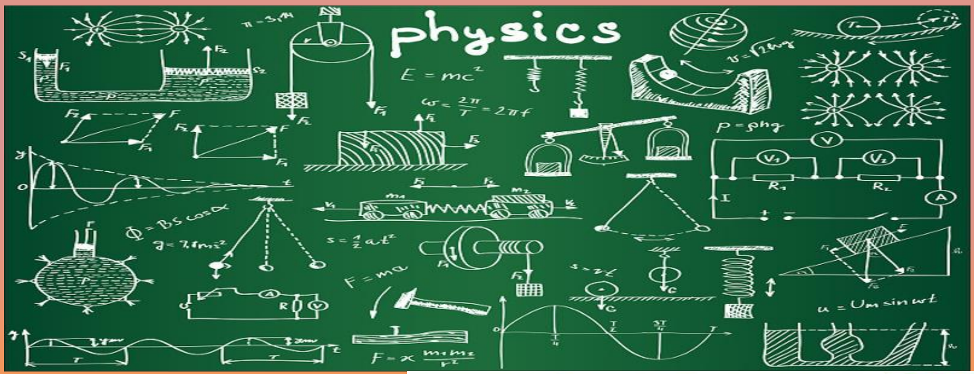
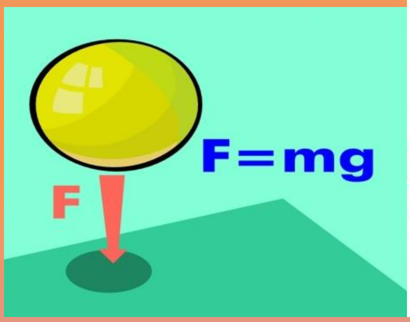
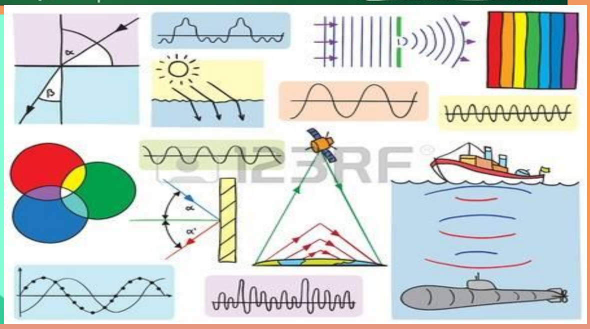
KENDRIYA VIDYALAYA SANGATHAN, NEW DELHI

NUMERICAL WORKSHEETS FOR CLASS XII

SUBJECT: - PHYSICS







ZONAL INSTITUTE OF EDUCATION AND TRAINING, MUMBAI

KVS COMPLEX, NCH COLONY, KANJUR MARG (W), MUMBAI

FOREWORD

This small pocket book on numerical problems has been designed to help students of Class XII to improve their performance in solving numerical problems, and improving their individual scores. Numericals are an important part of Physics and many students score less than their potential because of neglecting this area. This book, prepared by Mr. M Gopala Reddy, PGT Physics of ZIET Mumbai, can be used as a regular workbook in class or can be used as a resource book and kept in the library.

My earnest request to the Principals and teachers is to ensure that this resource material reaches the individual student. Please do send us your feedback so that the errors and shortcomings, if any, can be overcome.

Wishing all my dear students of Kendriya Vidyalayas the very best of luck for their crucial board exams.

USHA ASWATH IYER

DIRECTOR

KVS ZIET MUMBAI

INDEX

SUBJECT: -- PHYSICS **CLASS:-XII**

KENDRIYA VIDYALAYA SANGATHAN, NEW DELHI

KENDRIYA VIDYALAYA SANGATHAN, REGIONAL OFFICE----------------

WORK SHEET FOR SOLVING NUMERICAL PROBLEMS IN PHYSICS

NAME OF THE UNIT:--- **CLASS:-XII**

NAME OF THE CHAPTER/S:-

NAME OF THE KENDRIYA VIDYALAYA:- -------------------------------

NAME OF THE STUDENT:- --------------------------------------- ROLL NO.------------

DATE OF ISSUE OF WORK SHEET:---------------- DATE OF SUBMISSION:--------------

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SIGNATURE OF THE PARENT:---------------- SIGNATURE OF THE STUDENT:------------

GRADE/.MARKS:-------------------- NAME OF THE SUBJECT TEACHER:---------------------

SIGNATURE OF THE SUBJECT TEACHER

COUNTER SIGNATURE OF THE PRINCIPAL/VICE PRINCIPAL

UNIT—I—ELECTROSTATICS

IMPORTANT FORMULAE

1. **Electrostatic force between two charges**
   $F = K.\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0\epsilon_r}.\frac{q_1 q_2}{r^2}$
   For air, $\epsilon_r = 1$
   Fair = $\frac{1}{4\pi\epsilon_0}.\frac{q_1 q_2}{r^2} = 9\times 10^9\ \frac{q_1 q_2}{r^2}$
2. **Electric field intensity due to a point charge,** $\vec{E} = \lim_{q_0\to 0}\frac{\vec{F}}{q_o}$
3. **Electric field intensity due to infinite linear charge density (λ)**
   $E = \frac{1}{4\pi\epsilon_0}.\frac{2\lambda}{r}$
4. **Electric field intensity near an infinite thin sheet of surface charge density** σ
   $E = \frac{\sigma}{2\epsilon_0}$
   For thick sheet $= \frac{\sigma}{\epsilon_0}$.
5. **Electric potential,** $V = \lim_{q_0\to 0}\frac{w}{q_o}$
   Electric potential due to a point charge, $V = \frac{1}{4\pi\epsilon_0}.\frac{q}{r}$
6. **Relation between electric field and potential** $E = -\frac{dV}{dr} = \frac{V}{r}$ **(numerically)**
7. **Dipole moment,** $\vec{P} = q.2\vec{l}$
8. **Torque on a dipole in uniform electric field,** $\vec{\tau} = \vec{p}\times\vec{E}$.
9. **Potential energy of dipole,** $U = -\vec{p}.\vec{E} = -pE\cos\theta$
10. **Work done in rotating the dipole in uniform electric field from orientation Q_1 to Q_2 is**
    $W = U_2 - U_1 = pE(\cos\theta_1 - \cos\theta_2)$
11. **Electric field due to a short dipole**
    (i) **at axial point,** $E_{axis} = \frac{1}{4\pi\epsilon_0}.\frac{2p}{r^3}$
    (ii) **at equatorial point,** $E_1 = \frac{1}{4\pi\epsilon_0}.\frac{p}{r^3}$
12. **Electric potential due to a short dipole**
    (i) **At axial point,** $V_{axis} = \frac{1}{4\pi\epsilon_0}.\frac{p}{r^2}$
    (ii) **At equatorial point,** $V = 0$.
13. **Dielectric constant,** $K = \frac{\epsilon}{\epsilon_0} = \frac{C_{med}}{C_{air}}$
14. **Capacitance of parallel plate capacitor**
    (i) $C = \frac{A\epsilon_0 K}{d}$ **, in medium of dielectric constant K**

(ii) $C = \frac{A\epsilon_0}{d-t(1-\frac{1}{K})}$; **if space between plate partially filled with dielectric of thickness t.**

15. Combination of capacitors :-

(i) **In series,** $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$, $q_1 = q_2 = q_3$, $V = V_1 + V_2 + V_3$

(ii) **In parallel,** C= $C_1 + C_2 + C_3$, $q = q_1 + q_2 + q_3$, $V_1 = V_2 = V_3 = V$

16. Energy stored by capacitor

$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$

17. Electrostatic energy density

$\vartheta_e = \frac{1}{2}\epsilon_0 E^2$, **in air**

$\vartheta_e = \frac{1}{2}\epsilon E^2$, **in medium**

18. Total electric flux, $\Phi = \oint \vec{E}.\overrightarrow{ds} = \frac{1}{\epsilon_0} \times net\ charge\ enclosed\ by\ the\ surface$

NUMERICALS

LEVEL I

1. What is the charge acquired by a body when 1 million electrons are transferred to it?
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2. An attractive force of 5N is acting between two charges of +2.0 μC & -2.0 μC placed at some distance. If the charges are mutually touched and placed again at the same distance, what will be the new force between them?
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3. A charge of $+3.0 \times 10^{-6}$ C is 0.25 m away from a charge of -6.0×10^{-6}C.
   a. What is the force on the 3.0×10^{-6} C charge?
   b. What is the force on the -6.0×10^{-6} C charge?
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4. An electric dipole consist of a positive and a negative charge of 4μC each placed at a distance of 5mm. Calculate dipole moment.
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5. Three capacitors of capacitances 2μF, 3μF and 4μF are connected in parallel. What is the equivalent capacitance of the combination? Determine charge on each capacitor, if the combination is connected to 100V supply?
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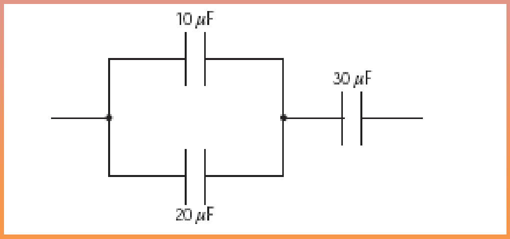
6. An electric dipole with dipole moment $4x10^{-9}$C-m is aligned at 30^0 with direction of electric field of magnitude $5x10^4$N/C. Calculate the magnitude of the torque acting on the dipole.

7. A point charge of 2µC is at the centre of cubic Gaussian surface 9.0 cm in edge. What is the net electric flux through the surface?

8. What is the amount of work done in moving a 200nC charge between two points 5 cm apart on an equipotential surface?

9. How much work must be done to charge a 24 µF capacitor, when the potential difference between the plates is 500 V?

10. What is the equivalent capacity of the network given below?



LEVEL II

1. What is the work done in moving a charge of 100μC through a distance of 1cm along the equatorial line of dipole?

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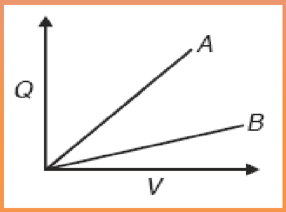
2. The given graph shows that variation of charge q versus potential difference V for two capacitors C_1 and C_2. The two capacitors have same plate separation but the plate area of C_2 is double than that of C_1. Which of the lines in the graph correspond to C_1 and C_2 and why?



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3. Two point charges 5μC and – 4 μC are separated by a distance of 1 m in air. At what point on the line joining the charges is the electric potential zero?

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4. Two charges +5μC and +20μC are placed 15 cm apart. At what point on the line joining the two charges is the electric field zero?

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5. Two charges +16μC and −9μC are placed 8 cm apart. At what point on the line joining the two charges is the electric field zero?

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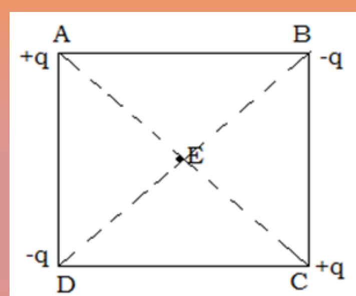
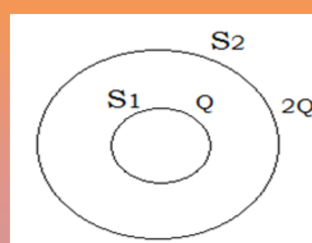
6. A 600 pF capacitor is charged by a 200 V supply. It is then disconnected and from the supply and is connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the process.

7. Keeping the voltage of the charging source constant, what will be the percentage change in the energy stored in a parallel plate capacitor if the separation between its plates were to be decreased by 10%.

8. Four charges are placed at the vertices of a square of side d as shown in the figure.(i) Find the work done to put together this arrangement. (ii) A charge $q_0$is brought to the center E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?



9. If S_1 and S_2 are two hollow spheres enclosing charges Q and 2Q respectively as shown in the figure



(i) What is the ratio of the electric flux through S_1 and S_2?

(ii) How will the flux through the sphere S_1 change, if a medium of dielectric constant 5 is filled in the space inside S_1.

10. A charge of 24μC is given to a hollow sphere of radius 0.2m. Find the potential
(i) at the surface of the sphere, and
(ii) at a distance of 0.1 m from the centre of the sphere.
(iii)at the centre

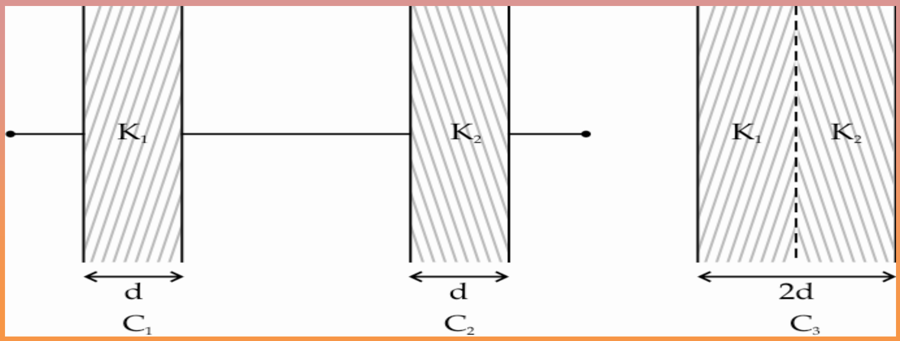
LEVEL III

1. A slab of material of dielectric constant κhas the same area as the plates of a parallel plate capacitor but has a thickness *3d* / 4, where *d* is the separation of the plates. How is the capacitance changed when the slab is inserted between the plates?

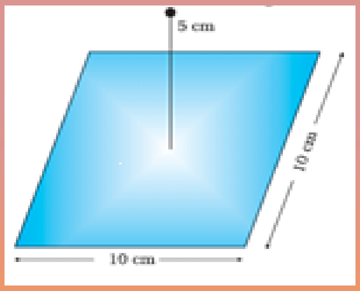
2. A parallel plate capacitor with air between the plates has a capacitance of 8μF. What will be the capacitance if the distance between the plates is doubled and the space between them is filled with a substance of dielectric constant K=6?

3. Two dipoles, made from charges ±q and ±Q, respectively, have equal dipole moments. Give the (i) ratio between the 'separations' of these two pairs of charges (ii) angle between the dipole axis of these two dipoles.

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



5. A point charge +10μC is at a distance 5cm directly above the centre of a square of side 10cm as shown in fig. What is the magnitude of flux through the square?



6. Calculate equivalent capacitance of the given network and determine the charge and voltage across each capacitor.

7. Two identical charges ,Q each are kept at a distance r from each other. A third charge q is placed on the line joining the two charges such that all the three charges are in equilibrium. What is magnitude, sign and position of the charge q?

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8. ABCD is a square of side 5m. Charges of +50C, -50C and +50C are placed at A,C and D respectively . Find the magnitude of resultant electric field at B.

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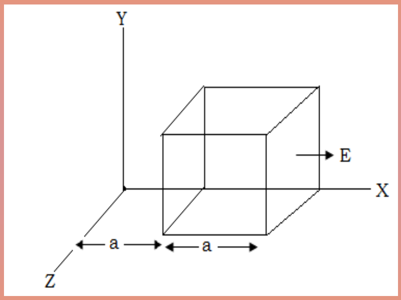
9. A cube with each side a is kept in electric field given by E = Cx as shown in the figure where C is a positive dimensional constant. Find
(i) The electric flux through the cube, and

(ii) The net charge inside the cube.



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10. Two parallel plate capacitor X and Y have same area of plates and same separation between them. X has air between the plates whereas Y has a dielectric of constant k=4

(i) Calculate capacitance of each capacitor if equivalent capacitance is4 μF.

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

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

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UNIT: I ELECTROSTATICS

ANSWERS

LEVEL I

1. Q = Ne 1.6 $x10^{-13}$C
2. F=0
3. F_{AB} = F_{BA}=2.736N
4. P=2$x10^{-8}$ C-m
5. 9 µF, 0.02 µC, 0.03 µC, 0.04 µC
6. 10^{-4}Nm
7. 2,26$x10^{5}$Nm^{2}/C
8. W=0
9. W=3J
10. C=15µF

LEVEL II

1. 0
2. A
3. $\frac{5}{9}m$ from 5µC charge
4. 5 cm from 5 µC charge
5. 24cm from -9 µC charge
6. 6$x10^{-6}$ J
7. 11.11%
8. $\frac{q^2}{4\pi\epsilon_0}(4-\sqrt{2})$, 0
9. $1:3, \quad \emptyset = \frac{Q}{5\epsilon_0}$
10. (i) 1.08$x10^{6}$V (ii) 1.08$x10^{6}$V (iii)1.08$x10^{6}$V

LEVEL III

1. $\frac{4k}{k+3}C_0$
2. 24 µF
3. q a=Q A or a/A=Q/q θ = 0
4. C_3= C_{eq}
5. 1.88$x10^{5}$Nm^{2}/C
6. $\frac{200}{3}pF$,100 V, 50V, 50V, 200V,10^{-8}C, 10^{-8}C, 10^{-8}C,2$x10^{-8}$ C

7. Q/4, Positive, r/2
8. $2.7x10^{10}$N/C
9. a^3C N-m^2/C, $a^3C\epsilon_0$ Coulombs.
10. C_x=5μF C_y= 20Mf

UNIT- II- CURRENT ELECTRICITY

Important Formulae

1 Electric current $=\frac{Charge}{Time}$ or I = $\frac{q}{t}$ = $\frac{ne}{t}$

2. In case of an electron revolving in a circle of radius r with speed v, period of revolution is T = $\frac{2\pi r}{v}$

Frequency of revolution, v = $\frac{1}{T}$ = $\frac{v}{2\pi r}$, Current, I = ev = $\frac{ev}{2\pi r}$

3. Ohm's law, R = $\frac{v}{I}$ or V = IR

4. Current in terms of drift velocity (V_d) is I = enAv_d

5. Resistance of a uniform conductor, R = $\rho\ \frac{l}{A} = \frac{ml}{ne^2\tau A}$

6. Resistivity or specific resistance, $\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$

7. Conductance = $\frac{1}{R}$

8. Conductivity = $\frac{1}{Resistivity}$ or σ = $\frac{1}{\rho}$ = $\frac{l}{RA}$

9. Current density = $\frac{Current}{Area}$ or j = $\frac{I}{A}$ = env_d

10. Relation between current density and electric field,

j = σ E or E = ρ j

11. Mobility μ = $\frac{V_d}{E}$

12. Temperature coefficient of resistance, α = $\frac{R_2 - R_1}{R_1(t_2 - t_1)}$

13. The equivalent resistance R_s of a number of resistances connected in series is given by

$$R_s = R_1 + R_2 + R_3 + \ldots..$$

14. The equivalent resistance R_p of a number of resistances connected in parallel is given by

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots.$$

15. EMF of a cell, E = $\frac{W}{q}$

16. For a cell of internal resistance r, the emf is E = V + Ir = I (R + r)

17. Terminal p.d of a cell, V = IR = $\frac{E\,R}{R+r}$

18. Terminal p.d. when a current is being drawn from the cell, V = E – Ir

19. Terminal p.d. when the cell is being charged, V = E + Ir

20. Internal resistance of a cell, r = R $[\frac{E-V}{V}]$

21. For n cell in series, I = $\frac{nE}{R+nr}$

22. For n cells in parallel, I = $\frac{nE}{nR+r}$

23. Heat produced by electric current, H = I^2Rt joule = $\frac{I^2\text{Rt}}{4.18}$ cal

24. Electric power, P = $\frac{W}{t}$ = VI = I^2R = $\frac{V^2}{R}$

25. Electric energy, W = Pt = VIt = I^2Rt

26. Potential gradient of the potentiometer wire, k = $\frac{V}{l}$

27. For comparing e.m.f.s of two cells, $\frac{E_2}{E_1} = \frac{l_2}{l_1}$

28. For measuring internal resistance of a cell, r = $\frac{l_1 - l_2}{l_2}$ x R

29. For a balanced Wheatstone bridge, $\frac{P}{Q} = \frac{R}{S}$, If X is the unknown resistance $\frac{P}{Q} = \frac{R}{X}$ or X = $\frac{RQ}{P}$

30. In a slide wire bridge, if balance point is obtained at l cm from the zero end, then $\frac{P}{Q} = \frac{R}{X} = \frac{l}{(100-l)}$

WORKSHEET (NUMERICALS) : LEVEL - I

1. What happens to the power dissipation if the value of electric current passing through a conductor of constant resistance is doubled?

Ans…………..
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2. A cell of emf 2 V and internal résistance 0.1 Ω is connected to a 3.9 Ω external resistance. What will be the current in circuit?

Ans…………..
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3. Calculate the resistivity of a material of a wire 1 m long, 0.4 mm in diameter and having a resistance of 2 ohm.

Ans…………..
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4. In a potentiometer arrangement; a cell of emf 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell?

Ans…………..
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5. A current is maintained in a conductor of cross-section 10^{-4} m^2. If the number density of free electrons be 9 x 10^{28} $m^{-3}$and the drift velocity of free electrons be 6.94 x10^{-9} m/s, calculate the current in the conductor.

Ans…………..
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6. A silver wire has a resistance of 2.1 Ω at 27.5 ^{0}C, and a resistance of 2.7 Ω at 100 ^{0}C. Determine the temperature coefficient of resistivity of silver.

Ans……………………………………………………………………………………………………
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7. Three resistors 1 Ω, 2 Ω and 3 Ω are combined in series. (a) What is the total resistance of the combination? (b) If the combination is connected to a battery of emf 12 V and negligible internal resistance, determine the total current drawn from the battery.

Ans……………………………………………………………………………………………………
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8. (a) Three resistors 2 Ω, 4 Ω and 5 Ω are combined in parallel. What is the total resistance of the combination? (b) If the combination is connected to a battery of emf 20 V and negligible internal resistance and the total current drawn from the battery.

Ans……………………………………………………………………………………………………
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9. A Voltage of 30V is applied across a carbon resistor with first second and third rings of blue, black and yellow colours respectively. Calculate the value of current in mA, through the resistor.

Ans……………………………………………………………………………………………………
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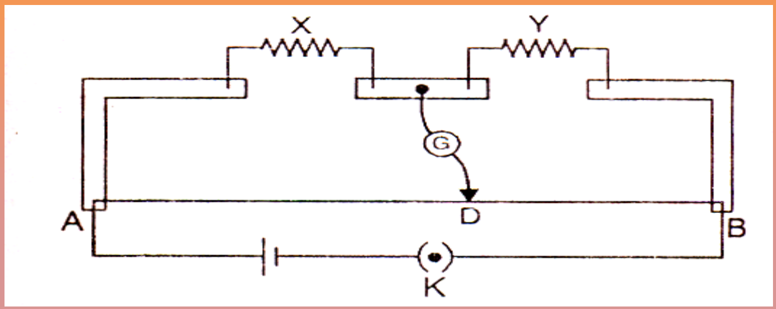
10. In a meter bridge the balance point is found to be 39.5 cm from one end A, when the resistor Y is of 12.5 Ω . Determine the resistance of X.



Ans……………..
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LEVEL - II

1. A cell of emf 2 V and internal résistance 0.1 Ω is connected to a 3.9 Ω external resistance. What will be the p.d. across the terminals of the cell?

