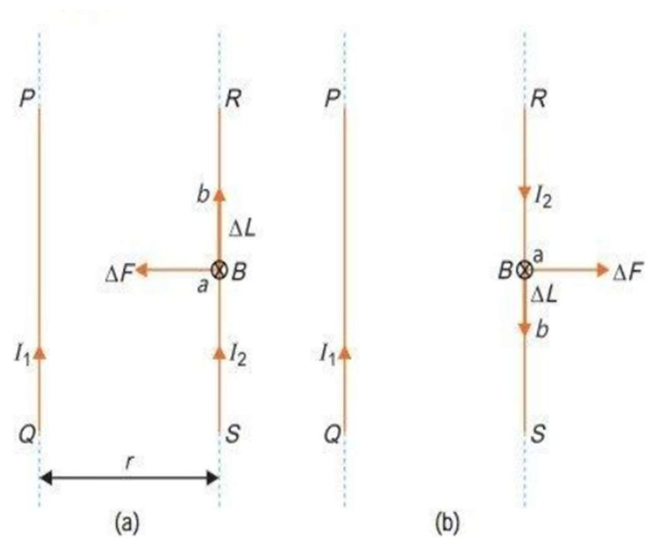
$\oint_{pqrs} B.dl = \int_{pq} B.dl$ = B.l

By Ampere's law

$\oint B.dl = \mu_0$ x (net current enclosed by the loop)

⇒ $\oint B.dl = \mu_0$ x (nl x I)

∴ **B =μ_0 nI**



(a) (b)

Ans-23: Suppose two thin long straight conductors PQ and RS are placed parallel to each other

in vacuum carrying currents I_1 and I_2 respectively. It has been observed experimentally that when currents in the wires are in the same direction, they experienced a attractive force (fig. a) and whey they carry currents in opposite direction they experienced a repulsive force (fig. b). Let the conductors PQ and RS carrying currents I_1 and I_2 in same direction placed at a separation distance r.

Consider a current carrying element 'ab' of length δl of wire RS. The magnetic field produced by the current carrying conductors PQ at the location of other wire RS.

$$B_1 = \frac{\mu 0\, I1}{2\pi R}$$

According the Maxwell's right hand rule, the direction of B will be perpendicular to the plane of paper and directed downward. Due to this magnetic field, each element of other wire experience a force. The direction of current element is perpendicular to the magnetic field so the magnetic force on the current element 'ab' of length δl other wire will be

$$\triangle F = I_2 B_1 \delta l \sin\theta = \frac{\mu 0\, I1}{2\pi R} \text{ x } I_2\, \delta l \sin 90^0$$

$$\triangle F = \frac{\mu 0\, I1}{2\pi R} \text{ x } I_2\, \delta l.$$

∴ Total force on the conductors of length L

$$F = \sum \triangle F$$

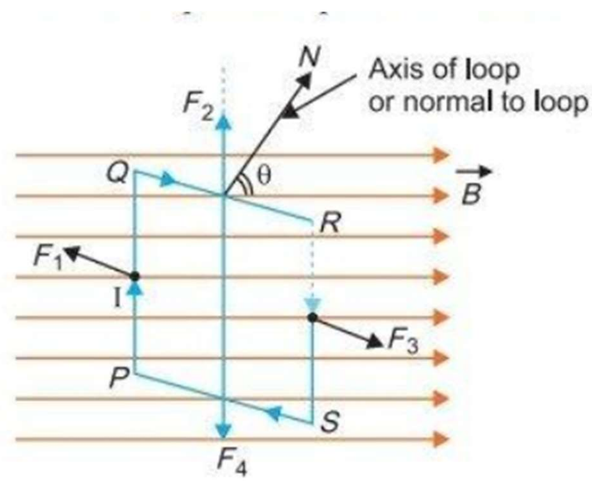
$$= \frac{\mu 0\, I1}{2\pi R} \text{ x } I_2 \sum \delta l$$

$$= \frac{\mu 0\, I1}{2\pi R} \text{ x } I_2\, L$$

$$F = \frac{\mu 0\, I1 I2}{2\pi R} L.$$

The force per unit length of the conductors

$$f = \frac{F}{L} = \frac{\mu 0\, I1 I2}{2\pi R} \text{ N/m.}$$



According to the Fleming left hand rule, The direction of force will be toward PQ i.e., the force will be attractive.

On the other hands if the currents I_1 and I_2 in the wires are in opposite direction then the force will be repulsive. The magnitude will be same.

<u>**Definition of SI unit of current (Ampere):-**</u> In SI system of fundamental unit of current 'ampere' is define assuming the force between two current carrying wires as standards.

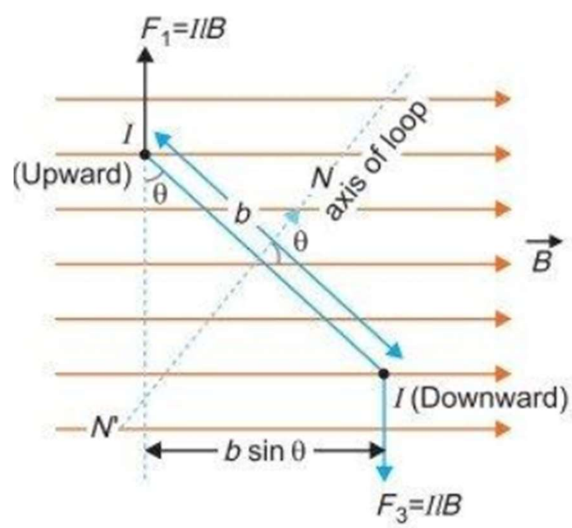
The force between two currents carrying wires of separation 'r' is

$$f = \frac{\mu 0\, I1 I2}{2\pi R}$$

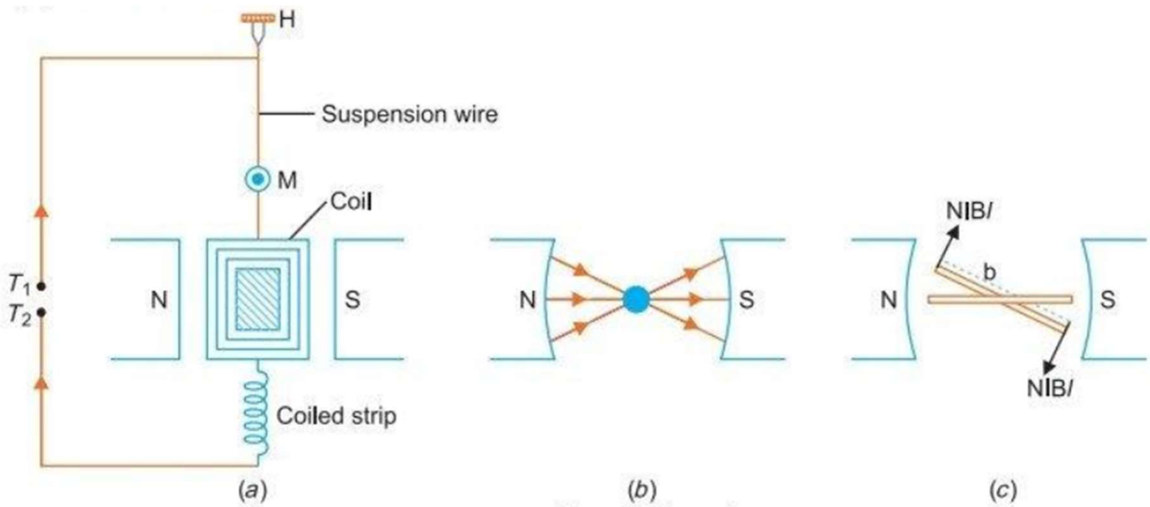
If $I_1 = 1A$, $I_2 = 1A$. r =1m than

$$f = \frac{\mu 0}{2\pi} = 2 \text{ x} 10^{-7} \text{ N/m.}$$

Thus the 1 ampere is the current which when flowing in each of parallel conductors placed at separation distance of 1m in vacuum exerts a force of 2 x 10^{-7} N per unit length of either wire.



Ans-24: Consider a rectangular loop PQRS of length '*l*' and bread 'b' suspended in a uniform magnetic field. Let at any instant the normal of the plane of the loop makes an angle θ with the magnetic field and I be the current in the loop. We know that a force acts on a wire when it placed in a uniform magnetic field. Therefore, each side of loop will experience a force. The net force and torque on the loop will be determined by the forces acting on each side of the loop.



(*a*) (*b*) Magnetic lines of force of radial magnetic field (*c*)

Suppose that the forces on the sides PQ, QR, RS and SP are F_1, F_2, F_3 and F_4 respectively. The sides QR and SP makes an angle $(90^0 - \theta)$ with the direction of magnetic field. Therefore, each of the forces F_2 and F_4 acting on these sides have same magnitude $F = IBbSin(90^0 - \theta) = IBbCos\theta$. According to the Fleming left hand rule these forces F_2 and F_4 are same in magnitude and acting in opposite direction on the same line of action. So these force cancel each other and the resultant of F_2 and F_4 is Zero.

The side PQ and RS are perpendicular to the magnetic field. Therefore, the magnitude of these forces is $F = IBlSin90^0 = IBl$.

According to Fleming left hand rule, these force F_1 and F_3 acting on side PQ and RS are equal and opposite but their line of action are different so these force form a couple of forces called deflecting couple or torque.

When the normal of the plane of loop makes an angle with direction of the magnetic field the perpendicular distance between the F_1 and F_3 is $bSin\theta$.

∴ Moment of the torque = Magnitude of force(F) x perpendicular distance

= $IBl \times b\,Sin\theta = IB\,lb\,Sin\theta$

∴ $A = lb$

So Torque $(\tau) = IBASin\theta$

If the loop contains N no. of turns.

Torque $(\tau) = NIBASin\theta$

In Vector form

Torque $(\tau) = NI\,(\mathbf{A} \times \mathbf{B})$

We know that the magnetic dipole moment m=NIA

So the Torque $(\tau) = \mathbf{m} \times \mathbf{B}$.

The current loop will be in equilibrium if the magnetic moment is in the direction of magnetic field.

Ans-25: **Moving Coil Galvanometer:** A galvanometer is device used to detect the current.

Construction: It consists of a rectangular coil wound on a non-conducting metallic frame and is suspended by phosphorus bronze strip between the ends pole (N and S) of a strong magnetic field.

A soft iron core in the cylindrical form is placed between the coil.

One end of coil is attached to the suspension wire which also serves as one terminal (T_1) of the galvanometer. The other end of the coil is connected to the loosely coiled strip, which serves as the other terminal (T_2).

A mirror is fixed on the phosphorus bronze strip by means of which the deflection of the coil is measured by the lamp and scale arrangement.

The levelling screw are also provided at the base of instrument. The pole piece of the permanent magnet are cylindrical so that the magnetic field is radial at the position of the coil.

Principal and Working: When current I passed in the coil, Toque (τ) acts on the coil, given by

$\tau = NIBASin\theta$.

A current carrying coil, in the presence of magnetic field, experience a toque, which produce proportional deflection.

i.e. deflection $\theta \propto$ Torque (τ)

when the field is radial as in the case of cylindrical pole piece and soft iron core, then every positions of plane of the coil is parallel to magnetic field lines, so that $\theta = 90^0$ and $Sin90^0 = 1$, and coil experience the maximum torque.

Deflecting torque $\tau = NIAB$

If C is the torsional rigidity of the wire and is the twist of the suspension strip, then restoring torque = $C\theta$

For equilibrium,

deflecting torque = Restoring torque

$$NIAB = C\theta$$

$$\theta = \frac{NAB}{C} I$$

$$\theta \propto I$$

i.e., The deflection of the coil is directly proportional to the current flowing through the coil and hence we can construct the linear scale.

Importance of uniform radial magnetic field: Torque for current carrying coil in a magnetic field is $\tau = NIABSin\theta$. In a radial magnetic field $Sin\theta = 1$ because $\theta = 90^0$ So torque is τ = NIAB. This make the deflection proportional to the current. Hence the radial magnetic field makes linear scale.

- The cylindrical soft iron core make the field radial and increase the strength of magnetic field i.e. magnitude of the torque.

Sensitivity of the galvanometer:

Current Sensitivity: It is defined as the deflection of coil per unit current flowing in it.

$$\text{Sensitivity } S_I = \frac{\theta}{I} = \frac{NBA}{C} \text{ ....} \textbf{equ (ii)}$$

Voltage Sensitivity: It is defined as the deflection of coil per unit potential across its ends.

Sensitivity $S_V = \frac{\theta}{V} = \frac{NBA}{Rg\ C}$ **……………………equ(iii)**

where Rg is the resistance of the galvanometer.

From equ (ii) and (iii), we have

$$\frac{Sv}{Si} = \frac{1}{G} \quad \Rightarrow \quad S_v = \frac{1}{G} S_I$$

Clearly the voltage sensitivity depends upon the current sensitivity and the resistance of the galvanometer. If we increase the current sensitivity, It is not certain the voltage sensitivity will be increased. Thus, the increase of current sensitivity does not imply the increase of voltage sensitivity.

QUESTION BANK PHYSICS CLASS XII CH-5 MAGNETISM

MULTIPLE CHOICE QUESTIONS (1 MARK)

1.A large magnet is broken into two pieces so that their lengths are in the ratio 2:1. The pole strengths of the two pieces will have ratio

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

2. Work done in rotating a bar magnet from 0 to 120°

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

3. Gauss's law for magnetism is

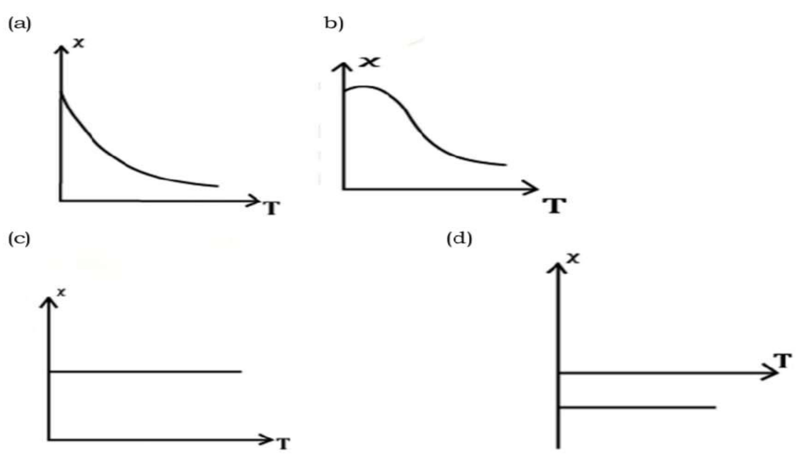
(a) the net magnetic flux through any closed surface is $\vec{B} \cdot \Delta\vec{S}$

(b) the net magnetic flux through any closed surface is $\vec{E} \cdot \Delta\vec{S}$

(c) the net magnetic flux through any closed surface is zero

(d) Both (a) and (c)

4. The variation of magnetic susceptibility (χ) with temperature for a diamagnetic substance is best represented by



(a) a (b) b (c) c (d) d

5. The relative permeability of a substance X is slightly less than unity and that of substance Y is slightly more than unity, then

(a) X is paramagnetic and Y is ferromagnetic

(b) X is diamagnetic and Y is ferromagnetic

(c) X and Y both are paramagnetic

(d) X is diamagnetic and Y is paramagnetic

6. A bar magnet of length 3 cm has points A and B along its axis at distances of 24 cm and 48 cm on the opposite sides. Ratio of magnetic fields at these points will be

(a) 8 (b) 3 (c) 4 (d) $\frac{1}{2\sqrt{2}}$

7. Ferromagnetism show their properties due to

(a) filled inner subshells (b) vacant inner subshells

(c) partially filed inner subshells (d) all the subshells equally filled

8. The relative permeability of a substance is 0.9999. The nature of substance will be

(a) diamagnetic (b) paramagnetic

(c) magnetic moment (d) intensity of magnetic field

9. If a bar magnet is broken into two halves, by a plan passing through its North-South pole, then

(a) monopoles develops (b) magnet losses its attractive property

(c) it has no more directional property in it (d) None of the above

10. The intensity of magnetic field at a point X on the axis of a small magnet is equal to the field intensity at another point Y on equatorial axis. The ratio of distance of X and Y from the centre of the magnet will be

(a) 2^{-3} (b) $2^{-1/3}$ (c) 2^{3} (d) $2^{1/3}$

11. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 5.0 cm at a distance of 50 cm from its mid-point? The magnetic moment of a bar magnet is 0.40 Am^2. (a) 3.2×10^{-6}T, 6.4×10^{-7}T (b) 4.2×10^{5}T, 6×10^{-7}T

(c) 5×10^{-6}T, 3.2×10^{-7}T (d) 3.2×10^{-7}T, 6.4×10^{-7}T

12.The resemblance of magnetic field lines of a bar magnet and a solenoid suggest that

(a) a bar magnet may be thought of as a large number of circulating currents in analogy with solenoid

(b) cutting a bar magnet in half is like cutting a solenoid

(c) both a and b

(d) Neither a nor b

13. With reference to magnetic dipole, match the terms of Column I with the terms of Column II and choose the correct option from the codes given

Column I	Column II
A. Dipole moment B. Equitorial field for a short dipole C. Axial field for a short dipole D. External field: Torque E. External field: Energy	1. – M.B 2. MxB 3. - $\frac{\mu_0 M}{4\pi r^3}$ 4. M 5. - $\frac{\mu_0 2M}{4\pi r^3}$

(a) A-4 B-3 C-5 D-2 E-1 (b) A-5 B-3 C-4 D-1 E-2

(c)A-3 B-5 C-1 D-2 E-4 (d) A-1 B-4 C-2 D-3 E-5

14. A short bar magnet placed with its axis at 30◦ with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to 4.5×10^{-2} J. The magnitude of magnetic moment of the magnet is

(a) 0.38 J (b) 0.96 J/T (c) 0.48 J/T (d) 0.36 J/T

15. Which of the following relation is correct?

(a) $\mu = \mu_0 (1+\chi)$ (b) $\mu = \mu_0 \mu_r$ (c) $\mu = 2 \mu_0 \mu_r$ (d) both a and b

16. Which of the following substances have tendency to move from stronger to the weaker part of the external magnetic field?

(a) Paramagnetic (b) Diamagnetic (c) Ferromagnetic (d) All of these

17.Which of the following statement(s) is/are correct?

I. Paramagnetic substances are those which get weakly magnetized when placed in an external magnetic field.

II. Paramagnetic substances has tendency to move from a region of weak magnetic field to strong magnetic field.

(a) both I and II are correct (b) I is correct and II is incorrect

(c) I is incorrect and II is correct (d) I and II are incorrect

18. For a paramagnetic material both χ and μ_r depends upon

(a) pressure (b) material (c) T(temperature) (d) both b and c

19. Match the term of column I with the items of Column II and choose the correct from codes given below .

Column I	Column II
A. Negative susceptibility B. Positive and small susceptibility C. Positive and large susceptibility	1. Ferromagnetic 2. Diamagnetic 3. Paramagnetic

(a) A-3 B-2 C-1 (b) A-1 B-2 C-3 (c) A-2 B-3 C-1 (d) A-2 B-1 C-3

20. Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet brought to them will

(a) attract N_1 strongly, N_2 weakly and repel N_3 weakly

(b) attract N_1 strongly but repel N_2 and N_3 weakly

(c) attract all three of them

(d) attract N_1 and N_2 strongly but repel N_3.

ASSERSION AND REASON TYPE QUESTION (1 MARK)

(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, but R is true/both A and R are false.

1. Assertion(A): The electric dipole moment is dimensionally same as the magnetic dipole moment. Reason(R): A magnetic dipole held in a uniform magnetic field experiences zero net force and a net torque like an electric dipole held in uniform electric field.

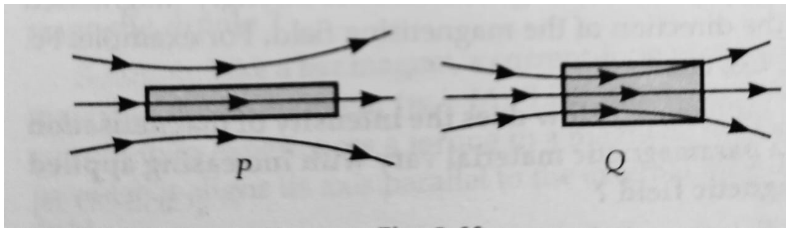
2. Assertion(A): Monopoles exists only as electric charges, not in magnetism.
Reason(R): Gauss law states that the net magnetic or electric flux through any closed surface is always zero.

3. Assertion(A): Permanent substances are weakly attracted to magnets.
Reason(R): The individual atoms of a paramagnetic substances do Not possess a permanent magnetic dipole moment.

4. Assertion(A): When radius of a circular wire carrying current is doubled, its magnetic moment becomes four times.
Reason(R): Magnetic moment is directly proportional to area of loop.
5. Assertion(A): The net magnetic flux coming out of a closed surface is always zero.
Reason(R): Unlike poles of equal strength exist together.
6. Assertion(A): The poles of a magnet cannot be separated by breaking it into two pieces.
Reason(R): The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.
7. Assertion(A): Relative magnetic permeability has no units and no dimensions.
Reason(R): $\mu_r = \frac{\mu}{\mu_0}$, where the symbols have their standard meaning.
8. Assertion(A): A current carrying carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.
Reason(R): A square loop occupies more area than a circular loop, both made of wire of the same length.
9. Assertion(A): Diamagnetic substances exhibit magnetism.
Reason(R): Diamagnetic substances do not have permanent magnetic dipole moment.
10. Assertion(A): When a bar of copper is placed in an external magnetic field, the field lines gets concentrated inside the bar.
Reason(R): Copper is paramagnetic substances.

VERY SHORT ANSWER TYPE QNS(2 MARKS)

1.The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties.
2.What is the magnitude of the equatorial and axial fields due to a bar magnet of length 5cm at a distance of 50cm from mid point? The magnetic moment of the bar magnet is 0.40 Am^2.
3. Two small magnets are placed horizontally, perpendicular to the magnetic meridian .Their north poles are at 60 cm east and 40 cm west from a compass needle. If the compass needle remains undeflected, compare the magnetic moments of the magnets.
4.A short bar magnet of magnetic moment 0.9 JT^{-1} is placed with its axis at 30◦ to a uniform magnetic field. It experiences a torque of 0.063 J. (i) Calculate the magnitude of the magnetic field. (ii) In which orientation will the bar magnet be in stable equilibrium in the magnetic field?
5. State Gauss's Law of magnetism. Explain its significance.
6. Two similar bars P and Q 'made from different materials', are introduced in two identical uniform magnetic fields. The figures given below show the redistribution of magnetic lines of force. Which of these materials is paramagnetic and why?



7.(i) Magnetic field lines shows the direction at every point which a small magnetized needle takes up at that point . Do the magnetic field lines also represent the ' lines of force' on a moving charged particle at every point? (ii) If magnetic monopole existed, how would Gauss' Law of magnetism be modified?

8. A coil of N turns ' and radius R' carries a current I. It is unwound and rewound to make another coil of radius R/2 , current remaining the same . Calculate the ratio of the magnetic moments of the new coil and the original coil.

9.The susceptibility of a magnetic material is 0.9853. Identify the type of the magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.

10. Out of the two magnetic materials, 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of materials 'A' and 'B'. Will their susceptibilities be positive or negative?

SHORT ANSWER TYPE QUESTIONS (3 marks)

1.A bar magnet of magnetic moment 6 J/T is aligned at 60◦ with a uniform external magnetic field of 0.44 T. Calculate

(a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and

(b) the torque on the magnet in the final orientation in case (ii)

2.(a) The susceptibility of a magnetic material is 0.9774. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.

(b) Out of the following, identify the materials which can be classified as :

(i) paramagnetic, (ii) diamagnetic : Aluminum, Bismuth, Copper and Sodium.

Write one property to distinguish between paramagnetic and diamagnetic materials.

3. A bar magnet of magnetic moment 1.5 JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.22 T.

(a) what is the amount of work required to turn the magnet so as to align its magnetic moment (i) normal to the field direction (ii) opposite to the field direction

(b) What is the torque on the magnet in cases (i) and (ii)?

4. (a) Show that the time period(T) of oscillations of a freely suspended magnetic dipole of magnetic moment(m) in a uniform magnetic field (B) is given by $T= 2\pi\sqrt{\frac{I}{mB}}$, where I is moment of inertia of the magnetic dipole. (b) Identify the following magnetic materials: (i) A material having susceptibility $\chi_m = -0.00015$ (ii) A material having susceptibility $\chi_m = 10^{-5}$

5. Write three points of differences between para-, dia-, and ferro-magnetic materials, giving one example of each.

6. Two similar bars, made from two different materials P and Q, are placed one by one in a non Uniform magnetic field. It is observed that

(i) bar P tends to move from the weak to the strong field region.

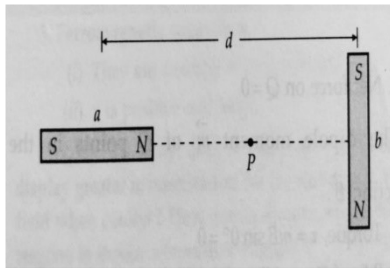
(ii) bar Q tends to move from the strong to weak field region.

What is the nature of the magnetic materials used for making these two bars?

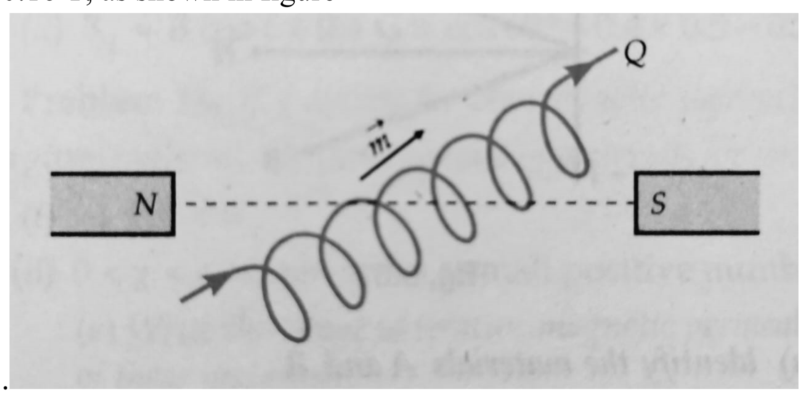
Show with the help of a diagram, the behavior of the field lines, due to an external magnetic field , near each of these two bars.

7.(i)Two magnets of magnetic moments M and M√3 are pointed 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.
(ii) A magnetized needle of magnetic moment $4.8x10^{-2}$ JT^{-1} is placed at 30◦ with the direction of uniform magnetic field of magnitude $3x10^{-2}$ T. What is the torque acting on the needle?

8. Two identical short magnets a and b of magnetic moments m each are placed at a distance d with their axes perpendicular to each other, as shown in figure. Find the magnetic field at a point P midway between the two dipoles .



9. A closely wound solenoid of 1000 turns and area of cross-section $2.0x10^{-4}m^2$ carries a current of 2.0 A. It is placed with its horizontal axis at 30◦ with the direction of a uniform horizontal magnetic field of 0.16 T, as shown in figure



(a) What is the torque experienced by the solenoid due to the field?
(b) If the solenoid is free to turn about the vertical direction, specify it orientations of stable and unstable equilibrium. What is the amount of work needed to display the solenoid from its stable orientation to its unstable orientation?

10. Three identical specimens of magnetic materials Nickel, Antimony, Aluminum are kept in a uniform magnetic field. Draw the modification in the field lines in each case. Justify your answer.

LONG ANSWER TYPE QNS(5 MARKS)

1.(a) Show that a current carrying solenoid behaves like a small bar magnet. Write the expressions for the magnetic field at an external point lying on its axis and on equatorial position.

(b) A steady current of 2 A flows through a circular coil having 5 turns of radius 7 cm. The coil lies in xy-plane with its centre at the origin. Find the magnitude and direction of the magnetic dipole moment of the coil.

2. (a) How does a paramagnetic material behave in the presence of an external magnetic field??(b) What happens when the temperature of a paramagnetic sample is lowered? (c) To which of the two – a polar dielectric or a non-polar dielectric – does a paramagnetic material correspond? Justify your answer.

3. (i) Write the expression for the equivalent magnetic moment of a planer current loop of area A, having N turns and carrying a current 'i'. Use the expression to find the magnetic dipole moment of a revolving electron.

(ii) A circular loop of radius r, having N turns and carrying current I, is kept in the XY plane. It is then subjected to a uniform magnetic field $\vec{B} = B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k}$. Obtain expression for the magnetic potential energy of the coil-magnetic field system.

4. (i) A long solenoid with air core has n turns per unit length and carries a current I. Using Ampere's circuital law, derive an expression for the magnetic field B at an interior point on its axis. Write an expression for magnetizing intensity $\vec{H}$ in the interior of the solenoid. (ii) A small bar of material, having magnetic susceptibility χ, is now put along the axis and near the centre, of the solenoid which is carrying a d.c. current through its coils. After some time, the bar is taken out and suspended freely with an unspun thread. Will the bar orient itself in magnetic meridian if (a) $\chi < 0$ (b) $\chi > 1000$.

5. Distinguish the magnetic properties of a dia-, para- and ferromagnetic substances in terms of (i) susceptibility (ii) magnetic permeability (iii) Effect of temperature.

Give one example of each of these materials.

Draw the field lines due to an external magnetic field near a (i) diamagnetic, (ii) paramagnetic substance.

CASE BASED QUESTION (4 MARKS)

1. When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called intensity (H) H= B/ μo - M where M is the magnetisation of the material, μo is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity is appropriately called the magnetic susceptibilty : tor a certain class of magnetic materials, intensity of magnetisaton directly proportional to the magnetic intensity

(i) Magnetization of a sample is

(a) volume of sample per unit magnetic moment

b) net magnetic moment per unit volume

(c) ratio of magnetic moment and pole strength

(d) ratio of pole strength to magnetic moment.

(ii) Identify the wrongly matched quantity and unit pair.

(a) Pole strength - Am (b) Magnetic susceptibility - dimensionless number

(c) Intensity of magnetization - A /m (d) Magnetic permeability - Henry m

(iii) A bar magnet has length 3 cm. cross- sectional area 2 cm^2 and magnetic moment 3 Am^2. The intensity of magnetisation of bar magnet

(a) 2×10^5 A/m (b) 4×10 A/m (c) 3×10^5 A/m (d) 5×10^5 A/m

(iv) A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1A. The number of turns of the solenoid is 500 per metre. The magnetization of the material is nearly

(a) 2.5 x $10^{'3}$ A/m (b) 2.5x 10^5 A/m (c) 2.0 x 10^3 A/ m (d) 2.0x 10^5 A/m

(v) The relative permeability of iron is 6000. Its magnetic susceptibility is

(a) 5999 (b) 6001 (c) 6000×10^{-7} (d) 6000×10^7

2. Read the following paragraph and answer the questions:

Substances behave differently when placed in a magnetic field. Some have feeble repulsive interaction; others have weak attractive interaction whereas a few others are strongly attracted. These substances find different application based on their characteristics.

(i) Name different categories into which substances are classified based on their behaviour in the magnetic field.

(ii) What is the basic difference in a paramagnetic atom and a diamagnetic atom?

(iii) Discuss the behaviour of a ferro-magnetic substance explaining its strong magnetisation as compared to that of a paramagnetic substance.

OR

Draw hysteresis loop of a magnetic substance. How does the loop help us to identify a substance suitable for making: (a) electromagnet? (b) permanent magnet?

3. Before nineteenth century, scientists believed that magnetic properties were confined to a few materials like iron, cobalt and nickel. But in 1846, Curie and Faraday discovered that all the materials in the universe are magnetic to some extent. These magnetic substances are categorized into two groups. Weak magnetic materials are called diamagnetic and paramagnetic materials. Strong magnetic materials are called ferromagnetic materials. According to the modern theory of magnetism, the magnetic response of any material is due to circulating electrons in the atoms. Each such electron has a magnetic moment in a direction perpendicular to the plane of circulation. In magnetic materials all these magnetic moments due to the orbital and spin motion of all the electrons in any atom, vectorially add upto a resultant magnetic moment. The magnitude and direction of these resultant magnetic moment is responsible for the behavior of the materials. For diamagnetic materials x is small and negative and for paramagnetic materials x is small and positive. Ferromagnetic materials have large x and are characterised by non-linear relation between $\vec{B}$ and $\vec{H}$

(I). Magnetic susceptibility of a diamagnetic substance

(a) decreases with temperature

(b) is not affected by temperature

(c) increases with temperature

(d) first increases then decreases with temperature.

(II). When a bar is placed near a strong magnetic field and it is repelled, then the material of bar is (a) diamagnetic (b) ferromagnetic (c) paramagnetic

(d) anti-ferromagnetic.

(III). The universal (or inherent) property among all substances is
(a) diamagnetism (b) paramagnetism (c) ferromagnetism (d) both (a) & (b)
(IV). For a paramagnetic material, the dependence of the magnetic susceptibility x on the absolute temperature is given as
(α) $\chi \propto T$ (b) $\chi \propto T$ (c) $\chi \propto 1/T^2$ (d) independent.
OR
(V). The value of the magnetic susceptibility for a superconductor is
(a) zero (b) infinity (c) +1 (d) -1
4. Read the following paragraph and answer the questions:
All the materials in nature respond to magnetic field to different extent and in different ways, The materials are classified as ferromagnetic; also known as strong magnetic materials and (diamagnetic; paramagnetic) the weak magnetic materials. The behaviour of a substance in a magnetic field is governed by the spin and the orbital motion of the electrons. Every electron has a magnetic moment associated with its spin and orbital motion. These magnetic moments of all the electrons in an atom add up to give the net magnetic moment of an atom or a molecule. This resultant magnetic moment of atom/molecule and the mutual interaction with other atoms and molecules explains the behaviour of the material in a magnetic field. Some materials have low magnetic suscepti- bility while some others have large magnetic susceptibility.
(i) How does a paramagnetic substance differ from a diamagnetic substance?
(ii) What is the effect of rise in temperature on the magnetic susceptibility of a
(a) diamagnetic substance? (b) paramagnetic substance?
(iii) What is the difference between atom/ molecule of a diamagnetic substance and paramagnetic substance? How do these materials affect the magnetic field lines when placed in magnetic field?
OR
How does a paramagnetic substance differ from a ferromagnetic substance? Explain.
5. Read the following and answer any four questions.
All materials can be magnetised, feebly or strongly, when they are subjected to a strong magnetising field. Materials can be divided broadly into the following three categories:
(i) Diamagnetic Substances(ii) Paramagnetic Substances(iii) Ferromagnetic Substances
Diamagnetic substances are those which have a tendency to move from stronger to the weaker part of the external magnetic field. Unlike the way a magnet attracts metal like iron, it would repel a diamagnetic substance.
Paramagnetic substances are those which get weakly magnetised when placed in an external magnetic field. They have tendency to move from a region of weak magnetic field to strong magnetic field i.e., they get weakly attracted to a magnet.
Ferromagnetic substances are those which gets strongly magnetised when placed in an external magnetic field. They have strong tendency to move from a region of weak magnetic field to strong magnetic field, i.e., they get strongly attracted to a magnet.
1. Which of the following cannot be ferromagnetic ?
(a) Liquids (b) Solids (c) Gases (d) Alloys
2. Which of the following is an example of para-magnetic materials ?
(a) Superconductors (b) Alkali metals (c) Transition metals (d) Ferrites

3. Water is an example of

(a) Diamagnetic substance (b) Paramagnetic substance

(c) Ferromagnetic substance (d) All of these

4. A paramagnetic substance of susceptibility 3 x 10^{-4} is placed in a magnetising field of 4 x 10^{4} Am^{-1}, The intensity of magnetisation is

(a) 10 Am^{-1} (b) 11 Am^{-1} (c) 12 Am^{-1} (d) none of these

5. For which of the following is magnetic susceptibility negative?

(a) Paramagnetic and Ferromagnetic materials (b) Paramagnetic materials only

(c) Ferromagnetic materials only (d) Diamagnetic materials

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SOLUTION OF QUESTION BANK PHYSICS CLASS XII CH-5 MAGNETISM

SOLUTIONS:

MCQ: 1(d), 2(b), 3(c), 4(d), 5(d), 6(a), 7(c),8(a), 9(d), 10(d), 11(d),12(c), 13(a), 14(d),15(d), 16(b), 17(a), 18(d), 19(c), 20(a)

ASSERSION REASON : 1(d),2(c), 3(c), 4(a), 5(a), 6(b), 7(a),8(d) both false, 9(b), 10(d)both false.

VERY SHORT ANSWER TYPE

1.The magnetic material having negative susceptibility is diamagnetic in nature. Properties: (i) This material has + ve but low relative permeability. (ii) They have the tendency to move from stronger to weaker part of the external magnetic field.

2. Here m = 0.40 Am^2, r = 50 cm = 0.50 m, 2l = 5.0 cm

(i) At equatorial position, B = $\frac{\mu_0}{4\pi}\cdot\frac{m}{r^3} = \frac{10^{-7}}{(0.5)^3}$x0.4 = 3.2x$10^{-7}$T

(ii) At axial position, B = $\frac{\mu_0}{4\pi}\cdot\frac{2m}{r^3} = \frac{10^{-7}}{(0.5)^3}$x2x0.4 = 6.4x$10^{-7}$T

3.The compass needle at C lies on the axial line of the two magnets. As it remains undeflected, the fields of the two magnets at C must be equal and opposite.

∴ $B_1 = B_2$ or $\frac{\mu_0}{4\pi}\cdot\frac{2m_1}{r^3} = \frac{\mu_0}{4\pi}\cdot\frac{2m_2}{r^3}$

Or $\frac{m_1}{m_2} = \left[\frac{r_1}{r_2}\right]^3 = \left[\frac{40}{60}\right]^3 = \frac{8}{27}$ = 8:27

4.Here m = 0.9 JT^{-1}, $\theta = 30°, \tau = 0.063\,J$

(i) B = $\frac{\tau}{m\sin\theta} = \frac{0.063}{0.9\times\sin 30°}$ = 0.14 T

(ii) The P.E. of a magnetic dipole in a uniform magnetic field is

U = - mBcos θ, In stable equilibrium, the P.E. is minimum.

