XII- Important Physics problems

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JAYA PHYSICS

1 Electrostatics

1.1 Calculate the number of electrons in one coulomb of negative charge.

Given: Q=1C   e=1.6 x $10^{-19}C$

Solution: $q = n\,e$

$$n = \frac{q}{e} = \frac{1}{1.6 \text{ x } 10^{-19}} = \frac{1}{16 \text{ x } 10^{-20}}$$

$$n = \frac{1}{16} \text{ x } 10^{20} = \frac{100}{16} \text{ x } 10^{18}$$

$$n = 6.25 \text{ x } 10^{18} \text{ electrons}$$

1.2 A sample of HCl gas is placed in a uniform electric field of magnitude 3 × 10^4 N C^{-1}. The dipole moment of each HCl molecule is 3.4 × 10^{-30} Cm. Calculate the maximum torque experienced by each HCl molecule.

Given: $E = 3 \text{ x } 10^4 \text{ NC}^{-1}$, $p = 3.4 \text{ x } 10^{-30} Cm$

Solution:

Torque experienced by dipole in an electric field

$$\tau = p\,E\,\text{Sin}\Theta$$

When dipole is perpendicular to electric field, it experiences maximum torque

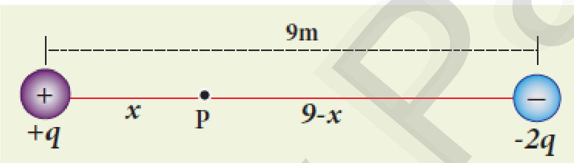
When $\Theta = 90^0$, $\tau_{max} = p\,E$

$$\tau_{max} = 3.4 \text{ x } 10^{-30} \text{ x } 3 \text{ x } 10^4$$

$$\tau_{max} = 10.2 \text{ x } 10^{-26} N\,m$$

1.3 Consider a point charge +q placed at the origin and another point charge -2q placed at a distance of 9 m from the charge +q. Determine the point between the two charges at which electric potential is zero.

Given:



Solution:

Let P be a point at a distance x from the charge +q. At P, the sum of the potentials due to each charge is zero.

$$V_q + V_{-2q} = 0$$

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{-2q}{9-x} = 0$$

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2q}{9-x}$$

$$\frac{\cancel{1}}{\cancel{4\pi}\varepsilon_0}\cdot\frac{\cancel{q}}{x} = \frac{\cancel{1}}{\cancel{4\pi}\varepsilon_0}\cdot\frac{2\cancel{q}}{9-x}$$

$$\frac{1}{x} = \frac{2}{9-x}$$

$$2x = 9 - x$$

$$3x = 9$$

$$x = 3\text{m}$$

At a distance of 3 m from the charge +q, electric potential is zero

1.4 A water molecule has an electric dipole moment of 6.3 × 10^{-30} Cm. A sample contains 10^{22} water molecules, with all the dipole moments aligned parallel to the external electric field of magnitude 3 × 10^5 NC^{-1} How much work is required to rotate all the water molecules from $\theta = 0^o$ to 90^o?

Given: $E = 3 \text{ x } 10^5 \text{ NC}^{-1}$, $p = 6.3 \text{ x } 10^{-30} Cm$

Solution:

Work done to rotate single water molecule dipole from initial angle Θ_i to final angle Θ_f

$$w = p\,E\,[Cos\Theta_i - Cos\Theta_f]$$

$$w = p\,E\,[Cos0^0 - Cos90^0]$$

$$w = p\,E\,[1 - 0] = p\,E$$

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Work done to rotate 10^{22} water molecules

$$w = 10^{22} p\,E$$

$$w = 10^{22} \text{x } 6.3 \text{ x } 10^{-30} \text{ x } 3 \text{ x } 10^5$$

$$w = 18.9 \text{ x } 10^{-3} \text{J}$$

1.5 Calculate the electric flux through the rectangle of sides 5 cm and 10 cm kept in the region of a uniform electric field 100 NC^{-1}. The angle θ is 60^o. If θ becomes zero, what is the electric flux?

Given: $E = 100 \text{ NC}^{-1}$, ℓ= 10 cm = 10 x $10^{-2}m$

b = 5 cm = 5 x $10^{-2}m$

Solution:

Electric Flux $\phi_E = E\,A\,\text{Cos}\Theta$

When $\Theta = 60^0$ $\phi_E = E\,\ell\,b\text{Cos}\Theta$

$$\phi_E = 100 \text{ x } 10 \text{ x } 10^{-2} \text{x } 5 \text{ x } 10^{-2} \text{x Cos}60^0$$

$$\phi_E = 10^3 \text{x } 10^{-4} \text{x } 5 \text{ x } 0.5$$

$$\phi_E = 2.5 \text{ x } 10^{-1} \text{ N m}^2\,C^{-1}$$

When $\Theta = 0^0$

$$\phi_E = E\,\ell\,b\text{Cos}\Theta$$

$$\phi_E = 100 \text{ x } 10 \text{ x } 10^{-2} \text{x } 5 \text{ x } 10^{-2} \text{x Cos}0^0$$

$$\phi_E = 10^3 \text{x } 10^{-4} \text{x } 5 \text{ x } 1$$

$$\phi_E = 5 \text{ x } 10^{-1} \text{ N m}^2\,C^{-1}$$

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1.6 A parallel plate capacitor has square plates of side 5 cm and separated by a distance of 1 mm. (a) Calculate the capacitance of this capacitor. (b) If a 10 V battery is connected to the capacitor, what is the charge stored in any one of the plates?

Given: $\mathbf{a} = 5 \times 10^{-2} m \quad A = a^2 = [5 \times 10^{-2}]^2$

$d = 1mm = 1 \times 10^{-3} m$

Solution:

The capacitance of the capacitor is

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times [5 \times 10^{-2}]^2}{10^{-3}}$$

$$C = \frac{8.85 \times 10^{-12} \times 25 \times 10^{-4}}{10^{-3}}$$

$$C = 221.25 \times 10^{-13} = 22.125 \times 10^{-12}$$

$$C = 22.125 \text{ p F}$$

The charge stored in any one of the plates is

$$Q = CV = 22.125 \times 10^{-12} \times 10$$

$$Q = 221.25 \times 10^{-12} C$$

1.7 A parallel plate capacitor filled with mica having ε_r = 5 is connected to a 10 V battery. The area of each parallel plate is 6 cm^2 and separation distance is 6 mm.
(a) Find the capacitance and stored charge.

(b) After the capacitor is fully charged, the battery is disconnected and the dielectric is removed carefully. Calculate the new values of capacitance, stored energy and charge.

Given: $\varepsilon_r = 5 \quad A = 6\, cm^2 \quad A = 6 \times [10^{-2}]^2$

$A = 6 \times 10^{-4}\ m^2 \quad d = 6mm = 6 \times 10^{-3} m$

Solution:

The capacitance of the capacitor with dielectric is

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$C = \frac{8.85 \times 10^{-12} \times 5 \times \cancel{6} \times 10^{-4}}{\cancel{6} \times 10^{-3}}$$

$$C = 44.25 \times 10^{-13} = 4.425 \times 10^{-12}$$

$$C = 4.425 \text{ p F}$$

The charge stored in any one of the plates is

$$Q = CV = 4.425 \times 10^{-12} \times 10$$

$$Q = 44.25 \times 10^{-12} C \qquad Q = 44.25 \text{ p C}$$

The energy of the capacitor with dielectric is

$$U = \frac{C V^2}{2} = \frac{4.425 \times 10^{-12} \times 10^2}{2}$$

$$U = 2.212 \times 10^{-10} J$$

(b) when dielectric and battery are disconnected, the **total charge will not change**.
the **potential increases by ε_r times. Capacitance decreases ε_r times** and equals to original capacitance C_0 before introducing dielectric. Stored energy U increases by **ε_r times** and equals to original energy U_0 before introducing dielectric

The capacitance of the capacitor without dielectric is

$$C_0 = \frac{C}{\varepsilon_r} = \frac{4.425 \text{ p F}}{5} = 0.885 \text{ pF}$$

The energy of the capacitor without dielectric is

$$U_0 = \varepsilon_r U = 5 \times 2.212 \times 10^{-10} = 11.06 J$$

1.8 Dielectric strength of air is $3 \times 10^6\ V\ m^{-1}$. Suppose the radius of a hollow sphere in the Van de Graff generator is R = 0.5 m, calculate the maximum potential difference created by this Van de Graaff generator.

Given: $E = 3 \times 10^6\ Vm^{-1}, \quad R = 0.5\ m$

Solution: **JAYA PHYSICS**

potential on the surface of the hollow metallic sphere is

$$V_{max} = E_{max} R$$

$$= 3 \times 10^6 \times 0.5$$

$$= 1.5 \times 10^6\ V = 1.5 \text{ million volt}$$

1.9 When two objects are rubbed with each other, approximately a charge of 50 nC can be produced in each object. Calculate the number of electrons that must be transferred to produce this charge.

Given: Q=50 nC= $50 \times 10^{-9} C$ e=$1.6 \times 10^{-19} C$

$$n = \frac{q}{e} = \frac{50 \times 10^{-9}}{1.6 \times 10^{-19}} = \frac{50 \times 10^{-9}}{16 \times 10^{-20}}$$

$$n = \frac{50}{16} \times 10^{11} = 3.125 \times 10^{12}$$

$$n = 3.125 \times 10^{11} \text{ electrons}$$

1.10A spark plug consists of two electrodes separated by a gap of around 0.6 mm gap To create the spark, an electric field of magnitude $3 \times 10^6\ Vm^{-1}$ is required. (a) What potential difference must be applied to produce the spark? (b) If the gap is increased, does the potential difference increase, decrease or remains the same? (c) find the potential difference if the gap is 1 mm.

Given:$E = 3 \times 10^6\ Vm^{-1}$ $d = 0.6mm = 0.6 \times 10^{-3} m$

Solution:

a. $V = E\, d = 3 \times 10^6 \times 0.6 \times 10^{-3} = 1.8 \times 10^3 V = 1800\ V$

b. $V \propto d$ As gap distance d increases ,V also increases

c. $V = E\, d = 3 \times 10^6 \times 1 \times 10^{-3} = 3 \times 10^3 V = 3000\ V$

1.10 Calculate the electrostatic force and gravitational force between the proton and the electron in a hydrogen atom. They are separated by a distance of 5.3×10^{-11} m. The magnitude of charges on the electron and proton are 1.6×10^{-19} C. Mass of the electron is $m_e = 9.1 \times 10^{-31}$ kg and mass of proton is $m_p = 1.6 \times 10^{-27}$ kg.

Solution:

Electrostatic force between the proton and the electron

$$F_E = k\frac{q_1 \cdot q_2}{r^2} = k\frac{e \cdot e}{r^2}$$

$$F_E = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{[5.3 \times 10^{-11}]^2}$$

$$F_E = 9 \times 10^9 \times \frac{16 \times 10^{-20} \times 16 \times 10^{-20}}{[5.3]^2 \times 10^{-22}}$$

$$F_E = 9 \times \frac{256 \times 10^{-31}}{[5.3]^2 \times 10^{-22}}$$

$$F_E = 82 \times 10^{-9} N$$

$$F_E = 8.2 \times 10^{-8} N$$

log of 9 = 0.9542
log of 256 = 2.4082
3.3624
2log of 5.3=2 x 0.7243= − 1.4486
=1.9138
Antilog of1.9138 = 82.00

Gravitational force between the proton and the electron

$$F_G = G\frac{m_1 \cdot m_2}{r^2} = G\frac{m_e \cdot m_p}{r^2}$$

$$F_G = 6.67 \times 10^{-11} \times \frac{9.1 \times 10^{-31} \times 1.6 \times 10^{-27}}{[5.3 \times 10^{-11}]^2}$$

$$F_G = 6.67 \times 10^{-11} \times \frac{9.1 \times 10^{-31} \times 1.6 \times 10^{-27}}{[5.3]^2 \times 10^{-22}}$$

$$F_G = \frac{6.67 \times 9.1 \times 1.6 \times 10^{-69}}{[5.3]^2 \times 10^{-22}}$$

$$F_G = 3.456 \times 10^{-47} N$$

log of 6.67 = 0.8241
log of 9.1 = 0.9590
log of 1.6 = 0.2041
1.9872
2log of 5.3=2 x 0.7243= − 1.4486
= 0.5386
Antilog of 0.5386 = 3.456

$$\frac{F_E}{F_G} = \frac{8.2 \times 10^{-8}}{3.456 \times 10^{-47}}$$

$$\frac{F_E}{F_G} = \frac{82 \times 10^{39}}{34}$$

$$\frac{F_E}{F_G} = 2.4 \times 10^{39}$$

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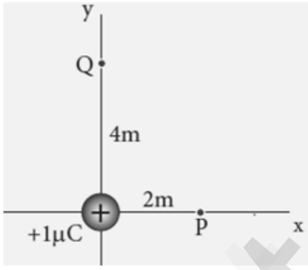
1.11Calculate the electric field at points P, Q as shown in the figure.



