# LIST OF MEMBERS WHO PREPARED QUESTION BANK FOR PHYSICS FOR CLASS XII

## TEAM MEMBERS

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Designation</th>
</tr>
</thead>
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<tr>
<td>1.</td>
<td>Pundrikaksh Kaudinya</td>
<td><em>Principal</em> RPVV Rajniwas Mar, Delhi</td>
</tr>
<tr>
<td></td>
<td><em>Group Leader</em></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Devendra Kumar</td>
<td><em>P.G.T. (Physics)</em> R.P.V.V., Civil Lines Delhi-110054</td>
</tr>
<tr>
<td></td>
<td><em>Member</em></td>
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<td><em>Member</em></td>
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<tr>
<td>4.</td>
<td>K.D. Sharma</td>
<td><em>P.G.T. (Physics)</em> R.P.V.V., Rajniwas Marg, Delhi</td>
</tr>
<tr>
<td></td>
<td><em>Member</em></td>
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</table>
# PHYSICS (CODE NO. 042)

## QUESTION PAPER DESIGN

### CLASS - XII (2014-15)

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Typology of Questions</th>
<th>VSA (1M)</th>
<th>SA-I (2M)</th>
<th>SA-II (3M)</th>
<th>Value based question (4M)</th>
<th>LA (5M)</th>
<th>Total Marks</th>
<th>% Weigh-tage</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td><strong>Remembering</strong> – (Knowledge based) Simple recall questions, to know specific facts, terms, concepts, principles, or theories; Identify, define, or recite, information</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>10%</td>
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<tr>
<td>2.</td>
<td><strong>Understanding</strong> – (Comprehension-to be familiar with meaning and to understand conceptually, interpret, compare, contrast, explain, paraphrase, or interpret information)</td>
<td>-</td>
<td>2</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>21</td>
<td>30%</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Application</strong> – (Use abstract information in concrete situation, to apply knowledge to new situations; Use given content to interpret a situation, provide an example, or solve a problem)</td>
<td>-</td>
<td>2</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>21</td>
<td>30%</td>
</tr>
<tr>
<td>4.</td>
<td><strong>High Order Thinking Skills</strong> – (Analysis &amp; Synthesis-classify, compare, contrast, or differentiate between different pieces of information; Organise and/or integrate unique pieces of information from a variety of sources)</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>10</td>
<td>14%</td>
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<tr>
<td>5.</td>
<td><strong>Evaluation and Multi-Disciplinary</strong> – (Appraise, judge, and/or justify the value or worth of a decision or outcome, or to predict outcomes based on values)</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>11</td>
<td>10%</td>
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**TOTAL - 2 Projects**

5×1=5 5×2=10 12×3=36 1×4=4 3×5=15 70(26) 100%

[Class XII : Physics] 2
QUESTION WISE BREAK-UP

<table>
<thead>
<tr>
<th>Type of Question</th>
<th>Mark per Question</th>
<th>Total No. of Questions</th>
<th>Total Marks</th>
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<tr>
<td>VSA</td>
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<tr>
<td>SA-I</td>
<td>2</td>
<td>5</td>
<td>10</td>
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<tr>
<td>SA-II</td>
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<td>12</td>
<td>36</td>
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<tr>
<td>VBQ</td>
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<td>1</td>
<td>04</td>
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<tr>
<td>LA</td>
<td>5</td>
<td>3</td>
<td>15</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>26</strong></td>
<td><strong>70</strong></td>
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1. **Internal Choices**: There is no overall choice in the paper. However, there is an internal choice in one question of 2 marks weightage, one question of 3 marks weightage and all the three questions of 5 marks weightage.

2. The above template is only a sample. Suitable internal variations may be made for generating similar templates keeping the overall weightage to different form of questions and typology of questions same.

PHYSICS (THEORY) : 2014-15

One Paper

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<th>Unit</th>
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<th>Marks</th>
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<td>Unit I</td>
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<td>Unit III</td>
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<td>Unit IV</td>
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<td>Unit V</td>
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<td>Unit VI</td>
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<td>Unit VII</td>
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<td>Unit VIII</td>
<td>14</td>
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<td>Unit IX</td>
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<tr>
<td>Unit X</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>160</strong></td>
<td><strong>70</strong></td>
</tr>
</tbody>
</table>

Unit I: **Electrostatics**  **22 Periods**

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).

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

Conductors and Insulators, free charges and bound charges inside a conductor, Dielectric and electric polarization, Capacitors and Capacitance, combination of capacitances in series and parallel, Capacitance of a parallel plate capacitor with or without dielectric medium between the plates energy stored in a capacitor, Van de Graaff Generator.

Unit II: Current Electricity 20 Periods

Electric current; flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current. Ohm’s law electrical resistance, V-I characteristics (linear and non-linear), Electrical energy and power, Electrical resistivity and connectivity, carbon resistors, colour code for carbon resistors; Series and parallel combinations of resistors; 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 laws and simple applications, wheatstone bridge, metre bridge.

Potentiometer-principle and its applications to measure potential difference and for comparing emf of two cells, measurement of internal resistance of a cell.

Unit III: Magnetic Effects of Current and Magnetism 22 Periods

Concept of magnetic field and 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 and toroidal solenoids. Force on a moving charge in uniform magnetic and electric fields. Cyclotron, 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 a uniform magnetic field. Moving coil Galvanometer – its current sensitivity. Moving Coil Galvanometer – Conversion to ammeter and voltmeter.

Current loop as a magnetic dipole and it’s magnetic dipole moment, Magnetic dipole moment of a revolving electron, Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to it’s axis. Torque on a magnetic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, Magnetic field lines Earth’s Magnetic field and magnetic elements.

Para-, dia- and ferro-magnetic substances with examples. Electromagnets and factors affecting their strengths, Permanent magnets.
Unit IV: Electromagnetic Induction and Alternating Currents 20 Periods
Electromagnetic induction; Faraday’s laws induced emf and current; Lenz’s law, Eddy currents. Self and mutual inductance. Need for displacement current. Alternating currents, peak and rms value of altering current/voltage Reactance and Impedance. Lc oscillations (qualitative treatment only). LCR series circuit; Resonance; Power in AC circuits, wattless current. AC generator and transformer.

Unit V: Electromagnetic Waves 04 Periods
Need for Displacement current, Electromagnetic waves and their characteristics (qualitative ideas only). Transverse nature of electromagnetic waves. Electromagnetic spectrum (radio-waves, micro-waves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

Unit VI: Optics 25 Periods

Unit VII: Dual Nature of Matter and Radiation 08 Periods
Dual nature of radiation, Photoelectric effect Hertz and Lenard’s observations; Einstein’s photoelectric equation, Particle nature of light. Matter waves-wave nature of particles, de-broglie relation Davisson Germer experiment (experimental details should be omitted; only conclusion should be explained).

Unit VIII: Atoms and Nuclei 14 Periods
Alpha-particles scattering experiment, Rutherford’s model of atom, Bohr Model, energy levels, Hydrogen spectrum.
Composition and size of Nucleus, atomic masses, isotopes, isobars; isotones, Radioactivity-alpha, beta and gamma particles/rays and their properties; radioactive decay law.
Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

Unit IX: Electronic Devices 15 Periods
Energy bands in conductors, Semi Conductors and insulators (qualitative ideas only)
Semiconductors diode-I-V characteristics in forward and reverse bias, diode as rectifier.
Special purpose p-n junction diodes: LED, Photodiodes, solarcell and Zener diode as a voltage regulator.
Junction transistor, transistor action, characteristics of a transistor. Transistor as an amplifier (common emitter configuration), basic idea and analog and digital signals, Logic gates (OR, AND, NOT, NAND and NOR).

Unit X: Communication Systems 10 Periods
Elements of communication system (block diagram) only, Band width signals (speech, TV and digital data) band width of transmission medium. Propagation of electromagnetic waves in the atmosphere, sky and space wave propagation, satellite communication. Need for modulation, Amplitude Modulation and frequency modulation, advantages of frequency modulation over amplitude modulation. Basic ideas about internet, mobile telephony and global positioning system (GPS).
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*Sample Papers*  

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### SECTION 1 (Unit I & II)

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<th>Physical Quantity</th>
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<th>SI Unit</th>
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<td>Quantization of charge</td>
<td>( q = \pm ne )</td>
<td>C</td>
</tr>
<tr>
<td>Coulomb's force</td>
<td>( \mathbf{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} )</td>
<td>N</td>
</tr>
<tr>
<td>In vector form</td>
<td>( \mathbf{F} )</td>
<td></td>
</tr>
<tr>
<td>Dielectric constant (or relative permittivity)</td>
<td>( \varepsilon_r )</td>
<td></td>
</tr>
<tr>
<td>Hence ( F_0 \geq F_m ) as free space has minimum permittivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear charge density</td>
<td></td>
<td>Cm(^{-1})</td>
</tr>
<tr>
<td>Surface charge density</td>
<td></td>
<td>Cm(^{-2})</td>
</tr>
<tr>
<td>Electric field due to a point charge</td>
<td>( \mathbf{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} )</td>
<td>NC(^{-1})</td>
</tr>
<tr>
<td>The components of electric field,</td>
<td>( \mathbf{E} )</td>
<td></td>
</tr>
<tr>
<td>Torque on a dipole in a uniform electric field</td>
<td>( \tau = \mathbf{p} \times \mathbf{E} )</td>
<td>Nm</td>
</tr>
</tbody>
</table>

**KEY POINTS**

- Quantization of charge: \( q = \pm ne \)
- Coulomb's force: \( \mathbf{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \)
- Dielectric constant: \( \varepsilon_r \)
- Linear charge density: Cm\(^{-1}\)
- Surface charge density: Cm\(^{-2}\)
- Electric field due to a point charge: \( \mathbf{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \)
- Torque on a dipole: \( \tau = \mathbf{p} \times \mathbf{E} \)
Electric dipole moment
Potential energy of a dipole in a uniform electric field
Electric field on axial line of an electric dipole
Electric field on equatorial line of an electric dipole
Electric field as a gradient of potential
Electrical potential differences between points A & B
Electric potential at a point
Electric potential due to a system of charges
Electric potential at any point due to an electric dipole
Total electric flux through a closed surface $S$

$$\text{Total electric flux} = E \times \text{Effective Area} = Nm^2 \, C^{-1}$$

Electric field due to line charge

$$\text{Electric field} = NC^{-1} \text{ (or V/m)}$$

Electric field due to an infinite plane sheet of charge

Electric field due to two infinitely charged plane parallel sheets

Electric field due to a uniformly charged spherical shell

Electrical capacitance

Capacitance of an isolated sphere
Capacitance of a parallel plate

Capacitors in series

Capacitors in parallel

\[ C = C_1 + C_2 + C_3 \]

Capacitance of a parallel plate capacitor with dielectric slab between plates

\[ \frac{C}{C_0} = \frac{d}{d_0} \]

Capacitance of a parallel plate capacitor with conducting slab between plates

Energy stored in a charged capacitor

\[ U = \frac{1}{2} CV^2 = \frac{1}{2} q^2 \]

Resultant electric field in a polarised dielectric slab

\[ E = E_0 + \chi E \]

Polarization density

\[ P = n \alpha E = \chi E \]

Dielectric constant (in terms of electric susceptibility or atomic polarisability)

\[ K_\infty = 1 + \chi \]

Potential difference between inner and outer shell in Van de Graaff generator

\[ V = \frac{1}{2} q \frac{1}{d_0} \]

\[ J \text{ c}^{-1} \]
<table>
<thead>
<tr>
<th>1. Drift Velocity</th>
<th>( v_d = \frac{e}{m} \times \text{electric field} )</th>
</tr>
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<tr>
<td>2. Relation b/w current and Drift Velocity</td>
<td>( I = neAv_d )</td>
</tr>
<tr>
<td>3. Ohm's Law</td>
<td>( V = RI )</td>
</tr>
<tr>
<td>4. Resistance</td>
<td>( R = \frac{V}{I} )</td>
</tr>
<tr>
<td>5. Specific Resistance or Resistivity</td>
<td>( \rho = \frac{V}{I} )</td>
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<tr>
<td>6. Current density</td>
<td>( j = \frac{I}{A} = neV_d )</td>
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<td>7. Electrical Conductivity</td>
<td>( \sigma = \frac{1}{\rho} )</td>
</tr>
<tr>
<td>8. Resistances in Series</td>
<td>( R_{eq} = R_1 + R_2 + R_3 )</td>
</tr>
</tbody>
</table>
9. Temperature Dependence of Resistance

\[ R_t = R_o (1 + \alpha t) \]

10. Internal Resistance of a cell

11. Power

\[ P = V I = I^2 R \]

12. Cells in Series

Equivalent emf

\[ E_{eq} = E_1 + E_2 \]

Equivalent Internal Resistance

\[ \text{req} = r_1 + r_2 \]

\( E_1 \) & \( E_2 \) are emf of two cells \( r_1 \) and \( r_2 \) are their internal resistances respectively.
13. Cells in parallel

Equivalent e.m.f: $\Sigma E$

Equivalent resistance: $\frac{1}{\Sigma \frac{1}{R}}$

14. Kirchoff's Laws

$\Sigma i = 0$ (at a junction)

$\Sigma iR = \Sigma E$ (in a closed loop)

$i = \text{Current}$

$R = \text{Resistance}$

$E = \text{e.m.f.}$

15. Wheatstone Bridge

(balanced condition)

$P, Q, R$ and $S$ are resistances in Ohm in four arms of Wheatstone Bridge.

16. Slide wire Bridge or metre Bridge

17. Potentiometer
Comparison of Emf

Internal Resistance

I₁ and I₂ are balancing lengths on polentiometer wire for cells E₁ and E₂

I₁ and I₂ are balancing lengths on polentiometer wire in open circuit and closed circuit.
UNIT I & UNIT II

ELECTROSTATICS AND CURRENT ELECTRICITY

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Draw schematically an equipotential surface of a uniform electrostatic field along x-axis.
   Ans.

2. Sketch field lines due to (i) two equal positive charges near each other (ii) a dipole.
   Ans.

3. Name the physical quantity whose SI unit is volt/meter. Is it a scalar or a vector quantity?
   Ans. Electric field intensity. It is a vector quantity.
4. Two point charges repel each other with a force $F$ when placed in water of dielectric constant 81. What will the force between them when placed the same distance apart in air?

**Ans.** $\frac{F}{r} \Rightarrow F_0 = \frac{F}{\varepsilon_0} \Rightarrow F_{m'} = 8F$

5. Electric dipole moment of CuSO$_4$ molecule is $3.2 \times 10^{-32}$ Cm. Find the separation between copper and sulphate ions.

**Ans.**

$$p = q(2a) \Rightarrow 2a = \frac{3.2 \times 10^{-32}}{2 \times 1.6 \times 10^{-19}} = 10^{-13}$$

6. Net capacitance of three identical capacitors connected in parallel is 12 microfarad. What will be the net capacitance when two of them are connected in (i) parallel (ii) series?

**Ans.**

$$C_p = 12 \mu F \Rightarrow C = \frac{12}{3} = 4 \mu F.$$  

$$C_p = C_1 + C_2 = 8 \mu F$$  

$$C_s = \frac{C_1C_2}{C_1 + C_2} + \frac{16}{8} = 2 \mu F$$

7. A charge $q$ is placed at the centre of an imaginary spherical surface. What will be the electric flux due to this charge through any half of the sphere.

**Ans.**

$$\phi = \frac{q}{\varepsilon_0}$$  

$$\phi' = \frac{\phi}{2} = \frac{q}{2 \varepsilon_0}$$

8. Draw the electric field vs distance (from the centre) graph for (i) a long charged rod having linear charge density $\lambda < 0$ (ii) spherical shell of radius $R$ and charge $Q > 0$. 

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[Class XII : Physics] 18
Diagrammatically represent the position of a dipole in (i) stable (ii) unstable equilibrium when placed in a uniform electric field.

10. A charge $Q$ is distributed over a metal sphere of radius $R$. What is the electric field and electric potential at the centre? **Ans.** $E = 0$, $V = \frac{kQ}{R}$

**Ans.** Electric field inside conductor $E = 0$

$$E = \frac{dv}{dr} = 0 \Rightarrow V = \text{Constant} = \frac{Q}{\frac{4\pi\epsilon_0}{R}} = \frac{kQ}{R}$$

11. If a body contains $n_1$ electrons and $n_2$ protons then what is the total charge on the body?

**Ans.** $Q = q_1 + q_2 + \ldots + q_n$. (Additive property of charge)

$Q = (n_2 - n_1)e$

12. What is the total positive or negative charge present in 1 molecule of water.

**Ans.** $H_2O$ has 10 electrons (2 of hydrogen and 8 of oxygen)

Total charge = 10e
13. How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in a uniform electric field.

**Ans.** Work done = \( p \ E(\cos 180^\circ - \cos 0^\circ) \)

\[ = -2p \ E \]

i. e. energy decreases.

14. Write the ratio of electric field intensity due to a dipole at a point on the equatorial line to the field at a point at a point on the axial line, when the points are at the same distance from the centre of dipole.

**Ans.**

\[ \frac{E_{\text{axial}}}{E_{\text{equatorial}}} = \frac{2Kp}{r^3} \]

\[ \therefore \frac{E_{\text{axial}}}{E_{\text{equatorial}}} = 2 \]

15. Draw equipotential surface for a dipole.

**Ans.**

16. An uncharged conductor A placed on an insulating stand is brought near a charged insulated conductor B. What happens to the charge and potential of B?

**Ans.** Total charge = 0 + q = q remains same.

P.D. decreases due to induced charge on A.

17. A point charge Q is placed at point O shown in Fig. Is the potential difference \( V_A - V_B \) positive, negative or zero, if Q is (i) positive (ii) negative charge.
Ans. \( V_A - V_B > 0 \) for \( Q > 0 \) and \( V_A - V_B < 0 \) for \( Q < 0 \)

As electric field lines are in the direction of decreasing potential.

18. An electron and proton are released from rest in a uniform electrostatic field. Which of them will have larger acceleration?

Ans. \[ \text{acceleration} = \frac{\text{force}}{\text{mass}}, \quad m_p > m_e \]
\[ a_p < a_e \]

19. In an uniform electric field of strength \( E \), a charged particle \( Q \) moves point A to point B in the direction of the field and back from B to A. Calculate the ratio of the work done by the electric field in taking the charge particle from A to B and from B to A.

Ans. \[ \frac{W_{AB}}{W_{BA}} = 1 \]

\[ W_{AB} + W_{BA} = 0 \]
\[ | W_{AB} | = | W_{BA} | \]

20. If a dipole of charge \( 2\mu \text{C} \) is placed inside a sphere of radius \( 2\text{m} \), what is the net flux linked with the sphere.

Ans. Net flux \[ = \frac{\text{Net charge}}{\varepsilon_0} = \frac{+q - q}{\varepsilon_0} = 0 \]

21. Four charges \(+q, -q, +q, -q\) are placed as shown in the figure. What is the work done in bringing a test charge from \( \infty \) to point 0.
Ans. $V_0 = \frac{qk}{AO} + \frac{kq}{OC} - \frac{kq}{OB} - \frac{kq}{OD} = 0$

$W = q \times V_0^0 = 0$

22. Calculate number of electric field lines originating from one coulomb charge.

Ans. Flux = Total electric field lines

$\phi = \frac{q}{\epsilon_0} = \frac{1c}{\epsilon_0}$

23. If the metallic conductor shown in the figure is continuously charged from which of the points A,B,C or D does the charge leak first. Justify.

Ans. Charge leaks from A first as surface charge density ($\sigma$) at A (sharp ends) is more.

24. What is dielectric strength? Write the value of dielectric strength of air.

Ans. $3 \times 10^6$ Vm$^{-1}$

25. Two charge $-q$ and $+q$ are located at points A ($0, 0, -a$) and B($0, 0, +a$). How much work is done in moving a test charge from point ($b, 0, 0$) to Q ($-b, 0, 0$)?

Ans. $W = \vec{F} \cdot d\vec{r} = q \vec{E} \cdot d\vec{r} = q Edr \cos90^\circ = 0$

$\therefore E$ along equatorial line of dipole is parallel to dipole, hence perpendicular to displacement.

26. If an electron is accelerated by a Potential difference of 1 Volt, Calculate the gain in energy in Joule and electron volt.

Ans. Gain in Energy = $eV = 1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}$J
= $\frac{1.6 \times 10^{-19}}{1.6 \times 10^{-19}}$ eV = 1 eV.

27. Draw schematically the equipotential surface corresponding to a field that uniformly increases in magnitude but remains in a constant (say z) direction.

Ans.

E increases therefore, equipotential surface are closer $d_1 > d_2$.

28. Figure shows five charged lumps of plastic and an electrically neutral coin. The cross-section of a Guassian surface $S$ is indicated. What is the net electric flux through the surface?

Ans. $\phi = \frac{+q_1}{\varepsilon_0} - \frac{q_2}{\varepsilon_0} + \frac{q_3}{\varepsilon_0} - \frac{q_6}{\varepsilon_0}$.

29. Without referring to the formula $C = \varepsilon_0 A/d$. Explain why the capacitance of a parallel plate capacitor reduces on increasing the separation between the plates?

Ans. $P D = V = E \times d$.

'd' increases $V$ increases.
as $C = \frac{Q}{V}$ ∴ $C$ decreases.

30. Draw field lines to show the position of null point for two charges $+Q_1$ and $-Q_2$ when magnitude of $Q_1 > Q_2$ and mark the position of null point.

Ans. $|Q_1| > |Q_2|$, $N$ is the neutral point.

31. How does the relaxation time of electron in the conductor change when temperature of the conductor decreases.

Ans. When temperature of the conductor decreases, ionic vibration in the conductor decreases so relaxation time increases.

32. Sketch a graph showing variation of resistivity with temperature of (i) Copper (ii) Carbon.

Ans.

33. The emf of the driver cell (Auxillary battery) in the potentiometer experiment should be greater than emf of the cell to be determined. Why?

Ans. If emf of a driver cell is less, then null point will not be obtained on the potentiometer wire.

34. You are required to select a carbon resistor of resistance $47\,\Omega \pm 10\%$ from a large collection. What should be the sequence of color bands used to code it?

Ans. Yellow, Violet, Orange, Silver.
35. The fig. here shows a part of a circuit. What are the magnitude and
direction of the current \( i \) in the lower right-hand wire? (5)

\[ \begin{align*}
\text{Ans.} & \quad \text{At 'P':} \quad +4 - 4 + 2 = 2 \text{A goes to B,} \\
& \quad \text{At 'Q':} \quad 3 + 2 \text{A} = 5 \text{A} = i \\
\end{align*} \]

36. Two wire one of copper and other of manganin have same resistance and
equal length. Which wire is thicker?

\[ \text{Ans.} \quad R = \rho_c \frac{L}{A_c} = \rho_m \frac{L}{A_m} \implies \frac{\rho_c}{\rho_m} = \frac{A_c}{A_m} < 1 \]

\[ \therefore \quad \text{Manganin is thicker.} \]

37. You are given three constantan wires P, Q and R of length and area of
cross-section \((L, A), \left(\frac{2L}{2}, \frac{A}{2}\right), \left(\frac{L}{2}, 2A\right)\) respectively. Which has highest
resistance?

\[ \text{Ans.} \quad R_p = \rho \frac{L}{A}, \quad R_Q = \rho \frac{2L}{2A} = 4L \rho \]

\[ R_Q = \frac{4\rho L}{A}, \quad R_R = \frac{\rho L}{4A} \]

\[ Q \text{ has the highest resistance.} \]

38. V – I graph for a metallic wire at two different temperatures \( T_1 \) and \( T_2 \) is
as shown in the figure. Which of the two temperatures is higher and why?

\[ \text{Ans.} \quad T_2 \text{ is higher because of the higher slope.} \]
Ans. Slope of $T_1$ is large, so $T_1$ represents higher temperature as resistance increases with temperature for a conductor

$$R = \frac{V}{I} = \text{slope.}$$

39. Out of $V - I$ graph for parallel and series combination of two metallic resistors, which one represents parallel combination of resistors? Justify your answer.

Ans. The resistance for parallel combination is lesser than for series combination for a given set of resistors. Hence B represents parallel combination since $\frac{I}{V}$ is more. Hence Resistance $= \frac{V}{I}$ is less.

40. Why is the potentiometer preferred to a voltmeter for measuring emf of a cell?

Ans. Emf measured by the potentiometer is more accurate because the cell is in open circuit giving no current.

41. How can a given 4 wires potentiometer be made more sensitive?

Ans. By connecting a resistance in series with the potentiometer wire in the primary circuit, the potential drop across the wire is reduced.

42. Why is copper not used for making potentiometer wires?

Ans. Copper has high temperature coefficient of resistance and hence not preferred.

43. In the figure, what is the potential difference between A and B?

Ans. $V_A - V_B = -8 \text{ Volt.}$
44. A copper wire of resistance \( R \) is uniformly stretched till its length is increased to \( n \) times its original length. What will be its new resistance?

\[ R' = n^2 R \]

Ans.

45. Two resistances 5\( \Omega \) and 7\( \Omega \) are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5\( \Omega \)?

\[ \text{Ans. } I = \frac{2}{5} A \]

46. Calculate the equivalent resistance between points A and B in the figure given below.

\[ \text{Ans.} \]

47. What is the largest voltage that can be safely put across a resistor marked 196\( \Omega \), 1W?

\[ \text{Ans. } P = \frac{V^2}{R}, V^2 = PR = 1 \times 196 = 196 \]

\[ V = 14 \text{ Volt.} \]
48. When does the terminal voltage of a cell become (i) greater than its emf (ii) less than its emf?

**Ans.**
(i) When the cell is being charged terminal potential difference (V) becomes greater than emf (E), 
\[ V = E + I r \]

(ii) When the cell is discharged, then \( V < E \)
\[ V = E - I r \]

49. A car battery is of 12V. Eight dry cells of 1.5 V connected in series also give 12V, but such a combination is not used to start a car. Why?

**Ans.** Dry cell used in series will have high resistance (=10Ω) and hence provide low current, while a car battery has low internal resistance (0.1Ω) and hence gives high current for the same emf, needed to start the car.

50. Two electric lamps A and B marked 220V, 100W and 220V, 60W respectively. Which of the two lamps has higher resistance?

**Ans.** As \( R = \frac{V^2}{P} \), 220V, 60W lamp has higher resistance.

51. Constantan is used for making the standard resistance. Why?

**Ans.** High resistivity and low temperature Coefficient of resistance.

52. A 16Ω thick wire is stretched so that its length becomes two times. Assuming there is no change in density on stretching. Calculate the resistance of new wire.

**Ans.** 
\[ R = \rho \frac{l}{A} = \rho \frac{l^2}{AI} = \rho \frac{l^2}{V} \]
\( R \) and \( V \) are constant

\[ \therefore R \propto l^2 \Rightarrow \frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2 \]

\[ \frac{16}{R_2} = \left(\frac{l_1}{2l_1}\right)^2 \Rightarrow R_2 = 64\Omega \]

53. State the Condition under which the terminal potential difference across a battery and its emf are equal.

**Ans.** When battery is in open circuit i.e. when no current is being drawn from the cell.
54. State the Condition for maximum current to be drawn from a Cell.

**Ans.** \( I = \frac{E}{R + r} \) for I maximum \( R = 0 \) i.e. for maximum current the terminals of a cell must be short circuited.

**SHORT ANSWER QUESTIONS (2 Marks)**

1. An oil drop of mass \( m \) carrying charge \( -Q \) is to be held stationary in the gravitational field of the earth. What is the magnitude and direction of the electrostatic field required for this purpose? **Ans :** \( E = \frac{mg}{Q} \), downward

2. Find the number of field lines originating from a point charge of \( q = 8.854 \mu C \).

**Ans :** \( \phi = 10^{12} \text{ NC}^{-1} \text{ m}^2 \)

3. If \( q \) is the positive charge on each molecule of water, what is the total positive charge in \( (360g) \) a Mug of water.

**Ans :** \( q \left( \frac{360}{18} \times 6.02 \times 10^{23} \right) \text{ C} \)

4. Derive an expression for the work done in rotating an electric dipole from its equilibrium position to an angle \( \theta \) with the uniform electrostatic field.

5. Show that there is always a loss of energy when two capacitors charged to different potentials share charge (connected with each other).

6. A thin long conductor has linear charge density of \( 20 \mu C/m \). Calculate the electric field intensity at a point \( 5 \text{ cm} \) from it. Draw a graph to show variation of electric field intensity with distance from the conductor.

**Ans. :** \( 72 \times 10^6 \text{ N/C} \)

7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole? **Ans :** 1:2

8. Show that the electric field intensity at a point can be given as negative of potential gradient.

9. A charged metallic sphere A having charge \( q_A \) is brought in contact with an uncharged metallic sphere of same radius and then separated by a distance \( d \). What is the electrostatic force between them.

**Ans :** \( \frac{1}{16\pi \varepsilon_0} \frac{q_A^2}{d^2} \)
10. An electron and a proton fall through a distance in an uniform electric field \( E \). Compare the time of fall.

11. Two point charges \(-q\) and \(+q\) are placed 2\( l\) metre apart, as shown in fig. Give the direction of electric field at points A,B,C and D.

12. The electric potential \( V \) at any point in space is given \( V = 20x^3 \) volt, where \( x \) is in meter. Calculate the electric intensity at point P (1, 0, 2).

   \[ \text{Ans} : 60 \text{NC}^{-1} \]


14. Find equivalent capacitance between A and B in the combination given below : each capacitor is of 2 \( \mu \)F.

   \[ \text{Ans.} : \frac{6}{7} \mu \text{F} \]

15. What is the electric field at O in Figures (i), (ii) and (iii). ABCD is a square of side \( r \).

   \[ \text{Ans : (i) Zero, (ii) } \frac{q}{4\pi \varepsilon_0} \frac{1}{r^2} \text{ (iii) } \frac{2q}{4\pi \varepsilon_0} \]
16. What should be the charge on a sphere of radius 4 cm, so that when it is brought in contact with another sphere of radius 2 cm carrying charge of 10 µC, there is no transfer of charge from one sphere to other?

\[ \text{Ans} : V_a = V_b, \ Q = 20 \mu C \]

17. For an isolated parallel plate capacitor of capacitance \( C \) and potential difference \( V \), what will happen to (i) charge on the plates (ii) potential difference across the plates (iii) field between the plates (iv) energy stored in the capacitor, when the distance between the plates is increased?

\[ \text{Ans} : \ (i) \ \text{No change} \ (ii) \ \text{increases} \ (iii) \ \text{No change} \ (iv) \ \text{increases}. \]

18. Does the maximum charge given to a metallic sphere of radius \( R \) depend on whether it is hollow or solid? Give reason for your answer. \[ \text{Ans} : \text{No charge resides on the surface of conductor}. \]

19. Two charges \( Q_1 \) and \( Q_2 \) are separated by distance \( r \). Under what conditions will the electric field be zero on the line joining them (i) between the charges (ii) outside the charge?

\[ \text{Ans} : \ (i) \ \text{Charge are alike} \ (ii) \ \text{Unlike charges of unequal magnitude}. \]

20. Obtain an expression for the field due to electric dipole at any point on the equatorial line.

21. The electric field component in the figure are \( \vec{E}_x = 2x \hat{i}, \ \vec{E}_y = \vec{E}_z = 0 \). Calculate the flux through, (1,2,3) the square surfaces of side 5 m.

22. Calculate the work required to separate two charges 4 \( \mu \)C and -2 \( \mu \)C placed at (-3 cm, 0, 0) and (+3 cm, 0, 0) infinitely away from each other.

23. What is electric field between the plates with the separation of 2 cm and (i) with air (ii) dielectric medium of dielectric constant \( K \). Electric potential of each plate is marked in Fig.

\[ \text{(i) Ans. : } E_0 = 10^4 \text{ NC}^{-1}, \ E = \frac{10^4}{K} \text{ NC}^{-1} \]

31 [Class XII : Physics]
24. A storage capacitor on a RAM (Random Access Memory) chip has a capacity of 55pF. If the capacitor is charged to 5.3V, how may excess electrons are on its negative plate? 
\[ \text{Ans. } : 1.8 \times 10^9 \]

25. The figure shows the Q (charge) versus V (potential) graph for a combination of two capacitors. Identify the graph representing the parallel combination.

![Graph of Q vs V for capacitors]

\[ \text{Ans} : \text{A represents parallel combination} \]

26. Calculate the work done in taking a charge of 1 µC in a uniform electric field of 10 N/C from B to C given AB = 5 cm along the field and AC = 10 cm perpendicular to electric field.

\[ \text{Ans} : W_{AB} = W_{BC} = 50 \times 10^{-8} \text{ J}, \quad W_{AC} = 0 \text{ J} \]

27. Can two equi potential surfaces intersect each other? Give reasons. Two charges \(-q\) and \(+q\) are located at points A (0, 0, \(-a\)) and B (0, 0, \(+a\)) respectively. How much work is done in moving a test charge from point P(7, 0, 0) to Q(\(-3, 0, 0\))?

\[ \text{(zero)} \]

28. The potential at a point A is \(-500\text{V}\) and that at another point B is \(+500\text{V}\). What is the work done by external agent to take 2 units (S.I.) of negative charge from B to A.

29. How does the Potential energy of (i) mutual interaction (ii) net electrostatic P.E. of two charges change when they are placed in an external electric field.

30. With the help of an example, show that Farad is a very large unit of capacitance.

31. What is meant by dielectric polarisation? Why does the electric field inside a dielectric decrease when it is placed in an external field?
32. In charging a capacitor of capacitance \( C \) by a source of emf \( V \), energy supplied by the sources \( QV \) and the energy stored in the capacitor is \( \frac{1}{2}QV \). Justify the difference.

33. An electric dipole of dipole moment \( p \), is held perpendicular to an electric field; (i) \( p = E_0 \hat{i} \) (ii) \( E = E_0 \times \hat{i} \). If the dipole is released does it have (a) only rotational motion (b) only translatory motion (c) both translatory and rotatory motion?

34. The net charge of a system is zero. Will the electric field intensity due to this system also be zero.

35. A point charge \( Q \) is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side \( a \). What is the electric flux linked with the cube in (i) & (ii)?

36. There are two large parallel metallic plates \( S_1 \) and \( S_2 \) carrying surface charge densities \( \sigma_1 \) and \( \sigma_2 \) respectively \((\sigma_1 > \sigma_2)\) placed at a distance \( d \) apart in vacuum. Find the work done by the electric field in moving a point charge \( q \) a distance \( a \) \((a < d)\) from \( S_1 \) and \( S_2 \) along a line making an angle \( \pi/4 \) with the normal to the plates.

37. Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature?

38. On what factor does potential gradient of a potentiometer wire depend?

39. What are superconductors? Give one of their applications.

40. Two manganin wires whose lengths are in the ratio 1 : 2 and whose resistances are in the ratio 1 : 2 are connected in series with a battery. What will be the ratio of drift velocities of free electrons in the two wires?

41. The current through a wire depends on time as \( i = i_0 + at \) where \( i_0 = 4A \) and \( a = 2\text{As}^{-1} \). Find the charge crossing a section of wire in 10 seconds.

42. Three identical resistors \( R_1, R_2 \) and \( R_3 \) are connected to a battery as shown in the figure. What will be the ratio of voltages across \( R_1 \) and \( R_2^* \). Support your answer with calculations.

\[ E \quad \hat{H} \]

\( \text{Support your answer with calculations.} \)
43. In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor?

\[ \left( \frac{2}{3} \right) \]

44. A 100W and a 200W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly? Justify. (100W)

45. A 100W and a 200W domestic bulbs joined in parallel are connected to the mains. Which bulb will glow more brightly? Justify. (200W)

46. A battery has an emf of 12V and an internal resistance of 2Ω. Calculate the potential difference between the terminal of cell if (a) current is drawn from the battery (b) battery is charged by an external source.

47. A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between diametrically opposite points A and B. [Ans. R/4]

48. In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 63 cm. What is the emf of the second cell? [Ans. 2.25V]

49. In a meter bridge, the balance point is found to be 39.5 cm from end A. The known resistance Y is 12.5Ω. Determine unknown resistance X. [Ans. 8.16Ω]
50. A meterbridge is in balance condition. Now if galvanometer and cell are interchanged, the galvanometer shows no deflection. Give reason.

[Ans. Galvanometer will show no deflection. Proportionality of the arms are retained as the galvanometer and cell are interchanged.]

51. If the emf of the driving cell be decreased. What will be effect on the position of zero deflection in a potentiometer.

52. Why should the area of cross section of the meter bridge wire be uniform? Explain.

53. Given any two limitations of Ohm’s law.

54. Which one of the two, an ammeter or a milliammeter has a higher resistance and why?

55. Name two factors on which the resistivity of a given material depends? A carbon resistor has a value of 62kΩ with a tolerance of 5%. Give the colour code for the resistor.

56. If the electron drift speed is so small (~$10^{-3}$ m/s) and the electron’s charge is very small, how can we still obtain a large amount of current in a conductor

57. A battery of emf 2.0 volts and internal Resistance 0.1Ω is being charged with a current of 5.0A. What is the potential difference between the terminals of the battery?

\[ A \rightarrow \frac{5}{V} \rightarrow \frac{2.0}{A} \rightarrow \frac{0.1}{W} \rightarrow B \]

58. Why should the jockey be not rubbed against potentiometer wire?

59. What is meant by the sensitivity of a potentiometer of any given length?

60. Five identical cells, each of emf E and internal resistance r, are connected in series to form (a) an open (b) closed circuit. If an ideal voltmeter is connected across three cells, what will be its reading?