Ans……………..
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2. Out of the two bulbs marked 25W and 100W, which one has higher resistance.

Ans……………..
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3. A cell of 6 V and internal resistance 2Ω is connected to a variable resistor. For what value of current does maximum power dissipation occur in the circuit?

Ans……………..
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4. What is the largest voltage you can safely put across a resistor marked 98 Ω - 0.5 W?

Ans……………..
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5. Two heater wires of the same dimensions are first connected in series and them in parallel to a source of supply . What will be ratio of heat produced in two cases?

Ans……………..
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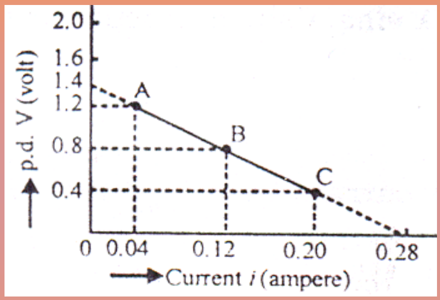
6. Using data given in graph determine (i) emf (ii) internal resistance of the cell.
 (iii) For what current, does maximum power dissipation occur in the circuit?



Ans...
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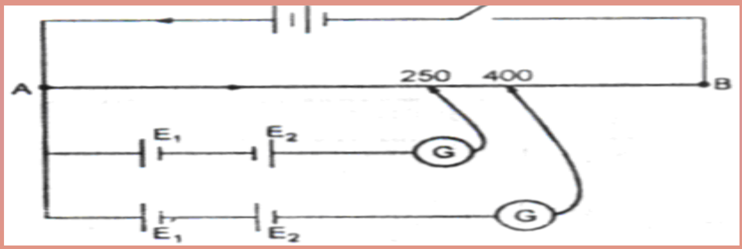
7. You are given 'n' resistors each of resistance 'r'. These are first connected to get of minimum possible resistance. In the second case these are again connected differently to get maximum possible resistance. Compute the ratio between the maximum and minimum values resistance so obtained.

8. Two primary cells of emf E_1 and E_2 ($E_1 > E_2$) are connected to the potentiometer wire as shown in the figure. If the balancing lengths for the cells are 250 cm and 400 cm. Find the ratio of E_1 and E_2.



Ans...
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9. Two identical cells of emf 1.5V each are joined in parallel providing supply to an external circuit consisting of two resistors of 13Ω each joined in parallel . A very high resistance voltmeter reads the terminal voltage of the cells to be 1.4V. Find the internal resistance of each cell.
   Ans...
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10. Three cells of emf 2V, 1.8V and 1.5V are connected in series. Their internal resistances are 0.05Ω, 0.7Ω and 1Ω respectively. If this battery is connected to an external resistance of 4Ω, calculate :

(i) the total current flowing in the circuit. (ii) the p.d. across the terminals of the cell of emf 1.5V.

Ans………
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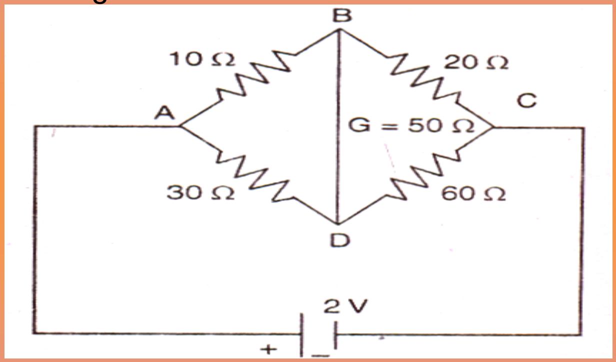
WORKSHEET (NUMERICALS): LEVEL - III

1. What is the current flowing in the arm BD of this circuit.



Ans………
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2. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.
   Ans………
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   ……………………………………………………………………………………………………

3. Two cells of EMF 1V, 2V and internal resistances 2Ω and 1Ω respectively are connected in (i) series, (ii) parallel. What should be the external resistance in the circuit so that the current through the resistance be the same in the two cases? In which case more heat is generated in the cells?

Ans………
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4. Calculate the temperature at which the resistance of a conductor becomes 20% more than its resistance at 27^0C. The value of the temperature coefficient of resistance of the conductor is 2×10^{-4} / K.

Ans………
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5. Two metallic wires of the same material have the same length but cross sectional area is in the ratio of 1:2. They are connected (i) in series and (ii) in parallel. Compare the drift velocities of electrons in the two wires in both the cases.

Ans………
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6. Two wires X, Y have the same resistivity but their cross-sectional areas in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a dc source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases.

   Ans……
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7. A room has AC run for 5 hours a day at a voltage of 220V. The wiring of the room consists of Cu of 1 mm radius and a length of 10m. Power consumption per day is 10 commercial units. What fraction of it goes in the joule heating in the wires? What would happen if the wiring is made of Al of the same dimensions? [$\rho_{Cu} = 1.7 \times 10^{-8}$ Ωm, $\rho_{Al} = 2.7 \times 10^{-8}$ Ωm]

Ans………
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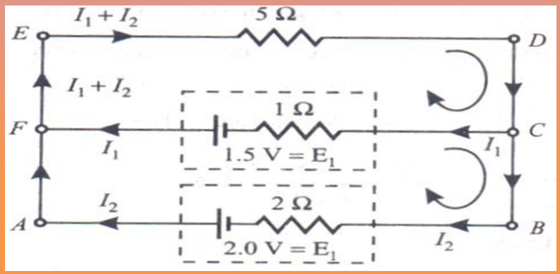
8. Two cells of emf 1.5 V and 2V and internal resistance 1 Ω and 2 Ω are connected in parallel to pass a current in the same direction through an external resistance of 5 Ω. (a) Draw Circuit Diagram. (b) Using Kirchhoff's laws, calculate the current through each branch of the circuit and p.d. across the 5 Ω resistor.



Ans………
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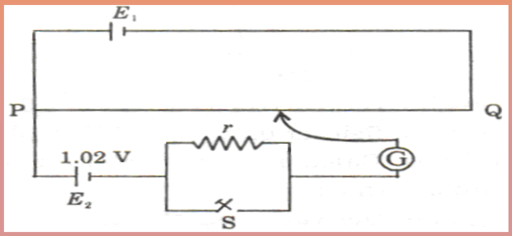
9. E_2 =1.02V, PQ=1m. When switch S open, null position is obtained at a distance of 51 cm from P. Calculate (i) potential gradient (ii) emf of the cell E_1 (iii) when switch S is closed, will null point move towards P or Q. Give reason for your answer.



Ans………...
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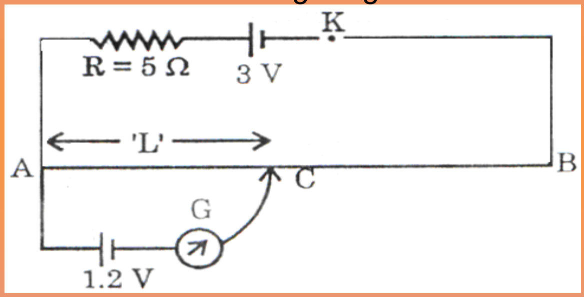
10. AB=100 cm, R_{AB}=10Ω. Find the balancing length AC.



Ans………...
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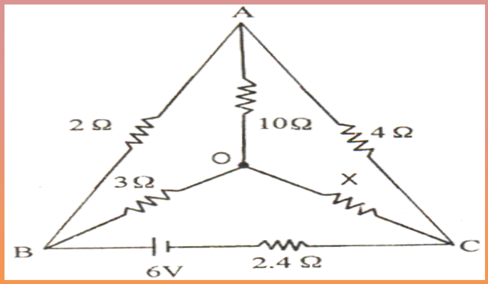
11. Find the value of the unknown resistance X in the circuit, if no current flows through the section AO. Also calculate the current drawn from the battery of emf 6V.



Ans………...
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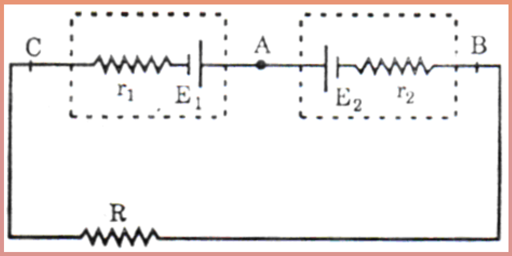
12. E_1 = 2V, E_2 = 4V, r_1 = 1Ω, r_2 = 2Ω, R = 5Ω
Calculate (i) current (ii) p.d. between B and A (iii) p.d. between A and C.



Ans………
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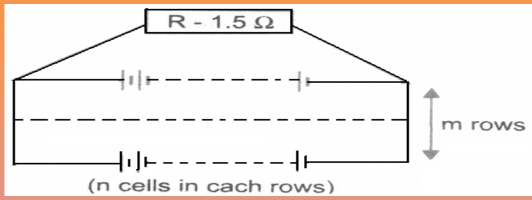
13. 12 cells, each of emf 1.5V and internal resistance 0.5Ω, are arranged in m rows each containing n cells connected in series, as shown. Calculate the values of n and m for which this combination would send maximum current through an external resistance of 1.5Ω



Ans………
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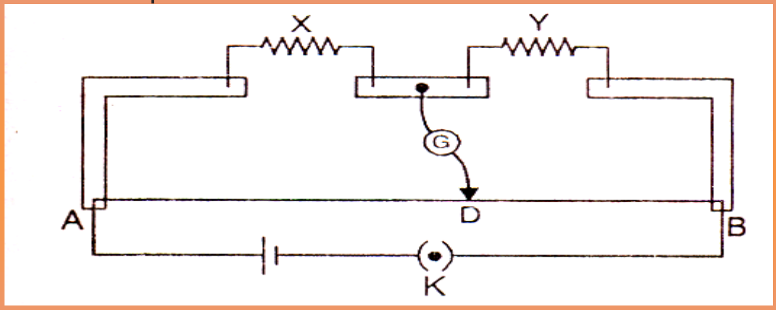
14. The given figure shows the experimental set up of a meter bridge. The null point is found to be 60cm away from the end A with X and Y in position as shown. When a resistance of 15Ω is connected in series with 'Y', the null point is found to shift by 10cm towards the end A of the wire. Find the position of null point if a resistance of 30Ω were connected in parallel with 'Y'.



Ans………
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15. A cell of unknown emf E and internal resistance r, two unknown resistances R_1 and R_2 (R_2>R_1) and a perfect ammeter are given. The current in the circuit is measured in five different situations : (i) Without any external resistance in the circuit, (ii) With

resistance R_1 only, (iii) With resistance R_2 only, (iv) With both R_1 and R_2 used in series combination and (v) With R_1 and R_2 used in parallel combination. The current obtained in the five cases are 0.42A, 0.6A, 1.05A, 1.4A, and 4.2A, but not necessarily in that order. Identify the currents in the five cases listed above and calculate E, r,, R_1 and R_2.

Ans

LEVEL-I

Q.No.	Expected Answers
1	P = I^2R. When electric current is doubled $I' = 2I$ Power becomes $P' = I'^2R = 4I^2R = 4P$
2	I = $\frac{E}{r+R}$ = 0.5A
3	$\rho = R\frac{A}{l} = R\frac{\pi D^2}{4l} = 2\times\frac{3.14\times(0.4\times10^{-3})^2}{4\times1} = 2.5\times10^{-7}\,\Omega m$
4	$\frac{E_1}{E_2} = \frac{l_1}{l_2} \Rightarrow \frac{1.25}{E_2} = \frac{35}{63} \Rightarrow E_2 = \frac{63}{35}\times1.25 = 2.25V$
5	$I = neAv_d = 9\times10^{28}\times1.6\times10^{-19}\times10^{-4}\times6.94\times10^{-9} = 10A$
6	$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \Rightarrow \alpha = \frac{2.7-2.1}{2.1(100-27.5)} = 0.0039^0C^{-1}$
7	(a) Total resistance $R_S = R_1 + R_2 + R_3 = 1+2+3 = 6\Omega$ (b) Current drawn from the battery $I = \frac{E}{R_S} = \frac{12}{6} = 2A$
8	(a) Total resistance, $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20}\Omega \Rightarrow R_P = \frac{20}{19}\Omega$ (b) Current drawn from the battery $I = \frac{E}{R_P} = \frac{20}{\left(\frac{20}{19}\right)} = 19A$

9	R = 60 x 10^4 Ω and $I = \frac{V}{R} = \frac{30}{60\times10^4} = 0.5\times10^{-4}A = 0.05mA$
10	$X = \frac{l}{100-l}Y = \frac{39.5}{100-39.5}\times12.5 = 8.16\Omega$

ANSWERS: LEVEL - 2

Q.No.	Expected Answers
1	I = $\frac{E}{r+R}$ = 0.5A. V = E – IR = 1.95 V
2	R = $\frac{V^2}{P}$ ⇒ R α $\frac{1}{P}$. The bulb marked 25W has higher resistance than the bulb marked 100W.
3	For maximum power dissipation, r = R = 2Ω . I = $\frac{E}{r+R}$ = 1.5A
4	V = $\sqrt{PR}$ = 7Volt.
5	$H_S = \frac{V^2}{2R}$ and $H_P = \frac{2V^2}{R}$ ∴ $H_S : H_P$ = 1:4
6	(i) Emf = 1.4V (ii) Internal resistance of the cell r = $\frac{E-V}{I}$ = 5Ω (iii)For maximum power dissipation I = $\frac{E}{r+R}$ = .14A
7	To get minimum, resistors are connected in parallel. $R_p = \frac{r}{n}$ To get maximum, resistors are connected in series. $R_s = nr$ $\frac{R_S}{R_P} = \frac{nr}{\left(\frac{r}{n}\right)} = n^2$
8	$E_1 - E_2$ = 250 ф $E_1 + E_2$ = 400 ф

	$\Rightarrow$ $E_1 : E_2 = 13 : 3$
9	1.5 – Ir = 13 I and 1.4 = 1.5 – Ir $\Rightarrow$ Ir = 0.1 $\Rightarrow$ I = $\frac{1.4}{13}$ A and r = $\frac{13}{14}\Omega$
10	(i) I = $\frac{2+1.8+1.5}{0.05+0.7+1+4} = \frac{5.3}{5.75} =$ 0.92A (ii) The p.d. across the terminals of the cell of emf 1.5V = E – Ir = 0.58V

ANSWERS: LEVEL - 3

Q.No.	Expected Answers
1	The Wheatstone bridge is a balanced because $\frac{P}{Q} = \frac{R}{S}$. Hence there is no current flowing through arm BD..
2	$Al = A'l' \Rightarrow A = \frac{105}{100}A'$ $R = \rho\frac{l}{A} \Rightarrow \frac{R_1}{R_2} = \frac{lA'}{l'A} \Rightarrow R_2 = (1.05)^2 R_1$ % Change = $\frac{R_2 - R_1}{R_1}\text{X}100 = 10.25\%$
3	For series combination, $I_S = \frac{3}{3+R}$ and For Parallel combination, $I_P = \frac{\frac{5}{3}}{\frac{2}{3}+R} = \frac{5}{3R+2}$ Given $I_S = I_P \Rightarrow R = \frac{9}{4}$ = 225 Ω . In series combination more heat is generated in the cells
4	$R_2 = R_1[1+\alpha(T_2 - T_1)] \Rightarrow R + 0.2R = R[1 + 2\times10^{-4}(T_2 - 300)] \Rightarrow T_2 = 1300K$
5	(i) In series, current in both wires is same. Drift velocity $v_d = \frac{I}{neA}$, $\frac{v_{d1}}{v_{d2}} = \frac{A_2}{A_1} = \frac{2}{1}$

	(ii) In parallel, p.d. across the both wires is same. Drift velocity $v_d = \frac{eV\tau}{ml}$ $\frac{v_{d1}}{v_{d2}} = \frac{l2}{l_1} = \frac{1}{1}$.
6	(i) When wires are connected in series: In series, the current remains the same; so we use the relation i = neAv$_d$, Resistivity, $\rho = \frac{m}{ne^2\tau} \Rightarrow n = \frac{m}{e^2\tau\rho} \Rightarrow i = \left\{\frac{m}{e^2\tau\rho}\right\} eAv_d$ or $i = \frac{m}{e\tau\rho} Av_d \Rightarrow v_d \propto \frac{1}{A} \therefore \frac{(v_d)_X}{(v_d)_Y} = \frac{A_Y}{A_X} = \frac{3}{2}$ (ii) When wires are connected in parallel: In parallel, the potential difference is same. In this case we apply the formula for drift velocity. $v_d = \frac{e\tau E}{m} = \frac{e\tau V}{ml}$ For same temperature τ is same, so $v_d \propto \frac{1}{l} \therefore \frac{(v_d)_X}{(v_d)_Y} = \frac{l_Y}{l_X} = \frac{2}{1}$
7	Power consumption = 2 units/hour = 2kW = 2000 J/s I = P/V = 9A Power loss in wire = $I^2R = I^2\rho l/A$ = 4 J/s =0.2% of total power consumption Power loss in Aluminium wire = 4 ρ_{Cu}/ρ_{Al} = 2.51J/s = 0.125 % of total power consumption
8	(b) $I = I_1+I_2$, $5I+ I_1 = 1.5$ and $5I+2I_2 = 2$ $\Rightarrow$ I = 5/17 A I_1 = 0.5/17 A and I_2 = 4.5/17 A. P.d. across 5 Ω resistance = 5I = 1.47V

9	(i) Potential gradient k = $\frac{E_2}{l_2}$ = 0.02V/cm (ii) emf of the cell $E_1 = k\,l_{PQ}$ = 2V When switch S is closed, null point is not affected because no current drawn from cell E_1 at the null point.
10	I = $\frac{E_1}{R_{AB}+R}$ = 0.2A ; ϕ = $\frac{IR_{AB}}{l_{AB}}$ = 2 x 10^{-2} V/cm ; E_2 = ϕ l_{AC} ⇒ l_{AC} = 60cm.
11	ABCD is a balanced Wheatstone bridge since there is no current in section AO. $\frac{P}{Q}=\frac{R}{S}\Rightarrow\frac{2}{4}=\frac{3}{X}\Rightarrow$ X = 6Ω, R_{BC} = 3.6 + 2.4 = 6Ω , Current drawn by circuit = 1A.
12	Net emf = $E_2 - E_1$ = 2V, Total resistance = R+ r_1 + r_2 = 8Ω (i) I = 0.25A (ii) V_{AB} = E_2- Ir_2 = 3.5V (iii) V_{AC} = E_1+ Ir_1 = 2.25V
13	Resistance of one row = nr, Resistance of m rows $R_{\text{int}} = \frac{nr}{m}$ For max. current, $R_{\text{int}} = R_{eext} \Rightarrow \frac{nr}{m} = R \Rightarrow 0.5n = 1.5m \Rightarrow n = 3m$ ……….(1) Total cells = nm…….. (2) ; On solving (1) & (2), n=6 and m= 2
14	Formula $\frac{X}{Y}=\frac{l}{100-l}$, $\frac{X}{Y}=\frac{60}{40}\Rightarrow 2X = 3Y$ ……………..(1) When a resistance of 15Ω is connected in series with 'Y' $\frac{X}{Y+15}=\frac{50}{50}\Rightarrow X = Y+15$ ………(2) On solving (1) & (2), X = 45 Ω , Y = 30Ω When a resistance of 30Ω is connected in series with 'Y' $\frac{X}{Y+30}=\frac{l}{100-l}\Rightarrow l = 75cm$ from end A.

15	(i) $I_1 = \frac{E}{r}$, (ii) $I_2 = \frac{E}{r+R_1}$, (iii) $I_3 = \frac{E}{r+R_2}$, (iv) $I_4 = \frac{E}{r+R_1+R_2}$, (v) $I_5 = \frac{E}{r + \frac{R_1 R_2}{R_1+R_2}}$ This is clear that $I_1 > I_5 > I_2 > I_3 > I_4$. Hence $I_1 = 4.2A, I_5 = 1.4A, I_2 = 1.05A, I_3 = 0.6A, I_4 = 0.42A.$ Putting these values in (i) to (v) and on solving, $E = 4.2V, R_1 = 3\Omega, R_2 = 6\Omega, r = 1\Omega$

UNIT –III- MAGNETIC EFFECTS OF CURRENTS & MAGNETISM

Formulae

- Biot-Savart law (Magnetic field due to current element)

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$$

- Force acting on a charge moving in a magnetic field

$F = qvB \sin\theta$ or $\vec{F} = q(\vec{v}\times\vec{B})$

- Magnetic field on the axis of a circular current loop

$$B = \frac{\mu_0 N I a^2}{2(r^2+a^2)^{3/2}}.$$

- Magnetic field due to an infinitely long straight current carrying wire

$$B = \frac{\mu_0 I}{2\pi r}$$

- Magnetic field at a point on the axis of a solenoid

$$B = \mu_0 nI$$

- Motion of a charged particle in a uniform magnetic field

$r = \frac{mv}{qB}$ $T = \frac{2\pi m}{qB}$

- Torque on a rectangular coil in a uniform magnetic field

$\tau = NIBA \sin\theta$

- Force per unit length acting on each of the two straight parallel metallic conductors carrying current

$$f = \frac{F_2}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

- Deflection in moving coil galvanometer

$$\alpha = \frac{NBAI}{k}$$

- Conversion of galvanometer into ammeter and voltmeter

$$S = \frac{I_g G}{(I - I_g)}$$

$$R = \frac{V}{I_g} - R_G$$

- Elements of Earth's magnetic field

$$H = B_E \cos\theta \qquad V = B_E \sin\theta$$

- P.E. of a magnetic dipole in a uniform magnetic field

$$U = -mB\cos\theta$$

- Magnetic dipole moment of a revolving electron

$$m = \frac{evr}{2} = n\left(\frac{eh}{4\pi m_e}\right)$$

- Magnetising field intensity

$$H = nI$$

- Intensity of magnetization

$$M = \frac{m}{V}$$

LEVEL I

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

Q. 2. A short bar magnet placed with its axis at 30^o to a uniform magnetic field of 0.2 T experiences a torque of 0.06 Nm. (i) Calculate the magnetic moment of the magnet. (ii) Find out what orientation of the magnet corresponds to its stable equilibrium in the magnetic field.

Q. 3. A solenoid has a core of a material with relative permeability 400. The winding of the solenoid are insulated from the core and carry a current of 2 A. If the number of turns is 1000 per meter, calculate (i) H, (ii) M and (iii) B.

Q. 4. In the Bohr model of hydrogen atom, an electron revolves around the nucleus in a circular orbit of radius 5.11 x 10^{-11} m at a frequency of 6.8 x 10^{15} Hz. What is the magnetic field at the Centre of the orbit?

Q. 5. Two long parallel wires carrying currents 8 A and 5 A in the same direction are separated by a distance of 4 cm. Estimate the force on 10 cm length of one wire due to the other wire.

Q. 6. A solenoid of 500 turns per meter is carrying a current of 3 *A*. Its core is made of iron of relative permeability 5000. Determine the magnitudes of magnetic intensity and magnetic field inside the core.

Q.7. A long straight wire carries a current of 35 A. What is the magnitude of magnetic field at a point 20 cm from the wire?

Q. 8. A circular coil of wire consisting of 100 turns, each of radius 8 cm carries a current of 0.4 A. What is the magnitude of magnetic field at its center?