The magnitude of the electric field at point P is

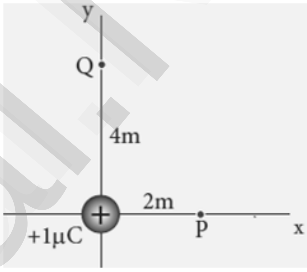
$$E_P = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

$$E_P = 9 \times 10^9 \times \frac{1 \times 10^{-6}}{2^2}$$

$$E_P = \frac{9 \times 10^3}{4} \qquad E_P = 2.25 \times 10^3\ N\,C^{-1}$$

Since the source charge is positive, the electric field acts outward from the charge

$$\vec{E_P} = 2.25 \times 10^3\ \hat{i}\ N\,C^{-1}$$



The magnitude of the electric field at point Q is

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

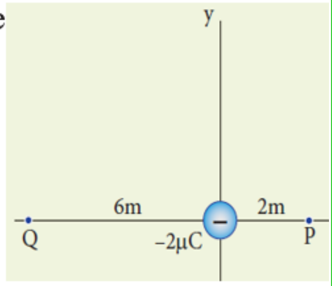
$$E_Q = 9 \times 10^9 \times \frac{1 \times 10^{-6}}{4^2}$$

$$E_Q = \frac{9 \times 10^3}{16} \qquad E_Q = 0.56 \times 10^3\ N\,C^{-1}$$

Since the source charge is positive, the electric field acts outward from the charge

$$\vec{E_Q} = 0.56 \times 10^3\ \hat{j}\ N\,C^{-1}$$

1.12 Calculate the electric field at points P, Q as shown in the figure



The magnitude of the electric field at point P is

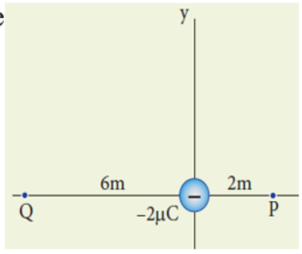
$$E_P = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

$$E_P = 9 \times 10^9 \times \frac{2 \times 10^{-6}}{2^2}$$

$$E_P = \frac{18 \times 10^3}{4} \qquad E_P = 4.5 \times 10^3\ N\,C^{-1}$$

Since the source charge is negative, the electric field acts inward towards the charge

$$\vec{E_P} = 4.5 \times 10^3\ \widehat{-i}\ N\,C^{-1}$$



The magnitude of the electric field at point Q is

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

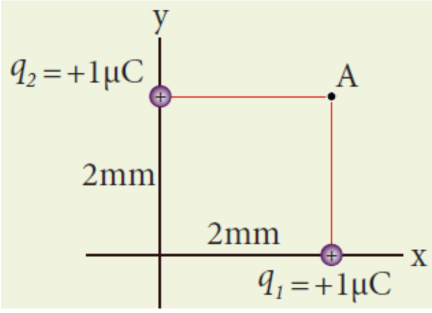
$$E_Q = 9 \times 10^9 \times \frac{2 \times 10^{-6}}{6^2}$$

$$E_Q = \frac{18 \times 10^3}{36} \qquad E_Q = 0.5 \times 10^3\ N\,C^{-1}$$

Since the source charge is negative, the electric field acts inward towards the charge

$$\vec{E_Q} = 0.5 \times 10^3\ \hat{i}\ N\,C^{-1}$$

1.13 Consider the charge configuration as shown in the figure. Calculate the electric field at point A. If an electron is placed at points A, what is the acceleration experienced by this electron? (mass of the electron = 9.1×10^{-31} kg and charge of electron = -1.6×10^{-19} C)



Electric field at point A due to q_1 is

$$E_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r^2} = 9 \times 10^9 \times \frac{1 \times 10^{-6}}{[2 \times 10^{-3}]^2} = \frac{9 \times 10^3}{4 \times 10^{-6}}$$

$$E_1 = 2.25 \times 10^9\ N\,C^{-1} \quad \vec{E_1} = \mathbf{2.25 \times 10^9 \hat{j}\ N\,C^{-1}}$$

Electric field at point A due to q_2 is

$$E_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{r^2} = 9 \times 10^9 \times \frac{1 \times 10^{-6}}{[2 \times 10^{-3}]^2} = \frac{9 \times 10^3}{4 \times 10^{-6}}$$

$$E_2 = 2.25 \times 10^9\ N\,C^{-1} \quad \vec{E_2} = \mathbf{2.25 \times 10^9 \hat{i}\ N\,C^{-1}}$$

Net Electric field at point A due to q_1 and q_2 is

$$\vec{E_A} = \vec{E_1} + \vec{E_2}$$

$$\vec{E_A} = 2.25 \times 10^9 \hat{j} + 2.25 \times 10^9 \hat{i}$$

$$\vec{E_A} = 2.25 \times 10^9 (\hat{i} + \hat{j})$$

$$E_A = 2.25 \times 10^9 \sqrt{1^2 + 1^2}$$

$$E_A = \sqrt{2} \times 2.25 \times 10^9 N\,C^{-1}$$

acceleration experienced by electron is

$$\vec{F} = \vec{E_A} e$$

$$m\vec{a} = \vec{E_A} e$$

$$\vec{a} = \frac{\vec{E_A} e}{m}$$

log of 2.25	=	0.3522
log of 1.6	=	0.2041
		0.5563
log of 9.1	=	0.9590
		$\bar{1}.5973$

Antilog of $\bar{1}.5973 = 0.3957$

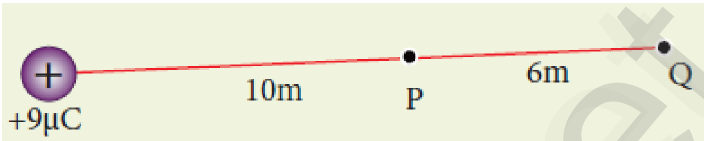
$$\vec{a} = \frac{2.25 \times 10^9 (\hat{i} + \hat{j}) \times -1.6 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$$\vec{a} = -0.3957 \times 10^{21} (\hat{i} + \hat{j})$$

The electron is accelerated in a direction exactly opposite to $\vec{E_A}$

1.14 a)Calculate the electric potential at points P and Q as shown in the figure below.

b)Calculate the work done to bring a test charge +2 μC from infinity to the point Q. Assume the charge +9 μC is held fixed at origin and +2 μC is brought from infinity to P.



a) Electric potential at point P due to +9μC is

$$V_P = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

$$V_P = 9 \times 10^9 \times \frac{9 \times 10^{-6}}{10} = \frac{81}{10} \times 10^3 = \mathbf{8.1 \times 10^3 V}$$

Electric potential at point Q due to +9μC is

$$V_Q = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

$$V_Q = 9 \times 10^9 \times \frac{9 \times 10^{-6}}{16} = \frac{81}{16} \times 10^3 = \mathbf{5.06 \times 10^3 V}$$

Potential difference between P and Q is

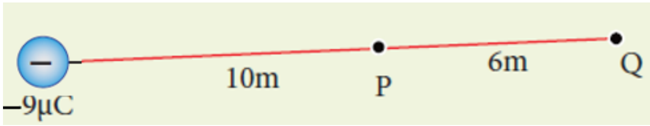
$$V_P - V_Q = 8.1 \times 10^3 - 5.06 \times 10^3 = 3.04 \times 10^3 V$$

b) work done to bring a test charge +2 μC from infinity to the point Q.

$$W = q\,V_Q$$

$$\mathbf{W = 5.06 \times 10^3 \times 2 \times 10^{-6} = 10.12 \times 10^{-3} J}$$

(c) Suppose the charge +9 μC is replaced by –9 μC find the electrostatic potentials at points P and Q



Electric potential at point P due to -9μC is

$$V_P = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

$$V_P = 9 \times 10^9 \times \frac{-9 \times 10^{-6}}{10} = -\frac{81}{10} \times 10^3 = \mathbf{-8.1 \times 10^3 V}$$

Electric potential at point Q due to -9μC is

$$V_Q = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

$$V_Q = 9 \times 10^9 \times \frac{-9 \times 10^{-6}}{16} = -\frac{81}{16} \times 10^3 = \mathbf{-5.06 \times 10^3 V}$$

Potential difference between P and Q is

$$V_P - V_Q = -8.1 \times 10^3 - (-5.06 \times 10^3) = -3.04 \times 10^3 V$$

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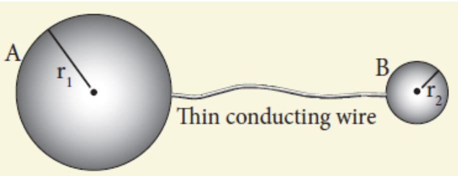
1.15 Two conducting spheres of radius $r_1 = 8$ cm and $r_2 = 2$ cm are separated by a distance much larger than 8 cm and are connected by a thin conducting wire as shown in the figure. A total charge of Q = +100 nC is placed on one of the spheres. After a fraction of a second, the charge Q is redistributed and both the spheres attain electrostatic equilibrium.

(a) Calculate the charge and surface charge density on each sphere.

(b) Calculate the potential at the surface of each sphere.

Since two conducting spheres are connected by a thin conducting wire, their potentials are equal



$$V_A = V_B$$

$$\frac{1}{4\pi\varepsilon_0}.\frac{q_1}{r_1} = \frac{1}{4\pi\varepsilon_0}.\frac{q_2}{r_2}$$

$$\frac{q_1}{q_2} = \frac{r_1}{r_2} = \frac{8}{2} = 4$$

$$q_1 = 4q_2$$

$$q_1 + q_2 = Q$$

$$4q_2 + q_2 = 100nC$$

$$5q_2 = 100nC$$

$$q_2 = 20nC$$

$$q_1 = 4q_2 = 4 \text{ x } 20nC$$

$$q_1 = 80nC$$

Electric potential of first sphere A is

$$V_A = \frac{1}{4\pi\varepsilon_0}.\frac{q_1}{r_1}$$

$$V_A = 9 \text{ x } 10^9 \text{x} \frac{80 \text{ x } 10^{-9}}{8 \text{ x } 10^{-2}} = 9\text{x } 10^3 = 9\ KV$$

Electric potential of Second sphere B is

$$V_B = V_A = 9\ KV$$

Charge density of first sphere A is

$$\sigma_A = \frac{q_1}{4\pi r_1^2} = \frac{80 \text{ x } 10^{-9}}{4 \text{ x } 3.14 \text{ x } [8 \text{ x } 10^{-2}]^2}$$

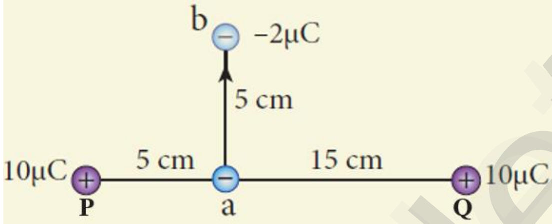
$$\sigma_A = \frac{8 \text{ x } 10^{-8}}{4 \text{ x } 3.14 \text{ x } 64 \text{ x}10^{-4}} = 0.99 \text{ x}10^{-6} C\ m^{-2}$$

Charge density of first sphere B is

$$\sigma_B = \frac{q_2}{4\pi r_2^2} = \frac{20 \text{ x } 10^{-9}}{4 \text{ x } 3.14 \text{ x } [2 \text{ x } 10^{-2}]^2}$$

$$\sigma_B = \frac{2 \text{ x } 10^{-8}}{4 \text{ x } 3.14 \text{ x } 4 \text{ x}10^{-4}} = 3.99 \text{ x}10^{-6} C\ m^{-2}$$

1.16 A point charge of +10 μC is placed at a distance of 20 cm from another identical point charge of +10 μC. A point charge of -2 μC is moved from point a to b as shown in the figure. Calculate the change in potential energy of the system? Interpret your result.



Initially when -2 μC is at point A

$$U_i = \frac{1}{4\pi\varepsilon_0}.\left[\frac{q_1 q_2}{PA} + \frac{q_2 q_3}{AQ}\right]$$

$$U_i = 9 \text{ x } 10^9 \left[\frac{10 \text{ x } 10^{-6} \text{ x } -2 \text{ x } 10^{-6}}{5 \text{ x } 10^{-2}} + \frac{-2 \text{ x } 10^{-6} \text{x } 10 \text{ x } 10^{-6}}{5 \text{ x } 10^{-2}}\right]$$

$$U_i = 9 \text{ x } 10^9 \text{x} \left[\frac{-20\text{x } 10^{-12}}{5 \text{ x } 10^{-2}} + \frac{-20 \text{x } 10^{-12}}{15 \text{ x } 10^{-2}}\right]$$

$$U_i = 9 \text{ x } 10^9 \text{x}[-4 - 1.33] \text{x } 10^{-10}$$

$$U_i = 9 \text{ x } 10^9 \text{x}[-5.33] \text{x } 10^{-10}$$

$$U_i = -47.97 \text{x } 10^{-1} \qquad U_i = -4.797\ J$$

Finally when -2 μC is at point B

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$$U_f = \frac{1}{4\pi\varepsilon_0}.\left[\frac{q_1 q_2}{PB} + \frac{q_2 q_3}{BQ}\right]$$

$$U_f = 9 \text{ x } 10^9 \left[\frac{10 \text{ x } 10^{-6} \text{ x } -2 \text{ x } 10^{-6}}{5\sqrt{2} \text{x } 10^{-2}} + \frac{-2 \text{ x } 10^{-6} \text{x } 10 \text{ x } 10^{-6}}{5\sqrt{10} \text{ x } 10^{-2}}\right]$$

$$U_f = 9 \text{ x } 10^9 \text{x} \left[\frac{-20\text{x } 10^{-10}}{5\sqrt{2}} + \frac{-20 \text{x } 10^{-10}}{5\sqrt{10}}\right]$$

$$U_f = 9 \text{ x } 10^9 \text{x} \left[\frac{-4\text{x } 10^{-10}}{\sqrt{2}} + \frac{-4 \text{ x } 10^{-10}}{\sqrt{10}}\right]$$

$$U_f = -9 \text{ x } 10^9 \text{x } 4 \text{ x } 10^{-10} \text{x} \left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{10}}\right]$$

$$U_f = -36 \text{ x } 10^{-1} \text{x}[0.707 + 0.30]$$

$$U_f = -3.6\text{x}[1.007]$$

$$U_f = -3.6 J$$

change in potential energy of the system

$$U_f - U_i = -3.6 - (-4.797)$$

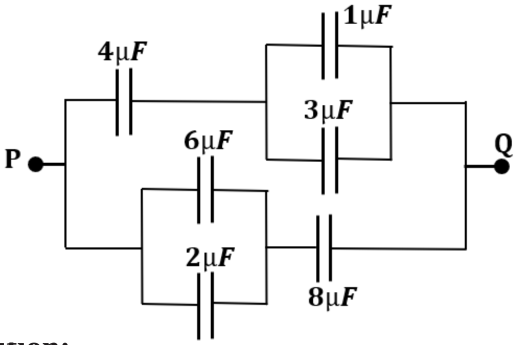
$$U_f - U_i = -3.6 + 4.797$$

$$U_f - U_i = -3.6 + 4.797$$

$$U_f - U_i = +1.197\ J$$

positive sign implies that to move the charge –2μC external work is required.

1.17 Find the equivalent capacitance between P and Q for the configuration shown below in the figure (a).



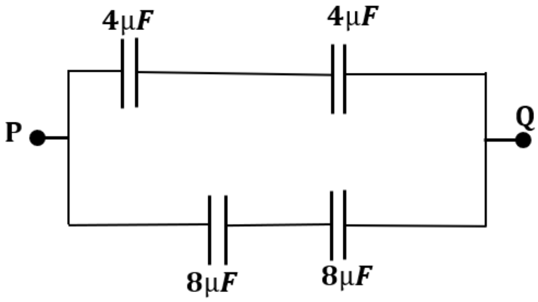
Solution:

6μF and 2μF capacitors are in parallel, their effective capacitance is

$$C_P = C_1 + C_2 = 6 + 2 = 8\mu F$$

1μF and 3μF capacitors are in parallel, their effective capacitance is

$$C_P = C_1 + C_2 = 1 + 3 = 4\ \mu F$$



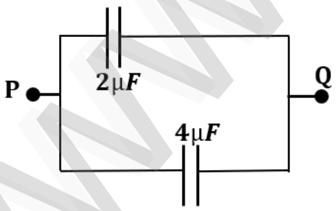
4μF and 4μF capacitors are in series, their effective capacitance is

$$C_S = \frac{C_1C_2}{C_1 + C_2} = \frac{4 \times 4}{4+4} = \frac{16}{8} = 2\ \mu F$$

8μF and 8μF are two equal capacitors are in series , their effective capacitance is

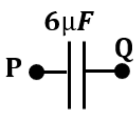
$$C_S = \frac{C}{n} = \frac{8}{2} = 4\ \mu F$$

JAYA PHYSICS

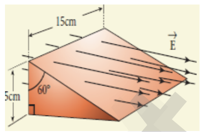


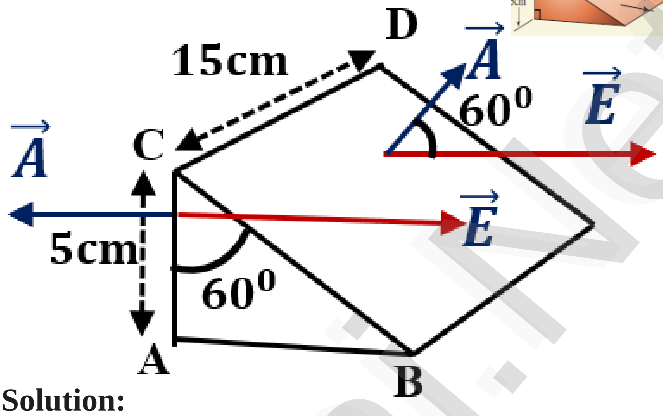
2μF and 4μF capacitors are in parallel, their effective capacitance is

$$C_P = C_1 + C_2 = 2 + 4 = 6\ \mu F$$



1.18 A closed triangular box is kept in an electric field of magnitude E = 2 × 10^3 N C^{-1} as shown in the figure. Calculate the electric flux through the (a) vertical rectangular surface (b) slanted surface and (c) entire surface.