[Ans. (a) 3E; (b) zero]

61. An electron in a hydrogen atom is considered to be revolving around a proton with a velocity \( \frac{e^2}{n} \) in a circular orbit of radius \( \frac{n^2}{me^2} \). If I is the equivalent current, express it in terms of m, e, n \( n = \frac{h}{2\pi} \cdot \left( \frac{me^5}{2\pi n^3} \right) \)
62. In the given circuit, with steady current, calculate the potential drop across the capacitor in terms of V.

\[ V_A = V_B = \frac{2V}{2R} \]

63. A cell of e.m.f. ‘E’ and internal resistance ‘r’ is connected across a variable resistor ‘R’. Plot a graph showing the variation of terminal potential ‘V’ with resistance ‘R’. Predict from the graph the condition under which ‘V’ becomes equal to ‘E’.

**SHORT ANSWER QUESTIONS (3 Marks)**

1. Define electrostatic potential and its unit. Obtain expression for electrostatic potential at a point P in the field due to a point charge.

2. Calculate the electrostatic potential energy for a system of three point charges placed at the corners of an equilateral triangle of side ‘a’.

3. What is polarization of charge? With the help of a diagram show why the electric field between the plates of capacitor reduces on introducing a dielectric slab. Define dielectric constant on the basis of these fields.

4. Using Gauss’s theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

5. Three capacitors are connected first in series and then in parallel. Find the equivalent capacitance for each type of combination.

6. A charge Q is distributed over two concentric hollow sphere of radii r and R (R>r), such that their surface density of charges are equal. Find Potential at the common centre.

7. Derive an expression for the energy density of a parallel plate capacitor.

8. You are given an air filled parallel plate capacitor. Two slabs of dielectric constants \( K_1 \) and \( K_2 \) having been filled in between the two plates of the
capacitor as shown in Fig. What will be the capacitance of the capacitor of initial area was A distance between plates d?

\[ C_1 = (K_1 + K_2)C_0 \]
\[ C_2 = \frac{K_1 K_2 C_0}{(K_1 + K_2)} \]

9. In the figure shown, calculate the total flux of the electrostatic field through the sphere \( S_1 \) and \( S_2 \). The wire AB shown of length \( l \) has a linear charge density \( \lambda \) given \( \lambda = kx \) where \( x \) is the distance measured along the wire from end A.

\[
\text{Ans. Total charge on wire AB} = Q = \int_{0}^{l} \lambda \, dx = \int_{0}^{l} kx \, dx = \frac{1}{2} Kl^2
\]

By Gauss's theorem.

Total flux through \( S_1 = \frac{Q}{\varepsilon_0} \)

Total flux through \( S_2 = \frac{Q + \frac{1}{2} Kl^2}{\varepsilon_0} \)

10. Explain why charge given to a hollow conductor is transferred immediately to outer surface of the conductor. (See Page 83. NCERT Vol I)
11. Derive an expression for total work done in rotating an electric dipole through an angle $\theta$ in an uniform electric field. Hence calculate the potential energy of the dipole.

12. Define electric flux. Write its SI unit. An electric flux of $\theta$ units passes normally through a spherical Gaussian surface of radius $r$, due to point charge placed at the centre.

(1) What is the charge enclosed by Gaussian surface?
(2) If radius of Gaussian surface is doubled, how much flux will pass through it?

13. A conducting slab of thickness 't' is introduced between the plates of a parallel plate capacitor, separated by a distance $d$ (t<d). Derive an expression for the capacitance of the capacitor. What will be its capacitance when $t = d$?

14. If a dielectric slab is introduced between the plates of a parallel plate capacitor after the battery is disconnected, then how do the following quantities change.
   (i) Charge
   (ii) Potential
   (iii) Capacitance
   (iv) Energy.

15. What is an equipotential surface? Write three properties Sketch equipotential surfaces of
   (i) Isolated point charge
   (ii) Uniform electric field
   (iii) Dipole

16. If a charge $Q$ is given to the parallel plates of a capacitor and $E$ is the electric field between the plates of the capacitor the force on each plate is $1/2QE$ and if charge $Q$ is placed between the plates experiences a force equal to QE. Give reasons to explain the above.

17. Two metal spheres A and B of radius $r$ and $2r$ whose centres are separated by a distance of $6r$ are given charge $Q$, are at potential $V_1$ and $V_2$. Find the ratio of $V_1/V_2$. These spheres are connected to each other with the help of a connecting wire keeping the separation unchanged, with is the amount of charge that will flow through the wire?
18. Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.

19. A potential difference $V$ is applied across a conductor of length $L$ and diameter $D$. How are the electric field $E$ and the resistance $R$ of the conductor affected when (i) $V$ is halved (ii) $L$ is halved (iii) $D$ is doubled. Justify your answer.

20. Define drift velocity. A conductor of length $L$ is connected to a dc source of emf $E$. If the length of conductor is tripled by stretching it, keeping $E$ constant, explain how do the following factors would vary in the conductor? (i) Drift speed of electrons (ii) Resistance and (iii) Resistivity.

21. Define potential gradient. How can potential gradient of a potentiometer be determined experimentally. In the graph shown here, a plot of potential drop versus length of the potentiometer is made for two potentiometers. Which is more sensitive –A or B?

22. Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon?

23. State the principle of potentiometer. Draw a circuit diagram used to compare the emf of two primary cells. Write the formula used.

24. The graph shows how the current $I$ varies with applied potential difference $V$ across a 12 V filament lamp (A) and across one metre long nichrome wire (B). Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

(i) when potential difference across them is 12 V.
(ii) when potential difference across them is 4 V. Give reason for the change in ratio of resistances in (i) and (ii).

25. Electron drift speed is estimated to be only a few mm/s for currents in the range of few amperes? How then is current established almost the instant a circuit is closed.

26. Give three points of difference between e.m.f and terminal potential difference of a cell.

27. Define the terms resistivity and conductivity and state their S.I. units. Draw a graph showing the variation of resistivity with temperature for a typical semiconductor.

28. The current flowing through a conductor is 2 mA at 50 V and 3 mA at 60 V. Is it an ohmic or non-ohmic conductor? Give reason.

29. Nichrome and copper wires of same length and area of cross section are connected in series, current is passed through them why does the nichrome wire get heated first?

30. Under what conditions is the heat produced in an electric circuit:

   (i) directly proportional
   (ii) inversely proportional to the resistance of the circuit

**LONG ANSWER QUESTIONS (5 MARKS)**

1. State the principle of Van de Graaff generator. Explain its working with the help of a neat labelled diagram.

2. Derive an expression for the strength of electric field intensity at a point on the axis of a uniformly charged circular coil of radius \( R \) carrying charge \( Q \).

3. Derive an expression for potential at any point distant \( r \) from the centre \( O \) of dipole making an angle \( \theta \) with the dipole.
4. Suppose that three points are set at equal distance $r = 90$ cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A closer to +ve charge and B closer to B) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole moment $3.6 \times 10^{-19}$ Cm at points A, B and C?

5. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness $t (t<d)$ between the plates separated by distance $d$. How would the following (i) energy (ii) charge, (iii) potential be affected if dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.

6. Derive an expression for torque experienced by dipole placed in uniform electric field. Hence define electric dipole moment.

7. State Gauss's theorem. Derive an expression for the electric field due to a charged plane sheet. Find the potential difference between the plates of a parallel plate capacitor having surface density of charge $5 \times 10^{-8}$ Cm$^{-2}$ with the separation between plates being 4 mm.

8. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness $t (t<d)$ between the plates separated by distance $d$. If the dielectric slab is introduced with the battery connected, then how do the following quantities change (i) charge (ii) potential (iii) capacitance (iv) energy.

9. Using Gauss's theorem obtain an expression for electric field intensity due to a plane sheet of charge. Hence obtain expression for electric field intensity in a parallel plate capacitor.

10. Write five to six important results regarding electrostatics of conductors. (See Page 68, NCERT Vol I).

11. State Kirchhoff's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance. How is it realized in actual practice in the laboratory? State the formula used.

12. Define emf and terminal potential difference of a cell. When is the terminal charging potential difference greater than emf? Explain how emf and terminal potential difference can be compared using a potentiometer and hence determine internal resistance of the cell.
13. For three cells of emf $E_1$, $E_2$ and $E_3$ with internal resistances $r_1$, $r_2$, $r_3$ respectively connected in parallel, obtain an expression for net internal resistance and effective current. What would be the maximum current possible if the emf of each cell is $E$ and internal resistance is $r$ each?


15. State the principle of potentiometer. How can it be used to:
   (i) Compare e.m.f of two cells
   (ii) Measure internal resistance of a cell?

16. Explain how does the conductivity of a:
   (i) Metallic conductor
   (ii) Semi conductor and
   (iii) Insulator varies with the rise of temperature.

17. Derive expression for equivalent e.m.f and equivalent resistance of a:
   (a) Series combination
   (b) Parallel combination

   of three cells with e.m.f $E_1$, $E_2$, $E_3$ & internal resistances $r_1$, $r_2$, $r_3$ respectively.

18. Deduce the condition for balance in a Wheatstone bridge. Using the principle of Wheatstone bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used. Write any two important precautions you would observe while performing the experiment.

**NUMERICALS**

1. What should be the position of charge $q = 5\mu C$ for it to be in equilibrium on the line joining two charges $q_1 = -4 \mu C$ and $q_2 = 16 \mu C$ separated by 9 cm. Will the position change for any other value of charge $q$? (9 cm from $-4 \mu C$)

2. Two point charges $4e$ and $e$ each, at a separation $r$ in air, exert force of magnitude $F$. They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged. (1/4 the original separation)
3. Two capacitors of capacitance 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. 

$$6E$$

4. Two point charges 6 µC and 2 µC are separated by 3 cm in free space. Calculate the work done in separating them to infinity. 

$$3.6 \text{ joule}$$

5. ABC is an equilateral triangle of side 10 cm. D is the mid point of BC, charge 100 µC, −100 µC and 75 µC are placed at B, C and D respectively. What is the force experienced by a 1 µC positive charge placed at A? 

$$90\sqrt{2} \times 10^3 \text{ N}$$

6. A point charge of 2 µC is kept fixed at the origin. Another point charge of 4 µC is brought from a far point to a distance of 50 cm from origin. Calculate the electrostatic potential energy of the two charge system. Another charge of 11 µC is brought to a point 100 cm from each of the two charges. What is the work done? 

$$3.2 \times 10^{-3} \text{ J}$$

7. A 5 MeV α particle is projected towards a stationary nucleus of atomic number 40. Calculate distance of closest approach. 

$$1.1 \times 10^{-4} \text{ m}$$

8. To what potential must a insulated sphere of radius 10 cm be charged so that the surface density of charge is equal to 1 µC/m². 

$$1.13 \times 10^4 \text{ V}$$

9. In the following fig, calculate the potential difference across capacitor C₂. Given potential at A is 90 V. C₁ = 20 µF, C₂ = 30 µF, and C₃ = 15 µF. 

$$\text{(Ans. 20V)}$$

10. A point charge develops an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge. 

$$2.9 \times 10^{-10} \text{ C, 25 cm}$$

11. Figure shows three circuits, each consisting of a switch and two capacitors initially charged as indicated. After the switch has been closed, in which circuit (if any) will the charges on the left hand capacitor (i) increase (ii) decrease (iii) remain same?

[Class XII : Physics]
12. For what value of C does the equivalent capacitance between A and B is
1µF in the given circuit.

\[
\text{Ans. : 2 } \mu\text{F}
\]

13. A pendulum bob of mass 80 mg and carrying charge of \(3 \times 10^{-8}\) C is
placed in an horizontal electric field. It comes to equilibrium position at an
angle of 37° with the vertical. Calculate the intensity of electric field.
\((g = 10\text{m/s}^2)\)

\(2 \times 10^4\) N/C

14. Eight charged water droplets each of radius 1 mm and charge \(10 \times 10^{-10}\)
C coalesce to form a single drop. Calculate the potential of the bigger drop.
\(3600\) V

15. What potential difference must be applied to produce an electric field that
can accelerate an electron to 1/10 of velocity of light.
\(2.6 \times 10^3\) V

16. A 10 \(\mu\)F capacitor can withstand a maximum voltage of 100 V across it,
whereas another 20 \(\mu\)F capacitor can withstand a maximum voltage of
only 25 V. What is the maximum voltage that can be put across their series
combination?
\(75\) V

17. Three concentric spherical metallic shells A < B < C of radii a, b, c
(a < b < c) have surface densities \(\sigma, -\sigma\) and \(\sigma\) respectively. Find the
potential of three shells A, B and (ii). If shells A and C are at the same
potential obtain relation between a, b, c.

18. Four point charges are placed at the corners of the square of edge a as
shown in the figure. Find the work done in disassembling the system of charges.

\[
\frac{kq^2}{a} \left(\sqrt{2} - 4\right) \text{J}
\]

19. Find the potential at A and C in the following circuit:

20. Two capacitors A and B with capacitances 3 \( \mu \)F and 2 \( \mu \)F are charged 100 V and 180 V respectively. The capacitors are connected as shown in the diagram with the uncharged capacitor C. Calculate the (i) final charge on the three capacitors (ii) amount of electrostatic energy stored in the system before and after the completion of the circuit.

21. Two identical parallel plate capacitors connected to a battery with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with dielectric of dielectric constant 3. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of dielectric.
22. The charge passing through a conductor is a function of time and is given as \( q = 2t^2 - 4t + 3 \) milli coulomb. Calculate (i) Current through the conductor (ii) Potential difference across it at \( t = 4 \) second. Given resistance of conductor is 4 ohm.  
\[ \text{Ans.: } I = 12 \text{A}, \ V = 48 \text{V} \]

23. The resistance of a platinum wire at a point 0°C is 5.00 ohm and its resistance at steam point is 5.40\( \Omega \). When the wire is immersed in a hot oil bath, the resistance becomes 5.80\( \Omega \). Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum.  
\[ \text{Ans.: } a = 0.004^\circ \text{C}; \ T = 200^\circ \text{C} \]

24. Three identical cells, each of emf 2V and internal resistance 0.2 ohm, are connected in series to an external resistor of 7.4 ohm. Calculate the current in the circuit and the terminal potential difference across an equivalent cell.  
\[ \text{Ans.: } I = 0.75; \ V = 5.55 \text{V} \]

25. Calculate the equivalent resistance and current shown by the ammeter in the circuit diagram given.  
\[ \text{Ans.: } R = 2\Omega; \ I = 5\text{A} \]

26. A storage battery of emf 12V and internal resistance of 1.5\( \Omega \) is being charged by a 12V dc supply. How much resistance is to be put in series for charging the battery safely, by maintaining a constant charging current of 6A.  
\[ \text{Ans.: } R = 16.5\Omega \]
27. Three cell are connected in parallel, with their like poles connected together, with wires of negligible resistance. If the emf of the cell are 2V, 1V and 4 V and if their internal resistance are 4Ω, 3Ω and 2 ohm respectively, find the current through each cell.

\[
\begin{bmatrix}
I_1 &= \frac{-2}{13} A, \\
I_2 &= \frac{-7}{13} A, \\
I_3 &= \frac{9}{13} A
\end{bmatrix}
\]

Ans. : \( \begin{bmatrix}
I_1 &= \frac{-2}{13} A, \\
I_2 &= \frac{-7}{13} A, \\
I_3 &= \frac{9}{13} A
\end{bmatrix} \)

28. A 16 ohm resistance wire is bent to form a square. A source of emf 9 volt is connected across one of its sides. Calculate the potential difference across any one of its diagonals.

[Ans. : 1V]

29. A length of uniform ‘heating wire’ made of nichrome has a resistance 72Ω. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it is not advisable to use the half length of wire?

[Ans. : (a) 200W (b) 400W. 400W >> 200W but since current becomes large so it is not advisable to use half the length]

30. With a certain unknown resistance \( X \) in the left gap and a resistance of 8Ω in the right gap, null point is obtained on the metre bridge wire. On putting another 8Ω in parallel with 8Ω resistance in the right gap, the null point is found to shift by 15cm. Find the value of \( X \) from these observations.

[Ans. : 8/3Ω]

31. Figure show a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance \( R = 10Ω \) is found to be 160 cm. While that with the unknown resistance \( X \) is 134.4 cm. Determine the value of \( X \).

[Ans. : 2Ω]

32. Two cells of E.M.F. \( E_1 \) and \( E_2 \) (\( E_1 > E_2 \)) are connected as shown in figure. Potentiometer is connected between points A and B. Calculate the ratio of...
33. Potential difference across terminals of a cell are measured (in volt) against
different current (in ampere) flowing through the cell. A graph was drawn
which was a straight line ABC. Using the data given in the graph, determine
(i) the emf. (ii) The internal resistance of the cell.

\[ \text{Ans. : } r = 5 \Omega \text{ emf } = 1.4 \text{V} \]

34. Four cells each of internal resistance 0.8Ω and emf 1.4V, \( d \) are connected
(i) in series (ii) in parallel. The terminals of the battery are joined to the
lamp of resistance 10Ω. Find the current through the lamp and each cell
in both the cases.

\[ \text{Ans. : } I_s = 0.424 \text{A}, \ I_p = 0.137 \text{A current through each cell is 0.03A} \]

35. In the figure an ammeter A and a resistor of resistance \( R = 4 \Omega \) have been
connected to the terminals of the source to form a complete circuit. The
emf of the source is 12V having an internal resistance of 2Ω. Calculate
voltmeter and ammeter reading.

\[ \text{Ans. : Voltmeter reading : 8V, Ammeter reading = 2A} \]
36. In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 20Ω resistance? 

\[ \text{Ans. : } R_V = 150 \Omega; \quad V = \frac{40}{3} V \]

37. For the circuit given below, find the potential difference b/w points B and D. 

[Ans. : 1.46 Volts]

38. (i) Calculate Equivalent Resistance of the given electrical network b/w points A and B.

(ii) Also calculate the current through CD & ACB if a 10V d.c source is connected b/w point A and B and the value of R = 2Ω
39. A potentiometer wire AB of length 1m is connected to a driver cell of emf 3V as shown in figure. When a cell of emf 1.5V is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell by a cell of unknown emf, the balance point shifts to 80cm:

(i) Calculate unknown emf of `ε´ the Cell.

(ii) Explain with reason, whether the circuit works if the driver cell is replaced with another a cell of emf IV.

(iii) Does the high resistance R, used in the secondary circuit affect the balance point? Justify your answer.

40. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

41. A network of resistances is connected to a 16V battery with internal resistance of 1Ω as shown in Fig. on next page:-

(i) Compute the Equivalent Resistance of the network.

(ii) Obtain the current in each resistor.

(iii) Obtain the voltage drop $V_{AB}$, $V_{BC}$ & $V_{CD}$.
42. The number density of conduction electrons in a Copper Conductor estimated to be $8.5 \times 10^{28}$ m$^{-3}$. How long does an electron take to drift from one end of a wire 3.0m long to its other end? The area of cross section of the wire is $2.0 \times 10^{-6}$ m$^2$ and it is carrying a current of 3.0 A.

43. A Voltmeter of resistance 400$\Omega$ is used to measure the potential difference across the 100$\Omega$ resistor in the circuit shown in figure. What will be the reading of voltmeter.

44. The Equivalent Resistance between points A and B of the adjoining circuit.

45. A copper wire of length 3m and radius $r$ is nickel plated till its radius becomes $2r$. What would be the effective resistance of the wire, if specific resistance of copper and nickel are $\rho_c$ and $\rho_n$ respectively.

[Hint : $P_c = P_e \frac{l}{\pi r^2}$; $R_n = \ln \frac{l}{\pi (2r)^2 - \pi r^2}$]
\[ R = \frac{R_c R_n}{R_c + R_n}. \]

46. In the figure, if the potential at point P is 100V, what is the potential at point Q?

\[ \text{Ans. : } -10V \]

47. Given two resistors X and Y whose resistances are to be determined using an ammeter of resistance 0.5\(\Omega\) and a voltmeter of resistance 20 k\(\Omega\). It is known that X is in the range of a few ohms, while Y is in the range of several thousand ohm. In each case, which of the two connection shown should be chosen for resistance measurement?

\[ \text{Ans. : Small resistance : X will be preferred; large resistance : Y will be preferred} \]

48. When resistance of 2\(\Omega\) is connected across the terminals of a battery, the current is 0.5A. When the resistance across the terminal is 5\(\Omega\), the current is 0.25A. (i) Determine the emf of the battery (ii) What will be current drawn from the cell when it is short circuited.

\[ \text{Ans. : } E = 1.5V, I = 1.5A \]

49. A part of a circuit in steady state, along with the currents flowing in the branches and the resistances, is shown in the figure. Calculate energy stored in the capacitor of 4\(\mu\)F capacitance.

\[ \text{Ans. : } V_{AB} = 20V, U = 8 \times 10^{-4} J \]
50. Sixteen resistors each of resistance 16Ω are connected in circuit as shown. Calculate the net resistance between A and B. [Ans.: 3Ω]

51. A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω. What will be the percentage error in the reading of the voltmeter. [Ans.: 0.8%]

VALUE BASED QUESTIONS

1. Geeta has dry hair. A comb ran through her dry hair attract small bits of paper. She observes that Neeta with oily hair combs her hair; the comb could not attract small bits of paper. She consults her teacher for this and gets the answer. She then goes to the junior classes and shows this phenomenon as Physics Experiment to them. All the junior feel very happy
and tell her that they will also look for such interesting things in nature and try to find the answers she succeeds in forming a Science Club in her school.

What according to you are the values displayed Geeta?

2. A picnic was arranged by schools for the student of XII class. After some time it was raining heavily accompanied by thundering & lightening. The Student got afraid. Some students went inside the room. The students asked for the key of the car and set inside the car folding their legs on the seat. The other students called them to come out but they refused. They knew that charge inside the conducting shell is zero as told by the teacher and told other not to stand near the electric pole when it is lightening.

What value was displayed by these students?

3. Renu, Ritu and Kajal lived in a resettlement colony where they observed most houses stole power from transmission lines using hooks. They had learnt in school about fire caused due to electric short circuit. They decided to make people aware to the risks involved an also the importance of paying their electricity bills. They got all their friends and responsible elders together and with the help of the electricity board, succeeded in changing the situation.

   (i) What value did Renu, Ritu and Kajal have?

   (ii) A low voltage supply from which one needs high currents must have a very low internal resistance, why?

   (iii) A high tension supply of say 6 KV must have a very large internal resistance. Why?

4. Rahul and Rohit bought an electric iron. They had a 2 pin plug. Rahul was keen to start using the new iron with the 2 pin plug. However, Rohit insisted that they buy a 3 pin plug before using it. Rahul got angry. Rohit patiently explained the importance of using a 3 pin plug and the earthing wire. He said that if the metallic body of the iron came in contact with the live wire at 220 volt, they would get an electric shock. If earthed, the current would go to the earth and the potential of the metallic body would not rise. The iron would then be safe to use hearing Rohit, Rahul calmed down and agreed.

   (i) What value did Rahul and Rohit have?
(ii) Which has greater resistance – 1 K watt electric heater or 100 watt electric bulb, both marked 220 volts?

2 MARKS QUESTIONS

1. In the capacitor the voltage increases from 0 to V, hence energy stored will correspond to average which will be \( \frac{1}{2} QV \). While the source is at constant emf V. So energy supplied will be QV. The difference between the two goes as heat and em radiations.

2. Construct a closed system such that charge is enclosed within it. For the charge on one face, we need to have two cubes placed such that charge is on the common face. According to Gauss’s theorem total flux through the gaussian surface (both cubes) is equal to \( \frac{q}{\varepsilon_0} \). Therefore the flux through one cube will be equal to \( \frac{q}{2\varepsilon_0} \).

3. Work done = \( \int \cos \theta = qEd \cos \theta = \frac{q(\sigma_1 - \sigma_2)}{\varepsilon_0} \frac{a}{\sqrt{2}} \)

4. \[ I = \frac{\text{Charge circulating}}{\text{Time for one revolution}} = \frac{e}{3\pi r/v} \quad v \rightarrow \text{speed} \]
   \[ = \frac{e}{2\pi} \frac{e^2/h}{h'me^2} \quad h = \frac{h}{2\pi} \]
   \[ = \frac{me^5}{2\pi h^3} \]

5. In steady state the branch containing C can be omitted hence the current
   \[ I = \frac{2V - V}{R + 2R} = \frac{V}{3R} \]

For loop EBCDE
   \[ -V_C - V + 2V - I(2R) = 0 \]
   \[ \Rightarrow \quad V_C = \frac{V}{3} \]
6. \( V = IR = \frac{ER}{R + r} = \frac{E}{\frac{r}{R} + 1} \)

When \( R \) approaches infinity \( V \) becomes equal to \( E \) (or for \( R \to 00 \))

7. If e.m.f decreases \( \Rightarrow \frac{V}{\ell} \) decreases \( \therefore \) position of zero deflection increases.

8. Otherwise resistance per unit length of Bridge wire be different over different length of meter Bridge.


10. Milliammeter. To produce large deflection due to small current we need a large number of turns we need a large number of turns in armature coil \( \therefore \) Resistance increases.

11. Temperature, Material Blue, Red, Orange Gold

10. The electron number density is of the order of \( 10^{29} \text{ m}^{-3} \). \( \therefore \) the net current can be very high even if the drift spread is low.

12. \( V = E + ir \)
    
    \[ = 2 + 0.15 \]
    
    \[ = 2.5 \text{ V} \]

13. Affects the uniformity of the cross-section area of wire and hence changes the potential drop across wire.

14. A potentiometer is said to be sensitive if:
   
   (i) It can measure very small potential differences.

   (ii) For a small change in potential diff. being measured it shows large change in balancing length.
3 MARKS QUESTIONS

1. If $E'$ be the electric field due to each plate (of large dimensions) then net electric field between them

$$E = E' + E' = \frac{E}{2}$$

Force on charge $Q$ at some point between the plates $F = QE$

Force on one plate of the capacitor due to another plate $F' = QE' = \frac{QE}{2}$

2. $$V_1 = \frac{kq}{r} + \frac{kq}{6r} = \frac{7kq}{6r}$$

$$V_2 = \frac{kq}{2r} + \frac{kq}{6r} = \frac{3kq + kq}{6r} = \frac{4kq}{6r}$$

$$\frac{V_1}{V_2} = \frac{7}{4}$$

$$V_{\text{common}} = \frac{2q}{4\pi\varepsilon_0 (r + 2r)} = \frac{2q}{12\pi\varepsilon_0 r} = V'$$

Charge transferred equal to

$$q' = C_1V_1 - C_1V' = \frac{r}{k} \cdot \frac{kq}{r} - \frac{r}{k} \cdot \frac{kq}{3r}$$

$$= q - \frac{2q}{3} = q$$

3. $$R_1 = \frac{V_1}{I_1} = \frac{50}{2 \times 10^{-3}} = 25,000\Omega$$

$$R_2 = \frac{V_2}{I_2} = \frac{60}{3 \times 10^{-3}} = 20,000\Omega$$

As Resistance changes with $I$, therefore conductor is non-ohmic.

4. Rate of Production of heat, $P = I^2R$, for given $I$, $P \propto R$. \(\therefore\) $\rho_{\text{nichrome}} > \rho_{\text{cu}}$

\(\therefore R_{\text{nichrome}} > R_{\text{cu}}\) of same length and area of cross section.

5. (i) If $I$ in circuit is constant because $H = I^2Rt$

(ii) If $V$ in circuit is Constant because $H = \frac{V^2}{R}t$
NUMERICALS

1. \( V_A = k \left[ \frac{q_1}{a} + \frac{q_2}{b} + \frac{q_3}{c} \right] \)
   \( = k \frac{4\pi \sigma}{a} - k \frac{4\pi \sigma}{b} + k \frac{4\pi \sigma}{c} \)
   \( = \frac{4\pi \sigma}{\varepsilon_0} (a - b + c) \)

\[ V_B = k \left[ \frac{q_1}{b} + \frac{q_2}{b} + \frac{q_3}{c} \right] = k \left[ \frac{4\pi a^2 \sigma}{b} - 4\pi kb \sigma + 4\pi k c \sigma \right] \]
\( = \frac{\sigma}{\varepsilon_0} \left( \frac{a^2}{b} - b^2 + c^2 \right) \)

\[ V_C = \frac{\sigma}{\varepsilon_0} \left( a^2 - b^2 + c^2 \right) \]

When \( V_A = V_C \)
\( \frac{\sigma}{\varepsilon_0} (a - b + c) = \frac{\sigma}{\varepsilon_0 c} \left( a^2 - b^2 + c^2 \right) \)
\( ac - bc + c^2 = a^2 - b^2 + c^2 \)
\( (a - b) = (a - b) (a + b) \)
\( c = a + b. \)

2. \( Q = CV \)

Total charge \( Q = \) Total capacitance in series \( \times \) voltage
\( = \left( \frac{5}{6} \times 10^{-3} \right) \times 12 = 10 \times 10^{-3} \) coulomb

\[ V_{AB} = \frac{Q}{c_1} = \frac{10 \times 10^{-3}}{1 \times 10^{-3}} = 10V \]

\[ V_{BC} = \frac{Q}{c_2} = \frac{10 \times 10^{-3}}{5 \times 10^{-3}} = 2V. \]
When B is earthed $V_B = 0$, $V_A = 10\text{V}$ and $V_C = -2\text{V}$.

3. Before dielectric is introduced.

$$E_A = \frac{1}{2} CV^2; \quad E_B = \frac{1}{2} CV^2$$

$$E = E_A + E_B = CV^2$$

After disconnecting the battery and then introducing dielectric

$$E'_A = \frac{1}{2} \left(\frac{3C}{2}\right) V^2$$

$$E'_B = \frac{Q^2}{2C} = \frac{\left(\frac{C}{2}\right)^2}{2 \times 3C} = \frac{1}{3} \frac{1}{2} CV^2 \quad E' = E'_A + E'_B$$

$$\frac{E'}{E} = \frac{5}{3}$$

4. $R_{AB} = 2\Omega$

$$I_{CD} = 0 \quad I_{ACB} = \frac{V}{2R} = \frac{10}{2 \times 2} = 2.5\text{A}$$

5. (i) \[ \frac{E_2}{E_1} = \frac{i_2}{i_1} \Rightarrow E_2 \frac{i_2}{i_1} = E_1 \frac{80}{60} \times 1.5 = 2.0\text{V} \]

(ii) The Circuit will not work if emf of driven Cell is IV, total Voltage across AB is IV, which cannot balance the voltage 1.5V.

(iii) No, since at balance point no current flows through galvanometer G, i.e., cell remains in open circuit.
6. \( E = I (R + r) \)
\[ 10 = 0.5 (R + 3) \]
\[ R = 17 \Omega \]
\[ V = E – Ir = 10 – 0.5 \times 3 = 8.5 \text{V} \]

7. \( \text{Req} = 7W \)
\[ I_{4\Omega} = 1A, \ I_{1\Omega} = 2A, \ I_{\frac{1}{2}\Omega} = \frac{2}{3}A, \ I_{\frac{3}{4}\Omega} = \frac{4}{3}A, \ V_{AB} = 4V, \ V_{BC} = 2V, \ V_{CD} = 8V \]

8. \( I_{eq} = \text{enAV_d} = \frac{enA}{I} \)
\[ t = \frac{enA}{I} = 2.7 \times 10^4 \text{s} \]

9. \( I = \frac{84}{\left(\frac{100 \times 400}{100 + 400} + 200\right)} = \frac{84}{280} = 0.3A \)

P.d across Voltmeter & 100Ω Combination
\[ = 0.3 \times \frac{100 \times 400}{100 + 400} = 24 \text{V} . \]

When, \( l < < r, \)

\[ B_{\text{axial}} = \frac{\mu_0}{4\pi} \frac{2M}{r^2} \]

Magnetic field on equatorial line of a bar magnet
\[ B_{\text{eq}} = \frac{\mu_0}{4\pi} \left[ \frac{M}{(r^2 + l^2)^{\frac{3}{2}}} \right] \text{T} \]
### KEY POINTS

#### SECTION 2 (Unit III & IV)

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When, $x = 0$, $B = \frac{\mu_0 I}{2}$

For $a << x$, $E = \frac{u}{2}$
Ampere’s Circuital Law
\[ \oint \mu = T - m \]
Magnetic field due to a long straight solenoid
\[ B = \mu_0 n I \]
At the end of solenoid,
\[ B = \mu r n I \]
If solenoid is filled with material having magnetic permeability \( \mu r \)
\[ B = \mu_0 \mu r n I \]
Magnetic field due to a toroidal solenoid
\[ B = \mu_0 n I \]
Motion of a charged particle inside electric field
\[ F = \frac{qE}{m} x \hat{a} \]
Magnetic force on a moving charge
\[ F = B q v \sin \theta \]
Or \( F = B q v \sin \theta \)
Lorentz Force (Electric and magnetic)
The Cyclotron

Radius of circular path

The period of circular motion

The cyclotron frequency

Maximum energy of the positive ions

The radius corresponding to maximum velocity

The maximum velocity

The radius of helical path when \( \mathbf{E} \) and \( \mathbf{B} \) are inclined to each other by an angle \( \theta \)

Force on a current carrying conduct placed in a magnetic field
Force per unit length between two parallel current carrying conductors

\[ f = \frac{I_1 I_2}{2\pi r} \quad \text{Nm}^{-1} \]

Magnetic dipole moment

\[ \mathbf{M} = \mathbf{I} \times \mathbf{A} \quad \text{Am}^2 \text{ or JT}^{-1} \]

Torque on a rectangular current carrying loop ABCD

\[ \tau = BIA \cos \theta \]
\[ \theta \rightarrow \text{angle between loop and magnetic field} \]

\[ \tau = n BIA \sin \alpha \]
\[ \alpha \rightarrow \text{angle between normal drawn on the plane of loop and magnetic field} \]

Period of oscillation of bar magnet if external magnetic field

\[ T = \frac{1}{2\pi} \frac{mL^2}{k} \quad \text{s} \]

The potential energy associated with magnetic field

\[ U = J \]
Current through a galvanometer \( \angle \) angle by which the coil rotates

Sensitivity of a galvanometer or

Current sensitivity \( \text{rad A}^{-1} \)

Voltage sensitivity \( \text{rad V}^{-11} \)

The current loop as a magnetic dipole

Gyromagnetic ratio \( \text{C Kg}^{-1} \)

Bohr magneton \( \text{Am}^2 \)

Magnetic dipole moment \( \text{JT}^{-1} \) or \( \text{Am}^2 \)

Magnetic field on axial line of a bar magnet \( \text{T} \)
When, \( l < < r \),

<table>
<thead>
<tr>
<th>Term</th>
<th>Formula</th>
<th>Unit</th>
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</thead>
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<tr>
<td>Gauss’s Law in magnetism</td>
<td>( \oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\varepsilon_0} )</td>
<td>Tm^2 or weber</td>
</tr>
<tr>
<td>Magnetic inclination (or Dip)</td>
<td>( \delta \rightarrow \text{angle of dip} )</td>
<td></td>
</tr>
<tr>
<td>Magnetic intensity (or Magnetic field strength)</td>
<td>( \mathbf{B} = \mathbf{B}_0 + \mu_0 \mathbf{H} )</td>
<td>Am⁻¹</td>
</tr>
<tr>
<td>Intensity of magnetization</td>
<td>( I_m \rightarrow Am^{-1} )</td>
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<tr>
<td>Magnetic flux</td>
<td>( \phi \rightarrow \text{Weber (Tm}^2) )</td>
<td></td>
</tr>
<tr>
<td>Magnetic induction (or Magnetic flux density or Magnetic field)</td>
<td>( B = B_0 + \mu_0 I_m )</td>
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<td>Magnetic susceptibility</td>
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<td>Magnetic permeability</td>
<td>( \mu \rightarrow \text{TmA}^{-1} )</td>
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<td>(or NA⁻²)</td>
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<td>Relative permeability (( \mu ))</td>
<td>( \mu = \frac{\mu_r \mu_0}{\mu_0} )</td>
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<td>Curie’s Law</td>
<td>( C \rightarrow \text{curie constant} )</td>
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**UNIT III & UNIT IV**

**MAGNETIC EFFECTS OF CURRENT AND MAGNETISM**

**&**

**E.M.I. AND ALTERNATING CURRENT**

**QUESTIONS**

**VERY SHORT ANSWER QUESTIONS (1 Mark)**

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

   **Ans.** No, pole exists only when the source has some net magnetic moment. There is no pole in tornoid. Magnetic field due to a toroid \( B = \mu_0 nI \)

2. How are the figure of merit and current sensitivity of galvanometer related with each other?

   **Ans.** Reciprocal.

3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section of radius ‘a’ and carrying steady currently as a function of distance \( r (a > r) \) from the axis of the conductor.

