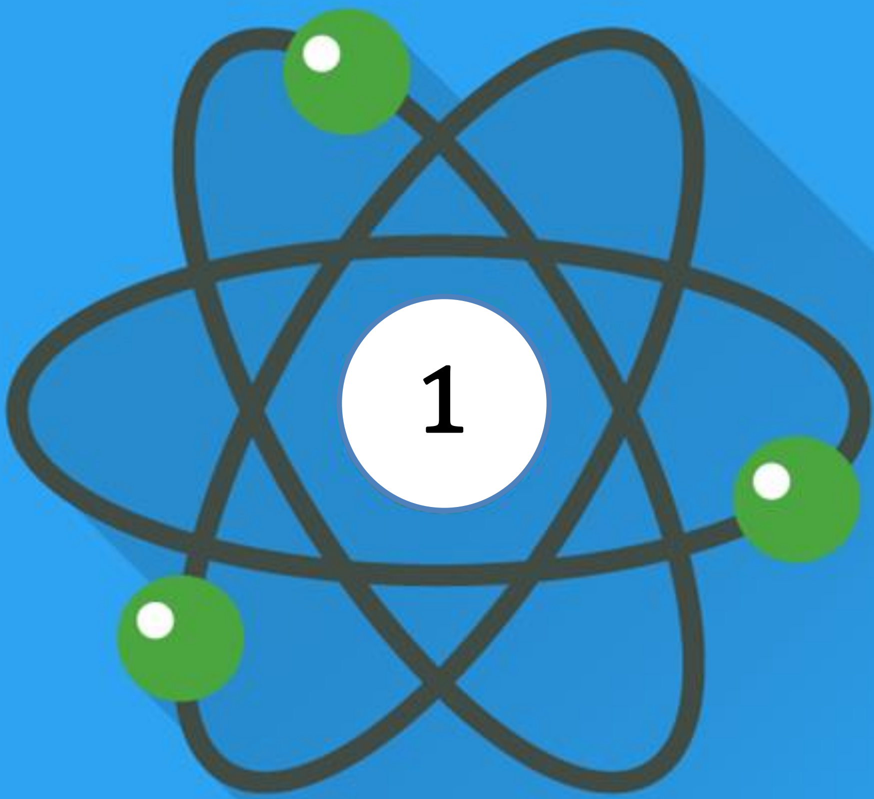
HANDBOOK

II PUC

2023 – 24

L P

Physics



MOST IMPORTANT PROBLEMS

PROF. LAKSHMIPATHI M N

ST. ANTHONY'S PU COLLEGE, MYSORE ROAD, B'LORE – 59

The weightage of the distribution of marks over different dimensions of the question paper is as follows:

A. Weightage to objectives:

Objective	Weightage	Marks
Knowledge	35%	41
Understanding	29%	33
Application	20%	23
Hots	16%	18

B. Weightage to content/ subject units:

Unit No.	Chapter No.	Topic	No. of Hours	Marks
I	1	Electric Charges and Fields	12	11
II	2	Electric Potential and Capacitance	12	11
III	3	Current Electricity	15	14
IV	4	Moving Charges and Magnetism	13	12
V	5	Magnetism and Matter	6	6
	6	Electromagnetic Induction	8	8
VI	7	Alternating Current	8	8
	8	Electromagnetic Waves	3	3
VII	9	Ray Optics and Optical Instruments	11	11
VIII	10	Wave Optics	8	7
IX	11	Dual Nature of Radiation and Matter	6	6
	12	Atoms	4	4
X	13	Nuclei	5	5
	14	Semiconductor Devices & Electronics	9	9
TOTAL			120	115

C. Weightage to form of questions:

QP Part	Type of questions	Number of questions to be set	Marks Alloted	Number of questions to be answered	Marks Alloted
A	Multiple Choice Questions (MCQ)	15	15	15	15
	Fill in the blank type (FIB)	05	05	05	05
B	Short Answer (SA1)	09	18	05	10
C	Short Answer (SA2)	09	27	05	15
D	Long Answer (LA)	06	30	03	15
	Numerical Problems (NP)	04	20	02	10
Total		115	115	35	70

D. Weightage to level of difficulty:

Level	Weightage	Marks
Easy	40%	46
Average	40%	46
Difficult	20%	23

General instructions

1. Variation of 1 mark in each chapter is permitted while preparing the blue print and total marks should not exceed 115.
2. The question paper should be prepared on the basis of blueprint following the weightage of marks fixed for each chapter. The questions must be framed to check the specific cognitive level as mentioned in the blue print.
3. Questions should be clear, unambiguous, understandable and free from grammatical errors.
4. Questions which are based on same concept, law, fact etc. and which generate the same answer should not be repeated under different forms (MCQ, FIB, VSA, SA, LA and NP).
5. The answers for the questions should be available in the prescribed text book or can be derived from the concepts of text book for application / reasoning / analytical / hot questions
6. When a question carrying 3 or 5 marks is split, the sub question should be derived from the same concept or different concepts of same chapter.
7. Only one 5 mark numerical problem has to be set from chapters corresponding to a pair of consecutive units like I & II, III & IV, V & VI, VII & VIII, IX & X.
8. In part A [I main] 3 MCQ and in part D [VI main] 3 numerical problems of same difficulty level must be framed to check higher order thinking skills.
9. Only one numerical problem can be included in each of the part B [2M] and part C [3M].

BLUE PRINT FOR THE PHYSICS QUESTION PAPER [33]

Unit	Chapter	Topic	Teaching Hours	Marks allotted	1 Mark (MCQ)	1 Mark (FIB)	2 Marks (SA1)	3 Marks (SA2)	5 Marks (LA)	5 Marks (NP)
I	1	Electric Charges and Fields	12	11	✔		✔	✔		✔
II	2	Electric Potential and Capacitance	12	11	✔		✔	✔	✔	
III	3	Current Electricity	15	14	✔			✔	✔	✔
IV	4	Moving Charges and Magnetism	13	12	✔	✔	✔	✔	✔	
V	5	Magnetism and Matter	6	6	✔		✔	✔		
	6	Electromagnetic Induction	8	8	✔ ✔	✔	✔	✔		
VI	7	Alternating Current	8	8	✔		✔			✔
	8	Electromagnetic Waves	3	3	✔		✔			
VII	9	Ray Optics and Optical Instruments	11	11	✔		✔	✔		✔
VIII	10	Wave Optics	8	7	✔	✔			✔	
IX	11	Dual Nature of Radiation and Matter	6	6	✔				✔	
	12	Atoms	4	4	✔			✔		
X	13	Nuclei	5	5	✔	✔		✔		
	14	Semiconductor Devices & Electronics	9	9	✔	✔	✔		✔	
TOTAL = 115 Marks			120	115	15	05	18	27	30	20

Note: Split type question [ST] [1+2+2] or [2+3] or [1+4] or [1+1+3]

LIST OF IMPORTANT FORMULAE

1. Number of electrons, n = $\frac{\text{Charge in coulumb (q)}}{\text{Charge of electron (e)}}$
2. Force between two point charges in air, $F_a = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r^2}\right)$
3. Force between two point charges in medium, $F_m = \frac{1}{4\pi\varepsilon_0\varepsilon r}\left(\frac{q_1q_2}{r^2}\right) = \frac{F_a}{\varepsilon r}$
4. If F_1 and F_2 are two forces acting at a point at an angle θ , then
   Resultant force, F = $\sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$
5. Direction of resultant force; tan α = $\left[\frac{F_2\sin\theta}{F_1 + F_2\cos\theta}\right]$
6. Electric intensity, $E = \frac{\text{FORCE [F]}}{\text{CHARGE [q]}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r^2}\right)$
7. Force, F = qE
8. If E_1 and E_2 are two electric fields acting at a point at an angle θ , then
   Resultant field E = $\sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$
9. Direction of resultant field, tan α = $\left[\frac{E_2\sin\theta}{E_1 + E_2\cos\theta}\right]$
10. Electric dipole moment, P = q x 2a
11. Axial field, E = $\frac{1}{4\pi\varepsilon_0}\frac{2px}{(x^2-a^2)^2}$
12. Equatorial field, E = $\frac{1}{4\pi\varepsilon_0}\frac{P}{(x^2+a^2)^{\frac{3}{2}}}$
13. Torque, τ = PE sin θ
14. Electric flux, $\varphi = EA\cos\theta$
15. Electric flux, $\varphi = \frac{q}{\varepsilon_0}$ [GAUSS LAW]
16. Linear density of charge; λ = $\frac{\text{CHARGE[q]}}{\text{LENGTH [L]}}$
17. Surface distribution of charge; σ = $\frac{\text{CHARGE[q]}}{\text{AREA [A]}}$
18. Volume distribution of charge; ρ = $\frac{\text{CHARGE [q]}}{\text{VOLUME [V]}}$
19. Electric field due to an infinitely long straight uniformly charged wire; E = $\frac{\lambda}{2\pi\varepsilon_0 r}$
20. Electric field due to a uniformly charged infinite plane sheet; E = $\frac{\sigma}{2\varepsilon_0}$
21. Electric potential due to charge +q placed in air, V = $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}\right)$
22. Electric potential due to charge −q placed in air, V = $\frac{1}{4\pi\varepsilon_0}\left(\frac{-q}{r}\right)$
23. Electric potential in dielectric medium; $V_m = \frac{V_{air}}{K}$ where K is dielectric constant
24. Work done in moving a charge, W = qV [or] dW = qdV
25. Electric field, $E = \frac{\text{POTENTIAL DIFFERENCE [dV]}}{\text{DISTANCE [dX]}}$
26. Potential difference, V = $V_A \sim V_B$

27. Electric potential due to group of point charges, $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \cdots\right)$

28. Dipole moment; $p = q \times 2a$

29. Electric potential due to dipole, $V = \frac{p\cos\theta}{4\pi\varepsilon_0(r^2 - a^2\cos^2\theta)}$

30. Potential energy of dipole, $U = -PE\cos\theta$

31. Electrostatic potential energy (U) of two charges, $U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r}\right)$

32. Electrostatic PE of system of three point charges; $U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_1} + \frac{q_2 q_3}{r_2} + \frac{q_1 q_3}{r_3}\right)$