Solution:

(a Electric flux through vertical rectangular face AC

$$E = 2 \times 10^3\ N\ C^{-1}$$

$$A = AC \times CD$$

$$A = 5 \times 10^{-2} \times 15 \times 10^{-2}$$

$$A = 75 \times 10^{-4} m^2$$

JAYA PHYSICS

Angle between $\vec{E}$ and $\vec{A}$ is 180^0

$$\phi_E = \vec{E}.\vec{A}$$

$$\phi_E = EA\ Cos\theta$$

$$\phi_E = 2 \times 10^3 \times 75 \times 10^{-4} \times\ Cos\ 180^0$$

$$\phi_E = 150 \times 10^{-1} \times (-1)$$

$$\phi_E = -15\ N\ m^2\ C^{-1}$$

b. Electric flux through slanted rectangular face

$$E = 2 \times 10^3\ N\ C^{-1}$$

$$Cos\ 60^0 = \frac{AC}{BC}$$

$$BC = \frac{AC}{Cos\ 60^0} = \frac{5}{1/2} = 10cm$$

$$A = BC \times CD$$

$$A = 10 \times 10^{-2} \times 15 \times 10^{-2} = 150 \times 10^{-4} m^2$$

Angle between $\vec{E}$ and $\vec{A}$ is 60^0

$$\phi_E = EA\ Cos\theta$$

$$\phi_E = 2 \times 10^3 \times 150 \times 10^{-4} \times\ Cos\ 60^0$$

$$\phi_E = 300 \times 10^{-1} \times (\frac{1}{2})$$

$$\phi_E = 15\ N\ m^2\ C^{-1}$$

C) Electric flux through entire face

No Electric flux comes through side faces

Total Electric flux through entire face

$$\phi_E = (-15 + 15)\ N\ m^2\ C^{-1}$$

$$\phi_E = 0$$

1.19 Suppose a charge $+q$ on Earth's surface and another $+q$ charge is placed on the surface of the Moon. (a) Calculate the value of q required to balance the gravitational attraction between Earth and Moon (b) Suppose the distance between the Moon and Earth is halved, would the charge q change?
(Take $m_E = 5.9 \times 10^{24}$ kg, $m_M = 7.9 \times 10^{22}$ kg)

Electrostatic repulsion between charges on Earth and Moon: $F_E = k\dfrac{q_1 \cdot q_2}{r^2} = k\dfrac{q \cdot q}{r^2}$

gravitational attraction between Earth and Moon: $F_G = G\dfrac{m_1 \cdot m_2}{r^2} = G\dfrac{m_E \cdot m_M}{r^2}$

To balance the gravitational attraction between Earth and Moon, $F_E = F_G$

$$k\frac{q \cdot q}{r^2} = G\frac{m_E \cdot m_M}{r^2}$$

$$q^2 = G\frac{m_E \cdot m_M}{k}$$

$$q^2 = 6.67 \times 10^{-11} \times \frac{5.9 \times 10^{24} \times 7.9 \times 10^{22}}{9 \times 10^9}$$

$$q^2 = \frac{6.67 \times 5.9 \times 7.9}{9} \times 10^{26}$$

$$q^2 = 6.67 \times 0.65 \times 7.9 \times 10^{26}$$

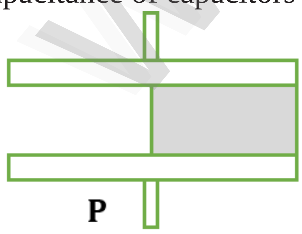
$$q = [6.67 \times 0.65 \times 7.9 \times 10^{26}]^{\frac{1}{2}}$$

$$\mathbf{q = 5.852 \times 10^{13}\ C}$$

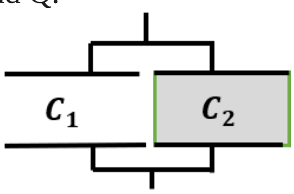
log of 6.67 = 0.8241
log of 0.65 = $\bar{1}.8129$
log of 7.9 = 0.8976
1.5346
1/2 of 1.5346 = 0.7673
Antilog of 0.7673 = 5.852

b) If the distance between the Moon and Earth is halved, then both gravitational and electrostatic repulsion will increase equally. **So Charge placed on them will not change.**

1.20 Capacitors P and Q have identical cross sectional areas A and separation d. The space between the capacitors is filled with a dielectric of dielectric constant *er* as shown in the figure. Calculate the capacitance of capacitors P and Q.



P



$$C_1 = \frac{\varepsilon_0 \frac{A}{2}}{d} = \frac{\varepsilon_0 A}{2\,d}$$

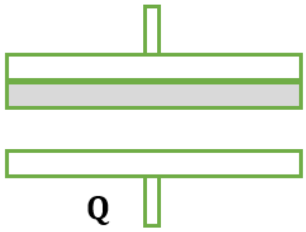
$$C_2 = \frac{\varepsilon_0 \varepsilon_r \frac{A}{2}}{d} = \varepsilon_r C_1$$

$$C_P = C_1 + C_2$$

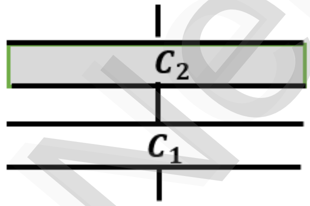
$$C_P = C_1 + \varepsilon_r C_1$$

$$C_P = C_1[1 + \varepsilon_r]$$

$$\boxed{C_P = \frac{\varepsilon_0 A}{2\,d}[1 + \varepsilon_r]}$$



Q



$$C_1 = \frac{\varepsilon_0 A}{\frac{d}{2}} = \frac{2\varepsilon_0 A}{d}$$

$$C_2 = \frac{\varepsilon_0 \varepsilon_r A}{\frac{d}{2}} = \frac{2\varepsilon_0 \varepsilon_r A}{d}$$

$$C_2 = \varepsilon_r C_1$$

$$C_S = \frac{C_1 C_2}{C_1 + C_2}$$

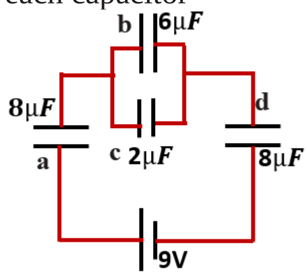
$$C_S = \frac{C_1 \varepsilon_r C_1}{C_1 + \varepsilon_r C_1}$$

$$C_S = \frac{C_1 \varepsilon_r C_1}{C_1(1 + \varepsilon_r)}$$

$$C_S = \frac{\varepsilon_r C_1}{(1 + \varepsilon_r)}$$

$$\boxed{C_S = \frac{\varepsilon_r}{(1 + \varepsilon_r)} \times \frac{2\varepsilon_0 A}{d}}$$

1.21 For the given capacitor configuration (a) Find the charges on each capacitor (b) potential difference across them (c) energy stored in each capacitor

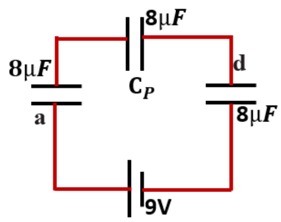


Solution:

6μF and 2 μF are in parallel,their effective capacitance is

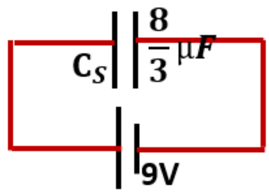
$$C_P = C_1 + C_2$$

$$C_P = 6 + 2 = 8\mu F$$



Three equal 8μF capacitors are in series, their effective capacitance is

$$C_S = \frac{C}{n} = \frac{8}{3}\mu F$$

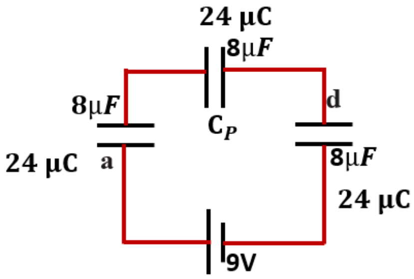


JAYA PHYSICS

Charge stored in effective capacitance

$$Q = C_S V = \frac{8}{3}\mu \text{ x } 9 = 24\ \mu C$$

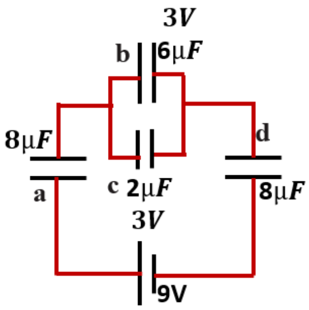
In series connection charge stored in a , C_P , d will be same



$$Q_a = 24\ \mu C$$
$$Q_d = 24\ \mu C$$
$$Q_{C_P} = 24\ \mu C$$

Voltage across C_P $V = \frac{Q}{C} = \frac{24\ \mu}{8\mu} = 3V$

6μF and 2 μF are in parallel, voltage developed across them is same



$$V_a = \frac{Q_a}{C_a} = \frac{24\ \mu}{8\mu} = 3V$$
$$V_d = \frac{Q_d}{C_d} = \frac{24\ \mu}{8\mu} = 3V$$
$$V_c = V_d = 3V$$

Charge stored in capacitor b and c is

$$Q_b = C_b V_b = 6\mu \text{ x } 3 = 18\ \mu C$$
$$Q_c = C_c V_c = 2\mu \text{ x } 3 = 6\ \mu C$$

JAYA PHYSICS

Energy stored in each capacitor is

$$U_a = \frac{1}{2} C_a V_a^2 = \frac{1}{2} \text{ x } 8\mu \text{ x} 3^2 = 36\ \mu J$$
$$U_b = \frac{1}{2} C_b V_b^2 = \frac{1}{2} \text{ x } 6\mu \text{ x} 3^2 = 27\ \mu J$$
$$U_c = \frac{1}{2} C_c V_c^2 = \frac{1}{2} \text{ x } 2\mu \text{ x} 3^2 = 9\ \mu J$$
$$U_d = \frac{1}{2} C_d V_d^2 = \frac{1}{2} \text{ x } 8\mu \text{ x} 3^2 = 36\ \mu J$$

1.22During a thunder storm, the movement of water molecules within the clouds creates friction, partially causing the bottom part of the clouds to become negatively charged. This implies that the bottom of the cloud and the ground act as a parallel plate capacitor. If the electric field between the cloud and ground exceeds the dielectric breakdown of the air (3×10^6 Vm^{-1}), lightning will occur.

(a) If the bottom part of the cloud is 1000 m above the ground, determine the electric potential difference that exists between the cloud and ground.

(b) In a typical lightning phenomenon, around 25 C of electrons are transferred from cloud to ground. How much electrostatic potential energy is transferred to the ground?

Electric potential difference that exists between the cloud and ground

$$V = E\ d = 3 \text{ x } 10^6 \text{ x } 1000 = 3 \text{ x } 10^9 V$$

Electrostatic potential energy is transferred to the ground

$$U = V\ q = 3 \text{ x } 10^9 \text{ x } 25 = 75 \text{ x } 10^9\ J$$

2 Current electricity

2.1 Compute the current in the wire if a charge of 120 C is flowing through a copper wire in 1 minute.

Given: Q=120C t=1 minute = 60 second

Solution:

Current in the wire $\Big]\ \mathbf{I = \frac{Q}{t} = \frac{120}{60} = 2A}$

2.2If an electric field of magnitude 570 N C^{-1}, is applied in the copper wire, find the acceleration experienced by the electron.

Given: E=570 N C^{-1}

mass of electron $\mathbf{9.11 \times 10^{-31}\ kg}$.

charge of electron= $\mathbf{1.6 \times 10^{-19} C}$

Solution: Force given by electric field $F = E e$

$$m\,a = E e$$

Acceleration of electron $a = \frac{\mathbf{E\,e}}{\mathbf{m}}$

$$a = \frac{\mathbf{570 \times 1.6 \times 10^{-19}}}{\mathbf{9.11 \times 10^{-31}}}$$

$$a = \frac{57 \times 16 \times 10^{-\cancel{19}}}{9 \times 10^{-\cancel{31}\ -12}}$$

$$a = \frac{912 \times 10^{12}}{9} \qquad \boldsymbol{a = 101.3 \times 10^{12}\ ms^{-2}}$$

2.3 A copper wire of cross-sectional area 0.5 mm^2 carries a current of 0.2 A. If the free electron density of copper is $8.4 \times 10^{28}\ m^{-3}$ then compute the drift velocity of free electrons.

Given: I=0.2 A, n=$8.4 \times 10^{28}\ m^{-3}$,

A=0.5 mm^2=$0.5 \times (10^{-3})^2\ m^2 = 0.5 \times 10^{-6} m^2$

$$\boldsymbol{A = 5 \times 10^{-7} m^2}$$

charge of electron= $\mathbf{1.6 \times 10^{-19} C}$

Solution:

Relation between drift velocity and current

$$I = n A v_d e$$

drift velocity $\mathbf{v_d} = \frac{\mathbf{I}}{\mathbf{n\,A\,e}}$

$$\mathbf{v_d} = \frac{\mathbf{0.2}}{\mathbf{8.4 \times 10^{28} \times 5 \times 10^{-7} \times 1.6 \times 10^{-19}}}$$

$$v_d = \frac{\cancel{2}}{8.4 \times 10^2 \times 5 \times \cancel{16}\ 8} = \frac{1}{8.4 \times 5 \times 8 \times 10^2}$$

$$v_d = \frac{10^{-2}}{8.4 \times 40} = \frac{10^{-2}}{336}$$

$$v_d = 0.0029 \times 10^{-2} \qquad \mathbf{v_d = 2.9 \times 10^{-4}\ ms^{-1}}$$

2.4 Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it.

Given: I=32 A, t = 1s

charge of electron= $\mathbf{1.6 \times 10^{-19} C}$

$$I = \frac{Q}{t} \qquad I = \frac{n\,e}{t}$$

Solution:

$$\mathbf{n = \frac{I\,t}{e} = \frac{32 \times 1}{1.6 \times 10^{-19}}} = \frac{\cancel{32}\ 2}{\cancel{16} \times 10^{-20}}$$

$$\mathbf{n = 2 \times 10^{20}}\ \text{electrons}$$

2.5 The resistance of a wire is 20 Ω. What will be new resistance, if it is stretched uniformly 8 times its original length?