   **Ans.**

4. The force per unit length between two parallel long current carrying conductor is \( F \). If the current in each conductor is tripled, what would be the value of the force per unit length between them?
Ans. \( F = \frac{\mu_0 I_1 I_2}{2 \pi r} \)

\[ F = \frac{\mu_0 (3 I_1)(3 I_2)}{2 \pi r} = 9 \text{ times} \]

5. How does the angle of dip vary from equator to poles?
Ans. \( 0^\circ \) to \( 90^\circ \)

6. What is the effect on the current measuring range of a galvanometer when it is shunted?
Ans. Increased.

7. An electric current flows in a horizontal wire from East to West. What will be the direction of magnetic field due to current at a point (i) North of wire; (ii) above the wire.
Ans. \( W \rightarrow E \)

   (i) Going into the plane of the paper
   (ii) Towards North.

8. Suggest a method to shield a certain region of space from magnetic fields.
Ans. By using a ferromagnetic case.

*9. Why the core of moving coil galvanometer is made of soft iron?
Ans. To increase magnetic flux linked and sensitivity.

10. Where on the earth's surface, is the vertical component of earth's magnetic field zero?
Ans. At equator.

11. If the current is increased by 1% in a moving coil galvanometer. What will be percentage increase in deflection?
Ans. 1%.

Ans. (i) \( \text{Am} \)
   (ii) \( \text{Am}^2 \)
13. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton (positive charge)

**Ans.** When velocity \( \vec{v} \) of positively charged particle is along x-axis and the magnetic field \( \vec{B} \) is along y-axis, so \( \vec{v} \times \vec{B} \) is along the z-axis (Fleming's left hand rule).

Therefore,

(a) for electron Lorentz force will be along \(-z\) axis;

(b) for a positive charge (proton) the force is along \(+z\) axis.

14. If a toroid uses Bismuth as its core, will the field in the core be lesser or greater than when it is empty?

**Ans.** Bismuth is diamagnetic, hence, the overall magnetic field will be slightly less.

15. An electron beam projected along + x-axis, experiences a force due to a magnetic field along the + y-axis. What is the direction of the magnetic field?

**Ans.** +Z axis.

16. What is the principle of a moving coil galvanometer?

**Ans.** When a current carrying coil is placed in uniform magnetic field, it experiences a torque.

17. What is the direction of magnetic dipole moment?

**Ans.** S to N

18. What is the angle of dip at a place where vertical and horizontal component of earth’s field are equal?

**Ans.** 45°

19. Is any work done on a moving charge by a magnetic field?

**Ans.** No, as magnetic field is in perpendicular direction.

20. Sketch the magnetic field lines for a current carrying circular loop.

**Ans.**
21. Why core of a transformer is laminated?

Ans. To reduce loss due to eddy currents.

22. What is the direction of induced currents in metal rings 1 and 2 seen from the top when current I in the wire is increasing steadily?

Ans.

23. In which of the following cases will the mutual inductance be (i) minimum (ii) maximum?

Ans. (i) b (ii) c
24. In a series $L$–$C$–$R$ circuit, voltages across inductor, capacitor, and resistor are $V_L$, $V_C$ and $V_R$ respectively. What is the phase difference between (i) $V_L$ and $V_R$ (ii) $V_L$ and $V_C$?

**Ans.** (i) $\frac{\pi}{2}$ (ii) $\pi$

25. Why can’t transformer be used to step up or step down dc voltage?

**Ans.** In steady current no induction phenomenon will take place.

26. In an a.c. circuit, instantaneous voltage and current are $V = 200 \sin 300t$ volt and $i = 8 \cos 300t$ ampere respectively. What is the average power dissipated in the circuit?

**Ans.** As the phase difference b/w current and voltage is $\frac{\pi}{2}$

$$\therefore P_{av} = I_v E_v \cos \frac{\pi}{2} = 0$$

27. Sketch a graph that shows change in reactance with frequency of a series LCR circuit.

**Ans.**

28. A coil A is connected to an A.C. ammeter and another coil B to a source of alternating e.m.f. What will be the reading in ammeter if a copper plate is introduced between the coils as shown.

**Ans.** Reading of ammeter will decrease due to eddy currents.
29. In a circuit instantaneously voltage and current are \( V = 150 \sin 314t \) volt and \( i = 12 \cos 314t \) ampere respectively. Is the nature of circuit is capacitive or inductive?

Ans. \( i = 12 \sin \left( 314 + \frac{\pi}{2} \right)t \)

i.e. Current is ahead the voltage by a phase difference of \( \frac{\pi}{2} \). Hence circuit is a capacitive circuit.

30. In a series L–C–R circuit \( V_L \neq V_C \neq V_R \). What is the value of power factor?

Ans. At Resonance \( \cos \phi = 1 \)

31. In an inductor \( L \), current passed \( I_0 \) and energy stored in it is \( U \). If the current is now reduced to \( I_0/2 \), what will be the new energy stored in the inductor?

Ans. \( U_L \propto I^2 \Rightarrow U' = \frac{U}{4} \)

32. A rectangle loop \( a \ b \ c \ d \) of a conducting wire has been changed into a square loop \( a' \ b' \ c' \ d' \) as shown in figure. What is the direction of induced current in the loop?

Ans. Clockwise.

33. Twelve wires of equal lengths are connected in the form of a skeleton of a cube, which is moving with a velocity \( \vec{v} \) in the direction of magnetic field \( \vec{B} \). Find the \( emf \) in each arm of the cube.
Ans. Emf in each branch will be zero since V & B are parallel for all arms

\[ \therefore \mathcal{E} = q \left( \mathbf{V} \times \mathbf{B} \right) = 0 \]

34. Current versus frequency \((I - \nu)\) graphs for two different series L–C–R circuits have been shown in adjoining diagram. \(R_1\) and \(R_2\) are resistances of the two circuits. Which one is greater—\(R_1\) or \(R_2\)?

\[ R_1 > R_2 \] as \(I\) is smaller in larger resistance.

35. Why do we prefer carbon brushes than copper in an a.c. generator?

Ans. Corrosion free and small expansion on heating maintains proper contact.

36. What are the values of capacitive and inductive reactance in a dc circuit?

\[ X_C = \infty \quad \text{for d c \ } \nu = 0 \]
\[ X_L = \frac{1}{\omega L} = \frac{1}{2\pi f C} = \infty \]
\[ X_L = 0 \quad \& \quad X_L = \omega L = 2\pi f L = 0 \]

37. Give the direction of the induced current in a coil mounted on an insulating stand when a bar magnet is quickly moved along the axis of the coil from one side to the other as shown in figure.

\[ \text{S} \quad \text{N} \]
Ans. If observer is situated at the side from which bar magnet enters the loop. The direction of current is clockwise when magnet moves towards the loop and direction of current is anticlockwise when magnet moves away from the loop.

38. In figure, the arm PQ is moved from \( x = 0 \) to \( x = 2b \) with constant speed \( V \). Consider the magnet field as shown in figure. Write

(i) direction of induced current in rod

(ii) polarity induced across rod.

![Diagram of a bar magnet and a loop with arrows indicating the direction of the induced current]

39. A wire moves with some speed perpendicular to a magnetic field. Why is emf induced across the rod?

Ans. Lorentz force acting on the free charge carrier of conducting wire hence polarity developed across it.

40. Predict the polarity of the capacitor in the situation described in the figure below.

Ans. Plate a will be positive with respect to 'b'.

![Diagram of a capacitor with an arrow indicating the direction of the induced current]

41. A circular coil rotates about its vertical diameter in a uniform horizontal magnetic field. What is the average emf induced in the coil?

Ans. Zero

42. Define RMS Value of Current.

Ans. RMS Value of ac is defined as that value of direct current which produces the same heating effect in a given resistor as is produced by the given alternating current when passed for the same time.
\[ I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = 0.77 I_0 \]

43. A conducting rod PQ is in motion at speed \( v \) in uniform magnetic field as shown in Fig. What are the polarities at P and Q?

\[ \begin{array}{c}
P \\
Q
\end{array} \]

Ans. Q (–)

P (+)

44. A long straight wire with current \( i \) passes (without touching) three square wire loops with edge lengths 2L, 1.5L, and L. The loops are widely spaced (so as to not affect one another). Loops 1 and 3 are symmetric about the long wire. Rank the loops according to the size of the current induced in them if current \( i \) is (a) constant and (b) increasing greatest first.

\[ \begin{array}{c}
1 \\
2 \\
3
\end{array} \]

Ans. (a) No induced current

(b) Current will be induced only in loop 2.

45. In an L–C circuit, current is oscillating with frequency \( 4 \times 10^6 \) Hz. What is the frequency with which magnetic energy is oscillating?

Ans. \( \nu_m = 2 \nu_{\omega} = 8 \times 10^6 \) Hz.
SHORT ANSWERS QUESTIONS (2 MARKS)

1. Write the four measures that can be taken to increase the sensitivity of a galvanometer.

2. A galvanometer of resistance 120Ω gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range 0 to 5A? Also determine the net resistance of the ammeter.

3. A current loop is placed in a uniform magnetic field in the following orientations (1) and (2). Calculate the magnetic moment in each case.

4. A current of 10A flows through a semicircular wire of radius 2cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b)?

5. A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

6. Which one of the two an ammeter or milliammeter, has a higher resistance and why?

7. Mention two properties of soft iron due to which it is preferred for making electromagnet.

8. A magnetic dipole of magnetic moment M is kept in a magnetic field B. What is the minimum and maximum potential energy? Also give the most stable position and most unstable position of magnetic dipole.
9. What will be (i) Pole strength (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces:
   (a) normal to its length?
   (b) along its length?

10. A steady current I flows along an infinitely long straight wire with circular cross-section of radius R. What will be the magnetic field outside and inside the wire at a point r distance far from the axis of wire?

11. A circular coil of n turns and radius R carries a current I. It is unwound and rewound to make another square coil of side 'a' keeping number of turns and current same. Calculate the ratio of magnetic moment of the new coil and the original coil.

12. 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 moment of the new coil and original coil.

13. At a place horizontal component of the earth's magnetic field is B and angle of dip at the place is 60°. What is the value of horizontal component of the earth's magnetic field.
   (i) at Equator; (ii) at a place where dip angle is 30°

14. A galvanometer coil has a resistance G. 1% of the total current goes through the coil and rest through the shunt. What is the resistance of the shunt?

15. Prove that the magnetic moment of a hydrogen atom in its ground state is \( \frac{eh}{4\pi m} \). Symbols have their usual meaning.

16. Each of eight conductors in figure carries 2A of current into or out of page.

   Two path are indicated for the line integral \( \oint B \cdot dT \). What is the value of the integral for the path (a) and (b).

17. What is the radius of the path of an electron (mass \( 9 \times 10^{-31} \) kg and charge \( 1.6 \times 10^{-19} \) C) moving at a speed of \( 3 \times 10^7 \) m/s in a magnetic field
of $6 \times 10^{-4}$ T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = $1.6 \times 10^{-19}$ J).

**Ans.** Radius, $r = \frac{mv}{qB}$

$$= 9.1 \times 10^{-31} \text{kg} \times 3 \times 10^7 \text{ ms}^{-1} / (1.6 \times 10^{-19} \text{ C} \times 10^{-4} \text{ T}) = 26 \text{ cm}$$

$v = \frac{v}{(2\pi r)} = 2 \times 10^8 \text{ s}^{-1} = 2 \times 10^8 \text{ Hz} = 200 \text{ MHz}.$

$E = \frac{1}{2}mv^2 = \frac{1}{2} \times 9 \times 10^{-31} \text{ kg} \times 9 \times 10^{14} \text{ m}^2/\text{s}^2$

$$= 40.5 \times 10^{-17} \text{ J} = 4 \times 10^{-16} \text{ J} = 2.5 \text{ keV}.$$

18. A particle of mass $m$ and charge $q$ moves at right angles to a uniform magnetic field. Plot a graph showing the variation of the radius of the circular path described by it with the increase in its kinetic energy, where, other factors remain constant.

**Ans.** $r \alpha \sqrt{E_K}$

19. Magnetic field arises due to charges in motion. Can a system have magnetic moments even though its net charges is zero? Justify.

**Ans.** Yes; for example the atoms of a paramagnetic substance possess a net magnetic moment though its net charge is zero.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed $'v'$, around an orbit of radius $'r'$ in hydrogen atom.

**Ans.** The product of the current in the loop to the area of the loop is the magnetic dipole moment of a current loop.

The magnetic moment of electron $\mu = -\frac{e}{2} (\vec{r} \times \vec{v}) = -\frac{e}{2m_e} (\vec{r} \times \vec{p}) = -\frac{e}{2m_e} \vec{\ell}$
21. An ac source of rms voltage \( V \) is put across a series combination of an inductor \( L \), capacitor \( C \) and a resistor \( R \). If \( V_L \), \( V_C \) and \( V_R \) are the rms voltage across \( L \), \( C \) and \( R \) respectively then why is \( V \neq V_L + V_C + V_R \)? Write correct relation among \( V_L \), \( V_C \) and \( V_R \).

22. A bar magnet is falling with some acceleration ‘\( a \)’ along the vertical axis of a coil as shown in fig. What will be the acceleration of the magnet (whether \( a > g \) or \( a < g \) or \( a = g \)) if (a) coil ends are not connected to each other? (b) coil ends are connected to each other?

23. The series \( L-C-R \) circuit shown in fig. is in resonance state. What is the voltage across the inductor?

24. The divisions marked on the scale of an a.c. ammeter are not equally spaced. Why?

25. Circuit shown here uses an airfield parallel plate capacitor. A mica sheet is now introduced between the plates of capacitor. Explain with reason the effect on brightness of the bulb \( B \).

26. In the figure shown, coils \( P \) and \( Q \) are identical and moving apart with same velocity \( V \). Induced currents in the coils are \( I_1 \) and \( I_2 \). Find \( I_1/I_2 \).
27. A 1.5 µF capacitor is charged to 57V. The charging battery is then disconnected, and a 12 mH coil is connected in series with the capacitor so that LC Oscillations occur. What is the maximum current in the coil? Assume that the circuit has no resistance.

28. The self inductance of the motor of an electric fan is 10H. What should be the capacitance of the capacitor to which it should be connected in order to impart maximum power at 50Hz?

29. How does an inductor behave in a DC circuit after the current reaches to steady state? Justify.

30. How does an inductor behave in a AC circuit at very high frequency? Justify.

31. An electric bulb is connected in series with an inductor and an AC source. When switch is closed and after sometime an iron rod is inserted into the interior of inductor. How will the brightness of bulb be affected? Justify your answer.

**Ans.** Decreases, due to increase in inductive reactance.

32. Show that in the free oscillation of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant with time.

**Ans.** Hint: \[ U = \frac{1}{2} L i^2 + \frac{1}{2} \frac{q^2}{C} \]

33. Show that the potential difference across the LC combination is zero at the resonating frequency in series LCR circuit

**Ans.** Hint P.d. across L is = IX_L
P.D. across $C$ is $-IX_C$

$\Rightarrow V = IX_L - IX_C$

at resonance $X_L = X_C$

$\Rightarrow V = 0$.

34. How does an capacitor behave in a DC circuit after the steady state? Explain your answer.

**Ans.** Capacitor acts as an open key.

35. For circuits used for transmitting electric power, a low power factor implies large power loss in transmission. Explain.

$P = VI \cos \phi$

Or $I = \frac{P}{V \cos \phi}$

if $\cos \theta$ is Low I will be high $\Rightarrow$ Large power loss.

36. An applied Voltage signal consists of a superposition of DC Voltage and an AC Voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the DC signal will appear across $C$ where as AC signal will appear across $L$.

37. A bar magnet $M$ is dropped so that is falls vertically through the coil $C$. The graph obtained for voltage produced across the coil Vs time is shown in figure.

(i) Explain the shape of the graph

(ii) Why is the negative peak longer than the positive peak?
38. What is the Significance of Q-factor in a series LCR resonant circuit?

39. How does mutual inductance of a pair of coils kept coaxially at a distance in air change when
   (i) the distance between the coils is increased?
   (ii) an iron rod is kept between them?

40. Two circular conductors are perpendicular to each other as shown in figure. If the current is changed in conductor B, will a current be induced in the conductor A,

   ![Diagram of two circular conductors](image)

**SHORT ANSWERS QUESTIONS (3 MARKS)**

1. Derive the expression for force between two infinitely long parallel straight wires carrying current in the same direction. Hence define ‘ampere’ on the basis of above derivation.

2. Define (i) Hysteresis (ii) Retentivity (iii) Coercivity

3. Distinguish between diamagnetic, paramagnetic and ferromagnetic substances in terms of susceptibility and relative permeability.

4. Name all the three elements of earth magnetic field and define them with the help of relevant diagram.

5. Describe the path of a charged particle moving in a uniform magnetic field with initial velocity
   (i) parallel to (or along) the field.
   (ii) perpendicular to the field.
   (iii) at an arbitrary angle \( \theta (0^\circ < \theta < 90^\circ) \).
6. Obtain an expression for the magnetic moment of an electron moving with a speed \( v \) in a circular orbit of radius \( r \). How does this magnetic moment change when:

(i) the frequency of revolution is doubled?

(ii) the orbital radius is halved?

7. State Ampere, circuital law. Use this law to obtain an expression for the magnetic field due to a toroid.

8. Obtain an expression for magnetic field due to a long solenoid at a point inside the solenoid and on the axis of solenoid.

9. Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.

10. Derive an expression for magnetic field intensity due to a bar magnet (magnetic dipole) at any point (i) Along its axis (ii) Perpendicular to the axis.

11. Derive an expression for the torque acting on a loop of \( N \) turns of area \( A \) of each turn carrying current \( I \), when held in a uniform magnetic field \( B \).

12. How can a moving coil galvanometer be converted into a voltmeter of a given range. Write the necessary mathematical steps to obtain the value of resistance required for this purpose.

13. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having \( n \) turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

**Ans.** When there is only one turn, the magnetic field at the centre,

\[
B = \frac{\mu_0 I}{2a}
\]

\[
2\pi a^1 x n = 2\pi a \Rightarrow a^1 = a/n
\]

The magnetic field at its centre, \( B_1 = \frac{\mu_0 nI}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B \)

The ratio is, \( B_1/B = n^2 \)

14. Obtain an expression for the self inductance of a straight solenoid of length \( l \) and radius \( r \) \((l >> r)\).
15. Distinguish between : (i) resistance and reactance (ii) reactance and impedance.

16. In a series L–C–R circuit $X_L$, $X_C$ and $R$ are the inductive reactance, capacitive reactance and resistance respectively at a certain frequency $f$. If the frequency of a.c. is doubled, what will be the values of reactances and resistance of the circuit?

17. What are eddy currents? Write their any four applications.

18. In a series L–R circuit, $X_L = R$ and power factor of the circuit is $P_1$. When capacitor with capacitance $C$ such that $X_L = X_C$ is put in series, the power factor becomes $P_2$. Find $P_1/P_2$.

19. Instantaneous value of a.c. through an inductor $L$ is $e = e_0 \cos \omega t$. Obtain an expression for instantaneous current through the inductor. Also draw the phasor diagram.

20. In an inductor of inductance $L$, current passing is $I_0$. Derive an expression for energy stored in it. In what forms is this energy stored?

21. Which of the following curves may represent the reactance of a series LC combination.

![Diagram of reactance curves]

[Ans. : (b)]

22. A sinusoidal e.m.f. device operates at amplitude $E_0$ and frequency $\nu$ across a purely (1) resistive (2) capacitive (3) inductive circuit. If the frequency of driving source is increased. How would (a) amplitude $E_0$ and (b) amplitude $I_0$ increase, decrease or remain same in each case?

23. The figure shows, in (a) a sine curve $\delta(t) = \sin \omega t$ and three other sinusoidal curves $A(t)$, $B(t)$ and $C(t)$ each of the form $\sin(\omega t - \phi)$. (a) Rank the three curves according to the value of $\phi$, most positive first and most negative last (b) Which curve corresponds to which phase as in
24. In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T them:
   (i) at what time is the energy stored completely electrical
   (ii) at what time is the energy stored completely magnetic
   (iii) at what time is the total energy shared equally between the inductor and capacitor.

   **Ans:**
   (i) \( t = 0, \frac{T}{2}, 3\frac{T}{2}, \ldots \ldots \)
   (ii) \( t = \frac{T}{4}, 3\frac{T}{4}, 5\frac{T}{4}, \ldots \ldots \)
   (iii) \( t = \frac{T}{8}, 3\frac{T}{8}, 5\frac{T}{8}, \ldots \ldots \)

25. An alternating voltage of frequency \( f \) is applied across a series LCR circuit. Let \( f_r \) be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when
   (i) \( f > f_r \)
   (ii) \( f < f_r \)? Explain your answer in each case.

   **Ans.**
   (i) Current will Lag because.
   \( V_L > V_C \) Hence \( V_L - V_C > 0 \)
   (i) Current will lead, because.
   \( V_L < V_C \) Hence \( V_L - V_C < 0 \)

26. Figure (a), (b), (c) Show three alternating circuits with the equal currents. If frequency of alternating emf be increased, what will be the effect on current in the three cases? Explain.
1. How will a diamagnetic, paramagnetic and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide suitability for making.

(i) Permanent magnet (ii) Electromagnet.

2. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance \( d \) from the centre of a circular coil of radius \( 'a' \) and carrying current \( I \). Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of \( d \) is \( \sqrt{3}a \).

3. Write an expression for the force experienced by a charged particle moving in a uniform magnetic field \( B \). With the help of diagram, explain the principle and working of a cyclotron. Show that cyclotron frequency does not depend on the speed of the particle.

4. Write the principle, working of moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phosphor bronze used in the construction of moving coil galvanometer?

5. Draw a labelled diagram to explain the principle and working of an a.c. generator. Deduce the expression for emf generated. Why cannot the current produced by an a.c. generator be measured with a moving coil ammeter?

6. Explain, with the help of a neat and labelled diagram, the principle, construction and working of a transformer.

**LONG ANSWER QUESTIONS (5 Marks)**

(i) No effect, \( R \) is not affected by frequency.

(ii) Current will decrease as \( X_L \) increase.

(iii) Current will increase as \( X_C \) decrease.
7. An L–C circuit contains inductor of inductance $L$ and capacitor of capacitance $C$ with an initial charge $q_0$. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.

(i) What is the total energy stored initially?

(ii) What is the maximum current through inductor?

(iii) What is frequency at which charge on the capacitor will oscillate?

(iv) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

8. An a.c. $i = i_0 \sin \omega t$ is passed through a series combination of an inductor (L), a capacitor (C) and a resistor (R). Use the phasor diagram to obtain expressions for the (a) impedance of the circuit and phase angle between voltage across the combination and current passed in it. Hence show that the current

(i) leads the voltage when $\omega < \frac{1}{\sqrt{LC}}$

(ii) is in phase with voltage when $\omega = \frac{1}{\sqrt{LC}}$.

9. Write two differences in each of resistance, reactance and impedance for an ac circuit. Derive an expression for power dissipated in series LCR circuit.

NUMERICALS

1. An electron travels on a circular path of radius 10m in a magnetic field of $2 \times 10^{-3}$ T. Calculate the speed of electron. What is the potential difference through which it must be accelerated to acquire this speed?

   [Ans. : Speed = $3.56 \times 10^8$ m/s; $V = 3.56 \times 10^7$ volts]

2. A ship is to reach a place 15° south of west. In what direction should it be steered if declination at the place is 18° west?

   [Ans. : 87° west of North]

3. Calculate the magnetic field due to a circular coil of 500 turns and of mean diameter 0.1m, carrying a current of 14A (i) at a point on the axis distance 0.12m from the centre of the coil (ii) at the centre of the coil.

   [Ans. : (i) $5.0 \times 10^{-3}$ Tesla; (ii) $8.8 \times 10^{-2}$ tesla]
4. An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli tesla. Calculate the time period of rotation of the electron in the magnetic field. \[ \text{Ans. : } 4.467 \times 10^{-8} \text{ s.} \]

5. If the current sensitivity of a moving coil galvanometer is increased by 20% and its resistance also increased by 50% then how will the voltage sensitivity of the galvanometer be affected? \[ \text{Ans. : } 25\% \text{ decrease} \]

6. A uniform wire is bent into one turn circular loop and same wire is again bent in two turn circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres. \[ \text{Ans. : } \text{Increased 4 times} \]

7. A horizontal electrical power line carries a current of 90A from east to west direction. What is the magnitude and direction of magnetic field produced by the power line at a point 1.5m below it? \[ \text{Ans. : } 1.2 \times 10^{-5} \text{ T south ward} \]

8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 225 mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be connected? \[ \text{Ans. : } 1910\Omega \text{ in series} \]

9. Two identical circular loops P and Q carrying equal currents are placed such that their geometrical axis are perpendicular to each other as shown in figure. And the direction of current appear’s anticlockwise as seen from point O which is equidistant from loop P and Q. Find the magnitude and direction of the net magnetic field produced at the point O.

\[
\text{Ans. : } \frac{\mu_0 I R^2 \sqrt{2}}{2 \left( R^2 + x^2 \right)^{3/2}}
\]

10. A cyclotron’s oscillator frequency is 10 MHz. What should be the operating
magnetic field for accelerating protons, if the radius of its dees is 60cm? What is the kinetic energy of the proton beam produced by the accelerator? Given $e = 1.6 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg. Express your answer in units of MeV [1MeV = $1.6 \times 10^{-13}$ J]. [Ans. : $B = 0.656$T, $E_{\text{max}} = 7.421$ MeV]

11. The coil of a galvanometer is $0.02 \times 0.08$ m$^2$. It consists of 200 turns of fine wire and is in a magnetic field of 0.2 tesla. The restoring force constant of the suspension fibre is $10^{-6}$ Nm per degree. Assuming the magnetic field to be radial.

   (i) what is the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection?

   (ii) what is the smallest, current that can be detected if the minimum observable deflection is 0.1°?

   [Ans. : (i) $4.69 \times 10^{-4}$ A; (ii) $1.56 \times 10^{-6}$ A]

12. A voltmeter reads 8V at full scale deflection and is graded according to its resistance per volt at full scale deflection as $5000 \, \Omega V^{-1}$. How will you convert it into a voltmeter that reads 20V at full scale deflection? Will it still be graded as $5000 \, \Omega V^{-1}$? Will you prefer this voltmeter to one that is graded as $2000 \, \Omega V^{-1}$?

   [Ans. : $7.5 \times 10^4 \, \Omega$]

13. A short bar magnet placed with its axis at 30° with an external field 1000G experiences a torque of 0.02 Nm. (i) What is the magnetic moment of the magnet. (ii) What is the work done in turning it from its most stable equilibrium to most unstable equilibrium position?

   [Ans. : (i) $0.4$ Am$^2$; (ii) $0.08$ J]

14. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 4cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is $0.5$ Am$^2$.

   [Ans. : $B_E = 7.8125 \times 10^{-7}$ T; $B_A = 15.625 \times 10^{-7}$ T]

15. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of 30° with the direction of a uniform magnetic field of 0.15T?

16. Two moving coil galvanometers, $M_1$ and $M_2$ have the following specifications.

   $R_1 = 10\Omega$, $N_1 = 30$, $A_1 = 3.6 \times 10^{-3}$m$^2$, $B_1 = 0.25$T
   $R_2 = 14\Omega$, $N_2 = 42$, $A_2 = 1.8 \times 10^{-3}$m$^2$, $B_2 = 0.50$T

   Given that the spring constants are the same for the two galvanometers,
determine the ratio of (a) current sensitivity (b) voltage sensitivity of \( M_1 \) & \( M_2 \).

17. In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows shown different positions and orientations of the magnetic moment of another identical magnetic needs B

(a) In which configuration is the system not in equilibrium?

(b) In which configuration is the system.

(i) stable and (ii) unstable equilibrium?

(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

18. In the circuit, the current is to be measured. What is the value of the current if the ammeter shown :

(a) is a galvanometer with a resistance \( R_G = 60\, \Omega \),

(b) is a galvanometer described in (i) but converted to an ammeter by a shunt resistance \( r_s = 0.02\, \Omega \)

(c) is an ideal ammeter with zero resistance?

19. An element \( \Delta l = \Delta x \cdot \hat{i} \) is placed at the origin and carries a large current \( I = 10A \). What is the magnetic field on the y-axis at a distance of 0.5m. \( \Delta x = 1\, \text{cm} \).
20. A straight wire of mass 200g and length 1.5 m carries a current of 2A. It is suspended in mid-air by a uniform horizontal magnetic field B. What is the magnitude of the magnetic field?

21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop?

Ans: \(7.82 \times 10^{-4}\) N towards the conductor

Hint:

\[
F_1 = \frac{\mu_0 I_1 I_2}{4\pi r_1} = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.02} = 9.38 \times 10^{-4}\text{ N attractive}
\]

\[
F_2 = \frac{\mu_0 I_1 I_2}{4\pi r_2} = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.12} = 1.56 \times 10^{-4}\text{ N repulsive}
\]

Net \(F = F_1 - F_2 = 7.82 \times 10^{-4}\) N

22. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of \(4.8 \times 10^6\) ms\(^{-1}\) normal to the field. Explain why the path of electron is a circle.

(a) Determine the radius of the circular orbit \((e = 1.6 \times 10^{-19}\text{ C}, m_e = 9.1 \times 10^{-31}\text{ kg})\)

(b) Obtain the frequency of resolution of the electron in its circular orbit.
Hint:

(a) \[
    r = \frac{m_e v}{eB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2 \text{cm}
\]

(b) \[
    \nu = \frac{1}{T} = \frac{eB}{2\pi m_e} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 1.8 \text{ MHz}
\]

23. The true value of dip at a place is 30°. The vertical plane carrying the needle is turned through 45° from the magnetic meridian. Calculate the apparent value of dip. 
   [Ans. : \(\delta' = 39^\circ 14'\)]

24. Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude \(B_1\) and \(B_2\). Its path in each region is a half circle. (a) Which field is stronger? (b) What are the directions of two fields? (c) Is the time spent by the electron in the \(B_1^+\) region greater than, less than, or the same as the time spent in \(B_2^-\) region?
   [Ans. : (a) \(B_1 > B_2\); (b) \(B_1\) inward; \(B_2\) outward. 
   (c) Time spent in \(B_1\) < Time spent in \(B_2\) ]

![Diagram of electron paths through magnetic fields](image)

25. In a series C–R circuit, applied voltage is \(V = 110 \sin 314t\) volt. What is the (i) The peak voltage (ii) Average voltage over half cycle?

26. Magnetic flux linked with each turn of a 25 turns coil is 6 milliweber. The flux is reduced to 1 mWb in 5 s. Find induced emf in the coil.

27. The current through an inductive circuit of inductance 4mH is \(i = 12 \cos 300t\) ampere. Calculate :
   (i) Reactance of the circuit.
   (ii) Peak voltage across the inductor.
28. A power transmission line feeds input power at 2400 V to a step down ideal transformer having 4000 turns in its primary. What should be number of turns in its secondary to get power output at 240V?

29. The magnetic flux linked with a closed circuit of resistance \(8\Omega\) varies with time according to the expression \(\phi = (5t^2 - 4t + 2)\) where \(\phi\) is in milliweber and \(t\) in second. Calculate the value of induce current at \(t = 15\) s.

30. A capacitor, a resistor and \(\frac{4}{\pi}\) henry inductor are connected in series to an a.c. source of 50 Hz. Calculate capacitance of capacitor if the current is in phase with voltage.

31. A series C–R circuit consists of a capacitance 16 mF and resistance 8\(\Omega\). If the input a.c. voltage is (200 V, 50 Hz), calculate (i) voltage across capacitor and resistor. (ii) Phase by which voltage lags/leads current.

32. A rectangular conducting loop of length \(l\) and breadth \(b\) enters a uniform magnetic field \(B\) as shown below.

The loop is moving at constant speed \(v\) and at \(t = 0\) it just enters the field.

B. Sketch the following graphs for the time interval \(t = 0\) to \(t = \frac{3l}{v}\).

(i) Magnetic flux – time

(ii) Induced emf – time

(iii) Power – time

Resistance of the loop is \(R\).

33. A charged 8mF capacitor having charge 5mC is connected to a 5mH inductor. What is:

(i) the frequency of current oscillations?

(ii) the frequency of electrical energy oscillations in the capacitor?
(iii) the maximum current in the inductor?
(iv) the magnetic energy in the inductor at the instant when charge on capacitor is 4mC?

34. A 31.4Ω resistor and 0.1H inductor are connected in series to a 200V, 50Hz ac source. Calculate
   (i) the current in the circuit
   (ii) the voltage (rms) across the inductor and the resistor.
   (iii) Is the algebraic sum of voltages across inductor and resistor more than the source voltage? If yes, resolve the paradox.

35. A square loop of side 12 cm with its sides parallel to X and Y-axis is moved with a velocity of 8 cm/s in positive x-direction. Magnetic field exists in z-directions.
   (i) Determine the direction and magnitude of induced current if field changes with $10^{-3}$ Tesla/cm along negative x-direction.
   (ii) Determine the direction and magnitude of induced current if field changes with $10^{-3}$ Tesla/s.

   Ans. (i) Rate of change of flux = induced emf = $(0.12)^2 \times 10^{-3} \times 8$
   = $11.52 \times 10^{-5}$ Wb/s.
   (ii) Rate of change of flux = induced emf = $(0.12)^2 \times 10^{-3}$
   = $1.44 \times 10^{-5}$ Wb/s.

36. Figure shows a wire of length $l$ which can slide on a U-shaped rail of negligible resistance. The resistance of the wire is R. The wire is pulled to the right with a constant speed $v$. Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire using this diagram.

\[\text{[Class XII : Physics]}\]
VALUE BASED QUESTIONS

1. Two girls Pooja and Ritu were very good observers and performed in the school function using their cassette player. One day when they were performing, tape got stuck up and the music stopped. But Pooja was determined not to let down the performance so she sang the song instead of dancing and Ritu completed the dance.

   (i) What were the value displayed by Pooja and Ritu?

   (ii) What kind of Ferro magnetic material is using for coating magnetic tapes used in cassette.

2. Tushar was using a galvanometer in the practical class. Unfortunately it fell from his hand and broke. He was upset, some of his friends advised him not to tell the teacher but Tushar decided to tell his teacher. Teacher listened to him patiently and on knowing that the act was not intentional, but just an accident, did not scold him and used the opportunity to show the internal structure of galvanometer to the whole class.

   (i) What are the value displayed by Tushar?

   (ii) Explain the principal, Construction and working of moving coil galvanometer.

3. Pooja went to the market with her mother and decided to come back home by metro. At Metro station they were made to pass through a gate way for security check. Pooja passed through it and was waiting for her mother to come. She heard a long beep when her mother passed through metal detector. Pooja was confused why metal detector beeped in case of her mother. She asked the duty staff, who explained her in detai. Both were satisfied with the security system.

   (i) What values are displayed by Pooja.

   (ii) What is cause of sound through metal detector

   (iii) Write the Principle on which a Metal detector works.

4. Mr. Sanjeev, a physics teacher, was doing an experiment in lab using dry cell battery. The dry cell was weak, giving less voltage, which was not sufficient to give proper reading. One of the student asked, “Sir, can’t we step-up the voltage using a transformer?” Teacher replied, No, we cannot
step up DC voltage using step-up transformer and explained the reason and working of a transformer the student then constructed a transformer for his Physics project and studied the factors responsible for losses in a transformer.

(i) What values are displayed by the student
(ii) Why transformer cannot be used to step-up DC voltage.

2 MARKS QUESTIONS

1. \[ S = \frac{I_g}{(I - I_g)} G = \frac{5 \times 10^{-3}}{5 - 5 \times 10^{-3}} \times 120 = 0.12 \Omega. \]

2. (i) – mB (ii) zero

3. (i) \[ B = \frac{10^{-7} \times \pi \times 10}{2 \times 10^{-2}} = 5\pi \times 10^{-5} T \text{ (outwards).} \]
   (ii) \[ B = 5p \times 10^{-5} T \text{ (inwards).} \]

4. \[ r_p = \frac{mv}{qB} \text{ and } r_a = \frac{4mv}{(2q)B} = 2r_a \Rightarrow \frac{r_p}{r_a} = \frac{1}{2}. \]

5. \( R_{mA} > R_A. \)

6. Low Retentivity and high permeability.

7. Minimum potential = – MB when \( \theta = 0 \) (most stable position)
   
   Maximum potential = MB when \( \theta = 180^\circ \) (most unstable position).

8. (a) Pole strength same; magnetic moment half.
   (b) Pole strength half; magnetic moment half.
9. \[ B(2\pi r) = \mu_0 \left( \frac{l}{\pi R^2} \right) \left( \frac{\pi r^2}{2} \right) . \]
\[ B = \left( \frac{\mu_0 l}{2\pi R^2} \right) r \quad (R \geq r) \]
\[ \int \vec{B} \cdot d\vec{l} = \mu_0 I \]
\[ \therefore \quad B = \frac{\mu_0 I}{2\pi r} \quad (r \geq R). \]

10. \[ M_1 = Ml\pi R^2; \quad M_2 = Ml a^2 \]
\[ 2\pi rN = 4aN \Rightarrow a = \frac{\pi R}{2} \]
\[ \frac{M_2}{M_1} = \frac{\pi}{4} \]

11. \[ \frac{m_{\text{new}}}{m_{\text{original}}} = \frac{2l \times \pi \left( \frac{r}{2} \right)^2}{l \times \pi R^2} = \frac{1}{2}. \]

12. 0° and 90°.