So, $\cos\theta = 1$ or $\theta = 0°$.

Hence the bar magnet will be in stable equilibrium when its magnetic moment $\vec{m}$ is parallel to the magnetic field $\vec{B}$.

5.Gauss' law in magnetism states that the total magnetic flux through any closed surface is zero.

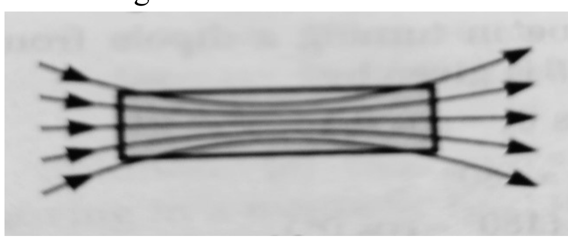
Mathematically, Magnetic flux, $\phi_B = \oint_C \vec{B}.\vec{dS} = 0$

Significance. This law implies that

(i) The magnetic monopoles do not exists.

(ii) The magnetic field lines always form closed loop.

6.The bar P is paramagnetic because magnetic lines of force are less dense in it than in Q.
7. (i) No. Force on a charged particle moving in a magnetic field is given by $\overrightarrow{F_m} = q(\vec{v} \times \vec{B})$. As the force $\overrightarrow{F_m}$ acts perpendicular to $\vec{B}$ as lines of force.
(ii) Gauss' law in magnetism states that the total magnetic flux through any closed surface is zero. Mathematically, Magnetic flux, $\phi_B = \oint_C \vec{B}.\overrightarrow{dS} = 0$
If magnetic monopole existed then the RHS of Gauss' law would be equal to μ_0 times the monopole(magnetic charge) q_m enclosed by closed surface S, i.e., $\oint_C \vec{B}.\overrightarrow{dS} = \mu_0 q_m$.
8. If L is length of wire, then $L = N\times 2\pi R = N^I \times 2\pi \frac{R}{2}$
$\therefore$ Number of turns in new coil, $N^I = 2N$
Original magnetic moment, $M = NIA = NI\times\pi R^2$
New magnetic moment, $M^I = N^I I A^I = 2NI\times \left(\frac{\pi R}{2}\right)^2 = NI\times\pi\frac{R^2}{2}$
$\frac{M^I}{M} = \frac{1}{2} = 1:2$
9. As the susceptibility has a small positive value, so the given material is paramagnetic in nature. When a piece of this material is placed in a uniform magnetic field, the lines of force get concentrated inside it as shown in Figure.



10. Relative permeability, $\mu_r = 1 + \chi$
$\therefore \quad \chi = \mu_r - 1$
As the relative permeability Of A is slightly greater than 1, so its susceptibility χ is small and positive and hence A is a paramagnetic substance.
As the relative permeability Of B is slightly less than 1, so its susceptibility χ is small and negaitive and hence B is a diamagnetic substance.

SHORT QUESTIONS SOLUTION

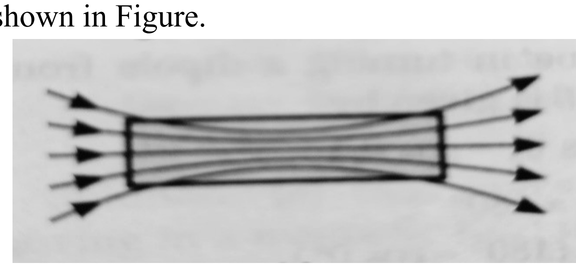
Q.1 (a) $W = mB(\cos\theta_1 - \cos\theta_2)$

(i) $W = mB(\cos60^\circ - \cos90^\circ) = mB(\frac{1}{2} - 0) = 6x0.44x\frac{1}{2} = 1.32$ J

(ii) $W = mB(\cos60^\circ - \cos180^\circ) = mB\{\frac{1}{2} - (-1)\} = \frac{3}{2}mB = \frac{3}{2}x6x0.44 = 3.96J$

(c) Torque = $mB\sin\theta = 6x0.44x\sin180^\circ = 0$

Q.2(a) As the susceptibility has a small positive value, so the given material is paramagnetic in nature. When a piece of this material is placed in a uniform magnetic field, the lines of force get concentrated inside it as shown in Figure.



(b)(i) Paramagnetic : Aluminium and sodium (ii) Diagmagnetic : Bismuth and copper

Difference: A diamagnetic specimen is repelled by a magnet while a paramagnetic specimen moves towards the magnet.

Q.3 (i) work = 0.33 J and Torque = 0.33 Nm

(ii) work = 0.66 J and Torque = 0

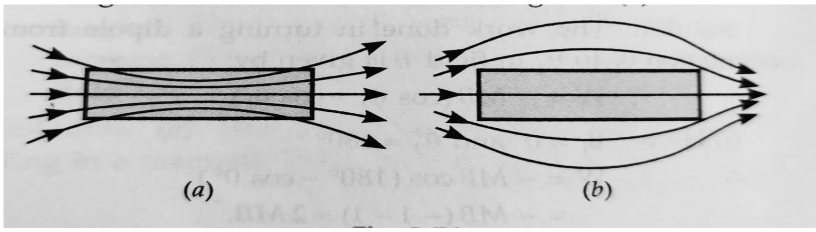
Q.4 (a) Derivation

(b) (i) Diamagnetic (ii) Paramagnetic

Q.5 Any three differences

Q.6 (i) P is a paramagnetic bar. The lines of force get concentrated inside the material as shown in figure(a).

(ii) Q is a diamagnetic bar. The lines of force get expelled from it as shown in fig(b)



Q.7 (i) In equilibrium, $\tau_{horz} = \tau_{vert}$

$MB\sin\Theta = MB\sin(90-\Theta)$

$\tan\Theta = \sqrt{3}$

$\Theta = 60^\circ$

(ii) $\tau = MB\sin\Theta = 4.8\times10^{-2}\times3\times10^{-2}\times\sin30^\circ = 7.2\times10^{-4}$J.

Q.8 As shown in figure the point P lies on the axial line of magnet a and on the equatorial line of magnet b.

$B_a = B_{axial} = \frac{\mu_0}{4\pi}\cdot\frac{2m}{(d/2)^3}$, along the axis of a

$B_b = B_{equa} = \frac{\mu_0}{4\pi}\cdot\frac{2m}{(d/2)^3}$, parallel to the axis of b

the resultant field at P is $B = \sqrt{(B_a^2 + B_b^2)}$

$= \frac{\mu_0}{4\pi}\cdot\frac{2m}{(d/2)^3}\sqrt{(1^2 + 2^2)} = 2\sqrt{5}\,\mu_0 m/\pi d^3$

If field B makes angle θ with B_a , then

$\tan\theta = \frac{B_b}{B_a} = ½ = 0.5$ or $\theta = 26.57°$

Q.9 magnetic moment $m = NIA = 1000\times2.0\times2.0\times10^{-4} = 0.40\ JT^{-1}$

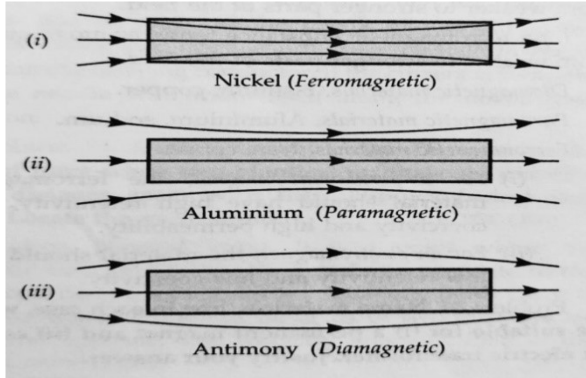
(a) Torque $\tau = mB\sin\theta = 0.40\times0.16\times\frac{1}{2} = 0.032$ Nm

(b) In stable equilibrium, $\theta = 0°$ $U_i = -mB\cos\theta = -0.40\times0.16\times1 = -0.064$J

In unstable equilibrium, $\theta = 180°$, $U_f = -mB\cos180° = -0.40\times0.16\times(-1) = +0.064$ J

Amount of work done $W = U_f - U_i = 0.064 - (-0.064) = +0.128$ J

Q.10 The modified field lines are shown in figure.



CASE BASED QNS ANSWER :

Q.1 ANSWER KEY: 1(b), 4(b), 2(d), 5(a), 3(d)

Q.3 Answer Key: (i)b (ii)a (iii)a (iv) c (v)d

Q.5 Answer Key : 1(c), 2(b), 3(a), 4(c), 5(d)

Chapter–6: Electromagnetic Induction

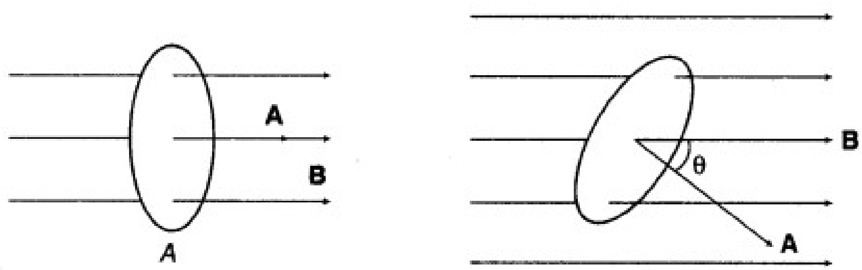
1. Magnetic Flux The magnetic flux linked with any surface is equal to total number of magnetic field lines passing normally through it. It is a scalar quantity.

Magnetic flux is defined as the number of magnetic field lines passing through a given closed surface. It provides the measurement of the total magnetic field that passes through a given surface area. Here, the area under consideration can be of any size and under any orientation with respect to the direction of the magnetic field.

$$\Phi_B = \vec{B}.\vec{A} = BACOS\theta$$

The θ represents the angle between A and B

Suppose, we consider small area dA in field B, then $\phi = \int \mathbf{B} \cdot d\mathbf{A}$



Magnetic flux, $\phi = BA$ = Maximum value   Magnetic flux, $\phi = BA$ $\theta = \mathbf{B} \cdot \mathbf{A}$

SI unit of magnetic flux is Weber (Wb).

CGS unit of magnetic flux is Maxwell (Mx).

$$1 \text{ Wb} = 10^8 \text{ Mx} = 1 \text{ Tm}^2$$

Magnetic flux is a scalar quantity and its dimensional formula is $[ML^2T^{-2}A^{-1}]$.

2. The phenomenon of generation of current or emf by changing the magnetic flux is known as Electromagnetic Induction (EMI).

3. Faraday's Law of Electromagnetic Induction-

First Law Whenever magnetic flux linked with the closed loop or circuit changes, an emf induces in the loop or circuit which lasts so long as change in flux continuous.

Second Law The induced emf in a closed loop or circuit is directly proportional to the rate of change of magnetic flux linked with the closed loop or circuit i.e. $$e \propto \frac{(-)\,\Delta\phi}{\Delta t} \;\Rightarrow\; e = -N\frac{\Delta\phi}{\Delta t}$$

where, N = number of turns in loop.

Negative sign indicates the Lenz's law.

4. Lenz's Law The direction of induced emf or induced current is such that it always opposes the cause that produce it.

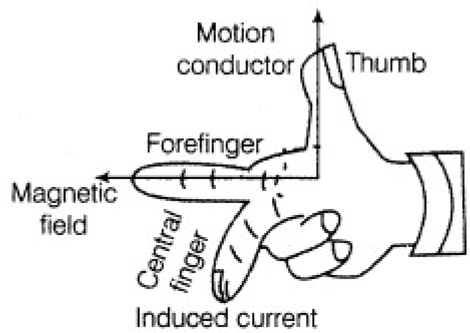
The Lenz's law states that the polarity of the emf which is induced tends to produce a current opposing to the change in the magnetic flux that produced it. The negative sign represents the opposition.

Lenz's law depends on the principle of conservation of energy and Newton's third law It is the most convenient method to determine the direction of the induced current. It states that the direction of an induced current is always such as to oppose the change in the circuit or the magnetic field that produces it.

5. If N is the number of turns and R is the resistance of a coil. The magnetic flux linked with its each turn changes by dΦ in short time interval dt, then induced current flowing through the coil is

$$I = \frac{|e|}{R} = -\frac{1}{R}\left(N\frac{\Delta\phi}{\Delta t}\right)$$

8. Fleming's Right Hand Rule If the thumb, forefinger and middle finger of right hand are stretched mutually perpendicular to each other such that the forefinger points the direction of magnetic field, thumb points towards the direction of magnetic force, then middle finger points towards the direction of induced current in the conductor.



9. The induced emf developed between two ends of conductor of length l rotating about one end with angular velocity ω in a direction perpendicular to magnetic field is given by,

$$\varepsilon = \frac{\bar{B}\omega l^2}{2}$$

Motional e.m.f is e = blv

I= e/R = blv/R

Power, $P = B^2l^2v^2/r$

Eddy Current –

Inducedemf is produced in the coil when there is a change in the magnetic flux linked with that coil. Eddy currents are named so because the current looks like eddies or whirlpools. When a conductor is placed in the changing magnetic field, the induced current in the conductor is termed as Eddy currents. We can define it as:

Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor according to Faraday's law of induction. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field.

I= induce e.m.f/resistance

I= e/R

e = -dϕ/dt

i = -dϕ/dt/R

Applications of eddy current-

(i) Electro magnetic damping

(ii) Induction furnace

(iii) Magnetic break

(iv) Induction Motor

(v) Electric power meters

Induction-

Induction is the magnetic field which is proportional to the rate of change of the magnetic field. This definition of induction holds for a conductor. Induction is also known as inductance. L is used to represent the inductance and Henry is the SI unit of inductance.

Types of Inductance

Two types of inductance are there:-

1.Self Induction 2. Mutual Induction

Self Induction-

When there is a change in the current or magnetic flux of the coil, an opposed induced electromotive force is produced. This phenomenon is termed as Self Induction. When the current starts flowing through the coil at any instant, it is found that, that the magnetic flux becomes directly proportional to the current passing through the circuit. The relation is given as:

$\phi= I$

$\phi = L I$

Where L is termed as self-inductance of the coil or the coefficient of self-inductance. The self-inductance depends on the cross-sectional area, the permeability of the material, or the number of turns in the coil.

The rate of change of magnetic flux in the coil is given as,

$e = – d\phi/dt = – d(LI)/dt$

or $e = – L\, dI/dt$

Mutual Induction-

. When there is a change in the current or magnetic flux linked with two coils an opposing electromotive force is produced across each coil, and this phenomenon is termed as Mutual Induction. The relation is given as:

$\phi = I$

$\phi = M I$

Where M is termed as the mutual inductance of the two coils or the coefficient of the mutual inductance of the two coils.

The rate of change of magnetic flux in the coil is given as,

$e = - d\phi/dt = - d(MI)/dt$

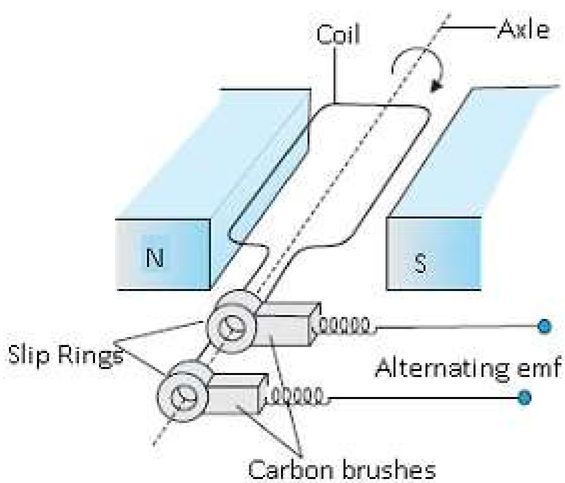
$e = - M\, dI/dt$

A.C. generator

A machine which convert mechanical energy into electric energy

Principle- Electromagnetic induction

Construction- diagram



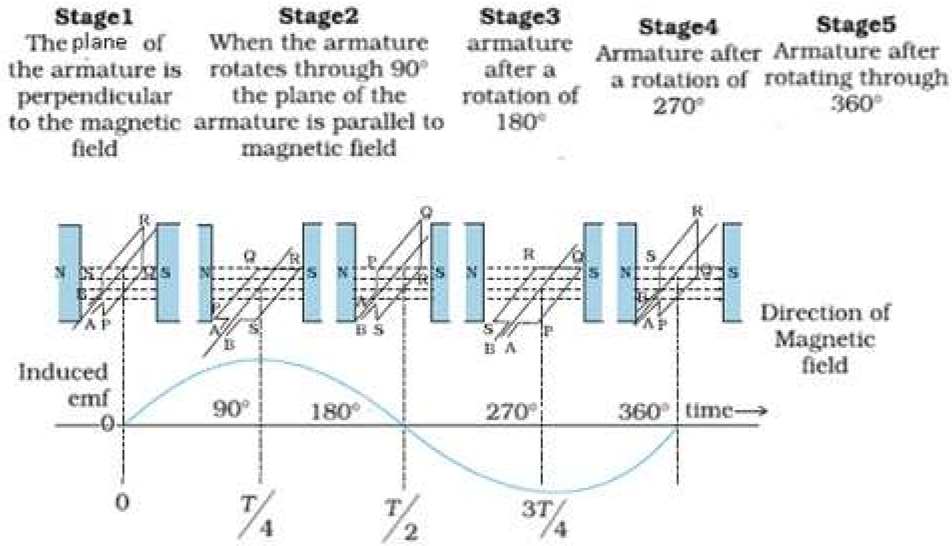
Working-

$\phi = N(B.A) = NBA\cos\theta = NBA\cos\omega t$

$e = - d\phi/dt = -d/dt(NBA\cos\omega t)$

$e = NAB\omega\sin\omega t$

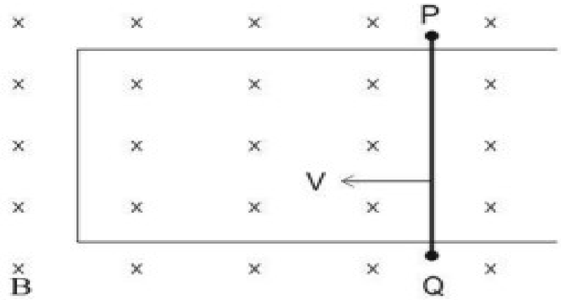
$e = e_0\sin\omega t \quad (e_0 = NAB\omega)$



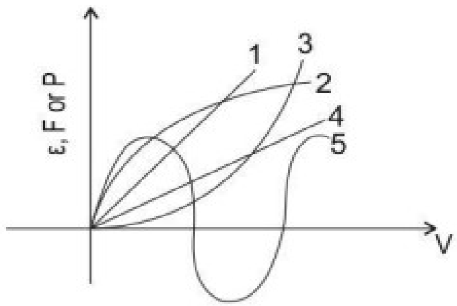
MCQ

1. A circular coil of radius 8.0 cm and 40 turns is rotated about its vertical diameter with an angular speed of $25/\pi$ rad/s in a uniform horizontal magnetic field of magnitude $3x10^{-2}$ T. The maximum emf induced in the coil is : (a) 0·12 V (b) 0·15 V (c) 0·19 V (d) 0·22 V
2. A planar loop is rotated in a magnetic field about an axis perpendicular to the field. The polarity of induced emf changes once in each : (a) 1 revolution (b) 1/2 revolution (c) 1/4 revolution (d) 3/4 revolution
3. A conducting circular loop is placed in a uniform magnetic field B = 50 mT with its plane perpendicular to the magnetic field. The radius of the loop is made to shrink at a constant rate of 1 mm/s. At the instant the radius of the loop is 4 cm, the induced emf in the loop is : (A) π μV (B) 2π μ V (C) 4π μV (D) 8π μV
4. The magnetic flux (in SI units) through a coil varies with time as $\varphi = 3t^2 + 4t + 7$. The ratio of emf induced in the coil at t = 2 s to that at t = 1 s will be : (a) 2 (b) 0·8 (c) 1·6 (d) 4
5. Which of the following statements is not correct ? (a) Lenz'S law is the consequence of the law of conservation of energy. (b) The magnitude of induced emf in a coil is directly proportional to the rate of change of magnetic flux. (c) Inserting an iron core in a coil decreases its self-inductance. (d) An emf can be induced in a straight conductor by moving it perpendicularly through a uniform magnetic field.
6. A circular coil of radius 10 cm is placed in a magnetic field B = (1·0 ^ i + 0·5 ^ j) mT such that the outward unit vector normal to the surface of the coil is (0·6 ^ i + 0·8 ^ j). The magnetic flux linked with the coil is : (A) 0·314 μWb (B) 3·14 μWb (C) 31·4 μWb (D) 1·256 μWb
7. The current in a coil of 15 mH increases uniformly from zero to 4 A in 0.004 s. The emf induced in the coil will be : (A) 22·5 V (B) 17·5 V (C) 15·0 V (D) 12·5 V
8. Consider a solenoid of length l and area of cross-section A with fixed number of turns. The self-inductance of the solenoid will increase if :
(A) both l and A are increased (B) l is decreased and A is increased (C) l is increased and A is decreased (D) both l and A are decreased
9. The magnetic flux ϕ (in Wb) through a closed loop of resistance 3·0Ω varies with time t (s) as $\phi = 6t^2 + 3{\cdot}0t + 5$. The value of the induced current in the loop at t = 1·0 s is: (A) 15·0 A (B) 3·0 A (C) 4·0 A (D) 5·0 A
10. The direction of induced current in the loop abc is : (a) along abc if I decreases (b) along acb if I increases (c) along abc if I is constant (d) along abc if I increases

11. A conducting rod PQ of a small resistance is moved at a constant velocity v under the effect of a constant force F through a region of the constant magnetic field as shown. Assume no energy losses.

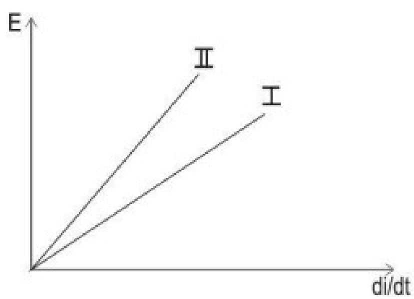


If the emf induced across PQ is ε and a force F and power P is used to move the rod, then which of the following graphs correctly represent ε, F, and P as a function of speed v respectively?

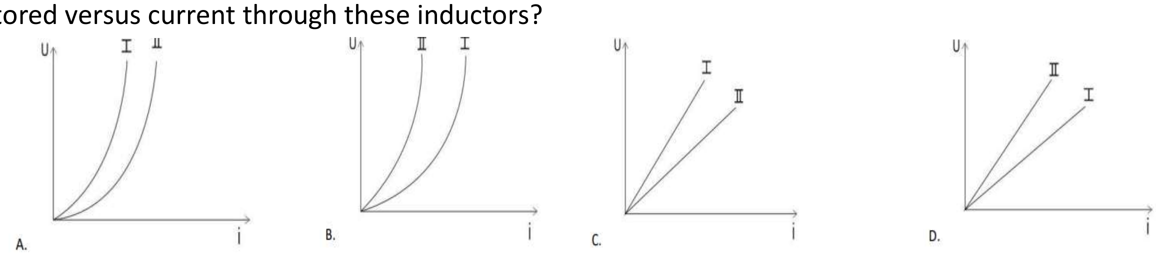


A. Graphs 5, 3 and 1 B. Graphs 2, 4 and 5 C. Graphs 4, 1 and 3 D. Graphs 3, 2 and 4

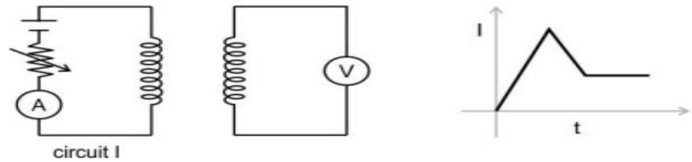
Q12. The following graphs represent emf induced with the rate of change of current for two different inductors.



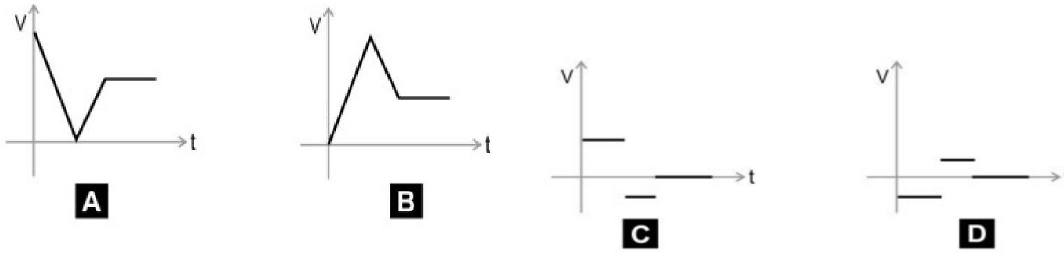
Which of the given options correctly represents the energy stored versus current through these inductors?



Q13. Circuit I consists of a coil of wire, a battery, a rheostat, and an ammeter. Another coil connected to a voltmeter is placed close to the circuit I as shown below. As the resistance of the rheostat is changed, the current in the coil of the circuit I changes. The graph below shows this change in current with time.



Which of the graphs correctly shows the voltage measured by the voltmeter with time?



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

Q14. Two coils have a mutual inductance 0.005 H. The current changes in the first coil according to equation I = I0 sinwt, where I0 = 10 A and w = 100p rad/sec. The maximum value of e.m.f. in the second coil is

(a) p (b) 5p (c) 2p (d) 4p

Q15. What is the self-inductance of a coil which produces 5 V when the current changes from 3 ampere to 2 ampere in one millisecond?

(a) 5000 henry (b) 5 milli-henry (c) 50 henry (d) 5 henry

Q16. A wire loop is rotated in a magnetic field. The frequency of change of direction of the induced e.m.f. is

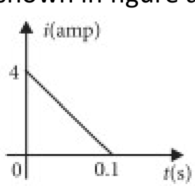
(a) four times per revolution (b) six times per revolution (c) once per revolution (d) twice per revolution

Q17. Two coils of self inductance 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is

(a) 16 mH (b) 10 mH (c) 6 mH (d) 4 mH

Q18. The total charge, induced in a conducting loop when it is moved in magnetic field depends on (a) the rate of change of magnetic flux (b) initial magnetic flux only (c) the total change in magnetic flux (d) final magnetic flux only

Q19. In a coil of resistance 10 W, the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in weber is



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

Q20. A metal ring is held horizontally and bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is

(a) more than g (b) equal to g (c) less than g (d) either(a) or (c)

REASON ASSERTION

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) Both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) Assertion is correct but Reason is incorrect.

(d) Assertion is incorrect but Reason is correct.

21. Assertion (A) : The mutual inductance between two coils is maximum when the coils are wound on each other.

Reason (R) : The flux linkage between two coils is maximum when they are wound on each other.

Q22. Assertion-- The mutual induction of two coils is doubled, if the self-inductance of the primary or secondary coil is doubled

Reason -- Mutual induction is proportional to self-inductance of primary and secondary coils

Q23. Assertion- If primary coil is connected by voltmeter and secondary coil by ac source. If large copper sheet is placed between two coils, induced emf in primary coil is reduced

Reason -- Copper sheet between coils has no effect on induced emf in primary coil

Q24. Assertion- Armature current in DC motor is maximum when the motor has just started

Reason -- Armature current is given by I=E-e/R where e is back emf, R is resistance of armature

Q25. Assertion- Only a change in magnetic flux through a coil maintain a current in the coil if the current is continues

Reason -- The presence of large magnetic flux through a coil maintain a current in the coil if the current is continues

Q26. Assertion- A spark occur between the poles of a switch when the switch is opened

Reason -- Current flowing in the conductor produce magnetic field

Q27. Assertion -In the phenomenon of mutual induction self-induction of each of coils persists

Reason -- Self-induction arises when strength of current in same coil change in the mutual induction, current is changing in both the individual

Q28. An induced emf is generated when magnet is withdrawn from the solenoid

Reason -- The relative motion between the magnet and solenoid induced emf

Q29. Assertion- If primary coil is connected by voltmeter and secondary coil by ac source. If large copper sheet is placed between two coils, induced emf in primary coil is reduced

Reason -- Copper sheet between coils has no effect on induced emf in primary coil

Q30. . Assertion : A bulb connected in series with a solenoid is connected to ac source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

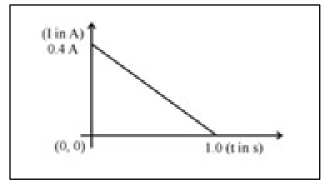
Reason : On introducing soft iron core in the solenoid, the inductance decreases.

VERY SHORT ANSWER

1. A jet plane is travelling towards west at a speed of 1800 km/h. (i) Estimate voltage difference developed between the ends of the wing having a span of 25 m if the earth's

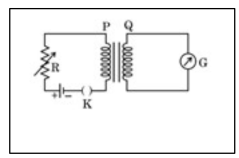
magnetic field at the location has a magnitude of 5×10^{-4} T and dip angle is 30°.How will the voltage developed be affected if the jet changes its direction from west to north ?

2. A 0·5 m long solenoid of 10 turns/cm has area of cross-section 1 cm^2. Calculate the voltage induced across its ends if the current in the solenoid is changed from 1 A to 2 A in 0·1 s.
3. A copper coil is taken out of a magnetic field with a fixed velocity. Will it be easy to remove it from the same field if its ohmic resistance is increased ?
4. A small flat search coil of area 5 cm^2 with 140 closely wound turns is placed between the poles of a powerful magnet producing magnetic field 0·09 T and then quickly removed out of the field region. Calculate change of magnetic flux through the coil.
5. When a conducting loop of resistance 10 Ω and area 10 cm^2 is removed from an external magnetic field acting normally, the variation of induced current in the loop with time is shown in the figure. Find the (i) total charge passed through the loop. (ii) change in magnetic flux through the loop. (iii) magnitude of the magnetic field applied. **(2020A)**



SHORT ANSWER

1. Consider the arrangement of two coils P and Q shown in the figure. When current in coil P is switched on or switched off, a current flows in coil Q. (a) Explain the phenomenon involved in it. (b) Mention two factors on which the current produced in coil Q depends. (c) Give the direction of current in coil Q when there is a current in the coil P and (i) R is increased, and (ii) R is decreased.



2. A 100-turn coil of radius 1·6 cm and resistance 5·0 Ω is co-axial with a solenoid of 250 turns/cm and radius 1·8 cm. The solenoid current drops from 1·5 A to zero in 25 ms. Calculate the current induced in the coil in this duration. (Take $\pi^2 = 10$)
3. A rectangular coil of N turns and area of cross-section A is rotated at a steady angular speed ω in a uniform magnetic field B. Obtain an expression for the emf induced in the coil at any instant of time.
4. Two coplanar and concentric circular loops L_1 and L_2 are placed coaxially with their centres coinciding. The radii of L_1 and L_2 are 1 cm and 100 cm respectively. Calculate the mutual inductance of the loops. (Take $\pi^2 = 10$)
5. The current flowing in a coil of inductance 50 mH is reduced from 10 A to 0 in 20 ms. Calculate the change in flux linked with the coil.

CASE STUDY BASED

41: An inductor is simply a coil or a solenoid that has a fixed inductance. It is referred to as a choke. The usual circuit notation for an inductor is as shown. Let a current i flows through the inductor from A to B. Whenever electric current changes through it, a back emf is generated. If the resistance of inductor is assumed to be zero (ideal inductor) then induced emf in it is given by e=VB-VA = - L di / dt Thus, potential drops across an inductor as we movein the direction of current. But potential also drops across a pure resistor when we move in the direction of the current. The main difference between a resistor and an inductor is that while a resistor opposes the current through it, an inductor opposes the change in current through it. Now answer the following questions.

(1) How does inductor behave when (a) a steady current flow through it?

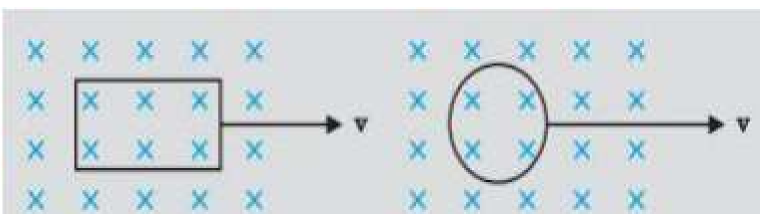
(b) a steadily increasing, current flows through it?

(c) a steadily decreasing current flows through it?

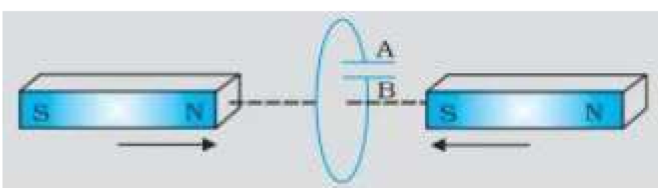
(d) Name the phenomenon in which change in current in a coil induces EMF in coil itself?

42. (a)A closed loop is held stationary in the magnetic field between the north and south poles of two permanent magnets held fixed. Can we hope to generate current in the loop by using very strong magnets? (b) A closed loop moves normal to the constant electric field between the plates of a large capacitor. Is a current induced in the loop (i) when it is wholly inside the region between the capacitor plates (ii) when it is partially outside the plates of the capacitor? The electric field is normal to the plane of the loop.

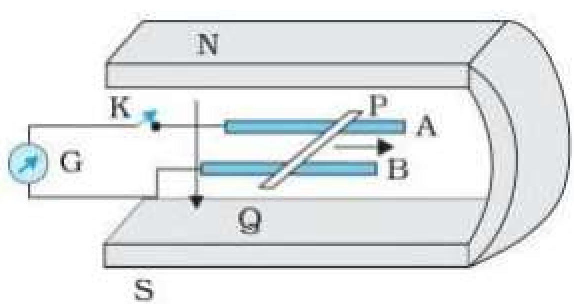
(c) A rectangular loop and a circular loop are moving out of a uniform magnetic field region (Figure) to a field-free region with a constant velocity v. In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops.



(d) Predict the polarity of the capacitor in the situation described by the figure



43. Given figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails, the rod, and the magnetic field are in three mutual perpendicular directions. A galvanometer G connects the rails through a switch K. Length of the rod = 15 cm, B = 0.50 T, resistance of the closed loop containing the rod = 9.0 mΩ. Assume the field to be uniform. (a) Suppose K is open and the rod is moved with a speed of 12 cm s-1 in the direction shown. Give the polarity and magnitude of the induced emf.



(b) Is there an excess charge built up at the ends of the rods when K is open? What if K is closed?

(c) With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ even though they do experience magnetic force due to the motion of the rod.

(d) What is the retarding force on the rod when K is closed?

44. 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. Alternating current is defined as an electric current which reverses in direction periodically. In most of the electric power circuits, the waveform of alternating current is the sine wave.

1. 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 2–√ times

2. 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

3. Lenz law is based on which of the following conservation

(a) Charge (b) Mass (c) Momentum (d) Energy

4. 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 due to gravity (c) It is less than due to gravity (d) It is more than due to gravity

45. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.

(a) Estimate the line power loss in the form of heat.

(b) How much power must the plant supply, assuming there is negligible power loss due to leakage? (c) Characterise the step up transformer at the plant.

(d) principle of transformer.

LONG ANSWER

1. Briefly explain the working of an ac generator with babbled diagram. Obtain the expression for the instantaneous value of the emf induced in the generator.
2. (i)Obtain the expression for the magnetic energy stored in a solenoid in terms of the magnetic field B, area A and length l of the solenoid through which a current I is passed. **(ii)** A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil ?
3. (i)Define the term self-inductance of a coil. Obtain an expression for self-inductance of a solenoid of area of cross-section A, length L and having n turns per unit length.
   (ii)In a given coil of self-inductance of 5 mH, current changes from 4 A to 1 A in 30 ms. Calculate the emf induced in the coil.
4. (i)Explain the meaning of mutual inductance of a solenoid S_1 with respect to the solenoid S_2.
   (ii) Consider two concentric circular coils, one of radius r_1 and the other of larger radius r_2 ($r_1 << r_2$), placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.
5. (i)Differentiate between self inductance and mutual inductance.
   (ii)The mutual inductance of two coaxial coils is 2H. The current in one coil is changed uniformly from zero to 0.5A in 100 ms. Find the : (i) change in magnetic flux through the other coil. (ii) emf induced in the other coil during the change.