Given: $R_1 = 20\ \Omega$, R_2= ?

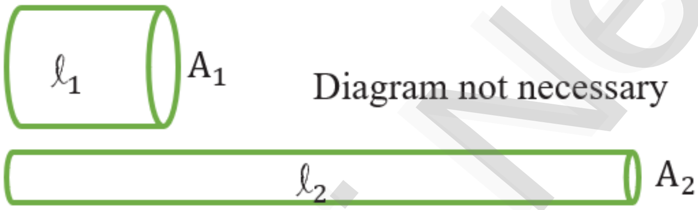


Diagram not necessary

Solution:

original length of the wire: ℓ_1

After stretching new length of the wire : $\ell_2 = 8\,\ell_1$

$$\boxed{\frac{\ell_2}{\ell_1} = \frac{8}{1}}$$

original cross section area of the wire: A_1

After stretch new cross section area of the wire: A_2

During stretching volume will not change

$$A_1\,\ell_1 = A_2\,\ell_2$$

$$\frac{\mathbf{A_1}}{\mathbf{A_2}} = \frac{\ell_2}{\ell_1} \qquad \boxed{\frac{\mathbf{A_1}}{\mathbf{A_2}} = \frac{\mathbf{8}}{\mathbf{1}}}$$

Resistance of the wire $R = \frac{\rho\,\ell}{A}$

Original Resistance $\mathbf{R_1} = \frac{\boldsymbol{\rho\,\ell_1}}{\mathbf{A_1}}$

New Resistance $\mathbf{R_2} = \frac{\boldsymbol{\rho\,\ell_2}}{\mathbf{A_2}}$

$$\frac{R_2}{R_1} = \frac{\frac{\rho\,\ell_2}{A_2}}{\frac{\rho\,\ell_1}{A_1}} = \frac{\ell_2}{\ell_1} \times \frac{A_1}{A_2} = \frac{8}{1} \times \frac{8}{1} = \frac{64}{1}$$

$$\mathbf{\frac{R_2}{R_1} = \frac{64}{1}} \qquad \mathbf{R_2 = 64 \times R_1} \qquad R_2 = 64 \times 20$$

$$\boldsymbol{R_2 = 1280\ \Omega}$$

stretching the length of the wire n times has increased its resistance n^2 times

JAYA PHYSICS

2.6 If the resistance of coil is 3 Ω at 20^0 C and α = 0.004/^{0}C then determine its resistance at 100 ^{0}C.

Given: $R_{20} = 3\ \Omega$, T = 100^{0}C, $T_0 = 20^0$C

$\alpha = 0.004$ per^0 C

Solution:

$$\mathbf{R_T = R_0[1 + \alpha\,(T - T_0)]}$$

$$R_{100} = R_{20}[1 + \alpha\,(100 - 20)]$$

$$\mathbf{R_{100} = 3[1 + 0.004\,(100 - 20)]}$$

$$R_{100} = 3[1 + 0.004\,(80)]$$

$$R_{100} = 3[1 + 0.320]$$

$$R_{100} = 3[1.32]$$

$$\mathbf{R_{100} = 3.96\ \Omega}$$

JAYA PHYSICS

As temperature increases, resistance of wire also increases

2.7 The resistance of a nichrome wire at 20^{0}C is 10 Ω. If its temperature coefficient of resistivity of nichrome is 0.004/^{0}C, find the resistance of the wire at boiling point of water. Comment on the result.

Given: $R_{20} = 10\ \Omega$, T = 100^{0}C, $T_0 = 20^0$C

$\alpha = 0.004$ per^0 C

Solution:

$$\mathbf{R_T = R_0[1 + \alpha\,(T - T_0)]}$$

$$R_{100} = R_{20}[1 + \alpha\,(100 - 20)]$$

$$\mathbf{R_{100} = 10[1 + 0.004\,(100 - 20)]}$$

$$R_{100} = 10[1 + 0.004\,(80)]$$

$$R_{100} = 10[1 + 0.320]$$

$$R_{100} = 10[1.32]$$

$$\mathbf{R_{100} = 13.2\ \Omega}$$

As temperature increases, resistance of wire also increases

2.8 Resistance of a material at 20^{0}C and 40^{0}C are 45 Ω and 85 Ω respectively. Find its temperature coefficient of resistivity.

Given: $T_0 = 20\ ^0$C, T = 40 ^{0}C, $R_{20} = 45\ \Omega$, R = 85 Ω

Solution

$$\boldsymbol{\alpha = \frac{1}{R_0} \times \left[\frac{\Delta R}{\Delta T}\right]}$$

$$\alpha = \frac{1}{R_{20}} \times \left[\frac{\Delta R}{\Delta T}\right]$$

$$\boldsymbol{\alpha = \frac{1}{45} \times \left[\frac{85 - 45}{40 - 20}\right]}$$

$$\alpha = \frac{1}{45} \times \left[\frac{40}{20}\right] = \frac{2}{45}$$

$$\boldsymbol{\alpha = 0.044\ \text{per}^0\ C}$$

2.9 Two resistors when connected in series and parallel, their equivalent resistances are 15 Ω and 56 15 Ω respectively. Find the values of the resistances.

Solution :

Let the two resistances are R_1 and R_2

$$R_S = 15\ \Omega$$

$$\mathbf{R_1 + R_2 = 15} \dashrightarrow (1)$$

$$R_2 = 15 - R_1$$

$$R_P = \frac{56}{15}\ \Omega$$

$$\mathbf{\frac{R_1R_2}{R_1 + R_2} = \frac{56}{15}}$$

$$\frac{R_1R_2}{15} = \frac{56}{15}$$

$$\mathbf{R_1\ R_2 = 56} \dashrightarrow (2)$$

$$\mathbf{R_1\ R_2 = 56}$$

$$R_1[15 - R_1] = 56$$

$$15\,R_1 - R_1^2 - 56 = 0$$

$$R_1^2 - 15\,R_1 + 56 = 0$$

By factorization

$$(R_1 - 7)\ (R_1 - 8) = 0$$

$$R_1 - 7 = 0 \quad \text{or} \quad R_1 - 8 = 0$$

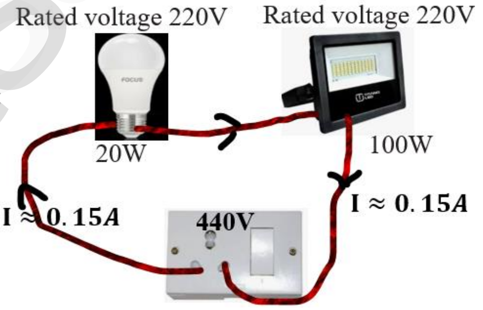
$$R_1 = 7 \quad \text{or} \quad R_1 = 8$$

$$\mathbf{If\ \ R_1 = 7\Omega\ ,\ then R_2 = 15 - 7 = 8\Omega}$$

$$\mathbf{If\ \ R_1 = 8\ \Omega\ ,\ then R_2 = 15 - 8 = 7\Omega}$$

2.10 Two electric bulbs marked 20 W – 220 V and 100 W – 220 V are connected in series to 440 V supply. Which bulb will get fused?

Diagram not necessary



Solution :

$$\text{Resistance} = \frac{[\text{Rated voltage}]^2}{\text{Rated power}} = \frac{V^2}{P}$$

Resistance of 20W bulb

$$\boldsymbol{R_{20} = \frac{V^2}{P} = \frac{220^2}{20}} = \frac{220 \times \overset{11}{\cancel{220}}}{\cancel{20}}$$

$$\boldsymbol{R_{20}} = 220 \times 11 = \mathbf{2420}\ \Omega$$

Resistance of 100W bulb

$$\boldsymbol{R_{100} = \frac{V^2}{P} = \frac{220^2}{100} = \frac{22\cancel{0} \times 22\cancel{0}}{1\cancel{00}}}$$

$$\boldsymbol{R_{100} = 484}\ \Omega$$

JAYA PHYSICS

Total Resistance of 20W and 100W bulbs in series

$$R_S = \mathbf{R_{20} + R_{100}}$$

$$R_S = \mathbf{2420 + 484}$$

$$R_S = \mathbf{2904}\ \Omega$$

When bulbs are connected in series, across 440V, same current flows in each bulb.

Current flowing in 20W and 100W bulbs in series

$$I = \frac{V}{R_S} = \frac{440}{2904} = \frac{440}{2904}$$

$$I \approx \frac{440}{2900} \approx \frac{44}{290}$$

$$\mathbf{I \approx 0.15A}$$

Voltage across 20W bulb

$$V_{20} = IR_{20} = 0.15 \times 2420$$

$$\boldsymbol{V_{20} = 363\ V}$$

Voltage drop across 20W bulb (363V) is greater than rated voltage 220V.

So, 20W bulb will get fused.

Voltage across 100W bulb

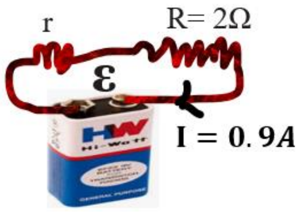
$$V_{100} = IR_{100} = 0.15 \times 484$$

$$\boldsymbol{V_{100} \approx 73V}$$

Voltage drop across 100W bulb (73V) is less than rated voltage 220V.

So, 100W bulb will not get fused.

2.11 A cell supplies a current of 0.9 A through a 2 Ω resistor and a current of 0.3 A through a 7 Ω resistor. Calculate the internal resistance of the cell.



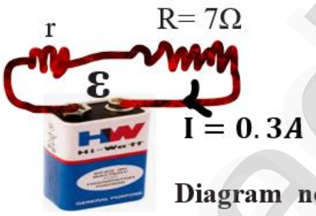


Diagram not necessary

Solution :

Current flowing in the cell $\quad I = \dfrac{\varepsilon}{R + r}$

First case $\quad 0.9 = \dfrac{\varepsilon}{2 + r} \dashrightarrow 1$

Second case $\quad 0.3 = \dfrac{\varepsilon}{7 + r} \dashrightarrow 1$

$$\frac{0.9}{0.3} = \frac{\frac{\varepsilon}{2+r}}{\frac{\varepsilon}{7+r}}$$

$$3 = \frac{7 + r}{2 + r}$$

$$6 + 3r = 7 + r$$

$$2r = 1$$

$$\mathbf{r = \frac{1}{2} = 0.5\Omega}$$

2.12 A battery has an emf of 12 V and connected to a resistor of 3 Ω. The current in the circuit is 3.93 A. Calculate (a) terminal voltage and the internal resistance of the battery (b) power delivered by the battery and power delivered to the resistor

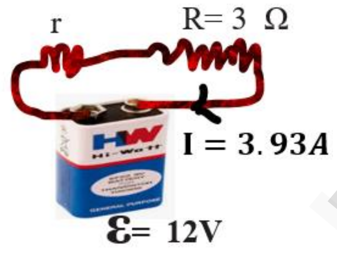


Diagram not necessary

Terminal voltage=?

Solution :

Terminal voltage

$$\mathbf{V = I\,R = 3.93 \times 3 = 11.79V}$$

Internal resistance

$$\mathbf{r = \left[\frac{\varepsilon - V}{V}\right] R = \left[\frac{12 - 11.79}{11.79}\right] 3}$$

$$r \approx \left[\frac{0.21}{\cancel{11.7}}\right] \cancel{3} \qquad 3.9 \qquad r \approx \frac{2.1}{39}$$

$$\mathbf{r = 0.05\ \Omega}$$

Actual Power delivered by battery

$$\mathbf{P = \varepsilon I = 12 \times 3.93 = 47.16W}$$

But Power delivered to the resistance R

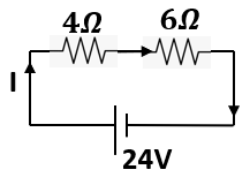
$$\mathbf{P = I^2R} = (3.93)^2 \times 3$$

$$= 15.4449 \times 3$$

$$\mathbf{= 46.3347\ W}$$

The remaining power P = (47.1 – 46.3) = 0.8 W is delivered to the internal resistance and cannot be used to do useful work

2.13 Calculate the equivalent resistance for the circuit which is connected to 24 V battery and also find the potential difference across each resistors in the circuit.



Solution :

1. Net Resistance in the circuit

$$\mathbf{R_S = R_1 + R_2 = 4 + 6 = 10\ \Omega}$$

2. Current flowing in the circuit

$$\mathbf{I = \frac{V}{R_S} = \frac{24}{10} = 2.4\ A}$$

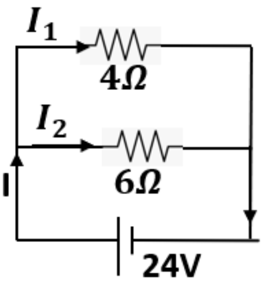
3. Potential difference across 4Ω

$$\mathbf{V = IR = 2.4 \times 4 = 9.6V}$$

Potential difference across 6 Ω

$$\mathbf{V = IR = 2.4 \times 6 = 14.4V}$$

2.14 Calculate the equivalent resistance in the following circuit and also find the values of current I, I_1 and I_2 in the given circuit.



Solution :

1. Net Resistance in the circuit

$$R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{4 \text{ x } 6}{4 + 6} = \frac{24}{10} = 2.4\,\Omega$$

2. Total Current flowing in the circuit

$$I = \frac{V}{R_P} = \frac{24}{2.4} = 10A$$

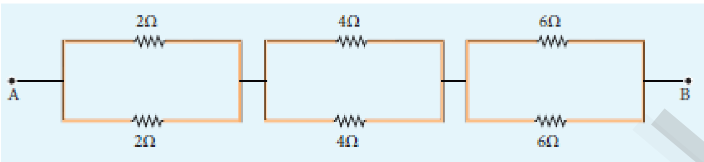
3. Current flowing in the resistance 4 Ω

$$I_1 = \frac{V}{R_1} = \frac{24}{4} = 6\,A$$

Current flowing in the resistance 6 Ω

$$I_2 = \frac{V}{R_2} = \frac{24}{6} = 4\,A$$

2.15 Calculate the equivalent resistance between A and B in the given circuit.



1. **2** Ω and **2** Ω are connected in parallel, their net Resistance

$$R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{2 \text{ x } 2}{2 + 2} = \frac{4}{4} = 1\,\Omega$$

2. 4 Ω and 4 Ω are connected in parallel, their net Resistance
   2 equal resistance connected in parallel

$$R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{4 \text{ x } 4}{4 + 4} = \frac{16}{8} = 2\,\Omega \text{ or } R_P = \frac{R}{n} = \frac{4}{2} = 2\,\Omega$$

3. 6 Ω and 6 Ω are connected in parallel, their net Resistance

$$R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \text{ x } 6}{6 + 6} = \frac{36}{12} = 3\,\Omega$$

4. 1 Ω , **2** Ω and 3 Ω are connected in series

$$R_S = R_1 + R_2 + R_3 = 1 + 2 + 3 = 6\,\Omega$$

2.16 In a Wheatstone's bridge P = 100 Ω, Q = 1000 Ω and R = 40 Ω. If the galvanometer shows zero deflection, determine the value of S.

$$\frac{P}{Q} = \frac{R}{S}$$

$$S = \frac{Q}{P} \text{x} R = \frac{1000}{100} \text{x} 40 = 400\Omega$$

2.17 What is the value of x when the Wheatstone's network is balanced?

P = 500 Ω, Q = 800 Ω, R = x + 400, S = 1000 Ω

$$\frac{P}{Q} = \frac{R}{S}$$

$$\frac{500}{800} = \frac{x + 400}{1000}$$

$$\frac{5}{8} = \frac{x + 400}{1000}$$

$$8x + 3200 = 5000$$

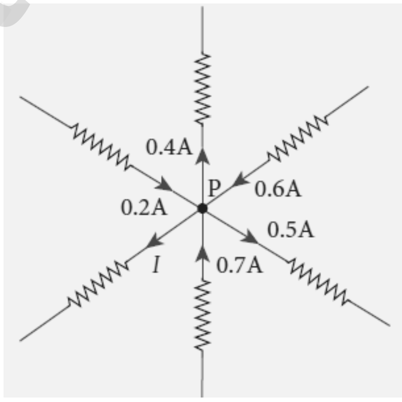
$$8x = 5000 - 3200$$

$$8x = 1800$$

$$x = \frac{1800}{8}$$

$$x = 225\,\Omega$$

2.18 For the given circuit find the value of I.



Solution

Applying Kirchhoff's rule to the point P in the circuit, The arrows pointing towards P are positive and away from P are negative.