13. (a) \[ \int \vec{B} \cdot d\vec{l} = \mu_0 I = 2\mu_0 \text{Tm} \]
(b) zero

22. (i) \( a = g \) because the induced emf set up in the coil does not produce any current and hence no opposition to the falling bar magnet.

(ii) \( a < g \) because of the opposite effect caused by induced current.

23. Current at resonance \( I = \frac{V}{R} \).
\[ \therefore \text{ Voltage across inductor } V_L = I \omega L = \frac{V}{R} (2\pi \omega) L. \]

24. A.C. ammeter works on the principle of heating effect \( H \propto I^2 \).
25. Brightness of bulb depends on current, \( P \propto I^2 \) and

\[ I = \frac{V}{Z} \quad \text{where} \quad Z = \sqrt{X_C^2 + R^2} \]

and

\[ X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \]

\[ X_C \propto \frac{1}{C}, \quad \text{when mica sheet is introduced} \quad \text{capacitance} \ C \text{ increases} \]

\[ C = \left( \frac{K \varepsilon_0 A}{d} \right), \]

\( X_C \) decreases, current increases and therefore brightness increases.

26. Current \( I = \frac{\varepsilon}{R} = \)

In coil \( P \), \( I_1 = \frac{E_1}{R} = \frac{Bvb}{R} \)

In coil \( Q \), \( I_2 = \frac{E_2}{R} = \frac{Bvl}{R} \quad \Rightarrow \quad I_1/I_2 = b/l \).

27. em energy is conserved

\[ \mu_{E}(\text{max}) = \mu_{B}(\text{max}) \]

\[ \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} LI^2 \]

\( I = 637 \text{ mA} \)

28. \( 10^{-6} \text{ F} \).

40. No current is induced in coil \( A \) since angle is 90.

ANSWER FOR NUMERICALS

15. Force experienced by current carrying conductor in magnetic field.

\[ F = IL \times \mathbf{B} = ILB \sin \theta \]

Hence, force permit length, \( f = \frac{F}{L}ILB \sin 30^\circ \)
16. (a) Current sensitivity, \( \frac{\phi}{I} = \frac{\text{NBA}}{K} \)

\[
\text{Ratio of current Sensitivity} = \left( \frac{N_1B_1A_1}{K} \right) / \left( \frac{N_2B_2A_2}{K} \right) = \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = \frac{5}{7}
\]

(b) Voltage sensitivity, \( \frac{\phi}{V} = \frac{\text{NBA}}{kR} \)

\[
\text{Ratio of voltage sensitivity} = \left( \frac{N_1B_1A_1}{kR_1} \right) / \left( \frac{N_2B_2A_2}{kR_2} \right) = \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1
\]

17. (a) For equilibrium, the dipole moment should be parallel or auto parallel to B. Hence, AB\(_1\) and AB\(_2\) are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : AB\(_5\) and AB\(_6\) (ii) for unstable equilibrium, the dipole moment should be anti parallel examples : AB\(_3\) and AB\(_4\)

(c) Potential energy is minimum when angle between M and B is 0°, i.e, \( U = -MB \) Example : AB\(_6\)

18. (a) Total resistance, \( R_G + 3 = 63\Omega \).

Hence, \( I = \frac{3V}{63\Omega} = 0.048A \)

(b) Resistance of the galvanometer as ammeter is

\[
\frac{R_GfS}{R_GfS} = \frac{60\Omega \times 0.02\Omega}{(60 + 0.02)} = 0.02\Omega
\]

Total resistance \( R = 0.02\Omega + 3\Omega = 3.02\Omega \)

Hence, \( I = \frac{3}{302} = 0.99A \)
For the ideal ammeter, resistance is zero, the current, \( I = \frac{3}{3} = 1.00 \text{A} \)

19. From Biot-Savart’s Law, \( \mathbf{d}\mathbf{B} = \mathbf{I}d\mathbf{l}\sin\theta / r^2 \)

\[ dl = \Delta x = 1 \text{ cm} = 10^{-2} \text{m}, I = 10\text{A}, r = y = 0.5\text{m} \]

\[ \mu_0/4\pi = 10^{-7} \text{ Tm/A}, \theta = 90^\circ \text{ so } \sin\theta = 1 \]

\[ \mathbf{d}\mathbf{B} = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8} \text{ T along } z \text{ axis} \]

20. Force experienced by wire \( F = BIl \) (due to map field)

The force due to gravity, \( F_g = mg \)

\[ mg = BIl \Rightarrow B = \frac{mg}{Il} = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657 \text{T} \]

[Earth’s magnetic field \( 4 \times 10^{-5} \text{T} \) is negligible]

**NUMERICALS**

25. (i) \( V_0 = 110 \text{ volt} \)

(ii) \( V_{av} = \frac{2V_0}{\pi} = \frac{2 \times 110 \times 7}{22} = 70 \text{ volt} \)

26. Induced emf \( \varepsilon = -N \frac{d\phi}{dt} = -25 \frac{(1 - 6) \times 10^{-3}}{.5} = 0.25 \text{ volt} \)

27. (i) Reactance \( X_L = \omega L = 300 \times 4 \times 10^{-3} = 1.2 \Omega \)

(ii) Peak Voltage \( V_0 = i_0X_L = 12 \times 1.2 = 14.4 \text{ volt} \)

28. In ideal transformer \( P_{in} = P_{0} \)

\[ \frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \]

\[ N_S = \left( \frac{V_S}{V_P} \right) N_P = \frac{240}{2400} \times 4000 = 400 \]
29. Induced current \( I = \frac{\varepsilon}{R} \)

where \( \varepsilon = -\frac{d\phi}{dt} = -10t + 4 \)

\( \varepsilon = -10(15) + 4 = -146 \) mV

where \( \phi = 5t^2 - 4t + 2 \) and \( R = 8 \) \( \Omega \). \( \therefore I = -\frac{146}{8} = -0.18 \) A

30. When \( V \) and \( I \) in phase

\[ X_L = X_C, \quad \nu = \frac{1}{2\pi \sqrt{LC}} \]

\[ C = \frac{1}{4\pi^2 \nu^2 L} = \frac{1}{4\pi^2 \times 50 \times 50 \times \frac{4}{\pi^2}} = 2.5 \times 10^{-5} = 25 \mu F. \]

31. Current in the circuit \( I = \frac{V}{Z} \)

When

\[ Z = \sqrt{X_C^2 + \frac{R^2}{\nu^2}}, \quad X_C = \frac{1}{\omega C} = \frac{1}{2\pi \nu C} \]

Then total voltage across capacitor and resistor

\[ V_C = i X_C, \quad V_R = iR. \]

32. 

\[ \phi = Blb \]

\[ \varepsilon = Bvb \]

\[ P = \frac{\varepsilon^2}{R} = \frac{B^2 v^2 b^2}{R} \]
33. (i) Frequency of current oscillations
\[ \nu = \frac{1}{2\pi\sqrt{LC}} \]

(ii) Frequency of electrical energy oscillation \( \nu_c = 2\nu \)

(iii) Maximum current in the circuit \( I_0 = \frac{q_0}{\sqrt{LC}} \)

(iv) Magnetic energy in the inductor when charge on capacitor is 4mC.
\[ U_L = U - U_C = \frac{1}{2} \frac{q_0^2}{C} - \frac{1}{2} \frac{q^2}{C} = \frac{q_0^2 - q^2}{2C} \]
Here \( q_0 = 5\text{mC}; \quad q = 4\text{mC} \)

34. Current in the circuit:

(i) \( I = \frac{V}{Z} \), where \( Z = \sqrt{X_L^2 + R^2} \)

(ii) RMS voltage across \( L \) and \( R \)
\[ V_L = I \cdot X_L; \quad V_R = IR \]

(iii) \( (V_L + V_R) > V \) because \( V_L \) and \( V_R \) are not in same phase.
UNIT V & UNIT VI

ELECTROMAGNETIC WAVES AND OPTICS

KEY POINTS

- EM waves are produced by accelerated (only by the change in speed) charged particles.
- $\vec{E}$ and $\vec{B}$ vectors oscillate with the frequency of oscillating charged particles.
- Properties of em waves:
  1. Transverse nature
  2. Can travel though vacuum.
  3. $E_0/B_0 = E/B = \nu$  
  4. Speed = $3 \times 10^8$ m/s in vacuum.
  5. In any medium $\nu = \frac{1}{\sqrt{\mu \varepsilon}}$
     Where $\mu = \mu_r \mu_0$, $\varepsilon = \varepsilon_r \varepsilon_0$
     $\sqrt{\varepsilon_r} = n$ refractive index of medium
     Also $\nu = c/n$
  6. Wave intensity equals average of Poynting vector $I = \left| \ave{\mathbf{S}} \right| = \frac{B_0 E_0}{2 \mu_0}$
  7. Average electric and average magnetic energy densities are equal.
In an em spectrum, different waves have different frequency and wavelengths.

- Penetration power of em waves depends on frequency. Higher, the frequency larger the penetration power.

- Wavelength $\lambda$ and frequency $\nu$ are related with each other $\nu = \lambda \nu$. Here $\nu$ is the wave velocity.

A wave travelling along $+x$ axis is represented by

$$E_y = E_{oy} \cos(\omega t - kx)$$
$$B_z = B_{oz} \cos(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi \nu \quad \frac{\omega}{k} = \lambda \nu = \nu \text{ wave speed}$$

$$k = \frac{2\pi}{\lambda} = 2\pi \frac{\nu}{\lambda}$$

$\nu \rightarrow \text{frequency}$

$$\frac{\nu}{\lambda} = \frac{1}{\nu} \text{ wave number.}$$
<table>
<thead>
<tr>
<th>Physical Quantity</th>
<th>Formulae</th>
<th>SI Unit</th>
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<tr>
<td>Ray Optics</td>
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<tr>
<td>Refractive index of medium ‘b’ w.r.t. ‘a’</td>
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<td>Refractive index of medium w.r.t. vacuum (or air)</td>
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<td>Refractive index in terms of Real and Apparent Depths</td>
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<td>Relation between refractive index of medium and critical angle</td>
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<td>Lateral shift</td>
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<td>Spherical refracting surface</td>
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<td>Lens Maker’s formula</td>
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<td>Magnification</td>
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</tbody>
</table>
Combination of thin lenses

Refraction in a prism

Cauchy’s formula (Relation b/w refractive index and λ)

Rayleigh’s criteria of scattering

**Compound Microscope**

Magnification

When image is formed at D

When image is formed at infinity

The limit of resolution

Numerical aperture

\[ P = P_1 + P_2 \quad \text{and} \quad m = m_1 \times m_2 \]

\[ \delta + A = i + e \]

\[ \text{Amount of scattering} \]

\[ \mu \sin \theta \]
The resolving power

**Astronomical Telescope**
Magnification

(a) When image is formed at infinity

\[ m = \frac{f_1}{f_2} \]

(b) When image is formed at \( D \)

Length of tube

\[ L = f_o + f_e \]

Angular limit of resolution

The resolving power

**Reflection Telescope**

Magnifying power

Brightness

**Young's Double Slit Experiment**

Intensity of light

**Wave Optics**
**Constructive Interference**

Phase difference

\[ \phi = 2n\pi \]

Path difference

\[ x = n\lambda \]

**Destructive Interference**

Phase difference

\[ \phi = (2n + 1)\pi \]

Path difference

\[ x = (2n + 1)\frac{\lambda}{2} \]

**Ratio of light intensity at maxima and minima**

\[ \left( \frac{I_{max}}{I_{min}} \right) = \left( \frac{2n + 1}{2n + 2} \right) \]

**Path difference**

\[ \beta = y_n - y_{n-1} = \lambda \frac{D}{d} \]

**Fringe width (For Dark and Bright Fringes)**

\[ \Delta = \frac{\lambda}{D} \]

The angular width of each fringe

**Single Slit Diffraction**

Central maximum

\[ \text{angle up to which central} \]

maximum extends on both sides from centre.

Angular width = 2\(\theta_1\)

\[ \sin \theta_1 = \frac{n\lambda}{a} \]

For \(n^{th}\) secondary minima

For \(n^{th}\) secondary maxima

Fringe width (For Dark and Bright Fringes)

\[ \Delta = \frac{a}{\lambda} \]
Brewster's Law

Law of Malus

If two coherent beams have different intensities \( I \) and \( I_2 \), the resulting minima and maxima will be

If two plane mirrors are kept at an angle \( \theta \) w.r.t. each other and an object is kept between them, then the number of images formed.
UNIT V & UNIT VI

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Every EM wave has certain frequency. Name two parameters of an em wave that oscillate with this frequency.

Ans. Electric field vector and Magnetic field vector.

2. What is the phase difference between electric and magnetic field vectors in an em wave?

Ans. \( \frac{\pi}{2} \)

3. Name em radiations used for detecting fake currency notes.

Ans. U.V. Radiation.

4. Give any two uses of microwaves.


5. Name the phenomenon which justifies the transverse nature of em waves.

Ans. Polarization.

6. Arrange the following em waves in descending order of wavelengths: \( \gamma \) ray, microwaves UV radiations.

Ans. Microwave, U.V radiation, \( \gamma \)-rays

7. Which component \( \vec{E} \) or \( \vec{B} \) of an em wave is responsible for visible effect?

Ans. \( \vec{E} \)
8. Write expression for speed of em waves in a medium of electrical permittivity \( \varepsilon \) and magnetic permeability \( \mu \).

\[ V = \frac{1}{\sqrt{\mu \varepsilon}} \]

Ans.

9. Which of the following has longest penetration power?
   UV radiation, X-ray, Microwaves.

Ans. X-rays

10. Which of the following has least frequency?
    IR radiations, visible radiation, radio waves.

Ans. Radiowaves.

11. Which physical quantity is the same for microwaves of wavelength 1 mm and UV radiations of 1600 A° in vacuum?

Ans. Speed.

12. Name two physical quantities which are imparted by an em wave to a surface on which it falls.

Ans. Energy and pressure.

13. Name the physical quantity with unit same as that of \( \varepsilon_0 \cdot \frac{d \phi_e}{dt} \) where \( \phi_e \rightarrow \text{electric flux.} \)

Ans. Current.

14. What is the source of energy associated with propagating em waves?

Ans. Oscillating/accelerated charge.

15. What is the wavelength range of em waves that were produced and observed by J.C. Bose?

Ans. Milimeter

16. Name the device used for producing microwaves.

Ans. Klystron valve and magnetron valve
17. Relative electric permittivity of a medium is $\varepsilon$ and relative permeability is close to unity. What is the speed of em waves in the medium.

**Ans.**

$$V = \frac{1}{\sqrt{\mu \varepsilon}} = \frac{1}{\sqrt{\left(\mu_0 \mu_r\right) \left(\varepsilon_0 \varepsilon_r\right)}} = \frac{1}{\sqrt{\mu_0 \varepsilon_0 \mu_r \varepsilon_r}}$$

$$V = \frac{C}{\sqrt{9}} = \frac{C}{3}$$

18. Identify the part of the electromagnetic spectrum to which the following wavelengths belong:

(i) $10^{-1}$ m (ii) $10^{-12}$ m

**Ans.** Microwave, $\gamma$-ray

19. Name the part of the electromagnetic spectrum of wavelength $10^{-2}$ m and mention its one application.

**Ans.** Microwave, microwave oven.

20. Which of the following, if any, can act as a source of electromagnetic waves?

(i) A charge moving with a constant velocity.

(ii) A charge moving in a circular orbit.

(iii) A charge at rest.

**Ans.** A charge moving in a circular orbit

21. Mention the pair of space and time varying E and B fields which would generate a plane em wave travelling in Z-direction.

**Ans.** $E_x$ and $B_y$

22. The charging current for a capacitor is 0.2A. What is the displacement current?

**Ans.** Remain same

23. Give the ratio of Velocities of light waves of wavelengths 4000Å and 8000Å in Vaccum.
24. Which physical quantity, if any, has the same value for waves belonging to the different parts of the electromagnetic spectrum?

Ans. Speed

25. Write the value of angle of reflection for a ray of light falling normally on a mirror.

Ans. Zero.

26. How does the dispersive power of glass prism change when it is dipped in water?

Ans. Decreases.

27. Light falls from glass to air. Find the angle of incidence for which the angle of deviation is 90° if refractive index of glass is $\sqrt{2}$.

Ans. 45°

28. Name the phenomenon due to which one cannot see through fog.

Ans. Scattering

29. What is the ratio of $\sin i$ and $\sin r$ in terms of velocities in the given figure.

Ans. $\frac{v_1}{v_2}$

30. What is the shape of fringes in Young's double slit experiment?

Ans. Hyperbolic.

31. An equiconcave lens of focal length 15 cm is cut into two equal halves along dotted line as shown in figure. What will be the new focal length of each half.
Ans. 30 cm.

32. For the same angle of the incidence the angle of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum?

Ans. A

33. What is the phase difference between two points on a cylindrical wave front?

Ans. Zero.

34. What is the ‘power’ of plane glass plate.

Ans. Zero.

35. How does focal length of lens change when red light incident on it is replaced by violet light?

Ans. Decreases, $\lambda_r > \lambda_v$

36. Lower half of the concave mirror is painted black. What effect will this have on the image of an object placed in front of the mirror?

Ans. The intensity of the image will be reduced (in this case half) but no change in size of the image.

37. An air bubble is formed inside water. Does it act as converging lens or a diverging lens?

Ans. Diverging lens

38. A water tank is 4 meter deep. A candle flame is kept 6 meter above the level. $\mu$ for water is 4/3. Where will the image of the candle be formed?

Ans. 6 m. below the water level.
1. Give one use of each of the following (i) UV ray (ii) γ-ray

2. Represent EM waves propagating along the x-axis. In which electric and magnetic fields are along y-axis and z-axis respectively.

3. State the principles of production of EM waves. An EM wave of wavelength $\lambda$ goes from vacuum to a medium of refractive index $n$. What will be the frequency of wave in the medium?

4. An EM wave has amplitude of electric field $E_0$ and amplitude of magnetic field is $B_0$ the electric field at some instant become $\frac{3}{4}E_0$. What will be the magnetic field at this instant? (Wave is travelling in vacuum).

5. State two applications of infrared radiations.

6. State two applications of ultraviolet radiations.

7. State two applications of x-rays.

8. Show that the average energy density of the electric field $\bar{E}$ equals the average energy density of the magnetic fields $\bar{B}$?

9. A near sighted person can clearly see objects up to a distance of 1.5m. Calculate power of the concave lens of focal length 1.5 m for the remedy of this defect. ($P = -0.67D$)

10. A person can adjust the power of his eye lens between 50D and 60D. His far point is infinity. Find the distance between retina and eye lens.

11. Calculate the value of $\theta$, for which light incident normally on face AB grazes along the face BC.
12. Name any two characteristics of light which do not change on polarisation.

13. Complete the path of light with correct value of angle of emergence.

\[ \mu = 1.5 \]

14. Define diffraction. What should be the order of the size of the aperture to observe diffraction.

15. Show that maximum intensity in interference pattern is four times the intensity due to each slit if amplitude of light emerging from slits is same.

16. Two poles-one 4m high and the other is 4.5 m high are situated at distance 40m and 50m respectively from an eye. Which pole will appear taller?

17. \( S_1 \) and \( S_2 \) are two sources of light separated by a distance \( d \). A detector can move along \( S_2P \) perpendicular to \( S_1S_2 \). What should be the minimum and maximum path difference at the detector?

\[ S_2 \]

\[ d \times \]

\[ S_1 \]

\[ P \]

18. If a jogger runs with constant speed towards a vehicle, how fast does the image of the jogger appear to move in the rear view mirror when

(i) the vehicle is stationery

(ii) the vehicle is moving with constant speed.

**Ans.** The speed of the image of the jogger appears to increase substantially, though jogger is moving with constant speed.

Similar phenomenon is observed when vehicle is in motion.

19. A person looking at a mesh of crossed wire is able to see the vertical wire more distinctly than the horizontal wire. Which defect he is suffering from? How can this defect be corrected?
20. Is optical density same as mass density? Give an example.

Ans. Optical density is the ratio of the speed of light in two media whereas mass density e.g. mass per unit volume of a substance. e.g. Mass density of turpentine in less than that of water but its optical density is higher.

21. When does (i) a plane mirror and (ii) a convex mirror produce real image of objects.

Ans. Plane and convex mirror produce real image when the object is virtual that is rays converging to a point behind the mirror are reflected to a point on a screen.

22. A virtual image cannot be caught on a screen. Then how do we see it?

Ans. The image is virtual when reflected or refracted rays divergent, these are converged on to the retina by convex lens of eye, as the virtual image serves as the object.

23. Draw a diagram to show the advance sunrise and delayed sunset due to atmospheric refraction.

24. Define critical angle for total internal reflection. Obtain an expression for refractive index of the medium in terms of critical angle.

25. The image of a small bulb fixed on the wall of a room is to be obtained on the opposite wall 's' m away by means of a large convex lens. What is the maximum possible local length of the lens required.

Ans. For fixed distance 's' between object and screen, for the lens equation to give real solution for \( u = v = 2f \), 'f' should not be greater than \( 4f = s \).

\[
\therefore f = \frac{s}{4}
\]

26. The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass. In what sense then does magnifying glass produce angular magnification?

Ans. The absolute image size is bigger than object size, the magnifier helps in bringing the object closer to the eye and hence it has larger angular size than the same object at 25 cm, thus angular magnification is achieved.

27. Obtain relation between focal length and radius of curvature of (i) concave mirror (ii) convex mirror using proper ray diagram.
28. Two independent light sources cannot act as coherent sources. Why?

29. How is a wave front different from a ray? Draw the geometrical shape of the wavefronts when.
   (i) light diverges from a point source,
   (ii) light emerges out of convex lens when a point source is placed at its focus.

30. What two main changes in diffraction pattern of single slit will you observe when the monochromatic source of light is replaced by a source of white light.

31. You are provided with four convex lenses of focal length 1cm, 3cm, 10cm and 100 cm. Which two would you prefer for a microscope and which two for a telescope.

32. Give reasons for the following
   (i) Sun looks reddish at sunset
   (ii) clouds are generally white

33. Using Huygens Principle draw ray diagram for the following
   (i) Refraction of a plane wave front incident on a rarer medium
   (ii) Refraction of a plane wave front incident on a denser medium.

34. Water (refractuive index µ) is poured into a concave mirror of radius of curvature 'R' up to a height h as shown in figure. What should be the value of x so that the image of object 'O' is formed on itself?

35. A point source S is placed midway between two concave mirrors having equal focal length f as shown in Figure. Find the value of d for which only one image is formed.
36. A thin double convex lens of focal length \( f \) is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii).

37. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container. \( (\mu = 4/3) \)?

38. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle, of prism A = 60° and \( \mu \) of material of prism is \( \sqrt{3} \) then find angle \( \theta \).

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**SHORT ANSWER QUESTIONS (3 Marks)**

1. Name EM radiations used (i) in the treatment of cancer.
   (ii) For detecting flaw in pipes carrying oil.
   (iii) In sterilizing surgical instruments.
2. How would you experimentally show that EM waves are transverse in nature?

3. List any three properties of EM waves.

4. Find the wavelength of electromagnetic waves of frequency $5 \times 10^{19}$ Hz in free space. Give its two applications.

5. Using mirror formula show that virtual image produced by a convex mirror is always smaller in size and is located between the focus and the pole.

6. Obtain the formula for combined focal length of two thin lenses in contact, taking one divergent and the other convergent.

7. Derive snell's law on the basis of Huygen's wave theory.

8. A microscope is focussed on a dot at the bottom of the beaker. Some oil is poured into the beaker to a height of $b$ cm and it is found that microscope has to raise through vertical distance of $a$ cm to bring the dot again into focus. Express refractive index of oil is terms of $a$ and $b$.


10. A plane wave front is incident on (i) a prism (ii) A convex lens (iii) a concave mirror. Draw the emergent wavefront in each case.

11. Explain with reason, how the resolving power of a compound microscope will change when (i) frequency of the incident light on the objective lens is increased. (ii) focal length of the objective lens is increased. (iii) aperture of objective lens is increased.

12. Derive Mirror formula for a concave mirror forming real Image.

13. Two narrow slits are illuminated by a single monochromatic sources.
   
   (a) Draw the intensity pattern and name the phenomenon
   
   (b) One of the slits is now completely covered. Draw the intensity pattern now obtained and name the phenomenon.

14. Explain briefly (i) sparkling of diamond (ii) use of optical fibre in communication.

15. Using appropriate ray diagram obtain relation for refractive index of water in terms of real and apparent depth.
16. Complete the ray diagram in the following figure where, \( n_1 \) is refractive index of medium and \( n_2 \) is refractive index of material of lens.

\[ n_1 < n_2 \] (i)
\[ n_1 = n_2 \] (ii)
\[ n_1 > n_2 \] (iii)

\[ n_1 < n_2 \] (iv)
\[ n_1 = n_2 \] (v)
\[ n_1 > n_2 \] (vi)

17. A converging beam of light is intercepted by a slab of thickness \( t \) and refractive index \( \mu \). By what distance will the convergence point be shifted? Illustrate the answer.

\[ x = \left( 1 - \frac{1}{\mu} \right) t \]

18. In double slit experiment \( SS_2 \) is greater than \( SS_1 \) by 0.25\( \lambda \). Calculate the path difference between two interfering beam from \( S_1 \) and \( S_2 \) for minima and maxima on the point \( P \) as shown in Figure.
LONG ANSWER QUESTIONS (5 MARKS)

1. With the help of ray diagram explain the phenomenon of total internal reflection. Obtain the relation between critical angle and refractive indices of two media. Draw ray diagram to show how right angled isosceles prism can be used to:
   (i) Deviate the ray through 180°.
   (ii) Deviate the ray through 90°.
   (iii) Invert the ray.
2. Draw a labelled ray diagram of a compound microscope and explain its working. Derive an expression for its magnifying power.
3. Diagrammatically show the phenomenon of refraction through a prism. Define angle of deviation in this case. Hence for a small angle of incidence derive the relation \( \delta = (\mu - 1) A \).
4. Name any three optical defects of eye. Show by ray diagram:
   (i) Myopic eye and corrected myopic eye.
   (ii) Hypermetropic eye and corrected hypermetropic eye.
5. Define diffraction. Deduce an expression for fringe width of the central maxima of the diffraction pattern, produced by single slit illuminated with monochromatic light source.
6. What is polarisation? How can we detect polarised light? State Brewster's Law and deduce the expression for polarising angle.
7. Derive lens maker formula for a thin converging lens.
8. Derive lens formula \( \frac{1}{f} = \frac{1}{u} - \frac{1}{v} \) for
   (a) a convex lens,
   (b) a concave lens.
9. Describe an astronomical telescope and derive an expression for its magnifying power using a labelled ray diagram.
10. Draw a graph to show the angle of deviation with the angle of incidence i for a monochromatic ray of light passing through a prism of refracting
angle A. Deduce the relation

\[ \mu = \frac{\sin \left( A + \delta_m \right) / 2}{\sin A / 2} \]

11. State the condition under which the phenomenon of diffraction of light takes place. Derive an expression for the width of the central maximum due to diffraction of light at a single slit. Also draw the intensity pattern with angular position.

**NUMERICALS**

1. The refractive index of medium is 1.5. A beam of light of wavelength 6000 \( \text{Å} \) enters in the medium from air. Find wavelength and frequency of light in the medium.

2. An EM wave is travelling in vaccum. Amplitude of the electric field vector is \( 5 \times 10^4 \) V/m. Calculate amplitude of magnetic field vector.

3. Suppose the electric field amplitude of an em wave is \( E_0 = 120 \text{ NC}^{-1} \) and that its frequency is \( \nu = 50.0 \text{ MHz} \).
   
   (a) Determine \( B_0, \omega, \kappa \) and \( \lambda \). (b) Find expressions for E and B.

4. A radio can tune into any station of frequency band 7.5 MHz to 10 MHz. Find the corresponding wave length range.

5. The amplitude of the magnetic field vector of an electromagnetic wave travelling in vacuum is 2.4mT. Frequency of the wave is 16 MHz. Find:
   
   (i) Amplitude of electric field vector and
   (ii) Wavelength of the wave.

6. An EM wave travelling through a medium has electric field vector.
   \[ E_y = 4 \times 10^5 \cos \left( 3.14 \times 10^8 t - 1.57 x \right) \text{ N/C}. \] Here \( x \) is in \( m \) and \( t \) in \( s \).

   Then find:
   
   (i) Wavelength
   (ii) Frequency
   (iii) Direction of propagation
   (iv) Speed of wave
   (v) Refractive index of medium
   (vi) Amplitude of magnetic field vector.
7. An object of length 2.5 cm is placed at a distance of 1.5f from a concave mirror where f is the focal length of the mirror. The length of object is perpendicular to principal axis. Find the size of image. Is the image erect or inverted?

8. Find the size of image formed in the situation shown in figure. 

[5 cm, Inverted]

9. A ray of light passes through an equilateral prism in such a manner that the angle of incidence is equal to angle of emergence and each of these angles is equal to 3/4 of angle of prism. Find angle of deviation. 

[Ans. : 30°]

10. Critical angle for a certain wavelength of light in glass is 30°. Calculate the polarising angle and the angle of refraction in glass corresponding to this. 

[\[ \mu_p = \tan^{-1} 2 \]]

11. A light ray passes from air into a liquid as shown in figure. Find refractive index of liquid. 

[\[ \mu_{\text{Liquid}} = \frac{\sqrt{3}}{2} \]]

12. At what angle with the water surface does fish in figure see the setting sun?

[At critical angle, fish will see the sun.]

13. In the following diagram, find the focal length of lens L₂. 

[40 cm]
14. A hypermetropic person whose near point is at 100 cm wants to read a book. Find the nature and power of the lens needed.

**Ans.**

\[ v = -100 \text{ cm} \]

\[ u = -25 \text{ cm} \]

\[ \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{-1}{100} + \frac{1}{25} = \frac{3}{100} \]

\[ f = \frac{100}{3} = \pm 33.3 \text{ cm} \] so a converging lens

\[ \rho = \frac{100}{f} = 3 \text{ dioptre} \]

15. For a man shortest distance of distinct vision is 20 cm. What will be the type and power of lens which would enable him to read a book at a distance of 60 cm?

**Ans.**

\[ v = -20 \text{ cm} \]

\[ u = -60 \text{ cm} \]

\[ \frac{1}{f} = \frac{-1}{20} + \frac{1}{60} = \frac{-2}{60} = -\frac{1}{30} \]

\[ f = -30 \text{ cm}. \] So a diverging lens

\[ \rho = \frac{100}{-30} = -3.3 \text{ dioptre} \]

16. Using the data given below, state which two of the given lenses will be preferred to construct a (i) telescope (ii) Microscope. Also indicate which is to be used as objective and as eyepiece in each case.
<table>
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<tr>
<th>Lenses</th>
<th>Power (p)</th>
<th>Apetune (A)</th>
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<tbody>
<tr>
<td>L_1</td>
<td>6 D</td>
<td>1 cm</td>
</tr>
<tr>
<td>L_2</td>
<td>3 D</td>
<td>8 cm</td>
</tr>
<tr>
<td>L_3</td>
<td>10 D</td>
<td>1 cm</td>
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**Ans.**: For telescope, less L_2 is chosen as objective as it aperture is largest, L_3 is chosen as eyepiece as its focal length is smaller.

For microscope lens L_3 is chosen as objective because of its small focal length and lens L_1, serve as eye piece because its focal length is not large.

17. Two thin converging lens of focal lengths 15 cm and 30 cm respectively are held in contact with each other. Calculate power and focal length of the combination.

\[
\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}
\]

F = 10 cm

P = 10 D.

**VALUE BASED QUESTIONS**

1. Lot of people like TV program CID. In this program there is some murder mystery which has to be solved by the team of CID people. Every member of CID team work with full dedication. They collect information from everywhere which can lead to correct conclusion. They use ultraviolet rays in forensic laboratory. Some people got surprised to see the advantage of ultraviolet rays because they only know that ultraviolet rays coming from SUN are harmful.

   (i) What values were displayed by CID team ?

   (ii) Give the use of Ultraviolet rays in forensic laboratory.

2. A child is observing a thin film such as a layer of oil on water show beautiful colours when illuminated by white light. He feels happy and
surprised to see this. His teacher explains him the reason behind it. The child then gives an example of spreading of kerosene oil on water to prevent malaria and dengue.

(i) What value was displayed by his teacher?
(ii) Name the phenomenon involved?

3. Ravi is using yellow light in a single slit diffraction experiment with slit width of 0.6 mm. The teacher has replaces yellow light by x-rays. Now he is not able to observe the diffraction pattern. He feels sad. Again the teacher replaces x-rays by yellow light and the diffraction pattern appears again.

(i) Which value is displayed by the teacher?
(ii) Give the necessary condition for the diffraction.

**ANSWER**

1. (i) Value—appreciation of Nature
(ii) Interference of light.

2. (i) Motivation
(ii) As the wavelength of x-rays is much smaller than that of yellow light, so the diffraction pattern is lost when the yellow light is replaced by x-rays.

**2 MARK QUESTIONS**

10. For point is infinity so in this case focal length is maximum. Hence power is minimum.

11. \( \theta = \sin^{-1} \left( \frac{8}{9} \right) \)

12. Speed and frequency

13. \( \sin^{-1} \left( \frac{3}{4} \right) \)

14. 4 m pole

15. Minimum path difference is zero (when p is at infinity)

   Maximum path difference = \( d \).
19. Astigmatism – Cylindrical lens

29. A wavefront is a surface obtained by joining all points vibrating in the same phase.

A ray is a line drawn perpendicular to the wavefront in the direction of propagation of light.

(i) Spherical

(ii) Plane

30. (i) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light. As fringe width \( \alpha \lambda \), \( \therefore \) red fringe with higher wavelength is wider than violet fringe with smaller wavelength.

(ii) In higher order spectra, the dispersion is more and it causes overlapping of different colours.

31. \( f_0 = 1 \) cm and \( f_e = 3 \) cm for Microscope and \( f_0 = 100 \) cm and \( f_e = 1 \) cm for a Telescope

33. N.C.E.R.T. Fig. 10.5; Fig. 10.4.

34. Distance of object from \( p \) should be equal to radius of curvature.

\[
R = \mu x + h \quad \Rightarrow \quad x = \frac{R - h}{\mu}.
\]

35. Distance between mirror will be \( 2f \) or \( 4f \).

36. (i) Focal length of combination is infinite.

(ii) \( f/2 \)

27.

---

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Real depth

$\frac{x}{\text{Apparent depth}} = \mu$

$\frac{x}{21 - x} = \frac{4}{3} \Rightarrow x = 12 \text{ cm.}$

38. This is a case of min. deviation $\theta = 60^\circ$.

### 3 MARKS QUESTIONS

11. R.P. of a compound Microscope

$$\frac{2\mu \sin \theta}{\lambda} = 2\mu \sin \frac{\nu}{c}$$

(i) When frequency $\nu$ increases, R.P. increases

(ii) R.P. does not change with change in focal length of objective lens.

(iii) When aperture increases, $\theta$ increases $\therefore$ R.P. increases.

17. $x = \left(1 - \frac{1}{\mu}\right) t$

18. Path diff. : $(SS_2 + S_2P) - (SS_1 + S_1P) = (SS_2 - SS_1) + (S_2P - S_1P) = (0.25\lambda + S_2P - S_1P)$

For maxima, path diff. = $n\lambda$.

So $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$.

For minima, path diff. = $(2n + 1)\frac{\lambda}{2}$

So $S_2P - S_1P = (2n + 0.5) \lambda/2$. 
UNIT VII

DUAL NATURE OF MATTER
AND RADIATION

KEY POINTS

- Light consists of individual photons whose energies are proportional to their frequencies.
- A photon is a quantum of electromagnetic energy:
  \[ E = h \nu = \frac{hc}{\lambda} \]
  Momentum of a photon:
  \[ \frac{h \nu}{c} = \frac{h}{\lambda} \]
  Dynamic mass of photon:
  \[ \frac{h \nu}{c^2} = \frac{h}{c\lambda} \]
  Rest mass of a photon is zero.
- *Photoelectric effect*: Photon of incident light energy interacts with a single electron and if energy of photon is equal to or greater than work function, the electron is emitted.
- Max. Kinetic energy of emitted electron =\( h(\nu - \nu_0) \) Here \( \nu_0 \) is the frequency below which no photoelectron is emitted and is called threshold frequency.
- A moving body behaves in a certain way as though it has a wave nature having wavelength,
  \[ \lambda = \frac{h}{mv} \]
Gieger-Marsden $\alpha$-scattering experiment established the existence of nucleus in an atom.

Bohr’s atomic model

(i) Electrons revolve round the nucleus in certain fixed orbits called stationary orbits.

(ii) In stationary orbits, the angular momentum of electron is integral multiple of $\hbar/2\pi$.

(iii) While revolving in stationary orbits, electrons do not radiate energy. The energy is emitted (or absorbed) when electrons jump from higher to lower energy orbits. (or lower to higher energy orbits). The frequency of the emitted radiation is given by $h\nu = E_f - E_i$. An atom can absorb radiations of only those frequencies that it is capable of emitting.