33. Capacitance of the conductor, $C = \frac{q}{V}$

34. Capacitance of a spherical conductor, $C = 4\pi\varepsilon_0 r$

35. Capacitance of a parallel plate capacitor without dielectric medium, $C = \frac{A\epsilon_o}{d}$

36. Capacitance of a parallel plate capacitor with dielectric medium, $C_m = \frac{A\epsilon_o \epsilon_r}{d} = C \times \epsilon_r$

37. Effective capacitance in series combination, $\frac{1}{C_{eff}} = \frac{1}{c_1} + \frac{1}{c_2} + \cdots + \frac{1}{c_n}$

38. For 2 capacitors; effective capacitance in series combination, $\frac{1}{C_{eff}} = \frac{1}{c_1} + \frac{1}{c_2}$ (or) $C_s = \frac{c_1 c_2}{c_1 + c_2}$

39. Effective capacitance in parallel combination , $C_p = C_1 + C_2 + \ldots + C_n$

40. Energy stored in capacitor, $U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q}{V}V^2 = \frac{1}{2}QV$

41. Common potential; $V_{Common} = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1 + q_2 + \cdots}{C_1 + C_2 + \cdots}$

MOST IMPORTANT PROBLEMS

1. Two charges 10nC and 20nC are placed at 5m apart. Calculate
   a) Force between the charges
   b) Force between the charges if a medium of relative permittivity 5 is introduced.
   c) Change in force between the charges
   d) Force between the charges when they are brought in contact and then replaced in their initial positions

Ans: Force between two point charges, $F = \left(\frac{1}{4\pi\varepsilon_0}\right) \cdot \frac{q_1 q_1}{d^2}$ .....(1)

a) Force between two point charges,

Eq (1) $\Rightarrow F_1 = \frac{9 \times 10^9 \times 10 \times 10^{-9} \times 20 \times 10^{-9}}{5^2} = 72 \times 10^{-9}$ N

b) Force between two point charges; $F_2 = \frac{F_1}{\varepsilon_r} = \frac{72 \times 10^{-9}}{5} = 14.4 \times 10^{-9}$ N

c) Change in force = $F_1 - F_2 = [72 - 14.4] \times 10^{-9} = 57.6 \times 10^{-9}$N

d) After contact, $q = \left(\frac{q_1 + q_1}{2}\right) = \left(\frac{10+20}{2}\right) \times 10^{-9} = 15 \times 10^{-9}$C

$\therefore q_1 = q_2 = 15 \times 10^{-9}$C

Force between two point charges, $F = \frac{9 \times 10^9 \times 15 \times 10^{-9} \times 15 \times 10^{-9}}{(5)^2}$ From equ(1)

$F = 81 \times 10^{-9}$ N

2. **Two charges 10nC and 20nC are placed at the corners of hypotenuse BC of a right angled triangle ABC of sides AB = 3m and AC = 4m. Find a)magnitude of force acting on corner 'A' of right angled triangle ABC if a charge +2nC is placed at corner 'A' and b) direction of resultant force at corner 'A'**

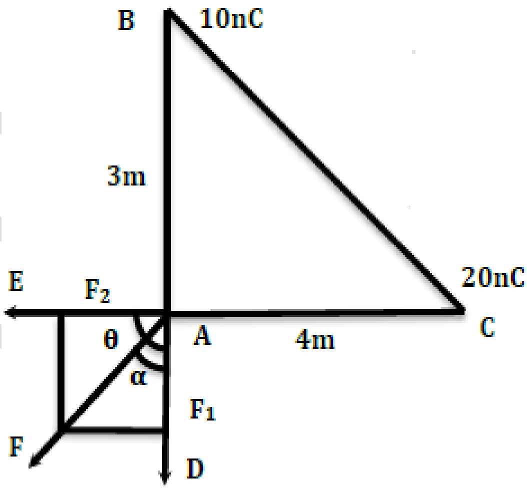
Ans: Force between two point charges, $F = \left(\frac{1}{4\pi\varepsilon_0}\right) \cdot \frac{q_1 q_1}{d^2}$ .....(1)

Force on 2nC due to 10nC;

$$\text{Eq (1)} \Rightarrow F_1 = \frac{9\times10^9 \times 2\times10^{-9} \times 10\times10^{-9}}{3^2} = 20 \times 10^{-9}\ \text{N along AD}$$

Force on 2nC due to 20nC;

$$\text{Eq (1)} \Rightarrow F_2 = \frac{9\times10^9 \times 2\times10^{-9} \times 20\times10^{-9}}{4^2} = 22.5 \times 10^{-9}\ \text{N along AE}$$



Magnitude of force on 2nC;

$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

Here $\theta = 90^0$

$$\therefore F = \sqrt{(20 \times 10^{-9})^2 + (22.5 \times 10^{-9})^2 + 0}$$

$$= 30.103 \times 10^{-9}\ \text{N along AF}$$

a) Direction of magnitude of force;

$$\tan\alpha = \left[\frac{F_2 \sin\theta}{F_1 + F_2\cos\theta}\right] = \frac{F_2}{F_1} \qquad [\text{Since } \theta = 90^0]$$

$$= \frac{22.5\times10^{-9}}{20\times10^{-9}}$$

$$\alpha = \tan^{-1}(1.125) = 48^0\ 22^1 \text{ with AD}$$

3. **Two charges 10nC and 20nC are placed at the corners of hypotenuse BC of a right angled triangle ABC of sides AB = 3m and AC = 4m. Find the direction of resultant electric intensity at corner 'A'**

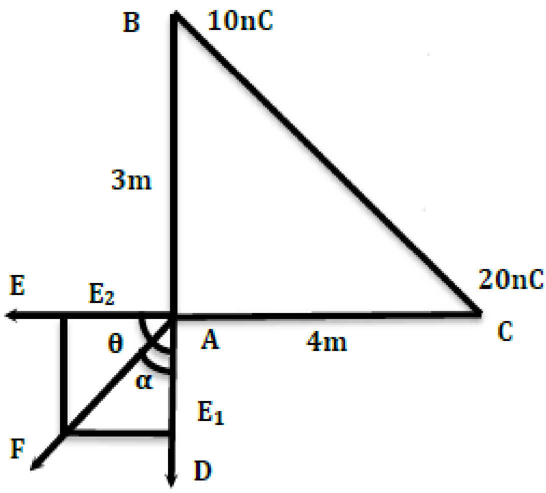
Ans: Electric field, $E = \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}$ .....(1)

Electric intensity at A due to 10nC;

$$\text{Eq (1)} \Rightarrow E_1 = \frac{9\times10^9\times10\times10^{-9}}{3^2} = 10\ \text{NC}^{-1}\ \text{along AD}$$

Electric intensity at A due to 20nC;

$$\text{Eq (1)} \Rightarrow E_2 = \frac{9\times10^9\times20\times10^{-9}}{4^2} = 11.25\ \text{NC}^{-1}\ \text{along AE}$$



Resultant electric intensity at A is

$$E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta} \qquad [\text{Here } \theta = 90^0]$$

$$= \sqrt{10^2 + 11.25^2}$$

$$E = \sqrt{226.6} = 15.05\ \text{NC}^{-1}\text{along AF}$$

Direction of resultant electric intensity;

$$\tan\alpha = \left[\frac{E_2\sin\theta}{E_1 + E_2\cos\theta}\right] = \left[\frac{E_2}{E_1}\right] = \left[\frac{11.25}{10}\right] = 1.125 \qquad [\because \theta = 90^0]$$

$\alpha = \tan^{-1}(1.125)$

$\alpha = 48^0\ 22^1$ with AD

4. Two charges +6nC and – 6nC are placed at 0.2m apart. Calculate

a) Dipole moment

b) Axial field at a distance of 0.2m from the center of dipole

c) Equatorial field at distance of 0.2m from the center of dipole

Ans: Given q = 6nC, 2a = 0.2m, x = 0.2m

a) Electric dipole moment, $p = q \times 2a = 6 \times 10^{-9} \times 0.2 = 1.2 \times 10^{-9}$Cm

b) Electric field; $E = \frac{1}{4\pi\varepsilon_0}\frac{2px}{(x^2-a^2)^2} = \frac{9\times10^9\times2\times1.2\times10^{-9}\times0.2}{(0.2^2-0.1^2)^2} = \frac{4.32}{0.03^2} = 4.8\times10^3\ NC^{-1}$

c) Electric field, $E = \frac{1}{4\pi\varepsilon_0}\frac{P}{(x^2+a^2)^{\frac{3}{2}}} = \frac{9\times10^9\times1.2\times10^{-9}}{(0.2^2+0.1^2)^{\frac{3}{2}}} = \frac{10.8}{0.0111} = 9.729\times10^2\ NC^{-1}$

5. Two point charges 1×10^{-8}C and 4×10^{-8}C are 0.06m apart in air. Find the location of the point between them at which resultant electric field is zero.

Ans: Electric field, $E = \frac{1}{4\pi\epsilon_0}\frac{q}{x^2}$........(1)

Let P be a point at a distance x from A where resultant electric field is zero.

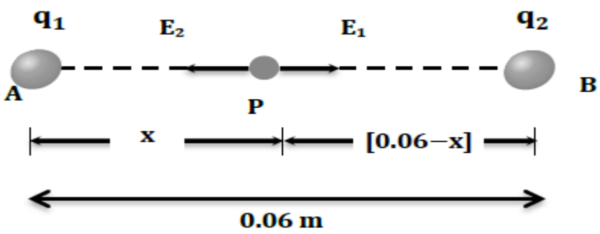
Electric intensity at a P due to 1×10^{-8}C is

Eq (1) $\Rightarrow$ $E_1 = \left[\frac{1}{4\pi\epsilon_0}\right]\times\frac{1\times10^{-8}}{x^2}$ along PB

Electric intensity at P due to 4×10^{-8}C is

Eq (1) $\Rightarrow$ $E_2 = \left[\frac{1}{4\pi\epsilon_0}\right]\times\frac{4\times10^{-8}}{(0.06-x)^2}$ along PA

At P, $E_1 = E_2$



$$\left[\frac{1}{4\pi\epsilon_0}\right]\frac{1\times10^{-8}}{x^2} = \left[\frac{1}{4\pi\epsilon_0}\right]\frac{4\times10^{-8}}{(0.06-x)^2}$$

$$\frac{(0.06-x)^2}{x^2} = \frac{4}{1}$$

$$\frac{0.06-x}{x} = \frac{2}{1}$$

$\therefore$ x = 0.02 m

Electric field is zero at a distance 0.02m from A

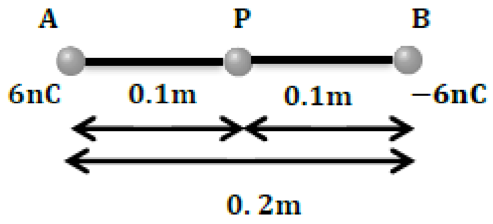
6. Two charges +6nC and – 6nC are placed at 0.2m apart. Calculate force experienced by the test charge of magnitude 1 nC when it is placed at midpoint on the line joining two charges.