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0.2A – 0.4A + 0.6A – 0.5A + 0.7A – I = 0

1.5A – 0.9A – I = 0

0.6A – I = 0

I = 0.6A

3 Magnetism and magnetic effects of electric current

3.1 The horizontal component and vertical component of Earth's magnetic field at a place are 0.15 G and 0.26 G respectively. Calculate the angle of dip and resultant magnetic field. (G-gauss, cgs unit for magnetic field 1G = 10^{-4} T) B_H = 0.15 G and B_V = 0.26 G

Solution:

$$\tan I = \frac{B_V}{B_H} = \frac{0.26}{0.15} = 1.732$$

$$I = \tan^{-1}(1.732)$$

angle of dip: $\mathbf{I = 60^0}$

Resultant magnetic field of the Earth

$$B = \sqrt{{B_H}^2 + {B_V}^2}$$

$$B = \sqrt{(0.15)^2 + (0.26)^2}$$

$$B = \sqrt{0.0225 + 0.0676}$$

$$B = \sqrt{0.0901}$$

$$\mathbf{B = 0.3\ G}$$

3.2 The repulsive force between two magnetic poles in air is 9 × 10^{-3} N. If the two poles are equal in strength and are separated by a distance of 10 cm, calculate the pole strength of each pole.

Given $r = 10cm = 10 \times 10^{-2}m = 10^{-1}m$

$F = 9 \times 10^{-3}N$. polestrength $q_{mA} = q_{mB} = q_m$

Solution:

magnitude of the force between two poles is

$$F = k\frac{q_{mA} \times q_{mB}}{r^2}$$

$$F = 9 \times 10^{-3}$$

$$k\frac{q_{mA} \times q_{mB}}{r^2} = 9 \times 10^{-3}$$

$$10^{-7} \times \frac{q_m \times q_m}{(10^{-1})^2} = 9 \times 10^{-3}$$

$$ {q_m}^2 = \frac{9 \times 10^{-3} \times 10^{-2}}{10^{-7}}$$

$$ {q_m}^2 = 9 \times 10^2 = 900$$

$$\mathbf{q_m = 30\ NT^{-1}}$$

3.3 A short bar magnet has magnetic moment of 0.5 J T^{-1}. Calculate magnitude and direction of the magnetic field produced by the bar magnet which is kept at a distance of 0.1 m from the centre of the bar magnet along (a) axial line of the bar magnet and (b) normal bisector of the bar magnet. **Given**

magnetic moment p_m = 0.5 J T^{-1} distance r = 0.1 m

Solution:

$$\vec{B}_{axial} = \frac{\mu_0}{4\pi}\left[\frac{2p_m}{r^3}\right]\hat{i}$$

$$\vec{B}_{axial} = \frac{4\pi \times 10^{-7}}{4\pi}\left[\frac{2 \times 0.5}{[10^{-1}]^3}\right]\hat{i}$$

$$\vec{B}_{axial} = 10^{-7}[1 \times 10^3]\hat{i}$$

$$\vec{B}_{axial} = 1 \times 10^{-4}\hat{i}\ T$$

direction of $\vec{B}_{axial}$ is towards South to North.

$$\vec{B}_{equatorial} = -\frac{\mu_0}{4\pi}\left[\frac{p_m}{r^3}\right]\hat{i}$$

$$\vec{B}_{equatorial} = -\left[\frac{\vec{B}_{axial}}{2}\right]\hat{i}$$

$$\vec{B}_{equatorial} = -\left[\frac{1 \times 10^{-4}}{2}\right]\hat{i}$$

$$\vec{B}_{equatorial} = -0.5 \times 10^{-4}\hat{i}\ T$$

direction of $\vec{B}_{equatorial}$ is towards North to South.

3.4 Compute the intensity of magnetisation of the bar magnet whose mass, magnetic moment and density are 200 g, 2 A m^2 and 8 g cm^{-3}, respectively.

magnetic moment p_m = 2 A m^2

Given Mass m=200g=200 x 10^{-3}kg

Volume V=8 g cm^{-3}= 8 x 10^{-3} kg $(10^{-2})^{-3}m^{-3}$

V **=8 x 10^3 kg m^{-3}**

Solution:

$$\text{Volume} = \frac{\text{mass}}{\text{Density}} = \frac{200 \times 10^{-3}}{8 \times 10^3}$$

$$\mathbf{V = 25 \times 10^{-6}\ m^3}$$

$$\text{Intensity of Magnetisation} = \frac{\text{magnetic moment}}{\text{Volume}}$$

$$M = \frac{p_m}{V} = \frac{2}{25 \times 10^{-6}} = \frac{2 \times 10^6}{25} = \frac{\cancel{2} \times 10^{\cancel{2}} \times 10^4}{\cancel{25}}$$

$$\mathbf{M = 8 \times 10^4 A\ m^{-1}}$$

3.5 Two materials X and Y are magnetised whose values of intensity of magnetisation are 500 A m^{-1} and 2000 A m^{-1} respectively. If the magnetising field is 1000Am^{-1}, then which one among these materials can be easily magnetized?.**Given**

H=1000Am^{-1} $\mathbf{M_X = 500\ A\ m^{-1}}$ $\mathbf{M_Y = 2000\ A\ m^{-1}}$

Solution: susceptibility of material X is

$$\chi_{mX} = \frac{M}{H} = \frac{500}{1000} = 0.5$$

susceptibility of material Y is

$$\chi_{mY} = \frac{M}{H} = \frac{2000}{1000} = 2$$

susceptibility of material Y is greater than that of material X, So, material Y can be easily magnetized.

3.6 A coil of a tangent galvanometer of diameter 0.24 m has 100 turns. If the horizontal component of Earth's magnetic field is 25 × 10^{-6} T then, calculate the current which gives a deflection of 60°.

Given r=0.12m N=100 turns B_H=25 × 10^{-6} T ϴ=60°

Solution

$$B_H = \frac{\mu_0 N}{2r}\left[\frac{I}{\tan\theta}\right]$$

$$I = \frac{B_H \cdot 2R\tan\theta}{\mu_0 N}$$

$$I = \frac{25 \times 10^{-6} \times 0.24 \times \tan 60^0}{4\pi \times 10^{-7} \times 100}$$

$$I = \frac{\cancel{25} \times 10^{-6} \times \overset{0.06}{\cancel{0.24}} \times \overset{0.433}{\cancel{1.732}}}{\cancel{4} \times 3.14 \times 10^{-7} \times \cancel{100}}$$

$$I = \frac{0.06 \times 0.433}{3.14 \times 10^{-1}}$$

$$I = \frac{0.02598 \times 10}{3.14}$$

$$I = \frac{0.2598}{3.14}$$

$$\mathbf{I = 0.082\ A}$$

3.7 Compute the magnitude of the magnetic field of a long, straight wire carrying a current of 1 A at distance of 1m from it. Compare it with Earth's magnetic field.

Given: I = 1 A and distance r = 1 m

Solution:

magnetic field due to long, straight current carrying wire : $B = \frac{\mu_0 I}{2\pi r}$

$$B = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 1}$$

$$B = 2 \times 10^{-7} T$$

Earth's magnetic field $B_H \approx 10^{-5} T$

$$B \approx 10^{-7} T \qquad \frac{B_H}{B} = \frac{10^{-5}}{10^{-7}} = 10^2$$

B is one hundred times smaller than B_H

3.8 Calculate the magnetic field inside a solenoid, when

(a) the length of the solenoid becomes twice with fixed number of turns

(b) both the length of the solenoid and number of turns are doubled

(c) the number of turns becomes twice for the fixed length of the solenoid

Solution:

magnetic field inside a solenoid : $B = \frac{\mu_0 N I}{L}$ $\boxed{B_{L,N} = \frac{\mu_0 N I}{L}}$

a)length of the solenoid becomes twice with fixed number of turns

$$B_{2L,N} = \frac{\mu_0 N I}{2L} = \frac{B_{L,N}}{2}$$

(b) both the length of the solenoid and number of turns are doubled

$$B_{2L,2N} = \frac{\mu_0 2N I}{2L} = \frac{\mu_0 N I}{L} = B_{L,N}$$

(c) the number of turns becomes twice for the fixed length of the solenoid

$$B_{L,2N} = \frac{\mu_0 2N I}{L} = \frac{2\mu_0 N I}{L} = 2 B_{L,N}$$

$$B_{L,2N} > B_{2L,2N} > B_{2L,N}$$

3.9 An electron moving perpendicular to a uniform magnetic field 0.500 T undergoes circular motion of radius 2.50 mm. What is the speed of electron?

Given: B =0.5 T and radius r **= 2.5mm =2.5 x 10^{-3}m**

mass of electron 9.11×10^{-31} kg.

charge of electron= 1.6×10^{-19}C

Centripetal force for the electron to travel in circular path is given by Lorentz force.

Solution:

$$\frac{m v^2}{r} = Bev$$

$$v = \frac{Ber}{m}$$

$$v = \frac{0.5 \times 1.6 \times 10^{-19} \times 2.5 \times 10^{-3}}{9.11 \times 10^{-31}}$$

$$v = \frac{\cancel{\frac{1}{2}}^{0.4} \times \cancel{1.6} \times 10^{-19} \times \cancel{\frac{5}{2}} \times 10^{-3} \times 10^{31}}{9.11}$$

$$v = \frac{2 \times 10^9}{9.11} \approx \frac{20 \times 10^8}{9}$$

$$v = 2.2 \times 10^8 \text{ m } s^{-1}$$

3.10 Suppose a cyclotron is operated to accelerate protons with a magnetic field of strength 1 T. Calculate the frequency in which the electric field between two Dees could be reversed.

Given:

Magnetic field B = 1 T

mass of proton 1.67×10^{-27} kg.

charge of proton= 1.6×10^{-19}C

Solution: **JAYA PHYSICS**

$$f_{osc} = \frac{B q}{2\pi m}$$

$$f_{osc} = \frac{1 \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 1.67 \times 10^{-27}}$$

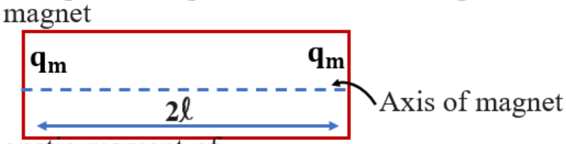
$$f_{osc} = \frac{1 \times \cancel{1.6} \times 10^{-19} \times 10^{27}}{6.28 \times \cancel{1.67}}$$

$$f_{osc} = \frac{10^8}{6.28} = \frac{100 \times 10^6}{6.3} = \frac{1000 \times 10^6}{63}$$

$$f_{osc} = 15 \times 10^6 \text{Hz} = 15 \text{ MHz}$$

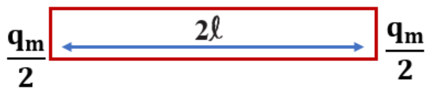
3.11 A bar magnet having a magnetic moment pm is cut into four pieces i.e., first cut into two pieces along the axis of the magnet and each piece is further cut along the axis into two pieces. Compute the magnetic moment of each piece.

q_m is the pole strength and 2ℓ is the magnetic length of a magnet



magnetic moment of unbroken magnet $\vec{p_m} = q_m \times 2\ell$

When magnet is cut along axis ,pole strength reduces two times but magnetic length is unchanged



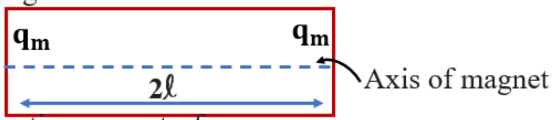
magnetic moment of each new magnet while cutting first $\vec{p_{m1}} = \frac{q_m}{2} \times 2\ell$ $\boxed{\vec{p_{m1}} = \frac{\vec{p_m}}{2}}$

magnetic moment of each new magnet while cutting second $\vec{p_{m2}} = \frac{q_m}{4} \times 2\ell$ $\boxed{\vec{p_{m2}} = \frac{\vec{p_m}}{4}}$

3.12 Let the magnetic moment of a bar magnet be *pm* whose magnetic length is $d = 2l$ and pole strength is *qm*. Compute the magnetic moment of the bar magnet when it is cut into two pieces (a) along its length (b) perpendicular to its length.

Solution: along its length

q_m is the pole strength and 2ℓ is the magnetic length of a magnet



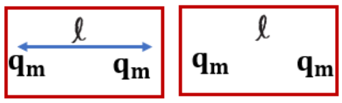
magnetic moment of unbroken magnet $\overrightarrow{p_m} = q_m \text{ x } 2\ell$

When magnet is cut along length (axis) ,pole strength reduces two times but magnetic length is unchanged

magnetic moment of each new magnet cut along length $\overrightarrow{p'_m} = \frac{q_m}{2} \text{ x } 2\ell$ $\boxed{\overrightarrow{p'_m} = \frac{\overrightarrow{p_m}}{2}}$

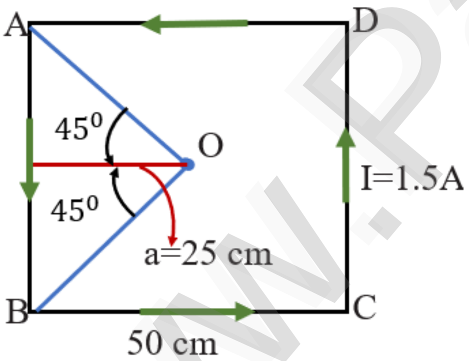
(b) perpendicular to its length.