As a result of the quantisation condition of angular momentum, the electron orbits the nucleus in circular paths of specific radii. For a hydrogen atom it is given by.

$$r_n = \left( \frac{n^2}{m} \right) \left( \frac{h}{2\pi} \right)^2 \frac{4\pi\varepsilon_0}{e^2} \Rightarrow r_n \propto n^2$$

The total energy is also quantised: $E_n = \frac{-me^4}{8n^2\varepsilon_0\hbar^2} = -13.6 \text{ eV}/n^2$

The $n = 1$ state is called the ground state.

In hydrogen atom, the ground state energy is $-13.6 \text{ eV}$. 

de Broglie’s hypothesis that electron have a wavelength \( \lambda = \frac{h}{mv} \) gave an explanation for the Bohr’s quantised orbits.

- Neutrons and protons are bound in nucleus by short range strong nuclear force. Nuclear force does not distinguish between nucleons.

- The nuclear mass ‘M’ is always less than the total mass of its constituents. The difference in mass of a nucleus and its constituents is called the **mass defect**.

  \[ \Delta M = [Zm_p + (A - Z)m_n] - M \] and \( \Delta E_b = (\Delta M)c^2 \)

  The energy \( \Delta E_b \) represents the binding energy of the nucleus.

  For the mass number ranging from \( A = 30 \) to \( 170 \) the binding energy per nucleon is nearly constant at about \( 8\text{MeV} \) per nucleon.

- **Radioactive Decay Law** : The number of atoms of a radioactive sample disintegrating per second at any time is directly proportional to the number of atoms present at that time. Mathematically :

  \[
  \frac{dN}{dt} = -\lambda N \quad \text{or} \quad N(t) = N_0 e^{-\lambda t}
  \]

  where \( \lambda \) is called decay constant. It is defined as the reciprocal of the time during which the number of atoms of a radioactive substance decreases to 1 with their original number.

- Number of radioactive atoms \( N \) in a sample at any time \( t \) can be calculated using the formula.

  \[
  N = N_0 \left( \frac{1}{2} \right)^{t/T}
  \]

  Here \( N_0 \) = no. of atoms at time \( t = 0 \) and \( T \) is the half-life of the substance.

  **Half life** : The half life of a radioactive substance is defined as the time during which the number of atoms disintegrate to one half of its initial value.

  \[
  T_{1/2} = \frac{\ln 2}{\lambda} = \ln 2 \times \text{mean life}
  \]

  or \( 0.693/\lambda = \frac{0.693}{\lambda} \)
Here $\lambda = \text{decay constant} = \frac{1}{\text{mean life}}$.

- Radius $r$ of the nucleus of an atom is proportional to the cube root of its mass number thereby implying that the nuclear density is the same (Almost) for all substances/nuclei.

- $\alpha$-decay: $^{A^Z}X \rightarrow ^{A-4^Z}Y + ^{2}He + Q$

- $\beta$-decay: $^{A^Z}X \rightarrow ^{A^Z}Y + ^{0}e + \bar{\nu} + Q$

- $\gamma$-decay: When $\alpha$ or $\beta$-decay leave, the nucleus in excited state; the nucleus goes to lower energy state or ground state by the emission of $\gamma$-ray(s).
UNIT VII & VIII

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. What is the rest mass of photon?

Ans. Zero

2. A good mirror reflects 80% of light incident on it. Which of the following is correct?

   (a) Energy of each reflected photon decreases by 20%.
   (b) Total no. of reflected photons decreases by 20%. Justify your answer.

Ans. (b) Total no. of reflected photons decreases by 20%.

3. Why in a photocell the cathode is coated with alkali metals?

Ans. Lower work function, sensitive to visible light.

4. Name the phenomenon which shows quantum nature of electromagnetic radiation.

Ans. Photoelectric effect.

5. Write Einstein's photoelectric equations and specify each term.

Ans. \( \frac{1}{2} m_{\text{max}} v^2 = h\nu - h\nu_0 \)


6. Which of the following radiations is more effective for electron emission from the surface of sodium?

   (i) Microwave
   (ii) Infrared
(iii) Ultraviolet.

**Ans.** (iv) Ultraviolet (Maxi frequency)

7. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it?

**Ans.** Yes

8. Name any two phenomena which show the particle nature of radiation.

**Ans.** Photoelectric effect & Compton effect

9. The photoelectric cut off voltage in a certain photoelectric experiment is 1.5V. What is the max kinetic energy of photoelectrons emitted?

**Ans.**

\[ 1.5 \text{ e Joule} \]
\[ = 1.5 \times 1.6 \times 10^{-19} \text{ J} \]
\[ = 2.4 \times 10^{-19} \text{ J} \]

10. What is the de-Broglie wavelength of a 3 kg object moving with a speed of 2m/s?

**Ans.**

\[ \lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{3 \times 2} = 1.1 \times 10^{-34} \text{ m.} \]

11. What factors determine the maximum velocity of the photoelectrons from a surface?

**Ans.** (a) frequency of incident radiation
(b) work function of surface.

12. What is the stopping potential applied to a photocell, in which electrons with a maximum kinetic energy of 5.6 eV are emitted.

**Ans.** 5.6 V

13. Work functions of caesium and lead are 2.14 eV and 4.25 eV respectively. Which of the two has a higher threshold wavelength?

**Ans.** Work function, \( \phi_0 = h\nu_0 = \frac{hc}{\lambda_0} \) or \( \lambda_0 \propto \frac{1}{\phi_0} \)
Hence caesium has a higher threshold wavelength for photoelectric emission.

14. What is the de-Broglie wavelength of a neutron at absolute temperature \( T \) K ?

\[
\lambda = \frac{h}{\sqrt{2m_nE_k}} = \frac{h}{\sqrt{2m_n \frac{3}{2} k_B T}} = \frac{h}{\sqrt{3m_n k_B T}} \quad K_B \rightarrow \text{Boltzmann's Constant}
\]

15. Define atomic mass unit. Write its energy equivalent in MeV.

\[
1 \text{ a.m.u} = \frac{1}{12} \text{ of the mass of a carbon isotope}
\]

\[12^6\text{C}_\text{a} \quad 1 \text{ u} = 931 \text{ MeV}\]

16. What was the drawback of Rutherford's model of atom?

Ans. Rutherford's model of atom failed to explain the stability of atom.

17. What are the number of electrons and neutrons in singly ionised \( ^{236}_{92}\text{U} \) atom?

Ans. No. of electrons 92

No. of neutrons 236–92=144.

18. Name the series of hydrogen spectrum which has least wavelength.

Ans. Lyman series

19. Any two protons repel each other, then how is this possible for them to remain together in a nucleus.

Ans. Nuclear force b/w two protons is 100 times stronger than the electrostatic force.

20. Define radioactive decay constant.

Ans. The decay constant of radioactive substance is defined as the reciprocal of that time in which the number of atoms of substance becomes \( \frac{1}{e} \) th times the atoms present initially.
21. You are given reaction: \( ^1H_2 + ^1H_2 \rightarrow ^2He^4 + 24 \text{ MeV} \). What type of nuclear reaction is this?

**Ans.** Nuclear Fusion.

22. After losing two electrons, to which particle does a helium atom get transformed into?

**Ans.** \( \alpha \) particle.

23. Write two important inferences drawn from Gieger-Marsden’s \( \alpha \)-particle scattering experiment.

**Ans.**

(i) Positive charge is concentrated in the nucleus

(ii) Size of nucleus is very small in comparison to size of atom.

24. What will be the ratio of the radii of the nuclei of mass number \( A_1 \) and \( A_2 \)?

**Ans.** \[
\frac{R_1}{R_2} = \left( \frac{A_1}{A_2} \right)^{1/3}
\]

25. In nuclear reaction \( ^1H \rightarrow ^1n + ^3P_Q X \) find \( P, Q \) and hence identify \( X \).

**Ans.** \( P = 0, \ Q = 1 \)

\( X \) is \( ^1e^0 \) a positron.

26. Binding energies of neutron \( ^1H \) and \( \alpha \)-particle \( ^2He^4 \) are 1.25 MeV/nucleon and 7.2 MeV/nucleon respectively. Which nucleus is more stable?

**Ans.** Binding energy of \( ^2He^4 \) is more than deutron \( ^1H_2 \). Hence \( ^2He^4 \) is more stable.

27. \( \alpha \)-particles are incident on a thin gold foil. For what angle of deviation will the number of deflected \( \alpha \)-particles be minimum?

**Ans.** 180°

28. If the amount of a radioactive substance is increased four times then how many times will the number of atoms disintegrating per unit time be increased?

**Ans.** Four times \( \therefore R = -\lambda N \)
29. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom?

Ans. Max number of spectral lines = \( \frac{n(n - 1)}{2} = \frac{4 \times 3}{2} = 6 \)

30. Under what conditions of electronic transition will the emitted light be monochromatic?

Ans. Only fixed two orbits are involved and therefore single energy evolve.

31. Why does only a slow neutron (.03eV energy) cause the fission in the uranium nucleus and not the fast one?

Ans. Slow neutron stays in the nucleus for required optimum time and disturbs the configuration of nucleus.

32. Write the relation for distance of closest approach.

Ans. \[ \gamma_0 = \frac{(Ze)(2e)}{4\pi \epsilon_0 \left( \frac{1}{2} \frac{mv^2}{e} \right)} \]

33. In Bohr’s atomic model, the potential energy is negative and has a magnitude greater than the kinetic energy, what does this imply?

Ans. The electron revolving is bound to the nucleus.

34. Name the physical quantity whose dimensions are same as Planck’s constant.

Ans. Angular momentum

35. Define ionisation potential.

Ans. The minimum accelerated potential which would provide an electron sufficient energy to remove from the outermost orbit.

36. The ionisation potential of helium atom is 24.6 V. How much energy will be required to ionise it?

Ans. 24.6 eV

37. What is the energy possessed by an electron whose principal quantum number is infinite?
13.6 eV
\[ n = \infty \]
\[ En = -\frac{13.6}{n^2} \text{ eV} = 0 \]

38. Write the value of Rydberg constant?

Ans. \(1.097 \times 10^7 \text{ m}^{-1}\)

39. Name the spectral series of hydrogen atom which lie in \(uv\) region.

Ans. Lyman Series

40. Name the series of hydrogen spectrum lying in the infra red region.

Ans. Paschan & \(P\) fund series

41. What is the order of velocity of electron in a hydrogen atom in ground state.

Ans. \(10^6 \text{ m/s}^{-1}\)

42. Write a relation for Paschen series lines of hydrogen spectrum.

Ans. \[ \bar{\nu} = R \left( \frac{1}{3^2} - \frac{1}{n^2} \right) n = 4, 5, \ldots \]

43. Arrange radioactive radiation in the increasing order of penetrating power.

Ans. \(\alpha, \beta, \gamma\)

44. Write a relation between average life and decay constant.

Ans. \[ J = \frac{1}{\lambda} = \text{average life} \]

45. Write two units for activity of radioactive element and relate them with number of disintegration per second.

Ans. 1 Curie (Ci) = \(3.7 \times 10^{10}\) decay/s

1 bequered (Bq) = 1 decaya/s
1 Ci = 3.7 \times 10^{10} \text{ Bq}

46. The half life of a radioactive element A is same as the mean life time of another radioactive element B. Initially, both have same number of atoms. B decay faster than A. Why?

Ans. \quad T_A = \tau_B = 1.44 T_B \quad \therefore T_A > T_B \quad \therefore \lambda_A < \lambda_B. \text{ Therefore B decay faster than A.}

47. Draw the graph showing the distribution of Kinetic energy of electrons emitted during \( \beta \) decay.

48. Compare radii of two nuclei of mass numbers 1 and 27 respectively.

Ans. \quad \frac{R_1}{R_2} = \left( \frac{1}{27} \right)^{1/3} = \frac{1}{3}

\quad R_1 : R_2 = 1 : 3

49. Which element has highest value of Binding Energy per nucleon.

Ans. \quad ^{56}\text{Fe}_{26}

50. Mention the range of mass number for which the Binding energy curve is almost horizontal.

Ans. \quad \text{For } A = 30 \text{ to } 120 \text{ (A is mass number)}

51. What is the ratio of nuclear densities of the two nuclei having mass numbers in the ratio 1 : 4?

Ans. \quad 1 : 1 \text{ Because nuclear density is independent of mass number.}
52. Draw a graph of number of undecayed nuclei to the time, for a radioactive nuclei. (N.C.E.R.T Page 447)

\[ N(t) \]

53. Write an equation to represent \( \alpha \) decay.

Ans. \[ ^{A-4}_{Z-2}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}\text{He} + Q. \]

**SHORT ANSWER QUESTIONS (2 Marks)**

1. Write one similarity and one difference between matter wave and an electromagnetic wave.

2. Does a photon have a de Broglie wavelength? Explain.

3. A photon and an electron have energy 200 eV each. Which one of these has greater de-Broglie wavelength?

4. The work function of the following metal is given Na = 2.75 eV, K = 2.3 eV, Mo = 4.14 eV, Ni = 5.15 eV which of these metal will not give a photoelectric emission for radiation of wave length 3300 \( \text{Å} \) from a laser source placed at 1m away from the metal. What happens if the laser is brought nearer and placed 50 cm away.

5. Name the experiment for which the followings graph, showing the variation of intensity of scattered electron with the angle of scattering, was obtained. Also name the important hypothesis that was confirmed by this experiment.

6. In a photoelectric effect experiment, the graph between the stopping potential \( V \) and frequency of the incident radiation on two different metals P and Q are shown in Fig.:
1. Which of the two metals has greater value of work function?

2. Find maximum K.E. of electron emitted by light of frequency \( v = 8 \times 10^{14} \text{ Hz} \) for metal \( P \).

3. Do all the photons have same dynamic mass? If not, why?

4. Why photoelectrons ejected from a metal surface have different kinetic energies although the frequency of incident photons are same?

5. Find the ratio of de-Broglie wavelengths associated with two electrons 'A' and 'B' which are accelerated through 8V and 64 volts respectively.

6. The photoelectric current at distances \( r_1 \) and \( r_2 \) of light source from photoelectric cell are \( I_1 \) and \( I_2 \) respectively. Find the value of \( \frac{I_2}{I_1} \).

Ans. \( I \propto \frac{I}{r^2} \Rightarrow \frac{I_2}{I_1} = \left( \frac{r_1}{r_2} \right)^2 \)

7. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals?

Ans. \( KE_{\text{max}} = hv - W_0 \Rightarrow KE_{\text{max}} \) decreases with increase in \( W_0 \).

8. Define distance of the closest approach. An \( \alpha \)-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an \( \alpha \)-particle of double the kinetic energy?

9. Show that nuclear density is independent of the mass number.

10. Which of the following radiations \( \alpha, \beta \) and \( \gamma \) are:

   (i) similar to x-rays?

   (ii) easily absorbed by matter
(iii) travel with greatest speed?
(iv) similar to the nature of cathode rays?

15. Some scientists have predicted that a global nuclear war on earth would be followed by ‘Nuclear winter’. What could cause nuclear winter?

16. If the total number of neutrons and protons in a nuclear reaction is conserved how then is the energy absorbed or evolved in the reaction?

17. In the ground state of hydrogen atom orbital radius is $5.3 \times 10^{-11}$ m. The atom is excited such that atomic radius becomes $21.2 \times 10^{-11}$ m. What is the principal quantum number of the excited state of atom?

18. Calculate the percentage of any radioactive substance left undecayed after half of half life.

19. Why is the density of the nucleus more than that of an atom?

20. The atom $\text{O}^{16}$ has 8 protons, 8 neutrons and 8 electrons while atom $\text{Be}^{8}$ has 4 protons, 4 neutrons and 4 electrons, yet the ratio of their atomic masses is not exactly 2. Why?

21. What is the effect on neutron to proton ratio in a nucleus when $\beta^-$ particle is emitted? Explain your answer with the help of a suitable nuclear reaction.

22. Why must heavy stable nucleus contain more neutrons than protons?

23. Show that the decay rate $R$ of a sample of radio nuclide at some instant is related to the number of radio active nuclei $N$ at the same instant by the expression $R = -N\lambda$.

24. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purposes?

25. Write two characteristic features of nuclear forces which distinguish them from coulomb force.

26. Half life of certain radioactive nuclei is 3 days and its activity is 8 times the ‘safe limit’. After how much time will the activity of the radioactive sample reach the ‘safe limit’?

27. Derive $mvr = \frac{nh}{2\pi}$ using de Broglie equation.
28. Draw graph of number of scattered particles to scattering angle in Rutherford’s experiment.

29. Show that nuclear density is same for all the nuclei.

30. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines?
   **Ans.**: 820nm, (ii) 365 nm

31. The radius of the inner most electron orbit of a hydrogen atom 0.53 Å. What are the radii of the \( n = 2 \) and \( n = 3 \) orbits.

32. The ground state energy of hydrogen atom is \(-13.6 \text{ eV}\). What are the Kinetic and potential energies of the electron in this state?

33. Write formula of frequency to represent (i) Lyman series (ii) Balmer series.

34. From the relation \( R = R_0 A^{1/3} \) where \( R_0 \) is a constant and \( A \) is the mass number of a nucleus, show that nuclear matter density is nearly constant.

   **Ans.**
   \[
   \text{Nuclear matter density} = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3} \pi R^3} = \frac{mA}{\frac{4}{3} \pi R_0^3 A} \]
   \[
   = \frac{m}{\frac{4}{3} \pi R_0^3} \approx 2.3 \times 10^{-17} \text{ kg/m}^3
   \]
   \[
   = \text{Constant}
   \]

35. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

   **Ans.**
   \[
   E = \Delta mc^2
   \]
   \[
   \Delta m = 1.6605 \times 10^{-27} \text{ kg}
   \]
   \[
   = 1.6605 \times 10^{-27} \times (3 \times 10^8)^2
   \]
   \[
   = 1.4924 \times 10^{-4} \text{ J}
   \]
   \[
   = \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} \text{ eV}
   \]
= 0.9315 \times 10^9 \text{ eV} = 931.5 \text{ MeV}

36. Write four properties of nuclear force.

**SHORT ANSWER QUESTIONS (3 Marks)**

1. Explain the working of a photocell? Give its two uses.

2. Find the de Broglie wavelength associated with an electron accelerated through a potential difference V.

3. What is Einstein’s explanation of photo electric effect? Explain the laws of photo electric emission on the basis of quantum nature of light.

4. If kinetic energy of thermal neutron is \( \frac{3}{2} kT \) then show that de-Broglie wavelength of waves associated with a thermal neutron of mass m at temperature T kelvin is \( \frac{h}{\sqrt{3mkT}} \) where k is boltzmann constant.

5. Explain Davisson and Germer experiment to verify the wave nature of electrons.

6. Explain the effect of increase of (i) frequency (ii) intensity of the incident radiation on photo electrons emitted by a metal.

7. X-rays of wave length \( \lambda \) fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be \( \sqrt{\frac{h\lambda}{2mc}} \).

8. A particle of mass M at rest decays into two particles of masses \( m_1 \) and \( m_2 \) having velocities \( V_1 \) and \( V_2 \) respectively. Find the ratio of de-broglie Wavelengths of the two particles.

**Ans.** 1 : 1

9. Give one example of a nuclear reaction. Also define the Q-value of the reaction. What does Q > 0 signify?

10. Explain how radio-active nucleus can-emit \( \beta \)-particles even though nuclei
do not contain these particles. Hence explain why the mass number of radioactive nuclide does not change during $\beta$-decay.

11. Define the term half life period and decay constant. Derive the relation between these terms.

12. State the law of radioactive decay. Deduce the relation $N = N_0 e^{-\lambda t}$, where symbols have their usual meaning.

13. Give the properties of $\alpha$-particles, $\beta$-particles and $\gamma$-rays.

14. With the help of one example, explain how the neutron to proton ratio changes during alpha decay of a nucleus.

15. Distinguish between nuclear fusion and fission. Give an example of each.

16. A radioactive isotope decays in the following sequence

$$A \xrightarrow{\beta^n} A_1 \xrightarrow{\alpha} A_2.$$ 

If the mass and atomic numbers of $A_2$ are 171 and 76 respectively, find mass and atomic number of $A$ and $A_1$. Which of the three elements are isobars?

17. Obtain a relation for total energy of the electron in terms of orbital radius. Show that total energy is negative of K.E. and half of potential energy.

$$E = -\frac{e^2}{8\pi\varepsilon_0 r}.$$  

18. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.

19. The total energy of an electron in the first excited state of the hydrogen atom is about $-3.4$ eV. What is

(a) the kinetic energy,

(b) the potential energy of the electron?

(c) Which of the answers above would change if the choice of the zero of potential energy in changed to (i) $+0.5$ eV (ii) $-0.5$ eV.

Ans. (a) When P.E. is chosen to be zero at infinity $E = -3.4$ eV, using $E = -$ K.E., the K.E. = $+3.4$ eV.
(b) Since P.E. = − 2E, PE = − 6.8 eV.

(c) If the zero of P.E. is chosen differently, K.E. does not change. The P.E. and T.E. of the state, however would alter if a different zero of the P.E. is chosen.

(i) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be

\[ −3.4 − 0.5 = − 3.9 \text{ eV} \]

(ii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be

\[ −3.4 − (−0.5) = −2.9 \text{ eV} \]

20. What is beta decay? Write an equation to represent β − and β + decay. Explain the energy distribution curve is β decay.

21. Using energy level diagram show emission of γ rays by $^{60}_{27}\text{Co}$ nucleus and subsequent β decay to obtain $^{60}_{28}\text{Ni}$. NCERT pg. 457

**LONG ANSWER QUESTIONS (5 Marks)**

1. State Bohr’s postulates. Using these postulates, drive an expression for total energy of an electron in the $n^{th}$ orbit of an atom. What does negative of this energy signify?

2. Define binding energy of a nucleus. Draw a curve between mass number and average binding energy per nucleon. On the basis of this curve, explain fusion and fission reactions.

3. State the law of radioactive disintegration. Hence define disintegration constant and half life period. Establish relation between them.

4. What is meant by nuclear fission and nuclear chain reaction? Outline the conditions necessary for nuclear chain reaction.

5. Briefly explain Rutherford’s experiment for scattering of α particle with the help of a diagram. Write the conclusion made and draw the model suggested.

6. State law of radioactive decay obtain relation

\[ N = N_0 e^{-\lambda t} \]

\[ R = R_0 e^{-\lambda t} \]

where $N$ is number of radioactive nuclei at time $t$ and
N₀ is number of radioactive nuclei at time \( t_0 \), \( \lambda \) is decay constant
\( R \) is rate of decay at any instant \( t \)
\( R_0 \) is rate of decay at any time \( t_0 \) (initial time).

**NUMERICALS**

1. Ultraviolet light of wavelength 350 nm and intensity 1W/m² is directed at a potassium surface having work function 2.2eV.
   (i) Find the maximum kinetic energy of the photoelectron.
   (ii) If 0.5 percent of the incident photons produce photoelectric effect, how many photoelectrons per second are emitted from the potassium surface that has an area 1cm².
   
   \[ E_{K_{\text{max}}} = 1.3 \text{ eV}; \quad n = 8.8 \times 10^{11} \frac{\text{photo electron}}{\text{second}} \]

2. A metal surface illuminated by \( 8.5 \times 10^{14} \text{ Hz} \) light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by \( 12.0 \times 10^{14} \text{ Hz} \) light emits elections whose maximum energy is 1.97eV. From these data find work function of the surface and value of Planck's constant. [Work Function = 3ev]

3. An electron and photon each have a wavelength of 0.2 nm. Calculate their momentum and energy.
   (i) \( 3.3 \times 10^{-24} \text{ kgm/s} \)
   (ii) 6.2 keV for photon
   (iii) 38eV for electron

4. What is the (i) Speed (ii) Momentum (ii) de-Broglie wavelength of an electron having kinetic energy of 120eV?
   **Ans.** (a) \( 6.5 \times 10^6 \text{ m/s} \); (b) \( 5.92 \times 10^{-24} \text{ kg m/s} \); (c) 0.112 nm.

5. If the frequency of incident light in photoelectric experiment is doubled then does the stopping potential become double or more than double, justify?
   (More than double)
6. A proton is accelerated through a potential difference $V$. Find the percentage increase or decrease in its deBroglie wavelength if potential difference is increased by 21%. 

7. For what Kinetic energy of a neutron will the associated de Broglie wavelength be $5.6 \times 10^{-10}$m?

**Ans.**

$$\sqrt{2m_n \times K.E.} = \frac{h}{\lambda} \Rightarrow K.E. = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$$

$$= \left(\frac{6.625 \times 10^{-34}}{5.6 \times 10^{-10}}\right)^2 \frac{1}{2 \times 1.67 \times 10^{-27}} = 3.35 \times 10^{-21} J$$

8. A nucleus of mass $M$ initially at rest splits into two fragments of masses $\frac{M}{3}$ and $\frac{2M}{3}$. Find the ratio of de Broglie wavelength of the fragments.

**Ans.** Following the law of conservation of momentum,

$$\frac{M}{3} v_1 + \frac{2M}{3} v_2 = 0 \quad \text{or} \quad \left|\frac{M}{3} v_1\right| = \left|\frac{2M}{3} v_2\right|$$

$$\lambda = \frac{h}{mv} \Rightarrow \frac{\lambda_1}{\lambda_2} = \left|\frac{2}{3} \frac{v_2}{\frac{M}{3} v_1}\right| = 1$$

9. An electron and a proton are possessing same amount of K.E., which of the two have greater de-Broglie, wavelength? Justify your answer.

**Ans.**

$$E_e = \frac{1}{2} m_e v_e^2 \quad \text{and} \quad E_p = \frac{1}{2} m_p v_p^2$$

$$\Rightarrow m_e v_e = \sqrt{2E_e m_e} \quad \text{and} \quad m_p v_p = \sqrt{2E_p m_p}$$

But, $E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$

$$\therefore \lambda_e > \lambda_p.$$
11. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in that orbit.
   **Ans.** \( r_3 = 4775 \, \text{A} \)° and \( E_3 = -2.43 \times 10^{-19} \, \text{J} \)

12. Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant = \( 1.0987 \times 10^7 \, \text{m}^{-1} \).
   **Ans.** \( \lambda_l = 6563 \, \text{A} \)°, \( \lambda_s = 3646 \, \text{A} \)°

13. What will be the distance of closest approach of a 5 MeV proton as it approaches a gold nucleus?
   **Ans.** \( 4.55 \times 10^{-14} \, \text{m} \)

14. A 12.5 MeV alpha – particle approaching a gold nucleus is deflected by 180°. What is the closest distance to which it approaches the nucleus?
   **Ans.** \( 1.82 \times 10^{-14} \, \text{m} \)

15. Determine the speed of the electron in \( n = 3 \) orbit of hydrogen atom.
   **Ans.** \( 7.29 \times 10^5 \, \text{ms}^{-1} \)

16. There are \( 4\sqrt{2} \times 10^6 \) radioactive nuclei in a given radio active element. If half life is 20 seconds, how many nuclei will remain after 10 seconds?
   **Ans.** \( 4 \times 10^6 \)

17. The half life of a radioactive substance is 5 hours. In how much time will 15/16 of the material decay?
   **Ans.** 20 hours

18. At a given instant, there are 25% undecayed radioactive nuclei in a sample. After 10 seconds, the number of undecayed nuclei reduces to 12.5%. Calculate the mean life of nuclei.
   **Ans.** 14.43

19. Binding energy of \( ^2\text{He} \) and \( ^3\text{Li} \) nuclei are 27.37 MeV and 39.4 MeV respectively. Which of the two nuclei is more stable? Why?
   **Ans.** \( ^2\text{He} \) because its BE/nucleon is greater

20. Find the binding energy and binding energy per nucleon of nucleus \( _{83}\text{Bi}^{209} \).
   Given: mass of proton = 1.0078254 u. mass of neutron = 1.008665 u.
   Mass of \( _{83}\text{Bi}^{209} \) = 208.980388u.
   **Ans.** 1639.38 MeV and 7.84 MeV/Nucleon

21. Is the fission of iron \( _{26}\text{Fe}^{56} \) into \( _{13}\text{Al}^{28} \) as given below possible?
   \[ _{26}\text{Fe}^{56} \rightarrow _{13}\text{Al}^{28} + _{13}\text{Al}^{28} + Q \]
   Given mass of \( _{26}\text{Fe}^{56} \) = 55.934940 and \( _{13}\text{Al}^{28} = 27.98191 \, \text{U} \)
   **Ans.** Since Q value comes out negative, so this fission is not possible
22. Find the maximum energy that $\beta$-particle may have in the following decay:

$$ _{8}O^{19} \rightarrow _{9}F^{19} + _{-1}e^{0} + \overline{\nu} $$

Given
- m ($_{8}O^{19}$) = 19.003576 a.m.u.
- m ($_{9}F^{19}$) = 18.998403 a.m.u.
- m ($e^{0}$) = 0.000549 a.m.u.

 Ans. : 4.3049 MeV

23. The value of wavelength in the lyman series is given as

$$ \lambda = \frac{93.4n_{i}^{2} \angstrom}{n_{i}^{2} - 1} $$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decreases or increase.

 Ans. :
- $$ \lambda_{21} = \frac{913.4 \times 2^{2}}{2^{2} - 1} = 1218 \ angstrok $$
- $$ \lambda_{31} = \frac{913.4 \times 3^{2}}{3^{2} - 1} = 1028 \ angstrok $$
- $$ \lambda_{41} = \frac{913.4 \times 4^{2}}{4^{2} - 1} = 974.3 \ angstrok $$

$$ \lambda_{41} < \lambda_{31} < \lambda_{21} $$

24. The half life of $^{238}_{92}U$ undergoing $\alpha$ decay is $4.5 \times 10^{9}$ years what is the activity of 1g. sample of $^{238}_{92}U$.

 Ans. : $T_{1/2} = 4.5 \times 10^{9}$ y
- $= 4.5 \times 10^{9} \times 3.16 \times 10^{7}$ s
- $= 1.42 \times 10^{17}$ s

1g of $^{238}_{92}U$ contains $= \frac{1}{238} \times 6.025 \times 10^{23}$ atom
\[ = 25.3 \times 10^{20} \text{ atoms} \]

\[ \therefore \text{decay rate} = R = \lambda N = \frac{0.693}{T} \times \lambda. \]

\[ = \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} \text{s}^{-1} \]

\[ = 1.23 \times 10^4 \text{ Bq}. \]

**VALUE BASED QUESTION**

1. In an experiment of photoelectric effect, Nita plotted graphs for different observation between photoelectric current and anode potential but her friend Kamini has to help her in plotting the correct graph. Neeta thanked Kamini for timely help.

   (i) What value was displayed were Kamini and Neeta.

   (ii) Draw the correct graph between I and V (NCERT).

2. A function was arranged in the school auditorium. The auditorium has the capacity of 400 students. When entry started students entered in groups and counting becomes a great problem. Then science students took responsibility at the gate. All the students entered the hall one by one. This helped them to maintain discipline and counting became easy with the help of a device used by these students.

   (i) What value is displayed by science?

   (ii) Name the device which is based on application of photoelectric effect.

3. Ruchi’s uncle who was a kabadiwalah was getting weak day by day. His nails were getting blue, he stated losing his hair. This happened immediately after he purchased a big contained of heavy mass from Delhi University Chemistry Department. Doctor advised him hospitalization and suspected he has been exposed to radiation. His uncle didn’t know much about radiations but Ruchi immediately convinced her uncle to get admitted and start treatment.
(i) What according to you are the values utilized by Rama to convince her uncle to get admitted in hospital.

(ii) Name the radioactive radiations emitted from a radioactive element.

4. Medha’s grandfather was reading an article in a newspaper. He read that after so many years of atomic bombing in Hiroshima or Nagasaki, Japan National census indicated that children born even now are genetically deformed. His grandfather was not able to understand the reason behind it. He asked his Granddaughter Medha who is studying in class XII Science. Medha sat with her grandfather and showed him pictures from some books and explained the harmful effects of radiations.

(i) What are the values/skills utilized by Kajal to make her grandfather understand the reason of genetically deformity?

(ii) Name the nuclear reactions that occurred in atom bomb.

**ANSWERS**

**VALUE BASED QUESTIONS**

3. (i) Value displayed - awareness, critical thinking, decision making.

   (ii) X ray and Gamma rays.

4. (i) Sympathy, compassion

   (ii) Nuclear-fission reactions.

**2 MARKS QUESTIONS**

7. No.

   \[ m = \frac{E}{c^2} = \frac{h\nu}{c^2} \]

   \[ \Rightarrow \quad m \text{ depends on frequency of photon.} \]

8. Because electrons lose their energy in collision. And energy is different for different electrons.

9. \(2\sqrt{2}\)
12. It will be halved.

13. Using the relation \( R = R_0 A^{1/3} \).

\[
\frac{R_1}{R_2} = \left( \frac{A_1}{A_2} \right)^{1/3} \Rightarrow \frac{\frac{4\pi R_1^3}{3}}{\frac{4\pi R_2^3}{3}} = \frac{A_1}{A_2} \quad \text{or} \quad \frac{\frac{4\pi R_1^3}{3}}{\frac{4\pi R_1^3}{3}} = \frac{\frac{4\pi R_2^3}{3}}{\frac{4\pi R_2^3}{3}}
\]

Hence nuclear density of 1st element = Nuclear density of 2nd element.

14. (i) Similar to x-rays — \( \gamma \)-rays.

(ii) \( \alpha \)-particle.

(iii) \( \gamma \)-rays.

(iv) \( \beta \)-particle.

15. Nuclear radioactive waste will hang like a cloud in the earth atmosphere and will absorb sun radiations.

16. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

17. \( n = 2 \) as \( r_n \propto n^2 \)

18. From relation \( \frac{N}{N_0} = \left( \frac{1}{2} \right)^{t/T} \) when \( t = T/2 \)

\[
\frac{N}{N_0} = \left( \frac{1}{2} \right)^{1/2} \quad \text{or} \quad \frac{N}{N_0} = \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.9\%.
\]

19. Because radius of atom is very large than radius of nucleus.

20. Due to mass defect or different binding energies.

21. Decreases as number of neutrons decreases and number of protons increases.

22. To counter repulsive coulomb forces, strong nuclear force required between neutron–neutron, neutron–proton and proton–proton.
23. \( N = N_0 e^{-\lambda t} \) differentiating both sides we get \( \frac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N \) \( i.e., \)
\[ R = \frac{dN}{dt} = -\lambda N. \]
decay rate

24. For fusion, temperature required is from \( 10^6 \) to \( 10^7 \) K. So, to carry out fusion for peaceful purposes we need some system which can create and bear such a high temperature.

25. Nuclear forces are short range forces (within the nucleus) and do not obey inverse square law while coulomb forces are long range (infinite) and obey inverse square law.

26. \( \left( \frac{A}{8A} \right) = \left( \frac{1}{2} \right)^{t/T_{1/2}} \)

or \( \left( \frac{1}{2} \right)^3 = \left( \frac{1}{2} \right)^{t/3} \)

or \( 3 = \frac{t}{3} \)

\[ \Rightarrow \quad t = 9 \text{ days}. \]
KEY POINTS

1. Solids are classified on the basis of

(i) Electrical conductivity

<table>
<thead>
<tr>
<th></th>
<th>Resistivity</th>
<th>Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>$\rho(\Omega m)$</td>
<td>$\sigma(\text{Sm}^{-1})$</td>
</tr>
<tr>
<td></td>
<td>$10^{-2} - 10^{-6}$</td>
<td>$10^2 - 10^8$</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>$10^{-5} - 10^6$</td>
<td>$10^6 - 10^5$</td>
</tr>
<tr>
<td>Insulators</td>
<td>$10^{11} - 10^{19}$</td>
<td>$10^{-19} - 10^{-11}$</td>
</tr>
</tbody>
</table>

(ii) Energy Bands

- **Metal**
  - C.B.:
  - V.B. Band Gap
  - Energy $E_g = 0$

- **Semiconductor**
  - C.B.:
  - V.B. $E_g < 3\text{eV}$
  - $E_g < 3\text{eV}$

- **Insulator**
  - C.B.:
  - V.B. $E_g > 3\text{eV}$
  - $E_g > 3\text{eV}$
2. Types of Semiconductors

2 Types of semiconductors

<table>
<thead>
<tr>
<th>Elemental</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic</td>
<td>Organic, Anthracene</td>
</tr>
<tr>
<td>CdS, GaAS, CdSe, InP etc.</td>
<td>Doped Phthalocyanines etc.</td>
</tr>
</tbody>
</table>

3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (e and h) are increased in numbers by ‘doping’.

4. An intrinsic semiconductor at 0 K temperature behaves as an insulator.

5. Pentavalent (donor) atom (As, Sb, P etc.) when doped to Si or Ge give $n$-type and trivalent (acceptor) atom (In, Ga, Al etc.) doped with Si or Ge give $p$-type semiconductor.

6. Net charge in $p$-type or $n$-type semiconductor remains zero.

7. Diffusion and drift are the two processes that occur during formation of $p$-$n$ junction.

8. Diffusion current is due to concentration gradient and direction is from $p$ to $n$ side. Drift current is due to electric field and its direction is from $n$ to $p$-side.

9. In depletion region movement of electrons and holes depleted it of its free charges.

10. Because of its different behaviours in forward biasing (as conductor for $V > V_b$) and reverse biasing (as insulator for $V < V_b$) a $p$-$n$ junction can be used as Rectifier, LED, photodiode, solar cell etc.