Ans: Electric intensity, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$ ....(1)

Electric intensity at P due to 6nC,

Eq (1) $\Rightarrow$ $E_A = \frac{9\times10^9 \times 6\times10^{-9}}{0.1^2}$

$= 5.4\times10^3\ NC^{-1}$ along AP



Electric intensity at P due to −6nC;

Eq (1) $\Rightarrow$ $E_B = \frac{9\times10^9 \times 6\times10^{-8}}{0.1^2}$

$= 5.4\times10^3\ NC^{-1}$ along PB

Resultant electric field, $E = E_A + E_B = [5.4+5.4]10^3 = 10.8\times10^3\ NC^{-1}$ along PB

❖ If test charge, $q = 1\times10^{-9}\ C$ placed at the center, the force experienced by test charge is F = qE

$F = 1\times10^{-9}\times 10.8\times10^3 = 10.8\times10^{-6}$ N along PB

7. A uniformly charged conducting sphere of radius 1.2m has surface charge density of $80\times10^{-6} C/m^2$. Find a) Charge on the sphere, b) Electric field at a distance of 2m from the center of the sphere, c) Electric field at a distance of 1m from the center of the sphere and d) Total flux leaving the surface.

Ans: Given: $\sigma = 80\times10^{-6} C/m^2$ and r =1.2m

a) Charge on the sphere; $q = \sigma\times Area = 80\times10^{-6}\times4\pi r^2$

$= 80\times10^{-6}\times4\times3.14\times1.2^2$

$= 1.45\times10^{-3}C$

b) Electric field at x = 2m, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2} = \frac{9\times10^9\times1.45\times\times10^{-3}}{2^2} = 3.262\times10^6\ NC^{-1}$

c) Here x = 1m [x < r]

Electric field, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2} = 0$ [Since charge lies on the surface of the sphere]

d) Total flux; $\Phi = \frac{q}{\varepsilon_0} = \frac{1.45\times10^{-3}}{8.85\times10^{-12}} = 1.6\times10^8 Nm^2C^{-1}$

8. Two charges +6nC and – 6nC are placed at 0.2m apart. Calculate torque experience by the dipole when it is making an angle of 30^0 with electric field of strength $1.35\times10^3\ NC^{-1}$ and also calculate potential energy of dipole

Ans: Given q = 6nC, 2a = 0.2m, x = 0.2m

a) Electric dipole moment, $p = q\times2a = 6\times10^{-9}\times0.2 = 1.2\times10^{-9}Cm$

b) Torque, $\tau = pE\sin\theta = 1.2\times10^{-9}\times1.35\times10^3\times\sin30^0 = 0.81\times10^{-6}Nm$

c) Potential energy; $U = pE\cos\theta = 1.2\times10^{-9}\times1.35\times10^3\times\cos30^0 = 1.402\times10^{-6}J$

9. Two charges $3\times10^{-8}C$ and -2×10^{-8} C are located 15cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

Ans: Given: $q_1 = +3\times10^{-8}C$, $q_2 = -2\times10^{-8}C$, V = ?

Electric potential, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

a) The Resultant potential at point P between the charges is zero.

i.e., $V_1 + V_2 = 0$

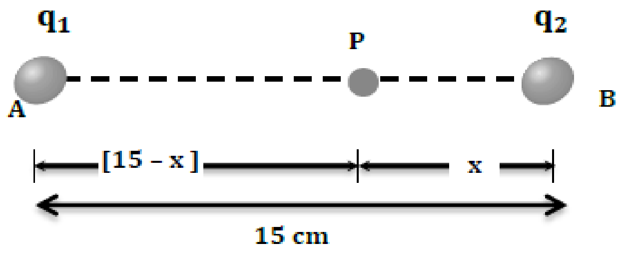
$\therefore \quad V_1 = -V_2$

$$\frac{1}{4\pi\varepsilon_0}\frac{3\times10^{-8}}{(15-x)} = \frac{1}{4\pi\varepsilon_0}\frac{2\times10^{-8}}{x}$$

$$\frac{3}{(15-x)} = \frac{2}{x}$$

$$30 - 2x = 3x$$

$$\therefore \quad x = 6 \text{ cm}$$



The electric potential is zero at a distance x = 6cm from -2×10^{-8}C.

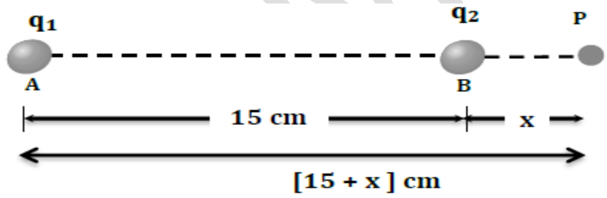
b) The resultant potential at point P beyond the charge

Here $\quad V_1 = -V_2$

$$\frac{3}{(15+x)} = \frac{2}{x}$$

$$3x = 30+2x$$

$$\therefore x = 30 \text{ cm}$$



The electric potential is zero at a distance x = 30cm from -2×10^{-8}C.

10. ABCD is a square of side 2m. Charges of +5nC, +10nC and −5nC are placed at corners A, B and C respectively. What is the work done in transferring a charge of 5μC from D to the point of intersection of the diagonals?

Ans: Given; $\quad q_A = 5\text{nC},\ q_B = 10\text{nC},\ q_C = -5\text{nC}$

Each side of square is 2m (i.e, AB = BC = CD = DA = 2m)

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

From figure, $AC = 2\sqrt{2}$ m = BD

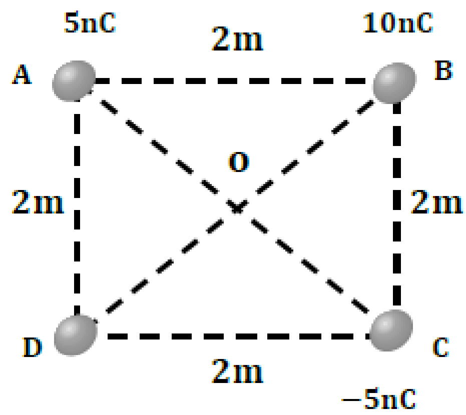
And $OA = OB = OC = OD = \sqrt{2}$m

Electric potential at D,

$$V_D = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_A}{AD} + \frac{q_B}{DB} + \frac{q_C}{DC}\right)$$

$$V_D = 9\times10^9\left(\frac{5\times10^{-9}}{2} + \frac{10\times10^{-9}}{2\sqrt{2}} - \frac{5\times10^{-9}}{2}\right)$$

$$V_D = \frac{90}{2\sqrt{2}} \text{ V}$$



Electric potential at O, $\quad V_O = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_A}{OD} + \frac{q_B}{OB} + \frac{q_C}{OC}\right)$

$$V_O = 9\times10^9\left(\frac{5\times10^{-9}}{\sqrt{2}} + \frac{10\times10^{-9}}{\sqrt{2}} - \frac{5\times10^{-9}}{\sqrt{2}}\right)$$

$$V_O = \frac{90}{\sqrt{2}} \text{ V}$$

Potential difference, $V = V_O - V_D = \frac{90}{\sqrt{2}} - \frac{90}{2\sqrt{2}} = \frac{90}{2\sqrt{2}} = \frac{45}{\sqrt{2}} = 31.8246$ V

Work (W) = Potential difference $\times$ (5μC Charge transferred from D to O)

$W = 31.8246 \times 5 \times 10^{-6}$

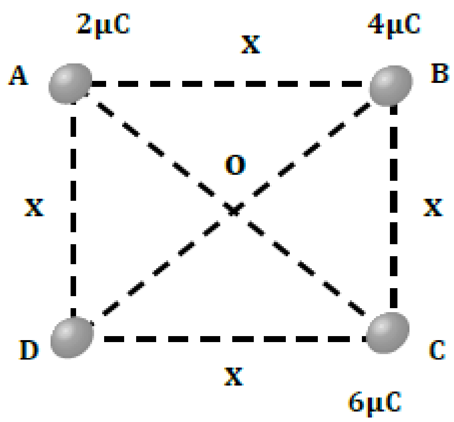
$W = 159.123 \times 10^{-6}$ J

11. Charges 2μC, 4 μC and 6μC are placed at the three corners A, B and C respectively of a square ABCD of side 'x' meter. Find what charge must place at the fourth corner so that the total potential at the center of the square is zero.

Ans: Given $q_A = 2\mu C$, $q_B = 4\mu C$, $q_C = 6\mu C$, $q_D = ?$

Each side of square is 'x' m (i.e, AB = BC = CD= DA= 'x' m)

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



From figure, $AC = x\sqrt{2}$ m = BD

And $OA = OB = OC = OD = x\frac{\sqrt{2}}{2}$ m

Electric potential at 0,

$$V_0 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_A}{OA} + \frac{q_B}{OB} + \frac{q_C}{OC} + \frac{q_D}{OD}\right)$$

$$0 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_A}{OA} + \frac{q_B}{OB} + \frac{q_C}{OC} + \frac{q_D}{OD}\right) \quad [\text{Since } V_0 = 0]$$

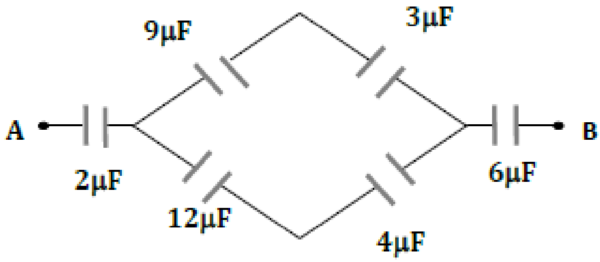
$$(\text{Or})\ \frac{1}{4\pi\varepsilon_0}\frac{1}{AO}(2\mu C + 4\mu C + 6\mu C + q_D) = 0$$

$$12\mu C + q_D = 0$$

$$q_D = -12\ \mu C$$

12. Calculate the effective capacitance between the points A and B shown in figure

Ans: Here 9μF and 3μF are in series.