Q. 9. A closely wound solenoid 80 cm long has 5 layers of winding of 400 turns each. If the current carried is 8 A, estimate the magnetic field inside the solenoid near its center.

Q. 10. A galvanometer of coil resistance 50 Ω shows full scale deflection for a current of 5 mA. How can it be converted into a voltmeter of range 0 to 15 V?

SOLUTIONS FOR LEVEL--I

Ans1.
$$\tan\delta = \frac{B_V}{B_H} = \frac{\sqrt{3}B_H}{B_H} = \sqrt{3}$$
$$\delta = 60^0$$

Ans2. (i) $M = \frac{\tau}{B\sin\theta} = \frac{0.06}{0.2\sin 60^0} = \frac{0.06}{0.2\times 0.5} = 0.6\,Am^2$

(ii) The P.E. of a magnetic dipole in a uniform magnetic field is
$$U = -mB\cos\theta$$
In stable equilibrium the P.E. is minimum, so $\cos\theta = 1 \quad or \quad \theta = 0^0$

Hence the bar magnet will be in stable equilibrium when its magnetic moment is parallel to the magnetic field.

Ans3. (i) $H = nI = 1000\times 2 = 2000\,Am^{-1}$

(ii) $B = \mu H = \mu_0\mu_r H = 4\pi\times 10^{-7}\times 400\times 2000 = 1T$

(iii) $M = \chi_m H = (\mu_r - 1)H = (400-1)\times 2000 = 8\times 10^5\,Am^{-1}$

Ans4.
$$B = \frac{\mu_0 I}{2r} = \frac{\mu_0 f e}{2r} = \frac{4\pi\times 10^{-7}\times 6.8\times 10^{15}\times 1.6\times 10^{-19}}{2\times 5.11\times 10^{-11}} = 13.4T$$

Ans5.
$$F = \frac{\mu_0 I_1 I_2}{2\pi r} l = \frac{4\pi\times 10^{-7}\times 8\times 5\times 0.1}{2\pi\times 0.04} = 2\times 10^{-5}\,N$$

Ans6. Magnetic intensity $H = nI = 500 \times 3 = 1500\ Am^{-1}$

Magnetic field inside the core $B = \mu H = \mu_0\mu_r H = 4\pi\times 10^{-7}\times 5000\times 1500 = 9.4T$

Ans7. Magnetic field due to a long straight wire is

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 35}{2\pi \times 0.2} = 3.5 \times 10^{-5}\, T$$

Ans8. Magnetic field at the center of a circular coil is

$$B = \frac{\mu_0 N I}{2 r} = \frac{4\pi \times 10^{-7} \times 100 \times 0.4}{2 \times 8 \times 10^{-2}} = 3.14 \times 10^{-4}\, T$$

Ans9. Turns per unit length of the solenoid

$$n = \frac{N}{l} = \frac{5 \times 400}{0.8} = 2500$$

Hence its magnetic field

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times 2500 \times 8 = 2.5 \times 10^{-2}\, T$$

Ans10. The series resistance to be connected with galvanometer to convert it into a voltmeter is

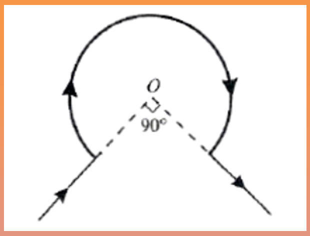
$$R = \frac{V}{I_g} - R_G = \frac{15}{5 \times 10^{-3}} - 50 = 2950\,\Omega$$

LEVEL II

Q. 1. Two identical magnetic dipoles of magnetic moment 1Am^2 each are placed at a separation of 2 m with their axes perpendicular to each other. What is the resultant magnetic field at a point mid-way between the dipoles?

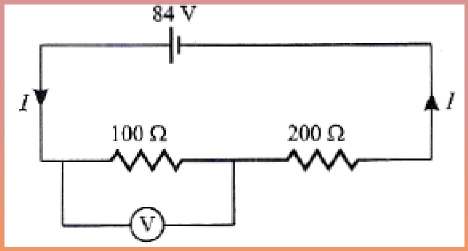
Q. 2. A magnetic dipole is under the influence of two magnetic fields. The angle between the field direction is 60^o and one of the field has a magnitude of 1.2 x 10^{-2} T. If the dipole comes to stable equilibrium at an angle of 15^o with this field, what is the magnitude of the other field?

Q. 3. The wire shown below carries a current *I*. Determine magnetic field at the centre. Radius of circular section is *R*.



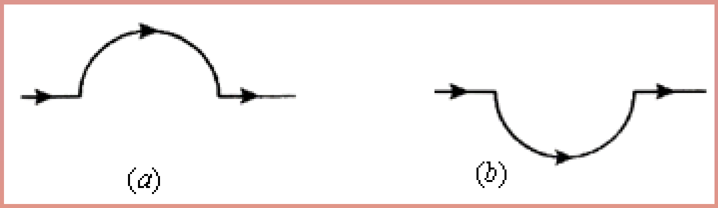
Q. 4. To increase the current sensitivity of a moving coil galvanometer by 50%, its resistance is increased so that the new resistance becomes twice its initial resistance. By what factor does its voltage sensitivity change?

Q. 5. A voltmeter *V* of resistance 400 Ω is used to measure the potential difference across a 100 Ω resistor as shown. What will be the reading of the voltmeter? Also find the potential difference across the resistor before the voltmeter is connected.



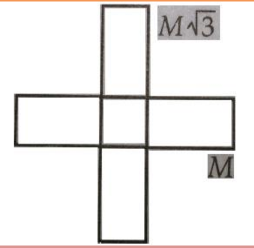
Q.6. A compass needle of magnetic moment 60 Am^2 pointing geographical north at a place where the horizontal component of earth's magnetic field is 40 μWb/m^2, experiences a torque of 1.2x10^{-3} Nm. What is the declination of the place?

Q. 7. A straight wire carrying a currant of 12 *A* is bent into a semicircular arc of radius 2 *cm* as shown below. What is the magnitude and direction of magnetic field at the centre of the arc? Would the answer change if it bent in the opposite way as shown in another figure?



Q.8. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid air by a uniform horizontal magnetic field. What is the magnitude of the field?

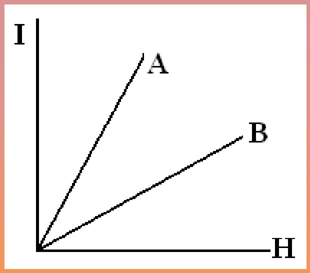
Q. 9. Two magnets of magnetic moments *M* and $M\sqrt{3}$ are joined to form a cross. The combination is suspended in a uniform magnetic field *B*. The magnetic moment *M* now makes an angle θ with the field direction. Find the value of θ.



Q. 10. The following figure shows the variation of intensity of magnetization versus the applied magnetic field intensity for two magnetic materials *A* and *B*.

(i) Identify the materials.

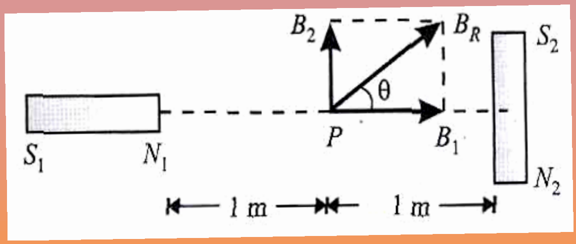
(ii) For the material *B*, plot the variation of intensity of magnetization versus temperature.



SOLUTIONS

LEVEL-II

Ans1. The situation is shown in the figure: The magnetic fields of the two magnets at the midpoint P are



$$B_2 = \frac{\mu_0}{4\pi}\frac{m}{r^3} = \frac{10^{-7}\times 1}{1^3} = 10^{-7}\,T\ (in\,vertical\,direction)$$

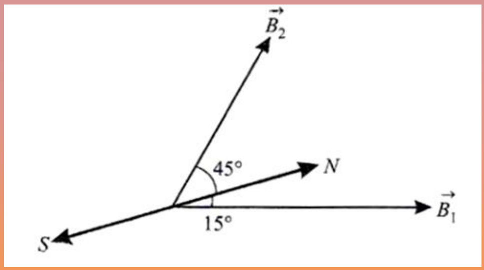
$$B_R = \sqrt{B_1^{\,2} + B_2^{\,2}} = \sqrt{5}\times 10^{-7}\,T$$

If the resultant field B_R makes angle θ with B_1, then

$$\tan\theta = \frac{B_2}{B_1} = \frac{10^{-7}}{2\times 10^{-7}} = 0.5$$

$$\theta = 26.57^0$$

Ans2.



Here, $B_1 = 1.2\times 10^{-2}T,\ \theta_1 = 15^0,\ \theta_2 = 60^0 - 15^0 = 45^0$

$In\ equilibrium \qquad \tau_1 = \tau_2$

$$mB_1\,Sin\theta_1 = mB_2\,Sin\theta_2$$

$$B_2 = \frac{B_1\,Sin\theta_1}{Sin\theta_2} = \frac{1.2\times 10^{-2}\sin 15^0}{\sin 45^0}$$

Or, $$B_2 = \frac{1.2\times 10^{-2}\times 0.2588}{0.7071} = 4.4\times 10^{-3}\,T$$

Ans3. As the circular portion is three-fourth of a circular loop. Therefore

$$B_O = \frac{3}{4}\frac{\mu_0 I}{2R} = \frac{3\mu_0 I}{8R}$$

Ans4. Current sensitivity $I_s = \frac{\alpha}{I}$

Voltage sensitivity $V_s = \frac{\alpha}{V} = \frac{\alpha}{I R_G} = \frac{I_s}{R_G}$

New current sensitivity $I_s' = I_s + \frac{50}{100} I_s = \frac{3}{2} I_s$

So, new voltage sensitivity $V_s' = \frac{I_s'}{2R_G} = \frac{3I_s/2}{2R_G} = \frac{3}{4}V_s$

Thus voltage sensitivity becomes 75% of initial value or decreases by 25%.

Ans5. Resistance of parallel combination of voltmeter and the resistor

$$R_1 = \frac{400\times 100}{400+100} = 80\,\Omega$$

Total resistance of the circuit $R = R_1 + 200 = 280\,\Omega$

Current in the circuit $I = \frac{E}{R} = \frac{84}{280} = \frac{3}{10} A$

Reading of the voltmeter $V = IR_1 = \frac{3}{10}\times 80 = 24V$

Total resistance before the voltmeter is connected = 100 + 200 = 300 Ω

Current $I = \frac{84}{300} = \frac{7}{25} A$

Potential difference across 100 Ω resistor,

$$V = IR = \frac{7}{25}\times 100 = 28V$$

Ans6. For a declination α, torque is

$\tau = mB\sin\alpha$

Therefore, $\sin\alpha = \frac{\tau}{mB} = \frac{1.2\times 10^{-3}}{60\times 40\times 10^{-6}} = \frac{1}{2}$

Or $\alpha = 30^0$

Ans7. The magnetic field at the centre of semicircular arc is

$$B = \frac{\mu_0 I}{4r}$$

$$= \frac{4\times10^{-7}\times12}{4\times0.02} = 1.9\times10^{-4}\,T$$

According to right hand rule, the field directs normally into the plane of paper. If the arc is bent in the opposite way, the magnitude of the field remains the same but direction will be opposite (normally out of the plane of the paper)

Ans8. For mid-air suspension, weight of the wire must be balanced by the magnetic force. Hence

$$IlB\sin 90^0 = mg$$

$$B = \frac{mg}{I\,l} = \frac{0.2\times9.8}{1.5\times2} = 0.65T$$

Ans9. The torque on a magnetic dipole $\tau = M\,B\sin\theta$

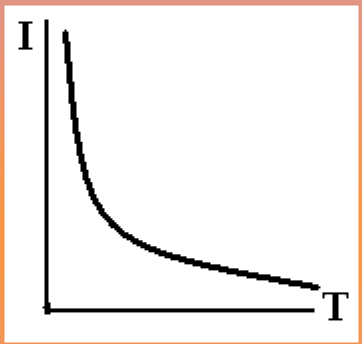
In the equilibrium of the system, torques on both the magnets balance each other. Thus

$$M\,B\sin\theta = \sqrt{3}\,M\,B\sin(90^o - \theta)$$

$$\tan\theta = \sqrt{3} \qquad \Rightarrow \qquad \theta = 60^o$$

Ans10. (i) The slope of I-H curve give susceptibility of the magnetic material. As the slope of *A* is positive and larger, it is ferromagnetic. The slope of *B* is positive and smaller, it is paramagnetic.

(ii) The *I-T* graph for paramagnetic material is shown below:

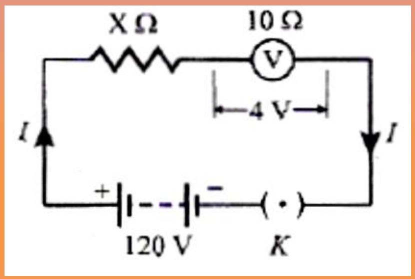


LEVEL III

Q. 1. A wire carrying a steady current is first bent in form of a circular coil of one turn and then in form of a circular coil of two turns. Fine the ratio of magnetic fields at the centers of the two coils.

Q. 2. A galvanometer gives deflection of 10 division per mA. The resistance of galvanometer is 60 Ω. If a shunt of 2.5 Ω is connected to the galvanometer and there are 50 divisions on the galvanometer scale, what maximum current can this galvanometer read?

Q. 3. A source of 120 *V* is connected to a large resistance *X*. A voltmeter of resistance 10 kΩ placed in series reads 4 *V*. What is the value of *X*? Why is voltmeter used instead of an ammeter?

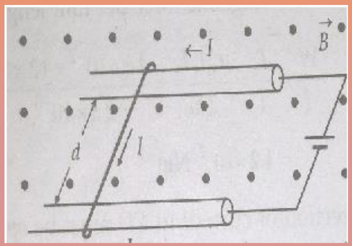


Q.4. Show that the magnetic field on the axis of a current carrying circular coil of radius *r* at a distance *x* from the centre of the coil is smaller by the fraction $3x^2/2r^2$ than the field at the centre of the coil.

Q. 5. A galvanometer can be converted into a voltmeter to measure upto
(i) V volt by connecting a resistance R_1 in series with coil.
(ii) V/2 volt by connecting a resistance R_2 in series with its coil.
Find the resistance in terms of R_1 and R_2 required to convert it into a voltmeter that can read upto '2V' volt.

Q. 6. A coil in the shape of an equilateral triangle of side 0.02 m is suspended from a vertex such that it is hanging in a vertical plane between the pole pieces of permanent magnet producing a horizontal magnetic field 5×10^{-2} T. Find the couple acting on the coil when a current of 0.1 A is passed through it and the magnetic field is parallel to its plane.

Q. 7. A metal wire of mass *m* slides without friction on two horizontal rails spaced at distance *d* apart as shown. The rails are situated in a uniform magnetic field *B*, directed vertically upwards and a battery is sending a current *I* through them. Find the velocity of the wire as a function of time assuming it to be at rest initially.



Q. 8. A hollow cylindrical conductor of radii *a* and *b* carries a current *I* uniformly spread over its cross section. Find the magnetic field *B* for points inside the body of the conductor at a distance *r* from the axis.

Q. 9. A straight horizontal conducting rod of length 0.6 m and mass 60 g is suspended by two vertical wires at its ends. A current of 5 A is set up in the rod through its wires. What magnetic field should be set up normal to the conductor in order that the tension in the wires is zero? What will be total tension in the wires if the direction of current is reversed?

Q. 10. A beam of proton passes undeflected through a region of mutually perpendicular electric and magnetic fields of magnitudes 50 kVm^{-1} and 100 mT respectively. Calculate the velocity of the beam. If this beam of current *I* strikes a screen with *n* protons per second, Find the force on the screen.

SOLUTIONS

LEVEL -III

Ans1. Let *l* be the length of the wire.

When it is bent in form of one turn circular coil,

$$l = 2\pi r_1 \qquad or \qquad r_1 = \frac{l}{2\pi}$$

Therefore $B_1 = \frac{\mu_0 N I}{2R} = \frac{\mu_0 \pi I}{l}$

When it is bent in two turn coil,

$$l = 2\times 2\pi r_1 \qquad or \qquad r_1 = \frac{l}{4\pi}$$

Therefore $B_2 = \frac{\mu_0 N I}{2R} = \frac{4\mu_0 \pi I}{l}$

Hence $B_1 : B_2$ = 4 : 1

Ans2. Current required for full scale deflection

I_g = current for one division deflection x total number of divisions

$$I_g = \frac{1}{10} \times 50 = 5\,mA$$

If *I* be the maximum current that a galvanometer can read, then

$$I = \frac{(R_G + S)I_g}{S} \qquad \left[As\ \ S = \frac{I_g R_G}{I - I_g} \right]$$

$$I = \frac{(60 + 2.5)5}{2.5} = 125\,mA$$

Ans3. Current through voltmeter $I = \frac{V}{R} = \frac{4}{10 \times 10^3} = 4 \times 10^{-4}\ A$

Also $I = \frac{Total\ emf}{Total\ resistance}$

So, $4 \times 10^{-4} = \frac{120}{X + 10^4}$

or $X = 29 \times 10^4 \Omega$

As the current is very small, the ammeter reading will be too small to be measured accurately. Hence this is an unusual use of voltmeter.

Ans4. $B_{centre} = \frac{\mu_0 N I}{2r}$ and $B_{axial} = \frac{\mu_0 N I r^2}{2(r^2 + x^2)^{3/2}}$

$$\therefore \quad \frac{B_{axial}}{B_{centre}} = \frac{r^3}{(r^2 + x^2)^{3/2}} = \frac{r^3}{r^3}\left[1 + \frac{x^2}{r^2}\right]^{-3/2} = \left[1 - \frac{3}{2}\frac{x^2}{r^2}\right]$$

The fractional decrease in the field

$$\frac{B_{centre} - B_{axial}}{B_{centre}} = \frac{3}{2}\frac{x^2}{r^2}$$

Ans5. For voltmeter of range V,

$$R_1 = \frac{V}{I_g} - R_g \quad or \quad \frac{V}{I_g} = R_1 + R_g$$

For voltmeter of range V/2

$$R_2 = \frac{V}{2I_g} - R_g \quad or \quad \frac{V}{2I_g} = R_2 + R_g$$

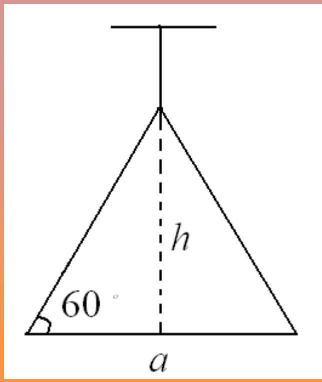
Dividing, we get

$$2 = \frac{R_1 + R_g}{R_2 + R_g} \quad \Rightarrow \quad R_g = R_1 - 2R_2$$

For a voltmeter of range 2V, the series resistance is

$$R = \frac{2V}{I_g} - R_g = 2(R_1 + R_2) - R_g = 3R_1 - 2R_2$$

Ans6. As shown in figure



Area of the triangle

$$A = \frac{1}{2} \times base \times height = \frac{1}{2} \times a \times a \sin 60^o = \sqrt{3} \times 10^{-4}\ m^2$$

Magnetic dipole moment of the coil

$$M = I\,A = 0.1 \times \sqrt{3} \times 10^{-4} = \sqrt{3} \times 10^{-5}\ Am^2$$

Thus torque acting on the coil $\tau = M\,B \sin 90^o = 5\sqrt{3} \times 10^{-7}\ Nm$

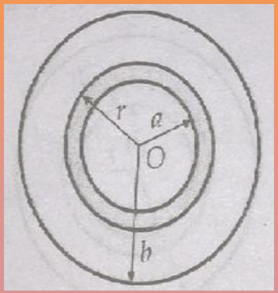
Ans7. Force on the wire $F = I\,B\,d \sin 90^o = I\,B\,d$

This force produces a constant acceleration in the wire. Thus velocity of the wire

$$v = u + a\,t = o + \frac{I\,B\,d}{m} t = \frac{I\,B\,d\,t}{m}$$

Ans8. Let us consider a cylindrical shell of radius *r*. Current enclosed by this shell

$$I' = \frac{I}{\pi (b^2 - a^2)} \times \pi (r^2 - a^2) = \frac{I (r^2 - a^2)}{(b^2 - a^2)}$$



Using Ampere's circuital law

$$B L = \mu_0 I'$$

$$B \times 2\pi r = \mu_0 \frac{I (r^2 - a^2)}{(b^2 - a^2)}$$

$$B = \frac{\mu_0 I (r^2 - a^2)}{2\pi r (b^2 - a^2)}$$

Ans9. For tension to be zero,

$$B I L = M g \quad \Rightarrow \quad B = \frac{60 \times 10^{-3} \times 10}{5 \times 0.6} = 0.2T$$

When the direction of the current is reversed, total tension is

$T = B I L + M g = 0.4T$

Ans10. For a charge particle to pass undeflected, $qE = qvB$.