11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

12. When a zener diode is reverse biased, voltage across it remains steady for a range of currents above zener breakdown. Because of this property, the diode is used as a voltage regulator.

13. In a transistor current goes from low resistances (forward biasing) to high resistance (reverse biasing).

\[ I_e = I_b + I_c \ (I_b \text{ is only } 2\% \text{ to } 8\% \text{ of } I_e) \]

15. In common emitter transistor characteristic we study
   \( I_b \) versus \( V_{BE} \) at constant \( V_{CE} \) (Input characteristic)
   \( I_c \) versus \( V_{CE} \) at constant \( I_B \) (output characteristic)

   Input resistance \[ r_i = \left( \frac{\delta V_{BE}}{\delta I_B} \right) V_{CE} \]

   Output resistance \[ r_o = \left( \frac{\delta V_{CE}}{\delta I_C} \right) I_B \]

16. Current amplifications factors
   \[ \beta_{ac} = \left( \frac{\delta I_C}{\delta I_B} \right) V_{CE} \]
   \[ \beta_{dc} = \frac{I_C}{I_B}. \]
   \[ \beta_{ac} = \beta_{dc}. \]
   Both \( \beta_{ac} \) and \( \beta_{dc} \) vary with \( V_{CE} \) and \( I_B \) Slightly.

17. Transistor is used (i) as a switch in cut off and saturation state. (ii) as amplifier in active region.

18. In CE configuration, transistor as amplifier output differ in phase them input by \( \pi \).

19. Transistor as an amplifier with positive feedback works as an oscillator.

20. Gates used for performing binary operations in digital electronics mainly consist of diodes and transistors.

21. NAND gates alone can be used to obtain OR gate and similarly a NOR gates alone can be used to obtain AND gate, OR gate.
UNIT X

COMMUNICATION SYSTEMS

KEY POINTS

- Communication is the faithful transfer of message from one place to another.
- A communication system consists of three basic elements.

\[\text{Input Information} \rightarrow \text{Transmitter} \rightarrow \text{Channel} \rightarrow \text{Receiver} \rightarrow \text{output Information}\]

- **Transmitter**: An equipment which converts the information data into electrical signal.
- A transmitter consists of
  1. Transducer or Converter
  2. Modulator
  3. Carrier Oscillator
  4. Transmitting Antenna

- **Channel**: It is the medium through which the electrical signals from the transmitter pass to reach the receiver.
- **Receiver**: An equipment which receives and retrieves information from the electrical signals.
- A Receiver section consists of
  1. Receiver Antenna
  2. Transducer/Converter
  3. Demodulator

- Two important forms of communication system are **Analog** and **Digital**. In Analog communication, the information is in analog form.
- In Digital communication, the information has only discrete or quantised values.
- Modulation is a process by which any electrical signal (called input,
baseband or modulating signal) of low frequency is mounted on to another signal (carrier) of high frequency.

- **Need of Modulation**:
  
  (i) To avoid interference between different base band signals.
  
  (ii) To have a practical size of antenna.
  
  (iii) To increase power radiated by antenna.

- **Demodulation**: It is a process by which a base band signal is recovered from a modulated wave.

- **Amplitude Modulation**: In this type of modulation, the amplitude of carrier wave is varied in accordance with the information signal, keeping the frequency and phase of carrier wave constant.

- **Bandwidth**: Bandwidth is the range of frequencies over which an equipment operates.

- Space communication uses free space between transmitter and receiver for transfer of data/information.

- **Ground Wave**: These are the waves radiated by antenna that travel at zero or lower angle with respect to earth surface. They are heavily absorbed by earth surface and not suitable for long range communication.

- **Space Wave**: These are the waves that travel directly through space between transmitting and receiving antennas. The space waves are within the troposphere region of atmosphere and have two **Modes of Transmission**:
  
  (i) Line of sight communication
  
  (ii) Satellite communication

<table>
<thead>
<tr>
<th>Physical Quantity</th>
<th>Formulae</th>
<th>SI Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power radiated by an antenna</td>
<td>$\frac{1}{\lambda^2}$</td>
<td>W</td>
</tr>
<tr>
<td>Sinusoidal carrier wave</td>
<td>$E = E_c \cos(\omega_c t + \phi)$</td>
<td>V</td>
</tr>
<tr>
<td>The range of tower</td>
<td>$d = \sqrt{\frac{2Rh}{\lambda}}$</td>
<td>m</td>
</tr>
</tbody>
</table>

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The number of channels

Bandwidth

The maximum range of broadcast between transmitting and receiving tower $h_t$ and $h_r$ → height of transmitting and receiving towers

$\text{Bandwidth per channel}$

$\text{max} = \sqrt{2Rh_t} + \sqrt{2Rh_r}$

where $R$ → Radius of earth

1. BASIC IDEA ABOUT INTERNET

The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to link several billion devices worldwide.

The Internet is a global system that makes it possible for computers worldwide to share information via a variety of languages called protocols.

It is a network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless, and optical networking technologies.

1.1 History of Internet

Evolution of internet is started in 1969 by the development of first network called ARPANET.

(i) **ARPANET** It tends for Advance Research project Ajency network. It was invented in 1969. In U.S.A Department of Defence sponsored a project called ARPANET whose goal is to connect the computer of U.S. defence. This model is designed to share the maximum information.

(ii) **NSFnet** It tends for national science foundation network. It was invented in 1980. In U.S.A. a new project after ARPANET was started to connect the computer of different universities so that the students can share maximum information.

(iii) Internet In 1990 the internetworking of ARPANET, NSFnet and other private network revisited into internet. So, an internet is an interconnection of different network through world wide. The information of world can be shared through internet.

Note: If we want to define the internet in one sentence then we can say that “An internet is a network of network”.

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Note: The original ARPANET was shut down in 1990, and the NSF net was disconnected in 1995. These two are converted into the internet.

1.3 Who Govern the Internet

The internet is not run by any individual, so many organizations take responsibilities to govern the internet from which the main three organizations are.

1. **IAB (internet architecture board)**: This organization acts as representative of the internet concerned with standards and other technical and organizational issues relevant to the world-wide Internet.

2. **IETF (internet Engineering Task Force)**: The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.

3. **Inter NIC (Internet Network Information Center)**: This is responsible for providing Public Information Regarding Internet Domain Name Registration Services.

1.4 WWW (Started in 1990)

It tends for worldwide web. It is a set of programmes & protocols that allow the users to create & display the combination of text, photographs, graphics, videos, audio & other multimedia files. Before www, the internet was mainly used for obtaining textual information only, multimedia file can’t be accessed.

**Attributes of WWW**

1. **Hypertext**: A hypertext is a text through which we can access or get other information of that text by clicking on it.

2. **Hypermedia**: A hypermedia is a file or any image or any other media through which we can access or get other information of that media by clicking on it.

3. **Hyperlink**: Hyperlink refer to the link through which we can open the other new web page by clicking on it.

1.5 Hyper Text Transfer Protocol

**HTTP**: It tends for Hypertext transfer protocol. It is an internet protocol that is used for fetching the information from server side. It fetch only textual informa-
tion. The HTTP protocol consists of two fairly distinct items: the set of requests from browser to servers and set of responses going back to the other way. Although HTTP was designed for use in the web.

1.6 Web Page

A web page is a document on the internet, that can contain textual files, multimedia files & hyper links. A web page is made up by using hyper text markup language (HTML).

1.7 Web Site

A location on a net server or on internet is called a web site. Each web site has a unique address called URL (uniform resource location). For example - Website of Harsh Publishers has the web address - www.harshpublishers.com

1.8 Home Page

It is the top level web page of a website. When a website is opened its homepage is displayed.

1.9 Differentiate b/w web browser & web server

A www client is called web browser & www server is called web server. A web browser sends a request of user to the web server to open a desired web page on the web browser through which user can access the information.

1.10 URL (Uniform Resource Locator)

A web address is also known as an URL, which stands for Uniform Resource Locator for example www.harshpublishers.com is an URL of Harsh Publishers Websites. Each URL represents a specific location on the Web.

2. MOBILE TELEPHONY

2.1 The Mobile Telephone System

The traditional telephone system will still not be able to satisfy a growing group of users: people on the go. People now expect to make phone calls, send e-mail and surf the Web from airplanes, cars, swimming pools, and while jogging in the park. Consequently, there is a tremendous amount of interest in wireless telephony.
A mobile phone (also known as a cellular phone, cell phone, and a hand phone) is a phone that can make and receive telephone calls over a radio link while moving around a wide geographic area. It does so by connecting to a cellular network provided by a mobile phone operator, allowing access to the public telephone network. By contrast, a cordless telephone is used only within the short range of a single, private base station.

*Note:* The first hand-held cell phone was demonstrated by John F. Mitchell and Dr Martin Cooper of Motorola, in 1973, using a handset weighing around 2.2 pounds (1 kg).

### 2.2 Working of Mobile Telephone System

In this techniques a message can be divided into some fixed size of packets that can be transferred across the network. At the receiver side these packets are further collected to make an original message.

The communication protocol used by mobile telephone is TCP / IP. Here TCP is responsible for transferring of information. TCP is responsible for dividing a message into packets and also responsible for combining these packets into original form at other ends.

Internet protocol is responsible for handling the address of destination. So that the packets can be transferred at their proper destination.
2.3 Generation of Mobile Phone

Mobile phones have gone through three distinct generations, with different technologies:

1. Analog voice.
2. Digital voice.
3. Digital voice and data (Internet, e-mail, etc.).

2.3.1 First-Generation Mobile Phones: Analog Voice

This system used a single large transmitter on top of a tall building and had a single channel, used for both sending and receiving. To talk, the user had to push a button that enabled the transmitter and disabled the receiver. Such systems, known as push-to-talk systems, were installed in several cities beginning in the late 1950s. CB-radio, taxis, and police cars on television programs often use this technology.

In the 1960s, IMTS (Improved Mobile Telephone System) was installed. It, too, used a high-powered (200-watt) transmitter, on top of a hill, but now had two frequencies, one for sending and one for receiving, so the push-to-talk button was no longer needed. In this case the mobile users could not hear each other (unlike the push-to-talk system used in taxis).

IMTS supported 23 channels spread out from 150 MHz to 450 MHz. Due to the small number of channels, users often had to wait a long time before getting a dial tone. Also, due to the large power of the hilltop transmitter, adjacent systems had to be several hundred kilometers apart to avoid interference. All in all, the limited capacity made the system impractical.

Advanced Mobile Phone System

All that changed with AMPS (Advanced Mobile Phone System), invented in 1982.
In all mobile phone systems, a geographic region is divided up into cells, which is why the devices are sometimes called cell phones. The key idea that gives cellular systems far more capacity than previous systems is the use of relatively small cells and the reuse of transmission frequencies in nearby (but not adjacent) cells. Thus, the cellular design increases the system capacity. Furthermore, smaller cells mean that less power is needed, which leads to smaller and cheaper transmitters and handsets.

In an area where the number of users has grown to the point that the system is overloaded, the power is reduced, and the overloaded cells are split into smaller microcells to permit more frequency reuse.

![Diagram of cellular phone system](image)

**Fig. (a)** Frequencies are not reused in adjacent cells. **(b)** To add more users, smaller cells can be used.

At the center of each cell is a base station to which all the telephones in the cell transmit. The base station consists of a computer and transmitter/receiver connected to an antenna. In a small system, all the base stations are connected to a single device called an MTSO (Mobile Telephone Switching Office) or MSC.
2.3.2 Second-Generation Mobile Phones: Digital Voice

The first generation of mobile phones was analog; the second generation was digital. Four systems are in use now: D-AMPS, GSM, CDMA, and PDC. Below we will discuss the first three. PDC is used only in Japan and is basically D-AMPS modified for back-ward compatibility with the first-generation Japanese analog system. The name PCS (Personal Communications Services) is sometimes used in the marketing literature to indicate a second-generation (i.e., digital) system. Originally it meant a mobile phone using the 1900 MHz band, but that distinction is rarely made now.

D-AMPS—the Digital Advanced Mobile Phone System: The second generation of the AMPS systems is D-AMPS and is fully digital. D-AMPS was carefully designed to co-exist with AMPS so that both first- and second-generation mobile phones could operate simultaneously in the same cell. In particular, D-AMPS uses the same 30 kHz channels as AMPS and at the same frequencies so that one channel can be analog and the adjacent ones can be digital. Depending on the mix of phones in a cell, the cell's MTSO determines which channels are analog and which are digital, and it can change channel types dynamically as the mix of phones in a cell changes.

GSM—the Global System for Mobile Communications: D-AMPS is widely used in the U.S. and (in modified form) in Japan. Similarly GSM (Global System for Mobile communications) is used everywhere in the world, and it is even starting to be used in the U.S. on a limited scale. To a first approximation, GSM is similar to D-AMPS. Both are cellular systems.

CDMA—Code Division Multiple Access: CDMA is completely different from AMPS, D-AMPS, and GSM. Instead of dividing the allowed frequency range into a few hundred narrow channels, CDMA allows each station to transmit over the entire frequency spectrum all the time. Multiple simultaneous transmissions are separated using coding theory. CDMA also relaxes the assumption that colliding frames are totally garbled. Instead, it assumes that multiple signals add linearly.

Thus, the key to CDMA is to be able to extract the desired signal while rejecting everything else as random noise.

2.3.3 Third-Generation Mobile Phones: Digital Voice and Data

Many people are drooling over a lightweight, portable device that acts as a telephone, CD player, DVD player, e-mail terminal, Web interface, gaming machine, word processor, and more, all with worldwide wireless connectivity to the Internet.
at high bandwidth. This device and how to connect it is what third generation mobile telephony is all about.

    The basic services are:
    1. High-quality voice transmission.
    2. Messaging (replacing e-mail, fax, SMS, chat, etc.).
    3. Multimedia (playing music, viewing videos, films, television, etc.).
    4. Internet access (Web surfing, including pages with audio an video)

2.4 Mobile Related Term

SIM (Subscriber Identity Module) : A subscriber identity module or subscriber identification module (SIM) is an integrated circuit that securely stores the international mobile subscriber identity (IMSI) and the related key used to identify and authenticate subscribers on mobile telephone devices (such as mobile phones and computers).

IMEI (International Mobile Equipment Identity) : The IMEI number is used by a GSM network to identify valid devices and therefore can be used for stopping a stolen phone from accessing that network. For example, if a mobile phone is stolen, the owner can call his or her network provider and instruct them to “blacklist” the phone using its IMEI number. This renders the phone useless on that network and sometimes other networks too, whether or not the phone’s SIM is changed.

GSM (Global System for Mobile Communications)--See above

CDMA (Code Division Multiple Access)--See above

BLUETOOTH—Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the I M band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994

Infrared—Infrared (IR) is electromagnetic radiation with longer wave length than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers (nm) to 1 mm. This range of wavelengths corresponds to a frequency range of approximately 430 THz down to 300 GHz. Infrared radiation was discovered in 1800 by astronomer William Herschel

3. GPS

Using the Global Positioning System (GPS), a process used to establish a
position at any point on the globe) the following two values can be determined anywhere on Earth:

1. One’s exact location (longitude, latitude and height co-ordinates) accurate to within a range of 20 m to approx. 1 mm.

2. The precise time (Universal Time Coordinated, UTC) accurate to within a range of 60ns to approx. 5ns.

Speed and direction of travel (course) can be derived from these co-ordinates as well as the time. The co-ordinates and time values are determined by 28 satellites orbiting the Earth.

GPS receivers are used for positioning, locating, navigating, surveying and determining the time.

GPS (the full description is: Navigation System with Timing And Ranging Global Positioning System, NAVSTAR GPS) was developed by the U.S. Department of Defense (DoD) and can be used both by civilians and military personnel. The civil signal can be used freely by the general public, whilst the military signal can only be used by authorised government agencies.

During the development of the GPS system, particular emphasis was placed on the following three aspects:

1. It had to provide users with the capability of determining position, speed and time, whether in motion or at rest.

2. It had to have a continuous, global, 3-dimensional positioning capability with a high degree of accuracy, irrespective of the weather.

3. It had to offer potential for civilian use.

The GPS system functions according to exactly the same principle. In order to calculate one’s exact position, all that needs to be measured is the signal transit time between the point of observation and four different satellites whose positions are known and using distance = (speed)(time)

3.1 Generating GPS Signal Transit Time

If the time measurement is accompanied by a constant unknown error, we will have four unknown variables in 3-D space:

- longitude (X)
- latitude (Y)
It therefore follows that in three-dimensional space four satellites are needed to determine a position.

### 3.2 Determining a Position in 3-D Space

In order to determine these four unknown variables, four independent equations are needed. The four transit times required are supplied by the four different satellites (sat. 1 to sat. 4). The 28 GPS satellites are distributed around the globe in such a way that at least 4 of them are always “visible” from any point on Earth.

Despite receiver time errors, a position on a plane can be calculated to within approx. 5-10 m.
UNIT IX & X

ELECTRONIC DEVICES AND COMMUNICATION SYSTEM

QUESTIONS

VERY SHORT ANSWER QUESTIONS

1. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.

Ans. \[ n_e = n_h \]

2. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.

Ans. (i) Zero  (ii) infinite

3. Write any one use of (i) photodiode (ii) LED.

(i) Use of Photodiode  
(a) In detection of optical signal.
(b) In demodulation of optical signal
(c) In light operated switches
(d) In electronic counters

(ii) Use of LED  
(a) Infrared LEDs are used in burglar alarm
(b) In optical communication
(c) LED's are used as indicator lamps in radio receivers
(d) In remote controls
4. Write the truth table for a two input AND gate.

\[
\begin{array}{ccc}
A & B & Y \\
0 & 0 & 0 \\
0 & 1 & 0 \\
1 & 0 & 0 \\
1 & 1 & 1 \\
\end{array}
\]

5. At what temperature does a semiconductor behave as an insulator?

Ans. Fermi temperature

6. If L and C are the inductance and capacitance of the tank circuit of an oscillator, what will be the frequency of oscillation?

Ans. Frequency of AC \( f = \frac{1}{2\pi\sqrt{LC}} \)

7. Semiconductors do not support strong current \( i.e. \), a semiconductor is damaged when strong current passes through it. Why?

Ans. Because bonds break up, crystal breakdown takes place and crystal becomes useless.

8. Draw \( I-V \) characteristic of a solar cell.

Ans. \( V_{oc} \rightarrow \text{Open Circuit Voltage} \)
\( I_{sc} \rightarrow \text{Short Circuit Current} \)

9. What is the phase difference between input and output waveform in the common emitter transistor amplifier?

Ans. Phase difference between input and output wave is \( \pi \) or 180°.

10. What is the direction of diffusion current in a junction diode?

Ans. The direction of diffusion current is from P to N in a semiconductor junction diode.

11. Draw a circuit diagram showing the biasing of a photodiode.
12. Name the semiconductor device that can be used to regulate an unregulated dc power supply.

**Ans.** Zener diode

13. Name the p.n. junction diode which emits spontaneous radiation when forward biased.

**Ans.** Light emitting diode (LED)

14. Name any one semiconductor used to make LED.

**Ans.** Ga As, Ga P

15. What is meant by ‘regulation’ as applied to a power supply?

**Ans.** Constant Power Supply

16. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. When polarity of the battery is reversed, the current drops to almost zero. Name the semiconductor device.

**Ans.** P–N junction

(Junction Diode)

17. In the following diagram write which of the diode is forward biased and which is reverse biased?

(i) Reverse biased

(ii) Forward biased

18. How does the energy gap in a semiconductor vary, when doped, with a pentavalent impurity?

**Ans.** The energy gap decreases.
19. What is the order of energy gap in a conductor, semiconductor and insulator.

**Ans.**
- Conductor - no energy gap
- Semiconductor <3eV
- Insulator >3eV

20. The ratio of the number of free electrons to holes \( \frac{n_e}{n_h} \) for two different materials A and B are 1 and < 1 respectively. Name the type of semiconductor to which A and B belong.

**Ans.**
\[
\frac{n_e}{n_h} = 1 \Rightarrow n_e = n_h \quad \therefore \text{Intrinsic semiconductor}
\]
\[
\frac{n_e}{n_h} < 1 \Rightarrow n_e < n_h \quad \therefore \text{p type extrinsic semiconductor}
\]

21. What are ground waves?

**Ans.** The em. wave radiated from antenna which are transmitted through space along the ground. If a radiowave from the transmitting antenna reaches to the receiving antenna either directly or after reflection from the ground, it is called a ground wave.

22. What are the two basic modes of communication?

**Ans.** (1) Analog (2) Digital

23. On what factors does the maximum coverage range of ground wave communication depend?

**Ans.**
(i) the frequency of transmitted wave
(ii) the power of the transmitter.

24. What is a base band signal?

25. What is the least size of an antenna required to radiate a signal of wavelength \( \lambda \)?

**Ans.** \( \frac{\lambda}{4} \)
26. Why do we use high frequencies for transmission?

Ans. To reduce the height of antenna.

27. Why is ionisation low near the earth and high, far away from the earth?

Ans. The U.V. radiation and other high energy radiations coming from the outer space on entering ionosphere of Earth’s atmosphere, are largely absorbed by the molecules of the layer of atmosphere. Due to this molecules get ionised. The degree of ionisation varies with height. At high attitude solar intensity is high, but density of Earth’s atmosphere is low. Therefore, there are few air molecules to be ionised. On the other hand, close to the earth, the density of Earth’s atmosphere is high but the radiation intensity is low. Due to of ionisation is low.

28. Define the modulation index.

Ans. Modulation index is defined as the ratio of the change in the amplitude of the carrier wave to the amplitude of the original carrier wave. It is also known as modulation factor.

29. What should be the length of dipole antenna for a carrier wave of frequency $2 \times 10^6$ Hz?

Ans. Length of dipole antenna : \[
\frac{\lambda}{2} = \frac{C}{2u}
\]

\[
L = \frac{3 \times 10^8}{2 \times 2 \times 10^6} = 0.75 \times 10^2 \text{ m}
\]

30. Why is the transmission of signals using ground wave communication restricted to a frequency of 1500 kHz?

Ans. The energy loss of a ground wave increases rapidly with the increase in frequency. Hence ground wave propagation is possible at low frequencies i.e. 500 KHz to 1500 KHz

31. What is meant by transducer? Give one example of a transducer.

Ans. Any device which converts energy from one from to another is called transducer e.g. a microphone converts sound energy (signal) into an electrical energy (signal).
32. A T.V. transmitting antenna is 81m tall. How much service area can it cover if the receiving antenna is at ground level?

**Ans.** The maximum distance up to which the signal transmitted from 80m tall T.V. antenna can be received.

\[ d = \sqrt{2hR} = \sqrt{2 \times 80 \times 6400000} = 32000m = 3.2km \]

Area = \(\pi d^2\) m²

33. What is attenuation?

**Ans.** Attenuation is the loss of strength of a signal during its propagation through the communication channel.

34. Why are repeaters used in communication?

**Ans.** Repeater is the combination of a transmitter an amplifier and a receiver which picks up retransmits it to the receiver sometimes with a change of carrier frequency. Multiple repeaters helps in extending the range of communication system.

35. What is the significance of modulation index? What is its range?

**Ans.** Modulation index determines the strength and quality of the transmitted signal. High modulation index ensures better quality and better strength. Its range is 0 to 1.

**SHORT ANSWER QUESTIONS (2 Marks)**

1. If the frequency of the input signal is f. What will be the frequency of the pulsating output signal in case of:

   (i) half wave rectifier?  
   (ii) full wave rectifier?

2. Find the equivalent resistance of the network shown in figure between point A and B when the p-n junction diode is ideal and:

   (i) A is at higher potential  
   (ii) B is at higher potential

![Diagram of network with 20Ω resistors and a diode](image-url)
3. Potential barrier of p.n. junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why?

4. Diode is a non linear device. Explain it with the help of a graph.

5. A n-type semiconductor has a large number of free electrons but still it is electrically neutral. Explain.

6. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated? Give reason.

7. What is the field ionisation in zener diode? Write its order of magnitude.

8. Power gain of a transistor is high. Does it mean the power is generated by the transistor itself? Explain.

9. What is the role of feedback in an oscillator circuit?

10. Why is a photo diode used in reverse bias?

11. Give four advantages of LED over incandescent lamp.

12. Explain the amplifying action of a transistor.


14. The output of a 2 input AND gate is fed as input to a NOT gate. Write the truth table for the final output of the combination. Name this new logic gate formed.

15. Write the truth table for the combination of gates shown.
16. The following figure shows the input waveform ‘A’ and ‘B’ and output waveform Y of a gate. Write its truth table and identify the gate.

<p>| | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>A</td>
<td>B</td>
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<td>t1</td>
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<td>t4</td>
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<tr>
<td>t7</td>
<td>t8</td>
<td></td>
</tr>
</tbody>
</table>

17. In the given circuit, D is an ideal diode. What is the voltage across R. When the applied voltage V makes the diode.

(a) Forward bias?
(b) Reverse bias?

18. A transistor is a current operated device. Explain.

19. Given here is a circuit diagram of a transistor as a NOT gate. Here the transistor has been represented by a circle with the emitter (e), base (b) and collector (c) terminals marked clearly. Carefully look at the polarity of the voltages applied and answer the following question.

(a) What is the type of transistor pnp or npn?
(b) Is the transistor in saturation or cutoff?
20. Why is photodiode used in reverse bias? Give one use of a photodiode.

21. Which special type of diode can act as a voltage regulator? Give the symbol of this diode and draw the general shape of its V-I characteristics.

22. In the working of a transistor, emitter base junction is forward biased, while the collector base junction is reverse biased, why?

23. In a transistor, base is slightly doped and is a thin layer, why?

24. Show the donor energy level in energy band diagram of n-type semiconductor.

25. Show the acceptor energy level in energy band diagram of p-type semiconductor.

26. What is the value of knee voltage in
   (a) Ge junction diode.
   (b) Si junction diode.

27. Which of the input and output circuits of a transistor has a higher resistance and why?

28. Draw the transfer characteristic for a transistor, indicating cut off region, active region and saturation region.

29. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two are joined end to end and connected to a battery as shown.

   ![Diode Circuit](image)

   (i) Will the junction be forward biased or reversed biased?
   (ii) Sketch a V–I graph for this arrangement.

30. In only one of the circuits given below the lamp L lights. Which circuits is it? Give reason for your answer.
31. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7V. Draw the output voltage waveform.

32. Why are Si and GaAs preferred materials for solar cell.

33. Write two differences between point to point communication and broadcast mode of communication. Give one example of each.

34. An audio signal of amplitude one fourth of the carrier wave, is used in amplitude modulation. What is the modulation index?

35. What are the essential components of a communication system? Explain with the help of a Block diagram.

36. Explain by a diagram, how space waves are used for Television broadcast.

37. Long distance radio broadcasts use short wave bands. Why?

Ans. The short waves are the waves of wavelength less than 200m or frequency greater than 1.5 MHz. They are absorbed by the earth due to their high frequency. These waves are reflected from ionosphere. These waves after reflection from ionosphere reach the surface of earth only at a large distance from the place of transmission. It means attenuation is less for short waves. It is due to this reason; the short waves are used in long distance broadcasts.

38. What is modulation? Why do we need modulation? Give two reasons.

40. Explain the propagation of sky wave in ionospheric layers with the help of a neat, labelled diagram.

41. Derive an expression for maximum range of an antenna of height ‘h’ for LOS communication.

42. Plot amplitude v/s frequency for an amplitude modulated signal.

43. Draw block diagram of simple modulator to obtain amplitude modulated signal.

44. It is necessary to use satellites for long distance TV transmission. Why?

   Ans. Yes, TV signals being of high frequency are not reflected by the ionosphere. Therefore, to reflect these signals, satellites are needed. That is why; satellities are used for long distance TV transmission.

45. What is the basic difference between an analog communication system and a digital communication system?

   Ans. An analog communication system makes use of analog signals, which vary continuously with time. A digital communication system makes use of a digital signal, which has only two values of voltage either high or low.

46. What is ground wave? Why short wave communication over long distance is not possible via ground waves?

   Ans. The amplitude modulated radiowaves having frequency 1500 kHz to 40 MHz (or wavelength between 7.5 m to 200 m) which are travelling directly following the surface of earth are known as ground waves. The short wave communication over long distance is not possible via ground because the bending of these waves become severe round the corners of the objects on earth and hence, their intensity falls with distance. Moreover the ground wave transmission becomes weaker as frequency increases.

**SHORT ANSWER QUESTIONS (3 MARKS)**

1. What is depletion region in p-n junction diode. Explain its formation with the help of a suitable diagram.

2. Explain the working of npn transistor as an amplifier and find an expression for its voltage gain.

3. What is rectification? With the help of a labelled circuit diagram explain half wave rectification using a junction diode.
4. Explain the working of a transistor as a switch with the help of a suitable circuit diagram.

5. Using block diagram show the feedback in an oscillator.

6. With the help of a circuit diagram explain the V–I graph of a p-n junction in forward and reverse biasing.

7. With the help of a circuit diagram, explain the input and output characteristic of a transistor in common emitter configuration.

8. What is p-n junction? How is p-n junction made? How is potential barrier developed in a p-n junction?


10. Give three differences between forward bias and reverse bias.


12. Write three differences between n-type semiconductor and p-type semiconductor.

13. Construct AND gate using NAND gate and give its truth table.


15. With the help of Block Diagram show how an amplitude modulated wave can be demodulated.

16. How an amplitude modulated wave can be produced? Give the equation of amplitude modulated wave.

17. What is amplitude modulation? Derive the equation of an amplitude modulated wave.

18. What are the different ways of propagation of radio waves? Explain briefly.

19. Draw block diagram for a :
   (a) Transmitter
   (b) Receiver
20. Write the band width of the following:
   (1) Telephonic communication
   (2) Video signal
   (3) TV signal

21. Explain the following terms:
   (1) Ground waves
   (2) Space waves
   (3) Sky waves

   **Ans.**
   (i) At low frequencies ($v < 2\text{MHz}$), radio-waves radiated by antenna travel directly following the surface of earth and are known as ground waves. [*($v < 2\text{MHz}$) (About this frequency, it weakens rapidly)]

   (ii) Frequencies ranging from 100-200 MHz penetrate ionosphere and hence can only be transmitted by using line-of-sight antenna or satellites, are known as space wave propagation.

   (iii) Frequencies between 2-20 MHz are reflected by the ionosphere and known as sky waves (or ionospheric propagation)

22. What does 'LOS communication¹ mean? Name the types of waves that are used for this communication. Give typical examples, with the help of suitable figure, of communication systems that use space mode propagation.

   **Ans.** Mode of radiowave propagation by space waves, in which the wave travels in a straight line from transmitting antenna to the receiving antenna, is called line-of-sight (LOS) communication. Two types of waves that are used for LOS communication are: Space wave and Ground wave. At frequencies above 40 MHz, LOS communication is essentially limited to line-of-sight paths.

**LONG ANSWER QUESTIONS (5 Marks)**

1. How does a transistor work as an oscillator? Explain its working with suitable circuit diagram. Write the expression for frequency of output.

2. What is the function of base region of a transistor? Why is this region made thin and lightly doped? Draw a circuit diagram to study the input and output characteristics of $npn$ transistor in a common emitter configuration. Show these characteristics graphically.
3. What is p-n junction diode? Define the term dynamic resistance for the junction. With the help of labelled diagram, explain the working of p-n junction as a full wave rectifier.

4. What are logic gates? Why are they so called? Draw the logic symbol and write truth table for AND, OR and NOT gate.

5. Describe (i) NAND gate (ii) NOR gate and (iii) XOR gate.

6. Two signals A, B as given below are applied as input to (i) AND (ii) NOR and (iii) NAND gates. Draw the output waveform in each case.

![Waveforms for input A and B](image)

**NUMERICALS**

1. In a p-n junction, width of depletion region is 300 nm and electric field of $7 \times 10^5$ V/m exists in it.
   (i) Find the height of potential barrier.
   (ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the n-side to the p-side?

2. In an npn transistor circuit, the collector current is 10mA. If 90% of the electrons emitted reach the collector, find the base current and emitter current.

3. An LED is constructed from a p-n junction of a certain semiconducting material whose energy gap is 1.9eV. What is the wavelength of light emitted by this LED?

4. Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt).
5. Determine $V_0$ and $I_d$ for the network.

6. A $p$-$n$ junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm? Justify your answer.

7. Determine $V_0$, $I_{d1}$ and $I_{d2}$ for the given network. Where $D_1$ and $D_2$ are made of silicon.

8. Two amplifiers with voltage gain 10 and 20 are connected in series. Calculate the output voltage for an input signal of 0.01 volt. 

9. A transistor has a current gain of 30. If the collector resistance is 6kΩ and input resistance 1kΩ. Calculate the voltage gain.

10. If the current gain of a CE – Amplifier is 98 and collector current $I_c = 4mA$, determine the base current.

11. Pure Si at 300 K has equal electron ($n_e$) and hole ($n_h$) concentration of $1.5 \times 10^{16}/m^3$. Doping by indium increases $n_h$ to $4.5 \times 10^{22}/m^3$. Calculate $n_e$ in the doped silicon.

12. The solar radiation spectrum shows that maximum solar intensity is near to energy $h\nu = 1.5$ eV. Answer the following :
   (i) Why are Si and GaAs are preferred materials for solar cells.
   (ii) Why CdS or CdSe ($E_g \sim 2.4$ eV) are not preferred.
(iii) Why we do not use materials like PbS ($E_g \sim 0.4 \text{ eV}$).

**Ans.**

(i) For photo-excitation, $h\nu > E_g$. Si has $E_g \sim 1.1 \text{ eV}$ and for GaAs, $E_g \sim 1.53 \text{ eV}$.

GaAs is better than Si because of its relatively higher absorption coefficient.

(ii) If we choose CdS or CdSe, we can use only the high energy component of the solar energy for photo-conversion and a significant part of energy will be of no use.

(iii) The condition $h\nu > E_g$ is satisfied, but if we use PbS, most of solar radiation will be absorbed on the top-layer of solar cell and will not reach in or near depletion region.

---

**NUMERICALS**

13. A sinusoidal carrier wave of frequency 1.5 MHz and amplitude 50 volt is amplitude modulated by sinusoidal wave of frequency 10 kHz producing 50% modulation. Calculate the frequency

(i) amplitude; (ii) frequencies of lower and upper side bands.

\[
\begin{align*}
\text{Lower side band} &= 1490 \text{ kHz} \\
\text{Upper side band} &= 1510 \text{ kHz} \\
\text{Amplitude} &= 125 \text{ volt}
\end{align*}
\]
14. An amplitude modulator consist of L–C circuit having a coil of inductance 8mH and capacitance of 5pF. If an audio signal of frequency 10kHz is modulated by the carrier wave generated by the L–C circuit, find the frequency of upper and lower side bands.

\[ \text{Ans. } f_c = 7.96 \times 10^5 \text{ Hz; Lower side band = 786 kHz; Upper side band = 806 kHz} \]

15. A T.V. Tower has height of 70m.

(i) How much population is covered by the T.V. broadcast if the average population density around the tower is 1000km\(^{-2}\)? Radius of earth is 6.4 \(\times\) 10\(^6\) m.

(ii) By How much should the height of the tower be increased to double the coverage area?

\[ \text{Ans. : Population covered = 28.16 lacs; Change in height = 70m} \]

16. A communication system is operating at wavelength \( \lambda = 750 \text{ nm} \). If only 1% of the frequency is used as channel bandwidth for optical communication then find the number of channels that can be accommodated for transmission of

(i) an Audio signal requiring a bandwidth of 8 kHz.

(ii) an Video T.V. signal requiring a bandwidth of 4.5 KHz.

17. Calculate the percentage increase in the range of signal reception, if the height of TV tower is increased by 44%. \[ \text{Ans. : 20% increase} \]

18. A transmitting antenna at the top of a tower has a height 32m and the hight of the receiving antenna is 50m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4 \(\times\) 10\(^6\)m.

\[ d_m = \sqrt{2 + 64 \times 10^5 \times 32 + \sqrt{2} \times 64 \times 10^5 \times 50} \]

\[ \text{Sol : } = 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10} \text{ m} \]

\[ = 144 \times 10^2 \times \sqrt{10} \text{ m} = 45.5 \text{ km} \]

19. A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.
Sol: (a) Modulation index = 10/20 = 0.5 = $\frac{A_m}{A_c}$

(b) The side bands are at (1000 + 10) kHz = 1010 kHz and (1000 – 10) kHz = 990 kHz.

20. A carrier wave of peak voltage 12\(v\) is used to transmit a message signal. What should be the peak voltage of the modulating signal in order to have a modulation index of 75%?

Sol: $\mu = 0.75 \frac{A_m}{A_c}$

Hence, $A_m = 0.75 \times 12 \text{ V} = 9 \text{ V}$

21. A modulating signal is a square wave, as shown in figure. The carrier wave is given by $c(t) = 2 \sin (8 \pi t)$ volts.

(i) Sketch the amplitude modulated waveform
(ii) What is the modulation index?

Sol: (i)

(ii) $\mu = 0.5$
22. For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is found to be 2 V. Determine the modulation index, \( \mu \).

What would be the value of \( \mu \) if the minimum amplitude is zero volt?