Effective capacitance, $C_s = \frac{c_1 c_2}{c_1 + c_2} = \frac{9 \times 3}{9+3} = 2.25$ μF

12μF and 4μF are in series.

Effective capacitance, $C_s = \frac{c_1 c_2}{c_1 + c_2} = \frac{12 \times 4}{12+4} = 3$ μF

2.25μF and 3μF are parallel to each other

Effective capacitance, $C_p = C_1 + C_2 = 2.25 + 3 = 5.25$ μF

2 μF, 5.25 μF and 6 μF are in series,

We have $\frac{1}{C_{eff}} = \frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3} = \frac{1}{2} + \frac{1}{5.25} + \frac{1}{6}$

$\therefore C_{eff} = 1.168$ μF

13. Two capacitors of capacitance 600 pF and 900 pF are connected in series across a 200 V supply. Calculate (i) the effective capacitance of the combination, (ii) the total charge stored in the system and (iii) the p.d across each capacitor

Ans: Given, $C_1 = 600$ pF, $C_2 = 900$ pF, V = 200 V.

a) The effective capacitance is given by

$$C_S = \frac{C_1 C_2}{C_1 + C_2} = \frac{600 \times 900}{600+900}$$

$= 360$ pF

b) The total charge stored in the system is

$$q = C_S V = 360 \times 10^{-12} \times 200 = 72 \times 10^{-9}\ C$$

c) Potential difference across C_1 is, $V_1 = \frac{q}{C_1} = \frac{72 \times 10^{-9}}{600 \times 10^{-12}} = 120$ V

Potential difference across C_2 is, $V_2 = \frac{q}{C_2} = \frac{72 \times 10^{-9}}{900 \times 10^{-12}} = 80$ V

14. Two condensers of capacity 5 μF and 10 μF are charged to 16V and 13 V respectively. When they are connected in parallel, calculate

a] Charge on each condenser

b] Total charge of the combination

c] Effective capacitance [or] total capacitance

d] Common potential difference

Ans: a] Charge on 5 μF capacitor, $q_1 = C_1 V_1 = 5 \times 16 = 80\mu C = 80 \times 10^{-6} C$

Charge on 10μF capacitor, $q_2 = C_2 V_2 = 10 \times 13 = 130\mu C = 130 \times 10^{-6} C$

b] Total charge; $q = q_1 + q_2 = 80 + 130 = 210\mu C = 210 \times 10^{-6} C$

c] Effective capacitance; $C_p = C_1 + C_2 = 5 + 10 = 15\mu F = 15 \times 10^{-6} F$

d] Common potential difference; $V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{210\times10^{-6}}{15\times10^{-6}} = 14V$

15. In a parallel plate capacitor with air between the plates, each plate has an area 8×10^{-3} m^2 and distance between the plates is 2mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 50V supply, what is the charge on each plate of the capacitor?

(Given: Absolute permittivity of free space = $8.85 \times 10F^{-12}$ Fm^{-1})

Ans: Given $A = 8 \times 10^{-3} m^2$, $d = 2 \times 10^{-3} m$, V = 50 volt, c = ? and q = ?

Capacitance of parallel capacitor, $C = \frac{\varepsilon_0 A}{d} = \frac{(8.85 \times 10^{-12})(8 \times 10^{-3})}{2 \times 10^{-3}}$

$$C = 35.4 \times 10^{-12}\ F$$

Charge on each plate of capacitor, $q = CV = 35.4 \times 10^{-12} \times 50$

$$q = 1.77 \times 10^{-9}\ C$$

16. Energy stored in a system of two capacitors in series and connected across 1kV line is 2J. When the same two capacitors are in parallel across the same line, energy stored is 9J. Find the capacitance of the capacitors.

Ans: Let C_1 and C_2 be the capacities of two capacitors.

For parallel combination, Energy stored,

$E = ½\ C_p V^2$

$9 = \frac{1}{2} \times C_p \times [10^3]^2$

$\therefore C_p = 18 \times 10^{-6}$ F

$C_1 + C_2 = 18 \times 10^{-6}$ ....(1)

For series combination, Energy stored,

$E = \frac{1}{2} C_s V^2$

$2 = \frac{1}{2} \times C_s \times 10^6$

$\therefore C_s = 4 \times 10^{-6}$F

$\frac{C_1 C_2}{C_1 + C_2} = 4 \times 10^{-6}$

$C_1 C_2 = 4 \times 10^{-6} \times (C_1 + C_2)$

$= 4 \times 10^{-6} \times 18 \times 10^{-6}$

$= 72 \times 10^{-12}$

We have $(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4 C_1 C_2$

$= (18 \times 10^{-6})^2 - (4 \times 72 \times 10^{-12})$

$= (324 - 288)\, 10^{-12}$

$(C_1 - C_2)^2 = 36 \times 12$

$C_1 - C_2 = 6 \times 10^{-12}$............(2)

Add equ (1) and equ (2), we get

$C_1 + C_2 = 18 \times 10^{-6}$

$C_1 - C_2 = 6 \times 10^{-6}$

$2C_1 = 24 \times 10^{-6}$

$\therefore C_1 = 12 \times 10^{-6}$F and

$C_2 = 6 \times 10^{-6}$F from equ (1) or equ(2)

17. A 400 pF capacitor charged by a 100 V dc supply is disconnected from the supply and connected to another uncharged 400pF capacitor, calculate the loss of energy.

Ans: Case – 1;

Initial energy, $E_1 = \frac{1}{2} C_1 V^2 = \frac{1}{2} \times 400 \times 10^{-12} \times 100^2 = 2 \times 10^{-6}$ J

Charge on C_1 / Total charge on C_1, $Q = C_1 V = 400 \times 10^{-12} \times 100 = 4 \times 10^{-8}$ C

Case – 2;

When both the capacitors are connected together, both attain same potential

$V_{Common} = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{4 \times 10^{-8}}{(400+400)10^{-12}} = 50$ V

Final energy, $E_2 = \frac{1}{2} C_p V^2_{Common} = \frac{1}{2} (400 + 400) 10^{-12} \times 50^2 = 1 \times 10^{-6}$ J

Loss of energy, $\Delta E = E_1 - E_2 = (2 - 1)\, 10^{-6} = 1 \times 10^{-6}$ J

LIST OF IMPORTANT FORMULAE

1. Steady current, $I = \frac{q}{t}$
2. Potential difference across the conductor, $V = IR$ [Ohms 's law]
3. Resistance, $R = \frac{\rho L}{A}$
4. Conductance, $G = \frac{1}{R}$
5. Resistivity of material, $\rho = \frac{RA}{L}$
6. Conductivity, $\sigma = \frac{1}{\rho}$
7. Drift velocity, $v_d = \frac{eE\tau}{m}$
8. Mobility, $\mu = \frac{v_d}{E}$
9. Electric current in terms of drift velocity, $I = nAeV_d$
10. Current density, $J = \frac{I}{A}$
11. Current density in terms of conductivity and EF, $J = \sigma E$
12. Conductivity of a conductor, $\sigma = \frac{ne^2\tau}{m}$
13. Electrical energy; $Q = VIt$
14. Electrical power, $P = VI = I^2R = \frac{V^2}{R}$
15. Combination of resistors
    - For series combination; $R_s = R_1 + R_2 + R_3 + \cdots \ldots$
    - For parallel combination; $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \ldots \ldots$
16. Branch currents:

    Current through R_1, $I_1 = \frac{IR_2}{R_1 + R_2}$

    Current through R_2, $I_2 = \frac{IR_1}{R_1 + R_2}$
17. Current in the circuit; $I = \frac{E}{R+r}$
18. Terminal potential difference across R, $V = IR = \left(\frac{E}{R+r}\right)R = \frac{ER}{R+r}$
19. Cells in series:
    - Equivalent emf, $E_{eq} = E_1 + E_2$
    - Equivalent internal resistance, $r_{eq} = r_1 + r_2$
20. Cells in parallel:
    - Equivalent emf, $E_{eq} = \left(\frac{E_1r_2 + E_2r_1}{r_1 + r_2}\right)$

- Equivalent internal resistance, $r_{eq} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$

21. The condition for balancing of Wheat stone's network; $\frac{P}{Q} = \frac{R}{S}$
22. Force on a charge in a magnetic field, $F = qvB \sin\theta$
23. Force on a current carrying wire in a magnetic field, $F = BIL \sin\theta$
24. Charge moving in circular path
    a) Speed of particle, $v = \frac{qBr}{m}$
    b) Frequency of rotation, $f = \frac{v}{2\pi r}$
    c) Time period, $T = \frac{1}{f}$
    d) Angular frequency, $\omega = 2\pi f = 2\pi\left[\frac{v}{2\pi r}\right] = \frac{v}{r}$
25. Magnetic field at a point 'P' from the centre of coil, $B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\pi n I a^2}{(a^2 + x^2)^{3/2}}$
26. Magnetic field at the centre of coil; $B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\pi n I}{a} = \frac{\mu_0 n I}{2a}$
27. If B_1 and B_2 are two fields acting at a point at an angle θ , then
    Resultant field, $B = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos\theta}$
28. Magnetic field, $B = \frac{\mu_0}{2\pi}\frac{I}{r}$ [Ampere's circuital law]
29. Magnetic field
    a] At a point on the axis of a long solenoid; $B = \mu_o n I$
    b] Magnetic field inside the air core toroid; $B = \mu_o n I$
    Where $n = \frac{N}{L}$; Number of turns per unit length
30. Force between the two conductors carrying current, $F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 l}{d}$
31. Torque, $\tau = mB \sin\theta$
32. Dipole moment; $m = nIA$
33. In G into V: High resistance, $R = \frac{V}{I_g} - G$
34. In G into A: Low resistance $S = \frac{I_g G}{I - I_g}$