Thus $$v = \frac{E}{B} = \frac{50 \times 10^3}{100 \times 10^{-3}} = 5 \times 10^5 \; ms^{-1}$$

When the beam strikes the screen, its final momentum becomes zero. Thus the force exerted,

$$F = \frac{mv}{t} = \frac{mv}{q/I} = \frac{mvI}{ne}$$

UNIT-IV- ELECTROMAGNETIC INDUCTION AND A.C.
Formulae at a glance

Physical Quantity	Formula	SI unit	Dimension
Magnetic flux (ϕ)	$\vec{B}\bullet\vec{A}=BA\cos\theta=\int\vec{B}\bullet d\vec{A}$	Wb = Tm^2	$[ML^2T^{-2}A^{-1}]$
Induced emf (e)	$\varepsilon=-\frac{d\phi}{dt}$ Induced current $i=\frac{\varepsilon}{R}=-\frac{N}{R}\frac{d\phi}{dt}$ Induced charge $q=i\Delta t=-\frac{N}{R}\Delta\phi$ Motional emf induced in a straight conductor (i) Linear motion = Blv (ii) Rotation about one end = $Bl^2\omega/2$	Volt	$[ML^2T^{-1}A^{-1}]$
Self-inductance	$L=\phi/I$ and $L=\frac{\lvert\varepsilon\rvert}{dI/dt}$ Self-inductance of a long solenoid $L=\mu_r\mu_0 n^2 A\ l$	Henry	$[ML^2T^{-2}A^{-2}]$
Mutual inductance	$M_{12}=\phi_2/I_1$ and $M_{12}=\frac{\lvert\varepsilon_2\rvert}{dI_1/dt}$ Mutual-inductance of two long co-axial solenoids $M_{12}=\mu_0 n_1 n_2 \pi r^2 l$, $M_{12}=\sqrt{^3L_1L_2'}$	Henry	$[ML^2T^{-2}A^{-2}]$
Magnetostatic energy stored	$U=\frac{1}{2}LI^2$	Joule	$[ML^2T^{-2}]$
Alternating current and voltage	$e=E_0\sin(\omega t+\phi)$ or $e=E_0\cos(\omega t+\phi)$ $i=I_0\sin(\omega t+\phi)$ or $i=I_0\cos(\omega t+\phi)$ $I_{rms}=I_o/\sqrt{2}=0.707\ I_0$ and $E_{rms}=E_o/\sqrt{2}=0.707\ E_0$		
Phase relationship	**For R** : No phase difference bet^n V and I **For L**: Voltage leads the current by π/2 **For C**: Current leads the voltage by π/2 **For LCR circuit**: **if f > f_r** $\phi=\tan^{-1}\left(\frac{X_L-X_C}{R}\right)$ or $\phi=\tan^{-1}\left(\frac{V_L-V_C}{V_R}\right)$ **If f<f_r** $\phi=\tan^{-1}\left(\frac{X_C-X_L}{R}\right)$ or	Unit less	Dimensionless

	$\phi = \tan^{-1}\left(\frac{V_C - V_L}{V_R}\right)$		
Reactance and impedance	Inductive reactance $X_L = \omega L$ Capacitive reactance $X_C = 1/\omega C$ Impedance of LR circuit $Z = \sqrt{X_L^2 + R^2}$ Impedance of RC circuit $Z = \sqrt{X_C^2 + R^2}$ Impedance of LCR circuit $Z = \sqrt{(X_L - X_C)^2 + R^2}$	Ohm	$[ML^2T^{-1}A^{-2}]$
Resonance frequency	$f_r = \frac{1}{2\pi\sqrt{LC}}$, angular frequency $\omega_r = \frac{1}{\sqrt{LC}}$	Hertz, rad/s	$[T^{-1}]$
Quality factor	Q = $\frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\omega_r}{2\Delta\omega} = \frac{\omega_r L}{R} = \frac{1}{\omega_r CR}$	Unit less	Dimensionless
Power dissipated in ac circuit	In pure inductor and capacitor: Zero In pure resistive circuit: $I^2R/2$ In a combination of L,C and R: $V_{rms}I_{rms}\cos\phi$	Watt	$[ML^2T^{-3}]$
Power factor	$\cos\phi = R/Z$	Unit less	Dimensionless
Wattles current	$I_{rms}\cos\phi$	Ampere	[A]
Frequency of LC oscillations	$f_r = \frac{1}{2\pi\sqrt{LC}}$	Hertz	$[T^{-1}]$
Energy of ideal LC oscillator	$\frac{1}{2}Q^2/C + \frac{1}{2}LI^2 = \frac{1}{2}Q_0^2/C$	Joule	$[ML^2T^{-2}]$
Transformation ratio and efficiency of transformer	$\frac{v_S}{v_P} = \frac{N_S}{N_P}$ Efficiency:- $\eta = \frac{v_s I_s}{v_p I_p} = \frac{P_0}{P_i}$	Unit less	Dimensionless

NUMERICALS

LEVEL I

1. What is the self-inductance of a coil in which magnetic flux of 40mWb is produced when 2A current flow through it?

Ans.____

2. If the self inductance of an air core inductor increases from 0.01mH. to 100mH on introducing an iron core into it. What is relative permeability of the core used?

Ans.____

3. What is the power dissipated in an a.c circuit in which voltage and current are given by $V=230 \sin(\omega t + \pi/2)$ and $I=10 \sin\omega t$?

Ans.____

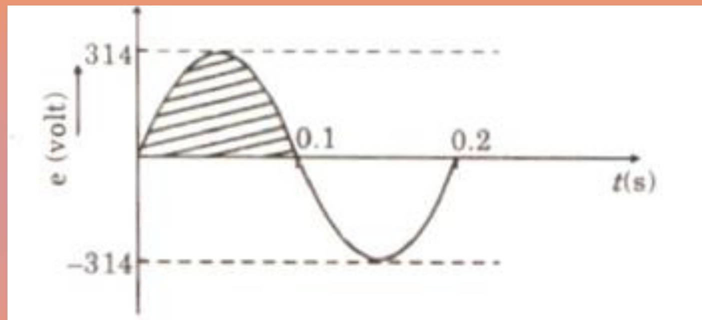
4. When a lamp is connected to an a.c. supply it light with the same brightness as when connected to a 12V d.c battery. What is the peak value of alternating voltage?

Ans.____

5. Find the capacitance of the capacitor that would have reactance of 100 □□when used with a.c. source of frequency $\frac{5}{\pi}$ kHz ?

Ans.____

6. What is the average value of the emf for the shaded part of graph?



Ans.

7. In a series LCR circuit the voltage across an inductor, a capacitor and a resistor are 20V, 20V and 60V respectively. What is the phase difference between the applied voltage and the current in the circuit?

Ans.

8. A circular coil of radius 8 cm and 20 turns rotates about its vertical diameter with an angular speed of 50/s in a uniform horizontal magnetic field of magnitude 3×10^{-2} T. Find the max. and average value of the emf induced in the coil.

Ans.

9. The instantaneous current from an a.c. source is I = 5 sin (314 t) ampere. What are the average and rms values of the current?

Ans.

10. An inductor L, a capacitor 20 μF, a resistance 10Ω.are connected in series with an ac source of frequency 50 Hz. If the current is in phase with voltage, calculate the Inductance L.

Ans.

LEVEL II

Q1. A conductor of length 1.0 m falls freely under gravity from a height of 10 m so that it cuts the lines of force of the horizontal component of earth's magnetic field of $3x10^{-5}$ Wbm^{-2}. Find the emf induced in the conductor.

Q2. A 0.4 m long straight conductor is moved in a magnetic field of induction 0.9 Wbm^{-2} with velocity of 7 ms^{-1}. Calculate the maximum emf induced in the conductor.

Q3. A metal disc of radius 200 cm is rotated at a constant angular speed of 60 $rads^{-1}$ in a plane at right angles to an external field of magnetic induction 0.05 Wbm^{-2} .Find the emf induced between the centre and a point on the rim.

Q4. Find the maximum value of current when an inductance of one Henry is connected to an a.c. source of 200 volts, 50 Hz.

Q5. What is the inductive reactance of a coil if current through it is 800 mA and the voltage across it is 40 V?

Q6. A transformer has 300 primary turns and 2400 secondary turns .If the primary supply voltage is 230 V, what is the secondary voltage?

Q7. A transformer of 100% efficiency has 500 turns in the primary and 10,000 turns in the secondary coil. If the primary is connected to 220 V supply, what is the voltage across the secondary coil?

Q8. A capacitor in series with a resistance of 30 ohm is connected to a.c. mains. The reactance of the capacitor is 40 ohm. Calculate the phase difference between the current and the supply voltage.

Q9. Determine the impedance of a series LCR-circuit if the reactance of C and L are 250 ohm and 220 ohm respectively and R is 40 ohm.

Q10. A series circuit with L=0.12 H, C=0.48 mF and R=25 ohm is connected to a 220 V variable frequency power supply. At what frequency is the circuit current maximum?

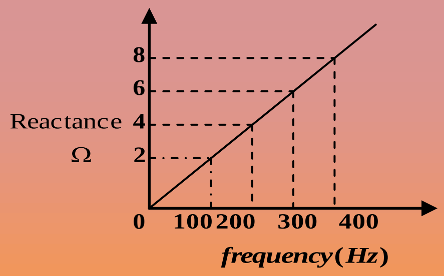
LEVEL III

1. A bulb of resistance 10Ω, connected to an inductor of inductance L, is in series with an ac source marked 100V, 50Hz. If the phase angle between the voltage and current is $\frac{\pi}{4}$ radian, calculate the value of L.

2. Figure shows how the reactance of an inductor varies with frequency.

(a) Calculate the value of inductance of the inductor using the information given in the graph.

(b) If this inductor is connected in series to a resistor of 8 ohm, find what would be the impedance at 300 Hz.



3. In a series RC circuit, R = 30 Ω, C = 0.25 μ F, V = 100 V and ω = 10,000 radian per second. Find the current in the circuit and calculate the voltage across the resistor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? If yes, resolve the paradox.

4. When an alternating voltage of 220V is applied across a device *X*, a current of 0.5A flows through the circuit and in phase with the applied voltage. When the same voltage is applied across another device *Y*, the same current again flows through the circuit but it leads the applied voltage by *π*/2 radians. (i) Name the devices *X* and *Y*, (ii) Calculate the current flowing in the circuit when the same voltage is applied across the series combination of *X* and *Y*.

5. In the series LCR circuit, suppose R = 300 Ω, L = 60 mH, C = 0.5 μ F. An ac source of emf 50 V, angular frequency 10,000 rad/s is connected across the combination. Find the reactance X_L, and X_C, the impedance Z, the current amplitude I, the phase angle φ, and the voltage amplitude across each circuit element.

6. In a series RC circuit with an AC source, R = 300 Ω, C = 25 μF, e_0 = 50 V and ν = $\frac{50}{\pi}$ Hz, find the peak current and the average power dissipated in the circuit.

7. An inductor 200 mH, capacitor 500 μ F, resistor 10 Ω are connected in series with a 100 V, variable frequency ac source. Calculate the (i) frequency at which the power factor of the circuit is unity; (ii) current amplitude at this frequency; (iii) Q-factor.

8. A resistor of resistance 400 Ω, and a capacitor of reactance 200 Ω, are connected in series to a 220 V, 50 Hz ac source. If the current in the circuit is 0.49 A, find the (i) voltage across the resistor and capacitor (ii) value of inductance required so that voltage and current are in phase.

9. A resistor of 200 Ω and a capacitor of 15 μ F are connected in series to a 220 V, 50 Hz ac source. (a) Calculate the current in the circuit; (b) calculate the voltage (rms) across the resistor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? If yes, resolve the paradox.

10. A town is situated 15 km away from a power plant generating power at 440V, requires 800 kW of electric power at 220V. The resistance of the two wire line carrying power is 0.5 ohm per km. The town gets power from the line through a 4000-220V step down transformer at a substation in the town.

(i) Find the line power losses in the form of heat.

(ii) How much power must the plant supply, assuming there is negligible power loss due to leakage?

(iii) Characterize the step up transformer at the plant.

11. An ac generator consists of a coil of 50 turns and area 2.5 m^2 rotating at an angular speed of 60 rad/s in a uniform magnetic field B = 0.3 T between two fixed pole pieces. The resistance of the circuit including that of the coil is 500 Ω. Determine the Calculate

(i) maximum current drawn from the generator. (ii) maximum power dissipation in the coil.

(iii) What will be orientation of the coil with respect to the magnetic field to have (*a*) maximum, (*b*) zero magnetic flux? (iv) Would the generator work if the coil was stationary and instead the pole pieces rotated together with the same speed as above?

12. A circular coil having 20 turns, each of radius 8 cm, is rotating about its vertical diameter with an angular speed of 50 radian/s in a uniform horizontal magnetic field

of magnitude 30 mT. Obtain the maximum average and rms value of the emf induced in the coil. If the coil forms a closed loop of resistance 10 Ω, how much power is dissipated as heat in it?

13. An athlete peddles a stationary tricycle whose pedals are attached to a coil having 100 turns each of area 0.1m^2. The coil, lying in the X-Y plane, is rotated, in this plane, at the rate of 50 rpm, about the Y-axis, in a region where a uniform magnetic field, $\vec{B}$ = (0.01) $\hat{k}$ tesla, is present. Find the (i) maximum emf (ii) average e.m.f generated in the coil over one complete revolution.

Answers
Level I

1. 20 mH. 2. *1000* 3. zero 4. *16.92V* 5. *10^{-6} F*
6. *200V* 7. *0 rad.* 8. *εmax = 0.6 V ; ε_{av} =0 V* 9. average value of current = 0, rms value of current= $\frac{5}{\sqrt{2}}$ A 10. 2X 10^5 H]

Level II

Q1:- 4.2×10^{-4} V , Q2:- 2.52 V , Q3:- 6 V , Q4:- 0.9 A , Q5:- 50 ohm , Q6:- 1.84 kV , Q7:- 4400 V , Q8:- $\tan^{-1} 4/3$, Q9:- 50 ohm , Q10:- 21 Hz

Level III

Ans1. Cos $\phi = \frac{R}{Z}$ $\Rightarrow \cos\frac{\pi}{4} = \frac{R}{\sqrt{R^2 + X_L^2}}$ $\Rightarrow X_L = R$ $\Rightarrow L = 3.14 \times 10^{-2}$ H

Ans2. (a) L $= \frac{X_L}{2\pi\nu}$ (b) at 300 Hz; $X_L = 6\ \Omega$, R = 8 Ω $\Rightarrow Z = \sqrt{R^2 + X_L^2}$ = 10 Ω

Ans3. $X_C = \frac{1}{2\pi\nu C}$ =400 Ω; Z = $\sqrt{R^2 + X_C^2}$ = 500 Ω; $i = \frac{e}{Z} = \frac{100}{500}$ =0.2 A

rms voltage drop on R = $V_R = i_{rms}$ R = 60 V; rms voltage drop on C = $V_C = i_{rms} X_C$ = 80 V

$V_L + V_C$ = 140 V > e; This paradox occurs because being phasor quantities, V_R and V_C cannot be added algebraically.

Ans4. Since current and voltage are in phase, so, device X is resistor. R = $\frac{220}{0.5} = 440\Omega$

For device Y, current leads the voltage in phase by $\frac{\pi}{2}$, so, Y is a capacitor. X_C = $\frac{220}{0.5} = 440\Omega$

When R and C are connected in series then $i_{rms} = \frac{e_{rms}}{\sqrt{R^2 + X_C^2}}$ =0.3535 A

Ans5. $X_L = \omega L = 600\ \Omega$; $X_C = \frac{1}{\omega C}$ =200 Ω; Z $= \sqrt{R^2 + (X_L - X_C)^2}$ = 500 Ω;

$i_0 = i_{rms}\sqrt{2}$ = 0.1414 A

Phase angle, $\phi = \cos^{-1}\frac{R}{Z} = \cos^{-1}(0.6)$; V_o (across R) = i_0 R = 42.42 V; V_o (across L) = $i_0 X_L$ = 84.84 V;

V_o (across C) = $i_0 X_C$ = 28.28 V

Ans 6. Peak current = $i_0 = \frac{e_0}{Z} = \frac{e_0}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} = 0.1A$;

Power dissipated = $e_{rms}\, i_{rms} \cos\phi = \frac{e_0}{\sqrt{2}} \frac{i_0}{\sqrt{2}} \frac{R}{Z}$ = 1.5 Watt

Ans7. Power factor is unity when circuit is in resonance for which the frequency is $\nu = \frac{1}{2\pi\sqrt{LC}}$ =15.9 Hz

At resonant frequency, Z = R; Current amplitude = $i_0 = \frac{e_0}{Z} = \frac{e_0}{R} = \frac{e_{rms}\sqrt{2}}{R}$ =14.14 A

Quality factor Q = $\frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\omega_r}{2\Delta\omega}$ =2

Ans8. (i) $V_R = i_{rms} R = 196$ V; $V_C = i_{rms} X_C = 98$ V (ii) If the circuit is LCR as V and I are in phase then LCR circuit is in resonance for which $X_L = X_C$ $\Rightarrow$ L = 0.628 H

Ans 9. $X_C = \frac{1}{2\pi\nu C}$ =210 Ω; $i_{rms} = \frac{e_{rms}}{Z} = \frac{e_{rms}}{\sqrt{R^2 + X_C^2}}$ =0.76 A; rms potential drop on R = $V_R = i_{rms} R = 152$ V

rms potential drop on C = $V_C = i_{rms} X_C = 159.6$ V; Sum of V_L and V_C = 312 V which is > than applied voltage 200 V; As V_R and V_C are phasor quantities, so, they cannot be added algebraically.

Ans 10. (i)Assuming transformer to be ideal, the current in the transmission line I = 800000/4000 = 200 A

Therefore line power loss = $I^2R = (200)^2 \times 15$ = 600 kW (ii) the plant should supply 1400 kW power (iii) the output voltage of step up transformer at the plant = 1400000/200 = 7000 V. therefore the characterization of step up transformer is 440 V – 7000 V

Ans11. (i) Maximum current $i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R}$ =4.5 A; (ii) Maximum power dissipation = $i_0^2 R$ = 10125 W

(iii) (a) For maximum flux, coil must be $\perp$ to $\vec{B}$; (b) for minimum flux, coil must be || to $\vec{B}$

(iv) If pole pieces are rotates then also, the flux of coil changes thus generator works.

Ans 12. $e_{ave} = 0$; $e_{rms} = \frac{e_0}{\sqrt{2}} = \frac{NBA\omega}{R}$ =0.4242 V; Power dissipated = $i_{rms}^2 R = \frac{e_{rms}^2}{R} = \frac{e_0^2}{2R}$ =18 x 10^{-3} W

Ans 13. (i) Maximum emf 'e' generated in the coil is e = NBAω = 0.52 V (ii) The average emf generated in the coil over one complete revolution = 0

UNIT—V-ELECTROMAGNETIC WAVES

GIST ,FORMULAE AND SHORTCUT FOURMULAE

1. **Concept of displacement current**
   Displacement current is that current which appears in a region in which the electric field (and hence electric flux) is changing with time.
   Note- We have $I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA) = = \varepsilon_0 \frac{d}{dt}(\frac{q}{\varepsilon_{0A}} A) = = \frac{dq}{dt} = I$
2. **Modified Ampere's circuital Law**
   $\oint B.dl = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$
3. **Electromagnetic Waves**
   We know, Maxwell's equations in vacuum
   $$\oint \vec{E}.\vec{dl} = -\frac{d\phi_B}{dt} \quad \& \quad \oint \vec{B}.\vec{dl} = \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$
   These equations leads to the conclusion that, either of the electric or magnetic fields change with time, the other field is induced in space. The net result of these interacting changing fields is the generation of electromagnetic disturbance, called electromagnetic waves which travel with the speed of light.
4. **Mathematical Expression of EM waves**

$$E_y = E_0 \sin 2\pi(\frac{x}{\lambda} - \frac{t}{T}) j$$

$$B_Z = B_0 \sin 2\pi(\frac{x}{\lambda} - \frac{t}{T}) k$$

5. **Properties of em waves**

(i) E. M. waves are produced by accelerated charged particles.

(ii) E.M. waves do not require any medium for their propagation. These waves can propagate in vacuum as well as in a medium.

velocity of em waves in a free space is given by

$$v = c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/s}$$

Velocity of em waves in a medium is given by

$$v = \frac{c}{\sqrt{\mu_r K}}$$

(iii) E.M. waves are transverse in nature i,e, $\vec{E}$ & $\vec{B}$ are perpendicular to each other as well as perpendicular to the direction of

propagation of the wave. $\vec{E}$ & $\vec{B}$ are related as follows -

$$\frac{E_0}{B_0} = c \quad \text{or} \quad \frac{E}{B} = c$$

(iv) E.M. waves carry energy, which is shared equally by electric and magnetic fields.

The average energy density of an em wave is given by

$$u = u_E + u_B = 2\,u_E = 2\,u_B$$

Where $u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (Bc)^2$ $\quad [\because \frac{E}{B} = c]$

$= \frac{1}{2}\varepsilon_0 B^2 (\frac{1}{\sqrt{\mu_0\varepsilon_0}})^2$ $\quad [\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}]$

⇨ $u_E = \frac{B^2}{2\mu_0} = u_B$

(v) E.M. waves carry momentum & exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$ & momentum $p = \frac{U}{c}$

(vi) E.M. waves transport energy. The rate of energy of em wave transported per unit area is represented by a quantity called

Pointing vector (S) and is given by

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$$

(Vii) Electric vector of an em wave is responsible for optical effects, as E_0 >> B_0.

(viii) Intensity of an em wave is given by

$$I = \frac{1}{2} c\, \varepsilon_0 E = \frac{B\,c}{2\mu_0}$$

LEVEL –I

ONE MARK QUESTIONS

1. Write the expression for the displacement current?
2. The charging current for capacitor is 0.5 A. What is the displacement current across its plate?
3. Write an expression for the speed of e.m. waves in free space.
4. For an electromagnetic wave, write the relationship between amplitude of electric and magnetic fields in free space.
5. What was the range of wavelength of em waves produced by Professor J.C.Bose?

TWO MARKS QUESTIONS

6. What is displacement current? Why was this concept introduced?
7. Give one uses of each of the following:
    a. Microwave
    b. Infra-red wave
    c. Ultra violet radiation
    d. Gamma rays

8. Identify the following electromagnetic radiation as per the wavelength given below. Write one application of each.
    a. 1mm
    b. 10^{-3}nm

THREE MARKS QUESTIONS

9. Identify the following electromagnetic radiation as per the wavelength given below. Write one application of each.
6. 10^{-12}m
7. 10^{-4}m
8. 10^{6}m
10. Name the electromagnetic radiation having the wavelength range from 1mm to 700nm. Give its two important applications.
11. What is meant by electromagnetic spectrum? Give its four uses.

Answers

LEVEL -I

1. $I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA)$
2. According to the property of conductivity,
   The displacement current = Charging current. = 0.25A
3. The speed of an em wave in free space is
   $c = \frac{1}{\sqrt{\mu^\circ \epsilon^\circ}}$
4. $c = E^\circ / B^\circ$
5. 25mm to 5mm
6. The displacement current is that current which comes into existence, in addition in to the conduction current, whenever the electric field and hence the electric flux changes with time.
7. A. radar b. treatment of muscular complaints c. sterilizing surgical instruments d. radiation therapy.
8. A. microwave used in radar system b. infra red used in treatment of muscular complaints.
9. Identification:- a. gamma rays use- radiotherapy b. Infrared rays use – haze photography c. long radio wave use in radio communication.
10. X-rays used in a. medical diagnosis and b. in study of crystal structure.
11. All the known radiation from the big family of electromagnetic wave which stretch over a long range of wavelengths. The orderly distribution of the electromagnetic wave in accordance with their wavelengths or frequency in to distinct group having widely different properties is called electromagnetic spectrum. For example the X rays is one part of spectrum whose use are-

(i) used in detecting fractures in bones
(ii) used in detecting faults,cracks,haws & holes in metal sheets
(iii) used in studying crystal structure
(iv) used in radiotherapy
(v) used in detecting pearls, oysters etc.