6.

q.no.	answer	marks
1	C	1
2	B	1
3	C	1
4	C	1
5	C	1
6	C	1
7	C	1
8	B	1
9	D	1
10	A	1
11	C	1
12 13	B D	1 1
14	B	1
15	B	1
16	D	1
17	D	1
18	C	1
19	B	1
20	C	1
21	A	1
22	C	1
23	A	1

24	B	1
25	C	1
26	B	1
27	B	1
28	A	1
29	A	1
30	D	1
31	3.125 V	2
32	6.28X 10^{-4} V	2
33	YES	2
34	Φ= 6.3X 10^{-3} wb	2
35	Q= AREA OF THE CURVE=0.2 C Δϕ =RΔq =2 wb B= Δϕ/ΔA =2 X 10^{3} T	2
36	(a) Mutual induction (b) Resistance and no of turns (c) i. clockwise, ii. Anti clockwise	3
37	I = 3 X 10^{-4} A	3
38	Correct expression	3
39	M = 2 x 10^{-10} H	3
40	Δϕ =0.5 wb	3
41	(i) (a) As electric current is steady therefore di / dt = 0; :: induced emf = e = 0 and the inductor behaves as short circuit. (b) in the expression e= - L di / dt as di / dt is positive EMF is negative. that is VB < VA. That is back EMF is genreted that opposses the increase in current. (c) di / dt is negative, therefore EMF is positive. that is VB > VA. Forward EMF is generated that opposses fall in current. (d) Self induction.	1 Mark each
42	(a) No. However strong the magnet may be current can be induced only by changing the magnetic flux through the loop. (b) No current is induced in either case. Current can not be induced by changing the electric flux. (c) The induced emf is expected to be constant only in the case of the rectangular loop. In the case of circular loop, the rate of change of area of the loop during its passage out of the field region is not constant, hence induced emf will vary accordingly, (d) The polarity of plate 'A' will be positive with respect to plate 'B' in the capacitor.	1 Mark each

43	(a) EMF = vBL = 0.12 0.50 x 0.15 = 9.0 mV; P positive end and Q negative end. (b) Yes. When K is closed, the excess charge is maintained by the continuous flow of current. (c) Magnetic force is cancelled by the electric force set-up due to the excess charge of opposite signs at the ends of the rod. (d) Retarding force = IBL 9 mV / 9 mΩ x 0.5 T x 0.15 m = 75 x 10-3 N	1 Mark each
44	(a) By doubling the current (b)3 times (d) Energy (c) It is less than due to gravity	1 1 1 1
45	Line resistance = 30 X 0.5 = 15Ω rms current in the line . 800 x 1000 W / 4000 V = 200 A (a) Line power loss = (200 A)2 x 15 Ω = 600 kW. (b) Power supply by the plant = 800 kW + 600 kW = 1400 kW. (c) Voltage drop on the line = 200 A 15Ω = 3000 V. The step-up transformer at the plant is 440 V - 7000 V. (d) mutual induction.	1 mark each
46	Diagram-1 Mark Working-1 Mark Derivation-3 Marks	5
47	Expression- 3 marks Numerical- 2 marks	5
48	Expression- 3 marks Numerical- 2 marks	5
49	Definition – 1 mark Expression – 4 marks	5
50	Difference- 2 marks Numerical- 3 marks	5

STUDY MATERIAL CLASS XII PHYSICS CHAPTER 7 (ALTERNATING CURRENT)

I) MULTIPLE CHOICE QUESTIONs:- (1 MARK EACH)

1) In an ac circuit, *V* and *I* are given by :-

V = 100 sin (100 *t*) *volts*, $I = 100 \sin\left(100t + \frac{\pi}{3}\right) mA$. The power dissipated in circuit is

(a) 10^4 *watt* (b) 10 *watt* (c) 2.5 *watt* (d) 5 *watt*

2) In an ac circuit *I* = 100 sin 200 πt. The time required for the current to achieve its peak value will be:-

(a) $\frac{1}{100} sec$ (b) $\frac{1}{200} sec$ (c) $\frac{1}{300} sec$ (d) $\frac{1}{400} sec$

3) A generator produces a voltage that is given by $V = 240 \sin 120\, t$, where *t* is in seconds. The frequency and *r.m.s.* voltage are:-

(a) 60 *Hz* and 240 V (b) 19 *Hz* and 120 V (c) 19 *Hz* and 170 V (d) 754 *Hz* and 70 V

4) A sinusoidal ac current flows through a resistor of resistance *R*. If the peak current is I_p , then the power dissipated is

(a) $I_p^2 R \cos\theta$ (b) $\frac{1}{2} I_p^2 R$ (c) $\frac{4}{\pi} I_p^2 R$ (d) $\frac{1}{\pi} I_p^2 R$

5) The peak value of an alternating e.m.f. *E* is given by $E = E_0 \cos \omega t$ is 10 *volts* and its frequency is 50 *Hz*. At time $t = \frac{1}{600} sec$, the instantaneous e.m.f. is:-

(a) 10 *V* (b) $5\sqrt{3}\ V$ (c) 5 *V* (d) 1 *V*

6) An alternating current is given by the equation $i = i_1 \cos\omega t + i_2 \sin\omega t$. The *r.m.s.* current is given by:-

(a) $\frac{1}{\sqrt{2}}(i_1 + i_2)$ (b) $\frac{1}{\sqrt{2}}(i_i + i_2)^2$ (c) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$ (d) $\frac{1}{2}(i_1^2 + i_2^2)^{1/2}$

7) Voltage and Current in an ac circuit are given by $V = 5 \sin\left(100\pi t - \frac{\pi}{6}\right)$ and $I = 4 \sin\left(100\,\pi t + \frac{\pi}{6}\right)$

(a) Voltage leads the current by 30^o (b) Current leads the voltage by 30^o

(c) Current leads the voltage by 60^o (d) Voltage leads the current by 60^o

8) Current in the circuit is wattless, if:-

(a) Inductance in the circuit is zero (b) Resistance in the circuit is zero

(c) Current is alternating (d) Resistance and inductance both are zero

9) An alternating current of frequency 'f' is flowing in a circuit containing a resistance *R* and a choke *L* in series. The impedance of this circuit is:-

(a) *R* + 2$\pi f L$ (b) $\sqrt{R^2 + 4\pi^2 f^2 L^2}$ (c) $\sqrt{R^2 + L^2}$ (d) $\sqrt{R^2 + 2\pi f L}$

10) A resistance of 300 Ω and an inductance of $\frac{1}{\pi}$ henry are connected in series to a ac voltage of 20 *volts* and 200 *Hz* frequency. The phase angle between the voltage and current is:-

(a) $\tan^{-1}\frac{4}{3}$ (b) $\tan^{-1}\frac{3}{4}$ (c) $\tan^{-1}\frac{3}{2}$ (d) $\tan^{-1}\frac{2}{5}$

11) *L*, *C* and *R* denote inductance, capacitance and resistance respectively. Pick out the combination which does not have the dimensions of frequency:-

(a) $\frac{1}{RC}$ (b) $\frac{R}{L}$ (c) $\frac{1}{\sqrt{LC}}$ (d) $\frac{C}{L}$

12) If an $8\,\Omega$ resistance and $6\,\Omega$ reactance are present in an ac series circuit then the impedance of the circuit will be:-

(a) 20 *ohm* (b) 5 *ohm* (c) 10 *ohm* (d) $14\sqrt{2}$ *ohm*

13) For series *LCR* circuit, wrong statement is:-

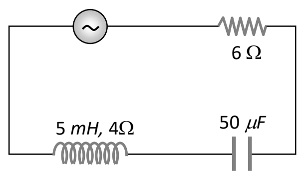
(a) Applied e.m.f. and potential difference across resistance are in same phase

(b) Applied e.m.f. and potential difference at inductor coil have phase difference of $\pi/2$

(c) Potential difference at capacitor and inductor have phase difference of $\pi/2$

(d) Potential difference across resistance and capacitor have phase difference of $\pi/2$

14) In the circuit shown below, the ac source has voltage $V = 20\cos(\omega t)$ volts with ω = 2000 *rad/sec*. the amplitude of the current will be nearest to:-



(a) $2A$

(b) $3.3A$

(c) $2/\sqrt{5}A$

(d) $\sqrt{5}A$

15) In an ac circuit, the power factor:-

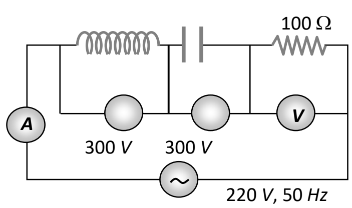
(a) Is zero when the circuit contains an ideal resistance only

(b) Is unity when the circuit contains an ideal resistance only

(c) Is zero when the circuit contains an ideal inductance only

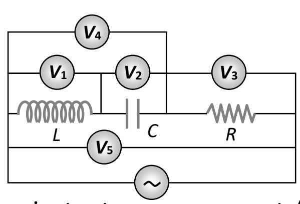
(d) Is unity when the circuit contains an ideal inductance only

16) In the circuit shown below, what will be the readings of the voltmeter and ammeter:-



(a) 800 *V*, 2*A* (b) 300 *V*, 2*A* (c) 220 *V*, 2.2 *A* (d) 100 *V*, 2*A*

17) In the adjoining ac circuit the voltmeter whose reading will be zero at resonance is:-



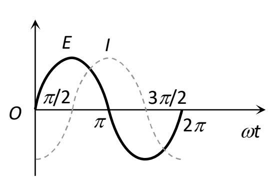
(a) V_1

(b) V_2

(c) V_3

(d) V_4

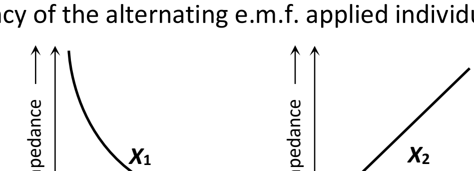
18) The variation of the instantaneous current (*I*) and the instantaneous emf (*E*) in a circuit is as shown in fig. Which of the following statements is correct:-



(a) The voltage lags behind the current by $\pi/2$ (b) The voltage leads the current by $\pi/2$

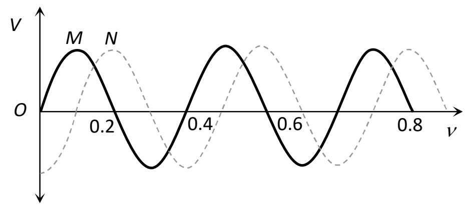
(c) The voltage and the current are in phase (d) The voltage leads the current by π

19) The graphs given below depict the dependence of two reactive impedances X_1 and X_2 on the frequency of the alternating e.m.f. applied individually to them. We can then say that:-



(a) X_1 is an inductor and X_2 is a capacitor
(b) X_1 is a resistor and X_2 is a capacitor
(c) X_1 is a capacitor and X_2 is an inductor
(d) X_1 is an inductor and X_2 is a resistor

20) Two sinusoidal voltages of the same frequency are shown in the diagram. What is the frequency, and the phase relationship between the voltages:-



Frequency in *Hz*	Phase lead of *N* over *M* in radians
(a) 0.4	$-\pi/4$
(b) 2.5	$-\pi/2$
(c) 2.5	$+\pi/2$
(d) 2.5	$-\pi/4$

II) <u>ASSERTION & REASON</u>:- (1 MARK EACH)

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** : In series *LCR* circuit resonance can take place.

Reason : Resonance takes place if inductance and capacitive reactances are equal and opposite.

2) **Assertion** : The alternating current lags behind the e.m.f. by a phase angle of $\pi/2$, when ac flows through an inductor.

Reason : The inductive reactance increases as the frequency of ac source decreases.

3) **Assertion** : Capacitor serves as a block for dc and offers an easy path to ac.

Reason : Capacitive reactance is inversely proportional to frequency.

4) **Assertion** : When capacitive reactance is smaller than the inductive reactance in *LCR* current, 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.

5) **Assertion** : If the frequency of alternating current in an ac circuit consisting of an inductance coil is increased then current gets decreased.

Reason : The current is inversely proportional to frequency of alternating current.

6) **Assertion** : Average value of ac over a complete cycle is always zero.

Reason : Average value of ac is always defined over half cycle.

7) **Assertion** : When ac circuit contain resistor only, its power is minimum.

Reason : Power of a circuit is independent of phase angle.

8) **Assertion** : An electric lamp connected in series with a variable capacitor and ac source, its brightness increases with increase in capacitance.

Reason : Capacitive reactance decrease with increase in capacitance of capacitor.

9) **Assertion** : An inductance and a resistance are connected in series with an ac circuit. In this circuit the current and the potential difference across the resistance lag behind potential difference across the inductance by an angle $\pi/2$.

Reason : In *LR* circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

10) **Assertion** : A capacitor of suitable capacitance can be used in an ac circuit in place of the choke coil.

Reason : A capacitor blocks dc and allows ac only.

III) <u>VARY SHORT ANSWER TYPE QUESTION</u>:- (1 MARK EACH)

1) State the underlying principle of a transformer.

The principle of transformer is based upon the principle of mutual induction

2) Define capacitor reactance. Write its SI units?

Virtual resistance offered by a capacitor to the flow of an alternating current is called capacitive reactance. Its SI unit is ohm.

3) Why is the use of ac voltage preferred over dc voltage? Give two reasons.Ans.

(i) The generation of ac is more economical than dc.

(ii)Alternating voltage can be stepped up or stepped down as per requirement during transmission frompower generating station to the consumer

4) The peak value of an Alternating current is 6 amp, then r.m.s. value of current will be ?

$3\sqrt{2}$ A

IV) <u>SHORT ANSWER TYPE QUESTION</u>:- (2/3 MARKS EACH)

1) A bulb and a capacitor are connected in series to an a. c. source of variable frequency. How will the brightness of the bulb change on increasing the frequency of the a. c. source? Give reason.

2) Using phasor diagram derive an expression for the impedence of an series LCR Circuit. State the condition of resonance

3) Show graphically the variation of resistance ,inductive reactance and capacitive reactance with frequency of the applied ac voltage.

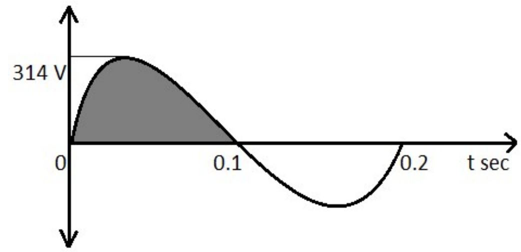
4) . State the formula for average power dissipation in a series LCR circuit. Hence find its value in case of a pure resister , pure inductor and pure capacitor.

5) A series *LCR* circuit connected to a variable frequency 230V source *L*= 5.0H, *C* = 80μF, *R* =40 Ω

(a) Determine the source frequency which drives the circuit in resonance.

(b) Obtain the impedance of the circuit and the amplitude of current at the resonating frequency

6) This figure shows the variation of an alternating emf with time. What is the average value of the emf for the shaded part of the graph?



7) The primary coil of transformer has 200 turns and the secondary coil has 1000 turns if the power output from the secondary at 1000V is 9kW calculate the primary voltage and the heat loss in the primary coil if the resistance of the primary coil is 0.2 ohm and efficiency of transformer is 90%.

.

VI) VERY LONG ANSWER TYPE QUESTION:- (5 MARKS EACH)

1) The primary coil of an ideal step-up transformer has 100 turns and transformation ratio is also 100. Theinput voltage and power are 220 V and 1100 W respectively. Calculate

(a) the number of turns in the secondary coil.

(b) the current in the primary coil.

(c) the voltage across the secondary coil.

(d) the current in the secondary coil.

(e) the power in the secondary coil.

(*a*) Transformation ratio $r = \dfrac{\text{Number of turns in secondary coil}(N_S)}{\text{Number of turns in primary coil }(N_P)}$

Given $N_P = 100$, $r = 100$

$\therefore$ Number of turns in secondary coil, $N_S = rN_P = 100 \times 100 = \mathbf{10{,}000}$

(*b*) Input voltage $V_P = 220$ V, Input power $P_{in} = 1100$ W

Current in primary coil $I_p = \dfrac{P_{in}}{V_P} = \dfrac{1100}{220} = \mathbf{5\ A}$

(*c*) Voltage across secondary coil (V_S) is given by

$$r = \frac{V_S}{V_P}$$

$\Rightarrow$ $V_S = rV_P = 100 \times 220 = 22{,}000\ \text{V} = \mathbf{22\ kV}$

(*d*) Current in secondary coil is given by

$$r = \frac{I_P}{I_S} \Rightarrow I_S = \frac{I_P}{r} = \frac{5}{100} = \mathbf{0.05\ A}$$

(*e*) Power in secondary coil, $P_{out} = V_S I_S = 22 \times 10^3 \times 0.05 = \mathbf{1100\ W}$

Obviously power in secondary coil is same as power in primary. This means that the transformer is ideal, *i.e.*, there are no energy losses.

SOLUTION OF STUDY MATERIAL CLASS XII PHYSICS CHAPTER 7 (ALTERNATING CURRENT)

I) MULTIPLE CHOICE QUESTIONs:- (1 MARK EACH)

1) (c) 2.5 *watt*
2) (d) $\frac{1}{400} sec$
3) (c) 19 *Hz* and 170 V
4) (b) $\frac{1}{2} I_p^2 R$
5) (b) $5\sqrt{3}\ V$
6) (c) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$
7) (c) Current leads the voltage by 60^o
8) (b) Resistance in the circuit is zero
9) (b) $\sqrt{R^2 + 4\pi^2 f^2 L^2}$
10) (a) $\tan^{-1}\frac{4}{3}$
11) (d) $\frac{C}{L}$
12) (c) 10 *ohm*
13) (c) Potential difference at capacitor and inductor have phase difference of $\pi/2$
14) (a) $2A$
15) (b) Is unity when the circuit contains an ideal resistance only

    (c) Is zero when the circuit contains an ideal inductance only
16) (c) 220 *V*, 2.2 *A*
17) (d) V_4
18) (b) The voltage leads the current by $\pi/2$
19) (c) X_1 is a capacitor and X_2 is an inductor
20) Frequency in *Hz* Phase lead of *N* over *M* in radians

    (b) 2.5 $-\pi/2$

II) ASSERTION & REASON:- (1 MARK EACH)

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) (a)
2) (c)
3) (a)
4) (b)
5) (a)

6) (b)

7) (d)

8) (a)

9) (b)

10) (b)

III) VARY SHORT ANSWER TYPE QUESTION:- (1 MARK EACH)

1) The principle of transformer is based upon the principle of mutual induction

2) Virtual resistance offered by a capacitor to the flow of an alternating current is called capacitive reactance. Its SI unit is ohm.

3) (i)The generation of ac is more economical than dc.
(ii)Alternating voltage can be stepped up or stepped down as per requirement during transmission frompower generating station to the consumer

4) 3 √2 A

IV) SHORT ANSWER TYPE QUESTION:- (2/3 MARKS EACH)

7) a) 50 rad/s b) 40 ohm

8) 200 V

9) 50 A ,500 W

VI) VERY LONG ANSWER TYPE QUESTION:- (5 MARKS EACH)

1)

(a) Transformation ratio $r = \dfrac{\text{Number of turns in secondary coil}(N_S)}{\text{Number of turns in primary coil }(N_P)}$

Given $N_P = 100$, $r = 100$

$\therefore$ Number of turns in secondary coil, $N_S = rN_P = 100 \times 100 = \mathbf{10{,}000}$

(b) Input voltage $V_P = 220$ V, Input power $P_{in} = 1100$ W

Current in primary coil $I_p = \dfrac{P_{in}}{V_P} = \dfrac{1100}{220} = \mathbf{5\ A}$

(c) Voltage across secondary coil (V_S) is given by

$$r = \frac{V_S}{V_P}$$

$\Rightarrow$ $V_S = rV_P = 100 \times 220 = 22{,}000\text{ V} = \mathbf{22\ kV}$

(d) Current in secondary coil is given by

$$r = \frac{I_P}{I_S} \Rightarrow I_S = \frac{I_P}{r} = \frac{5}{100} = \mathbf{0.05\ A}$$

(e) Power in secondary coil, $P_{out} = V_S I_S = 22 \times 10^3 \times 0.05 = \mathbf{1100\ W}$

Obviously power in secondary coil is same as power in primary. This means that the transformer is ideal, *i.e.*, there are no energy losses.

CHAPTER 8

Electromagnetic Waves

20 MCQ's

1. Maxwell in his famous equations of electromagnetism introduced the concept of
   (a) ac current
   (b) displacement current
   (c) impedance
   (d) reactance
2. The conduction current is same as displacement current when source is
   (a) ac only
   (b) dc only
   (c) either ac or dc
   (d) neither dc nor ac
3. If a variable frequency ac source is connected to a capacitor then with decrease in frequency the displacement current will
   (a) increase
   (b) decrease
   (c) remains constant
   (d) first decrease then increase
4. An electromagnetic wave can be produced, when charge is
   (a) moving with a constant velocity
   (b) moving in a circular orbit
   (c) falling in an electric field
   (d) both (b) and (c)
5. Which of the following statement is false for the properties of electromagnetic waves?
   (a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
   (b) The energy in electromagnetic waves is divided equally between electric and magnetic field vectors.
   (c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
   (d) These waves do not require any material medium for propagation.
6. Which of the following has/have zero average value in a plane electromagnetic wave?
   (a) Both magnetic and electric fields
   (b) Electric field only
   (c) Magnetic field only
   (d) None of these

7. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. The frequency of electromagnetic waves produced by the oscillator is
   (a) 10^6 Hz
   (b) 10^7 Hz
   (c) 10^8 Hz
   (d) 10^9 Hz

8. If E and B denote electric and magnetic fields respectively, which of the following is dimensionless?

(a) $\sqrt{\mu_0 \varepsilon_0}\ \frac{E}{B}$ (b) $\mu_0 \varepsilon_0\ \frac{E}{B}$

(c) $\mu_0 \varepsilon_0 \left(\frac{B}{E}\right)^2$ (d) $\frac{E}{\varepsilon_0}\frac{\mu_0}{B}$

9. The ultra high frequency band of radio waves in electromagnetic wave is used as in
   (a) television waves
   (b) cellular phone communication
   (c) commercial FM radio
   (d) both (a) and (c)
10. The waves used by artificial satellites for communication is
    (a) microwaves
    (b) infrared waves
    (c) radio waves
    (d) X-rays
11. Which of the following electromagnetic waves is used in medicine to destroy cancer cells?
    (a) IR-rays
    (b) Visible rays
    (c) Gamma rays
    (d) Ultraviolet rays
12. Electromagnetic waves are transverse wave in nature is evident by
    a. polarisation b. interference c. reflection d. diffraction
13. Which radiations are used in treatment of muscle ache?
    a. infrared b. ultraviolet c. microwave d. X-rays
14. From Maxwell,s hypothesis, a changing electric field gives rise to
    a. an electric field b. an induced emf c. a magnetic field d. a magnetic dipole.
15. The structure of solids is investigated by using
    a. cosmic rays b. X-rays c. γ-rays d. infrared rays
16. .If E and B represent electric and magnetic field vectors of the electromagnetic wave , the direction of propagation of electromagnetic wave is along
    a. E b. B c. B X E d. E X B
17. Which of the following has maximum penetrating power
    a. γ-rays b. ultraviolet radiation c. microwaves d radio waves
18. As compared to visible light microwave has frequency and energy:
    a. More than visible light b. less than visible light
    c. Equal to visible light d. frequency is less but energy is more
19. This equation $\int E.dl = -d\,\Phi B/dt$ represents which law?
    a. Gauss law b. Faraday's law c. Ampere's law d. none
20. The value of E/B is
    a. speed of object b. speed of light c. momentum of object d. none

10 Question Assertion and Reason

Assertion (A) and 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 true.

Q1. Assertion (A) : Accelerated charged particle produces electromagnetic waves.
Reason(R): Electromagnetic waves are charged one.

Q2. Assertion (A):visible light are transverse in nature.
Reason(R):All electromagnetic waves are transverse in nature .

Q3. Assertion (A) : Force exerted by electromagnetic wave on a perfect reflector is more than a Perfect absorber.
Reason (R) The rate of change in momentum of electromagnetic wave is more in case of a perfect reflector than a perfect absorber .

Q4. Assertion(A): Radio waves can be polarized .
Reason: Sound waves in air are longitudinal in nature.

Q5. Assertion(A) : Microwaves are considered suitable for radar system.
Reason(R): Microwaves are of shorter wavelength.

Q6. Assertion(A) : velocity of E M waves is given by relation $v=1/\sqrt{\mu\varepsilon}$
Reason(R): speed of E M waves depends on properties of electric and magnetic fields

Q7. Assertion(A) : E M waves are produced by time varying electric and magnetic fields.
Reason(R): E M waves are deflected by electric and magnetic field.

Q8. Assertion(A) : Microwaves are used in microwave oven.
Reason(R): The resonant frequency of water molecule is close to microwave.

Q9. Assertion(A) : when radio active nucleus disintegrates certain radiations are produced.
Reason(R): This radiations having frequency close to gamma rays.

Q10. Assertion(A) : Maxwell found an inconsistency in the Ampere's law and suggested the existence of an additional current, called displacement current.
Reason(R): To remove this inconsistency. This displacement current is due to time-varying electric field

Very Short Answers

Q1. What is displacement current?
Q2. What is source of EM waves?
Q3. If propagation of EM wave along Y direction electric field along Z direction than direction of electric field will be?
Q4. Which EM waves are used for photography during fog conditions?
Q5. Which EM waves are used to treat cancer tumor?

Answers

MCQ's

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

Assertion and Reason

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

Very short Answers

Ans 1. Current produced by time varying electric field or time varying magnetic field.
Ans 2. Source of EM waves is oscillating charged particle.
Ans 3. Direction of electric field is along X axis.
Ans 4. X rays are used.
Ans 5. Gamma rays are used.

CHAPTER 9 RAY OPTICS

MCQs

1.A glass lens is immersed in water. What will be the effect on the power of lens?

(A) increase (B) decrease (C) constant(D) not depends

2.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 a

(A) infinity(B) 20cm(C) 40cm(D) 60cm

3.The characteristic feature of light which remains unaffected on refraction is

(A) speed(B) frequency(C) wavelength(D) velocity of light

4. The air bubble inside water shine due to

(A) Reflection(B) Refraction(C) T.l.R (D) None of these

5. When a convex lens placed inside a transparent medium of refracting index greater than that of its own material

(A) It behaves as concave lens

(B) It behaves as convex lens

(C) It behaves as a glass slab

(D) It behaves as a glass prism

6.The angle of deviation for a prism is greatest for:

(A) violet(B) red(C) orange(D) yellow

7. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then

(A) the magnification is 1000

(B) the length of the telescope tube is 20.02 m

(C) the image formed of inverted

(D) all of these

8. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will

(A) become zero

(B) become infinite

(C) become small, but non-zero

(D) remain unchanged

9. A man stands in front of a mirror of special shape. He finds that his image has a very small head, a fat body, and legs of normal size. What can we say about the shapes of the three parts of the mirror?

(A) Convex, Concave, Plane

(B) The plane, Concave, Convex

(C) Concave, Convex, Plane

(D) Convex, Plane, Concave

10.Which of the following colour of white light deviated most when passes through a prism?

A. Red light B. Violet light C. Yellow light D. Both (i) and (ii)

11. 27. A convergent lens will become less convergent in :

A. oil B. water C. both of (i) and (ii) D. none of these

12. 29. When light is refracted into a medium,

A. its wavelength and frequency both increase

B. its wavelength increases but frequency remains unchanged

C. its wavelength decreases but frequency remains unchanged
D. its wavelength and frequency both decrease
13. 33. When a beam of light is incident on a plane mirror, it is found that a real image is formed. The incident beam must be
A. Converging B. Diverging
C. Parallel D. Formation of real image by a plane mirror is impossible
14. 49. A man runs towards a mirror at a rate of 6 m/s if we assume the mirror to be at rest, the image will have velocity -
A. +12 m/s B. -12 m/s C. +6 m/s D. -6 m/s
15. 50. Refractive index of water is 5/3. A light source is placed in water at a depth of 4 m. Then what must be the maximum radius of disc placed on water surface so that the light of source can be stopped ?
A. 3 m B. 4m C. 5m D. Infinity
16. 56. Which of the following is possible application of fibre optics?
A. Endoscopy
B. High speed internet traffic
C. Radio, TV & Telephone signals
D. All of these
17. Focal length of the objective and eyepiece of a telescope are respectively 50 cm and 5 cm. The magnifying power of the telescope in its normal adjustment is
A. 0.1 B. 10 C. 11 D. 1.1
18. Total internal reflection occurs when
A. Light travels from a denser to rarer medium
B. Light travels from a denser to rarer medium. and the angle of incidence is less than the critical angle
C. Light travels from a rarer to denser medium. and the angle of reflection is less than the critical angle
D. Light travels from a denser to rarer medium. and the angle of incidence is greater than the critical angle
19. Objects are visible in light due to :
A. Scattering B. Refraction C. Absorption D. Fluorescence
20. 72. A lens behaves as a converging lens in air and as a diverging lens in water. The refractive index of the material is :
A. Equal to unity B. Equal to 1.33 C. Between unity and 1.33 D. Greater than 1.33

Assertion & Reasoning Based MCQs

For question numbers 1 to 10, 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
1. Assertion(A) : The height of an object is always considered positive.
Reason (R) : An object is always placed above the principal axis in the upward direction.
2. Assertion(A): Virtual images are always erect.
Reason (R) : Virtual images are formed by diverging lenses only.

3. Assertion(A) : Refractive index has no units.
Reason (R) : The refractive index is a ratio of two similar quantities.
4. Assertion (A): Air bubbles shine in water.
Reason (R): Air bubbles shine in water due to total internal reflection of light.
5. Assertion (A): A diamond of refractive index $\sqrt{6}$ is immersed in a liquid of refractive index $\sqrt{3}$. If light travels from diamond to liquid, total internal reflection will take place when angle of incidence is 30°.
Reason (R): $\mu = 1/\sin C$, where μ is the refractive index of diamond with respect to the liquid
6. Assertion : Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light.
7. Assertion : Assertion : The optical instruments are used to increase the size of the image of the object.
Reason : The optical instruments are used to increase the visual angle.
8. Assertion :- Assertion : An object is placed at a distance of f from a convex mirror of focal length f its image will form at infinity.
Reason : The distance of image in convex mirror can never be infinity .
9. Assertion:- The focal length of an equiconvex lens of radius of curvature R made of material of refractive index $\mu = 1.5$, is R.
Reason : The focal length of the lens will be R/2.
10. Assertion : The focal length of the convex mirror will increase, if the mirror is placed in water.
Reason : The focal length of the lens will be R/2.

Very Short Answer Type Questions (VSA)

Q.1 Two thin lenses of power -2D and 2D are placed in contact coaxially. What is the focal length of the combination?
Q.2 When red light passing through a convex lens is replaced by light of blue colour, how will the focal length of the lens change?
Q.3 A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens?
Q.4 An object is kept in front of a concave lens. What is the nature of the image formed?
Q.5 Two thin lenses of power -4D and 2D are placed in contact coaxially. Find the focal length of the combination.
Q 6. When a thin convex lens is put in contact with a thin concave lens of the same focal length, the resultant combination had focal length equal to:
Q .7 The magnifying power of an astronomical telescope can be increased if we:
Q .8 Two convex lenses of focal lengths 0.3 m and 0.05 m are used to make a telescope. The distance kept between them is equal to :
Q .9 If refractive indices for water and glass are 4/3 and 5/3 respectively and light is tending to go from glass to water, the critical angle is :
Q .10 A ray of light of wavelength 600 nm propagates from air into a medium. If its wavelength in the medium becomes 400 nm, the refractive index of the medium is

Short Answer Type Questions

Q.1 Why convex mirror used as drivers mirror?

Q. 2 When monochromatic light travels from one medium to another, its wavelength change but frequency remains the same. Explain.

Q. 3 A concave mirror and a convex lens are held in water. What change, if any, do you expect in the irrespective focal lengths as compared to their values in air?

Q.4 What is meant by dispersion of light.

Q.5Write two merits of a reflecting type telescope over refracting type telescope.

Q.6 A glass lens of refractive index 1.5 is placed in a trough of liquid. What must be the refractive index of the liquid in order to mark the lens disappear?

Q.7 How does the power of a convex lens vary, if the incident red light is replaced by violet light?

Q.8 How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced with red light?

Q.9 How does the angle of minimum deviation of a glass prism of refractive index 1.5 change, if it is immersed in a liquid of refractive index 1.3?

Q.10 State the conditions for the phenomenon of total internal reflection to occur.

Long Answer Type Questions

Q.1 (i)Draw a ray diagram to show the refraction of light through a glass prism. Hence obtain the relation for angle of deviation in terms of angle of incidence, angle of emergence and angle of prism.

(ii)) A ray of light incident on an equilateral glass prism shows minimum deviation of 30o . Calculate the speed of light through the prism.

Q.2 (i) Derive Lens Maker's Formula by using suitable diagram.

(ii) A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm each other. A point object lies 60 cm in front of the convex lens. Determine the nature position of the image formed.

Q.3 Define magnifying power of a microscope. With the help of a ray diagram, explain the formation of image by a compound microscope. Derive the expression for its magnifying power when the final image is formed at the near point.

Q.4 (i) Calculate the distance of an object of height h from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification 2

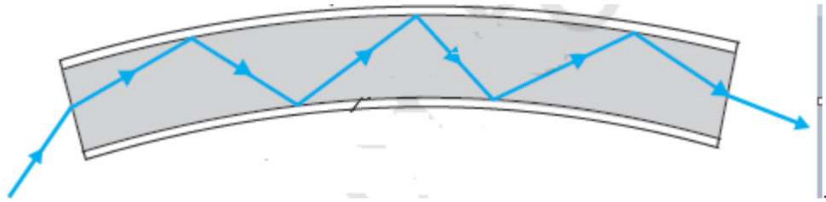
(ii) The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.

Q.5 (i) A ray of light, incident on an equilateral glass prism ($\mu_g = \sqrt{3}$) moves parallel to the base line of the prism inside it. Find the angle of incidence for this ray.

(ii) Draw a labelled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope.

CASE BASED QUESTIONS

1.Nowadays optical fibres are extensively used for transmitting audio and video signals through long distances. Optical fibres too make use of the phenomenon of total internal reflection. Optical fibres are fabricated with high quality composite glass/quartz fibres. Each fibre consists of a core (Inner) and cladding (outer).When a signal in the form of light is directed at one end of the fibre at a suitableangle, it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end



Since light undergoes total internal reflection at each stage, there is no appreciable loss in the intensity of the light signal. Optical fibres are fabricated such that light reflected at one side of inner surface strikes the other at an angle larger than the critical angle. Even if the fibre is bent, light can easily travel along its length. Thus, an optical fibre can be used to act as an optical pipe.

i. Light cannot escape an optical fibre due to refraction. This is because:
a) Critical angle for core with reference to cladding is too large
b) Its critical angle for core with reference to cladding is too small
c) The core is transparent
d) none of above.

ii. For total internal reflection to take place
(a) the ray must go from rarer to denser medium.
(b) angle of incidence should be less than critical angle.
(c) the ray must go from denser to rarer medium.
(d) angle of incidence should be zero.

iii. In optical fibre
(a) refractive index of core is kept less than that of cladding
(b) refractive index of core is kept more than that of cladding
(c) refractive index of core is equal to that of cladding
(d) refractive index of core is 1

iv. Find the refractive index of the core of an optical fiber if the critical angle is 60∘ and the refractive index of the cladding is $\sqrt{3}$?
(a) $\sqrt{2}$ (b) 2 (c) 3 (d) 2.5

v. If angle of incidence is greater than critical angle than
(a) very small amount of light refract to cladding.
(b) small amount of light gets reflected in core.
(c) total light is refracted into cladding
d) total light gets reflected in core.

2. Power (P) of a lens is given by-reciprocal of focal length (f) of the lens i.e.,$P=1/f$ where f is in meter and P is in diopter. For a convex lens, power is positive and for a concave lens, power is negative. When a number of thin lenses of powers P_1, P_2, P_3, ...are held in contact with one another, the power of the combination is given by algebraic sum of the powers of all the lenses i.e., $P = P_1 + P_2 + P_3 + ...$

(i) A convex and a concave lens separated by distance d are then put in contact. The focal length of the combination
(a) becomes 0 (b) remains the same (c) decreases (d) increases.

(ii) If two lenses of power +1.5D and +1.0D are placed in contact, then the effective power of combination will be
(a) 2.5 D (b) 1.5D (c) 0.5 D (d) 3.25 D

(iii) If the power of a lens is +5 diopter, what is the focal length of the lens?