MOST IMPORTANT PROBLEMS

1. **100mg mass of Nichrome metal is drawn into a wire of area of cross section 0.05mm² carries current of 2A. Calculate a] Length of wire, b] Resistance of wire, c]Drift velocity of electrons and d]Time taken by the electron to drift from one end to another end of wire [Given: Density of Nichrome 8.4×10^3 kgm^{-3} and the resistivity of the material is $1.2 \times 10^{-6}\,\Omega$m, number of free electrons per m^3, $n = 8 \times 10^{28}$ and Charge on an electron, $e = 1.6 \times l10^{-19}$C]**

   Ans: Here m =100mg $= 10^{-4}$ kg and A = 0.05mm² $= 5 \times 10^{-8}$ m^2

   a) Length; $L = \frac{\text{Mass}}{\text{Density} \times \text{Area}} = \frac{10^{-4}}{8.4 \times 10^3 \times 5 \times 10^{-8}} = 0.238$ m

   b) Resistance, $R = \rho\frac{L}{A} = \frac{1.2 \times 10^{-6} \times 0.238}{5 \times 10^{-8}} = 5.712\ \Omega$

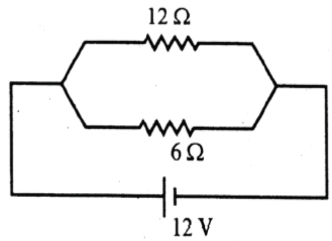
c) Drift velocity, $V_d = \frac{I}{neA} = \frac{2}{8\times10^{28}\times1.6\times10^{-19}\times5\times10^{-8}} = 3.125\times10^{-3}\ ms^{-1}$

d) Time, $t = \frac{Distance}{Velocity} = \frac{0.238}{3.125\times10^{-3}} = 76.16\ s$

2. A network of resistors is connected to a 12V battery as shown in the figure

(a) Calculate the equivalent resistance of the network

(b) Obtain current in 12Ω and 6Ω resistors.



Ans: Given: $V = 12\ V$, $R_1 = 12\Omega$, $R_2 = 6\ \Omega$

Effective resistance, $R_P = \frac{R_1R_2}{R_1+R_2} = \frac{12\times6}{18} = 4\ \Omega$

Current through 12Ω, $I_1 = \frac{V}{R_1} = \frac{12}{12} = 1\ A$

Current through 6Ω, $I_2 = \frac{V}{R_2} = \frac{12}{6} = 2\ A$

3. Three resistors 1Ω, 2Ω and 3Ω are connected in series, what is the total resistor of the combination? If the combination is connected to a battery of emf 12 V and negligible internal resistance then obtain the potential drop across each resistor.

Ans: Effective resistance, $R_S = R_1 + R_2 + R_3 = 1 + 2 + 3 = 6\ \Omega$

Current, $I = \frac{E}{R_s + r} = \frac{12}{6+0} = 2\ A$

Potential drop across 1Ω, $V = IR_1 = 2\times1 = 2\ V$

Potential drop across 2Ω, $V = IR_2 = 2\times2 = 4\ V$

Potential drop across 3Ω, $V = IR_3 = 2\times3 = 6\ V$

4. Two resistors are connected in series with 5V battery of negligible internal resistance. A current of 2A flows through each resistor. If they are connected in parallel with the same battery a current of $\frac{25}{3}A$ flows through combination. Calculate the value of each resistance.

Ans: Current, $I = \frac{E}{R+r}$

For series combination, $I = \frac{E}{R_s+r} = \frac{E}{R_s+0}$

$R_S = \frac{E}{I} = \frac{5}{2}$

$R_1 + R_2 = 2.5\ \Omega$ .... (1)

For parallel combination, $R_P = \frac{E}{I} = \frac{5}{25/3}$

$\frac{R_1R_2}{R_1+R_2} = \frac{15}{25}\Omega$

$\frac{R_1R_2}{2.5} = \frac{3}{5}\Omega$

$R_1R_2 = 1.5$ ....(2)

But $(R_1 - R_2)^2 = (R_1 + R_2)^2 - 4R_1R_2$

From (1) and (2), $(R_1 - R_2)^2 = 6.25 - 6 = 0.25\ \Omega$

$R_1 - R_2 = 0.5\ \Omega$...... (3)

Equation (1) + (3) we get, $R_1 = 1.5\ \Omega$

Using equation (1) or (3) we get $R_2 = 1\ \Omega$.

5. **Two cells of emf 2V and 4V and internal resistance 1Ω and 2 Ω respectively are connected in parallel so as to send the current in the same direction through an external resistance of 10Ω. Find the potential difference across the 10Ω resistance.**

Ans: Equivalent emf, $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{2 \times 2 + 4 \times 1}{1+2} = 2.666\ V$

Equivalent internal resistance, $r_{eq} = \frac{r_1\, r_2}{r_1 + r_2} = \frac{1 \times 2}{1+2} = 0.666\ \Omega$

Potential difference across 10 Ω, $V = \frac{E_{eq}\ R}{R + r_{eq}} = \frac{2.666 \times 10}{10 + 0.666} = 2.5\ V$

6. **Two identical cells either in series or parallel in combination give the same current of 0.5A through an external resistance of 4Ω. Find the emf and internal resistance of each cell.**

Ans: Given $R = 4\ \Omega$, $I = 0.5A$, $r_1 = r_2 = r = ?$ and $E_1 = E_2 = E = ?$

For series combination [For two identical cells], $E_{eq} = 2E$ and $r_{eq} = 2r$

For parallel combination [For two identical cells], , $E_{eq} = E$ and $r_{eq} = \frac{r}{2}$

Current, $I = \frac{E_{eq}}{R + r_{eq}}$

$\therefore$ For parallel combination, $0.5 = \frac{E}{R + r/2} = \frac{2E}{2R + r}$....... (1)

For series combination, $0.5 = \frac{2E}{R+2r}$ .... (2)

From equation (1) and (2), $\frac{2E}{R+2r} = \frac{2E}{2R+r}$

$R + 2r = 2R + r$

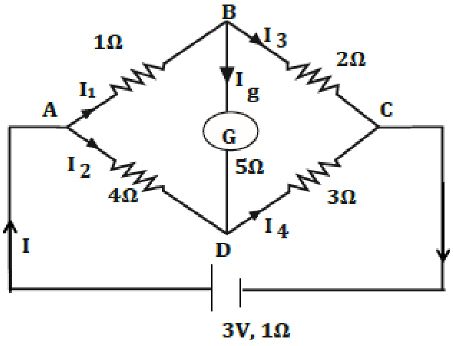
$\therefore\ r = R$

$r = 4\ \Omega$ (Given)

Consider equ [2]; we get $0.5 = \frac{2E}{4 + [2 \times 4]}$

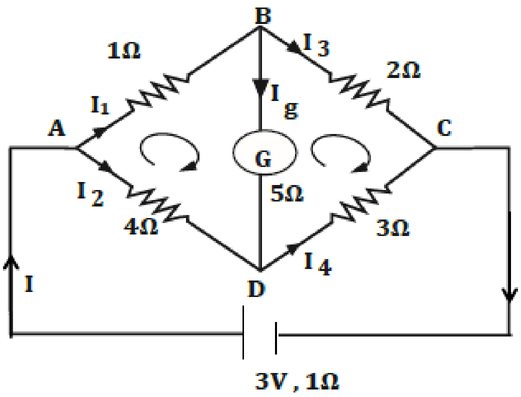
$\therefore E = 3\ V$

7. **In the given circuit, calculate the current I_g through the galvanometer.**



Ans: Apply KVL to the loop ABDA;

$-I_1 - 5I_g + 4I_2 = 0$ .....(1)



Apply KVL to the loop BCDB;

$-2I_3 + 3I_4 + 5I_g = 0$

$-2(I_1 - I_g) + 3(I_2 + I_g) + 5I_g = 0$

$-2I_1 + 10I_g + 3I_2 = 0$ .....(2)

Apply KVL to the loop ADCA;

$-4I_2 - 3I_4 - 1I + 3 = 0$

$-4I_2 - 3(I_2 + I_g) - 1(I_1 + I_2) + 3 = 0$

$-I_1 - 8I_2 - 3I_g = -3$

$I_1 + 8I_2 + 3I_g = 3$.......(3)

Eq (1) × 2 ⟹ $-2I_1 - 10I_g + 8I_2 = 0$.....(4)

Eq (4) − eq (2), we get

$-20I_g + 5I_2 = 0$

$I_2 = 4I_g$ ....(5)

Substitute Eq (5) in eq (1), we get

$-I_1 + 11I_g = 0$

$I_1 = 11I_g$ ....(6)

Substitute Eq (5) and eq (6) in Eq (3), we get

$11I_g + 32I_g + 3I_g = 3$

$46I_g = 3$

$\therefore I_g = 0.0652A$

8. A straight wire of length π/2 is bent into a circular shape. 'O' is the center of the circle formed and P is a point on its axis which is at a distance 3 times the radius from O. A current of 1 A is passed through it. Calculate the magnitude of the magnetic field at the points O and P.

Ans: Given: $I = 1A$, $n = 1$, $x = 3a$, $C = \frac{\pi}{2}$

Circumference of circular path, $2\pi a = \frac{\pi}{2}$

∴ Radius of the loop, $a = 0.25$ m

Magnetic field at the centre 'O' of the current loop is

$$B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\pi n I}{a} = \frac{10^{-7} \times 2 \times 3.14 \times 1 \times 1}{0.25} = 2.5 \times 10^{-6}\ T$$

Magnetic field at a point 'P' on the axis of a current loop is

$$B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\pi n Ia^2}{(a^2 + x^2)^{3/2}} = \frac{10^{-7} \times 2 \times 3.14 \times 1 \times 1 \times (0.25)^2}{[(0.25)^2 + (0.75)^2]^{\frac{3}{2}}} = 0.079 \times 10^{-6}\ T$$

9. A and B are two identical coils each of diameter 0.314m having 10 turns each. They are placed concentrically with their planes at right angles to each other. A current of 1A flows through each coil. Calculate the resultant magnetic field at their common centre.