When magnet is cut perpendicular bisecting length (axis) ,pole strength is unchanged but magnetic length reduces two times



magnetic moment of each new magnet cut perpendicular to length $\overrightarrow{p'_m} = q_m \text{ x } \ell$ $\boxed{\overrightarrow{p'_m} = \frac{\overrightarrow{p_m}}{2}}$

3.13 Calculate the magnetic field at the centre of a square loop which carries a current of 1.5 A, length of each side being 50 cm.



Solution:

magnetic field due to finite conductor AB alone at O $\mathbf{B = \frac{\mu_0 I}{4\pi a}[Sin\phi_1 + Sin\phi_2]}$

magnetic field due to all 4 conductors (AB,BC,CD,DA) acts outwards at O

magnetic field due to entire square at O $B = 4 \text{ x } \frac{\mu_0 I}{4\pi a}[\text{Sin}\phi_1 + \text{Sin}\phi_2]$

$$\mathbf{B = 4 \text{ x } \frac{\mu_0 I}{4\pi a}[Sin\phi_1 + Sin\phi_2]}$$

$$\mathbf{B = 4 \text{ x } \frac{4\pi \text{ x } 10^{-7} \text{ x } 1.5}{4\pi \text{ x } 25 \text{ x } 10^{-2}}[Sin45^0 + Sin45^0]}$$

$$B = 4 \text{ x } \frac{10^{-5} \text{ x } 1.5}{25}\left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right]$$

$$B = 4 \text{ x } \frac{10^{-6} \text{ x } 15}{25}\left[\frac{2}{\sqrt{2}}\right]$$

$$B = 120 \text{ x } \frac{10^{-6}}{25}\left[\frac{1}{\sqrt{2}}\right]$$

$$B = \overset{24}{\cancel{120}} \text{ x } \frac{10^{-6}}{\underset{5}{\cancel{25}}} \text{x} 0.707$$

$$B = 24 \text{ x } \frac{10^{-6}}{\cancel{5}} \text{x} \overset{0.14}{\cancel{0.70}}$$

$$\mathbf{B = 3.36 \text{ x} 10^{-6}\ T}$$

3.14 The resistance of a moving coil galvanometer is made twice its original value in order to increase current sensitivity by 50%. Find the percentage change in voltage sensitivity.

Voltage sensitivity $\boldsymbol{V_s = \frac{I_s}{R_g}}$

New Resistance $\boldsymbol{R_g{}' = 2R_g}$

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

New Voltage sensitivity $V_s{}' = \frac{I_s{}'}{R_g{}'} = \frac{\frac{3I_s}{2}}{2R_g} = \frac{3}{4}\frac{I_s}{R_g} = \frac{3}{4}V_S$

percentage change in voltage sensitivity $= \frac{\text{change in value}}{\text{original value}} \text{x } 100\%$

$$= \mathbf{\frac{V_S{}' - V_S}{V_S} \text{x } 100\%}$$

$$= \frac{\frac{3}{4}V_S - V_S}{V_S} \text{x } 100\%$$

$$= \frac{\left[\frac{3}{4} - 1\right] \cancel{V_S}}{\cancel{V_S}} \text{x } 100\%$$

$$= \frac{1}{4} \text{x } 100\% \quad = \mathbf{25\%}$$

3.15The coil of a moving coil galvanometer has 5 turns and each turn has an effective area of 2×10^{-2} m^2. It is suspended in a magnetic field whose strength is 4×10^{-2} Wb m^{-2}. If the torsional constant K of the suspension fibre is 4×10^{-9} N m deg^{-1}.

(a) Find its current sensitivity in division per micro - ampere.

(b) Calculate the voltage sensitivity of the galvanometer for it to have full scale deflection of 50 divisions for 25 mV.

(c) Compute the resistance of the galvanometer.

Given: $A = 2 \times 10^{-2}$ m^2 $B= 4 \times 10^{-2}$ Wb m^{-2} N=5 **K**=4×10^{-9} N m deg^{-1}

Solution:

a) Current sensitivity

$$I_S = \frac{N\,B\,A}{K}$$

$$I_S = \frac{5 \text{ x } 2 \text{ x } 10^{-2} \text{x } 4 \text{ x } 10^{-2}}{\cancel{4} \text{ x } 10^{-9}}$$

$$I_S = \frac{10 \text{ x } 10^{-4} \text{x} \cancel{4} \text{ x } 10^{9}}{\cancel{4}}$$

$$I_S = 10^6 \text{division /ampere}$$

Current	Current sensitivity
1A	10^6**division /ampere**
1μA	?

Current sensitivity $I_S = \dfrac{10^6 \frac{\text{division}}{\text{ampere}} \text{ x } 1\mu A}{1 \text{ A}}$

$$I_S = \frac{10^6 \frac{\text{division}}{\text{ampere}} \text{x1 x } 10^{-6} A}{1 \text{ A}}$$

$$I_S = 1 \frac{\text{division}}{\text{ampere}}$$

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b) Voltage sensitivity

$$V_S = \frac{\theta}{V}$$

$$V_S = \frac{50 \text{ division}}{25 \text{ x } 10^{-3}}$$

$$V_S = 2 \text{ x} 10^3 \text{division /volt}$$

c) Resistance of the galvanometer

$$R_g = \frac{I_S}{V_S}$$

$$R_g = \frac{10^6 \frac{\cancel{\text{division}}}{\text{ampere}}}{2 \text{ x } 10^3 \frac{\cancel{\text{division}}}{\text{volt}}}$$

$$R_g = \frac{10^3}{2} \frac{\text{volt}}{\text{ampere}} = \frac{1000}{2} \text{ohm}$$

$$R_g = 500\,\Omega$$

4.Electromagnetic Induction

4.1A circular antenna of area 3 m^2 is installed at a place in Madurai. The plane of the area of antenna is inclined at 47^o with the direction of Earth's magnetic field. If the magnitude of Earth's field at that place is 4.1 × 10^{-5} T find the magnetic flux linked with the antenna.

Given:

$\theta = 90^0 - 47^0 = 43^0 \quad A = 3\, m^2 \quad B = 4.1 \text{ x } 10^{-5}\text{T}$

Solution:

$$\Phi_B = B\, A\, Cos\theta$$
$$\boldsymbol{\Phi_B = 4.1 \text{ x } 10^{-5} \text{ x } 3 \text{ x } Cos\, 43^0}$$
$$\Phi_B = 12.3 \text{ x } 10^{-5} \text{ x } 0.7314$$
$$\Phi_B = \mathbf{8.996 \text{ x } 10^{-5}}\text{Wb}$$

4.2A closed coil of 40 turns and of area 200 cm^2, is rotated in a magnetic field of flux density 2 Wb m^{-2}. It rotates from a position where its plane makes an angle of 30^o with the field to a position perpendicular to the field in a time 0.2 s. Find the magnitude of the emf induced in the coil due to its rotation.

$\theta_i = 90^0 - 30^0 = 60^0 \quad N = 40 \quad B = 2\, Wb\, m^{-2}$

$\theta_f = 90^0 - 90^0 = 0 \quad A = 200\, cm^2 = 200 \text{ x } 10^{-4}\, m^2$

Solution:

$$\Phi_{Bi} = B\, A\, Cos\theta$$
$$= 2 \text{ x } 200 \text{ x } 10^{-4} \text{ Cos } 60^0$$
$$= 400 \text{ x } 10^{-4} \text{ x } \frac{1}{2}$$
$$\Phi_{Bi} = \mathbf{200 \text{ x } 10^{-4}}\text{Wb}$$

$$\Phi_{Bf} = B\, A\, Cos\theta$$
$$= 2 \text{ x } 200 \text{ x } 10^{-4} \text{ Cos } 0^0$$
$$= 400 \text{ x } 10^{-4} \text{ x } 1$$
$$\Phi_{Bf} = \mathbf{400 \text{ x } 10^{-4}}\text{Wb}$$

Change in magnetic flux

$$\mathbf{d\Phi_B = \Phi_{Bf} - \Phi_{Bi}}$$
$$d\Phi_B = 400 \text{ x } 10^{-4} - 200 \text{ x } 10^{-4}$$
$$d\Phi_B = 200 \text{ x } 10^{-4}\text{Wb}$$

Emf induced

$$\varepsilon = N \frac{d\Phi_B}{dt}$$
$$\varepsilon = 40 \text{ x } \frac{200 \text{ x } 10^{-4}}{0.2}$$
$$\varepsilon = 40 \text{ x } \frac{2000 \text{ x } 10^{-4}}{2}$$
$$\varepsilon = 40 \text{ x}1000 \text{ x } 10^{-4}$$
$$\boldsymbol{\varepsilon = 4\text{ V}}$$

4.3A circular loop of area 5 x 10^{-2} m^2 rotates in a uniform magnetic field of 0.2 T. If the loop rotates about its diameter which is perpendicular to the magnetic field as shown in figure. Find the magnetic flux linked with the loop when its plane is (i) normal to field (ii) inclined 60^o to field (iii) parallel to the field.

(i) normal to the field

$$\theta = 90^0 - 90^0 = 0^0$$
$$\Phi_B = B\, A\, Cos\theta$$
$$\boldsymbol{\Phi_B = 5 \text{ x } 10^{-2} \text{ x } 0.2 \text{ x } Cos\, 0^0}$$
$$\Phi_B = 1 \text{ x } 10^{-2} \text{ x } 1$$
$$\boldsymbol{\Phi_B = 1 \text{ x } 10^{-2}\text{ Wb}}$$

(ii) inclined 60^o to the field

$$\theta = 90^0 - 60^0 = 30^0$$
$$\Phi_B = B\, A\, Cos\theta$$
$$\boldsymbol{\Phi_B = 5 \text{ x } 10^{-2} \text{ x } 0.2 \text{ x } Cos\, 30^0}$$
$$\Phi_B = 1 \text{ x } 10^{-2} \text{ x } \frac{\sqrt{3}}{2} = 10^{-2} \text{ x } \frac{1.732}{2}$$
$$\boldsymbol{\Phi_B = 0.866\text{x } 10^{-2}\text{ Wb}}$$

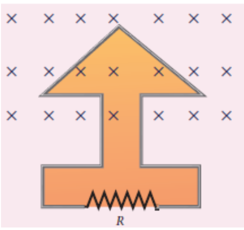
(iii) parallel to the field.

$$\theta = 90^0 - 0^0 = 90^0$$
$$\Phi_B = B\, A\, Cos\theta$$
$$\boldsymbol{\Phi_B = 5 \text{ x } 10^{-2} \text{ x } 0.2 \text{ x } Cos\, 90^0}$$
$$\Phi_B = 1 \text{ x } 10^{-2} \text{ x } 0$$
$$\boldsymbol{\Phi_B = 0}$$

JAYA PHYSICS

4.4The magnetic flux passes perpendicular to the plane of the circuit and is directed into the paper. If the magnetic flux varies with respect to time as per the following relation: $\Phi_B = 2t^3 + 3t^2 + 8t + 5$ mWb , what is the magnitude of the induced emf in the loop when t = 3 s? Find out the direction of current through the circuit.

$$\varepsilon = N \frac{d\Phi_B}{dt}$$
$$\varepsilon = 1\text{x}\frac{d}{dt}[2t^3 + 3t^2 + 8t + 5]\text{x}10^{-3}$$
$$\varepsilon = [6t^2 + 6t + 8]\text{x}10^{-3}$$



At t = 3 s,

$$\varepsilon = [6 \text{ x } (3^2) + 6(3) + 8]\text{x}10^{-3}$$
$$= [6\text{x } 9 + 18 + 8]\text{x}10^{-3}$$
$$= [54 + 18 + 8]\text{x}10^{-3}$$
$$\boldsymbol{\varepsilon = 80 \text{ x } 10^{-3} V}$$

To oppose the flux increase, the induced current flows in anti-clockwise direction.

4.5A conducting rod of length 0.5 m falls freely from the top of a building of height 7.2 m at a place in Chennai where the horizontal component of Earth's magnetic field is 4.04×10^{-5} T. If the length of the rod is perpendicular to Earth's horizontal magnetic field, find the emf induced across the conductor when the rod is about to touch the ground. (Assume that the rod falls down with constant acceleration of 10 m s^{-2})

Given:

$\ell = 0.5$ m, $h = 7.2$ m, $g = 9.8\ ms^{-2}$, $B_H = 4.04 \times 10^{-5}T$

Solution:

Final Velocity

$v^2 = u^2 + 2aS$

$v^2 = u^2 + 2gh$

$v^2 = 0^2 + 2 \times 10 \times 7.2$

$v^2 = 144$

$\mathbf{v = 12ms^{-1}}$

Emf induced

$\boldsymbol{\varepsilon = B\ell v}$

$\boldsymbol{\varepsilon = 4.04 \times 10^{-5} \times 0.5 \times 12}$

$\varepsilon = 4.04 \times 10^{-5} \times 6$

$\boldsymbol{\varepsilon = 24.24 \times 10^{-5} V}$

JAYA PHYSICS

4.6The current flowing in the first coil changes from 2 A to 10 A in 0.4 s. Find the mutual inductance between two coils if an emf of 60 mV is induced in the second coil. Also determine the magnitude of induced emf in the second coil if the current in the first coil is changed from 4 A to 16 A in 0.03 s. Consider only the magnitude of induced emf.

1. Change in current: $\boldsymbol{di_1 = 10 - 2 = 8A}$

Mutual inductance $\mathbf{M} = \dfrac{\varepsilon_2}{\dfrac{di_1}{dt}} = \dfrac{60 \times 10^{-3}}{\dfrac{8}{0.4}}$

$$M = \frac{15}{2} \times 0.4 \times 10^{-3}$$

$$M = 15 \times 0.2 \times 10^{-3}$$

$$\mathbf{M = 3 \times 10^{-3} H}$$

2. Change in current: $\boldsymbol{di_1 = 16 - 4 = 12\ A}$

Mutual inductance $\mathbf{M} = \dfrac{\varepsilon_2}{\dfrac{di_1}{dt}}$

$$\varepsilon_2 = M\frac{di_1}{dt}$$

$$\varepsilon_2 = 3 \times 10^{-3} \times \frac{12}{0.03}$$

$$\varepsilon_2 = 3 \times 10^{-3} \times \frac{12}{3 \times 10^{-2}}$$

$$\boldsymbol{\varepsilon_2 = 1.2V}$$

4.7Write down the equation for a sinusoidal voltage of 50 Hz and its peak value is 20 V. Draw the corresponding voltage versus time graph.