12. An oscillating charge radiates electromagnetic waves and these waves carry energy.

UNIT – VI—OPTICS
ALL THE POSSIBLE FORMULAE

- Relation between focal length and radius of curvature of a mirror/lens, f = R/2
- Mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
- Magnification produced by a mirror: m = - $\frac{v}{u}$ = - $\frac{f}{u - f}$
- Snell's law: $\frac{\sin i}{\sin r} = {}^{1}n_{2} = \frac{n_2}{n_1}$
- ${}^{2}n_{1} = \frac{1}{{}^{1}n_{2}}$
- n = $\frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{\lambda_{air}}{\lambda_{medium}}$
- If object is in medium of refractive index n, then n = $\frac{\text{real depth}}{\text{apparent depth}} = \frac{t}{t_{app}}$
- Apparent shift, $x = t - \frac{t}{n} = t\left(1 - \frac{1}{n}\right)$
- Critical angle for total internal reflection: sin C = $\frac{1}{{}^{r}n_{d}} = \frac{1}{n}$
- Refraction at spherical (convex) surface: For object in rarer medium and real image in denser medium, the formula is $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ where n_2 & n_1 are the refractive indices of denser and rarer media.
- Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- Linear magnification produced by a lens: m = $\frac{I}{O} = \frac{v}{u}$
- Lens maker's formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = ({}^{a}n_{g} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ = (n – 1) $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$
- Power of a lens: P = $\frac{1}{f}$ diopter (f is in metre)
- Lenses in contact: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ or $P = P_1 + P_2$
- Focal length of lens in liquid: $f_l = \frac{n_g - 1}{\frac{n_g}{n_l} - 1} \times f_a$
- Refraction through a prism: $r_1 + r_2 = A$ and $i + e = A + \delta$ where A is angle of prism and δ is angle of deviation.
- For minimum deviation, i = e = i and $r_1 + r_2 = r$. Therefore, $\delta_m = 2i - A$
- Refractive Index of the material of prism: $n = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$
- For a thin prism: δ = (n – 1)A
- Angular dispersion = $\delta_V - \delta_R$
- Dispersive power, $\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{n_V - n_R}{n_Y - 1}$
- Simple microscope: Magnifying power $M = 1 + \frac{D}{f}$ (if final image is at D)
  = $\frac{D}{f}$ (if final image is at infinity)
- Compound microscope:

i) Magnification M = $m_o m_e$

ii) Magnification M = $-\frac{v_o}{u_o}\left\{1+\frac{D}{f_e}\right\} \approx -\frac{L}{f_o}\left\{1+\frac{D}{f_e}\right\}$ (for final image at D)

ii) Magnification M = $-\frac{v_o}{u_o}\{\frac{D}{f_e}\} \approx -\frac{L}{f_o}\left\{\frac{D}{f_e}\right\}$ (for final image at infinity)

- Astronomical Telescope:
  - i) M = $-\frac{f_o}{f_e}$ and L= $f_o + f_e$ (for final image at infinity)
  - ii) M = $-\frac{f_o}{f_e}\left\{1+\frac{f_e}{D}\right\}$ and L= $f_o + u_e$ (for final image at D)

- Resolving power:
  - i) **For microscope**: - The resolving power is the reciprocal of limit of resolution or separation between two points such that they are distinct. So, the resolving power is given by R.P.= $\frac{1}{d} = \frac{2\,n\,sin\theta}{\lambda}$

    Here, d = $\frac{\lambda}{2\,n\,sin\theta}$ is limit of resolution, $n\,sin\theta$ is numerical aperture and θ is the well resolved semi-angle of cone of light rays of wavelength λ entering the microscope.
  - ii) **For telescope**: - The resolving power is the reciprocal of angular limit of resolution or angle subtended between two points such that they are distinct. So, the resolving power is given by R.P.= $\frac{1}{d\theta} = \frac{a}{1.22\,\lambda}$

    Here, dθ = $\frac{1.22\,\lambda}{a}$ is the angular limit of resolution, 'a' is the aperture or diameter of objective lens.
  - The distance for which ray optics is good approximation for an aperture D and wavelength λ is called Fresnel distance, given by $Z_F = \frac{D^2}{\lambda}$.

- Interference of light:-
  - i) If two waves of same intensity I_o interfere, then the resultant intensity will be I = 4 $I_o \cos^2\frac{\emptyset}{2}$ where ϕ is the initial phase difference between the waves.
  - ii) Resultant intensity at a point in the region of superposition is $I = a_1^2 + a_2^2 + 2a_1a_2\cos\emptyset = I_1 + I_2 + 2\sqrt{I_1\,I_2}\,\cos\emptyset$ where $I_1 = a_1^2$ is the intensity of one wave & $I_2 = a_2^2$ is the intensity of other wave.
  - iii) Condition for maxima: - Phase difference ϕ = 2nπ & path difference Δ= n λ where n = 0,1,2,3,…..
  - iv) Condition for minima: - Phase difference ϕ = (2n-1)π &

Path difference $\Delta = (2n-1)\frac{\lambda}{2}$ where n = 0,1,2,3,…..

v) Fringe width $\beta = \frac{D\lambda}{d}$ where D = distance between the slits & the screen,
d= separation between the slits and λ is the wavelength of light used.

vi) Angular fringe width , $\beta_\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

vii) Minimum amplitude, $A_{min} = (a_1 - a_2)$

viii) Minimum intensity, $I_{min} = (a_1 - a_2)^2 = I_1 + I_2 - 2\sqrt{I_1 I_2}$

ix) Position of n^{th} maxima, $y_n = \frac{nD\lambda}{d}$

x) Position of n^{th} minima, $y_n = (n - ½)\frac{D\lambda}{d}$

- Diffraction of light: -

  i) The condition for the position of n^{th} minima : $d \sin\theta = n\lambda$ where d is the width of slit, θ is angle of diffraction and λ is the wavelength of light used.

  ii) Linear half-width of central maximum : $y = \frac{D\lambda}{d}$

  iii) Total linear width of central maximum : β_o or $2y = \frac{2D\lambda}{d}$

- Polarisation of light:-

  i) Brewster's law:- $n = \tan i_p$ Malus law : $I = I_o \cos^2\theta$

LEVEL – I

1. An object is placed at the principal focus of a concave lens of focal length f. Where will its image be formed?
(1)

2. A prism of angle 60° gives a minimum deviation of 30°. What is the refractive index of the material of the prism?
(1)

3. An equi-convex lens has refractive index 1.5. Write its focal length in terms of radius of curvature R. (1)

4. Estimate the distance for which ray optics is good approximation for an aperture of 4mm and wavelength 400nm.
(1)

5. What is Brewster's angle for air to glass transition? Refractive index of glass = 1.5. (1)

6. In Young's double slit experiment the slits are separated by 0.28mm and the screen is placed 1.4m away. The distance of 4^{th} bright fringe is measured to be 1.2cm. Determine the wavelength of light used in this experiment. (2)

7. An astronomical telescope uses two lenses of powers 10D and 1D. What is its magnifying power in normal adjustment? (2)

8. Light of wavelength 500nm falls, from a distant source, on a slit 0.5mm wide. Find the distance between the two dark bands, on either side of the central bright band of the diffraction pattern observed, on a screen placed 2m from the slits. (2

9. An illuminated object and a screen are placed 90cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object. (2

10. The near vision of an average person is 25cm. To view an object with an angular magnification of 10, what should be the power of the microscope?
(2)

LEVEL – II

1. A mirror is turned through 15°. Through what angle will the reflected ray turn?
(1)

2. Velocity of light in a liquid is 1.5×10^{8} m/s and in air, it is 3×10^{8} m/s. If a ray of light passes from liquid into the air, calculate the value of critical angle.
(1)

3. Why does a convex lens of glass of refractive index 1.5 behave as a diverging lens when immersed in carbon disulphide of refractive index 1.65?
(1)

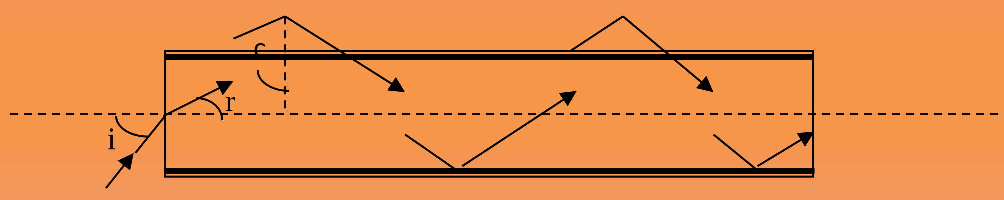
4. Find the angular dispersion produced by a thin prism of 5° having refractive index for red light 1.5 and for violet light 1.6.
(1)

5. If a person uses spectacles of power +1.0D, what is the nearest distance of distinct vision for him? Given that near point of the person is 75cm from the eye. (2)

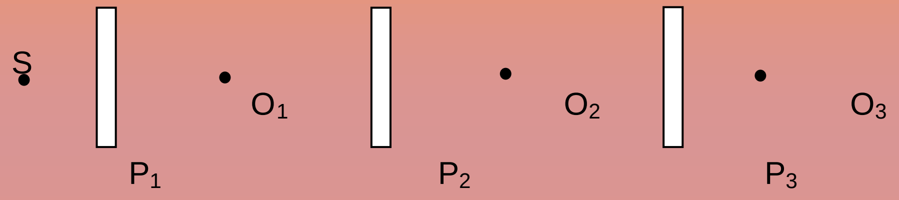
6. In Young's double slit experiment, light waves of wavelength 5.4×10^{-7} m and 6.85×10^{-8} m are used in turn keeping the same geometry. Compare the fringe width in the two cases. (2)

7. If the two slits in Young's experiment have width ratio 1:4, deduce the ratio of intensity at maxima and minima in the interference pattern. (2)

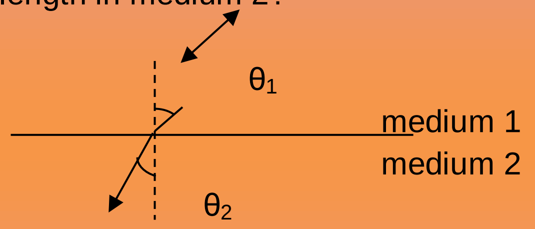
8. Figure shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of incident rays with the axis of the pipe for which total reflections inside the pipe take place as shown. (3)



9. Three identical Polaroid sheets P_1, P_2 and P_3 are oriented so that the (pass) axis of P_2 and P_3 are at angles of 60° and 90° respectively, with respect to the pass axis of P_1. A monochromatic source, S, of intensity I_o , 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. (3)



10. Light of wavelength λ_1 propagates from medium 1 incident at angle θ_1. The angle inside medium 2 is θ_2 . What is its wavelength in medium 2?
(3



LEVEL – III

1. A ray if light is incident on a concave mirror after passing through its center of curvature. What is the value of angle of reflection?
(1)

2. What is the ratio of fringe width for dark and bright fringes in Young's double slit experiment? (1)

3. A dentist uses a small concave mirror of focal length 16mm to view a cavity in the tooth of a patient by holding the mirror at a distance of 8mm from the cavity. Calculate the magnification. (2)

4. Show that for a concave mirror, a virtual object forms a real image which is always diminished. (2)

5. A point source of light is placed at the bottom of a lake with refractive index 4/3. Show that only 17% light can emerge out of the water surface. (2)

6. Why does violet colour deviate more than red in prism? (2)

7. A ray of light is incident at an angle of incidence 'i' on one surface of a prism of small angle 'A' and it is found to emerge normally from the opposite surface. If the refractive index of the material of the prism is 'n' , calculate the angle of incidence. (3)

8. Calculate the number of fringes displaced when a thin sheet of refractive index 'n' and thickness 't' is introduced in the path of one of the interfering rays. (3)

9. A few coloured fringes, around a central white region, are observed on the screen when the source of monochromatic light is replaced by white light in Young's double slit experiment. Give reason. (3)

10. Light from two sources has intensity ratio 1:9 and is monochromatic. The light is made to superpose. What will be the resultant intensity obtained if the sources are (i) incoherent & (ii) coherent? (3)

KEY/ANSWERS TO NUMERICAL PROBLEMS (UNIT – OPTICS)

Level – I

1. Given: u = -f, and for a concave lens f = - f, v = ?
   Calculations: From lens formula, $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$
   On substituting the values and on simplifying, we get, v = -f/2
   That is image will be formed between optical Centre and focus of lens: towards the side of the object.
2. Given: A=60°, δ_m=30°, n = ?
   Calculations: Use the formula, n= $\frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ to get n = 1.41
3. Using the formula, $\frac{1}{f}$= (n −1) $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ we get, $\frac{1}{f}$ = (1.5 −1) $\left[\frac{1}{R} - \frac{1}{-R}\right]$= $\frac{1}{R}$
   ∴ f = R
4. The distance for which ray optics is good approximation for an aperture D and wavelength λ is called Fresnel distance, given by $Z_F = \frac{D^2}{\lambda}$.
   Given: D = 4mm = 4x10^{-3} m , λ=400nm = 400 x 10^{-10} m , Z_F = ?
   Calculations: Using the above formula, on substituting the values and simplification, we get,
   Z_F = 40m
5. Given: n = 1.5, i_p = ?
   Calculations: Using the formula, n = tan i_p , we get , i_p = $\tan^{-1}$(n) = $\tan^{-1}$(1.5) = 56.3°

6. Given: d = 0.28mm = 0.28 x10^{-3} m , D = 1.4m , n = 4, y_4 = 1.2cm = 1.2 x10^{-2} m , λ = ?
   Calculations: Using the formula for the position of nth bright fringe, y_n = nDλ/d we get,
   λ = y_4 d / 4 D
   On substituting the values and on simplification we get, λ = 6 x 10^{-7} m = 600 nm
7. M = - $\frac{f_o}{f_e}$ = - $\frac{P_e}{P_o} = \frac{-10}{1} = -10$
8. The distance between two dark bands on either side of central bright bands is equal to the total width of bright band and is given by β_o= $\frac{2 D \lambda}{d}$
   Given: D=2m , λ=500nm = 500 x 10^{-10} m , d = 0.5mm = 0.5 x10^{-3} m , β_o = ?
   Calculations: On substituting the values and on simplification we get, β_o = 4 x10^{-3} m = 4 mm
9. Given: u + v = 90cm ….. (i)
   m = |v| / |u| = 2 or |v| = 2 |u| ….. (ii)

From (i) and (ii), |u| = 30cm, |v| = 60cm
By sign convention, u = - 30cm, v = 60cm
Substituting the values in equation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ and after simplification we get,

f = 20cm (convex lens)

10. Given: D = 25cm, M=10 , P =?
Calculations: Using the formula, M = D / f , we get, f = D/M = 25/10 cm = 0.025m
Now, P = 1 / f (in m) = 1 / 0.025m = 40D

Level – II

1. 30°, as the reflected ray turns through twice the angle through which mirror is turned.
2. n=c/v = 1/sinC , therefore, sinC = v/c =1.5 x 10 ^{8} / 3 x 10 ^{8} = 0.5
Now, C = sin $^{-1}$ (0.5) = 30°
3. This is because n = $\frac{n_g}{n_c} = \frac{1.5}{1.65} < 1$
From lens maker's formula, 'f ' becomes negative. Therefore, the lens behaves as a diverging lens.
4. Given: A=5°, $n_r = 1.5$, $n_v = 1.6$, angular dispersion = ?
Calculations: On substituting the values in equation, angular dispersion = $(n_v - n_r)A$, and on
simplification, we get, angular dispersion =0.5°=30'
5. Given: P = 1 D, f = 100/P = 100/1 = 100cm, nearest distance of distinct vision u = ? ; v = - 75cm
Calculations: Using lens formula, we get, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
$\therefore \frac{1}{u} = \frac{1}{v} - \frac{1}{f} = -\frac{1}{75} - \frac{1}{100} = \frac{-4-3}{300}$ = - 7/300 or u = - 42.9cm
6. Given: λ_1 = 5.4 x 10 $^{-7}$ m, λ_2 =6.85 x 10 $^{-8}$ m, β_1/β_2 = ?
Calculations: As β = $\frac{D\lambda}{d}$ and geometry is same i.e., D and d remain same, therefore,
$\beta_1/\beta_2 = \lambda_1/\lambda_2$ =5.4 x 10 $^{-7}$/6.85 x 10 $^{-8}$ = 8 (approximately)
7. Intensity ∝ width (w) of slit
Also, intensity ∝ square if the amplitude, $\therefore \frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{a^2}{b^2} = \frac{1}{4}$ or $\frac{a}{b} = \sqrt{\frac{1}{4}} = \frac{1}{2}$
or b = 2a
Now, $\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2} = \frac{(a+2a)^2}{(a-2a)^2} = \frac{9}{1}$
8. Given: n_2 =1.68 , n_1 =1.44, i_{max} = ?
Calculations: As n = $\frac{n_2}{n_1} = \frac{1}{sinC}$ ∴ sin C = $\frac{n_1}{n_2} = \frac{1.44}{1.68}$ = 0.8571 So, C = sin $^{-1}$ (0.8571) =59°

Total internal reflection would take place when i > C i.e., i >59° or when $r < r_{max}$, where

r_{max} = 90°- C = 90° - 59° = 31°

As $\frac{Sin\,(i)_{max}}{Sin\,(r)_{max}} = 1.68$ $\therefore Sin\,(i)_{max} = 1.68\,Sin\,(r)_{max}$ = 1.68 x sin 31° = 1.68 x 0.5156= 0.8662

$\therefore\; i_{max}$ = $\sin^{-1}$ (0.8662) = 60°

9. Intensity observed by $O_1 = I_o / 2$

   Intensity observed by $O_2 = (I_o / 2) \cos^2 (60°) = (I_o / 2) \times (1 / 2)^2 = I_o / 8$

   Intensity observed by $O_3 = (I_o / 8) \cos^2 (90° - 60°) = (I_o / 8) \cos^2(30°) = (I_o / 8)(\sqrt{3}/2)^2 = (3/32)\, I_o$

10. Snell's law says, $v_2 \sin \theta_1 = v_1 \sin \theta_2$

    The ratio of wavelengths is equal to the ratio of the speeds of light.

    $\therefore\; \lambda_1 / \lambda_2 = v_1 / v_2$

    Or, wavelength in medium 2, $\lambda_2 = (\sin \theta_2 / \sin \theta_1)\, \lambda_1$

<u>LEVEL – III</u>

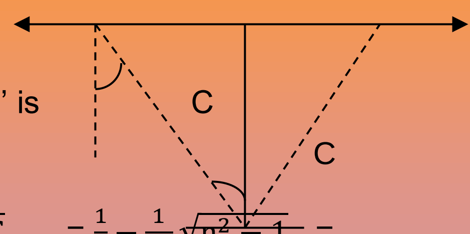
1. 0°. A ray of through center of curvature is incident normal to the surface of the mirror.
2. 1:1 , since the widths of bright and dark bands are equal.
3. Given: u = -8mm, f = - 16mm, m = ?

   Calculations: $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-16} - \frac{1}{-8} = \frac{1}{16}$ $\therefore$ v = 16 mm

   Now, |m| = v /u = 16/8 = 2
4. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$. Here, 'u' is positive, 'f ' is negative, v =?

   Giving signs to u, v and f, we have $\frac{1}{v} + \frac{1}{u} = \frac{1}{-f}$ or $v = -\{\frac{f\,u}{f+u}\}$ which is negative.

   Also, $|m| = |v/u| = \frac{1}{\left[\frac{u}{f}+1\right]} < 1$ Hence, the image is diminished.
5. The fraction of light energy that can escape is the fraction of the solid angle which allows it to pass without total internal reflection.

   Let the critical angle be C, so that, $\sin C = \frac{1}{n}$ where 'n' is the refractive index of water.

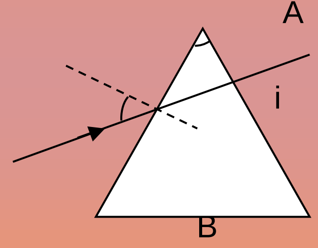
   Fraction of solid angle = $\frac{2\pi}{4\pi}(1 - \cos C) = \frac{1}{2} - \frac{1}{2}\sqrt{1 - \sin^2 C}$ $= \frac{1}{2} - \frac{1}{2n}\sqrt{n^2 - 1}$ =

$\frac{1}{2} - \frac{1\times3}{2\times4}\sqrt{\left(\frac{4}{3}\right)^2 - 1}$ = 0.17= 17%

6. For a prism, $\delta = (n - 1)A$ and $n = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \cdots$

   As $\lambda_v < \lambda_R$ $\therefore$ $n_v > n_R$ Hence, $\delta_v > \delta_R$ So, violet deviates more than red.

7. For refraction through a prism: we have



   $\angle i + \angle e = \angle A + \angle \delta$

   But, $\angle e = 0$

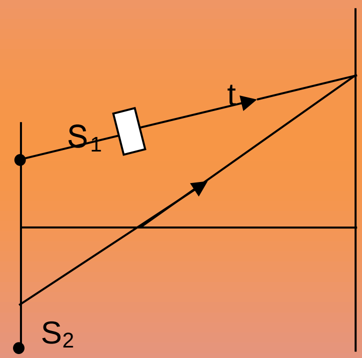
   $\therefore$ $\angle i = \angle A + \angle \delta$

   Also, $\delta = (n - 1)A$

   $\therefore$ $\angle i = A + (n - 1)A = n A$

   C

8. Let the central maximum shift from P_o to P'_o.



   P'_o

   The sheet introduces an optical path nt and decreases air path by 't'.

   $\therefore$ path difference = $S_2 P'_o - S_1 P'_o = (n - 1)\ t$ ….(i)

   From the figure, $S_2 P'_o - S_1 P'_o = \frac{2xd}{D+D} = \frac{xd}{D}$ …. (ii)

   P_o

   From (i) and (ii), $\frac{xd}{D} = (n - 1)\ t$

   $\therefore$ number of fringes shifted, $N = \frac{x}{\beta} = \frac{(n - 1)\ t}{\lambda}$

9. For the central maxima, path difference, $p = n\lambda = 0$ (since $n = 0$) and is independent of λ.

   Hence , all the colours superpose constructively producing central white fringe.

   For position of other maxima, $x_n = \frac{nD\lambda}{d}$

   So, the position depends on λ.

   As $\lambda_{red} > \lambda_{blue}$, So, the fringes closest to the central white are blue on either side and farthest are red.

   After a few fringes, no clear fringe pattern is observed.

10. As $\frac{I_1}{I_2} = \frac{1}{9}$ (intensity ratio)

   Then, $\frac{a}{b} = \sqrt{\frac{I_1}{I_2}} = \frac{1}{3}$ (amplitude ratio)

   If the sources are incoherent, the intensities add up.

   i.e., the resultant intensity will be 10. $(= I_1 + I_2 = a^2 + b^2)$

   If the sources are incoherent, we get interference maxima and minima.

   At minima, amplitude, $a_{min} = 3 - 1 = 2$

   $I_{min} = (2)^2 = 4$

   At maxima, amplitude, $a_{max} = 3 + 1 = 4$

   $I_{max} = (4)^2 = 16$

   So, the intensity will vary from 4 to 16.