Ans: Diameter, d = 0.314. ∴ Radius, $a = \frac{d}{2} = 0.157\text{m}$

Magnetic field at the centre of each coil;

$$B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\pi n I}{a}$$

$$= \frac{10^{-7} \times 2 \times 3.14 \times 10 \times 1}{0.157}$$

$$B = 4 \times 10^{-5}\ \text{T}$$

Resultant field, $B = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos\theta}$

Here $\theta = 90^0$ and $B_1 = B_2$

$\therefore B = \sqrt{2B_1^2} = \sqrt{2}\ B_1 = 1.414 \times 4 \times 10^{-5}$

$B = 5.656 \times 10^{-5}$ T

10. Two long and parallel straight wires 'A' and 'B' carrying currents of 8A and 5A in the same direction are separated by a distance of 4cm. Estimate the force on a) wire 'A' of section 10cm and b) wire 'B' of section 10cm. What is the nature of force between two wires?

Ans: Force experienced by the conductor; $F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 l}{d}$

∴ a) Force on wire 'A'; $F_a = \frac{2\times10^{-7}\times 8 \times 5 \times 10\times10^{-2}}{4\times10^{-2}} = 200\times10^{-7} = 2\times10^{-5}\text{N}$

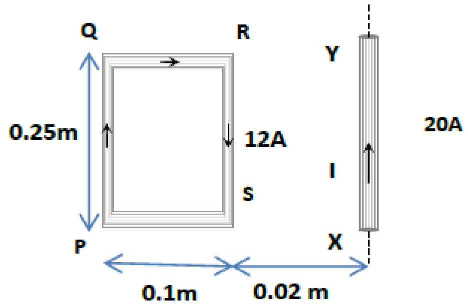
b) Force on wire 'B'; $F_b = \frac{2\times10^{-7}\times 8 \times 5 \times 10\times10^{-2}}{4\times10^{-2}} = 200\times10^{-7} = 2\times10^{-5}\text{N}$

- Force between the two wires 'A' and 'B' is attractive.

11. A rectangular coil of sides 0.25m and 0.1m carrying current 12A is placed with its longer side parallel to a long straight conductor 0.02m apart carrying a current of 20A. Calculate the net force on the current loop.

Ans: Force experienced by the conductor; $F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 l}{d}$ .....(1)

∴ Force experienced by the conductor PQ;



Equ (1) ⟹ $F_1 = \frac{2\times10^{-7}\times 12 \times 20\times 0.25}{12\times10^{-2}}$

$= 1 \times 10^{-4}\text{N}$ [Attractive]

Force experienced by the conductor RS;

Equ (1) ⟹ $F_2 = \frac{2\times10^{-7}\times 12 \times 20\times 0.25}{2\times10^{-2}}$

$= 6 \times 10^{-4}\text{N}$ [Repulsive]

Net force on the loop PQRS;

$F = F_2 - F_1 = [6 - 1]10^{-4} = 5 \times 10^{-4}$ N [Repulsive]

The net force is directed away from long straight conductor XY.

12. An α-particle is describing a circle of radius 0.45m in a magnetic field of 1.2T. Calculate its speed, frequency of rotation, time period and angular frequency

Given: Mass of α-particle = 6.8×10^{-27}kg.

Charge of α-particle = 3.2×10^{-19}C.

Ans: Given: r = 0.45m, B = 1.2T, m = 6.8×10^{-27}kg, q = 3.2×10^{-19}C

Speed, $v = \frac{qBr}{m} = \frac{3.2 \times 10^{-19} \times 1.2 \times 0.45}{6.8 \times 10^{-27}} = 2.6 \times 10^{7}$ ms^{-1}

Frequency of rotation, $f = \frac{v}{2\pi r} = \frac{2.6 \times 10^{7}}{2 \times 3.14 \times 0.45} = 9.2 \times 10^{6}$ Hz

Time period; $T = \frac{1}{f} = \frac{1}{9.2 \times 10^{6}} = 0.1086 \times 10^{-6}$ s

Angular frequency; $\omega = 2\pi f = 2 \times 3.14 \times 9.2 \times 10^{6} = 57.776 \times 10^{6}$ rads^{-1}

13. A square coil of side 10 cm consists of 20 turns and carries a current of 12A. The coil is suspended vertically and normal to the plane of the coil makes an angle of 30^0 with the direction of a uniform horizontal magnetic field of magnitude 0.81T. Calculate dipole moment and the magnitude of torque experienced by the coil?

Ans: Given: N = 20, I = 12A, A = 0.1×0.1=0.01 m^2 and B = 0.81T

Dipole moment; M = NIA = $20 \times 12 \times 0.01$ = 2.4 Am^2

Torque, $\tau = MB \sin\theta = 2.4 \times 0.81 \times \sin 30^0$

$= 1.944 \times 0.5 = 0.972$ Nm

QUESTION NUMBER: 47 EMI AND ALTERNATING CURRENT

LIST OF IMPORTANT FORMULAE

1. Angular speed $\omega = 2\pi f$
2. Emf, $|e| = \frac{d\phi}{dt}$
3. Motional emf, $e = Blv$
4. Emf, $e = Blv \sin\theta$
5. Emf, $|e| = L\frac{dI}{dt}$
6. Self-inductance, $L = \frac{|e|\, dt}{dI}$
7. The maximum induced emf, $e_0 = nBA\omega$
8. Instantaneous value of emf, $e = e_0 \sin\omega t$

9. Maximum current, $I = \frac{e_0}{R}$

10. Instantaneous value of AC

    - Instantaneous voltage, $V = V_0 \sin \omega t$
    - Instantaneous current, $I = I_0 \sin\omega t$

11. Mean value of AC

    - $V_m = \left(\frac{2}{\pi}\right)$ times to peak value = $\frac{2V_0}{\pi}$
    - $I_m = \left(\frac{2}{\pi}\right)$ times to peak value = $\frac{2I_0}{\pi}$

12. Root mean square value of a AC

    - $V_{rms} = \frac{V_0}{\sqrt{2}}$
    - $I_{rms} = \frac{I_0}{\sqrt{2}}$

13. Inductive reactance, $X_L = \omega L = 2\pi f L$

14. Capacitive Reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

15. Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

16. Current in series LCR circuit, $I = \frac{V}{Z}$

17. Phase angle between V and I, $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

18. Time lag between voltage and current, $t = \frac{\Phi}{\omega}$

19. Angular resonant frequency, $\omega_0 = \frac{1}{\sqrt{LC}}$

20. Resonant frequency, $f_0 = \frac{1}{2\pi\sqrt{LC}}$

21. Power factor, $\cos \phi = \frac{R}{Z}$

22. Power in an AC circuit, $P = V_{rms} \, I_{rms} \cos \phi$

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1. A square coil of 10cm side and with 60 turns is rotated at a uniform speed of 500rpm about an axis at right angles to a uniform field of 0.5T. Calculate the maximum emf developed in the coil. Find the instantaneous value of emf, when the plane of the coil makes an angle of 30^0 with the magnetic field.

Ans: Given: $l = 10$ cm, $n = 60$, $f = 500$ rpm $= \left(\frac{500}{60}\right)$ rps, $B = 0.5$ T

Area of the coil $A = l^2 = (10 \times 10^{-2})^2 \text{ m}^2 = 10^{-2} \text{ m}^2$

Angular speed $\omega = 2\pi f = 2\pi\left(\frac{500}{60}\right) \text{ rad s}^{-1}$

The maximum induced emf is given by

$$e_0 = nBA\,\omega$$

$= 60 \times 0.5 \times 10^{-2} \times 2\pi \left(\frac{500}{60}\right)$

$e_0 = 15.7$ V

The plane of the coil makes an angle of 30° with the magnetic field,

Then θ = 90° – 30° = 60° or ωt = 60°

Instantaneous value of emf, $e = e_0 \sin\omega t$

$= 15.7 \times \sin 60°$

$= 15.7 \times 0.866$

e = 13.6 V

2. **A circular coil of radius 10cm and 25 turns is rotated about its vertical diameter with angular speed of 40radian per second in a uniform horizontal magnetic field of magnitude 5×10^{-2}T. Calculate the maximum emf induced in the coil. Also find the maximum current in the coil if the resistance of the coil is 15Ω.**

Given; r = 0.1m, n =25, ω =40 rad/s, $B = 5 \times 10^{-2}$T, e_0=?

Maximum induced emf, $e_0 = nBA\,\omega = nB\pi r^2\omega$

$= 25 \times 5 \times 10^{-2} \times 3.14 \times (0.1)^2 \times 40$

= 1.57 V

Maximum current, $I = \frac{e_0}{R} = \frac{1.57}{15}$

I = 0.1047 A

3. **A conductor of length 3m moving in a uniform magnetic field of strength 100T. It covers a distance of 70m in 5 Sec. Its plane of motion makes an angle of 30^0 with direction of magnetic field. Calculate the emf induced in it.**

Ans: Given: l = 3 m, B =100 T, d = 70m, t = 5 s and θ = 30^0

Emf, $e = BlV \sin\theta = B\,l\left[\frac{d}{t}\right]\sin\theta$

$= 100 \times 3 \times \left[\frac{70}{5}\right] \sin 30^0$

$= 300 \times 14 \times 0.5$

e = 2100 V

4. **An AC is given by the expression I = 200 sin(314 *t*). Where 'I' and 't' are in SI units. Calculate maximum current (peak value), rms value, mean value, frequency and time period of AC.**

Ans: We have, Alternating current, I = 200 sin(314 t)....(1)

It is of the form of $I = I_0 \sin(\omega t)$..........(2)

Compare equ (1) and equ (2), we get

1) Peak value, I_0 = 200 A

2) $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{200}{1.414} = 141.442$ A

3) $I_{mean} = \frac{2}{\pi}$ (peak value) $= \frac{2}{3.14}(200) = 127.388$ A

4) Frequency, $f = \frac{\omega}{2\pi} = \frac{314}{2 \times 3.14} = 50$ Hz

5) Time period, $T = \frac{1}{f} = \frac{1}{50} = 0.02$ s

5. **A resistance of 50Ω, an inductance of 10mH and a capacitance 20μF are connected in series to a 220V, 50Hz AC source. Calculate the current in the circuit and the power factor.**

Ans: Given $R = 50\Omega$, $L = 10 \times 10^{-3}$ H, $C = 20 \times 10^{-6}$F, V_{rms}=220V, f = 50Hz

1) Inductive reactance, $X_L = 2\pi fL = 2 \times 3.14 \times 50 \times 10 \times 10^{-3} = 3.14\ \Omega$

2) Capacitive reactance, $X_C = \frac{1}{2\pi fC} = \frac{1}{2 \times 3.14 \times 50 \times 20 \times 10^{-6}} = 159.1\ \Omega$

3) Impedence, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(50)^2 + (159.1 - 3.14)^2} = 163.8\ \Omega$

4) Current, $I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{163.8} = 1.343$ A

5) Power factor, $\cos\Phi = \frac{R}{Z} = \frac{50}{163.8} = 0.3053$

6. **An ac source of 250v, 50Hz is connected to a circuit consisting of an electric lamp rated 100W, 50V and capacitor in series. What should be the capacity of the capacitor to work the lamp with rated value?**

Ans: Current, $I = \frac{P}{V} = \frac{100}{50} = 2$ A.