**Sol:** The AM wave is given by \((A_c + A_m \sin \omega_m t) \cos \omega_c t\),

The maximum amplitude is \( M_1 = A_c + A_m \) while the minimum amplitude is \( M_2 = A_c - A_m \)

Hence the modulation index is

\[
\mu = \frac{A_m}{A_c} = \frac{M_1 - M_2}{M_1 + M_2} = \frac{8}{12} = \frac{2}{3}.
\]

**VALUE BASED QUESTIONS**

1. A child uses a semi conductor device in listening radio & seeing pictures on T.V. He was asked to suggest the techniques as the cost of LPG/CNG is going up, to cope up with future situations.

(i) What are the values developed by the child?

(ii) What may be the suitable semi conductor material used for utilization of maximum solar energy with reasons?

2. Raju was enjoying TV programme at his home with his family at night. Suddenly the light went off causing darkness all over. Mother asked Raju to bring candle along with matchstick from kitchen to put on TV switch off. Raju at once picked the mobile phone and pressed the buttons lighting up the surrounding. Her mother was surprised and asked where from the light was coming. Raj proudly showed her the mobile.

(i) Which values displayed by Raju?

(ii) Which material is used in LED?
1. (i) Awareness of social problems, Generates new idea with fluency.
   (ii) See NCERT at Page No. 49 & 490.

2. (ii) Creative thinking
   (iii) NCERT (SEMI conductors).

3. Deepa's uncle wants to talk to his son in USA. He does not have much money to spend on telephone calls. He has a computer at his home. Deepa told her uncle that he can talk to his son with the help of computer and told him about internet. Her uncle now talks to his son every day. He thanked Deepa for giving useful advice.
   (i) What according to you are the values displayed by Deepa.
   (ii) How does internetwork?

4. Renu has to take admission in some professional college. It was last date of admission and Renu left her birth certificate at her home. College was very far from the home. She called her brother and he faxed the birth certificate. She got the admission and thanked her brother.
   (i) What value was displayed by Renu?
   (ii) What value was displayed by her brother?

ANSWER

3. (i) Caring and creating awareness.
   (ii) NCERT

4. (i) Awareness
   (ii) Understanding
VERY SHORT ANSWER QUESTIONS (1 Mark)

1. \( n_e = n_h \).

2. (i) zero  (ii) Infinite

7. Frequency of A.C. \( f = \frac{1}{2\pi\sqrt{LC}} \).

8. Because bonds break up, crystal breakdown takes place and crystal becomes useless.

9. \( I - V \) characteristic of solar cell:

10. Phase difference between input and output waveform is \( \pi \) or 108°.

11. Positive feedback.

12. Direction of diffusion current is from P to N in a semiconductor junction diode.

15. Light emitting diode.

16. GaAs, GaP.

17. Constant power supply.

20. The energy gap decreases.

21. Conductor – no energy gap

   Semi conductor – \(< 3 \text{ eV}\)

   Insulator – \(> 3 \text{ eV}\).

22. \( \frac{n_e}{n_h} = 1 \Rightarrow n_e = n_h \) : intrinsic semiconductor.
\[ \frac{n_e}{n_n} < 1 \Rightarrow n_e = n_n : p\text{-type extrinsic semiconductor.} \]

**SHORT ANSWER QUESTIONS (2 Marks)**

1. Frequency of output in half wave Rectifier is \( f \) and in full wave rectifier is \( 2f \).

2. Equivalent resistance is
   
   (i) \( 10 \Omega \)
   
   (ii) \( 20 \Omega \)

3. Because there is no free charge carrier in depletion region.

6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.

10. In this case diode is sensitive and it gives very large amount of current in this situation.

15.

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17. (a) V.  
    (b) Zero

18. Change in \( I_c \) is related to \( I_b \) and not to the base voltage change \( (\delta V_{be}) \).

19. (a) \( npn \)  
    (ii) saturation

21. Zever diode

(i) Reverse Bias

(ii) Iosmard Bias
22. To make transistor to act as an amplifier.

24. N.C.E.R.T. pg. 477

25. N.C.E.R.T. pg. 477

26. Ge ~ 0.2V
Si ~ 0.7 V.

27. Output circuit is reverse biased, which has large resistance.

28. (i) Reverse bias

\[ \text{(ii) } \]

\[ V \]

\[ I (\text{HA}) \]

29. (b)

30. Output waveform is:

\[ 2V \]

\[ V \]

\[ \text{T/2 } \]

\[ T \]

\[ 3T/2 \]

\[ t \]

\[ \text{T period of AC input} \]

**NUMERICALS**

1. (i) \( V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21V \)

(ii) Kinetic energy = eV = 0.21 eV

2. Emitter current \( I_e = \frac{10}{90} \times 100 = 11.11 \text{ mA} \)
Base current \( I_b = I_e - I_c = 11.11 \text{ mA} \)

4. \[ I = \frac{E_1 - E_2 - V_d}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95 \text{ mA} \]

5. \[ V_0 = E - V_{sl} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2 \text{ V} \]

\[ I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82 \text{ mA}. \]
1. Define the term ‘Mobility’ of charge carriers in a conductor. Write its S.I. unit.

**Ans.** Velocity per unit electric field with the charges is called as Mobility or 
\[ \mu = \frac{V}{E} \]
S.I. unit = \( N^1 \) C m s\(^{-1}\) or m\(^2\) V\(^{-1}\) s\(^{-1}\) [1/2]

2. The carrier wave is represented by 
\[ C(t) = 2 \sin (8\pi t) \text{ volt} \]
A modulating signal is a square wave as shown. Determine modulation index.

![Modulation Index Diagram]

**Ans.** \( A_m = 1, A_c = 2 \), [1/2]
\[ \mu = \frac{A_m}{A_c} = 1/2 = 0.5 \] [1/2]

3. “For any charge configuration, equipotential surface through a point is normal to the electric field.” Justify.

**Ans.** If the field were not normal to the equipotential surface, it would have non-zero component along the surface. This field may move the charge along the surface without any energy supply violating the law of conservation of energy. [1]

4. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?
Due to motion, in metallic bob, eddy current will be produced which will oppose the motion and slows the metallic bob. It will take more time in reaching the ground. So, the glass bob will reach the ground earlier. [1]

5. Show variation of resistivity of Copper as a function of temperature in a graph.

\[
\rho = f(T)
\]

6. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?

Ans. Since image coincides with object, it implies that ray must be falling normally on the plane mirror. This implies that the ray after passing through lens becomes parallel. So, object must be at the focus of lens.

So, focal length of lens = 20 cm.

7. Write the expression, in a vector form, for the Lorentz magnetic force \( \vec{F} \) due to a charge moving with velocity \( \vec{v} \) in a magnetic field \( \vec{B} \). What is the direction of the magnetic force?

Ans. \( \vec{F} = q(\vec{v} \times \vec{B}) \)

The direction of magnetic force must be perpendicular to the plane containing \( \vec{v} \) and \( \vec{B} \) and is given by Fleming’s left hand rule. [1/2]

8. The figure given below shows the block diagram of a generalized communication system. Identify the element labelled ‘X’ and write its function.
9. Out of the two magnetic materials, ‘A’ has relative permeability slightly greater than unity while ‘B’ has less than unity. Identify the nature of the materials ‘A’ and B’ Will their susceptibilities be positive or negative.

Ans. Material A is paramagnetic. Material B is diamagnetic. Susceptibility of A is positive and susceptibility of B is negative.

10. Given a uniform electric field \( E = 5 \times 10^3 \, \text{i N/C} \), find the flux of this field through a square of side 10 cm, whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x-axis?

Ans. When plane of square in parallel to YZ-plane, flux of electric field

\[
\phi = \vec{E} \cdot \vec{A} \text{ as area vector is parallel along } x\text{-axis}
\]

\[
= \left( 5 \times 10^3 \right) \left( 10 \times 10 \times 10^{-4} \right) = 50 \text{Vm}
\]

\[
\phi_1 = 50 \, \text{Vm}
\]

When plane make 30° with x-axis

\[
\phi_2 = EA \cos \theta \left( 5 \times 10^3 \right) \left( 10 \times 10 \times 10^{-4} \right) \cos 60 = 25 \text{Vm}
\]

11. For a single slit of width “d”, the first minimum of the interference pattern of a monochromatic light of wavelength \( \lambda \) occurs at an angle of \( \frac{\lambda}{d} \). At the same angle of \( \frac{\lambda}{a} \), we get a maximum for two narrow slits separated by a distance “a”. Explain.
Ans. The condition for minima is single slit is
\[ a \sin \theta = n\lambda. \]
For first minima and for small angle
\[ a\theta = \lambda, \]
\[ \theta = \frac{\lambda}{a}. \]
The minima can be explained by dividing two slits in two equal halves. For every secondary source in upper slit cancels the corresponding contribution of secondary source in second slit which differ’s in path length by \( \frac{\lambda}{2} \). [1]
Whereas the condition for maxima in two narrow slits is
\[ a \sin \theta = n\lambda. \]
for first maxima and for small angle \( \theta = \frac{\lambda}{a} \) [1]
In this case the path difference between the waves reaching screen is \( \lambda \) and will be contributing to maximum.

12. Write the truth table for the combination of the gates shown. Name the gates used.

Ans. R is OR Gate
\[ \left[ \frac{1}{2} + \frac{1}{2} + 1 \right] \]
and S in AND Gate

Truth table:

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<th>A</th>
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12. Identify the logic gates marked ‘P’ and ‘Q’ in the given circuit. Write the truth table for the combination.

![Logic gate circuit diagram]

Ans. P in NAND Gate  
Q is OR Gate

[1/2+1/2+1]  
Truth Table:

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13. State Kirchhoff’s rules. Explain briefly how these rules are justified.

Ans. **Kirchhoff’s Current (Junction) Rule**: At any junction, the sum of the currents entering the junction is equal to the sum of current leaving the junction.

When currents are steady, there is no accumulation of charge at any junction or at any point in a line. This is based on the conservation of charge.

**Kirchhoff loop rule**: The algebraic sum of changes in potential difference across all the elements in any closed loop involving resistors and cells is zero.

This law is based on the conservation of energy. [1]

14. A capacitor ‘C’ a variable resistor ‘R’ and a bulb ‘B’ are connected in series to the ac main; in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?
(a) When dielectric slab is introduced between the plates of capacitor, its capacitance increases and reactance decreases. This increases the current flowing in bulb and so the bulb glows brighter with resistance unaltered.

(b) When resistance increases, current flowing in circuit decreases. Glow of bulb decreases.

15. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.

Ans. Cyclotron: It is a device used to accelerate positively charged particles like protons, deuterons, a-particles etc to very high energies.

Principle: A charged particle can be accelerated to very high energies with the help of smaller values of oscillating electric field. A perpendicular magnetic field which throws the charged particle into a circular motion, repeatedly brings the charge into the oscillating electric field such that repeated acceleration can happen.

Working

1. Suppose the positive ion enters the gap between the two dees & finds D, to be negative and it gets accelerated towards D₁.

2. As it enters D, it doesn’t experience any electric field due to shielding effect of the metallic dee.

3. The perpendicular magnetic field throws it into a circular path.

4. At the instant the ion comes out of D₁, it finds D₁ to be +ve & D₁ –ve. It now gets accelerated towards dee D₂.

5. It now moves faster through D₂ describing a larger semicircle than before.

6. Thus, the +ve ion will go on accelerating every time it comes into the gap between the dees and will go on describing circular path of greater and greater radius with greater speed and finally acquire a sufficiently high energy.
7. The accelerated ion is ejected through a window by a deflecting voltage and hits the target.

16. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of ±8 nC.

Ans. Torque $\tau = PE \sin \theta$

$$E = 4 \times 10^{-11} V / m$$

Potential energy of dipole

$$U = -PE \cos \theta$$

$$U = -8 \times 10^{-9} \times 4 \times 10^{-11} \times \frac{1}{2} = -64 J$$

$$U = -64 J$$

17. A proton and a deuteron are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less momentum. Give reasons to justify your answer.

Ans. $V = $ Accelerating potential

(i) DeBroglie Wavelength $\lambda = \frac{h}{mv} = \frac{h}{p}$

since $p = \sqrt{2m \times eV}$

$$\lambda_d = \frac{h}{\sqrt{2 \times 2m \times eV}} = \frac{h}{\sqrt{4m \times eV}}$$

The de Broglie wavelength for proton is more than deBroglie wavelength of deuteron.
(ii) Kinetic energy of proton $K_p = eV$. So momentum $P_p = \sqrt{2meV}$

Kinetic energy of deuteron $K_d = 2eV$. So momentum $P_d = \sqrt{4m \times eV}$

So, momentum of proton is less than that of the deuteron.

18.(i) Monochromatic light of frequency $6.0 \times 10^{14}$ Hz is produced by a laser. The power emitted is $2.0 \times 10^{-3}$ 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.

Ans. (i) We know energy of photon = $hv$

$$= 6.63 \times 10^{-34} \times 6 \times 10^{14} \text{ Joule} = 6 \times 6.63 \times 10^{-20}$$

So, No. of photons emitted per second on an average by the source is

$$= \frac{\text{Power}}{\text{Energy of one photon}} = \frac{2 \times 10^{-3}}{6.63 \times 6 \times 10^{-20}} = \frac{10^{17}}{19.89} = 5.03 \times 10^{15}$$

(ii)

![Plot showing variation of photoelectric current versus intensity of incident radiation](image)

19. A $12.5 \text{ eV}$ beam of electrons is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited?

Calculate the wavelength of the first member of Lyman and first member of Balmer series.

Ans. (i) $\Delta E = 12.5 \text{ eV}$

Energy in first shell = $-13.6 \text{ eV}$

Energy in $n$th shell = $\frac{13.6}{n^2}$
13.6 - 12.5 = \frac{13.6}{n^2}

n^2 = \frac{13.6}{1.1}

n^2 = 12.36

n = 4 (Maximum 4th level)

(ii) For Layman series, \( \frac{1}{\lambda} = R \left( \frac{1}{n_1} - \frac{1}{n_2} \right) = \frac{3R}{4} \)

For Balmer series, \( n_1 = 2, n_2 = 3 \)

\( \frac{1}{\lambda} = R \left( \frac{1}{2^2} - \frac{1}{3^2} \right) \Rightarrow \lambda = \frac{36}{5R} \)

20. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents that this move would be a health hazard.

Ultimately her parents agreed:

(1) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health?

(2) By objecting to this move of her parents, what value did Sunita display?

(3) Estimate the range of e.m. waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km)

Ans. (1) Mobile tower requires giant structure at the top level of any building. All through the year it will be an action point where link will be made with mobiles. In case of large scale wind, there is a fear of fall of the structure. Also, the signals wavering around may affect all human life in the neighbourhood. [1+1+1]

(2) By objecting to this move of her parents, Sunita displaced the values that [Any One]

(i) She is concerned about large scale damage caused by cyclone/high speed wind with probable loss of life.
(ii) She is keeping track (knowledgeable) of the research that is going on in the influence of these signals on human life when exposed for long duration.

(iii) She has foresight of the problems that they may face at large.

(iv) She is concerned about the welfare of the community.

(3) \[ \text{Range} = R = \sqrt{2hR_e} = \sqrt{2 \times 20 \times 6400 \times 10^3} \]
\[ = \sqrt{4 \times 64 \times 10^6} = 2 \times 8 \times 10^3 = 16 \text{Km} \]

21. A potentiometer wire of length 1.0 m has a resistance of 10.0. It is connected to a 6 V battery in series with a resistance of SS1. Determine the emf of the primary cell which gives a balance point at 40 cm.

Ans. At balancing point,

![Potentiometer Diagram]

Current flowing in the primary circuit is \[ i = \frac{6}{10 + 5} = \frac{6}{15} = \frac{2}{5} \text{A} \]

Potential difference across wire AB

\[ V = \frac{2}{5} \times 10 = 4 \text{volt} \]

Potential gradient \[ \frac{V}{L} = \frac{4}{1} = 4 \text{V} / \text{m} \]

At balance point \[ \varepsilon = \frac{V}{L} \times 1 = 4 \times \frac{40}{100} = 1.6 \text{Volt} \]

\[ \varepsilon = 1.6 \text{Volt} \] \[1\]

22.(a) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.
(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.

Ans. (a) Compound Microscope

(b) Magnification produced by eye-piece

\[ m_e = \frac{D}{u_e} = 5 \]

\[ \Rightarrow \quad u_e = \frac{20}{5} = 4 \text{ cm} \]

For eye-piece

\[ \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \]

\[ \frac{1}{-20} - \frac{1}{-4} = \frac{1}{f_e} \]

\[ \frac{-1+5}{20} = \frac{1}{f_e} \]

\[ f_e = \frac{20}{4} \text{ cm} = 5 \text{ cm} \]

Since

\[ m = m_0 \times m_e = \frac{V_0}{f_0} \times \frac{D}{u_e} = \frac{V_0}{f_0} \times 5 \]
20 = \frac{v_0 \times D}{f_0} = \frac{v_0 \times 5}{f_0}

v_0 = 14 - 4 = 10 \text{ cm}

f_0 = \frac{v_0 \times 5}{20} = \frac{10 \times 5}{20} = 2.5 \text{ cm}

23. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.

(b) Suppose the lower half of the concave mirror’s reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain.

Ans. (a) Image formation of a mobile as an object is shown. Image of one end of the mobile OD is at the same place while the image of the other end AB is A’B’.

The magnification is not uniform along the length and height as, based on the position of the portion of the object, magnification is formed. The portion O of the object and the portion A of the object are separated by a length causing the variation in magnification as \[ m = \frac{v}{u}. \]

(b) We know intensity of image is directly proportional to area of the reflecting surface. When half part is covered reflecting surface area decreases. So, intensity of image decreases. But full image of the object will be formed at the same position as light falls at every point on the mirror from every point of the object.

24. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

(b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop a b c d a.
Ans. (a) Assume the capacitor is being charged and, at some moment, has a charge \( q \) on it.

The small work needed to transfer a charge \( dq \) from one plate to the other:

\[
dW = Vdq = \frac{q}{C} dq
\]

The total work required:

\[
W = \int_0^Q \frac{q}{C} dq = \frac{Q^2}{2C}
\]  \[2+1\]

The energy can be considered to be stored in the electric field between the plates.

**Energy Density**

Suppose we have a parallel plate capacitor, as in figure, the field strength between the plates and total charge are given in terms of charge density \( \sigma \) and plate area \( A \) by

\[
E = \frac{\sigma}{\varepsilon_0}
\]

\[
Q = A\sigma
\]
So, energy stored can be expressed in terms of field strength

\[ U = \frac{1}{2} Q^2 \]

\[ \therefore \quad U = \frac{1}{2} (A\sigma)^2 \frac{d}{\varepsilon_0 A} \]

\[ \therefore \quad U = \frac{1}{2} A^2 \sigma^2 d \frac{\varepsilon_0}{\varepsilon_0 A} \]

\[ \therefore \quad U = \frac{1}{2} \varepsilon_0 \sigma^2 d \]

making \( U = \frac{1}{2} \varepsilon_0 E^2 \times (\text{Volume between the plates}) \)

So, energy density, i.e., energy stored per unit volume \((u_E)\) is

\[ u_E = \frac{U}{\text{Volume}} = \frac{1}{2} \varepsilon_0 E^2 \]

(b) Since, electrostatic field that exists between the positive and negative plate is a conservative field, the amount of work done in the given path is zero.

OR

24.(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area \(A\) and plate separation \(d\).

(b) Two charged spherical conductors of radii \(R\), and \(R\), when connected by a conducting wire acquire charges \(q\), and \(q\), respectively. Find the ratio of their surface charge densities in terms of their radii.

**Ans.**

(a) Let \(A = \text{surface area of each plate} \).

\( d = \text{Separation between the plates} \)

If \(\sigma\) is surface charge density of the plates, then electric field between the plates is given by \( E = \frac{\sigma}{\varepsilon_0} \)

Since, the field is uniform, the potential difference between the plates is
\[ V = Ed = \frac{\sigma d}{\varepsilon_0} \]

The total charge on each plate is \( \pm Q = \pm \sigma A \)

\[ \therefore \text{ Capacitance of a parallel plate capacitor.} \]

\[ C = \frac{Q}{V} = \frac{\sigma A}{\sigma d} \text{ making } C = \frac{\varepsilon_0 A}{d} \]

(b) Since, they are connected, their potentials will be equal with the charges.

\[ \text{Ratio of surface charge densities, } \frac{\sigma_1}{\sigma_2} = \frac{\frac{q_1}{4\pi R_1^2}}{\frac{q_2}{4\pi R_2^2}} = \frac{q_1 (R_2)^2}{q_2 (R_1)^2} \]

25.(a) State Ampere's circuital law, expressing it in the integral form.

(b) Two long coaxial insulated solenoids, S, and S', of equal lengths are wound one over the other as shown in the figure. A steady current "I" flow through the inner solenoid S, to the other end B, which is connected to the outer solenoid S', through which the same current "I" flows in the opposite direction so as to come out at end A. If \( n_1 \) and \( n_2 \) are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system.

Ans.(a) Integral of magnetic field \( [\bar{B} \cdot d\bar{l}] \) around a closed imaginary loop is \( \mu_0 \) times current encircled by the loop.

\[ [\bar{B} \cdot d\bar{l}] = \mu_0 I \] [1]
(b)(i) Magnetic field at any point inside the long solenoid is $\mu_0 n I$

Magnetic field due to bigger solenoid = $\mu_0 n_2 I$ towards point ‘B’

Magnetic field due to smaller solenoid = $\mu_0 n_1 I$ towards point ‘A’  \[1\]

So, net magnetic field = $\mu_0(n_1 - n_2) I$ towards point ‘A’  \[1\]

(ii) Net field due to long solenoid outside is zero, as the fields due to two diametrically opposite elementary lengths will be zero.  \[1\]

26. Answer the following :

(a) Name the em waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

(b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.

(c) An em wave exerts pressure on the surface on which it is incident. Justify

Ans.(a)Microwaves

Frequency range = $3.0 \times 10^{11}$ Hz to $1 \times 10^9$ Hz  \[1+1+1\]

(b) In the absence of atmosphere, the surface temperature will be less as the higher wavelength rays reflected from the surface will not be trapped.

(c) For a given em wave of energy $E$ moving with a speed $c$, momentum transfer is $P = \frac{E}{c}$ happens in a very short time with high velocity. So the momentum transfer of smaller magnitude will exert a force and pressure on any surface.
27. (a) Deduce the expression, \( N = N_0 e^{-\lambda t} \), for the law of radioactive decay.

(b) (i) Write symbolically the process expressing the \( \beta^+ \) decay of \( ^{22}_{11}\text{Na} \). Also write the basic nuclear process underlying this decay.

(ii) Is the nucleus formed in the decay of the nucleus \( ^{22}_{11}\text{Na} \), an isotope or isobar?

Ans. (a) Let \( N_0 \) = Total number of atoms present originally in a sample at time \( t = 0 \).

\( N \) = Total number of atoms left undecayed in the sample at time \( t \)

\( dN \) = A small number of atoms that disintegrate in a small interval of time \( dt \)

\( \therefore \) Rate of disintegration of the element

\[ R = -\frac{dN}{dt} \quad \text{[Minus sign indicates that the number of atoms left undecayed decreases with time]} \]

According to radioactive decay law,

\[ -\frac{dN}{dt} \propto N \]

\[ R = -\frac{dN}{dt} = \lambda N \]

\( \lambda \) = Disintegration constant

\[ \frac{dN}{N} = -\lambda dt \]

Integrating both side \( \int \frac{dN}{N} = \int [-\lambda dt] \)

\[ \log_e N = -\lambda t + C \]

\( C \) = Constant of integration \( \quad \) \( t = 0 \)

\( N = N_0 \)

\( \log_e N_0 = \lambda \times 0 + C \)
\[ C = \log_e N_0 \]
\[ \log_e N = -\lambda t + \log_e N_0 \]
\[ \log_e N - \log_e N_0 = -\lambda t \]
\[ \log \frac{N}{N_0} = -\lambda t \]

i.e., \[ \frac{N}{N_0} = e^{-\lambda t} \]

\[ N = N_0 e^{-\lambda t} \]

(b)(i) The basic nuclear process underlying this +β decay.

\[ p \rightarrow n + e^+ + \nu \]

The reaction is \[ ^{22}_{11}\text{Na} \rightarrow \beta^+ + ^{22}_{10}\text{Ne} + \nu \]

(ii) It is an isobar.

28.(a) (i) 'Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.

(ii) Light waves each of amplitude "a" and frequency "f" of emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by \[ y_1 = a \cos \omega t \] and \[ y_2 = a \cos(\omega t + \phi) \] where \( \phi \) is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(b) In Young’s double slit experiment, using monochromatic light of wavelength \( \lambda \), the intensity of light at a point on the screen where path difference is \( \lambda \), is K units. Find out the intensity of light at a point where path difference is \( \lambda /3 \).

Ans. (a)(i) In independent monochromatic sources phase difference changes at a rate of \( 10^8 \) Hz. Hence, the interference pattern obtained also fluctuates with \( 10^8 \) Hz and therefore, it is not sustainable as result of peristance of vision.

(ii) The phase difference between two waves arising from slits A and B is \( \phi \). Then,
y_1 = a \cos \omega t \text{ and } y_2 = a \cos(\omega t + \phi).

Therefore, the resultant displacement will be given by

\[ y = y_1 + y_2 = a \cos \omega t + a \cos(\omega t + \phi) \]

\[ y = 2a \cos \frac{\phi}{2} \cos \left( \omega t + \frac{\phi}{2} \right) \]

The amplitude of the resultant displacement is given by

\[ R = 2a \cos \left( \frac{\phi}{2} \right) \]

As, intensity \( \propto \) (amplitude)^2

\[ \therefore \text{Resultant intensity}, \quad I = 4a^2 \cos^2 \left( \frac{\phi}{2} \right) \]

(b) As the resultant intensity at a point, \( I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi \)

When the path difference = \( \lambda \), phase difference = 0°

\[ \therefore I_R = I_1 + 1 + 2\sqrt{I_1 \times 1} \cos 0° = 2I + 2\sqrt{I^2} \times 1 = 2I + 2I = 4I = K. \]

When the path difference = \( \frac{\lambda}{3} \), phase difference = \( \frac{2\pi}{3} \).

\[ \therefore I'_R = I_1 + 1 + 2\sqrt{I_1} \cos \left( \frac{2\pi}{3} \right) = 2I + 2\sqrt{I^2} \times \left( -\frac{1}{2} \right) = 2I - \frac{2I}{2} = I \]

\[ \therefore I' = \frac{K}{4} \]

**OR**

30. (a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a Polaroid gets polarised?

(b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when \( \mu = \tan i_B \), where \( \mu \) is the refractive index of glass with respect to air and \( i_B \) is the Brewster's angle.
Ans. (a)

Polariser has a pass axis along which if any electric field vector lies, it will get transmitted to the other side. If an electric field vector which is perpendicular the pass axis, falls on the polariser then, it gets absorbed. We know that an unpolarised light has two components of electric field vector, one of which is parallel to the pass axis and the other which is perpendicular to the pass axis. Since, the perpendicular component gets absorbed, the output light obtained is a polarised light whose electric field vector is parallel to the pass axis.

(b) When unpolarised light is incident on the interface of two transparent media the reflected light is polarised. If the unpolarised light is incident at the angles 0° or 90°, the reflected ray remains unpolarised. When the reflected wave is perpendicular to the refracted wave, the reflected wave is totally polarised. The angle of incidence in this case is called polarising angle or Brewster’s angle \((i_p)\).

Brewster’s Law says that when an unpolarised light is incident on a transparent surface of refractive index \((n)\) at the polarising angle \((i_p)\) such that the reflected ray and the refracted ray are perpendicular to each other, the reflected light is totally plane polarised and in that condition \(n = \tan i_p\).

From the diagram,

\[ i_p + 90° + r = 180° \]

\[ i_p + r = 90° \text{ or } r = 90 - i_p \]
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29. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.

(b) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of

(i) Magnetic flux versus the current

(ii) Induced emf versus $\frac{dl}{dt}$

(iii) Magnetic potential energy stored versus the current.

Ans. (a) As shown in the figure, moving the magnetic closer to the coil increases the flux associated with the coil. To oppose the rise in magnetic flux, a north pole is developed in the coil, this causes an induced current in the anti-clockwise direction as seen from the side of the magnet. [2+1+1+1]

(b) (i) Magnetic flux $\phi_B = LI$

(ii) $\varepsilon = -\frac{L dl}{dt}$
(iii) \[ u_B = \frac{l}{2\mu_0}B^2 = \frac{l}{2\mu_0}(\mu_0 n i)^2 \]

\[ i \rightarrow \text{current} \]

\[ u_B = \frac{\mu_0}{2}n^2i^2 \]

\[ u_B \propto i^2 \]

OR

29.(a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of

(i) Magnetic flux and

(ii) Alternating emf versus time generated by a loop of wire rotating in a magnetic field.

(b) Why is choke coil needed in the use of fluorescent tubes with ac mains?

Ans.(a) \[2+1+1\]

**Principle:** A dynamo or generator is a device which converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction. Magnetic flux changes as the coils orientation varies with the rotation \( (\phi = BA \cos \theta = BA \cos \omega t) \)

**Construction:** It consists of four main parts—
• **Field magnet:** It produces the magnetic field. For a low power dynamo, the magnetic field is generated by a permanent magnet but for a large power dynamo, the magnetic field is produced by an electromagnet.

![Diagram of a dynamo with labeled parts: Field magnet, Armature, Slips rings, Brushes, Load resistance.]

- **Armature:** It consists of a large number of turns of insulated copper wire on a soft iron core. It can revolve round the axis between the two poles of the field magnet. The soft iron core provides support to the coils and increases the magnetic field through the coil.

- **Slip rings:** The slip rings R₁ and R₂ are two metal rings to which the ends of the armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.

- **Brushes (B₁ and B₂):** These are flexible metal plates or carbon rods which are fixed and constantly touch the revolving rings. The output current in external load resistance R_L is taken through these brushes.

  (i) \( \phi_B = NBA \cos \cot \)

  \[ T = \frac{2\pi}{\omega} \] (Time period)

  (ii) \( E = \frac{d\phi}{dt} = NAB\omega \sin \omega t = E_0 \sin \omega t \) making \( E_D = NAB\omega \)

\[217\]
(b) Fluorescent tubes have a choke coil which has some inductive reactance, which causes a delay in the growth of current, thereby reducing the voltage across fluorescent tube. This allows the low frequency to pass through. [1]

30. (a) State briefly the processes involved in the formation of p-n junction explaining clearly how the depletion region is formed.

(b) Using the necessary circuit diagrams, show how the V-I characteristics of a p – n junction are obtained in (i) Forward biasing (ii) Reverse biasing. How are these characteristics made use of in rectification? [2+1+1+1]

Ans. (a) Formation of p – n junction: Part of p-type can be converted into n-type by adding pentavalent impurity. There is concentration gradient between p and n sides, holes diffuse from p side to n side (p → n) and electrons move from (n → p) creating a layer of positive and negative charges on n and p side respectively called depletion layer. External bias is applied to cause charges to flow.

(b) p – n junction under forward bias: When p - side is connected to positive terminal and n - side to negative terminal of external voltage, it is said to be forward biased. The applied voltage V is opposite to built in potential V₀ hence depletion layer width decreases and barrier height is reduced to (V₀ – V). There is minority carrier injection, hence charges begin to flow. Current is in the order of mA.
**p – n junction under reverse bias:** The direction of applied voltage is same as direction of barrier potential, so barrier height increases to \( \nu_0 + V \). This suppresses flow of electrons from \( n \rightarrow p \) and holes from \( p \rightarrow n \). Diffusion current decreases but drift of electrons and holes under the electric field affect remains. This drift current is few \( \mu \text{A} \).

**Study of V – I characteristics of a diode:** The circuit to study the variation of current as a function of applied voltage is shown. Battery is connected to potentiometer (or rheostat) to change applied voltage. In forward bias we use milliammeter and reverse bias we use microammeter.
**Half wave rectifier**: Junction diode allows current to pass through only if it is forward biased, hence a pulsating voltage will appear across the load only during positive half cycles when diode is F.B.

(a) Diode rectification Circuit

(b) Input ac and output voltage waveforms

OR

30.(a) Differentiate between three segments of a transistor on the basis of their size and level of doping.
(b) How is a transistor biased to be in active state?

(c) With the help of necessary circuit diagram, describe briefly how n-p-n transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the ac current gain.

**Ans.** (a)

<table>
<thead>
<tr>
<th></th>
<th>Emitter</th>
<th>Base</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doping</td>
<td>Highest doping</td>
<td>Least doping</td>
<td>Moderate Doping</td>
</tr>
<tr>
<td>Size</td>
<td>Moderate</td>
<td>Least</td>
<td>Largest</td>
</tr>
</tbody>
</table>

(b) Forward bias of input circuit is more than the barrier potential across the input junction. Collector base junction is reverse biased.

(c) **Transistor as an amplifier (C E configuration):** Transistor works in active region.

Output, \( V_O = V_{CC} - I_C R_C \) \( \ldots(1) \)

If input voltage increases, output voltage decreases. \( V_i \) and \( V_O \) are out of phase.

\[ A_V = \text{small signal voltage gain} = \frac{DV_O}{DV_i} \] \( \ldots(2) \)

Since \( V_{CC} \) and \( R_C \) are constant,

\[ \Delta V_O = 0 - R_C \Delta I_C \] (from (1), differentiate)

Input \( V_i = I_B R_B + V_{BE} \)
\[ \Delta V_i = R_B \Delta I_B + \Delta V_{BE} \] ...(3)

Since \( \Delta V_{BE} \) = small, neglect it, using (1), (3) in (2),

\[ A_x = \frac{R_c \Delta I_c}{R_b \Delta I_b} = \beta \frac{R_c}{R_b} \] where \( \beta \) is the current gain.

Voltage gain, \( A_V = \frac{\Delta V_{ce}}{R_b \Delta I_b} \)
SOLVED SAMPLE PAPER - 1

Candidate must write the Code on the title page of the answer-book

- Please check that this question paper contains 26 questions
- Code number given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
- Please write down the Serial Number of the question before attempting it.
- 15 minutes time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer script during this period.

Time allowed : 3 hours Maximum Marks: 70

Q1. What is the geometrical shape of equipotential surfaces due to a single isolated charge?

Ans. For an isolated charge the equipotential surfaces are concentric spherical shells. (This answer can also be expressed using diagram).

Q2. Which of the following wave can be polarized (i) Heat waves (ii) Sound waves? Give reason to support your answer.

Ans. Heat waves can be polarized because heat waves are transverse waves whereas sound cannot be polarized as sound waves are longitudinal waves. Only transverse wave can be polarised.

Q3. 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 radiations. Identify the pairs of curves that correspond to different materials but some intensity of incident radiation.
Ans. Curve 1 and 2 correspond to similar materials while curves 3 and 4 represent similar but different materials, since the value of stopping potential for the pair of curves (1 and 2) & (3 and 4) are the same. For given frequency of the incident radiation the stopping potential is independent of its intensity.

Q4. Draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels.
Q5. Name the protocol used by internet to search the information over the network?

Q.6  
(i) A capacitor has been charged by a dc source. What are the magnitude of conduction and displacement current, when it is fully charged?

(ii) A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of $38\Omega$ as shown in the figure. Find the value of the current in circuit.

Ans. When capacitor is fully charged current through it is zero. Since magnitude of conduction current is same as magnitude of displacement current so both are zero.

Since, the positive terminal of the batteries are connected together, so the equivalent emf of the batteries is given by $\varepsilon = 200 - 100 = 190\,V$.

Hence, the current in the circuit is given by

$$I = \frac{\varepsilon}{R} = \frac{190}{38} = 5\text{Amp}.$$ 

Q7. State Lenz’s Law.

A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

Ans. Lenz’s law states that the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.

Yes, emf will be induced in the rod as there is change in magnetic flux. As metallic rod held horizontally along eastwest direction, is allowed to fall freely under gravity then it intersect the horizontal component of earth's magnetic field which is along south-north direction. Hence emf is induced in it.

(If it is dropped exactly at pole there will be no induced emf because there is no horizontal component of magnetic field).
Q8. (a) Write the necessary conditions for the phenomenon of total internal reflection to occur.

(b) Write the relation between the refractive index and critical angle for a given pair of optical media.

Ans. (a) Necessary conditions for total internal reflection to occur are:

(i) The incident ray on the interface should travel from optically denser medium to rarer medium.

(ii) The angle of incidence should be greater than the critical angle for the given pair of optical media.

(b) \[ n_b = \frac{1}{\sin C} \]

where \( n_b \) and \( b \) are the rarer and denser media respectively. \( C \) is the critical angle for the given pair of optical media.

Q9. Using Bohr’s postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom.

Ans. According to Bohr’s postulates, in a hydrogen atom, a single electron revolves around a nucleus of charge \( +e \). For an electron moving with a uniform speed in a circular orbit in a given radius, centripetal force is provided by Coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small.

So,

\[ \frac{mv^2}{r} = \frac{kq^2}{r^2} \]

or

\[ mv^2 = \frac{kq^2}{r} \]

...(1)

where

- \( m \) = mass of electron
- \( r \) = radius of electronic orbit
- \( v \) = velocity of electron.