UNIT –VII- DUAL NATURE OF MATTER & RADIATION

LIST OF FORMULAE

1. Energy of a photon $E = h\upsilon = \frac{hc}{\lambda}$
2. Number of photon emitted per second $N = \frac{P}{E}$
3. Momentum of photon $P = mc = \frac{h\upsilon}{c} = \frac{h}{\lambda} = \frac{E}{c}$
4. Equivalent mass of photon $m = \frac{h\upsilon}{c2} = \frac{E}{c2} = \frac{h}{c\lambda}$
5. Work function $W_0 = h\upsilon_0 = \frac{hc}{\lambda 0} =$
6. Kinetic energy of photoelectron is given by Einstein's photoelectric equation:

   $K_{max} = \frac{1}{2}mV^2 = h\upsilon - W_0 = h(\upsilon - \upsilon_0) = h\left(\frac{c}{\lambda} - \frac{c}{\lambda 0}\right)$
7. If V_0 is the stopping potential, the maximum kinetic energy of the ejected photoelectron, $K = \frac{1}{2}mv^2_{\max} = eV_0$
8. Kinetic energy of De-Broglie Waves $K = \frac{1}{2}mv2 = P^2/2m$
9. Momentum of De-Broglie Waves $P = \sqrt{2mK}$
10. Wavelength of De-Broglie Waves $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{(2mK)}}$
11. De –Broglie Wavelength of an electron beam accelerated through a potential difference of V volts is $\lambda = \frac{h}{\sqrt{(2meV)}} = \frac{1.23}{\sqrt{V}}$ nm $= \frac{12.27}{\sqrt{V}}$ A^0
12. De –Broglie Wavelength associated with gas molecules of mass m at temperature T kelvin is $\lambda = \frac{h}{\sqrt{(2mKT)}}$ K = Boltzmann constant
13. The value of hc = 12400eV A^0
14. The Value of $\frac{hc}{e} = 1240 \times 10^{-9}$ eV m

Level-I:- Numerical direct formula based (1 mark,2 mark)

1. If the maximum kinetic energy of electrons emitted by a photocell is 4ev.What is the Stopping potential?

2. What is the energy associated in joules with a photon of wavelength 4000A^0?

3. The photoelectric cut-off voltage in a certain experiment is 1.5V.What is the maximum Kinetic energy?

4. Calculate the work function of a metal in eV.If its threshold wavelength is 6800A^0?

5. What is the momentum of a photon of energy 120 MeV?

6. What is the de-broglie wavelength (in A^0) associated with an electron accelerated through

a Potential of 100V?

7.Calculate the ratio of de-Broglie wavelength associated with a deuteron moving with velocity 2V and an alpha particle moving with velocity V?

8. The work function of cesium metal is 2.14eV.When light of frequency 6 X 10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. What is the (a) Maximum kinetic energy of the emitted electron and (b) Stopping potential of the emitted photoelectron?

9.In an experiment on photoelectric effect, the slope of the cut-off voltage versus frequency

of incident light is found to be 4.12 X 10^{-15}Vs.Calculate the value of Planck's constant.

10. The threshold frequency for a certain metal is 3.3 X10^{14}Hz is incident on the metal; Predicts the cut-off voltage for photoelectric emission.

LEVEL-2

1.An electron and an alpha particle have same kinetic energy. Which of these particles has the shortest de- Broglie wavelength?

2.The de Broglie wavelength of an electron is 1 A^0. Find the velocity of the electron.

3.Determine the accelerating potential required for an electron to have a de-Broglie wavelength of 1 Å

4.An electron, an alpha particle and a proton have the same kinetic energy, which one of these particles has (i) the shortest and (ii) the largest, de, Broglie wavelength?

5.In an experiment on photo electric emission , following observations were made;

(i) wave length of incident light = 1.98×10^{-7}m
(ii) stopping potential = 2.5 V.
Find (a) kinetic energy of photo electrons with maximum speed
(b) work function & (c) threshold frequency

6. Monochromatic light of wavelength 632.8 nm is produced by a helium-neon laser. The power emitted is 9.42 mW.

(a) Find the energy and momentum of each photon in the light beam,

(b) How many photons per second, on the average, arrive at a target irradiated by this beam? (Assume the beam to have uniform cross-section which is less than the target area), and

(c) How fast does a hydrogen atom have to travel in order to have the same momentum as that of the photon?

7. In an experiment on photoelectric effect, the slope of the cut-off voltage versus frequency of incident light is found to be 4.12×10^{-15} V s. Calculate the value of Planck's constant.

8. The threshold frequency for a certain metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on the metal, predict the cutoff voltage for the photoelectric emission.

9. The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?

10. Light of wavelength 488 nm is produced by an argon laser which is used in the photoelectric effect. When light from this spectral line is incident on the emitter, the stopping (cut-off) potential of photoelectrons is 0.38 V. Find the work function of the material from which the emitter is made.

LEVEL -3

LEVEL-III:- 10 numericals challenging/difficulty level (1 mark, 2 marks, 3marks)

1. A radio transmitter operates at a frequency of 880 KHz and a power of 1KW.Find the

Number of photons emitted per second.

2 A blue lamp mainly emits light of wavelength 4500 A^0. The lamp is rated at 150 W and 8% of the energy is emitted as visible light. How many photons are emitted by the lamp per second?

3 Calculate the de-broglie wavelength of a proton of a momentum 2.55 X 10^{-22} $Kgms^{-1}$?

4The work function of Cesium is 2.14 eV.Find (a) the threshold frequency for Cesium, and (b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potential of 0.60eV?

5If the photoelectrons are to be emitted from a potassium surface with a speed of 6 X 10^6 ms^{-1}.What frequency of radiation must be used? (Threshold frequency for potassium is 4.22 X 10^{14} Hz, h= 6.6 X10^{-34} Js and m_e = 9.1 X 10^{-31} kg)

6.A sheet of silver is illuminated by monochromatic ultraviolet light of wavelength = 1810 A^0. What is the maximum energy of the emitted electron? Threshold wavelength of of silver is 2640 A^0.

7.By how much would be stopping potential for a given photosensitive surface go up if the frequency of the incident radiation were to be increased from 4 $X10^{15}$ Hz to 8 X 10^{15}? Given h= 6.6 $X10^{-34}$ Js, e = 1.6 X 10^{-19} C and c = 3 X 10^{8} ms^{-1}?

8.The photosensitive threshold wavelength for a metal is 10000 A^{0}.When light of wavelength 5461 A^{0} is incident on it, the retarding potential in Millikan's experiment is 1.02 Calculate the value of Planck's constant?

9.When light of wavelength 400 nm is incident on the cathode of a photocell, the stopping recorded is 6V.If the wave of the incident light is increased to 600nm.Calculate the new stopping potential?

10 The two identical photocathodes receive light of frequencies f_1 and f_2.If the velocity of the photoelectron (of mass m) coming out are respectively v_1 and v_2, then show that $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$.

ANWERS

LEVEL -1

1. 4 volt
2. $E = \frac{hc}{\lambda}$ =4.96 X 10 $^{-19}$joule
3. 5 eV
4. W =1.825 eV
5. 5.92 X 10 $^{-24}$ Kg m/sec
6. 1.23 A^0
7. $\frac{\lambda d}{\lambda_\alpha} = \frac{h/p_d}{h/p_\alpha} = \frac{m_\alpha v_\alpha}{m_d v_d} = \frac{1}{1}$
8. (a) K_{max} = 034 eV (b) 0.34 V
9. h = slope X e = 6.59 X 10^{-34} js
10. eV0 = h(υ - $υ_0$) , V0 = $\frac{h(υ - υ0)}{e}$ = 2V

LEVEL-2

1.: Alpha particle
2. 7.3 x 10 ^{6} m/s
3. V = 150.6 V
4.

$$\lambda \frac{h}{\sqrt{2mE_k}} \ \alpha \ \frac{1}{\sqrt{\mathrm{m}}}$$

5. (a) K_{max} = 2.5eV (b) work function = 3.76eV (c) threshold frequency = 9.1x 10^{14}Hz

6. Wavelength of the monochromatic light, λ = 632.8 nm = 632.8 × 10^{-9} m

Power emitted by the laser, P = 9.42 mW = 9.42 × 10^{-3} W

Planck's constant, h = 6.626 × 10^{-34}Js,Speed of light, c = 3 × 10^{8} m/s

Mass of a hydrogen atom, m = 1.66 × 10^{-27} kg

(a) The energy of each photon is given as:

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{632.8 \times 10^{-9}} = 3.141 \times 10^{-19} \text{ J}$$

The momentum of each photon is given as:

$$P = \frac{h}{\lambda}$$

$$= \frac{6.626 \times 10^{-34}}{632.8} = 1.047 \times 10^{-27} \text{ kg m s}^{-1}$$

(b) Number of photons arriving per second, at a target irradiated by the beam = *n*

Assume that the beam has a uniform cross-section that is less than the target area.

Hence, the equation for power can be written as:

$$P = nE$$

$$\therefore n = \frac{P}{E}$$

$$= \frac{9.42 \times 10^{-3}}{3.141 \times 10^{-19}} \approx 3 \times 10^{16} \text{ photon/s}$$

(c) Momentum of the hydrogen atom is the same as the momentum of the photon, $p = 1.047 \times 10^{-27} \text{ kg m s}^{-1}$

Momentum is given as:

$p = mv$ Where, *v* = Speed of the hydrogen atom

$$\therefore v = \frac{p}{m}$$

$$= \frac{1.047 \times 10^{-27}}{1.66 \times 10^{-27}} = 0.621 \text{ m/s}$$

7. The slope of the cut-off voltage (*V*) versus frequency (□) of an incident light is given as:

$$\frac{V}{\nu} = 4.12 \times 10^{-15}\ \text{Vs}$$

V is related to frequency by the equation:

$$h\nu = eV$$

Where, *e* = Charge on an electron = 1.6 × 10^{-19} C

h = Planck's constant

$$\therefore h = e \times \frac{V}{\nu}$$

$$= 1.6 \times 10^{-19} \times 4.12 \times 10^{-15} = 6.592 \times 10^{-34}\ \text{Js}$$

Therefore, the value of Planck's constant is 6.592×10^{-34} Js.

8. Threshold frequency of the metal, $\nu_0 = 3.3 \times 10^{14}$ Hz

Frequency of light incident on the metal, $\nu = 8.2 \times 10^{14}$ Hz

Charge on an electron, *e* = 1.6 × 10^{-19} C ,Planck's constant, *h* = 6.626 × 10^{-34}Js

Cut-off voltage for the photoelectric emission from the metal = V_0

The equation for the cut-off energy is given as:

$$eV_0 = h(\nu - \nu_0)$$

$$V_0 = \frac{h(\nu - \nu_0)}{e}$$

$$= \frac{6.626 \times 10^{-34} \times (8.2 \times 10^{14} - 3.3 \times 10^{14})}{1.6 \times 10^{-19}} = 2.0292\ \text{V}$$

Therefore, the cut-off voltage for the photoelectric emission is 2.0292 V.

9. No , Work function of the metal, $\phi_0 = 4.2$ eV

Charge on an electron, $e = 1.6 \times 10^{-19}$ C ,Planck's constant, $h = 6.626 \times 10^{-34}$Js

Wavelength of the incident radiation, $\lambda = 330$ nm $= 330 \times 10^{-9}$ m

Speed of light, $c = 3 \times 10^8$ m/s ,The energy of the incident photon is given as:

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{330 \times 10^{-9}} = 6.0 \times 10^{-19} \text{ J}$$

$$= \frac{6.0 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.76 \text{ eV}$$

It can be observed that the energy of the incident radiation is less than the work function of the metal. Hence, no

photoelectric emission will take place.

10. Wavelength of light produced by the argon laser, $\lambda = 488$ nm $= 488 \times 10^{-9}$ m

Stopping potential of the photoelectrons, $V_0 = 0.38$ V , 1eV $= 1.6 \times 10^{-19}$ J

 $V_0 = \frac{0.38}{1.6 \times 10^{-19}}$ eV

Planck's constant, $h = 6.6 \times 10^{-34}$Js,Charge on an electron, $e = 1.6 \times 10^{-19}$ C

Speed of light, $c = 3 \times 10$ m/s ,From Einstein's photoelectric effect, we have the relation involving the work function Φ_0 of the material of the

emitter as:

$$eV_0 = \frac{hc}{\lambda} - \phi_0$$

$$\phi_0 = \frac{hc}{\lambda} - eV_0$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 488 \times 10^{-9}} - \frac{1.6 \times 10^{-19} \times 0.38}{1.6 \times 10^{-19}}$$

$$= 2.54 - 0.38 = 2.16 \text{ eV}$$

Therefore, the material with which the emitter is made has the work function of 2.16 eV.

LEVEL-3

1. N = $\frac{p}{E}$ = $\frac{p}{h\upsilon}$ = 1.72 X10^{31} Photon/second
2. N = $\frac{8\% \, of \, P}{E}$ = $\frac{8P\lambda}{100hc}$ = 2.71 X10^{29} photon/second
3. λ = h/p = 0.026 A^0
4. (a)υ_0 = w/ h = 5.16 X 10^{14} Hz
   (b) λ = $\frac{hc}{\mathrm{eV0 + W}}$ = 453.7 nm
5. K.E = $\frac{1}{2}$ mv^2 = h(υ - υ_0)

   υ = = $\frac{1}{2}$ mv^2/h + υ_0 = 6.7 X 10^{14} Hz

6. K_{max} = hc ($\frac{1}{\lambda} - \frac{1}{\lambda'}$) = 2.16 eV

7. $V_{02} - v_{01}$ = $\frac{h(\upsilon_{2-}\ \upsilon_1}{e}$ = 16 volt
8. eV0 = hc ($\frac{1}{\lambda} - \frac{1}{\lambda'}$)
   h = 6.554 X 10^{-34} js

9. eV0 = hc (1/λ-w')
   Δ V0 = $V_{02} - v_{01}$ = $\frac{hc}{e}$ (1/λ-1/λ^')
   $V_{02} = v_{01}$ -1.03= 6-1.03= 4.97 V
10. $\frac{1}{2}$ mv^2 = hf – hf_0 or v^2 = $\frac{2hf}{m}$ - $\frac{2hf0}{m}$
    v_1^2= $\frac{2hf_1}{m}$ - $\frac{2hf0}{m}$

    v_2^2= $\frac{2hf_2}{m}$ - $\frac{2hf0}{m}$, v_1^2 - v_2^2 = $\frac{2h}{m}$ (f_1-f_2).

UNIT—VIII- ATOMS & NUCLEI
FORMULAE ANDSHORTCUT FORMULAE

1. **Rutherford's α-Particle scattering experiment (Geiger – Marsden experiment)**

IMPOTANT OBSERVATION

Scattering of α-particles by heavy nuclei is in accordance with coulomb's law. Rutherford observed that number of α-particles scattered is given by

$$N \propto \frac{1}{sin^4 \theta/_2}$$

2. **Distance of closest approach : Estimation of size of nucleus**

$$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{Ze\ X\ 2e}{\frac{1}{2}\mathrm{m}\, v^2}$$

3. **Impact Parameter (b)**

$$b = \frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0\, (\frac{1}{2} m\, u^2)}$$

4. **Bohr's atomic model**

Radius of orbit $r = \frac{(4\pi\ \varepsilon_0)n^2h^2}{4\pi^2\ m\ Ze^2}$ Frequency $v = \frac{2\pi\ Ze^2}{(4\pi\ \varepsilon_0)n\ h}$

$v = \frac{2\pi\ Ze^2}{(4\pi\ \varepsilon_0)c\ h} X \frac{c}{n} = \alpha\ \frac{c}{n}$ Where $\alpha = \frac{2\pi\ Ze^2}{(4\pi\ \varepsilon_0)c\ h} = \frac{1}{137}$ is called fine structure constant

5. **Energy of electron**

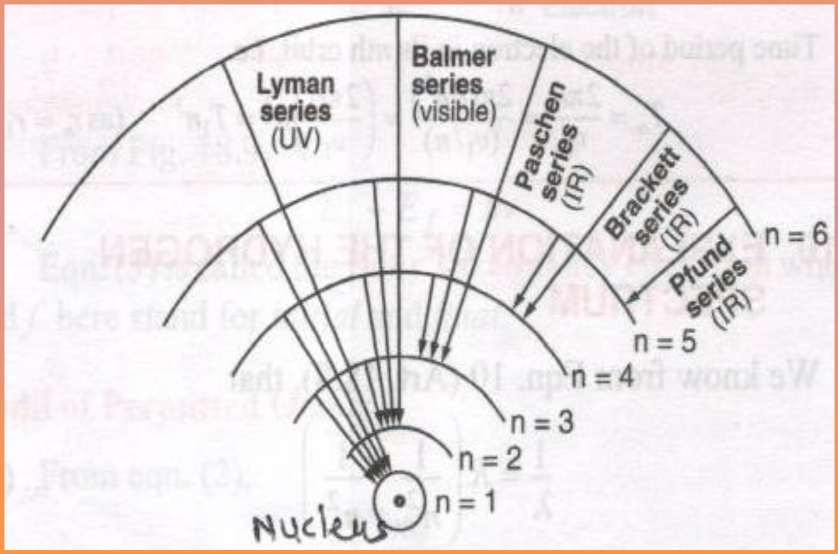
$\mathbf{E_n} = -\ \frac{m\, Z^2 e^4}{8\varepsilon_0^2 h^2}(\frac{1}{n^2})$ $\mathbf{E_n} = -\ \frac{Z^2 Rch}{n^2}$ $R = \frac{m\, e^4}{8\varepsilon_0^2\ ch^3} = 1.097$ X 10^7 m^{-1} and is called Rydberg constant.

$\mathbf{E_n} = -\ \frac{13.6}{n^2}$ eV $\bar{v} = R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right]$ where $\bar{v}$ is called wave number.

Short Cut Formula –

K.E. = - (Total Energy)
P.E. = - 2 K.E.

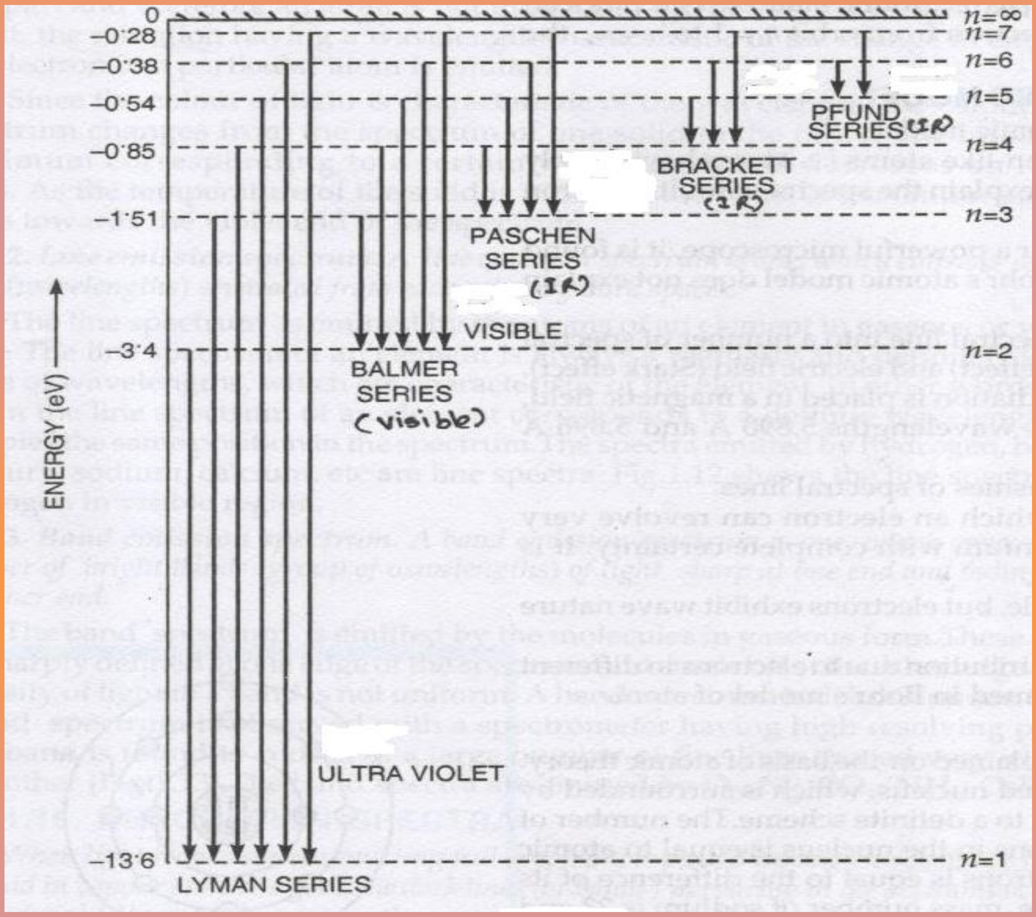
6. **Spectral Series of Hydrogen Atom**



7. **Energy level diagram for hydrogen atom**

We know that for hydrogen atom, energy of an electron in n^{th} orbit is given by

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$



8. **NOTE- Bohr's quantisation condition of angular momentum**

Let us consider the motion of an electron in a circular orbit of radius r around the nucleus of the atom. According to de-Broglie hypothesis, this electron is also associated with wave character. Hence a circular orbit can be taken to be a stationary energy state only if it contains an integral number of de-Broglie wavelengths i,e, we must have

$2\pi r$ = nλ

But λ = $\frac{h}{mv}$ $2\pi r$ = n $\frac{h}{mv}$ mvr = n $\frac{h}{2\pi}$, This is famous Bohr's quantisation condition for angular momentum.

9. Atomic Mass Unit (u)

One atomic mass unit is defined as $\frac{1}{12}$th of the actual mass of c-12 atom.

1 u = $\frac{1}{12}$ X mass of C-12 atom = $\frac{1}{12}$ X 1.992678 X 10^{-26} kg = 1.66 X 10^{-27} kg.

10. Electron Volt (eV)

It is the energy acquired by an electron when it is accelerated through a potential difference of 1 volt.

1 eV = 1.6 X 10^{-19} J

& 1 MeV = 1.6 X 10^{-13} J

11. Relation Between amu & MeV We know, 1 u = 1.66 X 10^{-27} kg ≈ 931 MeV

12. **Nuclear Density** (**ρ**) = 2.3 X 10^{17} Kg/m^3 obviously, nuclear density is independent of mass number A.

13. **Isotopes** The atoms of an element, which have the same atomic number but different mass numbers are called isotopes.

For examples Hydrogen has three isotopes $^{1}_{1}H$, $^{2}_{1}H$ & $^{3}_{1}H$

14. **Isobars**

The atoms having the same mass number but different atomic numbers are called isobars.

For examples $^{3}_{1}H$ & $^{3}_{2}He$, $^{37}_{17}Cl$ & $^{37}_{16}S$, $^{40}_{20}Ca$ & $^{40}_{18}Ar$

15. **Isotones** The nuclids having the same number of neutrons are called isotones.

For examples $^{37}_{17}Cl$ & $^{39}_{19}K$, $^{198}_{80}Hg$ & $^{197}_{79}Pu$

16. **Isomers** These are the nuclei having the same atomic number & same mass number but existing in different energy states. For example A nucleus in its ground state and the identical nucleus in metastable excited state, are isomers.

17. Properties of nuclear Forces

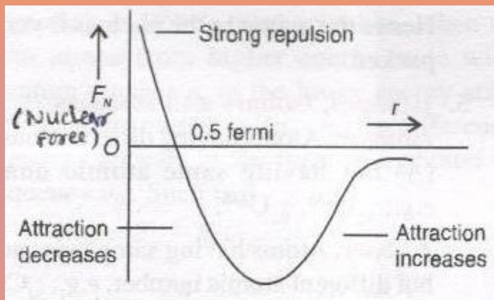
(i) Nuclear forces are very short range attractive forces.

(ii) Nuclear forces are charge independent.