Resistance of the bulb, $R = \frac{V}{I} = \frac{50}{2} = 25\ \Omega$.

Impedance, $Z = \frac{V_{rms}}{I_{rms}} = \frac{250}{2} = 125\ \Omega$

Impedance, $Z = \sqrt{R^2 + X_c^2}$

$X_c = \sqrt{Z^2 - R^2}$

$\frac{1}{2\pi fC} = \sqrt{Z^2 - R^2}$

$\therefore C = \frac{1}{2\pi f\sqrt{Z^2 - R^2}}$

$C = \frac{1}{2 \times 3.142 \times 50\sqrt{125^2 - 25^2}}$

$C = 26\ \mu F$

7. **A source of alternating emf of frequency 50Hz is connected in series with a resistance of 200Ω, an inductance of 0.1H and a capacitance of 30μF. Calculate the phase angle and time lag between voltage and current.**

Ans: Inductive reactance, $X_L = 2\pi fL = 2 \times 3.142 \times 50 \times 0.1 = 31.42\ \Omega$

Capacitive reactance, $X_C = \frac{1}{2\pi fC} = \frac{1}{2 \times 3.142 \times 50 \times 30 \times 10^{-6}} = 106.1\ \Omega$

Since $X_C > X_L$, Current leads the voltage.

Phase angle, $\Phi = \tan^{-1}\left[\frac{X_L - X_C}{R}\right] = \tan^{-1}\left[\frac{31.42-106.1}{200}\right] = \tan^{-1}(-0.3734)$

$$\Phi = -20^0 29^1$$

$$\text{(or)} \;\; \Phi = 20^0 29^1$$

Therefore current leads the voltage by $20^0 29^1$.

Time lag, $t = \frac{\Phi}{\omega} = \frac{20^0 29^1}{2\pi f} = \frac{20.48^0}{2\,\pi\,x\,50} = \frac{20.48^0}{100\pi} \times \frac{\pi}{180}$

$$t = 1.137 \times 10^{-3}\,s$$

8. **A series LCR circuit with R = 20Ω, L=1.5H and C=35µF is connected to a variable frequency of 200V AC supply when the frequency of the supply is equal to the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?**

Ans: At resonance, Impedance, $Z = R = 20\ \Omega$

Current, $I = \frac{V}{Z} = \frac{200}{20} = 10\ A$

Power, $P = VI = 200 \times 10 = 2000\ W$

9. **Calculate the angular resonant frequency and resonant frequency of a series LCR circuit with an inductance 4H, capacitance of 64µF and resistance of 20Ω.**

Ans: Angular resonant frequency, $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4 \times 64 \times 10^{-6}}} = 62.5\ rad/s$

Resonant frequency, $f_0 = \frac{\omega_0}{2\pi} = \frac{62.5}{2\times 3.14} = 9.952Hz$

Note: Resonant frequency, $f_0 = \frac{1}{2\pi\sqrt{LC}}$ or $f_0 = \frac{\omega_0}{2\pi}$

QUESTION NUMBER: 48 OPTICS

LIST OF IMPORTANT FORMULAE

1. Focal length of mirror, $f = \frac{R}{2}$
2. Mirror equation, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
3. In case of mirror, Magnification, $m = -\frac{v}{u}$
   - ❖ $m = \frac{f-v}{f}$
   - ❖ $m = \frac{f}{f-u}$
4. Snell's law, ${}_1n_2 = \frac{\sin i}{\sin r}$ (or) $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$
5. Law of reflection, i = r
6. Relative Refractive index, ${}_1n_2 = \frac{v_1}{v_2}$
7. Absolute refractive index, $n = \frac{c}{v}$

8. Lateral shift, $L_S = \frac{t \sin(i-r)}{\cos r}$

9. Normal shift, $N_S = t\left[1 - \frac{n_R}{n_D}\right]$

10. Relation between R.I and critical angle, $n = \frac{1}{\sin C}$

11. Refractive index of prism, $n = \frac{\sin\left(\frac{\hat{A}+D}{2}\right)}{\sin\left(\frac{\hat{A}}{2}\right)}$

12. Deviation produced by thin prism is given by d = A (n – 1).

13. Spherical surface formula, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

14. Lens Maker's formula, $\frac{1}{f} = (\frac{n_2}{n_1} - 1)\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\}$

15. Power of lens, $P = \frac{1}{f}$

16. Equivalent focal length of combination of two thin lenses, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

17. Lens formula, $\frac{1}{f} = \frac{1}{u} - \frac{1}{v}$

18. In case of lens, magnification, $m = \frac{v}{u}$

19. Relation between path difference and phase difference, $\delta = \frac{\lambda}{2\pi} \times$ Phase difference (ϕ)

20. Fringe width, $\beta = \frac{\lambda D}{d}$

21. In medium; Fringe width, $\beta_m = \frac{\beta_{air}}{n}$

22. The distance of n^{th} bright fringe, $x_n = \frac{n\lambda D}{d} = n\beta$

23. The distance of n^{th} dark fringe, $x_n = \frac{(2n-1)\lambda D}{2d} = (2n-1)\frac{\beta}{2}$

24. Intensity of light emerged from analyzer; $I = I_o \cos^2\theta$

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1. A needle 1 cm high is placed at a distance of 0.1m from a convex mirror of focal length 0.05m. Determine position and size of the image

Ans: Given: $u = -0.1$ m, $f = 0.05$ m and $h_0 = 1cm = 0.01$ m

Mirror formula, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{u-f}{fu}$$

$$v = \frac{fu}{u-f} = \frac{0.05 \times -0.1}{-0.01 - 0.05} = \frac{-0.005}{-0.15}$$

v = 0.033 m

v = 3.3 cm

Since 'v' is positive, image virtual and erect. Since v < u, image is diminished.

Magnification, $m = \frac{-v}{u} = \frac{-0.033}{-0.1}$

m = 0.33 m

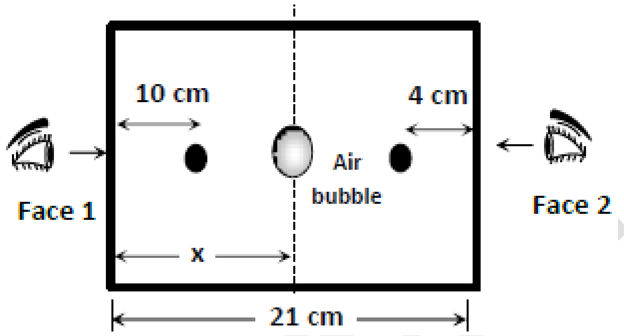
Magnification, $m = \frac{h_i}{h_o}$

$0.33 = \frac{h_i}{0.01}$

$h_i = 0.0033\text{ m}$

$h_i = 0.33\text{ cm}$

2. **An air bubble in a cube of glass of side 21cm appears to be at a depth of 10cm from one face and 4cm from other face. Find i) the actual depth of the bubble from the first face ii) R.I. of glass.**



Ans: Refractive index, $n = \frac{\text{Real depth}}{\text{Apparent depth}}$

For face -1;

$n = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{x}{10}$......(1)

For face -2;

$n = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{(21-x)}{4}$.....(2)

From eq (1) and eu (2)

$\frac{x}{10} = \frac{(21-x)}{4}$

4x = 210 – 10x

14x = 210

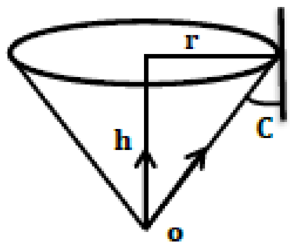
x = 15 cm

Actual position of the bubble from face -1 is 15cm

Consider eq (1), $n = \frac{x}{10} = \frac{15}{10} = 1.5$

Refractive index of glass is 1.5

3. **A small bulb is placed at the bottom of a tank containing water to a depth of 1m. Find the critical angle for water air interface and also calculate the diameter of the circular bright patch of light formed on the surface of water. [R.I. of water = 4/3].**



Ans: We have, $\sin C = \frac{1}{n}$

$C = \sin^{-1}\left[\frac{1}{4/3}\right]$

∴ Critical angle, $C = 48°35'$

In figure, $\tan C = \frac{r}{h}$

$r = h \times \tan C = 1 \times \tan 48°35'$

$r = 1 \times 1.134$

Radius, r = 1.134 m

∴ Diameter, d = 2.268 m

4. **A point object is placed at 50cm from the surface of a glass sphere of radius 10cm along a diameter. Where will the final image be formed after refraction at both the surfaces? (n = 1.5)**

Ans: Spherical surface formula, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ ....(1)

For first face,

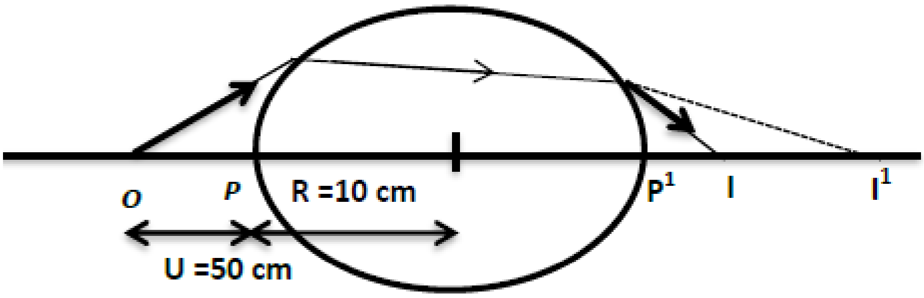
Equ (1) $\Rightarrow \frac{1.5}{v} - \frac{1}{-50} = \frac{1.5-1}{10}$