(a) 10 cm (b) 20 cm (c) 15 cm (d) 5 cm

(iv) **Two thin lenses of focal lengths +10 cm and -5 cm are kept in contact. The power of the combination is**

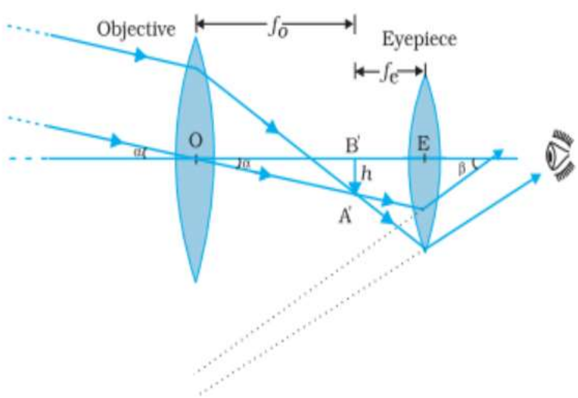
(a) -10 D (b) -20 D (c) 10 D (d) 15 D

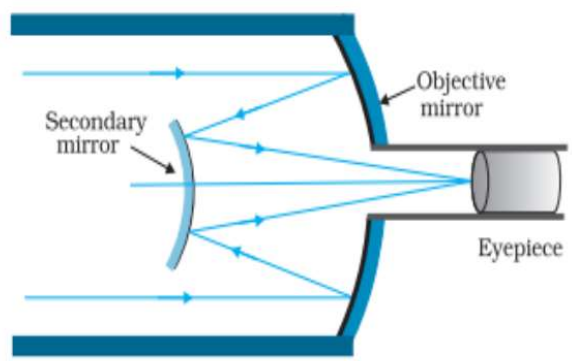
(v) **A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. The system will be**

(a) converging in nature (b) diverging in nature

(c) can be converging or diverging (d) None of the above

3. The telescope is used to provide angular magnification of distant objects. It also has an objective and an eyepiece. But here, the objective has a large focal length and a much larger aperture than the eyepiece. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point. The eyepiece magnifies this image producing a final inverted image. The magnifying power m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye. The main considerations with an astronomical telescope are its light gathering power and its resolution or resolving power. The former clearly depends on the area of the objective. With larger diameters, fainter objects can be observed. The resolving power, or the ability to observe two objects distinctly, which are in very nearly the same direction, also depends on the diameter of the objective. So, the desirable aim in optical telescopes is to make them with objective of large diameter. Further, it is rather difficult and expensive to make such large sized lenses which form images that are free from any kind of chromatic aberration and distortions. For these reasons, modern telescopes use a concave mirror rather than a lens for the objective. Telescopes with mirror objectives are called reflecting telescopes. They have several advantages. First, there is no chromatic aberration in a mirror. Second, if a parabolic reflecting surface is chosen, spherical aberration is also removed





i. An astronomical telescope consists of thin lenses,36cm apart and has a magnifying power 8. The focal lengths of objective and eyepiece are

a. Focal length of objective is 32cm and that of eyepiece is 4cm

b. Focal length of objective is 4 cm and that of eyepiece is 32cm

c. Focal length of objective is 8cm and that of eyepiece is 4cm

d. Focal length of objective is 4 cm and that of eyepiece is 8cm

ii. A pair of stars of actual separation one minute of are is observed with an astronomical telescope of magnifying power 100. What will be the separation of the image of the pair in degree?

a. 1.67’ b. 1.85’ c. 4’ d. 8’

iii. The final image formed in an astronomical telescope with respect to the object is :

a. real, inverted b. real, erect c. virtual, erect d. virtual, inverted

iv. The characteristic feature of light which remains unaffected on refraction is

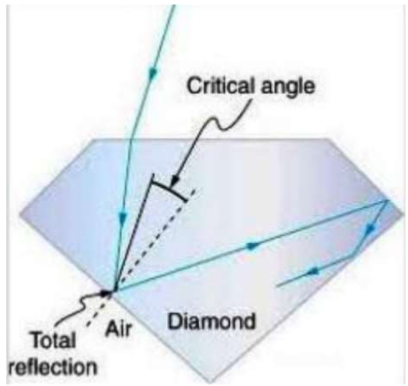
a. Speed b. Frequency c. Wavelength d. Velocity of light

v. An astronomical refracting telescope will have larger angular magnification and high angular resolution, when it has an objective lens of

a. Large focal length and large diameter   b. Large focal length and small diameter

c. small focal length and large diameter   d. Small focal length and small diameter

4. Sparking Brilliance of Diamond: The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.



i. Light cannot easily escape a diamond without multiple internal reflections. This is because:

a) Its critical angle with reference to air is too large

b) Its critical angle with reference to air is too small

c) The diamond is transparent

d) Rays always enter at angle greater than critical angle

ii. The critical angle for a diamond is 24.4o. Then its refractive index is

a) 2.42

b) 0.413

c) 1

d) 1.413

iii. The basic reason for the extraordinary sparkle of suitably cut diamond is that

a) It has low refractive index

b) It has high transparency

c) It has high refractive index

d) It is very hard

iv. A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will

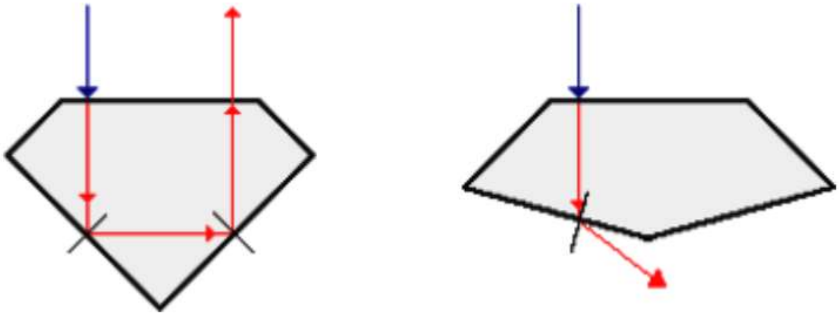
a) will depend on the nature of the liquid

b) decrease

c) remains the same

d) increase

v. The following diagram shows same diamond cut in two different shapes. The brilliance of diamond in the second diamond will be:

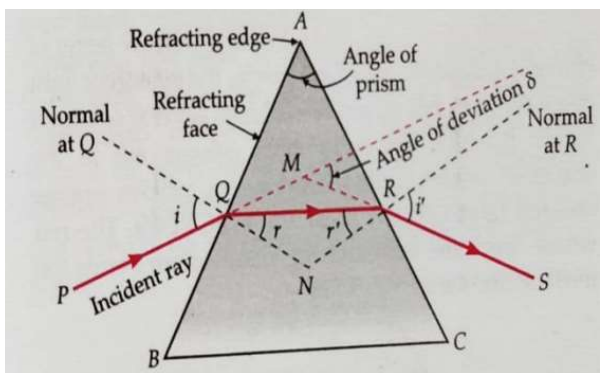


a) less than the first b) greater than first

c) same as first d) will depend on the intensity of light

5. A prism is a transparent refracting body bounded by plane faces which are inclined to each other at a particular angle called angle of prism denoted by A . When a ray of light passes through a prism, it suffers refraction twice and hence the ray deviates through a certain angle from its original path. The angle between the incident ray and emergent ray is called angle of deviation D and is related as (i +e =A + D) where i= angle of incidence and e =angle of emergence. The angle of deviation is also related as D = (μ-1) A, where μ is refractive index of the material of prism. The refractive index of the material of the prism is also given by

$$\mu == \frac{\text{Sin } (A+Dm)/2}{\text{Sin } A/2}$$



i. When light passes through a prism, the angle of deviation will be minimum if

A. i = e

B. Angle of refraction , r = r'

C. Refracted ray inside the prism is parallel to the base of prism

D. All the above

ii. For which colour the angle of deviation is minimum?

A. Red B. Blue C. Violet D. Yellow

iii. The deviation through the prism is maximum when angle of incidence is

A. 45^0 B. 70^0 C. 90^0 D. 60^0

iv. The refractive index of the material of an equilateral prism for which the angle of minimum deviation $60^0$is

A. 1 B. 2 C. $\sqrt{3}$ D. $\sqrt{2}$

v. A ray of light incident on an equilateral glass prism shows minimum deviation of 30^0. The speed of light in that prism is

A. $3x10^8$ m/s B. $2.12x10^8$ m/s C. $2x10^8$ m/s D. $1.5x10^8$ m/s

****

MCQs

ANSWER KEY

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

Assertion & Reasoning Based MCQs

ANSWER KEY

1.A	2.C	3.A	4.A	5.D	6.B	7.D	8.C	9.B	10.B

Very Short Answer Type Questions (VSA)

Ans. 1

Power of combination = -2D + 2D = 0

Focal Length =1/0=infinite

Ans. 2

Focal length of lens will decrease μv>μr

Ans3.

Converging.

Ans4

When an object is kept in front of a concave lens, the nature of image formed is virtual, erect and diminished.

Ans.5

Power of combination = – 4D + 2D = – 2D

f=100/-2=-50cm

Ans.6 infinite

Ans.7 Increase the focal length of the objective lens

Ans.8 0.175 cm

Ans.9 $\text{Sin}^{-1}(4/5)$

Ans. 10 1.5

Short Answer Type Questions

Q.1

Ans. The convex mirror is used as a driver's mirror as it gives a wide field of view of the traffic. However, it does not give the correct idea of the speed of the vehicles coming behind. As the convex mirror gives an erroneous idea of the traffic, it is not a perfect driver's mirror.

Q. 2

Ans. When monochromatic light travels from one medium lo another, its speed changes. The change in speed occurs due to change in wavelength. The frequency of light remains the same, as it is an inherent characteristic.

Q.3

Ans. The focal length of a concave mirror has nothing to do with the medium in which it is placed. Hence, it will remain unchanged. However, the focal length of a convex lens would change, when held in water. It increases due to the fact that the relative refractive index of the material of lens w.r.t. water is less than its refractive index w.r.t. air.

Q.4

Ans. The splitting of white light into its constituent colors on passing through a prism is called dispersion of light.

Q.5

Ans.

1. As the objective is a spherical mirror, the reflecting type telescope is free from chromatic aberration.
2. The defect of spherical aberration is reduced by using parabolic mirror as objective.

Ans. 6 In order to make the lens disappear the refractive index of liquid must be equal to 1.5 i.e. equal to that of glass lens

Ans. 7 According to Lens Maker's formula

Lens Maker's formula

$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\because \quad \mu_{violet} > \mu_{red}$

$\therefore$ power of the lens will be increased.

Ans. 8 We know that λ red > λ violet, therefore μ red < μ violet and hence δ red < δ violet.

When incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.

Ans. 9

Here ${}^a\mu_g = 1.5$ and ${}^a\mu_w = 1.3$

$\because \quad \delta = (\mu - 1)\,A$

For deviation in air, $\mu = \dfrac{\mu_g}{\mu_a} = \dfrac{1.5}{1} = 1.5$

$\therefore \quad \delta = (1.5 - 1) \times 60° = 30°$

For deviation in water, $\mu = \dfrac{\mu_g}{\mu_w} = \dfrac{1.5}{1.3} = 1.15$

$\therefore \quad \delta = (1.15 - 1) \times 60° = 0.15 \times 60° = \mathbf{9°}$

Hence angle of deviation is decreased.

Ans. 10

Two essential conditions for total internal reflection are :

1. Light should travel from an optically denser medium to an optically rarer medium.
2. The angle of incidence in the denser medium must be greater than the critical angle for the two media.

Long Answer

ANSWER

From the quadrilateral $AQNR$,

$$A + \angle QNR = 180^\circ$$

From the triangle QNR,

$$r + r' + \angle QNR = 180^\circ$$

$$\therefore \quad A = r + r'$$

Now, from the triangle MQR, the *deviation produced* by the prism is

$$\delta = \angle MQR + \angle MRQ$$

$$= (i - r) + (e - r')$$

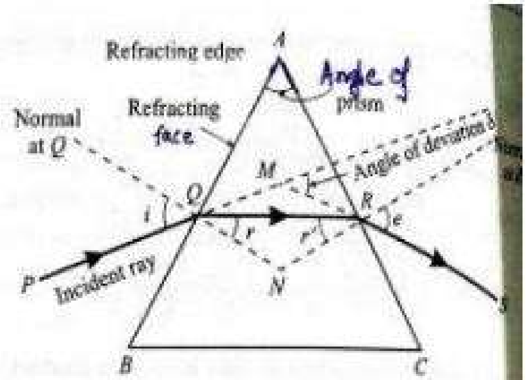


Figure 9.49 Refraction through a prism.

or δ = deviation at the first face + deviation at the second face $= (i + e) - (r +$

or $\delta = i + e - A$

or $i + e = A + \delta$

So when a ray of light is refracted through a prism, the sum of angle of incidence is equal and the angle of emergence is equal to the sum of the angle of prism and angle of deviation.

Ans 1 (i)

(ii)

Solution. Here $A = 60^\circ$, $\delta_m = 30^\circ$

Refractive index,

$$\mu = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}} = \frac{\sin \frac{60^\circ + 30^\circ}{2}}{\sin \frac{60^\circ}{2}}$$

$$= \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2} = 1.414$$

Velocity of light in glass,

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.414}$$

$$= 2.12 \times 10^8 \text{ ms}^{-1}$$

Ans 2

ANS (i)

Lens Maker's Formula:

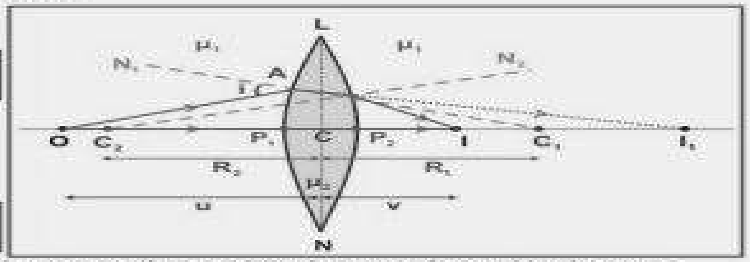
For refraction at LP_1N,

$$\frac{\mu_1}{CO} + \frac{\mu_2}{CI_1} = \frac{\mu_2 - \mu_1}{CC_1}$$

(as if the image is formed in the denser medium)

For refraction at LP_2N,

$$\frac{\mu_2}{-CI_1} + \frac{\mu_1}{CI} = \frac{-(\mu_1 - \mu_2)}{CC_2}$$



(as if the object is in the denser medium and the image is formed in the rarer medium)

Combining the refractions at both the surfaces,

$$\frac{\mu_1}{CO} + \frac{\mu_1}{CI} = (\mu_2 - \mu_1)\left(\frac{1}{CC_1} + \frac{1}{CC_2}\right)$$

Substituting the values with sign conventions,

$$\frac{1}{-u} + \frac{1}{v} = \frac{(\mu_2 - \mu_1)}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

ii) Ans : $1/v - 1/u = 1/f$

$1\ v = 1/120 + /1(-60)$

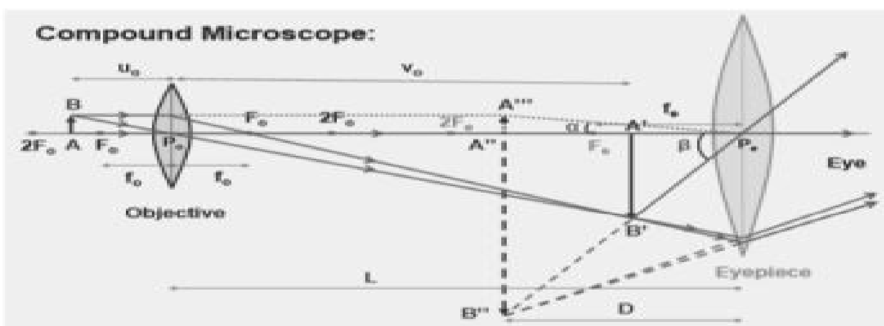
$\Rightarrow v = 60$ cmThe positive sign shows that the image is formed to the right of the lens.

$1/v + 1/u = /1f$

$u = -60$ and $f = 20\ cm$

v =15cm

And. 3 The magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final virtual image to the angle subtended at the eye by the object when both lies at the least distance of distinct division from eye.



$$M = \frac{\beta}{\alpha}$$

Since angles are small, $\alpha = \tan\alpha$ and $\beta = \tan\beta$

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$M = \frac{A''B''}{D} \times \frac{D}{A''A'''}$$

$$M = \frac{A''B''}{D} \times \frac{D}{AB}$$

$$M = \frac{A''B''}{AB}$$

$$M = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB}$$

$$M = M_e \times M_o$$

$$M_e = 1 - \frac{v_e}{f_e} \quad \text{or} \quad M_e = 1 + \frac{D}{f_e} \quad (v_e = -D = -25\text{ cm})$$

and $M_o = \frac{v_o}{-u_o}$ $\therefore$ $M = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right)$

Since the object is placed very close to the principal focus of the objective and the image is formed very close to the eyepiece, $u_o \approx f_o$ and $v_o \approx L$

$$M = \frac{-L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

or $M = \frac{-L}{f_o} \times \frac{D}{f_e}$ (Normal adjustment i.e. image at infinity)

Ans.4 (i) Given : f = -10 cm; Magnification, m = 2

To calculate : u = ?

We have : $\frac{h_1}{h_0} = \frac{-v}{u}$

Mirror formula : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

As image formed is to be real

$\frac{v}{u} = 2$ or $v = 2u$

or $\frac{-1}{10} = \frac{1}{2u} + \frac{1}{u}$ or $\frac{-1}{10} = \frac{3}{2u}$

or $u = -15$

∴ **Object distance = 15 cm**

(ii) Given : $R_1 = 10$ cm,

$R_2 = -15$ cm,

f = 12 cm

Using lens maker's formula, we have

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{12} = (n-1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$

$$\Rightarrow \frac{1}{12} = (n-1)\left(\frac{3+2}{30}\right)$$

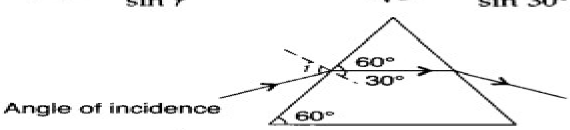
$$\Rightarrow (n-1) = \frac{30}{5} \times \frac{1}{12} = \frac{1}{2}$$

$$\therefore n = 1 + \frac{1}{2} = \frac{3}{2} = 1.5$$

Ans.5 (i)

$\mu_g = \sqrt{3} = {}_1n_2$

${}_1n_2 = \frac{\sin i}{\sin r}$ ∴ $\sqrt{3} = \frac{\sin i}{\sin 30°}$

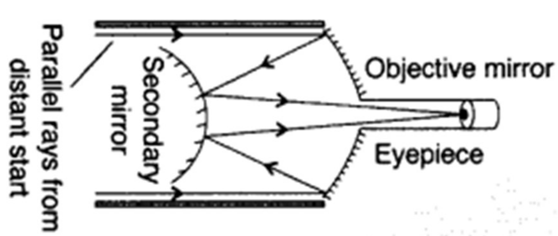


$\Rightarrow \sin i = \sqrt{3} \times \sin 30° = \sqrt{3} \times \frac{1}{2} = \frac{1.732}{2}$

$\Rightarrow \sin i = 0.866$

∴ Angle of incidence, i = 60°

(ii) Answer:



Two advantages over the refracting telescope:

1. There is no chromatic aberration as the objective is a mirror.
2. Spherical aberration is reduced using mirror objective in the form of a paraboloid.
3. Image is brighter compared to that in a refracting type telescope.
4. Higher resolving power.

CASE BASED QUESTIONS

ANSWER KEY

1.

i. a	**ii. c**	**iii. b**	**iv. b**	**v. d**

2.

i. c	**ii. a**	**iii. b**	**iv. a**	**v. b**

3.

i. a	**ii. a**	**iii. d**	**iv. b**	**v. a**

4.

i. b	**ii. a**	**iii. c**	**iv. d**	**v. a**

5.

i. d	**ii.a**	**iii. c**	**iv. c**	**v. b**

CHAPTER-10 WAVE OPTICS

Multiple Choice Questions

Choose the most appropriate option out of the given four choices in each question.

1. Which of the following phenomena is not explained by wave theory of light?
   a) Reflection b) Refraction c) Polarization d) Photoelectric effect
2. The principle of superposition of waves is applicable to:
   a) Longitudinal waves only
   b) Transverse waves only
   c) Both longitudinal and transverse waves
   d) Neither longitudinal nor transverse waves
3. In Young's double-slit experiment, the fringe width is:
   a) Directly proportional to the wavelength of light
   b) Inversely proportional to the wavelength of light
   c) Directly proportional to the slit separation
   d) Inversely proportional to the distance between slits and screen
4. When light is reflected its phase
   (a) does not change (b) changes by π (c) changes by 2 π (d) depends on speed
5. The angular width of the central maximum in a single-slit diffraction pattern is:
   a) Directly proportional to the slit width
   b) Inversely proportional to the slit width
   c) Directly proportional to the wavelength of light
   d) Inversely proportional to the wavelength of light
6. In a double-slit experiment, if the wavelength of light used is increased, the fringe separation:
   a)Increases b)Decreases c)Remains unchanged d)First increases, then decreases
7. Which of the following colours of light has the shortest wavelength?
   a) Red b) Yellow c) Green d) Blue
8. The term 'coherent sources' refers to sources that emit light waves which are:
   a) Of the same amplitude b) Of the same frequency
   c) In phase or have a constant phase difference d) Of the same speed
9. The intensity of light at a point in an interference pattern is directly proportional to:
   a) The amplitude of light waves
   b) The square of the amplitude of light waves
   c) The frequency of light waves
   d) The wavelength of light waves
10. The condition for constructive interference in thin films is that the path difference should be:
    a) An odd multiple of half-wavelength
    b) An even multiple of half-wavelength
    c) An odd multiple of quarter-wavelength
    d) An integral multiple of half-wavelength
11. When two non- coherent sources of intensity I_1 and I_2 superimpose the resultant intensity at a general point will be
    (a) $I_1 + I_2$ (b) $I_1 - I_2$ (c) $I_1 . I_2$ (d) $\sqrt{I_1^2 + I_2^2}$
12. In Young's double slit experiment if the slits width are in the ratio 1:9 , then the ratio of the intensity of maxima to minima will be
    (a) 9:1 (b) 3:1 (c) 4:1 (d) 25:16
13. When unpolarized light passes through a polarizer, the intensity of the transmitted light is:

a) Halved b) Doubled c) Unchanged d) Zero

14. In a Newton's rings experiment, the rings are:
    a) Concentric circles with bright and dark fringes
    b) Concentric circles with only bright fringes
    c) Parallel lines with bright and dark fringes
    d) Parallel lines with only bright fringes

15. The speed of light in a medium is given by the relation:
    a) $v=cn$v=nc b) $v=cn2$v=2cn
    c) $v=cn$v=cn d) $v=2cn$v=n2c

16. Which of the following phenomena can be explained by the wave nature of light but not by the particle nature of light?
    a) Photoelectric effect b)Compton effect c) Interference d) Blackbody radiation

17. The resolving power of a diffraction grating depends on:
    a) The wavelength of light used
    b) The number of lines per unit length on the grating
    c) The intensity of the light source
    d) The distance between the grating and the screen

18. In an interference pattern produced by two coherent sources of light, the position of the dark fringe corresponds to:
    a) Zero path difference
    b) Half-wavelength path difference
    c) Wavelength path difference
    d) Odd multiple of half-wavelength path difference

19. If two coherent waves of same intensity I each superimpose then the intensity at a point where path difference is $\lambda/3$ will be
    (a) I (b) 2I (d) 3I (d) I/3

20. Two slits 4mm apart are illuminated by light of wavelength 6000Å. What will be the fringe width on a screen placed 2m from the slits
    (a) 0.12mm (b)0.3mm (c) 3mm (d) 4mm

Given below are two statements labelled as Assertion (A) and Reason (R)

Select the most appropriate answer from the options given below:

(i) Both A and R are true and R is the correct explanation of A

(ii) Both A and R are true but R is not the correct explanation of A.

(iii)A is true but R is false.

(iv) A is false and R is also false.

1. Assertion (A): In Young's double-slit experiment, if one of the slits is covered, the interference pattern disappears.
   Reason (R): Interference occurs due to the superposition of waves from two coherent sources
2. Assertion (A): Diffraction is more pronounced when the size of the aperture is comparable to the wavelength of light.
   Reason (R): Diffraction is a consequence of the wave nature of light
3. Assertion (A): Light waves can be polarized.
   Reason (R): Light waves are transverse in nature.
4. Assertion (A): The central maximum in a single-slit diffraction pattern is wider than the other maxima.
   Reason (R): The central maximum is the result of constructive interference at all points on the slit.

5. Assertion (A): In a double-slit experiment, if the wavelength of light is increased, the fringe width increases.
   Reason (R): Fringe width is directly proportional to the wavelength of light used
6. Assertion (A): In the phenomenon of interference, the points where the waves meet in phase produce bright fringes.
   Reason (R): Bright fringes are produced where the path difference is an odd multiple of half-wavelength.
7. Assertion (A): Newton's rings are formed due to the interference of light reflected from the two surfaces of a thin air film.
   Reason (R): The thickness of the air film varies uniformly.
8. Assertion (A): The intensity of polarized light transmitted through an analyzer is maximum when the transmission axis of the analyzer is parallel to the polarization direction.
   Reason (R): The analyzer allows maximum transmission of light polarized along its transmission axis
9. Assertion (A): The resolving power of a microscope increases with an increase in the wavelength of light used.
   Reason (R): The resolving power of a microscope is inversely proportional to the wavelength of light
10. Assertion (A): In a diffraction grating, the angular separation of the principal maxima decreases with an increase in the wavelength of light used.
    Reason (R): The angular position of the principal maxima is directly proportional to the wavelength of light.

<u>VERY SHORT ANSWER TYPE QUESTIONS</u>

1. What is the principle behind the Young's double-slit experiment?
2. State the reason, why two independent sources of light cannot be considered as coherent sources
3. Define fringe width in the context of Young's double-slit experiment.
4. What is the condition for constructive interference in terms of path difference?
5. Name the phenomenon that causes the bending of light around corners of an obstacle.
6. What is the formula for the angular width of the central maximum in a single-slit diffraction pattern?
7. What happens to the intensity of light when two coherent light waves interfere destructively?
8. A interference pattern is obtained using a red light, what will be effect on interference fringes, if the red light is replaced by blue light?
9. Draw a diagram to show refraction of a plane wave front incident in a convex lens and hence draw the refracted wave front
10. In a diffraction grating, what does an increase in the number of lines per unit length do to the resolving power?

<u>SHORT ANSWER TYPE QUESTIONS</u>

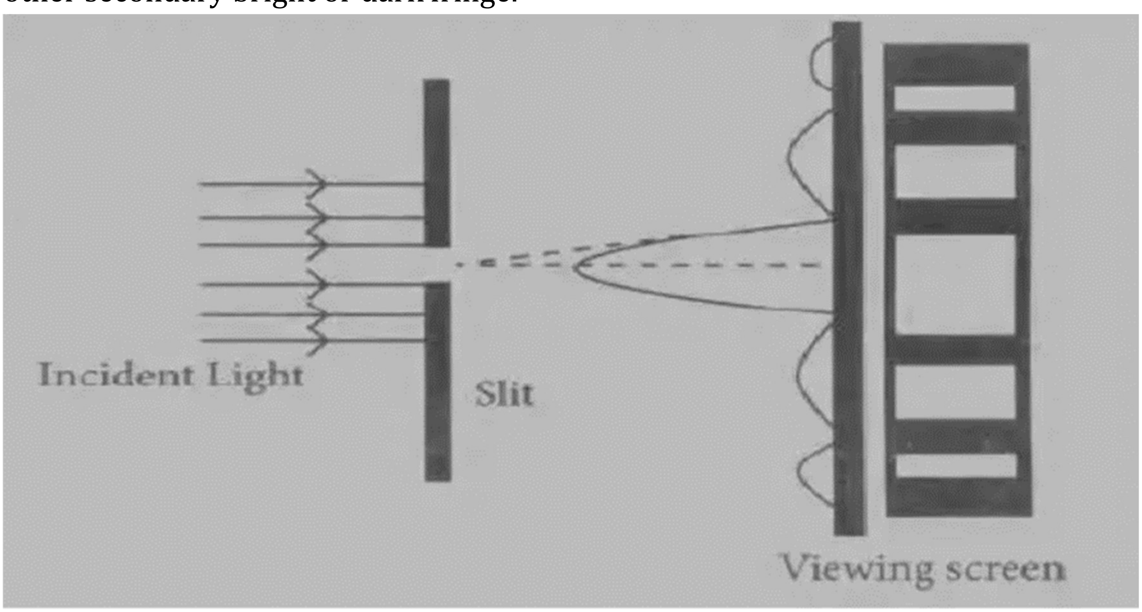
1. Draw reflected wavefront If a plane wave front is made Incident on the surface of (a) Concave Mirror (b)Convex lens
2. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width ‘a’. If the distance between the slits and the screen is 0.8 m and the distance of 2nd order maximum from the centre of the screen is. 15 mm, calculate the width of the slit
3. What are the salient features of corpuscular theory of light?
4. Distinguish between interference and diffraction
5. Two slits are made 1mm apart and the screen is placed away. What should be the width of each

slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern.

6. A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.
7. A beam of light consisting of two wavelength 800 nm and 600 nm is used to obtain the interference fringes in young's double slit experiment on a screen held 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum, where the bright fringes of the two wavelengths coincide.
8. In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is λ/3.
9. Prove laws of refraction with the help of Huygen's principle
10. Two monochromatic waves emanating from two coherent sources have the displacements represented by $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$, where ϕ is the phase difference between the two displacements.
    (a)Show that the resultant intensity at a point due to their superposition is given by $I = 4I_0 \cos^2 \phi/2$, where $I_0 = a^2$
    (b) Hence obtain the conditions for constructive and destructive interference

<u>CASE STUDY BASED QUESTIONS</u>

1. 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 screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that
   (I) 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) A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 A and diffraction bands are observed on a screen 0.5 m 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

(ii) A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?

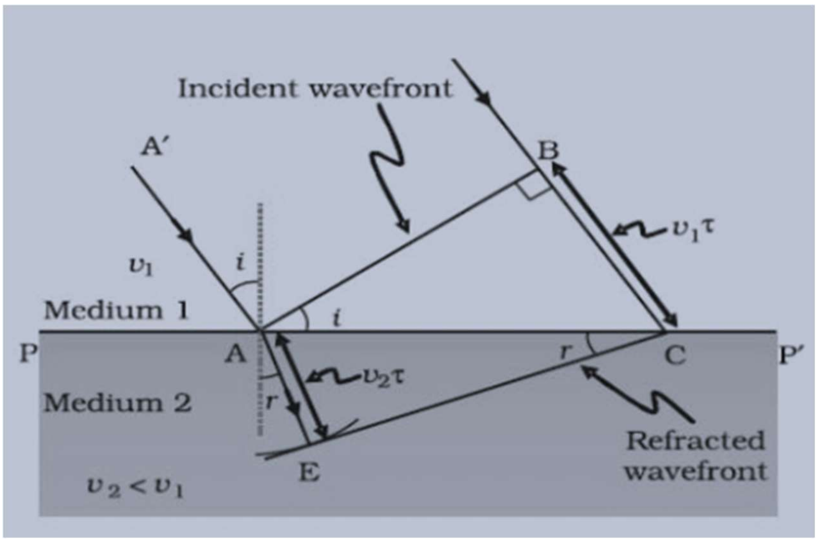
(a) bands disappear

(b) bands become broader and farther apart
(c) no change will take place
(d) diffraction bands become narrower and crowded together.

(iii) Diffraction aspect is easier to notice in case of the sound waves then in case of the light waves because sound waves
(a) Have longer wavelength
(b) Shorter wavelength
(c) Longitudinal wave
(d) Transverse wave

(iv) when 2nd secondary maxima is obtained in case of single slit diffraction pattern, the angular position is given by
(a) λ (b) $\lambda/2$ (c) $3\lambda/2$ (d) $5\lambda/2$

Q2. Refraction of a plane wave



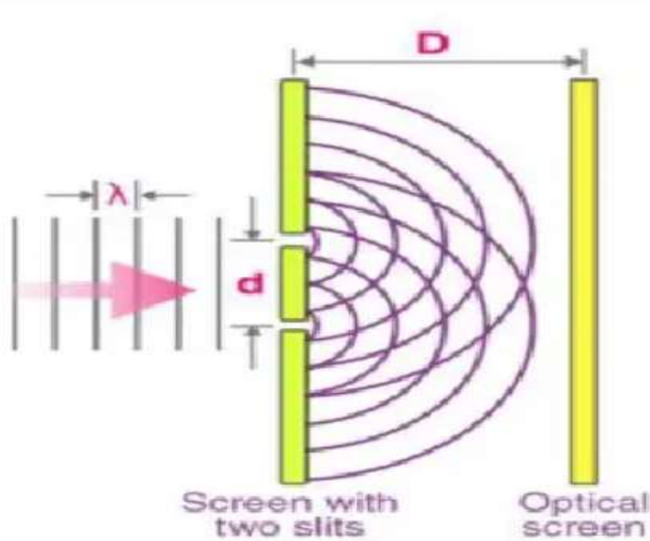
i) What is the angle made by the ray of light on the wave front?
a) 90˚ b) 0˚ c) 45˚ d) None of the above

ii) Which parameter remains unchanged while a ray of light propagates from one medium to another?
a) velocity b) Wave length c) frequency d) None of the above

iii) According to the above given fig., identify the correct expression for Snell's law.
a) $n_1 \sin i = n_2 \sin r$ b) $n_2 \sin i = n_1 \sin r$ c) $n_{21} = \sin r / \sin i$ d) None of the above

iv) When a ray of light travels from a denser to a rarer medium, it
a) it bends towards the normal
b) it travels in a straight line irrespective of angle of incidence.
c) it bends away from the normal
d) None of the above

Q3. Young's double-slit experiment uses two coherent sources of light placed at a small distance apart, usually, only a few orders of magnitude greater than the wavelength of light is used. Young's double-slit experiment helped in understanding the wave theory of light which is explained with the help of a diagram.
A screen or photo detector is placed at a large distance 'D' away from the slits as shown. The original Young's double-slit experiment used diffracted light from a single source passed into two more slits to be used as coherent sources. Lasers are commonly used as coherent source in the modern-day experiments.



Q.1 In Young's Double Slit Experiment, if instead of monochromatic light white light is used, what would be the observation?

(a) The pattern will not be visible

(b) The shape of the pattern will change from hyperbolic to circular

(c) Coloured fringes will be observed with a white bright fringe at the centre

(d) The bright and dark fringes will change position

Q.2 What kind of sources is required for Young's Double Slit experiment?

(a) Coherent (b) Incoherent (c) Intense (d) Bright

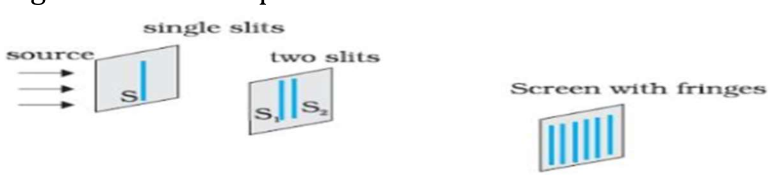
Q.3 If the distance between the two slits is doubled, the fringe width

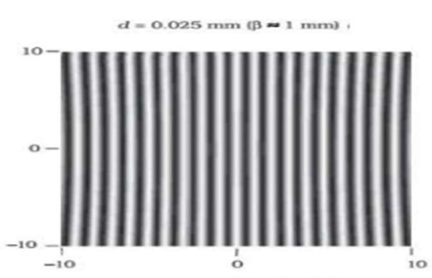
(a) Doubles (b) Halved (c) Four-times (d) Remains same

Q.4 What is the effect on the interference pattern when the screen is moved away from the slits

(a) Increase (b) Decreases (c) Halved (d) No effect

4. Young's Double slit experiment





(i) What is the path difference between the two light waves coming from coherent sources, which produces 3rd maxima.

(a) **λ** (b) 2 **λ** (c) 3 **λ** (d) 0

(ii) What is the correct expression for fringe width(⍰).

(a) **λ** d/D (b) **λ** /dD (c) d/ **λ** D (d) **λ** D/d

(iii) what is the phase difference between two interfering waves producing 1st dark fringe.

a) π b) 2π c) 3π d) 4π

(iv) The ratio of the widths of two slits in Young's double slit experiment is 4: 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.

a) 1:1 b) 1:4 c) 3:1 d) 9:1

5. Ram and Rahim were returning home from the cricket field, On their way they found a new 500 rupee note on the road. Rahim advised Ram to handover the money to the cashier of the charity home They did so and the cashier checked to see whether the currency was genuine or fake. He appreciated the boys and showed them how to check the currency. The number 500 at the centre of the note appears green when looked straight and blue when tilted at an angle. The cashier also explained that the colour shift on tilting is due to constructive interference of blue light produced by the variation of thickness of chemical layers specially added in the printing ink.

(i) colour shift on tilting is due to

(a) Constructive interference of blue light produced by the variation of thickness of chemical layers specially added in the printing ink.

(b) Destructive interference of blue light produced by the variation of thickness of chemical layers specially added in the printing ink.

(c) Diffraction of blue light produced by the variation of thickness of chemical layers specially added in the printing ink.

(d) None of these

(ii) Is it necessary that the amplitude be constant over a given wave front?

(a) Yes (b) No (c) Both a and b (d) Neither a nor b

(iii) Can two wave-fronts cross one another? Give reason.

(a) Yes (b) No (c) Both a and b (d) Neither a nor b

(iv) When a wave undergoes reflection at a denser medium, what happens to its phase?

(a) π/2 radian (b) π/4 radian (c) π radian (d) π/ 6 radian

<u>LONG ANSWER TYPE QUESTIONS</u>

1. What is interference of light? Write two essential conditions for sustainable interference pattern to be produced on the screen.

Draw a graph showing the variation of intensity versus the position on the screen in Young's exper iment when (a) both the slits are open, (b) one of the slits is closed

What is the effect on the interference pattern in Young's double slit experiment when (i) screen is moved closer to plane of the slits? (ii) separation between the two slits is increased? Explain your answer in each case

2. A beam of light consisting of two wavelengths 650 nm and 520 nm is used to obtain interference fringes in Young's doublet experiment. The distance between the planes of the slits and the screen is 1.2 m and the distance between the slits is 0.2 cm.

(a) find the distance of 3rd bright fringe on the screen from the central maxima for wavelength 650 nm.

(b) what is the least distance from the central maxima where the bright fringes due to both the wavelengths coincide.

3.i. An astronomical telescope consists of thin lenses,36cm apart and has a magnifying power 8. The focal lengths of objective and eyepiece are

a. Focal length of objective is 32cm and that of eyepiece is 4cm

b. Focal length of objective is 4 cm and that of eyepiece is 32cm

c. Focal length of objective is 8cm and that of eyepiece is 4cm

d. Focal length of objective is 4 cm and that of eyepiece is 8cm

ii. A pair of stars of actual separation one minute of are is observed with an astronomical telescope of magnifying power 100. What will be the separation of the image of the pair in degree?

a. 1.67’ b. 1.85’ c. 4’ d. 8’

iii. The final image formed in an astronomical telescope with respect to the object is :

a. real, inverted b. real, erect c. virtual, erect d. virtual, inverted

iv. The characteristic feature of light which remains unaffected on refraction is

a. Speed b. Frequency c. Wavelength d. Velocity of light

v. An astronomical refracting telescope will have larger angular magnification and high angular resolution, when it has an objective lens of

a. Large focal length and large diameter b. Large focal length and small diameter

c. small focal length and large diameter d. Small focal length and small diameter

4. . (a) Why cannot the phenomenon of interference be observed by illuminating two pin holes with two sodium lamps?

(b) Two monochromatic waves having displacements $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \theta)$ from two coherent sources interfere to produce an interference pattern.

(b) Derive the expression for the resultant intensity and obtain the conditions for constructive and destructive interference.

5. (a) Obtain the conditions for the bright and dark fringes in diffraction pattern due to a single narrow slit illuminated by a monochromatic source. Explain clearly why the secondary maxima go on becoming weaker with increasing n.

(b) When the width of the slit is made double, how would this affect the size and intentisity of central diffraction band? Justify.