$V = V_m Sin\omega t$

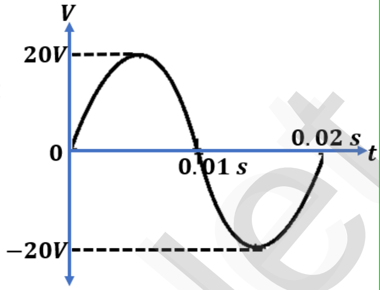
$\mathbf{V = V_m Sin2\pi ft}$

$\mathbf{V = 20\ Sin2 \times 3.14 \times 50t}$

$V = 20\ Sin\ 100 \times 3.14\ t$

$\mathbf{V = 20\ Sin\ 314\ t}$

$\boldsymbol{T = \frac{1}{f} = \frac{1}{50} = 0.02\ s}$



4.8The equation for an alternating current is given by $i = 77 \sin 314t$. Find the peak current, frequency, time period and instantaneous value of current at $t = 2$ ms.

$$i = 77\ Sin\ 314\ t$$

$$\mathbf{i = i_m Sin2\pi ft}$$

$\mathbf{i_m = 77\ A}$

$2\pi f = 314$

$f = \dfrac{314}{2 \times 3.14}$

$f = \dfrac{314 \times 100}{2 \times 3.14 \times 100}$

$f = \dfrac{314 \times 100}{2 \times 314}$

$\mathbf{f = 50Hz}$

$\boldsymbol{T = \frac{1}{f}}$

$T = \dfrac{1}{50}$

$\boldsymbol{T = 0.02\ s}$

$\mathbf{i = 77\ Sin\ 314 \times 2 \times 10^{-3}}$

$i = 77\ Sin\left(314 \times 2 \times 10^{-3} \times \dfrac{180^0}{3.14}\right)$

$i = 77\ Sin\left(314 \times 2 \times 10^{-3} \times \dfrac{180^0}{314 \times 10^{-2}}\right)$

$i = 77\ Sin(2 \times 10^{-1} \times 180^0)$

$i = 77\ Sin(36^0)$

$i = 77 \times 0.5878$

$\mathbf{i = 45.26\ A}$

4.9A 400 mH coil of negligible resistance is connected to an AC circuit in which an effective current of 6 mA is flowing.Find out the voltage across the coil if the frequency is 1000 Hz.

Inductive reactance

$$\boldsymbol{X_L = L\omega = L\ 2\pi f}$$

$$X_L = 400 \times 10^{-3} \times 2 \times 3.14 \times 1000$$

$$X_L = 800 \times 3.14$$

$$\boldsymbol{X_L = 2512\ \Omega}$$

Voltage across L $\quad \boldsymbol{V_L = I X_L}$

$= 6 \times 10^{-3} \times \mathbf{2512}$

$= 15072 \times 10^{-3}$

$\boldsymbol{V_L = 15.072\ V}$

5.Electromagnetic waves

5.1 The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.

Given: relative electrical permittivity $\varepsilon_r = 2.25$

relative magnetic permeability μ_r=2.5

Solution :

Refractive index of medium $\Big]$ $\mathbf{n = \sqrt{\varepsilon_r \mu_r}}$

$$\mathbf{n = \sqrt{2.25 \times 2.5}}$$

$$n = \sqrt{5.625} \qquad \mathbf{n = 2.37}$$

5.2 If the relative permeability and relative permittivity of a medium are 1.0 and 2.25 respectively, find the speed of the electromagnetic wave in this medium.

Given: relative permittivity $\varepsilon_r = 1$

relative permeability μ_r=2.25

Solution :

Refractive index of medium $\Big]$ $\mathbf{n = \sqrt{\varepsilon_r \mu_r}}$

$$\mathbf{n = \sqrt{1 \times 2.25}}$$

$$\boxed{\mathbf{n = \frac{c}{v}}} \qquad n = \sqrt{2.25} \qquad \mathbf{n = 1.5}$$

Velocity of light in a medium $\Big]$ $\mathbf{v = \frac{c}{n} = \frac{\overset{2}{\cancel{3}} \times 10^8}{\cancel{1.5}}}$

$$\mathbf{v = 2 \times 10^8 m\, s^{-1}}$$

5.3Compute the speed of the electromagnetic wave in a medium if the amplitude of electric and magnetic fields are 3 × 10^4 N C^–1 and 2 × 10^–4 T, respectively.

Given:

amplitude of electric field: $E_0 = 3 \times 10^4$ N C^{-1}

amplitude of magnetic field: $B_0 = 2 \times 10^{-4}$ T

Solution :

Velocity of light in a medium $\Big]$ $\mathbf{v = \frac{E_0}{B_0} = \frac{3 \times 10^4}{2 \times 10^{-4}}}$

$$\mathbf{v = 1.5 \times 10^8 m\, s^{-1}}$$

5.4 A magnetron in a microwave oven emits electromagnetic waves (em waves) with frequency f = 2450 MHz. What magnetic field strength is required for electrons to move in circular paths with this frequency?.

Given: Same formula used in lesson 3

Frequency f =2450 $\mathbf{\times 10^6}$ **Hz**

mass of electron $\mathbf{9.11 \times 10^{-31}}$ **kg**.

charge of electron= $\mathbf{1.6 \times 10^{-19} C}$

Solution :

$$f = \frac{Bq}{2\pi m} = \frac{B\,e}{2\,\pi\, m_e}$$

$$\mathbf{B = \frac{2\,\pi\, m_e\, f}{e}}$$

$$\mathbf{B = \frac{2 \times 3.14 \times 9.11 \times 10^{-31} 2450 \times 10^6}{1.6 \times 10^{-19}}}$$

$$B = \frac{2 \times 3 \times 9 \times 10^{-31} \times 245 \times 10^7}{16 \times 10^{-20}}$$

$$B = \frac{13230 \times 10^{-4}}{16} \qquad \mathbf{B = 826.8 \times 10^{-4}\, T}$$

JAYA PHYSICS

5.5 A transmitter consists of LC circuit with an inductance of 1 μH and a capacitance of 1 μF. What is the wavelength of the electromagnetic waves it emits?

Given:

Inductance L = 1μ Henry = 1 $\mathbf{\times 10^{-6}}$ **H**

Capacitance C = 1μ farad = 1 $\mathbf{\times 10^{-6}}$ **F**

Velocity of light = c = 3 $\mathbf{\times 10^8}$ **m** s^{-1}

Solution:

$$\text{Frequency} \quad \nu = \frac{1}{2\,\pi\sqrt{L\,C}} \qquad c = \nu\,\lambda$$

$$\frac{c}{\lambda} = \frac{1}{2\,\pi\sqrt{L\,C}}$$

$$\mathbf{\lambda = c \times 2\,\pi\sqrt{L\,C}}$$

$$\mathbf{\lambda = 3 \times 10^8 \times 2 \times 3.14 \times \sqrt{1 \times 10^{-6} \times 1 \times 10^{-6}}}$$

$$\lambda = 6 \times 10^8 \times 3.14 \times 1 \times 10^{-6}$$

$$\mathbf{\lambda = 18.84 \times 10^2\, m}$$

6.Ray Optics

6.1An object is placed at a distance of 20.0 cm from a concave mirror of focal length 15.0 cm.
(a) What distance from the mirror a screen should be placed to get a sharp image? (b) What is the nature of the image? Given : $f = -15\text{cm}$, $u = -20\text{cm}$

Solution:

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$$
$$\frac{1}{v}=\frac{1}{-15}-\frac{1}{-20}$$
$$\frac{1}{v}=-\frac{1}{15}+\frac{1}{20}$$
$$\frac{1}{v}=\frac{-20+15}{300}$$
$$\frac{1}{v}=\frac{-20+15}{300}$$
$$\frac{1}{v}=\frac{-5}{300}$$
$$\frac{1}{v}=-\frac{1}{60}$$
$$\boxed{v=-60\text{ cm}}$$

The screen is to be placed at distance 60.0 cm to the left of the concave mirror.

Magnification $\mathbf{m = \frac{h'}{h} = -\frac{v}{u} = -\frac{-60}{-20} = -3}$

As the sign of magnification is negative, the image is inverted.
As the magnitude of magnification is 3, the image is enlarged three times.
As the image is formed to the left of the concave mirror, the image is real.

6.2 Pure water has refractive index 1.33. What is the speed of light through it? Given : $n = 1.33$

Solution:

$$n=\frac{c}{v}$$
$$v=\frac{c}{n}=\frac{3\times10^8}{1.33}=\frac{3\times10^8}{4/3}=\frac{9\times10^8}{4}$$
$$\boxed{v=2.25\times10^8\text{ ms}^{-1}}$$

6.3 Light travels from air into a glass slab of thickness 50 cm and refractive index 1.5.
(a) What is the speed of light in the glass slab?
(b) What is the time taken by the light to travel through the glass slab?
(c) What is the optical path of the glass slab?

Given : $n = 1.33, d = 50\text{cm}$

Solution: JAYA PHYSICS

a)
$$n=\frac{c}{v}$$
$$v=\frac{c}{n}=\frac{3\times10^8}{1.5}=\frac{3\times10^8}{3/2}=\frac{6\times10^8}{3}$$
$$\boxed{v=2\times10^8\text{ ms}^{-1}}$$

b)
$$\text{time}=\frac{\text{distance}}{\text{velocity}}$$
$$t=\frac{d}{v}=\frac{50\times10^{-2}}{2\times10^8}=25\times10^{-10}\text{s}$$

c) $\mathbf{d' = n\,d = 1.5 \times 50\times10^{-2} = 75\times10^{-2}\ m}$

6.4 Light travelling through transparent oil enters in to glass of refractive index 1.5. If the refractive index of glass with respect to the oil is 1.25, what is the refractive index of the oil?

Given : $n_g = 1.5$, $n_{go} = 1.25$ $n_o = ?$

Solution:

$$n_{go}=\frac{n_g}{n_o}$$
$$n_o=\frac{n_g}{n_{go}}=\frac{1.5}{1.25}=\frac{6}{5}=1.2$$

6.5 A coin is at the bottom of a trough containing three immiscible liquids of refractive indices 1.3, 1.4 and 1.5 poured one above the other of heights 30 cm, 16 cm, and 20 cm respectively. What is the apparent depth at which the coin appears to be when seen from air medium outside? In which medium the coin will appear?

Solution:
$$\text{Apparent depth}=\frac{\text{Real Depth}}{\text{Refractive Index}}$$
$$d'=\frac{d_1}{n_1}+\frac{d_2}{n_2}+\frac{d_3}{n_3}$$
$$d'=\frac{30}{1.3}+\frac{16}{1.4}+\frac{20}{1.5}$$
$$d'=\frac{300}{13}+\frac{160}{14}+\frac{200}{15}$$
$$d'=\frac{300}{13}+\frac{160}{14}+\frac{200}{15}$$
$$d'=23.0+11.4+13.3 \qquad \boxed{d'=47.7\text{ cm}}$$

coin will appear in the medium of refractive index 1.3.

6.6 What is the radius of the illumination when seen above from inside a swimming pool from a depth of 10 m on a sunny day? What is the total angle of view? refractive index of water is 4/3

Solution:

$$R=\frac{d}{\sqrt{n^2-1}}$$
$$R=\frac{10}{\sqrt{\left[\frac{4}{3}\right]^2-1}}$$
$$R=\frac{10}{\sqrt{\frac{16}{9}-1}}$$
$$R=\frac{10}{\sqrt{\frac{16-9}{9}}}$$
$$R=\frac{10}{\frac{\sqrt{7}}{3}}$$
$$R=\frac{30}{2.64}$$
$$R=11.3\text{ m}$$

$$i_c=\sin^{-1}\frac{1}{n}$$
$$i_c=\sin^{-1}\frac{1}{4/3}$$
$$i_c=\sin^{-1}\frac{3}{4}$$
$$i_c=\sin^{-1}0.75$$
$$i_c=48.6^0$$

total angle of view $= 2i_c = 2\times48.6^0 = 97.2^0$

6.7 If the focal length is 150 cm for a lens, what is the power of the lens?

Given: $f = 150\ cm$

Solution: $$P = \frac{1}{f} = \frac{1}{150 \times 10^{-2}} = \frac{100}{150} = \frac{2}{3}$$

$$P = 0.67\ D$$

As the power is positive, it is a converging lens.

6.8 A monochromatic light is incident on an equilateral prism at an angle 30° and is emergent at an angle of 75°. What is the angle of deviation produced by the prism?

Given: $i_1 = 30^0,\ i_2 = 75^0,\ A = 60^0$

Solution: $$d = i_1 + i_2 - A$$

$$d = 30^0 + 75^0 - 60^0$$

$$d = 45^0$$

JAYA PHYSICS

6.9 The angle of minimum deviation for an equilateral prism is 37°. Find the refractive index of the material of the prism.

Given : $D = 37^0,\ A = 60^0$

Solution: $$n = \frac{\sin\left[\frac{A+D}{2}\right]}{\sin\frac{A}{2}}$$

$$n = \frac{\sin\left[\frac{60^0 + 37^0}{2}\right]}{\sin\frac{60^0}{2}}$$

$$n = \frac{\sin\left[\frac{97^0}{2}\right]}{\sin 30^0}$$

$$n = \frac{\sin 48.5^0}{\sin 30^0}$$

$$n = \frac{0.7489}{0.5}$$

$$\boxed{n = 1.5}$$

6.10 Find the dispersive power of a prism if the refractive indices of flint glass for red, green and violet colours are 1.613, 1.620 and 1.632 respectively.

Given, $n_V = 1.632,\ n_R = 1.613,\ n_G = 1.620$

Solution: $$\omega = \frac{n_V - n_R}{n_G - 1}$$

$$\omega = \frac{1.632 - 1.613}{1.620 - 1}$$

$$\omega = \frac{0.019}{0.620} = \frac{19}{620}$$

$$\boxed{\omega = 0.030}$$

6.11 Find the ratio of the intensities of lights with wavelengths 500 nm and 300 nm which undergo Rayleigh scattering. Given, $\lambda_1 = 500\ nm,\ \lambda_2 = 300\ nm$

Solution: $$I \propto \frac{1}{\lambda^4}$$

$$\frac{I_1}{I_2} = \left[\frac{\lambda_2}{\lambda_1}\right]^4 = \left[\frac{300}{500}\right]^4 = \left[\frac{3}{5}\right]^4$$

$$\boxed{\frac{I_1}{I_2} = \frac{81}{625}}$$

6.12 An object is placed at a certain distance from a convex lens of focal length 20 cm. Find the object distance if the image obtained is magnified 4 times.

Given: f = 20 cm , m = 4

Solution: $$m = \frac{v}{u}$$

$$v = m\,u = 4u$$

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

$$\frac{1}{4u} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1-4}{4u} = \frac{1}{f}$$

$$-\frac{3}{4u} = \frac{1}{f}$$

$$u = -\frac{3}{4}f$$

$$u = -\frac{3}{4} \times 20$$

$$\boxed{u = -15cm}$$

6.13 An object of 4 cm height is placed at 6 cm in front of a concave mirror of radius of curvature 24 cm. Find the position, height, magnification and nature of the image.

Given : u= -6cm h = 4cm R=-24cm

Solution: $$f = \frac{R}{2} = \frac{-24}{2} = -12cm$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

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

$$\frac{1}{v} = \frac{1}{-12} - \frac{1}{-6}$$

$$\frac{1}{v} = \frac{1}{6} - \frac{1}{12}$$

$$\frac{1}{v} = \frac{2-1}{12}$$

$$\frac{1}{v} = \frac{1}{12}$$

$$\boxed{v = 12cm}$$

Magnification: $$m = -\frac{12}{-6} = 2$$

$$m = \frac{h'}{h}$$

$$h' = mh = 2 \times 4 = 8\ cm$$

As the sign of magnification is positive, the image is erect.