$\frac{1.5}{v} + 0.02 = 0.05$

$\frac{1.5}{v} = 0.05 - 0.02 = 0.03$

$v = 50$ cm

Image is formed at a distance of 50cm from 'P'



For second face, u = $PI^1 - PP^1$ = 50 cm − 20cm = 30 cm

Equ (1) $\Rightarrow \frac{1}{v} - \frac{1.5}{30} = \frac{1-1.5}{-10}$

$\frac{1}{v} - 0.05 = 0.05$

$\frac{1}{v} = 0.1$

v =10 cm

Image is formed at a distance of 10 cm from P^1

5. **The radii of curvature of two surfaces of a convex lens are 0.2m and 0.22m. Find the focal length of the lens if refractive index of the material of lenses 1.5. Also find the change in focal length, if it is immersed in water of refractive index 1.33.**

Ans: Given: $R_1 = 0.2$m, $R_2 = -0.22$m, $n_g = 1.5$, $n_w = 1.33$

Lens makers formula, $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For air, $\frac{1}{f_a} = (n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_a} = (1.5 - 1)\left(\frac{1}{0.2} + \frac{1}{0.22}\right)$

$\Rightarrow \frac{1}{f_a} = 0.209$ m

For water, $\frac{1}{f_w} = \left(\frac{n_g}{n_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_w} = \left(\frac{1.5}{1.33} - 1\right)\left(\frac{1}{0.2} + \frac{1}{0.22}\right)$

$\Rightarrow f_w = 0.819$ m

Change in focal length = $f_w - f_a$ = 0.819 – 0.209 = 0.61 m

6. **Two lenses of focal lengths 0.20m and 0.30m are kept in contact. Find the focal length of the combination. Calculate the powers of two lenses and combination.**

Ans: Focal length of the combination, $f = \frac{f_1 f_2}{f_1+f_2} = \frac{0.2 \times 0.3}{0.2+0.3}$

$$f = 0.12m$$

Power of first lens, $P_1 = \frac{1}{f_1} = \frac{1}{0.2} = 5\ D$

Power of second lens, $P_2 = \frac{1}{f_2} = \frac{1}{0.3} = 3.333\ D$

Power length of the combination, $P = P_1 + P_2 = 8.333\ D$

7. **An object of size 2cm is placed at 20cm in front of a convex lens of focal length 0.15m. Find the image distance and also size of image.**

Ans: Given: $h_0 = 2cm$, $u = -20m$ and $f = 0.15m = 15cm$

Lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

$$\frac{1}{v} = \frac{1}{15} - \frac{1}{20}$$

$$\frac{1}{v} = 0.01666$$

$$v = 60\ cm$$

Since 'v' is positive, image is real, inverted. Since $v > u$, image is magnified

We have, $\frac{\text{Image distance}}{\text{Object distance}} = \frac{\text{Size of image}}{\text{Size of object}}$

$$\frac{6o}{-20} = \frac{h_i}{2}$$

Size of image, $h_i = -6\ cm$

8. **Calculate the angle of minimum deviation produced by an equilateral prism of refractive index 1.65.**

Ans: Given; $A = 60^0$, $n = 1.65$

Refractive index, $n = \frac{\text{Sin}\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$$\sin\left(\frac{A+D}{2}\right) = n \times \sin\left(\frac{A}{2}\right) = 1.65 \times \frac{1}{2} = 0.825$$

$$\frac{A+D}{2} = \sin^{-1}(0.825) = 55.60$$

$$A + D = 111.2^0$$

$$D = 111.2^0 - 60^0$$

$$D = 51.2^0$$

9. **At what angle should ray of light be incident on the face of an equilateral prism, so that it just suffers total internal reflection at the other face? The refractive index of the material of the prism is 1.5**

Ans: Given; $A = 60^0$ and $n = 1.5$

Refractive index, $n = \frac{1}{\sin c}$

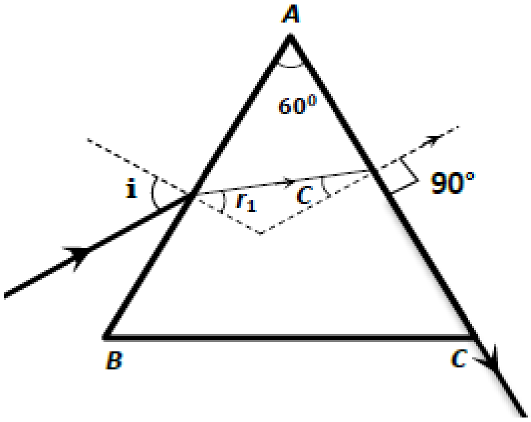
$C = sin^{-1}\left[\frac{1}{n}\right]$

$C = sin^{-1}(0.666)$

$C = 42^0$

We know that $A = r_1 + C$

$r_1 = A - C = 18^0$



We know that

$n = \frac{\sin i}{\sin r_1}$

$1.5 = \frac{\sin i}{\sin 18^0}$

$\sin i = 1.5 \times \sin 18^0$

$\sin i = 0.4635$

$i = \sin^{-1}(0.4635)$

$i = 28^0$

10. In YDS experiment, the distance between the slits is 1mm. The fringe width is found to be 0.6 mm. When the screen is moved through a distance of 0.25 m away from the slits, the fringe width becomes 0.75mm. Find the wavelength of light used.

Ans: Given: $d = 1$ mm, $\beta = 0.6$ mm, $D^1 = (D + 0.25)$ m, $\beta^1 = 0.75$ mm, $\lambda = ?$

Fringe width, $\beta = \frac{\lambda D}{d} \ldots (1)$ and $\beta^1 = \frac{\lambda D^1}{d} \ldots (2)$

Equ(2) – equ(1)

$\beta^1 - \beta = \frac{\lambda}{d}(D^1 - D)$

$(0.75 - 0.6)\, 10^{-3} = \frac{\lambda}{1 \times 10^{-3}}(D + 0.25 - D)$

$0.15 \times 10^{-6} = 0.25 \times \lambda$

∴ Wavelength, $\lambda = 0.6 \times 10^{-6}$

$\lambda = 600$ nm

11. In the young's double slit experiment by using a source of light of wavelength 4500Å, the fringe width is 5mm. If the distance between the screen and plane of the slits is reduced to half, what should be the wavelength of light to get the fringe width of 4mm?

Ans: Given; $\lambda_1 = 4.5 \times 10^{-7}$m $\beta_1 = 5 \times 10^{-3}$m, $\beta_2 = 4 \times 10^{-3}$m, $\lambda_2 = ?$

$D_2 = D/2$ m, $\lambda_2 = ?$

Fringe width, $\beta = \frac{\lambda D}{d}$

$\therefore \frac{\lambda_2}{\lambda_1} = \frac{\beta_2 D_1}{\beta_1 D_2} = \frac{4 \times 10^{-3}}{5 \times 10^{-3}} \frac{D}{D/2}$

$\frac{\lambda_2}{4.5 \times 10^{-7}} = \frac{8}{5}$

$$\lambda_2 = \frac{4.5\times10^{-7}\times8}{5}$$

λ_2 = 720 nm

12. Calculate the distance between fifth and fifteenth bright fringes in an interference pattern obtained by experiment due to narrow slits separated by 0.2mm and illuminated by light of wavelength 560nm. The distance between the slit and screen is 1m.

Ans: Given: d = 0.2mm, $\lambda = 560$nm and D =1 m

Fringe width, $\beta = \frac{\lambda D}{d} = \frac{560\times10^{-9}\times1}{0.2\times10^{-3}}$ = 2.8 mm

Distance of n^{th} bright fringe, $x_n = \frac{n\lambda D}{d} = n\beta$

For 5^{th} bright fringe, x_5 = 5 $\times$ 2.8 mm = 14 mm

For 15^{th} bright fringe, x_{15} = 15 $\times$ 2.8 mm = 42 mm

The distance between 15^{th} and 5^{th} bright fringe,

$x = x_{15} - x_5$ = 42 mm – 14 mm

= 28 mm

13. In a Young's double slit experiment wave length of light used in 5000 Å and distance between the slits is 2mm, distance of screen from the slits is 1m. Find fringe width and also calculate the distance of 7^{th} dark fringe from central bright fringe.

Ans: Fringe width, $\beta = \frac{\lambda D}{d} = \frac{5\times10^{-7}\times1}{2\times10^{-3}} = 2.5\times10^{-4}$ = 0.25 mm

Distance of n^{th} dark fringe, $x_n = (2n-1)\frac{\beta}{2} = \frac{(2\times7-1)\times2.5\times10^{-4}}{2}$

$= 16.25\times10^{-4}$ m

$x_n = 1.625$ mm

14. In YDS experiment, two slits are illuminated by a dichromatic light of wavelengths 750nm and 600nm. If the distance between the slits is 2 mm and the distance between the slits and screen is 2m, at what minimum distance from the central bright fringe will a bright fringe from interference pattern coincide with a bright fringe from other?

Ans: Given : $\lambda_1 = 750$ nm, $\lambda_2 = 600$ nm, d= 2 mm and D = 2 m

Distance of n^{th} bright fringe from the central pattern, $X_n = \frac{n\lambda D}{d}$

Here $X_{n_1} = X_{n_2}$

$\therefore n_1\frac{\lambda_1 D}{d} = n_2\frac{\lambda_2 D}{d}$

$\frac{n_1}{n_2} = \frac{600}{750}$

$\frac{n_1}{n_2} = \frac{4}{5}$

Now consider $X_{n_1} = \frac{n_1 \lambda_1 D}{d} = \frac{4 \times 750 \times 10^{-9} \times 2}{2 \times 10^{-3}}$

$$X_{n_1} = 3\text{ mm}$$

Bright fringes due to both wavelengths coincide at a distance of 3mm from the central pattern.