WAVE OPTICS ANSWERS

MCQ

Q NO	ANSWERS
1	d) Photoelectric effect
2	c) Both longitudinal and transverse waves
3	a) Directly proportional to the wavelength of light
4	b) Changes by π
5	b) Inversely proportional to the slit width
6	a) Increases
7	d) Blue
8	c) In phase or have a constant phase difference
9	b) The square of the amplitude of light waves
10	d) An integral multiple of half-wavelength
11	a) I_1+I_2
12	c) 4:1
13	a) Halved
14	a) Concentric circles with bright and dark fringes
15	a) $v=cn$v=nc
16	c) Interference
17	b) The number of lines per unit length on the grating
18	d) Odd multiple of half-wavelength path difference
19	a) I
20	b) 0.3 mm

ASSERTION & REASONING

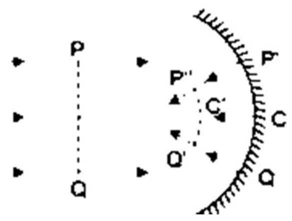
1	a) Both A and R are true, and R is the correct explanation of A.
2	a) Both A and R are true, and R is the correct explanation of A.
3	a) Both A and R are true, and R is the correct explanation of A.
4	b) Both A and R are true, but R is not the correct explanation of A.
5	a) Both A and R are true, and R is the correct explanation of A.
6	c) A is true, but R is false.
7	a) Both A and R are true, and R is the correct explanation of A.
8	a) Both A and R are true, and R is the correct explanation of A.
9	d) A is false, but R is true.
10	d) A is false, but R is true

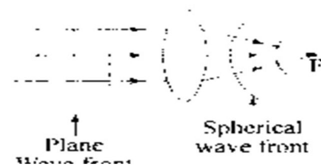
VSA

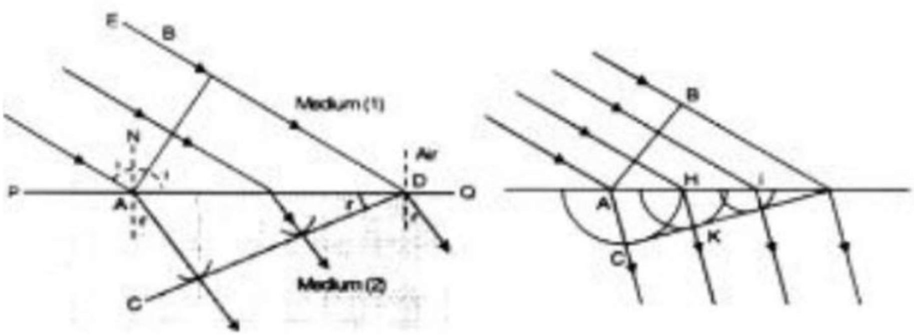
1	The principle of superposition of waves
2	Two independent sources of light cannot be coherent. This is because light is emitted by individual atoms, when they return to ground state. Even the smallest source of light contains billions of atoms which obviously cannot emit light waves in the same phase
3	The distance between two consecutive bright or dark fringes in an interference pattern
4	Path difference is an integral multiple of the wavelength, $n\lambda$nλ (where nn is an integer).

5	Diffraction.
6	$\theta=\lambda a\theta=a\lambda$, where $\lambda\lambda$ is the wavelength of light and aa is the slit width.
7	The intensity becomes zero as the waves cancel each other out
8	$\beta(water)=\beta(air)/n=\beta(air)/1.3$
9	Fringe width β is directly proportional to wavelength. The wave length of blue light is less than that of red light, hence if red light is replaced by the blue light, the fringe width decreases
10	The resolving power increases

SHORT ANSWER TYPE QUESTIONS

<table>
<tr><td>1</td><td>

(a) Concave mirror (b) 
</td></tr>
<tr><td>2</td><td>Position of nth maximum,
$y=(2n+1)\lambda D/2d$,
here n=2 $y=5\lambda D/2d$ Substituting and solving, we get, $d=80\mu m$</td></tr>
<tr><td>3</td><td>According to corpuscular theory.
(i)Light is emitted as tiny, massless and perfectly elastic particles called corpuscles.
(ii)As corpuscles are very small the source of light does not suffer appreciable loss of mass even if it emits light for a long time.
(iii)On account of high speed, they are affected by the force of gravity.
(iv) In a medium of uniform refractive index, their path is a straight line.
(v) The energy of light is the kinetic energy of these corpuscles.</td></tr>
<tr><td>4</td><td><table>
<tr><td></td><td>Interference</td><td>Diffraction</td></tr>
<tr><td>1</td><td>Interference is due to superposition of two distinct
waves coming from two coherent sources.</td><td>Diffraction is due to superposition of the secondary wavelets coming from different parts of the same wavefront.</td></tr>
<tr><td>2</td><td>Interference fringes may or may
not be of the same width.</td><td>Diffraction fringes are not to be of the same width</td></tr>
<tr><td>3</td><td>All bright fringes are of uniform
intensity</td><td>All bright fringes are of not uniform intensity</td></tr>
</table></td></tr>
<tr><td>5</td><td>, width of central maxima of single slit pattern = width of 10 maxima of
double slit pattern $2\lambda D/a=10(\lambda D/d)$ $a=0.2d$, $0.2\times10^{-3}=0.2\times10^{-3}m=0.2mm$</td></tr>
<tr><td>6</td><td>Path difference for nth minimum is $a\sin\theta=n\lambda$ or $a\theta=n\lambda$
Also,$\theta=x/D$ From this we get, $ax/D=n\lambda$ Substituting and solving we get. $a=2\times10^{-4}$ m</td></tr>
<tr><td>7</td><td>The two bright fringes will coincide when $n_1\lambda_1=n_2\lambda_2$
$\Rightarrow n_1\times800\times10^{-9}= n_2\times600\times10^{-9}$
$\Rightarrow 4n_1=3n_2$ where $n_1\neq=0,n_2\neq 0$
For y to be minimum and since n are integers,
$n_1=3,n_2=4$</td></tr>
</table>

	$y=n_1\lambda_1 D/d = 3\times800\times10^{-9}\times1.4/0.28\times10^{-3} \Rightarrow y=1.2\times10^{-2}m \Rightarrow y=1.2$ cm
8	Let I_1 and I_2 be the intensity of the two light waves. Their resultant intensities can be obtained For monochromatic light, $I_1 + I_2$ is the intensity. $I' = I_1 - I_2 - 2\sqrt{I_1 I_2}\cos\theta$ Phase difference is given by: $\phi = 2\pi \times \frac{\text{path difference}}{\lambda}$ $\phi = 2\pi \times \frac{\lambda}{\lambda}$ $= 2\pi$ So, the new intensity can be obtained as: $\Rightarrow I' = 4I_1$ given $I' = K, I_1 = K/4$, path difference $= \lambda/3$ phase difference is $2\pi \times 1/3$ Hence, $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos 2\pi/3$ $\Rightarrow I = I_1 = K/4$
9	 If ' τ' represents the time taken by the wavefront from the point B to C, then the distance $=v_1 \tau$ So, to determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 \tau$ from the point A in the second medium. Let CE represent a tangent plane drawn from the point C on to the sphere. Then, AE $= v_2 \tau$, and CE would represent the refracted wavefront. If we now consider the triangles ABC and AEC, we obtain $\sin i = BC/AC = v_1 \tau / AC$ $\sin r = AE/AC = v_2 \tau / AC$ where' i ' and ' r ' are the angles of incidence and refraction, respectively. Substituting the values of v_1 and v_2 in terms of $\sin i/\sin r = v_1/v_2 = n_{21}$ we get the Snell's Law
10	(a) Let the two waves be represented by equations $y_1 = a\cos\omega t, y_2 = a\cos(\omega t+\varphi)$ From the Principle of superposition of waves we get, $y=y_1+y_2=2a\cos(\varphi/2)\cos(\omega t+\varphi/2)$ Resultant Amplitude is A $=2a\cos(\varphi/2)$ Hence, Resultant Intensity α (amplitude)$^2 = 4a^2\cos^2(\varphi/2)$ (a) For constructive interference: $\cos(\Phi/2) = \pm1$ or $\Phi = 2n\pi$

	(b) (ii)For destructive interference: Cos (Φ/2) = 0 or Φ/2 = (2n-1)π/2 Φ =(2n-1)π

CBQ

1.

i	Minima for a single slit diffraction is given by: $\Rightarrow \sin\theta = \frac{m\lambda}{a}$ $\Rightarrow \theta = \sin^{-1}\left(\frac{3\times 6\times 10^{-7}}{0.1\times 10^{-3}}\right)$ sin θ is very small $\Rightarrow \sin\theta \simeq \tan\theta = \frac{y}{0.5}$ $\Rightarrow y = \frac{0.5\times 3\times 6\times 10^{-7}}{0.1\times 10^{-3}}$ $y = 9mm$ (C) 9mm $\Rightarrow y = 9mm$
Ii	(d) diffraction bands become narrower and crowded together
Iii	(a) Have longer wavelength
iv	(d) 5 **λ** /2

2.

i	(a) 90
Ii	(a) Coherent
Iii	(a) $n_1 \sin i = n_2 \sin r$
iv	(c)) it bends away from the normal

3.

i	(c) Coloured fringes will be observed with a white bright fringe at the centre
Ii	(c) frequency
Iii	(b) Halved
iv	(b) decreases

4.

i	(c) 3 **λ**
Ii	(d) **λ** D/d
Iii	(a) π
iv	(d) 9:1

5.

i	(a) Constructive interference of blue light produced by the variation of thickness of chemical layers specially added in the printing ink.
Ii	(a) Yes
Iii	(b) No
iv	(c) π radian

LONG ANSWER

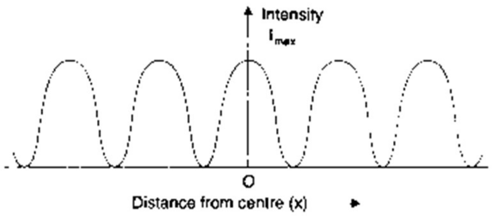
1.

Interference of light: Phenomenon of redistribution of light energy in a medium on account of superposition of light waves from two coherent sources is called interference of light. Conditions for sustained interference: The two essential conditions of sustained interference are as follows:

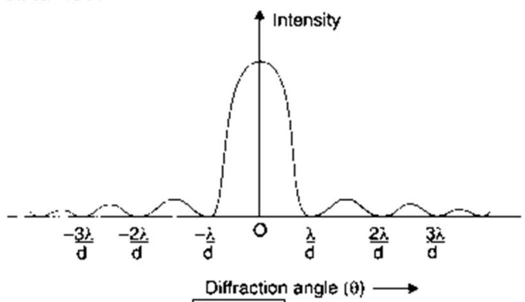
(i) The two sources of light should emit light continuously.

(ii) The light waves should be of same wavelength. (Monochromatic).

When both the slits are open, we get interference pattern on the screen. Then the following intensity distribution curve is obtained.



When one of the slits is closed, diffraction pattern is obtained on the screen. The following intensity curve is obtained.



Fringe width. $\beta = \frac{D\lambda}{d}$

(i) The distance D decreases, the fringe width β also decreases if screen is moved closer to the plane of the slits

(ii) Fringe width β decreases if separation d between two slits is increased.

2. The wavelength of the light is λ_1=650nm

The wavelength of second light,λ_2=520nm

Distance between the slit and the screen is 1.4m.

Distance between the slits is 0.28mm.

(a)

The relation between the n^{th} bright fringe and the width of fringe is:

$$x = n\lambda_1 \frac{D}{d}$$

For third bright fringe, n = 3

$$x = 3 \times 650 \frac{1.4}{0.28 \times 10^{-3}} = 1950 \times 5 \times 10^3 nm$$

$$x = 9.75 \times 10^{-3} m$$

$$= 9.75 mm$$

(b)

We can consider that n^{th} bright frind of λ_2 and the $(n-1)^{th}$ bright fringe of wavelength λ_1 coincide with each other.

$$n\lambda_2 = (n-1)\lambda_1$$

$$520n = 650n - 650$$

$$650 = 130n$$

$$n = 5$$

therefore, the least distance from the central maximum can be obtained as:

$$x' = n\lambda_2 \frac{D}{d}$$

$$x' = 5 \times 520 \frac{D}{d} = 2600 \frac{1.4}{0.28 \times 10^{-3}} nm$$

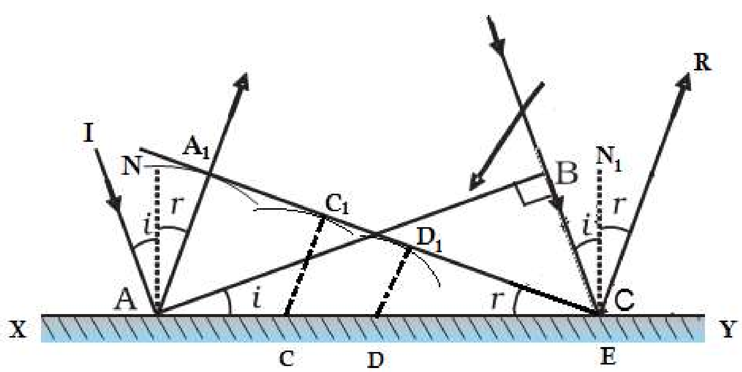
$$x' = 1.30 \times 10^{-2} m = 1.3 cm$$

3. (a) Wavefront :

A wavefront is defined as the continuous locus of all the particles which are vibrating in the same phase.

The perpendicular line drawn at any point on the wavefront represents the direction of propagation of the wave at that point.

Verification of Laws of Reflection using Huygen's Principle



In the given figure, AB is the wavefront incident on a reflecting surface XY with an angle of incidence i as shown in figure. According to Huygen's principle, every point on AB acts as a source of secondary wavelets. At first, wave incidents at point A and then to points C, D and E. They form a sphere of radii AA_1, CC_1 and DD_1 as shown in figure.

A_1E represents the tangential envelope of the secondary wavelet in forward direction.

In ΔABE and ΔAA_1E,

$\angle ABE = \angle AA_1E = 90°$

Side AE = Side AE
AA_1 = BE = distance travelled by wave in same time
So, these triangles are congruent.
So, ∠BAE = i and ∠BEA =r
Thus, i = r
Hence, angle of incidence is equal to the angle of reflection. This is the first law of reflection.
Since, the incident wavefront AB, normal and reflected wavefront A_1E lies in same plane, it verifies the second law of reflection.
(b)

Fringe width $\beta = \frac{D\lambda}{d}$

When immersed in water, the wavelength becomes $\lambda' = \frac{\lambda}{\mu}$

Thus the new fringe width = $\beta' = \beta \times \frac{\lambda'}{\lambda} = \beta \times \frac{1}{\mu} = 1.5\text{mm}$

4. (a) The interference phenomenon cannot be observed by using two illuminating pin holes with two
sodium lamps because the light emitted from sodium lamps undergoes abrupt phase changes in 1s which
will not have any fixed phase relationship as they are incoherent.
(b) The displacement equations for two monochromatic waves are given as
y_1 = acos wt and
y_2 = acos (wt + θ)
Now, net displacement y = $y_1 + y_2$ = acos wt + acos (wt + θ)

= acos wt + acos wt cos θ – asin wt. sinθ

= acos wt (1 + cosθ) – asin wt. sin θ

put a(1 + cos θ) = Asin φ...(i)

and – asin wt = Acos φ ...(ii)

y = Asin φ. cos wt + Acos φ sin wt

y = Asin (wt + φ)

Now, from equation (i) and (ii), $A^2 (\sin^2 \varphi + \cos^2 \varphi) = [a(1 + \cos wt)]^2 + (-a\sin wt)^2$

$A^2 = a^2 [1 + \cos 2 wt + \cos^2 wt + \sin^2 wt]$

$A^2 = 2a^2 [1 + \cos 2wt]$ $A^2 = 4a^2 \cos^2 wt/2$ This is the required expression.

For constructive interference, I should be maximum I max = $4a^2$, if wt= 0, ± 2π, ± 4 π...

For destructive interference, I should be minimum I min = 0, if wt = ± π, ± 3 π, ± 5 π....

5. (a) Diffraction of light at a single slit : When monochromatic light is made incident on a single slit, we get diffraction pattern on a screen placed behind the slit. The diffraction pattern contains bright and dark bands, the intensity of central band is maximum and goes on decreasing on both sides. Explanation : Let AB be a slit of width 'a' and a parallel beam of monochromatic light is incident on it. According to Fresnel the diffraction pattern is the result of superposition of a large number of waves, starting from different points of illuminated slit. Let θ be the angle of diffraction for waves reaching at point P of screen and AN the perpendicular dropped from A on wave diffracted from B.

The path difference between rays diffracted at points A and B,

$\Delta = BP - AP = BN$

In ΔANB, $\angle ANB = 90°$ $\therefore$ and $\angle BAN = \theta$

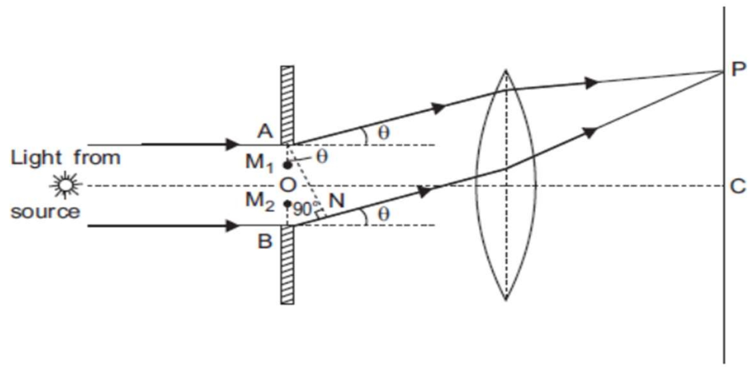
$\therefore$ $\sin\theta = \frac{BN}{AB}$ or $BN = AB \sin\theta$

As AB = width of slit $= a$

$\therefore$ Path difference,

$$\Delta = a \sin\theta \quad ....(i)$$

To find the effect of all coherent waves at P, we have to sum up their contribution each with a different phase. This was done by Fresnel by rigorous calculations, but the main features may be explained by simple arguments given below :



At the central point C of the screen, the angle θ is zero. Hence the waves starting from all points of slit arrive in the same phase. This gives maximum intensity at the central point C. If point P on screen is such that the path difference between rays starting from edges A and B is λ, then path difference

$$a \sin\theta = \lambda \Rightarrow \sin\theta = \frac{\lambda}{a}$$

If angle θ is small, $\sin\theta = \theta = \frac{\lambda}{a}$ ...(ii)

<u>Minima</u>: Now we divide the slit into two equal halves AO and OB, each of width a/2. Now for every point, M_1 in AO, there is a corresponding point M_2 in OB, such that $M_1 M_2 = a/2$; Then path difference between waves arriving at P and starting from M_1 and M_2 will be $a/2\sin\theta = \lambda/2$. This means that the contributions from the two halves of slit AO and OB are opposite in phase and so cancel each other. Thus equation (2) gives the angle of diffraction at which intensity falls to zero. Similarly it may be shown that the intensity is zero for $\sin\theta = n\lambda/a$, with n as integer. Thus the general condition of minima is

$a\sin\theta = n\lambda$...(iii)

Secondary Maxima: Let us now consider angle θ such that

$$\sin\theta = \theta = \frac{3\lambda}{2a}$$

which is midway between two dark bands given by

$$\sin\theta = \theta = \frac{\lambda}{a} \text{ and } \sin\theta = \theta = \frac{2\lambda}{a}$$

Let us now divide the slit into three parts. If we take the first two of parts of slit, the path difference between rays diffracted from the extreme ends of the first two parts

$$\frac{2}{3} a \sin\theta = \frac{2}{3} a \times \frac{3\lambda}{2a} = \lambda$$

Then the first two parts will have a path difference of λ/2 and cancel the effect of each other. The remaining third part will contribute to the intensity at a point between two minima. Clearly there will be a maxima between first two minima, but this maxima will be of much weaker intensity than central maximum. This is called first secondary maxima. In a similar manner we can show that there are secondary maxima between any two consecutive minima; and the intensity of maxima will go on decreasing with increase of order of maxima. In general the position of nth maxima will be given by

$a \sin\theta = (n + 1/2)\lambda$ [n =1, 2, 3, 4, ...] ...(iv)

The intensity of secondary maxima decrease with increase of order n because with increasing n, the contribution of slit decreases.

For n = 2, it is one-fifth, for n = 3, it is one-seventh and so on.

(b) Width of central Maxima ' β' = 2Dλ/a

a → size of slit

If size of slit is doubled, width of central maxima becomes half. Intensity varies as square of slit width. It width of slit is doubled. intensity gets four times.

CHAPTER 11 DUAL NATURE OF RADIATION AND MATTER

Q1. Multiple choice questions-

1) In a photoelectric experiment, if both the intensity and frequency of the incident light are doubled, then the saturation photoelectric current-
a) remains constant
b) Is halved
c) Becomes four times
d) Is doubled

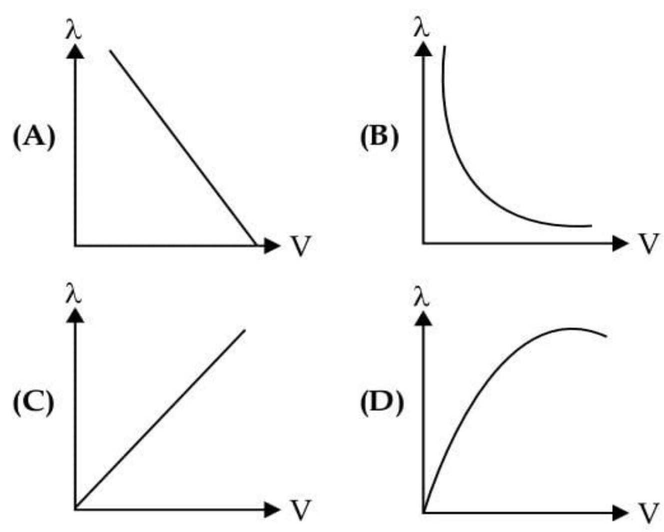
2) A metal's work function is:
a) The minimum current needed to remove an electron from a metal surface
b) The highest frequency needed to remove an electron from a metal surface
c) The least amount of energy required to remove an electron from a metal surface
d) None of the above

3) For a photosensitive material, the work function is 3.3×10^{-19} J. Find threshold frequency. (Take h= 6.6×10^{-34} Js)
a) 5×10^{14} Hz
b) 0.5×10^{14} Hz
c) 25×10^{14} Hz
d) 2.5×10^{14} Hz

4) Ratio of energies of two photons whose wavelengths are 200 Å and 600 Å respectively-
a) 1:3
b) 2:3
c) 3:1
d) 3:2

5) **The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted?**
a) 24×10^{-19} J
b) 2.4×10^{-19} J
c) 0.24×10^{-19} J
d) None of these

6) Which of the following graphs shows the variation of de Broglie wavelength with potential through which a particle of charge q and mass m is accelerated?



7) De Broglie wavelength of an electron with a kinetic energy of 120 eV is-

a) 0.1116×10^{-10} m

b) 1.116×10^{-10} m

c) 11.16×10^{-10} m

d) 111.6×10^{-10} m

8) A proton, a neutron, an electron and an alpha particle have the same energy. Then their de Broglie wavelengths compare as-

(a) $\lambda\alpha < \lambda p = \lambda n < \lambda e$

(b) $\lambda p = \lambda n > \lambda e > \lambda\alpha$

(c) $\lambda e < \lambda p = \lambda n > \lambda\alpha$

(d) $\lambda e = \lambda p = \lambda n = \lambda\alpha$

9) If alpha particle and proton have same momenta, the ratio of their de Broglie wavelength of alpha particle and proton is-

a) 1:4

b) 1:2

c) 1:1

d) 2:1

10) At stopping potential, the kinetic energy of emitted photoelectrons is-

(a) Minimum

(b) Maximum

(c) Zero

(d) Cannot be predicted

11) The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photo-electrons emission from this substance is approximately

(a) 540 nm (b) 400 nm (c) 310 nm (d) 220 nm

12) For a source of power 4 kW produces 1020 photons/second, the radiation belongs to a part of the spectrum called

(a) γ-rays (b) X-rays (c) ultraviolet rays (d) microwave

13) Photon of frequency v has a momentum associated with it. If c is the velocity of radiation, then the momentum is

(a) hv/c (b) v/c (c) hvc (d) hv/c^2

14) The time taken by a photoelectron to come out after the photon strikes is approximately

(a) 10^{-4} s (b) 10^{-10} s (c) 10^{-16} s (d) 10^{-1} s

15) Which of the following is not the property of cathode rays?

(a) It produces heating effect

(b) It does not deflect in electric field

(c) It casts shadow

(d) It produces fluorescence

16) If an electron and a photon propagate in the form of waves having the same wavelength, it implies that they have the same

(a) Energy (b) Momentum (c) Velocity (d) Angular momentum

17) Light of two different frequencies whose photons have energies is 1 eV and 2.5 eV respectively, successively illuminate a metallic surface whose work function is 0.5 eV. ratio of maximum speeds of emitted electrons will be

(a) 1 : 4 (b) 1 : 1 (c) 1 : 5 (d) 1 : 2

18) De Broglie wavelength λ associated with neutrons is related with Absolute Temperature T as

(a) $\lambda \propto T$ (b) $\lambda \propto 1/T$ (c) $\lambda \propto 1/\sqrt{T}$ (d) $\lambda \propto T^2$

19) A particle of mass M at rest decays into two particles of masses m1 and m2, having non-zero velocities. The ratio of de-Broglie wavelengths of the particles λ_1/λ_2, is

(a) m_1/m_2 (b) m_2/m_1 (c) 1.0 (d) $\sqrt{m_2}/\sqrt{m_1}$

20) The threshold wavelength, for photoelectric emission from a material is 5200 Å. Photoelectrons will be emitted when this material is illuminated with monochromatic radiation from a

(a)50 watt infrared lamp (b) 1 watt infrared lamp

(c)50 watt ultraviolet lamp (d) 1 watt ultraviolet lamp

Q2. Assertion reasoning questions-

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as:

(A)If both assertion and reason are true and reason is the 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 and reason is false

(D)If both assertion and reason are false

1) Assertion: de-Broglie equation is significant for microscopic particles.

Reason: de-Broglie wavelength is inversely proportional to the mass of a particle when velocity is kept constant.

(a)A (b) B (c) C (d) D

2) Assertion: Kinetic energy of photoelectrons emitted by a photosensitive surface depends upon the frequency of incident photon.

Reason: The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency.

(a)A (b) B (c) C (d) D

3) Assertion: In photoelectron emission, the velocity of electron ejected from near the surface is larger than that coming from interior of metal.

Reason. The velocity of ejected electron will be zero.

(a)A (b) B (c) C (d) D

4) Assertion: On increasing the intensity of light the photocurrent increases.

Reason: The photocurrent increases with increase of frequency of light.

(a)A (b) B (c) C (d) D

5) Assertion: The de Broglie equation has significance for any microscopic or sub microscopic particle.

Reason: The de Broglie wavelength is inversely proportional to the mass of the object if velocity is constant.
(a) A (b) B (c) C (d) D

6) Assertion: A particle of mass M at rest decay into particles of masses m1 and m2, having non-zero velocities will have ratio of de-Broglie wavelengths unity.
Reason: Here we cannot apply conservation of linear momentum.
(a) A (b) B (c) C (d) D

7) Assertion: Photoelectric effect demonstrates the wave nature of light.
Reason: The number of photoelectrons is proportional to the frequency of light.
(a) A (b) B (c) C (d) D

8) Assertion: When ascertain wavelength of light falls on a metal surface it ejects electron.
Reason: Light has wave nature.
(a) A (b) B (c) C (d) D

9) Assertion: As work function of a material increases by some mechanism, it requires greater energy to excite the electrons from its surface.
Reason. A plot of stopping potential (V2) versus frequency (v) for different materials, has greater slope for metals with greater work functions.
(a)A (b) B (c) C (d) D

10) Assertion: Light of frequency 1.5 times the threshold frequency is incident on photosensitive material. If the frequency is halved and intensity is doubled the photo current remains unchanged.
Reason. The photo electric current varies directly with the intensity of light and frequency of light.
(a)A (b) B (c) C (d) D

Q3. Very short answer type questions-

1) Will photoelectrons be emitted from a copper surface of work function 4.4 eV, when illuminated by a visible light?
2) The photoelectric work function of tungsten is 4.5 eV. Calculate its threshold wavelength.
3) Why is wave nature of matter not apparent to our daily observations?
4) de Broglie waves are also called matter waves. Why?
5) Write two characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.
6) Define the term "intensity" in photon picture of electromagnetic radiation.
7) Draw graphs showing variation of photoelectric current with applied voltage for two identical radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity.
8) Define the term "threshold frequency" in the context of photoelectric emission.
9) Light of wavelength 3500 Å is incident on two metals A and B. Which metal will yield more photoelectrons if their work functions are 5 eV and 2 eV respectively?
10) If photons of frequency v are incident on the surfaces of metals A and B of threshold frequencies v/2 and v/3 respectively. Find the ratio of the maximum kinetic energy of electrons emitted from A and B.

Q4.CASE STUDY BASED QUESTIONS-

CASE STUDY 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
(a) electron (b) quanta (c) frequency (d) neutron

2) One quantum of radiation is called
(a) Meter (b) meson (c) photon (d) quark

3) Energy associated with each photon
(a) hc (b) mc (c) hv (d) hk

4) Which of the following waves can produce photo electric effect
(a) UV radiation (b). Infrared radiation (c). Radio waves (d) .Microwaves

5) Work function of alkali metals is
(a) Less than zero
(b) Just equal to other metals
(c) Greater than other metals
(d) Quite less than other metals

CASE STUDY 2

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
(a) Diffraction and photo electric effect
(b) Photoelectric effect
(c) Refraction and interference
(d) Diffraction and reflection.

2. If the momentum of a particle is doubled, then its de-Broglie wavelength will
(a) Remain unchanged (b) Become four times
(c) Become two times (d) Become half

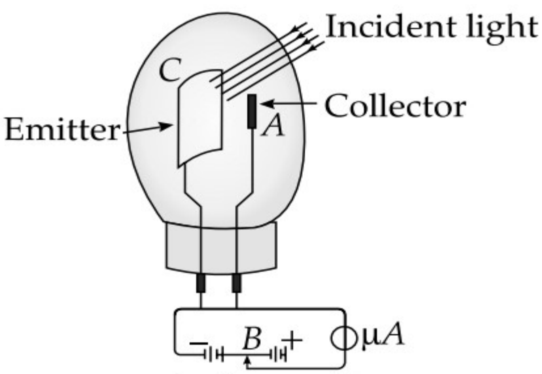
3. If an electron and proton are propagating in the form of waves having the same λ, it implies that they have the same
(a) Energy (b) Momentum (c) Velocity (d) angular momentum

4. Velocity of a body of mass m, having de-Broglie wavelength λ, is given by relation
(a) $v = \lambda h/m$ (b) $v = \lambda m/h$ (c) $v = \lambda/hm$ (d) $v = h/\lambda m$

5. Moving with the same velocity, which of the following has the longest de Broglie Wavelength?
(a)β -particle b) alpha particle (c) Proton d) neutron

CASE STUDY 3

A photocell is a technological application of the photoelectric effect. It is a device whose electrical properties are affected by light. It is also sometimes called an electric eye. A photocell consists of a semi- cylindrical photo-sensitive metal plate C (emitter) and a wire loop A (collector) supported in an evacuated glass or quartz bulb. It is connected to the external circuit having a High tension battery B and micro ammeter as shown in the figure.



A photo cell

Sometimes, instead of the plate C, a thin layer of photo sensitive material is pasted on the inside of the bulb. A part of the bulb is left clean for the light to enter it. When light of suitable wavelength falls on the emitter C, photo electrons are emitted. These photo electrons are drawn to the collector A. Photo current of the order of a few micro ampere can be normally obtained from a photo cell. A photocell converts a change in intensity of illumination into a change in photo current. This current can be used to operate control systems and in light measuring devices.

1) Photocell is an application of-
a) Thermoelectric effect
b) Photoelectric effect
c) Photoresistive effect
d) None of the above

2) Photosensitive material should be connected to-
a) –ve terminal of the battery
b) +ve terminal of the battery
c) Any of a) and b)
d) Connected to ground

3) Which of the following statement is true?
a) The photocell is totally painted black
b) A part of the photocell is left clean
c) The photocell is completely transparent
d) A part of the photocell is made black

4) The photocurrent generated is in order of-

a) Ampere b) Mill ampere c) Microampere d) none of the above

5) A photocell converts a change in____________ of incident light into a change in _________.
a) Intensity, photo voltage
b) Wavelength, photo voltage
c) Frequency, photocurrent
d) Intensity, photocurrent

CASE STUDY 4

Electron microscopes use electrons to illuminate a sample. In transmission electron microscopy (TEM), electrons pass through the sample and illuminate film or a digital camera.
Resolution in microscopy is limited to about half of the wavelength of the illumination source used to image the sample. Using visible lie the best resolution that can be achieved by microscope is about ~200 nm. Louis de Broglie showed that every particle or matter propagates like a wave. The wavelength of propagating electrons at a given accelerating voltage can be determined by

l= $\frac{h}{\sqrt{2mv}}$

Thus, p the wavelength of electrons is calculated to be 3.88 pm when the microscope is operated at 100 KeV, 2.74 pm at 2.24 pm at 300 KeV. However, because the velocity of electrons in an electron microscope each about 70% the speed of light with an accelerating voltage of 200 Kev, there are relative stick effects on these electrons. Due to this effect, the wavelength at 100 KeV, 200 KeV and 300KeV in electron microscopes is 3.70 pm, 2.51 pm and 1.96 pm respectively.
Anyhow, the wavelength of electrons is much smaller than that of photons (2.5 pm at 200 KeV). Thus, if electron wave is used to illuminate the sample, the resolution of an electron microscope theoretically becomes unlimited. Practically the resolution is limited to ~0.1 nm due to objective lens system in electron microscopes. Thus, electron microscopy can resolve subcellular structures that could not be visualised using standard fluorescence microscopy.
1) In electron microscope electron is used-
a) To charge the sample
b) To clean the sample
c) To illuminate the sample
d) All of the above

2) Who showed that electron also propagates like a wave-
a) Louis de Broglie
b) Albert Einstein
c) Phillip Lenard
d) Wilhelm Ludwig Franz Hallwachs

3) Why electron as wave is used in microscope to illuminate the sample?
a) The wavelength of electrons as wave is much larger than that of photons, hence resolution is much better.
b) The wavelength of electrons as wave is much smaller than that of photons, hence resolution is much better.
c) Electron as wave is much brighter than normal light and hence resolution is much better.
d) Speed of electron as wave is greater than speed of light and hence offers better resolution.

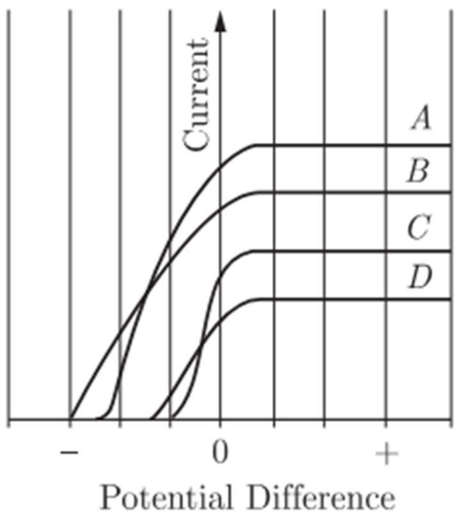
4) As the accelerating voltage increases the wavelength of electron as wave-

a) Decreases
b) Increases
c) Remain same
d) Up to 100 KeV increases then decreases

5) Wavelength of electron as wave at accelerating voltage 200 KeV is-
a) 2.5nm
b) 2.5 mm
c) 2.5 pm
d) 2.5 micrometre

CASE STUDY 5

Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams A, B, C and D of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions :



1.Which light beam has the highest frequency?
a)A b)B c)C d)D

2.Which light beam has the longest wavelength?
a)A b)B c)C d)D

3.Which light beam eject photoelectrons with maximum momentum?
a)A b)B c)C d)D

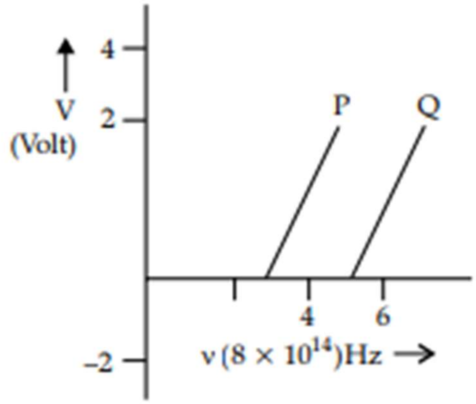
4.What is the effect on threshold frequency?
a)Increases b) decreases c) no effect d)None of these

Q5. Short answer type questions –

1) In case of photoelectric effect experiment, explain the following facts, giving reasons.
(a) The wave theory of light could not explain the existence of the threshold frequency.
(b) The photo electric current increases with increase in the intensity of incident light.

2) A photon emitted during the de-excitation of electron from a state n to the first excited state in a hydrogen atom, irradiates a metallic cathode of work function 2 eV, in a photo cell, with a stopping potential of 0.55 V. Obtain the value of the quantum number of the state n.

3). In the study of a photoelectric effect the graph between the stopping potential V and frequency v of the incident radiation on two different metals P and Q is shown below:



(i) Which one of the two metals has higher threshold frequency?
(ii) Determine the work function of the metal which has greater value.
(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8×10^{14} Hz for this metal.

4) a) How does one explain the emission of electrons from a photosensitive surface with the help of Einstein's photoelectric equation?.
b) Radiation of frequency 10^{15} Hz is incident on two photosensitive surfaces P and Q. There is no photoemission from surface P. Photoemission occurs from surface Q but photoelectrons have zero kinetic energy. Explain these observations and find the value of work function for surface Q.

6) **There are two sources of light, each emitting with a power of 100 W. One emits X-rays of wavelength 1 nm and the other visible light at 500 nm. Find the ratio of number of photons of X-rays to the photons of visible light of the given wavelength**

7) A proton and an α- particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds

8) The wavelength λ of a photon and the de-Broglie wavelength of an electron have the same value. Show that the energy of a photon is $2\lambda mc/h$ times the kinetic energy of electron. Where m, h and h have their usual meaning.

9) (i) Draw the graph showing the variation of de Broglie wavelength λ of a particle of charge q and mass m with the accelerating potential.
(ii) An electron and proton have the same de Broglie wavelengths. Explain, which of the two has more kinetic energy.