Again

\[ mvr = \frac{nh}{2\pi} \]
or \[ v = \frac{nh}{2\pi mr} \]

From eq.(1), we get,

\[ m\left(\frac{nh}{2\pi mr}\right) = \frac{ke^2}{r} \]

\[ \Rightarrow r = \frac{n^2h^2}{4\pi^2kme^3} \]  \hspace{1cm} (2)

(i) Kinetic energy of electron

\[ E_r = \frac{1}{2}mv^2 = \frac{ke^2}{2r} \]

Using eq (2), we get

\[ E_K = \frac{ke^3}{2} \frac{4\pi^2kme^2}{n^2h^2} \]

\[ = \frac{2\pi^2k^2me^4}{n^2h^2} \]

\[ E_K = \frac{ke^2}{2} \frac{4\pi^2kme^2}{n^2h^2} \]

\[ t=0 \text{ and } t=\frac{\pi}{\omega} \]

(ii) Potential Energy

\[ E_p = -\frac{k(e) \times (e)}{r} = -\frac{ke^2}{r} \]

Q10. Explain, with the help of a circuit diagram, the working of a photo-diode. Write briefly how it is used to detect the optical signals.

OR

Mention the important considerations required while fabricating a p-n junction diode to be used as a Light Emitting Diode (LED). What should be the order of band gap of on LED if it is required to emit light in the visible range?
Ans. A junction diode made from light sensitive semi-conductor is called a photodiode.

A photodiode is an electrical device used to detect and convert light into an energy signal through the use of a photo detector. It is a pn-junction whose function is controlled by the light allowed to fall on it. Suppose, the wavelength is such that the energy of a phonton, $\frac{hc}{\lambda}$, is sufficient to break a valance bond. When such light falls on the junction, new hole-electron pairs are created. The number of charge carriers increases and hence the conductivity of the junction increases. If the junction is connected in some circuit, the current in the circuit is controlled by the intensity of the incident light.

**OR**

1. The reverse breakdown voltages of LEDs are very low, typically around 5V. So care should be taken while fabricating a pn-junction diode so that the high reverse voltages do not appear across them.

2. There is very little resistance to limit the current in LED. Therefore, a resistor must be used in series with the LED to avoid any damage to it.

The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV (spectral range of visible light is from about 0.4 fYm to 0.7 fYm, i.e., from about 3 eV to 1.8 eV).

**Q11.** A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is $360 \, \mu C$. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes $120 \, \mu C$. 

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Calculate:

(i) The potential $V$ and the unknown capacitance $C$

(ii) What will be the charge stored in the capacitor, if the voltage applied had increased by 120 V?

OR

A hollow cylindrical box of length 1 m and area of cross-section 25 cm$^2$ is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given $E = 50x \hat{i}$, where $E$ is NC-1 and $x$ is in metres. Find

(i) Net flux through the cylinder.

(ii) Charge enclosed by the cylinder.

Ans. (i) Initial voltage, $V_1 = V$ volts and charge stored, $Q_1 = 360 \, \mu C$.

$Q_1 = CV_1$ ..(1)

Changed potential, $V_2 = V - 120$

$Q_2 = 120 \, \mu C$

$Q_2 = CV_2$ ..(2)

By dividing (1) by (2), we get

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2} \Rightarrow \frac{360}{120} = \frac{V}{V - 120} \Rightarrow V = 180 \text{ volts}$$

$$C = \frac{Q_1}{V_1} = \frac{360 \times 10^{-3}}{180} = 2 \times 10^{-2} F = 2 \mu F$$

(ii) If the voltage applied had increased by 120 V, then $V_3 = 180 + 120 = 300$ V. Hence, charge stored in the capacitor,
Given

\[ E = 50x \hat{i}, \quad \text{and} \quad \Delta s = 25cm^2 = 25 \times 10^{-4}m^2 \]

As the electric field is only along the x-axis, so, flux will pass only through the cross-section of cylinder.

Magnitude of electric field at cross-section

A, \( E_A = 50 \times 1 = 5 \text{ N C}^{-1} \)

Magnitude of electric field at cross-section

B, \( E_D = 50 \times 2 = 100 \text{ N C}^{-1} \)

The corresponding electric fluxes are:

\[ \phi = E\Delta s = 50 \times 25 \times 10^{-4} \times \cos 180^2 = -0.125Nm^2C^{-1} \]

So, the net flux through the cylinder,

(ii) Using Gauss's law:

Q12. A metallic rod of length 'l' is rotated with a frequency \( \nu \) with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius \( r \), about an axis passing through the centre and perpendicular to the plane of the ring. A constant uniform magnetic field \( B \) parallel to the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre and the metallic ring and hence obtained the expression for it. Ans. Suppose the length of the rod is greater than the radius of the circle and rod rotates anticlockwise and suppose the direction of electrons in the rod at any instant be along +y-direction.
Suppose the direction of the magnetic field is along +z-direction. Then, using Lorentz law, we get the following:

$$\vec{F} = -e(\vec{v} \times \vec{B})$$

$$\Rightarrow \vec{F} = -e(\vec{v} \times B\hat{k})$$

$$\Rightarrow \vec{F} = -e\vec{v}B\hat{i}$$

Thus, the direction of force on the electrons is along -x axis.

Thus, the electrons will move towards the center i.e., the fixed end of the rod. This movement of electrons will result in current and hence it will produce emf in the rod between the fixed end and the point touching the ring. Let \( rA \) be the angle between the rod and radius of the circle at any time \( t \).

Then, area swept by the rod inside the circle

$$= \frac{1}{2} \pi r^2 \theta$$

Induced emf = \( B \times \frac{d}{dt} \left( \frac{1}{2} \pi r^2 \theta \right) = \frac{1}{2} \pi r^2 B \frac{d\theta}{dt} \)

$$= \frac{1}{2} \pi r^2 B\omega = \frac{1}{2} \pi r^2 B (2\pi v) = \pi^2 r^2 B v$$

Q13. In a series LCR circuit connected to an ac source of variable frequency and voltage \( v = v_m \sin \omega t \), draw a plot showing the variation of current (I) with angular frequency (\( \omega \)) for two different values of resistance \( R_1 \) and \( R_2 \). Write the condition under which the phenomenon of resonance
occurs. For which value of the resistance out of the two curves, a sharper resonance is produced? Define Q-factor of the circuit and give its significance.

Ans. Figure shows the variation of $i_m$ with $\omega$ in a LCR series series circuit for two values of Resistance $R_1$ and $R_2$ ($R_1 > R_2$).

![Graph showing variation of current amplitude with angular frequency for two resistances](image)

The condition for resonance in the LCR circuit is $\omega_0 = \frac{1}{\sqrt{LC}}$

We see that the current amplitude is maximum at the resonant frequency $\omega$. Since $i_m = \frac{v_m}{R}$ at resonance, the current amplitude for case $R_2$ is sharper to that for case $R_1$.

Quality factor or simply the Q-factor of a resonant LCR circuit is defined as the ratio of voltage drop across the capacitor (or inductor) to that of applied voltage.

It is given by $Q = \frac{1}{R \sqrt{LC}}$

Significance: The Q factor determines the sharpness of the resonance curve. Less sharp the resonance, less is the selectivity of the circuit while higher is the Q, shaper is the resonance curve and lesser will be the loss in energy of the circuit.

Q14.(a) An ammeter of resistance 0.80 $\Omega$ can measure current up to 1.0 A.

(i) What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A?

(ii) What is the combined resistance of the ammeter and the shunt? What are permanent magnets? Give one example?
Ans. We have, resistance of ammeter, \( R_A = 0.8 \text{ ohm} \) and nuuciumicurrent across ammeter,\[ I_A = 1.0A \]

So, voltage across ammeter,\[ V = IR = 1.0 \times 0.80 = 0.8V. \]

Let the value be \( x \).

(i) Resistance of ammeter with shunt,\[ R = \frac{R_Ax}{R_A + x} = \frac{0.8x}{0.8 + x} \]

Current through ammeter, \( I = 5 \text{ A.} \)

\[ \therefore \left( \frac{0.8x}{0.8 + x} \right) \times 5 = 0.8 \]

\[ \Rightarrow 0.8(0.8 + x) = 4x \]

\[ \therefore x = \frac{0.64}{3.2} = 0.2 \]

Thus, the shunt resistance is 0.2 ohm

(iii) Combined resistance of the ammeter and the shunt,

\[ R = \frac{0.8x}{0.8 + x} - \frac{0.8 \times 0.2}{0.8 + 0.2} - \frac{0.16}{1} = 0.16 \text{ ohm} \]

Ans. Permanent mangets are those magnets which have high retentivity and coercivity. For example : Steel, earth, Uarnaagnet etc.

Q15.(a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment.

(b) Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2 x 101 m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases P.
Ans. (a) If the width of each slit is comparable to the wavelength of light used the interference pattern thus obtained in the double-slit experiment is modified by diffraction pattern due to each slit.

(b) Given that: Wavelength of the light beam, \( \lambda_1 = 590 \text{nm} = 5.9 \times 10^{-7} \text{ m} \)

Wavelength of another light beam, \( \lambda_2 = 596 \text{nm} = 5.96 \times 10^{-7} \text{ m} \)

Distance of the slits from the screen
\( = D = 1.5 \text{ m} \)

aperture = \( a = 2 \times 10^{-4} \text{ m} \)

For the first secondary maxima,
\[
\sin \theta = \frac{3\lambda_2}{2a} = \frac{x_1}{D}
\]

or
\[
x_1 = \frac{3\lambda_1 D}{2a} \quad \text{and} \quad x_2 = \frac{3\lambda_2 D}{2a}
\]

\( \therefore \) Spacing between the positions of first secondary maxima of two ocliuni lines
\[
x_1 - x_2 = \frac{3D}{2a} (\lambda_2 - \lambda_1)
\]

\( = 6.75 \times 10^{-5} \text{ m} \)

Q16. (i) Write the relationship between angle of incidence ‘i’, angle or prism ‘A’ and angle of minimum deviations for a triangular prism.

(ii) An em wave is travelling in a medium with a velocity \( \vec{v} = v \hat{p} \). Draw a sketch showing the propagation of the em wave, indicating the direction of the oscillating electric and magnetic fields.

(iii) How are the magnitudes of the electric and magnetic fields related to velocity of the em wave?

Ans. The relation between the angle of incidence \( i \), angle of prism, \( A \) and the angle of minimum deviation, \( \Delta_m \) for a triangular prism is given as is given by
\[
i - \frac{A + \Delta_m}{2}.
\]
Ans. (a) Given that velocity, \( V = v \hat{i} \), so electric and magnetic field should be in X-Y plane. Let electric field, \( E \) along Y-axis and magnetic field, \( B \) along Z-axis.

The propagation of EM wave is following:

\[
Y \quad E
\]
\[
Z \quad B
\]
\[
X
\]

(b) Speed of EM wave can be given as the ratio of magnitude of electric field \( E_0 \) to the magnitude of magnetic field \( B_0 \)

\[
c = \frac{E_0}{B_0}
\]

Q. 17 (i) A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. Will the system be converging or diverging in nature?

(ii) An air bubble is formed inside water. Does it act as converging lens or a diverging lens?

Ans. We have focal length of convex lens,

\[
f_1 = +25 \text{ cm} = +0.25 \text{ m}
\]

and focal length of concave lens,

\[
f_2 = -20 \text{ cm} = -0.20 \text{ m}
\]

Power of convex lens,

\[
P_1 = \frac{1}{f_1} = \frac{1}{0.25}
\]

Power of concave lens,

\[
P_2 = \frac{1}{f_2} = \frac{1}{-0.20}
\]

Power of the combination,

\[
P = P_1 + P_2 = \frac{1}{0.25} + \frac{1}{-0.20} = \frac{100}{25} + \frac{100}{-20}
\]
\[
\frac{400 - 500}{100} = \frac{-100}{100} = -1D
\]

As the power is negative, the system will be diverging in nature.

Air bubble behave as concave lens.

Q18.(a) In a typical nuclear reaction e.g.

\[\frac{2}{1}H + \frac{2}{1}H \rightarrow \frac{3}{2}He + n + 3.27MeV\]

although number of nucleons is conserved, yet energy is released. How? Explain.

(b) Show that nuclear density in a given nucleus is independent of mass number A.

Ans.(a) In a nuclear reaction, the sum of the largest nucleus \(\left(\frac{2}{1}H\right)\) and the bombarding particle \(\left(\frac{2}{1}H\right)\) may be greater of less than the sum of masses of the product nucleus \(\left(\frac{3}{1}He\right)\) and the outgoing particle \(\left(\frac{1}{0}n\right)\). So from the law of conservation of mass-energy, some energy \((3.27\, \text{MeV})\) is evolved or involved in a nuclear reaction. This energy is called Q-Value of the nuclear reaction.

(b) Density of the nucleus \(= \frac{\text{mass of nucleus}}{\text{volume of nucleus}}\)

mass of nucleus = A amu = \(A \times 1.66 \times 10^{-27} \text{ kg}\)

volume of nucleus

\[
= \frac{4}{3}nR^3 = \frac{4}{3}\pi\left(R_0A^{1/3}\right) = \frac{4}{3}\pi R_0^3 A.
\]

Thus, density

\[
= \frac{A \times 1.66 \times 10^{-2}}{\left(\frac{4}{3}\pi R_0^3\right) A} = \frac{1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)}
\]

which show the density is independent of mass number A.
Using \( R_0 = 1.1 \times 10^{-15} \, m \) and 

\[
\text{density} = 2.97 \times 10^{17} \, \text{kg m}^{-3} 
\]

Q19.(a) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.

(b) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Ans.(a) Wave nature of radiation cannot explain the following:

(i) The instantaneous ejection of photoelectrons.

(ii) The existence of threshold frequency for a metal surface.

(iii) The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon its frequency. Thus, the photoelectric effect cannot be explained on the basis of wave nature of light.

(b) Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light. Its basic features is:

a photon-particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, number of photons may not be conserved.

Q20. Write three important factors which justify the need of modulating a message signal. Show diagrammatically how an amplitude modulated wave is obtained when a modulating signal is superimposed on a carrier wave.

Ans. Three important factors which justify the need of modulating a message signal:

(i) **Size of antenna or aerial:** For communication within the effective but small length of the antennas, the transmitting frequencies should be high, so modulation is required.

(ii) **Effective power which is radiated by antenna:** Since the power radiated from a linear antenna is inversely proportional to the square of the transmitting wavelength. As high powers are needed for good transmission so, higher frequency is required which can be achieved by modulation.

(iii) The interference of signals from different transmitters: To avoid the
interference of the signals there is need of high frequency which can be achieved by the modulation.

![Carrier wave](image1)

![Modulating signal](image2)

![Amplitude modulated wave](image3)

21. Output characteristics of an n-p-n transistor in CE configuration is shown in the figure. Determine:

(i) dynamic output resistance

(ii) d.c current gain and

(iii) a.c current gain at an operating point

\( V_{CE} = 10V, \) when \( I_B = 30\mu A \)

Ans. (i) Dynamic output resistance is given as:

\[
R_t = \frac{\Delta V_{CI}}{\Delta I_C}
\]

(Note- The values 3.6 and 3.4 are arbitrary. It may vary for each observer i.e. student)

(ii) d.c current gain,

\[
\beta_{dc} = \frac{I_C}{I_B} = \frac{3.5mA}{30\mu A} = \frac{3.5 \times 10^{-3}}{30 \times 10^{-6}} = \frac{350}{3} = 116.67
\]

(iii) a.c. current gain,

\[
\beta_{ac} = \frac{\Delta I_C}{\Delta I_B} = \frac{(4.7 - 3.5)mA}{(40 - 30)\mu A} = \frac{1.2 \times 10^{-3}}{10 \times 10^{-6}} = 120
\]
in this case approximate values of Ic is used according to graph. It may vary for different observer while given value of Ib = 30\mu A is useless.

Q22. Explain the working of mobile telephon system to transfer the information from sending host to receiving host.

Ans. Refer support material content.

Q23. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It become very dark. He stoppd driving the car and waited for thunderstorm to stop. Suddenly he notices a child walking along on the road. He asked the boy to come inside the car till the thunderstorm stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.

Answer the following questions based on the above information :

(a) Why is it safer to sit inside a car during a thunderstorm?

(b) Which two values are displayed by Dr. Pathak in his action?

(c) Which values are reflected in parents response to Dr. Pathak?

(d) Give an example of similar action on your part in the past from everyday life.

Ans.(a) It is safer to be inside a car during thunderstorm because the car acts like a hollow sphere. Electric field inside a hollow sphere is zero so it is safe to sit in the closed car.

(b) Awareness and Humanity

(c) Gratitude and obliged

(d) I once came across to a situation where a puppy was struck in the middle of a busy road during rain and was not able go cross due to heavy flow, so I quickly rushed and helped him.

Q24.(a) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf’s of two primary cells. Obtain the required expression used for comparing the emfs.

(b) Write two possible causes for one sided deflection in a potentiometer experiment.
(a) State Kirchhoff’s rules for an electric network. Using Kirchhoff’s rules, obtain the balance condition in terms of the resistances of four arms of Wheatstone bridge.

(b) In the meterbridge experimental setup, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of meterbridge wire.

If a resistance of 10Ω is connected in series with \( R_1 \), null point is obtained at \( AD = 60 \) cm. Calculate the value of \( R_1 \) and \( R_2 \).

Ans. (a) Refer theory

(b) (i) The emf of the cell connected in main circuit may not be more than the emf of the primary cells whose emfs are to be compared.

(ii) The positive ends of all cells are not connected to the same end of the wire.

OR

(a) Refer NCERT

(b) Considering both the situations and writing them in the form of equations

Let \( R' \) be the resistance per unit length of the potential meter wire,

\[
\frac{R_1}{R_2} = \frac{R' \times 40}{R'(100 - 40)} = \frac{40}{60} = \frac{2}{3}
\]

\[
\frac{R_1 + 10}{R_2} = \frac{R' \times 60}{R'(100 - 60)} = \frac{60}{40} = \frac{3}{2}
\]
Class XII : Physics

\[
\frac{R_1}{R_2} = \frac{2}{3} \quad \text{(1)}
\]

\[
\frac{R_1 + 10}{R_2} = \frac{3}{2} \quad \text{(2)}
\]

Putting the value of \( R_1 \) from equation (1) and substituting in equation (2)

\[
\frac{2}{3} \cdot \frac{10}{R_2} = \frac{3}{2}
\]

\[
R_2 = 12\Omega
\]

Q.25(a) Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

(b) A proton and a deuteron having equal momenta enter in a region of a uniform magnetic field at right angle to the direction of a the field. Depict their trajectories in the field.

OR

(a) A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

(b) A compass needle, free to turn in vertical plane orient itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

Ans.(a) Refer NCERT

(b) We know, Lorentz force, \( F = Bqv \sin \theta \) where \( \theta \) = angle between velocity of particle in magnetic field

\[ \theta = 90^\circ \]

So, Lorentz force, \( F = Bqv \)

Thus, the particles will move in circular path.

\[ Bqv = \frac{mv^3}{r} \Rightarrow r = \frac{mv}{Bq} \]
Let \( m_p \) = mass of proton, \( m_d \) = mass of deuteron, \( v_p \) = velocity of proton and \( v_d \) = velocity of deuteron.

The charge of proton and deuteron are equal.

Given that \( m_p v_p = m_d v_d \)

\[
gr_p = \frac{m_p v_p}{Bq} \quad (1)
\]

\[
gr_d = \frac{m_p v_d}{Bq} \quad (2)
\]

As (1) and (2) are equal, so \( r_p = r_d = r \)

Thus, the trajectory of both the particles will be same.

---

OR

The torque on the needle is \( r = m \times B \)

In magnitude \( \tau = mB \sin \theta \)

Here \( \tau \) is restoring torque and \( \theta \) is the angle between \( m \) and \( B \).

Therefore, in equilibrium \( I = \frac{d^2 \theta}{dt^2} = -mB \sin \theta \).

Negative sign with \( mB \sin \theta \) implies that restoring torque is in opposition to deflecting torque. For small value of \( \theta \) in radians, we approximate \( \sin \theta \approx \theta \) and get

\[
I = \frac{d^2 \theta}{dt^2} = -mB \theta
\]
This represents a simple harmonic motion. The square of the angular frequency is \( \omega^2 = \frac{mB}{I} \) and the time period is,

\[
T = 2\pi \sqrt{\frac{I}{mB}}
\]

(b)(i) As, Horizontal component of earth’s magnetic field, \( B_H = B \cos \delta \)

Putting \( \delta = 90^\circ \)

\[
\therefore B_H = 0
\]

(ii) For a compass needle align vertical at a certain place angle of dip, \( \delta = 90^\circ \)

Q26.(a) Draw a ray diagram showing the image formation by a compound microscoped. Hence obtained expression for total magnification when the image is formed at infinity.

(b) What two main changes in diffraction pattern of single slit will you observe when the monochromatic source of light is replaced by a source of white light.

OR

(a) State hygeri s principle. Using theis principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a densesr medium. Hence verify Snell’s law of refraction.

(b) The monochromatic light travels from a rarer to a denser medium, explain the following giving reasons:

(i) Is the frequency of reflected and refracted light same as the frequency of incident light?

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?
Ans. (a) Refer NCERT

(b) Refer NCERT

OR

(a) Refer NCERT

(b)(i) The frequency of reflected and refracted light remains same as that of the frequency of incident light because frequency only depends on the source of light.

(ii) Since the frequency remains same, hence there is no reduction in energy.
SOLVED SAMPLE PAPER - 2

Time allowed : 3 hours  Maximum Marks: 70

Q1. Give one example each of a ‘system’ that uses the following mode of propagation.
   (i) Sky wave, (ii) Space wave

Q2. A concave mirror, of aperture 4 cm, has a point object placed on its principal axis at a distance of 10 cm from the mirror. The image, formed by the mirror, is not likely to be a sharp image. State the likely reason for the same.

Q3. Show, on a graph, the nature of variation, of the (associated) de-Broglie wavelength ($\lambda D$), with the accelerating potential ($V$), for an electron initially at rest.

Q4. Define the term ‘Transducer’ for a communication system.

Q5. The short wavelength limits of the Lyman, Paschen and Balmer Series, in the hydrogen spectrum, are denoted by $\lambda_L$, $\lambda_P$, $\lambda_B$ respectively. Arrange these wavelengths in increasing order.

Q6. 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.

OR

A capacitor is charged with a battery and then its plate separation is increased without disconnecting the battery. What will be the change in

(a) charge stored in the capacitor?
(b) energy stored in the capacitor?
(c) potential difference across the plates of the capacitor?
(d) electric field between the plates of the capacitor?
Q7. Draw the current versus potential difference characteristics for a cell. How can the internal resistance of the cell be determined from this graph?

Q8. Show that a series LCR circuit connected to an a.c. source exhibits resonance at its angular frequency equal to \( \frac{1}{\sqrt{LC}} \).

Q9. An observer can see through a pin-hole the top end of a thin rod of height \( h \), placed as shown in the figure. The beaker height is \( 3h \) and its radius \( h \). When the beaker is filled with a liquid up to a height \( 2h \), he can see the lower end of the rod. Then find the refractive index of the liquid.

[Image]

Q10. Calculate the half-life period of a radioactive substance if its activity drops to \( \frac{1}{16} \) of its initial value in 30 years.

Q11. The galvanometer, in each of the two given circuits, does not show any deflection. Find the ratio of the resistors \( R_1 \) and \( R_2 \), used in these two circuits.

[Image]

Q12. The capacitors \( C_1 \) and \( C_2 \), having plates of area \( A \) each, are connected in series, as shown. Compare the capacitance of this combination with the
capacitor C3, again having plates of area A each, but 'made up' as shown in the figure.

Q13. A pencil of $\beta$-particles, moving with a speed $v$, enters a region (region I), where a uniform electric and a uniform magnetic field are both present. These (3-particles then move into region II where only the magnetic field, (out of the two fields present in region I), exists. The path of the $\beta$-particles, in the two regions, is as shown in the figure.

(i) State the direction of the magnetic field

(ii) State the relation between ‘E’ and ‘B’ in region I.

(iii) Drive the expression for the radius of the circular path of the (3-particle in region II.

If the magnitude of magnetic field, in region II, is changed to n times its earlier value, (without changing the magnetic field in region I) find the factor by which the radius of this circular path would change.

Q14. Give expression for the average value of the a.c. voltage $V = V^* \sin \omega t$ over the time interval $t = 0$ and $t = \frac{\pi}{\omega}$.
Q15. Define the terms ‘magnetic dip’ and ‘magnetic declination’ with the help of relevant diagrams. Q16. Three identical polaroid sheets $P_1$ and $P_2$ and $P_3$ are oriented so that the (pass) axis of $P_2$ and $P_3$ are inclined at angles of $60^\circ$ and $90^\circ$, respectively, with respect to the (pass) axis of $P_1$. A monochromatic source, $S$ of intensity $I_0$ is kept in front of the polaroid sheet $P_1$. Find the intensity of this light, as observed by observers $O_1$, $O_2$, and $O_3$ positioned as shown below.

![Diagram of polaroid sheets and observers](image)

Q17. (i) The following data was recorded for values of object distance and the corresponding values of image distance in the experiment on study of real image formation by a convex lens of power $+5$ D.

One of these observations is incorrect. Identify this observation and give reason for your choice

<table>
<thead>
<tr>
<th>S.No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object distance (cm)</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>45</td>
<td>5U</td>
<td>55</td>
</tr>
<tr>
<td>Image distance (cm)</td>
<td>97</td>
<td>61</td>
<td>137</td>
<td>35</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

(ii) In following figure, AB is a lens. Identify this lens. Give reason too.

![Diagram of lens](image)
Q18. Write and explain three need of modulation.

OR

Is it necessary for the transmitting antenna and the receiving antenna to be of the same height for the line of sight communication? Find an expression for maximum line of sight distance $d_m$ between these two antennas of heights $h_T$ and $h_R$ .

Q19. Define the terms (i) mass defect (ii) binding energy for a nucleus and state the relation between the two.

For a given nuclear reaction the B.E./ nucleon of the product nucleus/ nuclei is more than that for the original nucleus/nuclei. Is this nuclear reaction exothermic or endothermic in nature? Justify your choice.

OR

(a) The number of nuclei, of a given radioactive nucleus, at times $t = 0$ and $t = T$, are $N_0$ and $(N_0/n)$ respectively. Obtain an expression for the half life $(T_{1/2})$ of this nucleus in terms of $n$ and $T$.

(b) Identify the nature of the ‘radioactive radiations’, emitted in each step of the ‘decay chain’ given below :

```
A-4  Y  A-4  Y  A-4  W
Z  Z-2  Z-2  Z-1
```

Q20. The electron, in a hydrogen atom, initially in a state of quantum number $n_l$ makes a transition to a state whose excitation energy, with respect to the ground state, is 10.2 eV. If the wavelength, associated with the photon emitted in this transition, is 487.5 mm, find the (i) energy in ev, and (ii) value of the quantum number, $n_l$ of the electron in its initial state.

Q21. Derive the relation between distance of object, distance of image and radius of curvature of a convex spherical surface, when refraction takes place from a rarer medium of refractive index $\mu_1$ to a denser medium of refractive index $\mu_2$ and the image produced is real.

An eye specialise prescribes spectacles having combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. What is the power of this lens combination in diopters?

Q22. Explain, with the help of a schematic diagram, the principle and working
of a Light Emitting Diode. What criterion is kept in mind while choosing the semiconductor material for such a device? Write any two advantages of Light Emitting Diode over conventional incandescent lamps.

OR

How is zener diode fabricated so as to make it a special purpose diode? Draw \( I - V \) characteristics of zener diode and explain the significance of breakdown voltage.

Q23. Group discussion was arranged in class XII on the topic atmosphere. Three groups were made. Teacher asked the Question. "Why can moon be not used as a communication satellite?" Answers were given by all the three groups. Each group can give only one reason. Teacher told them that reason given by each group is correct. The groups collected all the three reasons and come to correct conclusion.

(i) What values were showed by all the three groups?

(ii) Give the correct reason for the above question.

(iii) Explain the term sky wave.

Q24. A conducting rod \( XY \) slides freely on two parallel rails, A and B, with a uniform velocity \( 'V' \). A galvanometer \( 'G' \) is connected, as shown in the figure and the closed circuit has a total resistance \( 'R' \). A uniform magnetic field, perpendicular to the plane defined by the rails A and B and the rod \( XY \) (which are mutually perpendicular), is present over the region, as shown.

(a) With key \( k \) open:

(i) Find the nature of charges developed at the ends of the rod \( XY \).

(ii) Why do the electrons, in the rod \( XY \), (finally) experience no net force even through the magnetic force is acting on them due to the motion of the rod?
(b) How much power needs to be delivered, (by an external agency), to keep the rod moving at its uniform speed when key k is (i) closed (ii) open?

(c) With key k closed, how much power gets dissipated as heat in the circuit? State the source of this power.

Q25.(a) The following data was obtained for the dependence of the magnitude of the electric field, with distance, from a reference point o, within the charge distribution in the shaded region.

<table>
<thead>
<tr>
<th>Field point</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A’</th>
<th>B’</th>
<th>C’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude of Electric Field</td>
<td>E</td>
<td>E/8</td>
<td>E/27</td>
<td>E/2</td>
<td>E/16</td>
<td>E/54</td>
</tr>
</tbody>
</table>

(i) Identify the charge distribution and justify your answer.

(ii) If the potential due to this charge distribution, has a value V at the point A, what is its value at point A’?

(b) A uniform electric field E of 300 NC-1 is directed along PQ. A, B and C are three points in the field having x and y coordinates (in metre) as shown in the figure. Calculate potential difference between the points (i) A and B, and (ii) B and C.
An electric dipole of dipole moment \( p \) is placed in a uniform electric field \( E \). Write the expression for the torque \( T \) experienced by the dipole. Identify two pairs of perpendicular vectors in the expression. Show diagramatically the orientation of the dipole in the field for which the torque is (i) maximum, (ii) half the maximum value, (iii) zero. Fig (a) and (b) show the field lines of a single positive and negative charges respectively.

(a) Give the sign of the potential difference: \( V_P - V_Q \) and \( V_B - V_A \)

(b) Give the sign of the potential energy difference of a small negative charge between the points \( Q \) and \( P; A \) and \( B \).

(c) Give the sign of the work done by the field in moving a small positive charge from \( Q \) to \( P \).

(d) Give the sign of the work done by an external agency in moving a small negative charge from \( B \) to \( A \).

Q26.(i) A thin lens, having two surfaces of radii of curvature \( r_1 \) and \( r_2 \), made from a material of refractive index \( \mu_2 \), is kept in a medium of refractive index \( \mu_1 \). Derive the Lens Maker’s formula for this ‘set-up’
(ii) A convex lens is placed over a plane mirror. A pin is now positioned so that there is no parallax between the pin and its image formed by this lens-mirror combination. How can this observation be used to find the focal length of the convex lens? Give appropriate reasons in support of your answer.

OR

The figure, drawn here, shows a modified Young’s double slit experimental set up. If \( SS_2 - SS_1 = \lambda/4 \).

(i) state the condition for constructive and destructive interference

(ii) obtain an expression for the fringe width.

(iii) locate the position of the central fringe.
Candidate must write the Code on the title page of the answer-book

- Please check that this question paper contains 26 questions
- Code number given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
- Please write down the Serial Number of the question before attempting it.
- 15 minutes time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer script during this period.

Time allowed: 3 hours

Maximum Marks: 70

Q1. How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in a uniform electric field.

Q2. Relative electric permittivity of a medium is 8 and relative permeability is close to unity. What is the speed of EM waves in the medium.

Q3. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it?

Q4. Name the physical quantity whose dimensions are same as Planck’s constant.

Q5. Calculate number of electric field lines originating from one coulomb charge.

Q6. The electric field component in the figure are \( E_x = 2x\hat{i}, \ E_y = E_z = 0 \). Calculate the flux through (1, 2, 3) the square surfaces of side 5m.

\[ \text{Diagram:} \]

\[ \text{Diagram:} \]
Q7. A particle of mass m and charge q moves at right angles to a uniform magnetic field. Plot a graph showing the variation of the radius of the circular path described by it with the increase in its kinetic energy, where, other factors remains constant.

Q8. Water (refractive index µ) is poured into a concave mirror of radius of curvature 'R' up to a height h as shown in figure. What should be the value of x so that the image of object ‘O’ is formed on itself?

![Figure showing a concave mirror with water](image)

Q9. In a photoelectric effect experiment, the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q are shown in Fig. :

![Graph showing stopping potential vs frequency](image)

(i) Which of the two metals has greater value of work function?
(ii) Find maximum K.E. of electron emitted by light of frequency

\[ v = 8 \times 10^{14} \text{ Hz} \] for metal P.

OR

Derive \( mvr = \frac{nh}{2\pi} \) using de Broglie equation.

Q10. What is ground wave? Why short wave communication over long distance is not possible via ground waves?

Q11. Define drift velocity. A conductor of length L is connected to a dc source of emf E. If the length of conductor is tripled by stretching it, keeping E constant, explain how do the following factors would vary in the conductor?
(i) Drift speed of electrons, (ii) Resistance and (iii) Resistivity.

OR

The graph shows how the current $I$ varies with applied potential difference $V$ across a 12 V filament lamp (A) and across one metre long nichrome wire (B). Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

(i) when potential difference across them is 12 V.

(ii) when potential difference across them is 4V. Give reason for the change in ratio of resistances in (i) and (ii).

Q12. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having $n$ turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

Q13. In a series L-R circuit, $X_L = R$ and power factor of the circuit is $P_1$. When capacitor with capacitance $C$ such that $X_L = X_C$ is put in series, the power factor becomes $P_2$. Find $P_1/P_2$.

Q14. The figure shows, in (a) a sine curved $\delta(t) = \sin \omega t$ and three other sinusoidal curves $A(t), B(t)$ and $C(t)$ each of the form $\sin (\omega t - \phi)$. (a) Rank the three curves according to the value of $\phi$ most positive first and most negative last (b) Which curve corresponds to which phase as in (b) of the figure? (c) which curve leads the others?
Q15. List any three properties of EM waves.

Q16. Using mirror formula show that virtual image produced by a convex mirror is always smaller in size and is located between the focus and the pole.

Q17. In the following diagram, find the focal length of lens \( L_2 \).

![Diagram](image)

Q18. X-rays of wave length \( ? \), fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be \( \frac{h}{\lambda} = \frac{\sqrt{2mc}}{\lambda} \).

Q19. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV. What is

(i) the kinetic energy,

(ii) the potential energy of the electron?

(c) which of the answers above would change if the choice of the zero of potential energy in changed to (i) + 0.5 eV (ii) -0.5 eV.

Q20. Determine \( V_0, I_{d1} \) and \( I_{d2} \) for the given network. Where \( D_1 \) and \( D_2 \) are made of silicon.

\[
\left( I_{d1} = I_{d2} = \frac{I}{2} = 14.09 \, mA \right)
\]

Q21. A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.

Q23. Rahul and Rohit bought an electric iron. They had a 2 pin plug. Rahul was keen to start using the new iron with the 2 pin plug. However, Rohit insisted that they buy a 3 pin plug before using it. Rahul got angry. Rohit patiently explained the importance of using a 3 pin plug and the earthing wire. He said that if the metallic body of the iron came in contact with the live wire at 220 vols, they would get an electric shock. If earthed, the current would go to the earth and the potential of the metallic body would not rise. The iron would then be safe to use. Hearing Rohit, Rahul calmed down and agreed.

(i) What value did Rahul and Rohit have?

(ii) Which has greater resistance - 1 K watt electric heater or 100 watt electric bulb, both marked 220 volts?

Q24. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness \( t \) \((t<d)\) between the plates separated by distance \( d \). How would the following (i) energy (ii) charge, (iii) potential be affected if (a) dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.

OR

Suppose that three points are set at equal distance \( r = 90 \) cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A is closer to +ve charge and B is closer to B) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole moment \( 3.6 \times 10^{-19} \) C-m at points A, B and C?

Q25. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance \( d \) from the centre of a circular coil of radius ‘a’ and carrying current I. Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of \( d \) is \( \sqrt{3a} \).

OR

A rectangular conducting loop of length \( l \) and breadth \( b \) enters a uniform magnetic field \( B \) as shown below. \( R \) is resistance of the loop.
Draw the following graph:

(i) $\theta$-t  
(ii) $\varepsilon$-t  
(iii) $P$-t

- $\pi$ $\rightarrow$ Magnetic flux
- $\varepsilon$ $\rightarrow$ Induced EMF
- $P$ $\rightarrow$ Power

Q26.(i) A thin lens, having two surfaces of radii of curvature $r_1$ and $r_2$, made from a material of refractive index $\mu_2$, is kept in a medium of refractive index $\mu_1$. Derive the Lens Maker's formula for this 'set-up'.

(ii) A convex lens is placed over a plane mirror. A pin is now positioned so that there is no parallax between the pin and its image formed by this lens-mirror combination. How can this observation be used to find the focal length of the convex lens? Give appropriate reasons in support of your answer.

OR

The figure, drawn here, shows a modified Young’s double slit experimental set up. If $SS_2 - SS_1 = \lambda/4$.

(i) state the condition for constructive and destructive interference

(ii) obtain an expression for the fringe width.

(iii) locate the position of the central fringe.