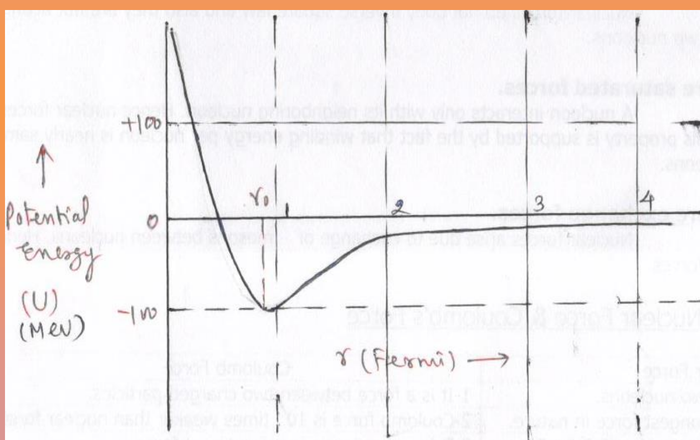
(iii) Nuclear forces are non-central forces.

(iv) Nuclear forces do not obey inverse square law.

18. Nuclear force as a separation between two nucleons



19. **Potential energy of a pair of nucleons as a separation between two nucleons**



20. Mass Defect (Δm) Δm = [Z m_p + (A – Z) M_n] – M_N

21. Packing fraction (P.F.)

It is defined as the mass defect per nucleon.

i,e, P.F. = $\frac{\Delta m}{A}$

Nucleus is stable if P.F.>1 & unstable if P.F.< 1

22. **Binding Energy (B.E.)** The binding energy of a nucleus may be defined as the energy required to break up a nucleus in to its constituent protons and neutrons and to separate them to such a large distance that they may not interact with each other. It is equivalent energy of mass defect.

i,e, B.E. = Δm X c^2

⇨ B.E. = [{Z m_p + (A – Z) M_n} – M_N] x c^2

23. Binding Energy per nucleon B.E. per nucleon = $\frac{B.E.}{A}$

LEVEL –I

Qn1.What is the ratio of the radii of orbits corresponding to first excited state and ground state in hydrogen atom?

Qn2. What is the impact parameter for scattering of α- particle by180^0?

Qn3. Two nuclei have mass numbers in the ratio 1: 8. Find the ratio of their nuclear radii and nuclear densities.

Qn4. What is the ground state energy of electron in case of $_3Li^7$?

Qn5. Find the energy equivalent of 1amu in MeV.

Qn6.Find first excitation energy and excitation potential ofhydrogen atom.

Qn7.Find ionisation energyand ionisation potential of hydrogen atom.

Qn8. Tritium has half-life of 12.5 years against β decay. What fraction of the sample will remain undecayed after 25 years ?

Qn9. What is the relation between decay constant and half-life of radioactiveelement?

Qn10. Name the series of hydrogen spectrum which lies in visible part of the spectrum.

ANSWER KEY

Q.No.	Expected Answer	Value Points
1	$r_2 / r_1 = (n_2 /n_1)^2$	1
	$= (2/1)^2$	1
	= 4: 1	
2	For Head on collision b = 0	1
3	$R_1 / R_2 = (A_1/ A_2)^{1/3}$	1
	$= (1/ 8)^{1/3} = 1 / 2$	
	d1/ d2 = 1:1	1
4	$E_n = - 13.6 Z^2 / n^2 eV$	1
	Putting Z= 3 , n = 2	

	$E_n = - 30.4$ eV	1
5	m = 1amu = 1.66×10^{-27} kg	1
	$E = m c^2$ J	
	$= m c^2 / 1.6 \times 10^{-13}$ MeV	1
	= 931.5 MeV	
6	$E = E_2 - E_1$	
	= -3.4 – (- 13.6) eV	1
	= 10.2 eV	
	Potential = 10.2 Volt	1
7	$E_n = - 13.6 Z^2 / n^2$eV	
	Z =1 , n=1	1
	$E_n = - 13.6$ eV	
	Hence ionisation energy = + 13.6 eV	
	ionisation potential = 13.6 V	1
8	$N/ N_0 = (1/2)^{t/T}$	1
	$= (1/2)^{25/12.5}$	
	= 1/4	1
9	T = 0.693/ λ	1
10	BalmerSeries.	1

LEVEL –II

Qn1. With the help of an example explain how the neutron to proton ratio changes during α – decay of nucleus.

Qn2. A radioactive isotope has half-life of 5 years after how much time is its activity reduces to 3.125% of its original activity?

Qn3. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.

Qn4. The ground state energy of hydrogen atom is -13.6eV.What is the K.E& P.E of the electron in this state?

Qn5. Select the pairs of isotopes & isotones from the following:

i. ${}_{6}C^{13}$ ii.${}_{7}N^{14}$iii.${}_{15}P^{30}$iv. ${}_{15}P^{31}$

Qn6.At a given instant there are 25% un-decayed radioactive nuclei in a sample. After 10 seconds the number of un-decayed nuclei reduces to 12.5 %.calculate the i) mean life of the nuclei ii) the time in which the number of the un-decayed nuclei will further reduce to 6.25 % of the reduced number.

Qn 7.A radioactive nucleus ‘A’ decays as given below:

βα

A ⟶ A1 ⟶ A2

If the mass number & atomic number of A1 are 180 & 73 respectively, find the mass number & atomic number of A &A2

Qn8. For an electron in the second orbit of hydrogen atom , what is the moment of linear momentum as per the Bohr’s model?

Qn 9.An alpha particle of energy 5 MeV is scattered through 180^0 at a target ofuranium nucleus. What is the order of the distance of the closest approach?

Qn10. By what factor must the mass number change for the nuclear radius to become twice?

ANSWER KEY

Q.No.	Expected Answer	Value Points
1	${}_{92}U^{238} \rightarrow {}_{92}Th^{234} + {}_{2}\alpha^{4}$	1
	N to P ratio before α-decay=$\frac{238-92}{92}$=$\frac{146}{92}$=1.59	
	N to P ratio after α-decay=$\frac{234-90}{90}$=$\frac{144}{90}$=1.60	
	$\frac{146}{92} < \frac{144}{90}$	1
	This show that the N to P **ratio** increases	

during α-decay of a nucleus

		1
2	We know that $\frac{R}{R0}$= $(\frac{1}{2})^n$	1
	$\frac{R}{R0}$=3.125/100 = 1/ 32 = $(1/2)^5$	
	n=5 and n=t/T or t= n x T = 5x5=25years.	1
3	Total energy of nucleus X = 240 × 7.6 = 1824 MeV	1
	Total energy of nucleus Y = 110 × 8.5 = 935 MeV	
	Total energy of nucleus Z = 130 × 8.5 = 1105 MeV	1
	Therefore, energy released from fission, Q = 935 + 1105 − 1824 = 216 MeV	
		1
4	K.E= - (Total Energy) =13.6 eV,	1
	P.E=-2K.E=-27.2 eV	
		1
5	Isotopes-iii &ivsame atomic number	1
	Isotones-i& ii same no of neutron	
		1
6	T =10s, λ=.0693/ T	1
	τ=1/λ= 1.44 T = 14.43 sec	1
	N=1/16(N_0/8) →t= n x T =4x10=40sec	
		1

7 For A— 180 & 72, 1

For A2—176 & 71 1

8 Angular Momentum L=n x (h / 2 π) 1

$= 2 \times (h/2\pi) = h/\pi$

(moment of linear momentum is angular momentum) 1

9 $r_0 = 1/4\pi\varepsilon_0 \times Ze * 2e / E$ 1

$= 9 \times 10^9 \times 235 \times 2 \times (1.6 \times 10^{-19})^2 / 5 \times 1.6 \times 10^{-13}$ 1

$= 10^{-14}$ m (appox)

10 Using 1

$R = R_0 (A)^{1/3}$

If mass is $2^{1/3}$ times Athen nuclear radius becomes twice 1

LEVEL –III

Qn1. What is the shortest wavelength present in the Paschen series of hydrogen spectrum?

($R = 1.097 \times 10^7\ m^{-1}$)

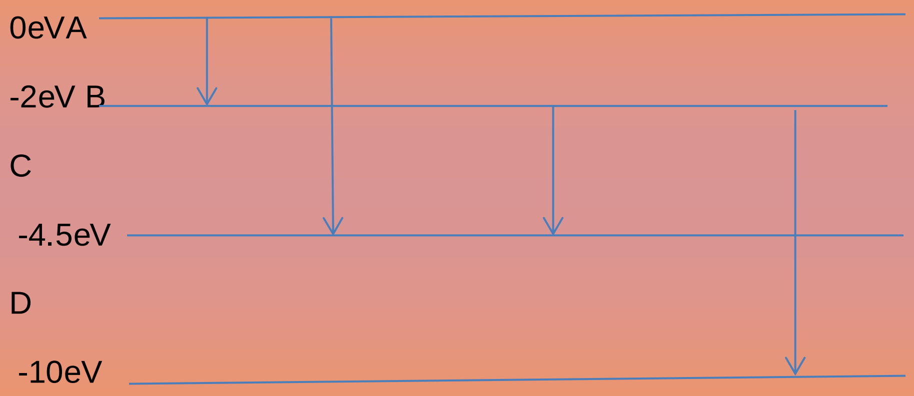
Qn2. Calculate the frequency of the photon which can excite an electron to -3.4 eV from

-13.6 eV.

Qn3. The radius of inner most electron orbit of H_2 atom is 5.3×10^{-11}m. What are theradii for second and third orbits in A^0.

Qn 4.A radioactive sample having N nuclei has activity R. Write an expression for its half-life in terms of R & N.

Qn5. The energy levels of an atom are as shown below. a) Which of them will result in the transition of a photon of wavelength 275 nm? b) Which transition corresponds to the emission of radiation maximum wavelength?



Qn6. If in a nuclear fusion reaction mass defect is 0.3 % , then find energy released in fusion of 1kg mass.

Qn7. Calculate the longest and shortest wavelength in the Balmer series of hydrogen atom. Given Rydberg constant, R = 1.09×10^{7} m^{-1}.

Qn8. The number of alpha particles scattered at 60^{0} is 100 per minute in an alpha particle scattering experiment. Calculate the number of alpha particles scattered per minute at 90^{o}.

Qn9. What is the power output of $^{235}_{92}U$ reactor if it takes 30 days to use up 2 kg of fuel and if each fission gives 185 MeV of usable energy?

Qn10. A sample of radioactive element has a mass of 10g at an instant t=0. Find the approximate mass of this element in the sample after two mean lives.

ANSWERS

Q.No.	Expected Answer	Value Points
1	$1/\lambda = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	1
	3, $n_2=\infty$	1
	$\lambda=9/R=8204$Å	
		1
	$E = E_2 - E_1$	1
2	$= -3.4 - (- 13.6)$ eV	
	$= 10.2$ eV $= 10.2 \times 1.6 \times 10^{-19}$ J	1
	$E = h\nu = 10.2 \times 1.6 \times 10^{-19}$ J	
	$\nu = 10.2 \times 1.6 \times 10^{-19} / 6.6 \times 10^{-34}$	1
	$= 2.5\times10^{15}$Hz	
3	$r_n = n^2 r_0$ $r_0 = 0.53$ A^0	1
	$r_1 = 4 \times 0.53 = 2.12$ A^0	1
	$r_2 = 9 \times 0.53 = 4.77$ A^0	
4	$R= - dN/dt = \lambda N$	1
	$T = 0.693/\lambda$	
	$T = 0.693N/R$	1
5	a. $E=hc/\lambda = 6.6 \times 10^{-34} \times 3\times 10^{8} / 275 \times10^{-9} \times 1.6 \times10^{-19}$	1
	$=4.5$eV	1
	transition B	

b. Eα 1/λ

transition A provides minimum energy of 2 eV

Hence maximum wavelength. 1

6 Δm = 0.3% of 1kg = 0.3/100 = 3 x10^{-3} kg. 1

$E = \Delta m \times c^2 = 3 \times 10^{-3} \times (3 \times 10^{8})^2$ 1

= 27 x10^{13} J

1

7 $\frac{1}{\lambda}=R[\frac{1}{2^2}-\frac{1}{n_2^2}]$ 1

For longest wavelength (H_α) $n_2=3$

$\frac{1}{\lambda}=1.09\times10^7 \times (5/36)$

1

Or, λ = 6563 A^o

For shortest wavelength, $n_2 = \infty$

Or, λ = R/4 = 3646 A^o

1

8 N(θ) α $1/\sin^4(\theta/2)$ 1

$N_2/N_1 = [\frac{\sin\theta_1/2}{\sin\theta_2/2}]^4$

$N_2/100 = [\frac{\sin 30^o}{\sin 45^o}]^4 = ¼$

1

Or, N_2 = 100/4 = 25

9 Mass of fuel consumed/sec = (2x10^3)/ 30x24x60x60 g 1

Number of atoms undergoing fission =

(6.02x10^{23}x2x10^3)/ 235x30x24x60x60 = 1.97x10^{18}

1

Power = Energy released/second

= 1.97x10^{18}x185 MeV/sec

$= 364.45 \times 10^{18} \times 1.6 \times 10^{-13}$ watt 1

$= 58.3 \times 10^{6}$ watt

10 $t = 2\tau = 2 \times 1.44\ T = 2.88\ T$ 1

$N/N_o = m/m_o = (½)^{t/T} = (½)^{2.88}$

$m = m_o(½)^{2.88}$

$= 10 \times (½)^{2.88}$ g 1

$= 10 \times 0.13$ g

$= 1.3$ g 1

UNIT IX

ELECTRONIC DEVICES

Formulae of this Unit:

1. $I = I_0\left[exp\left(\frac{eV}{nk_BT}\right) - 1\right]$
2. $R = \frac{V_i - V_z}{I}$
3. $I_E = I_C + I_B$
4. $\alpha = \frac{I_C}{I_E}$
5. $\beta = \frac{I_C}{I_B}$
6. $\alpha = \frac{\beta}{1+\beta}$
7. $\beta = \frac{\alpha}{1-\alpha}$
8. $r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$
9. $r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$
10. $A_V = \beta\left(\frac{R_{out}}{R_{in}}\right)$
11. (a) OR operation, Y= A+B

    (b) AND operation Y=A.B

    (c) NOT operation $\overline{Y}$= A
12. Combination of gates

    (a) NAND gate is combination of AND and NOT gates.

    (b) NOR gate is combination of NOT and OR gates.

    (c) XOR gate is combination of two NOT gates, two AND gates and one OR gate.

Level -01

(Numerical direct formula Based)

Q.1 : What is relation between voltage gain and trans conductor of a trimester amplifier?

Ans :- Voltage gain = Trans – Conductance X Output resistance.

Q. 2 : A transistor is being used as a common emitter amplifier. What is the value of phase difference, if any ,between the collector-emitter voltage and input signal?

Ans.: 180^0 or π radian

Q.3. Write is the phase relationship between the output and input voltage in the common faze transmitter amplifier?

Ans: Output voltage is in phase with the input signal voltage.

Q.4. Write the relation between current gains ∞ or β.

Ans : $\beta = \frac{\infty}{1-\infty}$

Q.5. Calculate the Current gain β of a transistor, if the current gain ∞ = 0.98

Ans: $\beta = \frac{\infty}{1-\infty} = \frac{0.98}{1+100}$ 49.

Q. 6 For a Transmitter the value of β is 100, what is the value of ∞ .

Ans $\infty = \frac{\beta}{1+\beta} = \frac{100}{1+100} =$ 0.99

Q.7. When the voltage drop across a p.n. Junction is increased from 0.65 v to 0.70, the charge in the diode current is 5 ma . What is the dynamic resistance of the diode ?

Ans. Here ,

$\Delta V = 0.7 - 0.65 = 0.05$ V

$\Delta I = 5mA = 5 \times 10^{-3}$ A

Dynamic resistance of junction diode is

$$rd = \frac{\Delta V}{\Delta I} = \frac{0.05}{5 \times 10^{-3}} = 10\ \Omega$$

Q.8. p – n – p transistor circuit, the collector is 10 ma , If 90 % of the reach the Collector, find emitter and base currents.

Ans: Here, I E = 10 m A

As 90 % of the holes reach the collector, so the collector current ,

I c = 90 % of I E = 90/100 IE

I E = 100/900 Ic = 100/90 x 10 = 11 m A.

Base Current, I B = I E – I c = 11-10 = 1 mA.

Q.9. A photodiode is fabricated froma semi conductor with band gap of 2.8 e V . Can it detect a wa$_{ve}$ of 6000 nm? Justify.

Ans : E$_{ne}$rgy Corresponding to Wa$_{ve}$ length 6000 nm is

$$E = \frac{hc}{\pi} = \frac{6.6 \times 10\text{-}34 \times 3 \times 108}{6000 \times 10\text{-}9} \text{ joule}$$

$$= 3.3 \times 10\text{-}20 \text{ J}$$

$$= \frac{3.3 \times 10\text{-}20}{1.6 \times 10\text{-}19} \quad 0.2\text{eV}$$

The photon e$_{ne}$rgy (E = 0.2 ev) of gi$_{ve}$n wa$_{ve}$leanth is much less then band gap (Eg.) , hance it ca$_{ne}$ot detevt the gi$_{ve}$n wa$_{ve}$length.

Q.10. The number of silicon atoms per m3 is 5 x 1022 atom per 33 of A$_{ne}$senice and 5 x 1020 per m3 atoms of Indian. Calculate the number of electrons and holes . Gi$_{ve}$n that Ni = 1.5 X 1016 per m3 . In the material N-type on P-Type?

Ans : Ar$_{ne}$sic is n-type impurty and indium is P-type impurity Number of electron, $_{ne}$ = n0 – nA = 5 x 1022 – 5 x 1020= 4.95 x 1022m-3

We ha$_{ve}$, ni2 = $_{ne}$nh

Gi$_{ve}$n, ni = 1.5 x 1016 m -3

$$\text{Number of holes, } _{ne} = \frac{ni2}{_{ne}} = \frac{(1.5 \times 1016)2}{4.95 \times 1022}$$

nh = 4.54 x 109m-3

as $_{ne}$ > $_{ne}$; so the material is an n-type semiconductor.

LEVEL –II

Q.1. When the voltage drop across a p-n junction diode is incrase from 0.65 v to 0.70 v , the change in the diode current is 5mA. What is the dynamic resistance of the diode?

Ans : $r_d = \frac{\Delta v}{\Delta I}$

$= \frac{0.70 - 0.65}{5x10\text{-}3}$

$= \frac{0.05}{5 \times 10\text{-}3}$

$= 10\Omega.$

Q.2. Diode used in figure has a constant voltage drop at 0.5 V at all current and a maximum power rating of 100mw. What should be the value of resistance R, co$_{ne}$ected in series for maximum current.

Ans : Current , I $= \frac{P}{V}$

$= \frac{100 \times 10\text{-}13}{0.5}$

=0.2 A

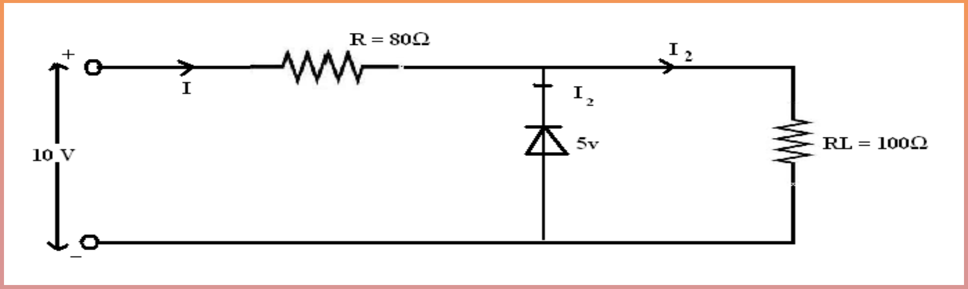
From Circuit ,

IR +0.5 = 1.5

i.e., 0.2 +0.5 = 1.5

i.e. $R = \frac{1.5 - 0.5}{0.2} = 5\ \Omega.$

Q.9. On the figure shown, find out the current passing through R_L and Ze$_{ne}$r diode :



Ans : Here,

$V2 = 5V$

Voltage drop across R = Input voltage – V_2

$= 10 – 5 = 5v$

$= I_L = V2 \quad 5v \quad 5 \times 10^{-2}A$

Here,

Current through R,

$$I = \frac{\text{Voltage drop across R}}{R} = \frac{5V}{80\Omega} \quad 6.25 \times 10^{-2} A$$

Applying Kirchoff's Law :

$I = I_2 + I_L$

$I_2 = I - I_L$

$= 6.25 \times 10^{-2}$

$= 1.25 \times 10^{-2}A.$

Q.4. A common emitter transistor has current gain of 100. If emitter current is 8.08 m A, find the base and collector current.

Ans: Here,

B = 100

IE = 8.08 MA

Using, $\frac{IC}{IB} = B$

We get

$Ic = BI_B = 100\ I_B$

Using , IE =IB + IC

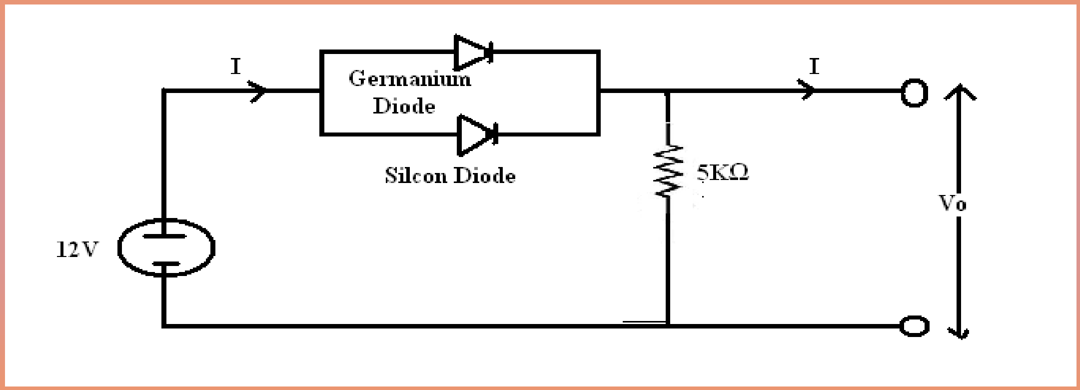
We get

IE = 101 IB

Or, $IB = \frac{IE}{101} = \frac{8.08}{101} = 0.08mA$

From Eq^n (i) IC = 100 x 0.08 = 8ma.

Q 5. (I) Calculate the value of output voltage V0 and Current I if Silicon diode and germanium diode conduct at 0.7 v and 0.3 v respectively (refer figure)



(II) If now Germanium diode is coneected 12 v in reverse polarity , find new value of V0 and I.

Ans.: (I) Germanium diode conducts at 0.3 v only , so curret will prefer to pass through germanium diode so,

V0 = 12 – 0.3 = 11.7 v

And,

$$I = \frac{11.7}{5 \times 10^3}$$

= 2.34 mA

(II) When germanium diode is reversed biased, the current will flow through the silicon diode.

Then,

V0 = 12 – 0.7 = 11.3 v

And ,

$$I = \frac{11.3}{5 \times 10^3} 2.26 \text{ mA}$$

Q.6 In a common –emitter transistor amplifier, the input resistance is 200Ω , RL = 20KΩ. Find (i) voltage gain and (ii) Power gain . Goven current gain B = 10.