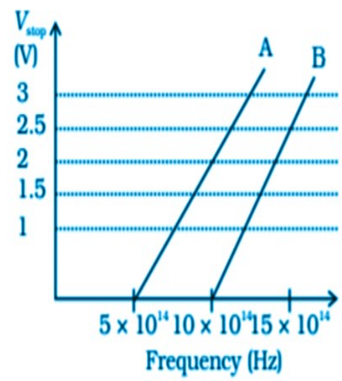
10) Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory.

Q6. Long answer type questions-

1) a) **A student performs an experiment on the photoelectric effect, using two materials A and B. A plot of Vstop vs v is given in the figure.**

(i) Which material A or B has a higher work function?

(ii) Given the electric charge of an electron = 1.6 × 10^{-19} C, find the value of h obtained from the experiment for both A and B. Comment on whether it is consistent with Einstein's theory



2) a)The work function of caesium metal is 2.14 eV. When the light of frequency 6 × 10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. Find the following:

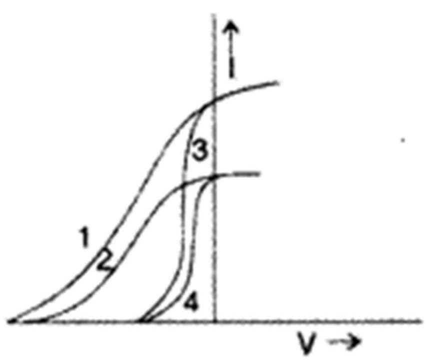
(i) The maximum kinetic energy of the emitted electrons

(ii) Stopping potential

(iii) The maximum speed of the emitted photoelectrons

And

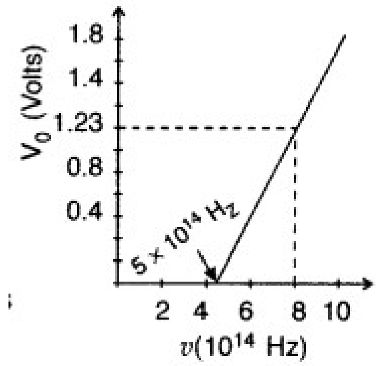
b) The given graph shows the variation of photo-electric current (I) versus applied voltage (V) for two different photosensitive materials and for two different intensities of the incident radiation. Identify the pairs of curves that correspond to different materials but same intensity of incident radiation.



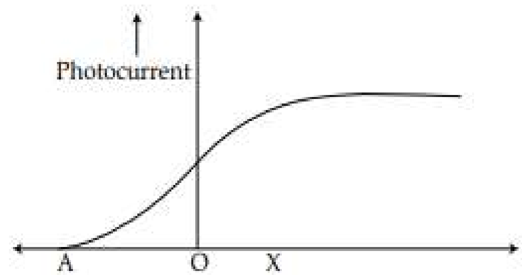
3) a)The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?

b) A proton and an α-particle are accelerated, using the same potential difference. How are the de Broglie wavelengths λp and λa related to each other?

c) Using the graph shown in the figure for stopping potential v/s the incident frequency of photons, calculate Planck's constant.

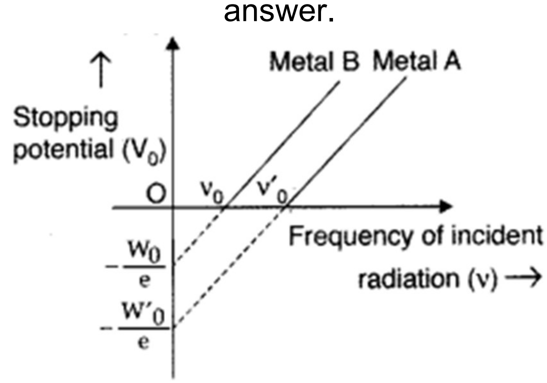


4) The following graph shows the variation of photocurrent for a photosensitive metal:



(i) Identify the variable X on the horizontal axis.
(ii) What does the point A on the horizontal axis represent?
(iii) Draw this graph for three different values of frequencies of incident radiation v_1 , v_2 and v_3 ($v_1 > v_2 > v_3$) for same intensity.
(iv) Draw this graph for three different values of intensities of incident radiation I_1,I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.

5) (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.
(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.
(iii)The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which one of the two has higher value of work- function? Justify your answer.



DUAL NATURE OF MATTER & RADIATION
ANSWER KEY

Q1. Multiple choice questions-

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(d) Is doubled	(c)	(a) 5×10^{14} Hz	(c) 3:1	(b) 2.4×10^{-19} J	(b)	(b) 1.116×10^{-10} m	(a)	(c) 1:1	(c) zero
Q11	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
(c)310nm	(b) X-rays	(a) hv/c	(b) 10^{-10} s	(b)	(b) Momentum	(d) 1:2	(c) $\lambda \propto 1/\sqrt{T}$	(c) 1	(c)50 watt ultraviolet

Q2. Assertion reasoning questions-

Q1. (a) Q2. (c) Q3 (c) Q4. (c) Q5. (a)
Q6. (a) Q7. (d) Q8. (b) Q9. (c) Q10. (d)

Q3. Very short answer questions

1. The threshold wavelength λ_0 corresponding to work function W is given by
$\lambda_0 = h\,v/W$ or $\lambda_0 = 12400/4.4 = 2820$ Å
Since λ_0 does not lie in the visible range (4000 Å → 7500 Å) therefore it cannot eject photoelectrons from copper.

2. 2763 Å

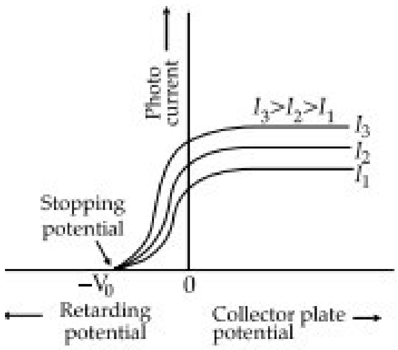
3 de-Broglie wavelength associated with a body of mass m, moving with velocity v is given by $\lambda = h/mv$ .Since, the mass of the object is large hence the de-Broglie wavelength associated with it is quite small hence it is not visible. Hence the wave nature of matter is not more apparent to our daily life.

4. Since de Broglie wave is associated with fast moving tiny material particles, it is also known as matter waves. The wavelength of such waves depend on the mass and velocity of the particles.

5. (i) Maximum Kinetic energy of emitted photoelectrons is independent of intensity of incident light
(ii) Instantaneous emission of photoelectrons
(iii) Existence of threshold frequency (Any Two)

6. Intensity of radiation is proportional to the number of energy quanta (photons) per unit area per unit time.

7.



8. Threshold frequency equals the minimum frequency of incident radiation that can cause photoemission from a given photosensitive surface.

9. Metal B will yield more photo electrons. Work function of Metal B is lower than that of A for the same wavelength of light. Hence metal B will give more electrons

10.

$$(K.E)_{max} = E - \phi = h\nu - \phi$$

For A,

$$(K.E)_{max} = E - \phi = h\nu - \frac{3h\nu}{4} = \frac{h\nu}{4}$$

For B,

$$(K.E)_{max} = E - \phi = h\nu - \frac{2h\nu}{3} = \frac{h\nu}{3}$$

$$\frac{((K.E)_{max})_A}{((K.E)_{max})_B} = \frac{\frac{h\nu}{2}}{\frac{2h\nu}{3}} = \frac{3}{4}$$

Q4. CASE STUDY BASED QUESTIONS-

<u>CASE STUDY 1</u>

1). (b) 2) (c) 3) (c) 4) (a) 5) (d)

<u>CASE STUDY 2</u>

Q1.(a) Q2.(d) Q3.(b) Q4.(d) Q5.(a)

<u>CASE STUDY 3</u>

1) b 2) a 3) b 4) c 5) d

<u>CASE STUDY 4</u>

1) c 2) a 3) b 4) a 5) c

CASE STUDY 5

1)B 2)C 3)B 4) C

Q5. Short answer type questions –

1.

Ans (a) Since energy of the wave is dependent on the square of its amplitude, the classical wave theory predicts that if sufficiently intense light is incident, the electrons would absorb that energy to escape. There should not be any threshold frequency for the emission of electrons from metal's surface due to incident light.

(b) According to classical wave theory, if intensity of light increases, the kinetic energy of an ejected electron will increase. This is because the greater the intensity of light, the larger the energy of the light wave striking the metal surface, so electrons are ejected with greater kinetic energy. However, it cannot explain the increase of number of ejected electrons i.e. the increase of photoelectric current, with the increase in intensity of incident light.

2.

Ans. E= $\frac{13.6}{n^2}$

For finding the value of n

From photoelectric equation,

hv = ϕ_0 + eV_0 = 2 + 0.55 = 2.55 eV

Given. E= $\frac{13.6}{n^2}$

The energy difference

$\Delta E = -3.4 - (-2.55)$ eV = –0.85 eV

$\therefore \frac{-13.6}{n^2} = -0.85$

$\therefore$ n = 4

3.

. (i) Q has higher threshold frequency

(ii) Work function, $\phi_0 = hv_0 = 6.6 \times 10^{-34} \times \frac{6x\ 10^{14}}{1.6x\ 10^{-19}}$ eV = 2.475 eV

iii) K_{max}= h (v-v_0) = $6.6 \times 10^{-34} \times \frac{2x\ 10^{14}}{1.6x\ 10^{-19}}$ eV = 0.825 eV

4.

Ans a) Einstein's Photoelectric equation is hv = $\phi_0 + K_{max}$

When a photon of energy 'hv' is incident on the metal, some part of this energy is utilized as work function to eject the electron and remaining energy appears as the kinetic energy of the emitted electron.

b) Since no photoelectric emission takes place from P. It means frequency of incident radiation (10^{15} Hz) is less than its threshold frequency (v_0).

Photo emission takes place from Q but kinetic energy of photoelectrons is zero. This implies that frequency of incident radiation is just equal to the threshold frequency of Q.

For Q, Work function,

$\phi_0 = hv_0 = 6.6 \times 10^{-34} \times \frac{10^{15}}{1.6x\ 10^{-1}}$ eV = 4.125 Ev

5.

Ans. Cut off frequency: It is that minimum frequency of incident radiation below which no photo emission takes place from a photo electric material.

K_{max} = hf- W_0

$\frac{1}{2} m v_1^2$ = 2hf- hf= hf

$\frac{1}{2} m v_2^2$ = 5hf- hf= 4hf

$\frac{v_1^2}{v_2^2} = \frac{1}{4}$

$\frac{v_1}{v_2} = \frac{1}{2}$

6) There are two sources of light, each emitting with a power of 100 W. One emits X-rays of wavelength 1 nm and the other visible light at 500 nm. Find the ratio of number of photons of X-rays to the photons of visible light of the given wavelength.

$E_x = h\nu_x$

$E_v = h\nu_v$

Let n_x and n_v be the no.of photons from x-rays and visible light are of equal energies and they emit 100 W power.

$n_x h\nu_x = n_v h\nu_v$

$n_x/n_v = \nu_v/\nu_x = \lambda_x/\lambda_v$

n_x/n_v = 1 nm/500 nm

$n_x : n_v$ = 1:500

7. Ans. (i) $\boldsymbol{\lambda} = \frac{h}{\sqrt{2\mathrm{mqV}}}$

$V = \frac{h^2}{2mq\lambda^2}$

$\frac{V_p}{V_a} = \frac{m_a}{m_p} \frac{q_a}{.q_p} = \frac{4m_p}{m_p} \frac{2q_p}{.q_p} = \frac{8}{1}$

(ii) λ= h/mv => v = h/mλ

$\frac{V_p}{V_a} = \frac{m_a}{m_p} = \frac{4m_p}{m_p} = \frac{4}{1}$

8. Ans. Energy of photon E = hc/λ

de-Broglie wavelength of electron,

$\boldsymbol{\lambda} = h/p$

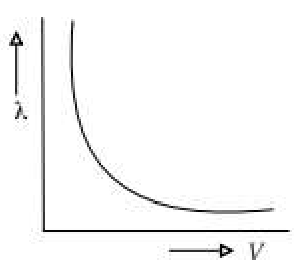
Kinetic energy of electron,

$E_k = p^2/2m = h^2/2m\lambda^2$

$\frac{E}{E_K} = \frac{\frac{hc}{\lambda}}{\frac{h^2}{2m\lambda^2}} = \frac{2m\lambda c}{h}$

$E = \frac{2mc\lambda}{h} E_k$

9. Ans. (i) Wavelength of a particle is given by $\lambda = \frac{h}{\sqrt{2mqV}}$



(ii) For an electron and proton,

qp = qe

mp > me

Since wavelength, $\lambda = \frac{h}{\sqrt{2mqV}}$, and both particles have same de-Broglie wavelength, λ& Kinetic energy is given by qV

Therefore $\frac{h}{\sqrt{2m_e KE_e}} = \frac{h}{\sqrt{2m_p KE_p}}$

⇨ $m_e KE_e = m_p KE_p$

⇨ $m_p > m_e$
⇨ K.E. of electron will be more.

10. Ans. Two features
In the photon picture, energy of the light is assumed to be in the form of photons, each carrying an energy hν. Einstein assumed that photoelectric emission occurs because of a single collision of a photon with a free electron.
The energy of the photon is used to:
(i) free the electrons from the metal. [For this, a minimum energy, called the work function (=W) is needed]. And
(ii) provide kinetic energy to the emitted electrons.
Hence
$(K.E.)_{max} = h\nu - W$
$\frac{1}{2} mv^2 = h\nu - W$
This is Einstein's photoelectric equation
Two features (which cannot be explained by wave theory):
(i) 'Instantaneous' emission of photoelectrons
(ii) Existence of a threshold frequency
(iii) 'Maximum kinetic energy' of the emitted photoelectrons, is independent of the intensity of incident light.

Q6. Long answer type questions-
1) The threshold frequency of A is
$\nu_{OA} = 5 \times 10^{14}$ Hz
The threshold frequency of B is
$\nu_{OB} = 10 \times 10^{14}$ Hz
Work function is $\phi = h\nu_0$
Since $\phi_{OA} / \phi_{OB} = 5 \times 10^{14} / 10 \times 10^{14} < 1$
hence
$\phi_{OA} < \phi_{OB}$
(ii) For metal A, slope = h/e= 2/ (10-15)10^{14}
Or h = $\frac{2e}{5 \, x \, 10^{14}} = \frac{2 \, x \, 1.6 \, x \, 10^{-19}}{5 \, x \, 10^{14}}$ = 6.4 x 10^{-34} Js
For metal B, slope = h/e= 2/ (15-10)10^{14}
Or h = $\frac{2.5 \, e}{5 \, x \, 10^{14}} = \frac{2.5 \, x \, 1.6 \, x \, 10^{-19}}{5 \, x \, 10^{14}}$ = 8 x 10^{-34} Js
Since the value of h from experiment for metals A and B is different.Hence experiment is not consistent with theory.
2.) a)Work function of caesium,
Φ_o = 2.14eV
Frequency of light, **ν = 6.0 x 10^{14} Hz**
(i) The maximum kinetic energy of the emitted electrons:
K = hν –Φ_o
Where,
h = Planck's constant **=** 6.626 x 10^{-34} Js
Therefore,
K =$\frac{6.626 \, x \, 10^{-34} \;\; x \, 6x \, 10^{14}}{1.6 \, x \, 10^{-19}}$ – 2.14
= 2.485 – 2.140 **=** 0.345 eV

Hence, 0.345 eV is the maximum kinetic energy of the emitted electrons.

(ii) For stopping potential V_o, we can write the equation for kinetic energy as:
$K = eV_o$
Therefore, $V_o = \frac{k}{e}$
$V_0 = 0.345 \times 1.6 \times 10^{-19} / 1.6 \times 10^{-19}$
= 0.345 V
Hence, 0.345 V is the stopping potential of the material.
(iii) Maximum speed of photoelectrons emitted **=** v
Following is the kinetic energy relation:
$K = \frac{1}{2} mv^2 \Rightarrow v^2 = \frac{2k}{m} = \frac{2x\ 0.345x\ 1.6\ x\ 10^{-19}}{9.1\ x\ 10^{-31}}$
$= 0.1104 \times 10^{12}$
Therefore, $v = 3.323 \times 10^5$ m/s **=** 332.3 km/s.
Hence**,** 332.3 km/s is the maximum speed of the emitted photoelectrons.

b) The pairs (2, 4) and (1, 3) have same intensity but different material..

3) (a)Work function of the metal,Φ_o= 4.2eV
Charge on an electron, $e = 1.6 \times 10^{-19}$ C
Planck's constant, $h = 6.626 \times 10^{-34}$ Js
Wavelength of the incident radiation,
λ= 330nm = 330×10^{-9} m
Speed of light, $c = 3 \times 10^8$ m/s
The energy of the incident photon is given as:
$E = hc/\lambda = 6.626 \times 10^{-34} \times 3 \times 10^8 / 330 \times 10^{-9}$
$= 6.0 \times 10^{-19}$ J $= 6.0 \times 10^{-19} / 1.6 \times 10^{-19}$
= 3.76 eV
The energy of the incident radiation is less than the work function of the metal. Hence, there is no photoelectric emission takes place.
b)The proton and α-particle are accelerated at the same potential difference.
$\lambda = h/\sqrt{2mqv}$
λ is proportional to $1/\sqrt{mq}$
$\lambda_p / \lambda_a = \sqrt{m_a q_a / m_p q_p} = \sqrt{8}$
Therefore, the wavelength of the proton is √8 times the wavelength of α-particle.
c)
According to Einstein's photoelectric equation,

$$V_0 = \frac{h}{e}\nu - \frac{\phi_0}{e}$$

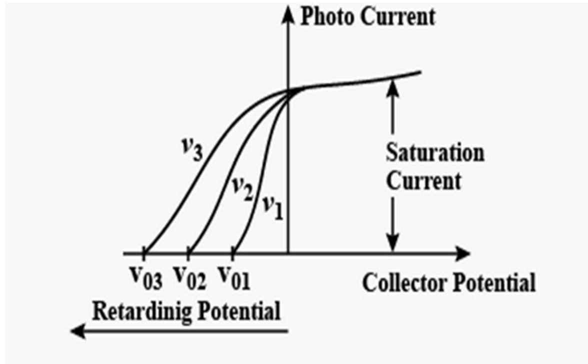
In the given graph :
Stopping potential, $V_0 = 1.23$ V
Change in frequency, $\Delta\nu = (8 \times 10^{14} - 5 \times 10^{14})$
$= 3 \times 10^{14}$ Hz

∴ Slope of the line $= \frac{h}{e}$

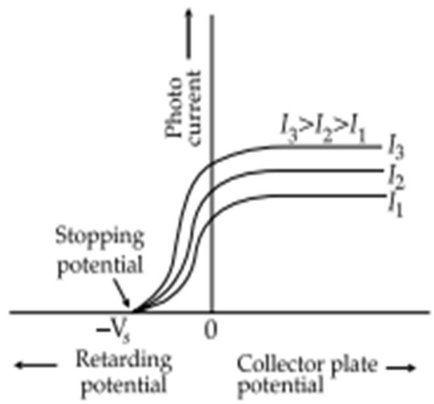
∵ $\frac{h}{e} = \frac{V_0}{\Delta\nu} = \frac{1.23}{3 \times 10^{14}}$, ∵ $e = 1.6 \times 10^{-19}$ C

∴ $h = \frac{1.23 \times 1.6 \times 10^{-19}}{3 \times 10^{14}}$ JS $= 6.6 \times 10^{-34}$ JS

4. Ans. (i) X is collector plate potential.
(ii) A is stopping potential.
(iii)



iv)



5.

(*i*) Given : $\nu = 6.0 \times 10^{14}$ Hz, $P = 2.0 \times 10^{-3}$ W

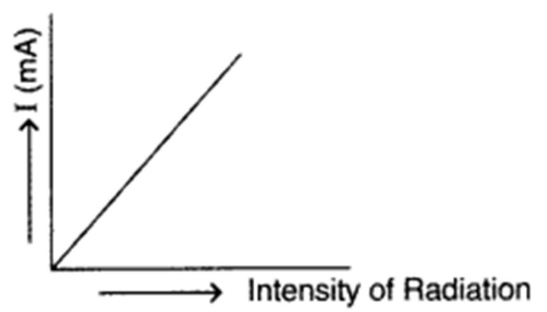
Energy of one photon = $h\nu$

$= (6.6 \times 10^{-34}) \times (6.0 \times 10^{14})$

Number of photons emitted per sec

$$= \frac{\text{Power}}{\text{Energy of one photon}}$$

$$n = \frac{2\times10^{-3}}{(6.6\times10^{-34})\times(6.0\times10^{14})} \quad \therefore\ n = 5 \times 10^{15}$$



ii)

(iii) $eV_0 = h\nu - h\nu_0$

Here, e is the charge of electron, h is planck's constant, ν_0 is the threshold frequency and ν is the frequency of incident light.

On comparing with the Y= mX + C we can observe that more the intercept on the Y axis or V_0 more is the frequency (ν_0).

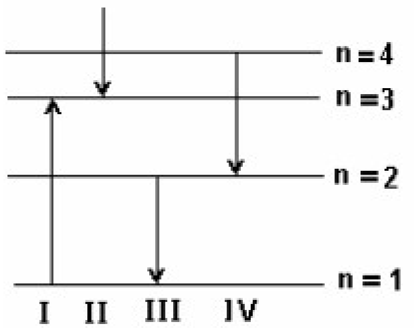
Hence from the graph, the threshold frequency of metal A is greater than the metal B, therefore the work function of metal A is more than metal B.

CLASS: XII CH.12 ATOMS

MCQs

1. **The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy**

   (a) IV (b) III (c) II (d) I



2. **Which of the following statements about the mass of an atom is true?**

A. It is evenly divided between the protons and the orbiting electrons.
B. It is evenly divided between the nucleons and the orbiting electrons.
C. It is concentrated in the electron cloud.
D. It is concentrated in the nucleus.
E. It is evenly divided between protons, neutrons and orbiting electrons.

3. **An alpha particle has**

A. a charge +e
B. a charge –e
C. a mass equal to that of deuteron
D. charge to mass ratio equal to that of a deuteron.

4. **If the second Bohr's radius of hydrogen atom is $4a_0$, then the radius of the fifth Bohr's orbit in hydrogen atom is**

   (a) $5a_0$ (b) $10a_0$ (c) $20a_0$ (d) $25a_0$

5. **In the Bohr model of the hydrogen atom is not correct**

   (a) the radius of the nth orbit is proportional to n^2
   (b) the total energy of the electron in the nth orbit is inversely proportional to n
   (c) the angular momentum of the electron in an orbit is an integral multiple of h / 2π
   (d) the magnitude of the potential energy of the electron in any orbit is greater than its kinetic energy

6. **In neutral atom, the electrons are bound to the nucleus by**

   a. Magnetic force
   b Electrostatic force
   c Friction force
   d Centripetal force

7. **Which series of hydrogen spectra exist in visible region**

a)Lymen b) Paschen c) Balmer d) Brackett

8. Which of the following transitions in a hydrogen atom emit the photon of highest frequency

a) Balmer series b) paschen series

c) Lymen series d) p – Fund Series

9. When an electron jumps from the fourth orbit to the second orbit , one gets the

A. second line of paschen series

B. second line of balmer series

C. first line of pfund series

D. second line of lyman series

10. Taking the Bohr radius as a_0= 53 pm, the radius of Li^{++} ion in its ground state, on the basis of Bohr's model, will be about:

a) 53 pm b) 27 pm c) 18 pm d) 13 pm

ASSERTION REASON TYPE QUESTIONS

For questions given below, two statements are are given-one labeled Assertion (A) and the other labeled Reason(R). Select the correct answer to these questions from the codes (a), (b), (c), (d) and (e) 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 and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is False but R is true.

(e) A is false but R is also false.

11. Assertion: During alpha particle scattering experiment most of the alpha particles pass through the gold foil undeviated.

Reason: The size of the nucleus is very small.

12. Assertion: The total energy of an electron in an orbit is negative.

Reason: Some energy is used in providing centripetal force.

13. Assertion: When transition of an electron takes place from higher energy level to lower energy level energy is radiate.

Reason: The amount of energy radiated is equal to the energy difference in the twolevels.

14. Assertion: Rydberg's constant varies with mass no. of a given element.

Reason: The 'reduced mass' of the electron is dependent on the mass of the nucleus only.

15. Assertion: Atom as a whole is electrically neutral.

Reason: Atom contains equal amount of positive and negative charges.

16. Assertion: Impact parameter for scattering of α-particles by 180° is zero.

Reason: Zero impact parameter means α-particle tends to hit the centre of the nucleus

17. Assertion: Distance of closest approach of α-particle to the nucleus is always greater than the size of the nucleus.

Reason: Strong nuclear repulsion does not allow α-particle to reach the surface of nucleus

18. Assertion: Paschen series lies in the infrared region.

Reason: Paschen series corresponds to the wavelength given by $\frac{1}{\lambda} = R(\frac{1}{3^2} - \frac{1}{n^2})$, where $n = 4, 5, 6, \ldots, \infty$

19. 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.

20. Assertion: Large angle of scattering of $\alpha -$ particles led to the discovery of atomic nucleus

Reason: Entire positive charge of atom is concentrated in the central core.

VERY SHORT ANSWER TYPE QUESTIONS

21. What is the shortest wavelength present in the Paschen series of hydrogen spectrum?

22. In the Rutherford's scattering experiment the distance of closest approach for an α −particle is d_0. If α −particle is replaced by a proton, how much kinetic energy in comparison to α −particle will it require to have the same distance of closest approach d_0 ?

23. Find the ratio of Bohr's radius in ground state and 1st excited state of H-atom?

24. The value of ground state energy of hydrogen atom is −13.6 eV.

(i) what does the negative sign signify?

(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state?

25. Use Rydberg formula to determine the wavelength of H_α line. (Given: Rydberg's constant R =1.03 X 10^7 m^{-1})

SHORT ANSWER TYPE QUESTIONS

26. The ground state energy of hydrogen atom is -13.6 ev. What are the kinetic and potential energy of the electron in that state?

27. Calculate the ratio of energies of photons produced due to transition of electron of hydrogen atoms from 2nd level to 1st and highest level to second level.

28. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in that orbit.

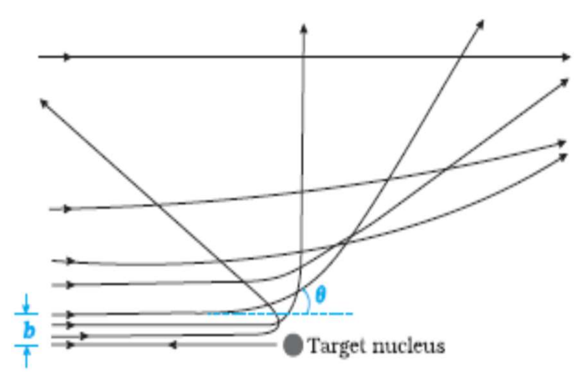
29. A monochromatic radiation of wavelength 975 Å excites the hydrogen atom from its ground state to a higher state. How many different spectral lines are possible in the resulting spectrum? Which transition corresponds to the longest wavelength amongst them.

30. What will be the distance of closest approach of a 5 MeV proton as it approaches a gold nucleus?

31. Calculate the ratio of energies of photons produced due to transition of electron of hydrogen atoms from 2nd level to1st level.

32. The spectrum of a star in the visible & the ultra violet region was observed and the wavelength of some of the lines that could be identified were found to be :824Å, 970Å, 1120Å, 2504Å, 5173Å &6100Å. Which of these lines cannot belong to hydrogen spectrum?

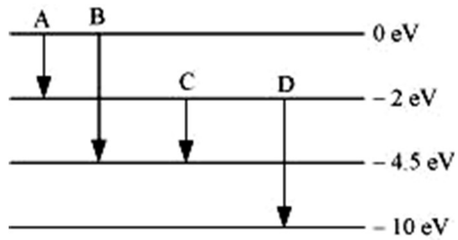
33. The trajectories, traced by different α −particles, in Geiger-Marsden experiment were observed as shown in figure.



(a) What names are given to the symbols 'b' and 'θ' shown here?

(b) What can we say about values of b for (i) θ =0^0 (ii) $\theta = \pi$ radians?

34. (a) The energy levels of an atom are as shown below. Which of them will result in the transition of a photon of wavelength 275 nm?



(b) Which transition corresponds to emission of radiation of maximum wavelength?

35. Consider two different H-atoms, the electron in each atom is in excited state. Is it possible for the electrons to have different energies but same orbital angular momentum according to Bohr model? Justify your answer.

LONG ANSWER TYPE QUESTIONS

36. State Bohr postulates and using Bohr's postulates, derive the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence, derive the expression for the orbital velocity and orbital period of the electron moving in the n^{th} orbit of hydrogen atom.

37. (A) Draw a schematic arrangement of the Geiger – Marsden experiment for studying α –particle scattering by a thin foil of gold. Describe briefly, by drawing trajectories of the scattered α –particles, how this study can be used toestimate the size of the nucleus? Draw a plot showing the number of particles scattered versus scattering angle θ.

(B) Determine the distance of closest approach when an alpha particle of kinetic energy $4.5\ \text{MeV}$ strikes a nucleus of$Z = 80$, stops and reverses its direction.

CASE BASED QUESTIONS

38. Lyman series is obtained when an electron jumps to first orbit from any subsequent orbit. Similarly, Balmer series is obtained when an electron jumps to 2^{nd} orbit from any subsequent orbit. Paschen series is obtained when an electron jumps to 3^{rd} orbit from any subsequent orbit. Whereas Lyman series in U.V. region, Balmer series is in visible region and Paschen series lies in infrared region. Series limit is obtained when $n_2=\infty$.

(i) The wavelength of first spectral line of Lyman series is
(a) 1215.4 A^0
(b) 1215.4 cm
(c) 1215.4 m
(d) 1215. 4 mm

(ii) The wavelength limit of Lyman series is
(a) 951.6 A^0
(b) 511.9 A^0
(c) 1215.4 A^0
(d) 911.6 A^0

(iii) The frequency of first spectral line of Balmer series is
(a) 1.097×10^7 Hz
(b) 4.57×10^{14} Hz
(c) 4.57×10^{15} Hz
(d) 4.57×10^{16} Hz

(iv) Which of the following transitions in hydrogen atom emit photon of highest frequency?
(a) n=1 to n=2

(b) n=2 to n=6
(c) n=6 to n=2
(d) n=2 to n=1

39. Each element is having specific properties as it emits or shows the specific emission spectrum of radiation. The emission line spectrum has bright lines on the dark surface. The hydrogen spectrum consist of series namely Balmer, Lyman, Paschen, Brackett and Pfund series. The Lyman series is formed in the ultraviolet region while Paschen, Brackett and Pfund series are in the infrared region. According to Bohr's first postulate, electrons are revolving in particular stable orbits without radiating any form of energy. And in his second postulate he told that, these electrons are revolving around the nucleus in stable orbits which are having angular momentum equal to integral multiple of h/2π. And third postulate tells us that, when electron jumps from higher energy state to lower energy state it will emits some amount of energy and which is equal to the energy difference between those energy levels.

And he gave the energy of an electron in an hydrogen atom as

$E_n = -13.6/ n^2$ eV

The negative sign shows that electron is tightly bound with the nucleus. And when n = 1, then corresponding energy of electron is called as ground state energy. Bohr's model is only applicable to single electron system like hydrogen and it cannot be applicable to helium atom also which is having two electrons.

(i) **In hydrogen atom, the ground state energy is given by___**

a) +13.6 eV
b) -13.6 J
c) -13.6 KJ
d) -13.6 eV

(ii) **According to Bohr's second postulate, the angular momentum L is given by**

a) L= h/2π
b) L = nh/2π
c) L = 2π/h
d) L = 2π/ nh

(iii) **What is the shortest wavelength in the Balmer series**

a) 656.3 nm
b) 364.6 nm
c) 656.3 mm
d) 364.6 mm

(iv) What is Balmer's formula

a) 1/wavelength = R*($1/2^2 - 1/n^2$)
b) 1/wavenumber= R*($1/2^2 - 1/n^2$)
c) **1/frequency**= R*($1/2^2 - 1/n^2$)
d) 1/wavelength = R*($1/2^2 - 1/3^2$)

40. Electrons are revolving around the nucleus in particular stable orbits. The energy of the electron is increasing as we go from the orbit closer to nucleus to outer side. The ground state energy is the lowest energy and it is -13.6 eV for hydrogen atom. Thus, the minimum amount of energy required to remove or free the electron from the ground state is the ionisation energy and it has value +13.6 eV. When electrons jumps from higher energy orbit to lower energy orbit emits energy in the form of photons which are in the form of spectral lines and called as emission lines. The light emitted by the ordinary source of light consist of different wavelength. But the laser light is the monochromatic one which emits light of single wavelength. In case of hydrogen atom, the ground state energy is that energy state for which n = 1. And the states for which n > 1, all are the excited states. Where n shows the principal quantum number.

(i) In hydrogen atom, the energy corresponding to principal quantum number n =2 is___

- **a.** -13.6 eV
- **b.** -3.4 eV
- **c.** +13.6 eV
- **d.** +3.4 Ev

(ii) For ground state of hydrogen atom the value of principal quantum number is___

a) n = 2
b) n = 0
c) n = 1
d) n = infinity

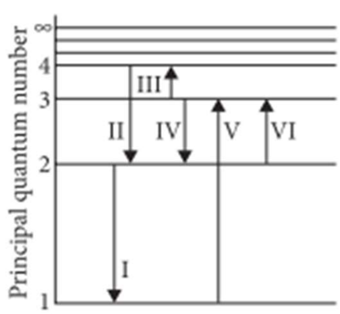
(iii) **The minimum energy required to remove the electron from the ground state of the hydrogen atom is called as___**

a) excitation energy
b) ionisation energy
c) ground state energy
d) excited state energy

(iv) The acronym LASER stands for?

a) Light Amplification bySimplification Estimation and Radiation
b) Light Amplification by Stimulated Emission of Radiation.
c) Light Amplification by Simulated Emission and Radio
d) Light Amplifier by Stimulated Emission of Radiation.

41. Read Bohr's model explains the spectral lines of the hydrogen atomic emission spectrum. While the electron of the atom remains in the ground state, its energy is unchanged. When the atom absorbs one or more quanta of energy, the electrons move from the ground state orbit to an excited state orbit that is farther away.



The given figure shows an energy level diagram of the hydrogen atom. Several transitions are marked as I, II, III, and so on. The diagram is only indicative and not to scale

i) In which transition is a Balmer series photon absorbed?

(a) II
(b) III
(c) IV
(d) VI

ii) The wavelength of the radiation involved in transition II is

(a) 291 nm

(b) 364 nm

(c) 487 nm

(d) 652 nm

iii) Which transition will occur when a hydrogen atom is irradiated with radiation of wavelength 1030 nm?

(a) I

(b) II

(c) IV

(d) V

iv) Number of spectral lines in a hydrogen atom is

(a) 8

(b) 6

(c) 15

(d) ∞

STUDY MATERIAL ANSWER KEY
CLASS: XII   CH.12 ATOMS

MCQs

1. **B**
2. D
3. D
4. D
5. B
6. B
7. C
8. D
9. B
10. C

ASSERTION REASON

11. B
12. C
13. A
14. E
15. A
16. A
17. A
18. A
19. B
20. A

VERY SHORT ANSWER

21. $\lambda = Rhc\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

n_1=3, n_2=infinity,

λ = 9/R

= 8204 Å

22. $E_{K_{\alpha}} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{d_0}$ & $E_{K_p} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{d_0} \Rightarrow E_{K_p} = \frac{1}{2}E_{K_\alpha}$

23. $1:4$

24. (i) Negative sign shows that electron is bound with the nucleus by electrostatic force

(ii) $\boldsymbol{E_n} = -\frac{\mathbf{13.6}}{\boldsymbol{n^2}}$ eV& For ground state n =1 and for first excited state n =2

$\Rightarrow \Delta E = E_2 - E_1 = -\frac{\mathbf{13.6}}{\mathbf{2^2}} - \frac{\mathbf{13.6}}{\mathbf{1^2}} = -3.4 + 13.6 = 10.2$ eV

25. For $\boldsymbol{H_\alpha}$ line, n_1=2 and n_2=3

$\Rightarrow \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36} \Rightarrow \lambda = \frac{36}{5R} = \frac{36}{5 \text{ X } 1.03 \text{ X} 10^7} = 6990\ A^0$

SHORT ANSWER

26. The potential energy of electron is given by –

$$Ep = \frac{1}{4\pi \in_0} \cdot \frac{e^2}{r}$$

and Kinetic energy is

$$E_k = \frac{1}{2} \cdot \frac{1}{4\pi \in_0} \cdot \frac{e^2}{r} = -\frac{1}{2} Ep$$

$$Ep + Ek = -13.6ev$$

Or, $Ep + \left(-\frac{1}{2} Ep\right) = -13.6ev$

Or, $\frac{1}{2} Ep = -13.6$

Or, $Ep = -27.2ev$

$\therefore Ek = 13.6ev$

27. $E_{2-1} = Rhc[\,1/n_1^2 - 1/n^2] = ¾\,Rhc$

$E_\infty - E_1 = Rhc(1/2^2 - 1/\infty) = Rhc / 4$

Ratio 3:1

28. r3 = 4775 A° and E3 = – 2.43 × 10–19 J

29.

'. The corresponding to the given wavelength

$$E = \frac{12400}{\lambda} = \frac{12400}{975} = 12.71\ eV$$

ıe excited state

$$E_n - E_1 = 12.71$$

$$-\frac{13.6}{n^2} + 13.6 = 12.71$$

$$\therefore \quad n = 3.9 \approx 4$$

$$total\ no\ of\ spectral\ lines\ emitted : \frac{n(n-1)}{2} = 6$$

ɔngest wavelength will corresponding to the transition n=1 to n=4.

30. 4.55 X 10-14m

31. $E_i = -\frac{Rhc}{{n_i}^2}$ & $E_f = -\frac{Rhc}{{n_f}^2}$

Energy of photon = $E_{2-1} = Rhc(\frac{1}{1^2} - \frac{1}{2^2})$

= ¾ Rhc

32. for hydrogen atom, $\lambda = \frac{\frac{1}{R}}{\frac{1}{{n_2}^2} - \frac{1}{{n_1}^2}} = \frac{970Å}{\frac{1}{{n_2}^2} - \frac{1}{{n_1}^2}}$

For Lyman series n_2= 1

Therefore, λ = 1293.3 Å, 1091 Å, 1034.6 Å, … … … , 970Å. (taking n_1 = 2,3,4…….∞)

For Balmer series n_2= 2

Therefore, λ = 824 Å, 1120 Å, 2504 Å, … … … , 3880Å. (taking n_2 = 2,3,4…….∞)

33. (a) symbol **'b'** represents **impact parameter**

&***'θ'*** represents **scattering angle**

(b) b = $\frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0 \left(\frac{1}{2} m u^2\right)}$

(i) **when θ =0^0**, **b** is maximum & represent the **atomic size**

(ii) **When $\theta = \pi$ radians, b** isminimum & represent **nuclear size**

34. Energy transitions for A, B, C, and D are:

A = 2 eV, B = 4.5 eV, C = 2.5 eV, D = 8 eV

$$E = \frac{hC}{\lambda}$$

Where,

E = Energy transition, λ = Wavelength, *h* = 6.63 × 10^{-34} Js, *c* = 3 × 10^8 m/s

For B, we have

$$\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.5\times1.6\times10^{-19}}$$

$$\lambda = 275 \text{ nm}$$

Thus, B will result in transition of a photon of wavelength of 275 nm.

(b)

$$E = \frac{hC}{\lambda} \Rightarrow \lambda = \frac{hC}{E}$$

For maximum wavelength, energy transition should be minimum.

A undergoes minimum energy transition.

A = 2 eV

Thus, photon in A will have the maximum wavelength

35. No

Because according to Bohr model energy of electron in n-th orbit of H-atom is given by

E_n=-13.6/n^2

Hence, electrons having different energies belong to different energy levels.

Therefore, their angular momentum will be different due to different values of n as

L = mvr = nh/2π

LONG ANSWER

36. Bohr's theory of H-atom :

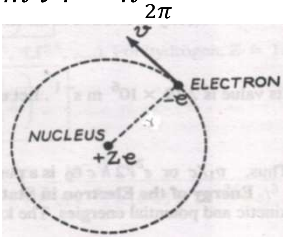
As the electrostatic force of attraction between electron and nucleus provides the necessary centripetal force

i,e, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$

$\Rightarrow mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z e^2}{r}$ ------------(1)

According to Bohr's quantum condition

$m\,v\,r = n\frac{h}{2\pi}$ -----------(2)



on squaring eqn (2) and dividing by eqn (1) we get

$$\frac{m^2v^2r^2}{m\,v^2} = \frac{n^2\mathrm{h}^2/\,4\pi^2}{\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}}$$

$\Rightarrow \boldsymbol{r} = \frac{\varepsilon_0\, n^2\, \mathrm{h}^2}{\pi\, m\, Ze^2} \Rightarrow \boldsymbol{r_n} \propto \boldsymbol{n^2}$

For H-atom $Z = 1$& for innermost orbit $n = 1$,

$\Rightarrow r_0 = \frac{\varepsilon_0 \mathrm{h}^2}{\pi\, m\, e^2}$ = 0.53 A^0. This is called **Bohr's orbit**

Energy of electron in stationary orbits

K.E. of electron, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right)$ $\quad\left[\because\, mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right]$

& P.E. $\mathrm{U} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

$\Rightarrow$ total energy of electron $E = E_K + \mathrm{U} = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right) - \frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r} = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

$E_n = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{\frac{\varepsilon_0\, n^2\, \mathrm{h}^2}{\pi\, m\, Z\, e^2}} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right)$

$\Rightarrow E_n = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right) \times \frac{ch}{ch} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,c\,h^3}\left(\frac{ch}{n^2}\right) = -\frac{\boldsymbol{Z^2Rch}}{\boldsymbol{n^2}}$

For H- atom $Z = 1$

$\Rightarrow \boldsymbol{E_n} = -\frac{\boldsymbol{Rch}}{\boldsymbol{n^2}} = -\frac{\mathbf{13.6}}{\boldsymbol{n^2}}\,\mathrm{eV}$

Where, $R = \frac{m\,e^4}{8\varepsilon_0^2\,ch^3}$ = 1.097 X 10^7 m^{-1} and is called Rydberg's constant.

Orbital velocity & time period of electron in stationary orbits

dividing by eqn (1) by (2)

$$\frac{m\,v^2}{m\,v\,r} = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r} \mathrm{X} \frac{2\pi}{n\mathrm{h}}$$

$\Rightarrow v = \frac{Ze^2}{(2\,\varepsilon_0)n\,\mathrm{h}} = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} \mathrm{X} \frac{c}{n} = \alpha\,\frac{c}{n} = \frac{1}{137}\frac{c}{n} \Rightarrow \boldsymbol{v} \propto \frac{\mathbf{1}}{\boldsymbol{n}}$

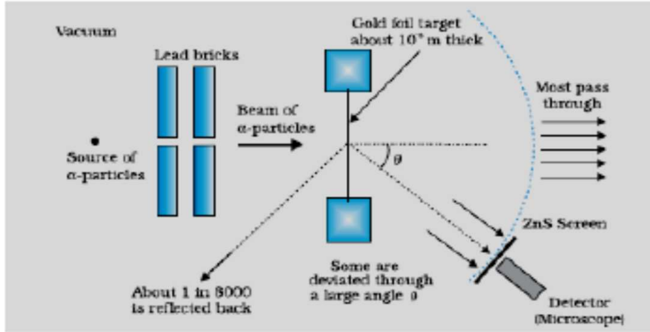
where $\alpha = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} = \frac{1}{137}$ and is called fine structure constant

Orbital period of electron in H-atom :

$$T = \frac{2\pi r}{v} = \frac{2\pi(mvr)}{mv^2} = \frac{2\pi\left(\frac{nh}{2\pi}\right)}{m\left(\frac{e^2}{2\varepsilon_0 n\,\mathrm{h}}\right)^2}$$

$\Rightarrow T = \frac{4\varepsilon_0^2\,n^3h^3}{me^4}$

37. (A)<u>Geiger-Marsden experiment</u> (Rutherford's α–Particle scattering experiment) :



High energetic collimated beam of α–Particles is allowed to fall on a very thin gold foil as shown. The scattered α- particles are observed through a rotating detector consisting of ZnS screen and microscope.

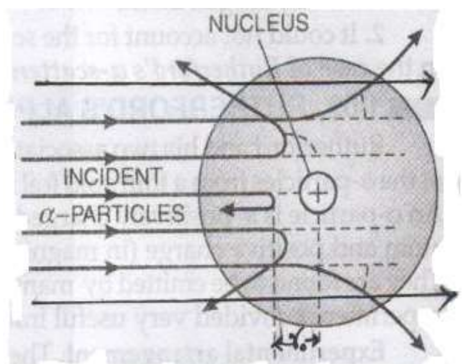
<u>Observations and Conclusions</u>:

(i) Most of the α–Particles passed un deflected through the foil. Itindicates that most of the space in an atom is empty.

(ii) Some α–Particles were deflected through small angles and only a few (1 in 8000) were deflected through large angles ($> 90^0$) to return back It concludes that whole of the positive charge and almost whole mass is concentrated in a tiny central core known as nucleus.

(iii)The number of α–Particles at a scattering angle θ is

$$N(\theta) \propto \frac{1}{sin^4(\theta/2)}$$

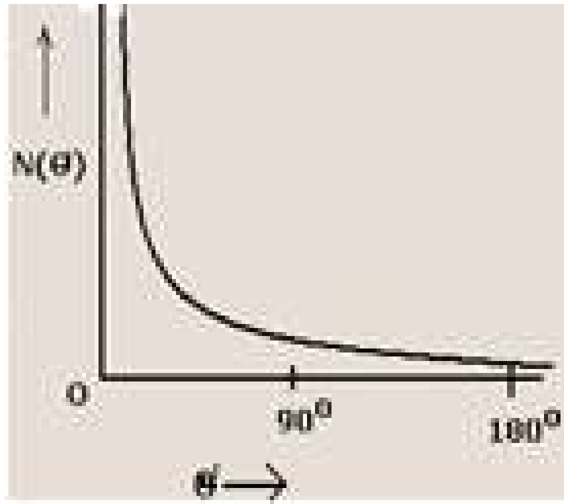


It is due to the fact that, scattering of α-particlesis in accordance withCoulomb's force.

Size of nucleus : It can be estimated by distance of closest approach

$$\frac{1}{2} m v^2 = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0}$$

$$\Rightarrow r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{\frac{1}{2}m v^2} = 2.5 \times 10^{-14} \text{ m }]$$



B)[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K} = 9\ X10^9$ X $\frac{2\ X\ 80\ X(1.6\ X1\ \ ^{-1}\ )^2}{4.5\ X10^6 X\ 1.6\ X1\ \ ^{-19}}$ = 5.12 x 10^{-14}m

CASE BASED QUESTIONS:

1. (i) A
(ii) C
(iii) C
(iv) D

2. (i) D
(ii) B
(iii) B
(iv) A

3. (i) B
(ii) C
(iii) C
(iv) B

4. (i) D
(ii) C
(iii) D
(iv) D

Multiple Choice Questions

1. The distance of closest approach of an *a*-particle fired towards a nucleus with momentum *p*, is *r*. What will be the distance of closest approach when the momentum of α-particle is 2*p*)
   a) 2*r*
   b) 4*r*
   c) *r/2*
   d) *r /4*

2. *b*-rays, emitted from a radioactive material, are known as
   a) charged particles emitted by nucleus
   b) neutral particles
   c) electrons orbiting around the nucleus
   d) electromagnetic radiations.

3. Order of magnitude of density of uranium nucleus is ($m_p = 1.67 \times 10^{-27}$ kg)
   a) 10^{20} kg/m^3
   b) 10^{17} kg/m^3
   c) 10^{14}/m^3
   d) 10^{11}/ m^3

4. Radius of nucleus $_2He^4$ is 3 Fermi. The radius of nucleus $_{82}Pb^{206}$ will be
   a) 5 Fermi
   b) 6 Fermi
   c) 11.16 Fermi
   d) 8 Fermi

5. Nuclear forces are
   a) Short ranged attractive and charge independent
   b) Short ranged attractive and charge dependent
   c) Long ranged repulsive and charge independent
   d) Long ranged repulsive and charge dependent

6. A nucleus ruptures into two nuclear parts which have their velocity ratio equal to 2:1. What will be the ratio of their nuclear size (nuclear radius)
   a) $2^{1/3} : 1$
   b) $1 : 2^{1/3}$
   c) $3^{1/2} : 1$
   d) $1 : 3^{1/2}$

7. If m, m_n and m_p are the masses of $_ZX^A$ nucleus, neutron and proton respectively

a) $m < Z m_p + (A-Z) m_n$
b) $m = Zm_p + (A-Z)m_n$
c) $m > Zm_p + (A-Z)m_n$
d) $m = Zm_n + (A-Z)m_p$

8. If a H_2 nucleus is completely converted into energy, the energy produced will be around
a) 1 MeV
b) 938 MeV
c) 1863 Mev
d) 238 MeV

9. The mass defect in a nuclear fusion reaction is 0.3 percent. What amount of energy will be liberated in one kg fusion reaction?
a) 1.6×10^{13} J
b) 3.7×10^{14} J
c) 2.7×10^{14}J
d) 0.5×10^{15}

10. In the reaction A+B=C if a,b and c are the binding energies in Mev, then energy released in the reaction is
a) c + a – b
b) c – a – b
c) a + b + c
d) a + b – c

11. In any fission process the ratio mass of fission product to fission reactant is
a) Less than 1
b) Greater than 1
c) Equal to 1
d) Depends on the mass of the parent nucleus

12. The fusion of hydrogen into helium is more likely to take place at
(a) low temperature and high pressure
(b) high temperature and high pressure
(c) low temperature and low pressure
(d) high temperature and low pressure

13. The mass of $_3Li^7$ is 0.042 a.m.u less than the sum of masses of its constituents. The binding energy per nucleon is :
(a) 5.586 MeV
(b) 10.522 MeV
(c) 2.433 MeV
(d) 3.739 MeV

14. The density of nucleus is a constant, for all nuclei because –
(a) Nuclear radius of depends on cube root of atomic mass of the atom.
(b) Nuclear radius of depends on cube of atomic mass of the atom.

(c) Nuclear radius is independent of atomic mass of the atom.
(d) None of these.

15. The use of moderator in nuclear reactors
(a) To slow down the fast-moving secondary neutrons produced during the fission
(b) To accelerate the fast-moving secondary neutrons produced during the fission
(c) To speed up the fast-moving secondary neutrons produced during the fission
(d) To neutralize the fast-moving secondary neutrons produced during the fission

16. A chain reaction in fission of uranium is possible because
(a) large amount of energy is released
(b) more than one neutron is given out
(c) small amount of energy is released
(d) fragments in fission are radioactive

17. 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 is repulsive.
(c) neutrons decay into protons through beta decay.
(d) nuclear forces between neutrons are weaker than that between protons.

18. The large-scale destruction, that would be caused due to use of nuclear weapons is known as
(a) neutron holocaust
(b) thermonuclear reaction
(c) neutron reproduction factor
(d) None of the above

19. The radius of germanium (Ge) nuclide is measured to be twice the radius of ($_4Be^9$).The number of nucleons In Ge are
(a) 72
(b) 73
(c) 74
(d) 75

20. The fission of $_{92}U^{235}$ can be triggered by the absorption of a slow neutron by a nucleus. Similarly, a slow proton can also be used. This statement is
(a) correct
(b) wrong
(c) information is insufficient
(d) None of the above

Assertion -reasoning type

Given below two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the following: (a) Both A and R are correct and R is the correct explanation of A (b)Both A and R are correct and R is not the correct explanation of A (c) A is true but R is false (d)Both A and R are false

21. Assertion : Binding energy per nucleon is nearly constant for element in the range A = 30 to A=170
Reason : The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometers.

22. Assertion : Neutron is used as a bombarding particle.
Reason : Neutron has no charge so it can penetrate the target without being repelled by the nucleus.

23. Assertion: Density of all nuclei is same.
Reason: Radius of nucleus is directly proportional to the cube root of mass number.

24. Assertion(A): The fusion process occurs at extremely high temperature.
Reason(R): For fusion of two nuclei, enormously high kinetic energy is required.

25. Assertion(A): Nuclear force is same between neutron-neutron, proton-proton and neutron-proton.
Reason(R): Nuclear force is charge dependent.

26. Assertion: The nuclear force becomes weak if the nucleus contains too many protons compared to neutrons
Reason: The electrostatic forces weaken the nuclear force.

27. Assertion: Heavy water is used as moderator in nuclear reactor.
Reason: Water cools down the fast neutron.

28. Assertion: Nuclei having mass number about 60 are most stable.
Reason: When two or more nuclei are combined into a heavier nucleus, then binding energy per nucleon increases.

29. Assertion: Two protons can attract each other.
Reason: The distance between the protons within the nucleus is about 10^{-15} m.

30. Assertion: Fast moving neutrons do not cause fission of a uranium nucleus.
Reason: A fast moving neutron spends very little time inside the nucleus.

Very short answer type (Section C)

31. Calculate the energy equivalent of 1 amu of substance.
32. How many electron volts make up one joule?
33. Write any two characteristic properties of nuclear force.
34. What are uncontrolled and controlled chain reactions?
35. Why do stable nuclei never have more protons than neutrons?
36. Why are heavy nuclei usually unstable?
37. Safety of nuclear reactors is an important issue. Guess some of the safety problems that a nuclear engineer must cope within reactor design
38. Write the name of reaction on which nuclear reactor is based, how number no of neutrons are controlled in nuclear reactor?
39. What is the main cause of energy released in nuclear reaction, Explain by giving one example.
40. If A is split into two nuclei B&C, which of them have least binding energy and why?

Short answer type

41. A chain reaction dies out some times, why? Give three reasons
42. Define nuclear fusion. Nuclear fusion is not possible in laboratory. Explain

43. What is mass defect of a nucleus? Express it mathematically. What light does it throw on the binding energy of nucleus?

44. Calculate the energy release in MeV in the deuterium fusion reaction

$_1H^2 + {}_1H^3$------$_2He^4$ +n , Using the following data

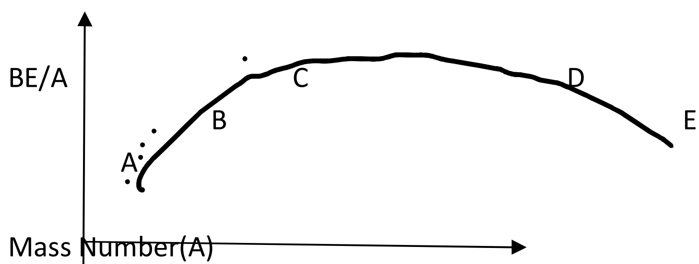
m($_1H^2$)= 2 014102 u, m($_1H^3$)= 3 016049 u, m($_2H^4$)= 4 002603 u, m_n= 1 008665 . u

1u =931.5MeV

45. Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the graph.

46. 46. A nucleus with mass number, A = 240 and BE /A = 7. 6 MeV breaks into two fragments each of A = 120 with BE /A = 8. 5 MeV Calculate the released energy.

47. 47. The figure shows the plot of binding energy (B.E.) per nucleon as a function of mass number A. The letters A,B,C,D and E represent the positions of typical nuclei on the curve. Point out, giving reasons, the two process (in terms of A,B,C,D and E), one of which can occur due to nuclear fission and the other due to nuclear fusion.



48. What are the utilities of moderator, coolant and controlling rods with reference to unclear reactor?

49. What do you mean by binding energy of nucleus? Obtain an expression for binding energy. How binding energy per nucleon explains the stability of nucleus?

50. Obtain the binding energy (in MeV) of a nitrogen nucleus ($_7N^{14}$) given m ($_7N^{14}$) =14.00307u

(LONG ANSWER QUESTIONS)

51. Draw the graph showing the variation of binding energy per nucleon with mass number. What inference you get from this graph. Also explain the importance of binding energy curve.

52. (i) Distinguish between nuclear fission and fusion giving an example of each (ii) Explain the release of energy in nucleus fission and fusion on the basis of binding energy per nucleon curve.

53. (i) How is the size of a nucleus found experimentally? Write the relation between the radius and mass number of a nucleus. (ii) Prove that the density of a nucleus independent of its mass number.

54. 54. Give reason for : (a) Lighter elements are better moderators for a nuclear reactor than heavier elements. (b) In a natural uranium reactor, heavy water is preferred moderator as compared to ordinary water. (c) Cadmium rods ar provided in a reactor. (d) Very high temperature as those obtained in the interior of the sun are required for fusion reaction.

55. What do you mean by binding energy of nucleus? Obtain an expression for binding energy. How binding energy per nucleon explains the stability o nucleus?

CASE BASED QUESTIONS :

Case Study 1:

1. Neutrons and protons are identical particles in the sense that their masses are nearly the same and the force, called nuclear force, does distinguish them. Nuclear force is the strongest force. Stability of the nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadruple moment and spin of nucleus depends on

even and odd mass number. Volume of the nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centered 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 the same as the force between a proton and neutron. The nature of the force is

(a) Electrical force (b) Weak nuclear force

(c) Strong nuclear force (d) Gravitational force

(iv) Two protons are kept at a separation of 40 A^0 . Fn is the nuclear force and Fe is the electrostatic force between them. Then

(a) Fn<< Fe (b) Fn = Fe (c) Fn>> Fe (d) Fn ≈ Fe

CASE STUDY 2

2. In the year 1939, German scientist Otto Hahn and Strassmann discovered that when a uranium isotope was bombarded with a neutron, it breaks into two intermediate mass fragments. It was observed that, the sum of the masses of new fragments formed were less than the mass of the original nuclei. This difference in the mass appeared as the energy released in the process. Thus, the phenomenon of splitting of a heavy nucleus (usually A> 230) into two or more lighter nuclei by the bombardment of proton, neutron, a-particle, etc. with liberation of energy is called nuclear fission.

$${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}n + Q$$

(i) Nuclear fission can be explained on the basis of

(a) Millikan's oil drop method (b) Liquid drop model

(c) Shell model (d) Bohr's model

(ii) For sustaining the nuclear fission chain reaction in a sample (of small size) ${}^{235}_{92}\mathrm{U}$, it is desirable to slow down fast neutrons by

(a) Friction (b) Elastic damping/scattering (c) Absorption (d) None of these

(iii) On an average, the number of neutrons and the energy of a neutron released per fission of a uranium atom are respectively

(a) 2.5 and 2 keV (b) 3 and 1 keV (c) 2.5 and 2 MeV (d) 2 and 2 keV

(iv) In any fission process, ratio of mass of daughter nucleus to mass of parent nucleus is

(a) Less than 1 (b) Greater than 1

(c) Equal to 1 (d) Depends on the mass of parent nucleus

CASE STUDY 3

3. The nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of alpha-particles by atoms. He found that the scattering results could be explained, if atoms consist of a small, central, massive and positive core surrounded by orbiting electron. The experimental results indicated that the size of the nucleus is of the order of 10^{-14} m and is thus 10000 times smaller than the size of atom.

(i) Ratio of mass of nucleus with mass of atom is approximately

(a) 1 (b) 10 (c) 10^3 (d) 10^{10}

(ii) Masses of nuclei of hydrogen, deuterium and tritium are in ratio

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

(iii) Nuclides with same neutron number but different atomic number are

(a) Isobars (b) Isotopes (c) Isotones (d) None of these

(iv) If R is the radius and A is the mass number, then log R versus log A graph will be

(a) A straight line (b) A parabola (c) An ellipse (d) None of these

CASE STUDY 4

4. The density of nuclear matter is the ratio of the mass of a nucleus to its volume. As the volume of a nucleus is directly proportional to its mass number A, so the density of nuclear matter is independent of the size of the nucleus. Thus, the nuclear matter behaves like a liquid of constant density. Different nuclei are like drops of this liquid, of different sizes but of same density. Let A be the mass number and R be the radius of a nucleus. If m is the average mass of a nucleon, then Mass of nucleus = mA

Volume of nucleus = $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi(R_0 A^{\frac{1}{3}})^3 = \frac{4}{3}\pi R_0{}^3 A$

Nuclear density, $\rho_{nu} = \frac{mass\ of\ nucleus}{volume\ of\ nucleus} = \frac{mA}{\frac{4}{3}\pi R_0{}^3 A} = \frac{m}{\frac{4}{3}\pi R_0{}^3}$

Clearly, nuclear density is independent of mass number A or the size of the nucleus. The nuclear mass density is of the order 10^{17} kg m^{-3} . This density is very large as compared to the density of ordinary matter, say water, for which $p = 1.0 \times 10^3$ kg m^{-3} .

(i) The nuclear radius of $^{16}_{8}O$ is 3 X 10^{-15} m. The density of nuclear matter is

(a) 2.9×10^{34} kg m^{-3} (b) 1.2×10^{17} kg m^{-3}

(c) 16×10^{27} kg m^{-3} (d) 2.4×10^{17} kg m^{-3}

(ii) What is the density of hydrogen nucleus in SI units? Given R_0 = 1.1 fermi and m_p = 1.007825 amu

(a) 2.98×10^{17} kg m^{-3} (b) 3.0×10^{34} kg m^{-3}

(c) 1.99×10^{11} kg m^{-3} (d) 7.85×10^{17} kg m^{-3}

(iii) Density of a nucleus is

(a) more for lighter elements and less for heavier elements.

(b) more for heavier elements and less for lighter elements

(c) very less compared to ordinary matter

(d) a constant

(iv) If the nucleus of $^{27}_{13}Al$ has a nuclear radius of about 3.6 fm, then $^{125}_{52}Te$ would have its radius approximately as

(a) 9.6 fm (b) 12 fm (c) 4.8 fm (d) 6 fm

CASE STUDY 5

5. NUCLEAR ENERGY: As per the population rise in our country, energy demand is also increasing especially the electrical energy. For fulfilment of such demand, one of the option is to utilize nuclear sources. Nuclear energy is obtained through the nuclear fission process, where a bi nucleus gets split into two or more than two smaller nuclei along with tremendous amount of energy. This energy can be used for either constructive purpose or destructive purpose for the humans. Nuclear reaction is of

two types- nuclear fission and nuclear fusion. In nuclear reactor , controlled nuclear fission reaction is carried out.

(i). The process taking out in the sun, due which we get light and heat energy

(A) Nuclear fission (B) Nuclear fusion

(C) Thermal reactions (D) Nuclear holocaust

(ii) The atomic energy programme in our country was launched under the leadership of

(A) C V Raman (B) H J Bhabha (C) A P J Abdul Kalam (D) Amit Bhatnagar

(iii). The temperature of the core of the sun is about

(A) 103 to 104K (B) 106 to 107K (C) 109 to 1010K (D) None of the above

(iv). To slow down the fast moving neutrons in nuclear reactor by

(A) Control rods (B) Moderator (C) Coolant (D) Plasamon

Multiple Choice Questions:

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

Solution of MCQ

1:- r α 1/k , p^2 =2mk so when p become 2p ,k become 4k so radius become r/4

4:-Use R1/R2 =$(A1/A2)^{1/3}$ R1=3,A1=4,A2=206

6:- A/C to law of conservation of momentum m_1v_1=m_2v2, m1/m2 = v1/v2 =2:1, now use R1/R2=$(A1/A2)^{1/3}$, A1/A2= 2:1

8:- Mass of H_2 is around 2 amu so energy released will be 2 x 931.5=1863 Mev.

9:- Einstein's equation E=mc^2 ,E=.3/100 X1 x$(3x10^8)^2$=2.7 x10^{14}J

13:-.042X931.5/7=5.58 Mev

19:-Use R1/R2=$(A1/A2)^{1/3}$, ½= $(9/A2)^{1/3}$,1/8 =9/A2 SO A2=72

Solution to assertion-reasoning type

21. (a) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometers. This leads to saturation of forces in a medium or a large-sized nucleus, which is the reason for the constancy of the binding energy per nucleon.
22. (a)
23. (a)
24. (a)
25. (c)
26. (c)
27. (a)
28. (a)
29. (a)
30. (a)

Section c (very short question answer)

31. 931.5 Mev
32. $1.6x10^{-19}$ J=1 eV, therefore 1J= 6.25 X 10^{18} eV
33. 1) It is short range force. 2) Charge independent force
34. Uncontrolled chain reaction-In which neutron released during chain reaction cause further fission reaction and it is a chain reaction causes release of tremendous amount of energy

    Control chain reaction-In this reaction neutrons are kept in control by absorbing material and process proceed in control way.
35. As no. of protons increases, the repulsive force increases, which make nuclei unstable and it tends to break so, to keep the nucleus stable more no of neutrons are needed.
36. In heavy nuclei no of proton increase so the repulsive force which become dominant and makes them unstable.
37. .i) As excessive heating is produced during nuclear reaction , they have to design reactor to avoid accident due to heating.2) they have to design reactor in such a way that hazardous errect due to radiation become minimum.
38. On an average 2.5 neutrons are released. (some process 2 and some process 3)
39. Mass defect is main reason ,during formation of nucleus ,there is some mass defect which convert into energy called binding energy.
40. A, because A breaks into 2 nuclei which are more stable, therefore A having least binding energy.

Short answer type

41. (i) Size of fissionable material may be less than the critical size. (ii) Mass of fissionable material may be less than the critical mass. (iii) Neutron absorbing material might absorb neutrons at a faster rate then the rate at which they are being produced.
42. When two or more light nuclei combine to form a heavy nucleus,it is called nuclear fusion reaction, in lab fusion reaction is not possible because it require huge temperature and pressure.
43. This missing mass is known as the 'mass defect' and it accounts for the energy released. The mass defect (**Δ**M) can be calculated by subtracting the original atomic mass (M_A) from the sum of the mass of protons (m_p= 1.00728 amu) and neutrons (m_n= 1.00867 amu) present in the nucleus.
44. In this reaction total mass of reactant is=5.030151 amu and total mass of product is 5.011268 ,so mass defect is 0.018883 amu so total energy released will be 0.018883x931.5=17.5895245 Mev'
45. *(1)* Nuclear for id attractive for r> r_0 (2) Nuc lear force is repulsive if two are separated by distance less than r_0
46. Since the nucleus as a mass number A = 240 and binding energy for nucleon is 7.6 MeV. Its total binding energy is E1 = 240 X 7.6 = 1824 MeV. As both fragments of mass number A = 120 as a binding energy for nucleon of 8.5 MeV, so total energy of fragments is E2 = 2 X 120 X 8.5 = 2040 MeV. Therefore energy released is = 2040 – 1824 =216 MeV.
47. A & B combine to for nuclear fusion reaction, E breaks and gives nuclear fission reaction.
48. Moderator -It slow down the neutron produce during reaction to make them enable for further fission.

    Coolent-It is used to absorb excessive pressure generated during fission.

    controlling rods-They are used to absorb undesired neutron to control chain reaction.
49. The energy evolve during formation of nucleus due to mass defect is called binding energy.

    Mass defect=(Zm_p+(Z-A)m_n-m_N($_zX^A$)) ,Binding energy =mass defectx931.5MeV

    Larger the binding energy per nucleon, the greater the work that must be done to remove the nucleon from the nucleus, the more stable the nucleus.
50. Nitrogen has 7 proton and 7 neutron so total mass of proton and neutron =7X1.00727647+7X1.0087 =14.11183539 ,mass defect will be=14.11183539-14.00307 = 0.10876529,so binding energy will be 0.010876529x931.5=101.314867635 MeV.

Case Syudy Answer

Case Study 1: (i) d (Ii) d (Iii) c (Iv) a

Case Study 2 : (i) b (Ii) b (Iii) c (Iv) a

Case Study 3: (i) a (Ii) a (Iii) c (Iv) a

Case Study 4: (i) d (Ii) a (Iii) d (Iv) d

Case Study 5: (i) b (Ii) b (Iii) b (Iv) b

CHAPTER 14: SEMICINDUCTOR

MCQs- 20

1. If semiconductor M has a knee voltage of 0.7 V whereas semiconductor N has a knee voltage of 0.3 V then ;

(a) M is silicon; N is Germanium (b) M is Germanium arsenide; N is silicon
(c) M is silicon; N is Germanium Arsenic (d) M is Germanium; N is silicon

2. What will be the resistance of a semiconductor at a low temperature?
(a) low (b) one (c) zero (d) high

3. If the number of valence electrons in an atom is less than 4 what is the substance called?
(a) A conductor (b) A semiconductor (c) neutral (d) A bad conductor

4. Within depletion reason of the p and junction diode:
(a) beside is positive and n side is negative (b) P side is negative and an side is positive
(c) both sides are either positive or negative (d) both sides are neutral

5. The depletion layer opposes the flow of:
(a) majority charge careers (b) minority charge carriers
(c) both minority and majority charge carriers (d) neither minority nor majority charge careers

6. The cause of the potential barrier in a p and junction diode is:
(a) depletion of positive charges near the junction (b) concentration of positive charges near the junction
(c) depletion of negative charges near the junction
(d) concentration of positive charge and negative charges near the junction

7. When voltage is applied across a semiconductor, holes will:
(a) flow towards negative terminal (b) flow in external circuit
(c) flow away from negative terminal (d) not flow

8. Doping of silicon with arsenic leads to:
(a) A conductor (b) an insulator (c) A p-type semiconductor
(d) an n-type semiconductor

9. The cause of the barrier layer in PN junction is :
(a) doping (b) recombination (c) barrier (d) ions

10. The formation of depletion region in a PN junction diode is due to :
(a) movement of dopant atoms (b) diffusion of both electrons and holes
(c) drift of electrons only (d) drift of holes only

11. When a voltmeter is connected across a forward biased diode, it will read a voltage approximately equal to:
(a) bias battery voltage (b) output voltage
(c) diode barrier potential (d) none of these

12. In an extrinsic semiconductor, the number density of holes is4×10^{20} m^{-3}. If the number density of intrinsic cariers is 1.2×10^{15} m^{-3}, the number density of electrons in it is :
(a) 1.8×10^{9} m^{-3} (b) 2.4×10^{10} m^{-3} (c) 3.6×10^{9} m^{-3} (d) 3.2×10^{10} m^{-3}

13. The current in the external wire for P type semiconductor is due to:
(a) free electrons (b) holes (c) positive ions (d) negative ions

14. The Forbidden energy gaping conductors, semiconductors and insulators are EG1,EG2 and EG3 respectively. The relation among them is:
(a) EG1=EG2=EG3 (b) EG1<EG2<EG3 (c) EG1>EG2>EG3 (d) EG1<EG2>EG3

15. The conductivity of semiconductor increases with temperature, because:
(a) number density of free current cariers increases (b) relaxation time increases
(c) both number density of cariers and relaxation time increases

(d) number density of carriers increases, relaxation time decreases but effect of decrease is much less than the increase in number density.

16. When an electric field is applied across a semiconductor :

(a) holes move from lower energy level to higher energy level in conduction band (b) electrons move from higher energy level to lower energy level in conduction band(c) holes in valance band more from higher to lower energy level (d) holes in valance band move from lower to higher energy level

17. Which of the following is responsible for electric conductivity in a semiconductor:

(a) only electrons(b) holes only (c)both holes and electrons (d) none of these

18. In the depletion reason of a diode:

(a) there are mobile charges(b) equal number of holes and electrons exist, making the region neutral

(c) recombination of holes and electrons has taken place (d) immobile charge ions do not exist

19. A p- type semiconductor can be obtained by adding:

(a) Arsenic to pure silicon (b) gallium to pure Si (c) Antimony to pure Ge (d) Phosphorus to pure Ge.

20. The breakdown in a reverse biased p-n junction diode is more likely to occur due to :

(a) large velocity of majority charge carriers if the doping concentration is small (b) large velocity of minority charge carriers if the doping concentration is large (c) strong electric field in a depletion region if doping concentration is small (d) strong electric field in a depletion region if doping concentration is large.

2. **ASSERTION & REASON - 10**

For the following 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.

1. **Assertion**: conductivity of a semiconductor increases on doping with pentavalent atoms.

Reason: pentavalent atoms can easily donate electrons due to their less ionization energy.

2. **Assertion**: conductivity of an n-type semiconductor is greater than that of p-type semiconductor**.**

Reason: electrons have greater mobility than holes.

3. **Assertion:** in a half wave rectifier if diode is short circuited the output from the rectifier will be identical to the wave of the input primary voltage.

Reason: since the diode is shorted it act as a piece of wire.

4. **Assertion:** full wave rectifier preferred to half wave rectifier.

Reason: the output of a full wave rectifier is twice as great as the half wave rectifier.

5. **Assertion:** the depletion region of a p-n junction is devoid of free electrons and holes.

Reason: we can take a slab of p-type semiconductor and join it physically to n- type and form a p-n junction.

6. **Assertion:** n-type material is negatively charged.

Reason: n-type material has excess of electrons which are negatively charged.

7. **Assertion:** the depletion layer in p-n junction under forward bias decreases.

Reason: the electric field due to external voltage supports the electric field due to potential barrier.

8. **Assertion:** for the same degree of doping the conductivity of n-type semiconductor is more than that of p-type semiconductor.

Reason: a hole represents a missing valence electron in a covalent bond, therefore a hole can be thought as a positive charge.

9. **Assertion:** a semiconductor is virtually an insulator at room temperature.

Reason: at room temperature almost all the valence electrons are engaged in the formation of covalent bond and there are practically very few free electrons.

10. **Assertion:** in a semiconductor, the conduction of electrons have a higher mobility than holes.

Reason: the electrons experience fewer collisions.

3. **Very Short Answer Questions (10):**

1. Why is it difficult to make intrinsic semiconductors?
2. What is an energy band in a solid.
3. What is the order of energy gap in a semiconductor?
4. Name two important processes involved in the formation of p-n junction.
5. What us the thickness of depletion layer in a p-n junction diode?
6. Why is a p-n junction is called junction diode?
7. Name two factors on which electrical conductivity of a pure semiconductor at a given temperature depends.
8. How does the conductivity of a semiconductor change with the rise in temperature?
9. What is an ideal junction diode?
10. What is the order of reverse current in reverse biased p-n junction?

.**4. Short Answer Questions (10):**

1. What is doping? Why is it needed?

2. Distinguish between intrinsic and extrinsic semiconductors.
3. C,Si and Ge have the same lattice structure. Why is C insulator while Si and Ge are intrinsic semiconductors?
4. A forward biased p and junction has a potential drop of 0.4 V across it, that is independent of the current. It can withstand a maximum current of 8 mA, beyond which it will burnout. If this diode is in series with 150 ohm of resistance, find the maximum battery voltage that should be applied when in forward bias.
5. Why are semiconductor diodes non-ohmic?
6. How does a semiconductor diode work?
7. What is p-type and n-type semiconductor?
8. Semiconductor diodes can be used as _______
9. What are the uses of semiconductor diodes?.
10. What happens when applying a forward bias to a PN junction diode?

<u>5. CASE STUDY BASED - 5</u>

1. A Silicon diode has forward voltage drop 1.0 V for a DC current of 50 mA. It has a reverse current of 1 microampere for a reverse voltage 5V. A bilateral element generally offers same value of resistance in either direction of current whereas unilateral elements do not offer same resistance.

(i) what is the resistance ofered by the diode in the forward direction?

(a) 10 ohm (b) 20 ohm (c) 30 ohm (d) 40 ohm

(ii) calculate the resistance offered by the diode in reverse direction.

(a) 5G ohm (b) 5 microohm (c) 5M ohm (d) 5m ohm

(iii) Is diode unilateral or bilateral?

(a) it is unilateral element as it does not offer different resistance for either direction of current.

(b) it is bilateral element as it offers different resistance for either direction of current.

(c) it is unilateral element as it does not offer same resistance for either direction of current.

(d) it is bilateral element as it does not offer same resistance for either direction of current.

(iv) observe the values calculated in part (i) and (ii) which one is higher and why?