Ans: Here ,

Ri = 200 Ω , RL = 20 k Ω

= 2×10^4 Ω

(i) Voltage gain, A_v = β $^{RL}/_{RI}$

$$= \frac{10 \times 2 \times 10^4}{200} 10^3 = 10^3$$

(ii) Power Gain$B^2\, ^{RL}/_{Ri}$ = $\frac{(10)^2 \times 2 \times 10^4}{200}$

= 10^4

Q.7. A full wave rectifier is built with help of two diodes each having resistance is 1.2 10-3 Ω. A.C. input signal has

(i) Maximum value of applied voltage
(ii) r.m.s. value of current
(iii) Current
(iv) Efficiency
(v) Ripple factor

Ans : (i) Vo = Io + (RL + RF)

= $\frac{1}{24}$ $(6+1.2)10^3$

= 300V

(ii) Irma = $\frac{Io}{\sqrt{2}}$ = $\frac{1}{24 \times \sqrt{2}}$

= 29.46×10^3A

(i) Id.c = $2\left(\frac{Io}{\pi}\right)$

= $\frac{2 \times 1}{24 \times 3.14}$

= $\frac{2 \times 1}{26.5 \times 10^3}$ (* there are 2 diodes)

(ii) N = $8^2\left(\frac{RL}{Rf + RL}\right)$

= $8.12\left(\frac{6.10^3}{(6+1.2)10^3}\right)$

= $\frac{8.12}{1.2}$

= 67.7 %

(iii) Ripple factor, $\left\{\left(\frac{Irms}{\ }\right)^2 - 1\right\}^{½} = \left\{\left(\frac{29.5}{\ }\right)^2 - 1\right\}^{½}$ = 0.48

Iav 26.5

Q.8. For a common emitter amplifier , current gain = 50. If the emitter current is 6.6 mA, Calculate gain , when emitter is working as common-base amplifier.

Ans. Here

$\beta = 50$

$I_E = 6.6mA$

Step 1. Since $\beta = \frac{IC}{IB}$

$= Ic = \beta I_B = 50I_B$

Step 2. Now ,

$I_E = Ic + I_B$

$6.6 = 50I_B + I_B$

$I_B = \frac{6.6}{} = 0.129$ mA

Hence, $Ic = 50 \times \frac{6.6}{51} = 6.47mA$

Step 3. $B = \frac{\infty}{1- \infty}$ or, $\infty = \frac{\beta}{1+ \beta}$

$= \frac{50}{51} = 0.98$

Q.9. For a transistor with β = 75 the maximum collector current for an emitter current of 5mA ?

Abs :- Here,

$\beta = 75$

$I_E = 5mA$

Step 1 :-

Using

$\beta = \frac{\infty}{1- \infty}$ we get,

$75 = \frac{\infty}{1-\infty}$ or, $75 – 75 \infty = \infty$

Or, $76\infty = 75$ or, $\infty = \frac{75}{76} \times 5$

Step 2.,

$\infty = Ic$ $Ic = \infty I_E = \frac{75}{76} \times 5 = 4.93mA.$

Q.10. In n p n transistor circuit, the collector current is 10 mA. If 95%of the electron emitted reach the collector, what is the base current ?

Ans : Step 1 :-

$Ic = 95\ \%$

$I_E = 0.95 I_E$

$I_E = \frac{Ic}{0.95}$

$= \frac{10}{0.95}$ (∵ Ic = 10 mA)

$= 10.53\ mA$

Step 2 :-

Now , $I_E = I_C + I_B$

$IB = I_E + I_C$

$= 10.53 - 10$

0.53mA

UNIT- X – COMMUNICATION SYSTEMS

All the possible formulae

1. **Modulation factor** ,$\mu = \frac{Am}{Ac}$ or $\mu = \frac{Am}{Ac}$ X 100 %
2. If A_{max} and A_{min} are the maximum and minimum amplitudes of the carrier wave, then

$$\mu = \frac{\text{Amax} - \text{Amin}}{\text{Amax} + \text{Amin}} \times 100\%$$

3. Modulating Voltage, m (t) = $Am \sin\omega_m t$
4. Carrier Voltage, , c (t) = $Ac \sin\omega_c t$
5. Instantaneous voltage of A.M wave is
   $C_m(t) = A_c(1 + \mu \sin\omega_m t)\sin\omega_c t = Ac \sin\omega_c t - \frac{\mu Ac}{2}\cos(\omega_c + \omega_m)t + \frac{\mu Ac}{2}\cos(\omega_c - \omega_m)t$
6. Component frequencies of A.M wave are:
   (a) Carrier frequency = f_c
   (b) USB = $f_c + f_m$
   (c) LSB = $f_c - f_m$
7. Bandwidth = (fc + fm) – (fc – fm) =2 fm
8. Length of dipole antenna $l = \frac{\lambda}{2} = \frac{c}{2v}$
9. Number of channels = $\frac{Total\ bandwidth\ of\ channel}{bandwidith\ needed\ per\ channel}$
10. Critical frequency for sky wave propagation $f_c = 9\,(N_{max})^{1/2}$
11. The range of TV transmission $d = \sqrt{2hR}$ Where h = height of antenna, R= Radius of Earth
12. Population Covered = population density X Area
13. Maximum distance covered in LOS communication:

$$d_M = d_T + d_R = = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

Level-1

1. A TV tower has a height of 71 m. what is the maximum distance up to which TV transmission can be received? Given that the radius of the earth = 6.4 x 10^4 m. [1]
2. What is the length of a dipole antenna to transmit signals of frequency 200 MHz? [1]
3. A 100 kHz bandwidth is to accommodate 10 A. M. broadcasts simultaneously. What is the maximum modulating frequency permissible for each station? [1]
4. Calculate the number of TV channels which can be accommodated in a band width of 4700 GHz.[1]
5. What should be the height of a transmitting antenna if the TV telecast is to cover a radius of 128 km? [1]
6. For amplitude modulated wave the maximum amplitude is found to be 15 V while the minimum amplitude is 3 V. Calculate the modulation index. Why modulation index is generally kept less than one? [2]
7. A carrier wave of peak voltage 18 V is used to transmit a signal. Calculate the peak voltage of the modulating signal in order to have a modulation index of 50%. [2]
8. A message signal of frequency 10 kHz and peak voltage of 10 V is used to modulate frequency of 1 MHz and peak voltage of 20 V. Determine (i) modulation index (ii) the side bands produced. [2]
9. A TV tower has a height of 100 m. how much population is covered by the TV broad cast if the average population density around the tower is 1000 km^{-2}. [2]
10. A transmitting antenna at the top of a tower has a height of 36 m and the height of the receiving antenna is 49 m. What is the maximum distance between them for satisfactory communication in the line of sight mode? (Radius of the earth = 6400 km) [2]

Level-II:-

1.A TV tower has a height of 300m. What is the maximum distance upto which this TV transmission can be received?

2. A carrier wave of peak voltage 20 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 80%?

3. The TV signal have a bandwidth of 4.7 MHz.What is the number of channels that can be
Accommodated in a bandwidth of 4700Ghz/

4. Calculate the length of half wave dipole antenna at 30 MHz?

5. What should be the height of a transmitting antenna if the TV telecast is to cover a radius

Of 128 Km?

6. The tuned circuit of oscillator in a single AM transmitter employs 50 uH coil and 1nF capacitor. The oscillator output is modulated by audio frequency up to 10KHz. Determine the range of AM wave.

7. What is the population covered by the transmission, if the average Population density around the tower is 1200km-2?

8.. A transmitting antenna at the top of tower has a height of 36m and the height of the receiving antenna is 49m. What is the maximum distance between them, for the satisfactory communication in the LOS mode? (Radius of the earth =6400km)

9. Frequencies higher than 10MHz are found not to be reflected by the ionosphere on a particular day at a place. Calculate the maximum electrons density of the ionosphere.

10. A message signal of frequency 10 kHz and peak value of 8 volts is used to modulate a carrier

Of frequency 1MHz and peak voltage of 20 volts.

Calculate: (i) Modulation index

(ii) The side bands produced.

LEVEL- III

1. A carrier wave of frequency 10MHz and peak value 10V is amplitude modulated by a 5KHz sine wave of amplitude 6V.Calculate the frequency and amplitude of the two sidebands.
2. A sinusoidal carrier voltage is amplitude modulated by a sinusoidal voltage of 10 KHz to a depth of 30%. Calculate the frequency and amplitude of the two sidebands if the carrier frequency is 10 MHz and its amplitude is 40 V.
3. A sinusoidal carrier voltage of frequency 1200 KHz is amplitude modulated by a sinusoidal voltage of frequency 20 KHz resulting in maximum and minimum modulated carrier amplitudes of 110 V and 90 V respectively. Calculate (i) the frequency of lower and upper sidebands (ii) the unmodulated carrier amplitude (iii) the modulation and (iv) the amplitude of each sideband.
4. . An amplitude modulated wave is represented as

   cm (t) = 5 (1 + 0.6 cos + 6280 t) sin 211 × 104 t, volts.

   (i)What are the minimum and maximum amplitudes of the A.M wave?

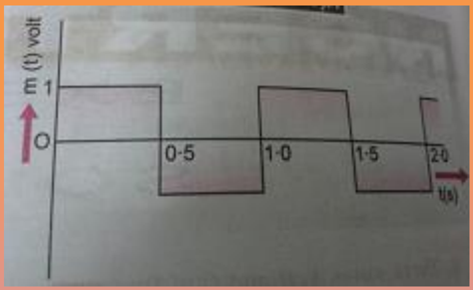
   (ii)What frequency components are contained in the modulated wave?

(iii)What are the amplitudes of the compounds?

5. Assume that light of frequency 4.5 × 1014 Hz is used in an optical communication system. If 2% of the frequency bandwidth is used, how many T.V. channels can be accommodated in this bandwidth? The bandwidth needed for T.V. transmission is 4.5 × 106 Hz / channel.
6. . A ground receiver station is receiving a signal at (a) 5 MHz and (b) 100 MHz, transmitted from a ground transmitter at a height of 3000 m located at a distance of 100 km. identify whether it is coming via space wave or sky wave propagation or satellite transponder. (given the value of radius of earth is 6400 km and maximum electron density, N_{max} = 1023 m-3).
7. On a particular day, the maximum frequency reflected from the ionosphere is 10 MHz. on another day, it was found to increase to 11 MHz. calculate the ratio of the maximum electron densities of the ionosphere on the two days. Point out a possible explanation for this.
8. . What will be the required height of a T.V tower which can cover the population of 60.3 lakhs if average population density around the tower is $1000km^{-2}$?
   [radius of earth = 6.4×10^6m]
9. The T.V transmission tower at a particular stationhas a height of 160 m. (a) what is its coverage range ?(b) how much population is covered by the transmission, if the average density around the tower is $1200km^{-2}$? (c) by how much should the height be increased to double its coverage range? Given radius of earth = 6400 km.
10. A transmitting antenna at the top of a tower has a height 32 m and that of the receiving antenna is 100 m. what is the maximum distance between them for satisfactory communication in LOS mode? given radius of earth 6.4 × 10 6 m.

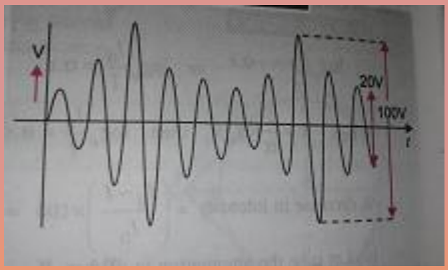
<u>SOME QUESTION BASED ON DIAGRAM</u>

1.A modulating signal is a square wave as shown in figure.The carrier wave is given by C(t) = 2 Sin(8∏t)volt

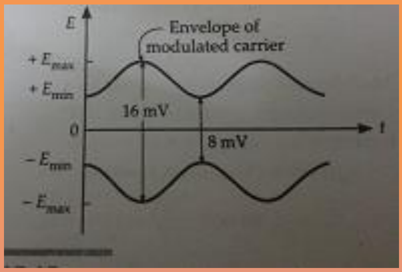


(a) Sketch the amplitude modulated wave form.
(b) What is the modulation index?

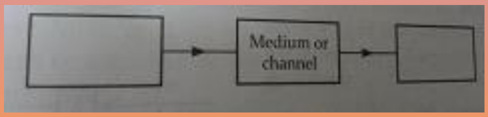
2. An amplitude modulated waves is as shown in figure Calculate (i) the percentage Modulation, (ii) peak carrier voltage and (iii) peak value of information voltage?



3. Find out the modulation factor from the given figure:

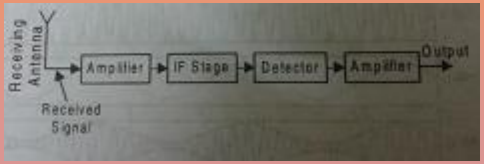


4. Complete the following block diagram depicting the essential elements of a basic communication System:

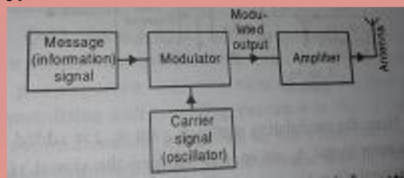


Name the two basic modes of communication. Which of these modes is used for the telephonic communication?

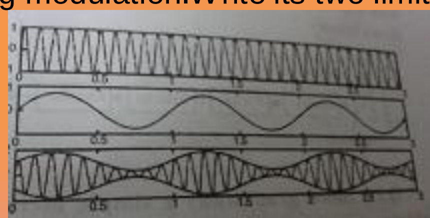
5. Explain with the help of a block diagram the detection of an amplitude modulated wave?



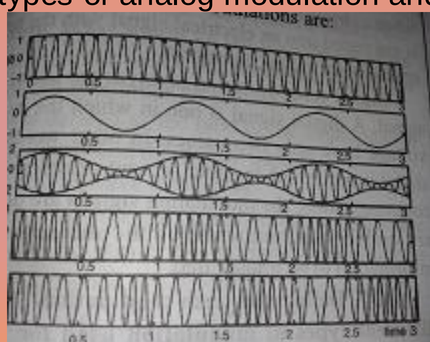
6. With the help of a block diagram, Explain how the process of modulation is carried out in radio
Broadcast?



7. Identify the analog modulation.Write its two limitations and two advantages?



8. Name the types of analog modulation and define each of them?



9. Draw the block diagram of transmitter and receiver?

10. On a particular day the maximum frequency reflected from the ionosphere is 10 MHz. On another day, it was found to increase to 11 MHz. Calculate the ratio of maximum electron density of the ionosphere on the two days. Point out a possible explanation for this. (2)

ANSWER KEY

(Level-1)

1. d = $\sqrt{2Rh}$ = 30 km
2. Length of dipole antenna = l = $\frac{\lambda}{2}$ = $\frac{c}{2\nu}$ = 75 cm
3. $\frac{100\ kHz}{2\ f}$ = 10 => f = 5kHz
4. No of TV channels = $\frac{\text{total bandwidth of the channel}}{\text{band width per TV channel}}$ = $\frac{4700 \times 10^9}{4.7 \times 10^6}$ = 10^6 channels
5. d = $\sqrt{2Rh}$ => h = $\frac{d^2}{2R}$ = 1280 m
6. μ = $\frac{A_m}{A_c}$ = $\frac{A_{max}-A_{min}}{A_{max}+A_{min}}$ = $\frac{10-2}{10+2}$ = $\frac{2}{3}$
7. μ = $\frac{A_m}{A_c}$ => $\frac{50}{100}$ = $\frac{A_m}{18}$ => A_m = 9 V
8. μ = $\frac{A_m}{A_c}$ = $\frac{1}{2}$
   Upper side band frequency = $f_c + f_m$ = 1 MHz + 10 kHZ = 1.01 MHz
   Lower side band frequency = $f_c - f_m$ = 1 MHz - 10 kHZ = 0.99 MHz
9. Area covered by antenna = πd^2 2 x 3.14x100x6.4 x 10^6 m^2
   Population covered = Area covered x population density = 4019200 persons
10. d_M = $\sqrt{2h_T R}$ + $\sqrt{2h_R R}$ = 46.54 km

LEVEL-II

1: d = √2Rh = √ 2 x 6400 x 1000 x 300 = 62km

2. Hint: Modulation index, ma = Em / Ec
Em = ma x Ec = 0.80 x 20 V = **16 V**

3.: Number of channels = $\frac{Total\ bandwidth\ of\ channel}{bandwidith\ needed\ per\ channel}$

= 4700GHz/4.7MHz = 10^6

4. :- Length of dipole antenna l = $\frac{\lambda}{2}$ = $\frac{c}{2\nu}$ = 5m

5. :- d = √2hR

h=d^2/2R = 1280m

6.: υc = 1/2π√LC ; USF = υc + υm ; LSF = υc – υm

7.**d** = √2Rh=√2×6.4×103 ×160×10-3 =45km Range 2d=2×45=90km
Population covered=area × population density=1200×6359= 763020

8.. Using d= √2Rht + √2Rhr we get =46.5km

9. Nmax = fc2/ 81 = (10 x 106)2 / 81 = 1.2 x 1012 m-

10.: (i) Modulation index, ma = Em / Ec = 8/20 = 0.4
(ii) Side bands frequencies = fc ± fm

Thus the side bands are at 1010 KHz and 990 kHz.

LEVEL -III

1.Here $f_c = 10$ MHz, $f_m = 5$ KHz = 0.005 MHz, $E_c = 10$ V, $E_m = 6$ V.

Frequency of USB = $f_c + f_m = 10 + 0.005 = 10.005$ MHz

Frequency of LSB = $f_c - f_m = 10 + 0.005 = 9.995$ MHz

$M = E_m / E_c = 6 / 10 = 0.6$

.`. amplitude of USB or LSB

$= m E_c / 2 = 0.6 \times 10 / 2 = 3$ V

2.. Here $f_m = 10$ KHz = 0.10 MHz, $\mu = 30\% = 0.30$,

$f_c = 10$ MHz, $A_c = 40$ V

frequency of USB = $f_c + f_m = 10 + 0.010 = 10.01$ MHz

frequency of LSB = $f_c – f_m = 10 – 0.010 = 9.99$ MHz

amplitude of each sideband = $\mu A_c / 2 = 0.30 \times 40 / 2$

$= 6.0$ V

3. (i) lower sideband frequency = $f_c – f_m = 1200 – 20 = 1180$ KHz

Upper sideband frequency = $f_c + f_m = 1200 + 20 = 1220$ KHz

(ii) unmodulated carrier amplitude = $A_{max} + A_{min} / 2 = 110 + 90 / 2 = 100$ V

(iii) modulation index,

$\mu = A_{max} – A_{min} / A_{max} + A_{min}$

$= 110 – 90 / 110 + 90 = 0.1$

Amplitude of each sideband = $\mu A_c / 2 = 0.1 \times 100 / 2$

$= 5$ V

4.Given the A.M wave,

$c_m(t) = 5 (1 + 0.6 \cos 6280 t) \sin 211 \times 10^4 t$, volts.

Comparing with the standard A.M wave,

$c_m(t) = A_c(1 + m\cos\omega_m t)\sin\omega_c t,$

we get $A_c = 5$ V , $\mu = 0.6$.

modulating frequency , $f_m = \omega_m / 2\Pi = 6280 / 2\Pi$

$= 1$ KHz

Carrier frequency , $f_c = \omega_c / 2\Pi = 211 \times 10^4 / 2\Pi$

$= 336$ KHz

(i) Minimum amplitude of A.M wave

$= A_c - \mu A_c = 5 - 0.6 \times 5 = 2$ V

Maximum amplitude of A.M wave

$= A_c + \mu A_c = 5 + 0.6 \times 5 = 8$ V

(ii) Frequency components of the A.M wave are

$F_c - f_m$, f_c , $f_c + f_m$ i.e., 336 – 1 , 336 , 336+1

Or 335 KHz , 336 KHz , 337 KHz

(iii) The amplitudes of the three components are

$\mu A_c / 2$, A_c , $\mu A_c / 2$

i.e., $0.6 \times 5 /2$, 5, $0.6 \times 5 / 2$

or 1.5 V , 5 V , 1.5 V

5. Optical frequency used = 4.5×10^{14} Hz

Total bandwidth of the channel = 2% of 4.5×10^{14} Hz = 9×10^{12} Hz

Bandwidth per T.V channels which can be accommodated

= total bandwidth of the channel / bandwidth needed per T.V channel

$= 9 \times 10^{12} / 4.5 \times 10^6$

$= 2 \times 10^6$ channels

6. Maximum distance covered by a space wave propagation

$= \sqrt{2Rh} = (2 \times 6.4 \times 10^6 \times 300)^{1/2}$ m

$= 62$ km

As the receiver-transmitter distance is 100 km, so space wave propagation is not possible for both 5 MHz and 100 MHz waves.

The critical frequency for ionospheric propagation is $f_c = 9\,(N_{max})^{1/2} = 9(10^{12})^{1/2}$

$= 9 \times 10^6$ Hz = 9 MHz

Since the frequency of signal (a) 5 MHz < f_c , so this signal comes via ionospheric propagation while signal (b) of 100 MHz comes via satellite transmission.

7. Here $f_c = 10$ MHz, $f'_c = 11$ MHz

But $f_c = 9\,(N_{max})^{1/2}$ and $f'_c = 9\,(N'_{max})$

$\therefore\; N'_{max} / N_{max} = (f'_c / f_c)^2 = (11/10)^2$

$= 1.21$

The degree of ionization of the ionosphere due to solar radiation may vary from day to day. This changes the refractive index and hence the frequency f_c .

8. Area covered × population density = population covered

$\therefore\; \Pi d^2 \times (1000\ km^{-2}) = 60.3$ lakhs

$\Pi d^2 \times 1000(1000\ m)^{-2} = 60.3 \times 10^5$

$d^2 = 60.3 \times 10^5 \times 1000 / \Pi$

$= 1.92 \times 10^9$

Height of T.V tower,

$h = d^2 / 2R = 1.92 \times 10^9 / 2 \times 6.4 \times 10^6$

$= 150$ m

9. Here, height of tower, h = 160 m

Population density, $p = 1200 km^{-2}$

Radius of earth, R = 6400 km = 64×10^5

(a) Coverage range,

$D = \sqrt{2\,hR} = \sqrt{2 \times 160 \times 64 \times 100000}$

$= 32000\sqrt{2} = 45248$ m = 45 km

(b) Population covered,

P = population density × area covered

$= p \times \Pi d^2 = 1200 \times \Pi \times (45)^2$

= 76.37 lakhs.

(c) To double the coverage range, the height h' must be such that

$$2\,d = \sqrt{2\,h'R} \quad \text{or} \quad 2\sqrt{2\,hR} = \sqrt{2h'R}$$

or $h' = 4\,h = 4 \times 160 = 640$ m

Height of the tower to be increased

$= h' - h = 640 - 160$

$= 480$ m.

<u>10.</u> Here $h_T = 32$ m, $h_R = 100$ m

$R = 6.4 \times 10^{6}$ m.

$$d_M = \sqrt{2\,Rh} + \sqrt{2\,Rh}$$

$$d_M = \sqrt{2 \times 64 \times 100000 \times 32} + \sqrt{2 \times 64 \times 100000 \times 50} \text{ m}$$

$$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^{3} \times \sqrt{10} \text{ m}$$

$$= 144 \times 10^2 \sqrt{10} \text{ m} = 45.5 \text{ km}$$