(a) reverse resistance as the reverse current is very low

(b) forward resistance as the reverse current is very low

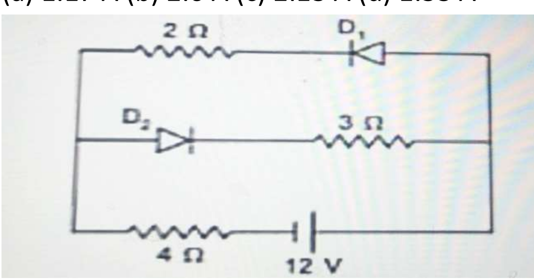
(c) reverse resistance as the reverse current is very high

(d) forward resistance as the reverse current is very high.

Or

(iv) the forward biased diode current is:

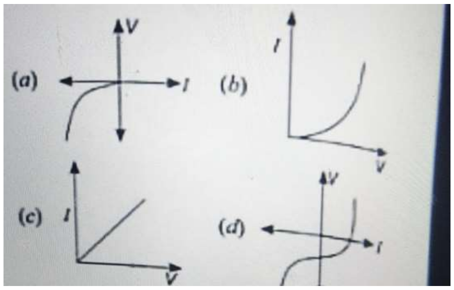
(a) more of drift current than the diffusion current
(b) predominantly drift current (c) predominantly diffusion current
(d) an equal combination of drift and diffusion current.
2. An alternative voltage V= 200 sin Omega t is applied to a divide that offers an ohmic resistance of 20 ohm to the flow of current in one direction, while blocked the flow of current in opposite direction.
(i) which device is used here?
(a) AC generator (b) Transformer (c) p-n junction diode (d) none of these
(ii) which type of circuit is this?
(a) inductive circuit (b) capacitive (c) half wave rectifier (d) full wave rectifier
(iii) what is the rms value of current in the above circuit for one cycle?
(a) 5 A (b) 6 A (c) 7A (d) 8 A
Or
What is the average value of current for one cycle?
(a) 1.18 A (b) 2.18 A (c) 3.18 A (iv) 4.18 A
(iv) how many diodes are used by a half wave rectifier circuit for the transformation?
(a) no diode used (b) one (c) two (d) four
3. There are different techniques of fabrication of p-n junction. In one such technique, called fused junction techniques, an aluminium film is kept on the wafer of n-type semiconductor and the combination is then heated to a high temperature (about 600 °C). As a result, aluminium fused into silicon and produces p-type semiconductor and in this way p-n junction is formed.
(i) when a PN junction is reversed by asked then how does the height of potential barrier change?
(a) no current flows (b) the depletion region is reduced (c) height of potential barrier is decreased
(d)height of potential barrier is increased
(ii) the cause of potential barrier in PN junction is:
(a) depletion of positive charges near the junction
(b) concentration of negative charges near the junction
(c) concentration of positive and negative charges near the junction
(d) depletion of negative charges near the junction
(iii) the circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit?
(a) 1.17 A (b) 2.0 A (c) 2.13 A (d) 1.33 A



(iv) Carbon, Germanium and silicon are 14th group elements:
(a) C and Ge are semiconductors (b) C and Si are semiconductor
(c) all C, Ge and Si are semiconductors (d) Si and Ge are semiconductors
Or
When a PN junction is forward biased then:
(a) only diffusion current flows
(b) both diffusion current and drift current flow but diffusion current is more than drift current
(c) only drift current flows
(d) both diffusion and drift current flow but drift current exceeds the diffusion current.

4. In forward bias arrangement the P side of a p-n junction is connected to positive terminal of battery and and n side to negative terminal of battery, the current flow increases very slowly tell the certain threshold voltage is reach. Beyond this value that diode current increases exponentially even for a very small increment in diode bias voltage. In Reverse bias the current suddenly increases at very high reverse bias this is called breakdown voltage.

(i) the characteristic curve for p-n junction in forward biased is:



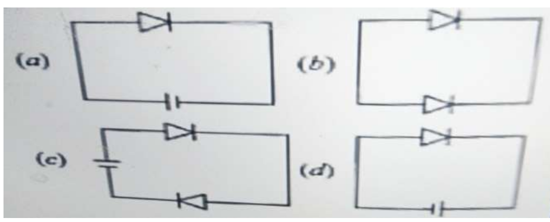
(ii) what is the approximate value of threshold voltage for a silicon diode?

(a) 0.7 V (b) 0.14 V (c) 0.7 eV (d) 0.14 eV

(iii) which of the following is a semiconductor device that emits visible light when it is forward biased?

(a) transistor (b) LED (c) p-n junction (d) none of these

(iv) which diagram represents the reverse bias of a p-njunction diode?



Or

How does current under reverse bias depend on applied voltage?

(a) it varies directly with potential (b)it varies inversely with potential

(c) it is almost independent of applied potential up to critical voltage

(d) it remains unchanged after critical voltage is reached.

5. From Bohr's atomic model we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap.

(i) in an insulator energy band gap is:

(a) $E = 0$ (b) $E<3eV$ (c) $E>3eV$ (d) none of these

(ii) in a semiconductor separation between conductors and valence band is of the order of:

(a) 0 eV (b) 1eV (c) 10eV (d) 50eV

(iii) based on the band theory of conductors insulators and semiconductors the forbidden gap is smallest in:

(a) conductors (b)insulator (c) semiconductors (d) all of these

(iv) solids having highest energy level partially filled with electrons are:

(a) semiconductor (b) conductor (c) insulator (d) none of these

Or

Carbon, Silicon and Germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate?

(a) the number of free electrons for conduction is significant only in Silicon and Germanium but small in carbon.

(b) the number of electrons is significant in carbon but small and silicon and Ge
(c) the number of free conduction electrons is negligibly small in all the three.
(d) the number of free electrons for conduction is significant in all the three.

6. **Long answer questions (05)**

1. (i)State briefly the processes involved in the formation of p-n junction, explaining clearly how the depletion region is formed.
(ii)Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in (a) forward biasing (b) reverse biasing How are these characteristics made use of in rectification?
2. Explain 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.
3. Explain how a depletion layer and barrier potential are formed in a junction diode.
4..(i) Describe briefly, with the help of a diagram, the role of the two important processes involved in the formation of a p-n junction.
(ii) Name the device which is used as a voltage regulator. Draw the necessary circuit diagram and explain its working.
5. Using the necessary circuit diagrams, show how the V – l characteristics of a p-n junction are obtained in Forward biasing and Reverse biasing.
How are these characteristics made use of in rectification?

Answers

MCQs- 20

1. Ans. (a) M is silicon; N is Germanium
Concept: • nebulties is the minimum voltage required for a significant current to flow through a forward biased diode.
• lower knee voltage indicates better conductivity in the semiconductor material.
• in this case semiconductor and has a lower knee voltage 0.3 V compared to semiconductor M 0.7 v
• Germanium typically has a new voltage around 0.3 V while Silicon has a k voltage around 7 v
• therefore based on the given knee voltage values semiconductor and is likely Germanium and semiconductor and is likely silicon.
2.Ans. (d) high
At low temperature the energy of the valence band electron is not enough to jump in the conduction band and their will be a very free electrons available for conduction hands at low temperature the resistance of a semiconductors at low temperatures is high.
3. Ans. (a) A conductor
The electrons in the last Orbit which also determinants mainly the electrical properties of the elements are known as Valence Electrons by electrical conductivity the elements are divided into three groups conductors semiconductors and insulators in conductors elements have less than 4 electrons in the outermost shell that means it has less than 4 Valence Electrons.
4. Ans. (b) P site is negative and n side is positive
5. Ans. (a) majority charge carriers.
6. Ans. (d) concentration of positive charge and negative charges near the junction.
7. Ans. (a) flow towards the negative terminal.
8. Ans. (d)an n-type semiconductor.
9. Ans. (b) recombination.
10. Ans. (b) diffusion of both electrons and holes.
11. Ans. (c)diode barrier potential.
12. Ans. (c)3.6×10^9 m^{-3}
13. Ans. (a) free electrons.

14. Ans. (b)G1 $<$ EG2 $<$ EG3
15. Ans. (d)number density of carriers increases, relaxation time decreases but effect of decrease is much less than the increase in number density.
16. Ans. (c) when electric field is applied across a semiconductor, electrons in the conduction band move from lower to higher energy level. While the holes in valance band move from higher to lower energy level, where they will be having more energy.
17. Ans. (c) both holes and electrons
18. Ans.(b)equal number of holes and electrons exist, making the region neutral
19. Ans. (b) Gallium to pure silicon
20. Ans. (d)strong electric field in a depletion region if doping concentration is large.
2. ASSERTION & REASON - 10
1. (a) 2. (a) 3. (a) 4. (a) 5. (c) 6. (d) 7. (c) 8. (b) 9. (a) 10.(c)
3. Very Short Answer Questions (10):
1.Ans. An intrinsic semiconductor has to be very pure with a purity level of 99.9999 %. It is very difficult to get this much purity.
2. Ans.The highest energy band filled with valence electrons is called valence band.
3. Ans. 1 eV.
4. Ans. 1. Diffusion 2. Drift
5. Ans. 1 micrometer
6. Ans.A junction diode allows a large current to flow through it when forward biased and offers higher resistance when it is reverse biased. This unidirectional property is similar to that of a vacuum diode. Thus a p-n junction is called a junction diode.
7. Ans.(i) the width of forbidden gap.
(ii) the intrinsic charge carrier concentration.
8. Ans. The conductivity of a semiconductor increases exponentially with temperature.
9. Ans. Junction diode which conducts when forward biased and does not conduct when reverse biased is called an ideal junction diode. It offers zero resistance in forward biasing and infinite resistance in reverse biasing.
10. Ans. It is few micro amperes
.4. Short Answer Questions (10):
1.Ans. The deliberate addition of desirable impurity is called doping.
At room temperature the conductivity of intrinsic semiconductor is very low. Hence, there is a necessity of improving their conductivity. This can be done by doping.
2. Ans. Intrinsic semiconductor:
(i) there is no impurity atom.
(ii) the number density of electrons is equal to the number density of holes.
Extrinsic semiconductor:
(i) they are dropped with impurity atoms(pentavalent or trivalent)
(ii) the number density of electrons is not equal to the number density of holes.
3. Ans. The four bonding electrons of C, Si or Ge lie respectively in the second,third and fourth Orbit. Hence, energy required to take out an electron from these atoms will be least for Ge, followed by Si and highest for C. Hence, the number of free electrons for conduction in Ge and Si are significantly but negligibly small for C.
4. Ans. Resistance offered by the diode;
$R = 0.4/ 8\times 10^{-3} = 50$ ohm
So total resistance in the circuit = 50 + 150= 200 ohm
The maximum battery voltage allowed
$V = 8\times10^{-3} \times 200 = 1.6$ V

5. Ans.The electrical conductors which do not follow Ohm's law are called non-ohmic conductors. The semiconductor diodes are non-ohmic because the voltage drop in the diode is constant even if the current is varied. Hence, there is no linear relationship between the current and voltage.
6. Ans.Semiconductor diodes operate due to an imbalance of electrons. This electron imbalance generates positive (where there are surplus protons) and negative (where there are excess electrons) charges at the two ends of the semiconductor material's surfaces. This is how a semiconductor operates.
7. The pure semiconductor. Examples of pentavalent impurities are Arsenic, Antimony, Bismuth etc. The pentavalent impurities provide extra electrons and are termed donor atoms. Electrons are the majority of charge carriers in n-type semiconductors.
8. Answer: rectifier
Explanation: Semiconductor diodes can be used as a rectifier. A rectifier's job is to convert alternating current to direct current by allowing current to flow in just one direction.
9. Ans.Semiconductor diodes have a wide range of applications, which includes the following:
1.Semiconductor diodes in logic gates.
2. Semiconductor rectifier
3. Semiconductor diode in clamping circuit.
4. Semiconductor diode in a clipping circuit
10. Ans.When a forward bias is applied to a PN junction diode, the value of the potential barrier decreases. The potential barrier opposes the applied voltage in the case of a forward bias. As a result, the potential barrier across the junction decreases.
5. CASE STUDY BASED - 5
1. (i) Ans.(b) Forward resistance = forward voltage drop/ forward DC current = $1.0/ 50\times10^{-3}$= 20 ohm
(ii) Ans. (c) reverse resistance = reverse voltage/ reverse current = $5/1\times10^{-4} = 5\times10^{6}$ ohm = 5M ohm
(iii) Ans.(c) Diode doesn't offer same resistance for either direction current. Hence, it is categorised under unilateral element.
(iv) Ans. (a)reverse resistance as the reverse current is very low
Or Ans. (c)predominantly diffusion current.
2. (i) Ans. (c) p-n junction diode
(ii) Ans. (c) half wave rectifier
(iii) Ans. (a) 5 A ,I(rms) = V (rms)/ R, V(rms) = 100V, I(rms) = 100/20 = 5 A
Or Ans.(c) 3.18 A
I(av) = V(av)/R, V(av) = 200/pi = 63.67, I(av) = 3.18 A
(iv) Ans.(b) one
3. (i) Ans. (d) Reason: in reverse biased p-n junction l, potential difference across a junction becomes [V+V(b)]
(ii) Ans. (c)concentration of positive and negative charges near the junction
(iii) Ans. (b)
Reason: D2 is reverse biased and D1 is forward biased. So, 2phm and 4 ohm are in series and connected to 12 V. Hence, I= 12/ (2+4) = 2A
(iv) Ans. (d) Si and Ge are semiconductors
Or Ans. (c) current almost remains unchanged till critical voltage is reached.
4. (i) Ans. (b)
(ii) Ans. (a) 0.7 V
(iii) Ans. (c) LED
(iv) Ans. (d) Or Ans. (c) it is almost independent of applied potential up to critical voltage
5. (i) Ans. (c) E>3eV
(ii) Ans. (b) 1eV
(iii) Ans. (a)conductors

(iv) Ans. (b) conductor or Ans. (a)the number of free electrons for conduction is significant only in Silicon and Germanium but small in carbon.

6. **Long answer questions (05)**

1. Ans.(i) p-n Junction A p-n junction is an arrangement made by a close contact of n-type semiconductor and p-type semiconductor. There are various methods of forming p-n junction diode. In one method, an n-type germanium crystal is cut into thin slices called wafers. An aluminium film is laid on an n-type wafer which is then heated in an oven at a temperature of about 600°C. Aluminium then diffuses into the surface of wafer. In this way, a p-type semiconductor is formed on n-type semiconductor.

Formation of Depletion Region in p-n Junction In an n-type semiconductor, the concentration of electrons is more than concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than that of concentration of electrons. During formation of p-n junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side (p—> n) and electrons diffuse from n-side to p-side (n —> p).

The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralise each other, (l) Thus, near the junction, positive charge is built on n-side and negative charge on p-side This sets up potential difference across the junction and an internal electric field Ej directed from n-side to p-side. The equilibrium is established when the field £, becomes strong enough to stop further diffusion of the majority charge carriers (however, it helps the minority charge carriers to diffuse across the junction).The region on either side of the junction which becomes depleted (free) from the mobile charge carriers is called depletion region or depletion layer. The width of depletion region is of the order of 10-6 m.The potential difference developed across the depletion region is called the potential barrier. Potential barrier depends on dopant concentration in the semiconductor and temperature of the junction.

(ii) (a) Forward Biased Characteristics

The circuit diagram for studying forward biased characteristics is shown in the figure. Starting from a low value, forward bias voltage is increased step by step (measured by voltmeter) and forward current is noted (by ammeter). A graph is plotted between voltage and current. The curve so obtained is the forward characteristic of the diode.

At the start when applied voltage is low, the current through the diode is almost zero. It is because of the potential barrier, which opposes the applied voltage. Till the applied voltage exceeds the potential barrier, the current increases very slowly with increase in applied voltage (OA portion of the graph).With further increase in applied voltage, the current increases very rapidly (AB portion of the graph), in this situation, the diode behaves like a conductor. The forward voltage beyond which the current through the junction starts increasing rapidly with voltage is called knee voltage. If line AB is extended back, it cuts the voltage axis at potential barrier voltage.

(b) Reverse Biased Characteristics

The circuit diagram for studying reverse biased characteristics is shown in the figure.

In reverse biased, the applied voltage supports the flow of minority charge carriers across the junction. So, a very small current flows across the junction due to minority charge carriers.

Motion of minority charge carriers is also supported by internal potential barrier, so all the minority carriers cross over the junction.Therefore, the small reverse current remains almost constant over a sufficiently long range of reverse bias, increasing very little with increasing voltage (OC portion of the graph). This reverse current is voltage independent upto certain voltage known as breakdown voltage and this voltage independent current – is called reverse saturation current.

Use of p-n Junction Characteristics in Rectification

From forward and reverse characteristics, it is clear that current flows through the junction diode only in forward bias not in reverse bias i.e. current flows only in one direction

2. Ans. (a) Forward Biased Characteristics

The circuit diagram for studying forward biased characteristics is shown in the figure. Starting from a low value, forward bias voltage is increased step by step (measured by voltmeter) and forward current is noted (by ammeter). A graph is plotted between voltage and current. The curve so obtained is the forward characteristic of the diode.At the start when applied voltage is low, the current through the diode is almost zero. It is because of the potential barrier, which opposes the applied voltage. Till the applied voltage exceeds the potential barrier, the current increases very slowly with increase in applied voltage (OA portion of the graph).With further increase in applied voltage, the current increases very rapidly (AB portion of the graph), in this situation, the diode behaves like a conductor. The forward voltage beyond which the current through the junction starts increasing rapidly with voltage is called knee voltage. If line AB is extended back, it cuts the voltage axis at potential barrier voltage.

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3. Ans.During formation of p-n junction, diffusion of charge takes place. As, soon as p-type semiconductor is joined with n-type semiconductor, diffusion of free charges across the junction starts.

For explanation of formation p-n junction

With the formation of p-n junction, the holes from p-region diffuse into the n-region and electrons from n-region diffuse into p-region and electron-hole pair combine and get annihilated.

This input produces potential barrier, VB across in junction which opposes the further diffusion through the junction. Thus, small region forms in the vicinity of the junction which is depleted of free charge carrier and has only immotile ions is called the depletion region.

Potential barrier The potential distribution near the p-n junction is known as potential barrier.

The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralise each other, (l) Thus, near the junction, positive charge is built on n-side and negative charge on p-side This sets up potential difference across the junction and an internal electric field Ej directed from n-side to p-side. The equilibrium is established when the field £, becomes strong enough to stop further diffusion of the majority charge carriers (however, it helps the minority charge carriers to diffuse across the junction).The region on either side of the junction which becomes depleted (free) from the mobile charge carriers is called depletion region or depletion layer. The width of depletion region is of the order of 10-6 m.The potential difference developed across the depletion region is called the potential barrier. Potential barrier depends on dopant concentration in the semiconductor and temperature of the junction.

4. Ans. The two process involved in the formation of p-n junction.

(a)Diffusion

(b)Drift

Holes and electrons diffuse from p to n and n to p respectively.

The majority charge carrier drifts under the influence of applied electric field such that

(a)holes along applied E and

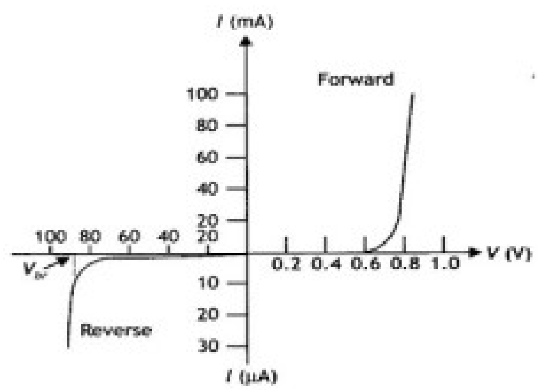
(b)electron opposite to E.

(ii) Zener diode is used as voltage regulator.
5. Ans. (a) A p-n junction diode under forwarding bias - The positive terminal is attached to the p-side, while the negative terminal is connected to the n-side. Applied voltage decreases as it passes through the depletion area.

The electron in the n-region goes towards the p-n junction, while the holes in the p-region move towards it. As the depletion layer's breadth diminishes, it provides less resistance. The majority of carriers are diffused throughout the junction. The forward current is the result of forwarding bias.

(b) A p-n junction diode under reverse bias - The battery's positive terminal is attached to the n-side, while the negative terminal is attached to the p-side. The possibility of a barrier is supported by reverse bias. As a result, the barrier height rises, as does the width of the depletion zone. There is no transmission across the junction due to the preponderance of carriers. After being boosted by the high reverse bias voltage, a few minority carriers pass the junction. This creates a reverse current, which is a current that flows in the opposite direction.
For V-I curves

As a half-wave rectifier, a p-n junction diode is employed. Its work is based on the fact that when the p-n junction is forward biassed, the resistance is low, and when it is reverse biassed, the resistance is high. In rectification, the diode's properties are exploited.



KENDRIYA VIDYALAYA SANGATHAN

BHOPAL REGION

SAMPLE PAPER

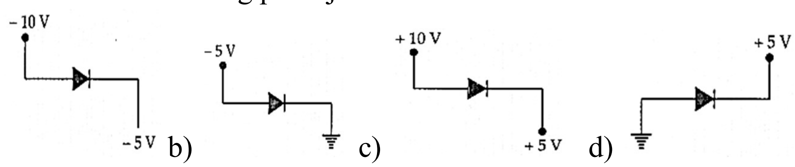
TIME: 3 Hours PHYSICS (042) M.M.70

General Instructions:Total no. of printed pages: 07

1. ***There are 33 questions in all. All questions are compulsory.***
2. ***This question paper has five sections: Section A, Section B, Section C, Section D and Section E.***
3. ***All the sections are compulsory.***
4. ***Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study based questions of four marks each and Section E contains three long answer questions of five marks each.***
5. ***There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.***
6. ***Use of calculators is not allowed.***

Section A

1 Which of the following p - n junction is forward biased? **[1]**



a) b) c) d)

2 The internal resistance of a cell of emf 2 V is 0.1Ω . It is connected to a resistance of 3.9 Ω . The voltage across the cell will be: **[1]**

a) 1.9 V b) 1.95 V c) 0.5 V d) 2 V

3 A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen, then **[1]**

a) no image will be formed b) complete image will be formed

c) intensity of the image will increase d) half the image will disappear

4 The susceptibility of ferromagnetic material is: **[1]**

a) inversely proportional to square of temperature b) inversely proportional to temperature

c) independent of temperature d) directly proportional to temperature

5 Two capacitors of 10μ F and 20 μ F are connected in series with a 30 V battery. The charges on the capacitors will be respectively: **[1]**

a) 200μ C, 100 μ C b) 200μ C, 200 μ C

c) 100μ C, 100 μ C d) 100μ C, 200 μ C

6 A galvanometer of resistance25Ω is shunted by a 2.5Ω wire. The part of total current I_o that flows through the galvanometer is given by **[1]**

a) $\frac{I}{I_0} = \frac{2}{11}$ b) $\frac{I}{I_0} = \frac{4}{11}$ c) $\frac{I}{I_0} = \frac{1}{11}$ d) $\frac{I}{I_0} = \frac{3}{11}$

7 Suppose the number of turns in a coil be tripled, the value of magnetic flux linked with it **[1]**

a) is tripled b) becomes$\frac{1}{3}$c) remains unchanged d) none of these.

8 An aeroplane having a wing span of 35m flies due north with the speed of 90 m/s, given that component of Earths magnetic field perpendicular to aeroplaneis , $B = 4\times 10^{-5}$ T. The potential difference between the tips of the wings will be [1]

a) 0.126 V b) 1.26 V c) 0.013 V d) 12.6 V

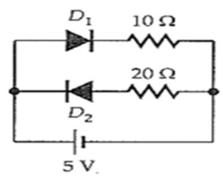
9 In Young's double - slit experiment, two slits are made 5 mm apart and the screen is placed 2 m away. What is the fringe separation when light of wavelength 500 nm is used? [1]

a) 2 mm b) 0.02 mm c) 0.002 mm d) 0.2 mm

10 Electric force between two charged spheres is 18 units. If the distance between the centres of the sphere is tripled, the electric force will be [1]

a) 2 units b) 54 units c) 3 units d) 6 units

11 Two ideal diodes are connected to a battery as shown in the circuit. Current supplied by the battery is [1]



a) zero b) 0.5 A c) 0.75 A d) 0.25 A

12 The magnifying power of telescope is high if [1]

a) the objective has a long focal length and the eye - piece has a short focal length
b) both objective and eye - piece have short focal lengths
c) the objective has a short focal length and the eye - piece has a long focal length
d) both objective and eye - piece have long focal length

Question 13 to 16 consists of statements of assertion (A) followed by a reason (R).
Mark the correct option as:

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

13 **Assertion (A):** In photoelectric effect, on increasing the intensity of light, both the number of electrons emitted and kinetic energy of each of them gets increased but the photoelectric current remains unchanged. [1]

Reason (R): The photoelectric current depends on wavelength of light.

14 **Assertion:** If the distance between parallel plates of a capacitor is halved and dielectric constant is increased to three times, then the capacitance of capacitor becomes 6 times. [1]

Reason: Capacity of a capacitor does not depend upon the nature of the material present between plates.

15 **Assertion (A):** In Young's double - slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase. [1]

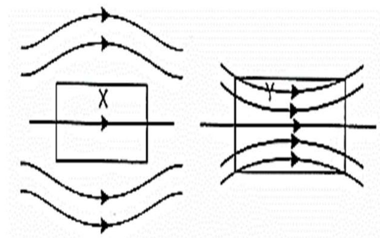
Reason (R): Maximum number of bright fringe on the screen is inversely proportional to the wavelength of light used.

16 **Assertion (A):** When capacitive reactance is smaller than the inductive reactance in series L-C-R circuit, voltage leads the current. **[1]**
Reason (R): In series L-C-R circuit inductive reactance is always greater than capacitive reactance.

Section B

17 The magnetic field in a plane electromagnetic wave is given by: **[2]**
$B_z = (2 \times 10^{-7})\ \sin(0.5 \times 10^{3} x + 1.5 \times 10^{11} t)$ T.
a. What is the wavelength and frequency of the wave?
b. Write an expression for the electric field.

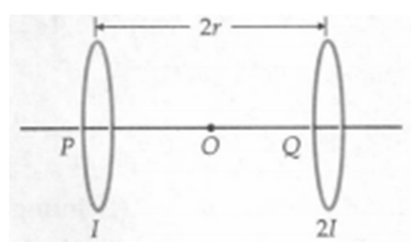
18 A uniform magnetic field gets modified as shown below, when two specimens X and Y are placed in it. **[2]**
1. Identify the two specimens X and Y.
2. State the reason for the behaviour of the field lines in X and Y.



19 Explain the terms depletion layerand potential barrierin a p - n junction diode. How are the **[2]**
1. width of depletion layer, and
2. value of potential barrier affected when the p - n junction is forward biased?

20 The value of ground state energy of hydrogen atom is **−13.6 eV**. **[2]**
1. Find the energy required to move an electron from the ground state to the first excited state of the atom.
2. Determine
   a. the kinetic energy and
   b. orbital radius in the first excited state of the atom.
   (Given, the value of Bohr's radius = 0.53 A^0)

21 Two identical circular loops, P and Q, of radius r and carrying currents I and 2Irespectively are lying in parallel planes such that they have a common axis. The direction of current in both the loops is clockwise as seen from O, which is equidistant from the both loops. Find the magnitude of the net magnetic field at point O. **[2]**

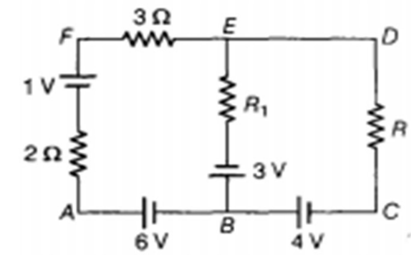


OR

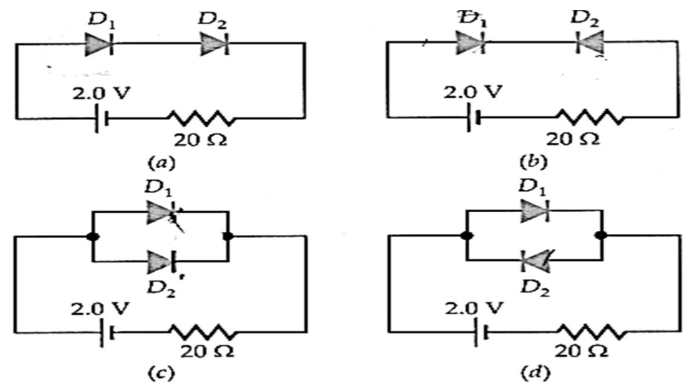
An α particle of mass 6.65×10^{-27} kg and charge twice that of an electron but of positive sign travels at right angles to a magnetic field with a speed of 6×10^{5} ms $^{-1}$. The strength of the magnetic field is 0.2 T.
1. Calculate the force on the α particle.
2. Also, calculate its acceleration.

Section C

22 Use Kirchhoff's rules to determine the potential difference between the points A and D. When no current flows in the arm BE of the electric network shown in the figure below: **[3]**



23 Determine the currents through the resistances of the circuits shown in figure. **[3]**



24 An electron and a proton are accelerated through the same potential. Which one of the two has **[3]**

(i) greater value of de - Broglie wavelength associated with it and

(ii) less momentum?

Justify your answer in both cases.

25 The neutron separation energy is defined as the energy required to remove a neutron from the nucleus. Obtain the neutron separation energies of the nuclei $^{41}_{20}Ca$ and $^{27}_{13}Al$ from the following data: **[3]**
m($^{40}_{20}Ca$) = 39.962591 u, m($^{41}_{20}Ca$) = 40.962278 u, m($^{26}_{13}Al$) = 25.986895 u,
m($^{27}_{13}Al$) = 26.981541 u, m_n=1.008665 u

26 1. Sketch the energy level diagram for hydrogen atom. **[3]**

2. Find the ratio of the longest and the shortest wavelength in Lyman series in hydrogen atom.

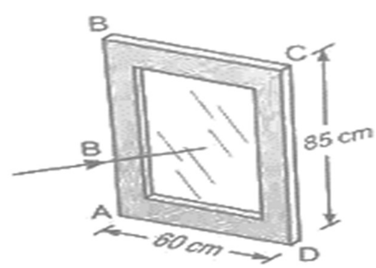
27 A beam of light consisting of two wavelengths 560 nm and 420 nm is used to obtain interference fringes in a Young's double slit experiment. Find the least distance from the central maximum, where the bright fringes, due to both the wavelengths coincide. The distance between the two slits is 4.0 mm and the screen is at a distance of 1.0 m from the slits. **[3]**

28 State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify this statement. **[3]**

OR

The aluminium frame ABCD of a window measures 85cm× 60cm, as illustrated in fig.

The window is hinged along the edge AB. When the window is closed, the horizontal component of the earth's magnetic field of flux density 1.8×10^{-4} T, is normal to the window.



1. Calculate the magnetic flux through the window.

2. The window is now opened in a time of 0.20s. When open, the plane of the window is parallel

to the horizontal component of earth's magnetic field. For the opening of the window, state the change in flux through the window and calculate the average e.m.f. induced in side CD of the frame.

3. Suggest, with a reason, whether the e.m.f. calculated in (2) gives rise to a current in the frame ABCD.

Section D

29 **Read the text carefully and answer the questions:** Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by c $=\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability. **[4]**

1. The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E = electric field) is
   a) MLT^{-1}
   b) $ML^{-1}T^{-2}$
   c) ML^2T^{-2}
   d) ML^2T^{-1}

2. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and A = electric current, then
   a) $[\varepsilon_0] = ML^2T^{-1}$
   b) $[\varepsilon_0] = MLT^{-2}A^{-2}$
   c) $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$
   d) $[\varepsilon_0] = M^{-1}L^{-3}T^2A$

3. An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium ofrelative permittivity$\varepsilon_r = 4$ and relative permeability $\mu_r = 1$. Then
   a) wavelength is halved and the frequency remains unchanged.
   b) wavelength and frequency both remain unchanged
   c) wavelength is doubled and the frequency remains unchanged
   d) wavelength is doubled and the frequency becomes half

OR

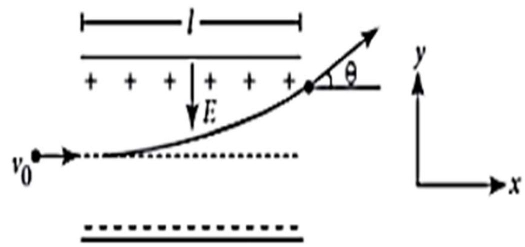
3. The electromagnetic waves travel with
   a) the speed of light c = 3×10^8 m s $^{-1}$ in fluid medium.
   b) the speed of light c = 3×10 m s $^{-1}$ in solid medium
   c) the speed of light c = 3×10^8 m s $^{-1}$ in free space
   d) the same speed in all media

4. Which of the following are not electromagnetic waves?cosmic rays, γ- rays, β - rays, X - rays
   a) β- rays
   b) X - rays
   c) γ- rays
   d) cosmic rays

30 **Read the text carefully and answer the questions:** When a charged particle is placed in an electric **[4]**

field, it experiences an electrical force. If this is the only force on the particle, it must be the net force. The net force will cause the particle to accelerate according to Newton's second law. So ,$\vec{F_e} = q\vec{E} = m\vec{a}$

If $\vec{E}$ is uniform, then $\vec{a}$ is constant and $\vec{a} = \frac{q\vec{E}}{m}$ .If the particle has a positive charge, its acceleration is in the direction of the field. If the particle has a negative charge, its acceleration is in the direction opposite to the electric field. Since the acceleration is constant, the kinematic equations can be used.



1. A charged particle is free to move in an electric field. It will travel
   a) along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force
   b) always along a line of force
   c) along a line of force, if its initial velocity is zero
   d) none of these.

2. An electron of mass m, charge efalls through a distance h meter in a uniform electric field E. Then time of fall,
   a) $t = \sqrt{\frac{2hm}{eE}}$ b) $t = \sqrt{\frac{2eE}{hm}}$ c) $t = \frac{2h}{eE}$ d) $t = \frac{2eE}{hm}$

3. An electron moving with a constant velocity v along X - axis enters a uniform electric field applied along Y - axis. Then the electron moves
   a) in a trajectory represented as y = ax
   b) in a trajectory represented as $y = ax^2$
   c) without any acceleration along Y - axis
   d) with uniform acceleration along Y - axis

4. Two equal and opposite charges of masses m_1 and m_2 are accelerated in an uniform electric field through the same distance. What is the ratio of their accelerations if their ratio of masses is
   $\frac{m_1}{m_2} = 0.5$?
   a) $\frac{a_1}{a_2} = 3$ b) $\frac{a_1}{a_2} = 1$ c) $\frac{a_1}{a_2} = 2$ d) $\frac{a_1}{a_2} = 0.5$

OR

4.A particle of mass mcarrying charge qis kept at rest in a uniform electric field Eand then released. The kinetic energy gained by the particle, when it moves through a distance yis
   a) qEy
   b) $qE^2 y$
   c) qEy^2
   d) $\frac{1}{2} qEy^2$

Section E

31 If light passes near a massive object, the gravitational interaction causes a bending of the ray. This can be thought of as happening due to a change in the effective refractive index of the medium **[5]**

given by$n(r) = 1 + \frac{2GM}{rc^2}$ where r is the distance of the point of consideration from the centre of the mass of the massive body, G is the universal gravitational constant, M the mass of the body and c the speed of light in vacuum. Considering a spherical object find the deviation of the ray from the original path as it grazes the object.

OR

i. a. Two independent monochromatic sources of light cannot produce a sustained interference pattern.
Give reason.

b. Light waves each of amplitude a and frequencyω , emanating from two coherent light sources superimpose at a point If the displacements due to these waves are given by $y_1 = a \cos \omega t$ and $y_2 = \cos(\omega t + \phi)$, where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point

ii. In Young's double - slit experiment using monochromatic light of wavelength λ , the intensity of light at a point on the screen where path difference is λ , is K units. Find out the intensity of light at a point, where path difference is $\frac{\lambda}{3}$.

32 **i**. If two similar large plates, each of area A having surface charge densities $+\sigma$ and - σ are separated by
a distance d in air, then find the expression for **[5]**

a. the field at points between the two plates and on the outer side of the plates. Specify the direction of the field in each case.
b. the potential difference between the plates.
c. the capacitance of the capacitor so formed.

ii. Two metallic spheres of radii R and 2R are charged so that both of these have the same surface charge densityσ . If they are connected to each other with a conducting wire, in which direction will the charge flow and why?

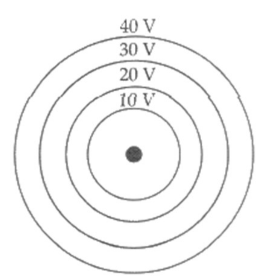
OR

i.Two isolated metal spheres A and B have radii R and 2R respectively, and the same charge q. Find which of the two spheres have greater:

a. capacitance and
b. energy density just outside the surface of the spheres

ii.

a. Show that the equipotential surfaces are close together in the regions of a strong field and far apart in the regions of a weak field. Draw equipotential surfaces for an electric dipole,
b. Concentric equipotential surfaces due to a charged body placed at the centre are shown.
c. Identify the polarity of the charge and draw the electric field lines due to it.



33 **i.**Draw graphs showing the variations of inductive reactance and capacitive reactance with the frequency of the applied ac source. **[5]**

ii. Draw the phasor diagram for a series RC circuit connected to an ac source and hence find the impedance of the circuit.

iii. An alternating voltage of 220 V is applied across a device X, a current of 0.25 A flows, which lag behind the applied voltage in phase by $\frac{\pi}{2}$ radian. If the same voltage is applied across another device Y, the same current flows but now it is in phase with the applied voltage.

a. Name the devices X and Y.
b. Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y.

OR

i.Describe, with the help of a suitable diagram, the working principle of a step - up transformer. Obtain the relation between input and output voltages in terms of the number of turns of primary and secondary windings and the currents in the input and output circuits.

ii. Given the input current 15 A and the input voltage of 100 V for a step - up transformer having 90% efficiency, find the output power and the voltage in the secondary if the output current is 3 A.

(End of the question paper)