As the magnitude of magnification is 2, the image is enlarged two times.

As the image is formed to the right of the concave mirror, v is positive, the image is virtual.

JAYA PHYSICS

7.Wave Optics

7.1 The wavelength of light from sodium source in vacuum is 5893Å.What are its (a) wavelength, (b) speed and (c) frequency when this light travels in water which has a refractive index of 1.33.

Given : $\lambda_A = 5893\ A^0,\ n_W = 1.3$

Solution:

(a) wavelength $n_W = \frac{\lambda_A}{\lambda_W}$

$$\lambda_W = \frac{\lambda_A}{n_W} = \frac{5893\ A^0}{1.33} = \frac{5893\ A^0}{4/3}$$

$$\lambda_W = \frac{5893 \times 3}{4} A^0 = 5893 \times 0.75 A^0$$

$$\boxed{\lambda_W = 4420\ A^0}$$

(b) speed

$$n_W = \frac{v_A}{v_W}$$

$$v_W = \frac{v_A}{n_W} = \frac{3 \times 10^8}{1.33} = \frac{3 \times 10^8}{4/3}$$

$$v_W = \frac{3 \times 10^8 \times 3}{4} A^0 = 3 \times 10^8 \times 0.75$$

$$\boxed{v_W = 2.25 \times 10^8\ ms^{-1}}$$

(c) frequency

$$\nu_A = \frac{C}{\lambda_a} = \frac{3 \times 10^8}{5893 \times 10^{-10}} = \frac{3 \times 10^{18}}{5893}$$

$$\nu_A = \frac{30000 \times 10^{14}}{5893} = 5 \times 10^{14} Hz$$

$$\boxed{\nu_W = \nu_A = 5 \times 10^{14} Hz}$$

7.2 Two light sources with amplitudes 5 units and 3 units respectively interfere with each other. Calculate the ratio of maximum and minimum intensities.

Given : $a_1 = 5, a_2 = 3$

Solution :

$$A_{max} = a_1 + a_2 = 5 + 3 = 8$$

$$A_{min} = a_1 - a_2 = 5 - 3 = 2$$

$$I \propto A^2$$

$$\frac{I_{max}}{I_{min}} = \frac{(A_{max})^2}{(A_{min})^2} = \frac{8^2}{2^2} = \frac{64}{4} = \frac{16}{1}$$

7.3 Two light sources of equal amplitudes interfere with each other. Calculate the ratio of maximum and minimum intensities. **Given :** $a_1 = a_2 = a$

Solution :

$$A_{max} = a_1 + a_2 = a + a = 2a$$

$$A_{min} = a_1 - a_2 = a - a = 0$$

$$I \propto A^2$$

$$\frac{I_{max}}{I_{min}} = \frac{(A_{max})^2}{(A_{min})^2} = \frac{(2a)^2}{0^2} = \frac{4a^2}{0}$$

7.4 Two light sources have intensity of light as $I0$. What is the resultant intensity at a point where the two light waves have a phase difference of $\pi/3$?

Given : $\Phi = \frac{\pi}{3}$

Solution:

The resultant intensity is $I = 4 I_0 C^2os \frac{\Phi}{2}$

$$I = 4 I_0 C^2os \frac{\frac{\pi}{3}}{2}$$

$$I = 4 I_0 C^2os \frac{\pi}{6}$$

$$I = 4 I_0 \left[\frac{\sqrt{3}}{2}\right]^2 = 4 I_0 \times \frac{3}{4} = 3I_0$$

7.5 The wavelength of a light is 450 nm. How much phase it will differ for a path of 3 mm?

Given : $\lambda = 450nm,\ \delta = 3mm$

Solution :

path difference	phase difference
λ	2π
δ	Φ

$$\Phi = \frac{2\pi.\delta}{\lambda} = \frac{2\pi \times 3 \times 10^{-3}}{450 \times 10^{-9}} = \frac{2\pi \times 3 \times 10^6}{450}$$

$$\Phi = \frac{\pi \times 10^6}{75} = \frac{3.14 \times 10^6}{75} = \frac{314 \times 10^4}{75}$$

$$\Phi = 4 \times 10^4 \text{ radian}$$

JAYA PHYSICS

7.6 In Young's double slit experiment, the two slits are 0.15 mm apart. The light source has a wavelength of 450 nm. The screen is 2 m away from the slits.

(a) Find the distance of the second bright fringe and also third dark fringe from the central maximum.

Given : $d = 0.15\text{ mm},\ D = 2m, \lambda = 450nm$

Solution : For n^th Bright fringe,

$$y_n = \frac{n\lambda D}{d}$$

$$y_2 = \frac{2 \times 450 \times 10^{-9} \times 2}{0.15 \times 10^{-3}} = \frac{45 \times 10^{-8} \times 4}{15 \times 10^{-5}}$$

$$y_2 = 3 \times 10^{-3} \times 4 = 12mm$$

For n^th dark fringe,

$$y_n = \frac{(2n-1)\lambda D}{2d}$$

$$y_3 = \frac{[2(3)-1] \times 450 \times 10^{-9} \times 2}{2 \times 0.15 \times 10^{-3}} = \frac{5 \times 45 \times 10^{-8} \times 2}{2 \times 15 \times 10^{-5}}$$

$$y_3 = 5 \times 3 \times 10^{-3} = 15\text{ mm}$$

7.6 In Young's double slit experiment, the two slits are 0.15 mm apart. The light source has a wavelength of 450 nm. The screen is 2 m away from the slits.
a)Find the fringe width.
b) How will the fringe pattern change if the screen is moved away from the slits?
c) What will happen to the fringe width if the whole setup is immersed in water of refractive index 4/3.
Given :$d = 0.15$ mm, $D = 2$m,$\lambda = 450$nm
Solution : a) fringe width

$$\beta = \frac{\lambda D}{d}$$

$$\beta = \frac{450 \times 10^{-9} \times 2}{0.15 \times 10^{-3}} = \frac{45 \times 10^{-8} \times 2}{15 \times 10^{-5}}$$

$$\beta = 3 \times 10^{-3} \times 2 = \mathbf{6mm}$$

b) fringe width $\beta \alpha D$
The fringe width will increase as D is increased,
c) **when light passes in any medium of refractive index n, wavelength of light λ decreases n times**
As fringe width β α λ, fringe width also decreases n times when passes in any medium of refractive index n.

$$\beta' = \frac{\beta}{n} = \frac{6mm}{4/3} = \mathbf{4.5mm}$$

7.7 Calculate the distance upto which ray optics is a good approximation for light of wavelength 500 nm falls on an aperture of width 0.5 mm.
Given :$a = 0.5$ mm, $\lambda = 500$nm
Solution:

$$z = \frac{a^2}{2\lambda} = \frac{[0.5 \times 10^{-3}]^2}{2 \times 500 \times 10^{-9}} = \frac{[5 \times 10^{-4}]^2}{2 \times 5 \times 10^{-7}}$$

$$z = \frac{25 \times 10^{-8}}{2 \times 5 \times 10^{-7}} = \frac{25 \times 10^{-1}}{10} = 25 \times 10^{-2}$$

$$\mathbf{z = 25\ cm}$$

7.8 A diffraction grating consists of 4000 slits per centimeter. It is illuminated by a monochromatic light. The second order diffraction maximum is produced at an angle of 30°. What is the wavelength of the light used?
Given :$\theta = 30^0$,$n = 2$

$$N = 5000 \frac{lines}{cm} = 5000 \times \frac{lines}{10^{-2}\ m} = 5 \times 10^5 \frac{lines}{m}$$

Solution:

$$\lambda = \frac{Sin\theta}{Nm} = \frac{Sin30^0}{5 \times 10^5 \times 2} = \frac{0.5}{10^6} = 0.5 \times 10^{-6}$$

$$\lambda = \mathbf{5000A^0}$$

7.9 Two polaroids are kept with their transmission axes inclined at 30°. Unpolarised light of intensity *I* falls on the first polaroid. Find out the intensity of light emerging from the second polaroid.
Solution :
intensity of light coming from the first polaroid(Polariser) $I_P = \frac{I}{2}$
intensity of light coming from the second polaroid (Analyser)

$$I_A = I_P \times C^2os\theta = \frac{I}{2}\ C^2os30^0 = \frac{I}{2} \times \left(\frac{\sqrt{3}}{2}\right)^2$$

$$I_A = \frac{I}{2} \times \frac{3}{4} = \frac{3I}{8}$$

7.10 Find the polarizing angles for (i) glass of refractive index 1.5 and (ii) water of refractive index 1.33.

$$\tan i_p = n \qquad \boxed{i_p = \tan^{-1} n}$$

For Glass $i_p = \tan^{-1} 1.5 = 56.3^0$

For water $i_p = \tan^{-1} 1.33 = 53.1^0$

7.11 What is the angle at which a glass plate of refractive index 1.65 is to be kept with respect to the horizontal surface so that an unpolarised light travelling horizontal after reflection from the glass plate is found to be plane polarised?
Solution : $\tan i_p = n \qquad \boxed{i_p = \tan^{-1} n}$

$$i_p = \tan^{-1} 1.65 = 58.8^0$$

The inclination with the horizontal surface

$$\theta = 90^0 - i_p = 90^0 - 58.8^0 = 31.2^0$$

7.12 Calculate the power of the lens of the spectacles needed to rectify the defect of nearsightedness for a person who could see clearly up to a distance of 1.8 m.
Solution :
The lens should have a focal length f = –x m = –1.8 m.
It is a concave (or) diverging lens.

$$P = \frac{1}{f} = \frac{1}{-1.8} = -0.56D$$

7.13 A person has farsightedness with the far distance he could see clearly is 75 cm. Calculate the power of the lens of the spectacles needed to rectify the defect.

$$f = \frac{25\ y}{y - 25} == \frac{25\ cm \times 75cm}{75cm - 25cm} = \frac{1875}{50} = 37.5\ cm$$

$$P = \frac{1}{f} = \frac{1}{37.5 \times 10^{-2}} = \frac{100}{37.5} = 2.6D$$

It is a convex (or) converging lens

7.14 The ratio of maximum and minimum intensities in an interference pattern is 36 : 1. What is the ratio of the amplitudes of the two interfering waves?

Given: $\frac{I_{max}}{I_{min}} = \frac{36}{1}$

Solution : $\frac{I_{max}}{I_{min}} = \frac{(A_{max})^2}{(A_{min})^2} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{36}{1}$

$$\frac{a_1 + a_2}{a_1 - a_2} = \frac{6}{1}$$

$$6a_1 - 6a_2 = a_1 + a_2$$

$$6a_1 - a_1 = 6a_2 + a_2$$

$$5a_1 = 7a_2$$

$$\boxed{\frac{a_1}{a_2} = \frac{7}{5}}$$

7.15 Light of wavelength of 5000Å produces diffraction pattern of the single slit of width 2.5 μm. What is the maximum order of diffraction possible?

Given : a = 2.5 μm, λ = 5000Å θ = 90

Solution : $n\lambda = a \sin\theta$

$$n = \frac{a \sin\theta}{\lambda} = \frac{2.5 \times 10^{-6} \times \sin 90^0}{5000 \times 10^{-10}} = \frac{25 \times 10^{-7} \times 1}{5 \times 10^{-7}}$$

$$\boxed{n = 5}$$

7.16 Light of wavelength 600 nm that falls on a pair of slits producing interference pattern on a screen in which the bright fringes are separated by 7.2 mm. What must be the wavelength of another light which produces bright fringes separated by 8.1 mm with the same apparatus?

Given : $\beta_1 = 7.2$mm, $\beta_2 = 8.1$mm, $\lambda_1 = 600$ nm

Solution :

$$\beta = \frac{\lambda D}{d} \qquad \beta \propto \lambda \qquad \boxed{\frac{\lambda_2}{\lambda_1} = \frac{\beta_2}{\beta_1}}$$

$$\lambda_2 = \frac{\beta_2}{\beta_1} \times \lambda_1 = \frac{8.1}{7.2} \times 600 \text{ nm} = \frac{9}{8} \times 600 \text{ nm}$$

$$\boxed{\lambda_2 = 675 \text{ nm}}$$

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8.Dual nature of matter and radiation

8.1 A radiation of wavelength 300 nm is incident on a silver surface. Will photoelectrons be observed? [work function of silver = 4.7 eV]

Given: λ=300nm =300 x $10^{-9}m$

Solution :

Energy of photon $E = h\nu = h\frac{c}{\lambda}$

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

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{300 \times 10^{-9} \times 1.6 \times 10^{-19}}\ eV$$

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$$= \frac{19.8 \times 10^{-26}}{480 \times 10^{-28}}\ eV$$

$$= \frac{19.8 \times 10^{2}}{480}\ eV = \frac{1980}{480}\ eV$$

$$E = 4.12\ eV$$

Since the **energy of the incident photon (4.12eV)is less than the work function of silver(4.7eV), photoelectrons are not emitted.**

8.2 Calculate the cut-off wavelength and cut-off frequency of x-rays from an x –ray tube of accelerating potential 20,000 V.

Solution :

The cut-off wavelength of x-rays in the continuous spectrum is

$$\lambda_0 = \frac{12400}{V}A^0$$

$$\lambda_0 = \frac{12400}{20000}A^0 = \frac{124}{200}A^0 = 0.62A^0$$

cut-off frequency of x-rays is

$$\nu_0 = \frac{c}{\lambda_0} = \frac{3 \times 10^{8}}{0.62 \times 10^{-10}}$$

$$\nu_0 = \frac{300 \times 10^{18}}{62} = 4.8 \times 10^{18}Hz$$

8.3 How many photons of frequency 10^{14} Hz will make up 19.86 J of energy?

Energy of single photon $E = h\nu$

Energy of 'n' number of photons $E = nh\nu$

$$E = 19.86$$

$$nh\nu = 19.86$$

$$n = \frac{19.86}{h\nu}$$

$$n = \frac{19.86}{6.6 \times 10^{-34} \times 10^{14}}$$

$$n = \frac{19.86}{6.6 \times 10^{-20}}$$

$$n = \frac{19.86}{6.6 \times 10^{-20}}$$

$$n = \frac{198.6 \times 10^{20}}{66}$$

$$n = 3 \times 10^{20} \text{photons}$$

8.4 How many photons per second emanate from a 50 *mW* laser of 640 *nm*?

$$E = 50 \times 10^{-3} Js^{-1}$$

$$nh\nu = 50 \times 10^{-3}$$

$$nh\frac{c}{\lambda} = 50 \times 10^{-3}$$

$$n = \frac{50 \times 10^{-3} \times \lambda}{hc}$$

$$n = \frac{50 \times 10^{-3} \times 640 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$$

$$n = \frac{50 \times 640 \times 10^{-12}}{19.8 \times 10^{-26}}$$

$$n = \frac{32000 \times 10^{14}}{19.8}$$

$$n \approx \frac{32 \times 10^{17}}{20}$$

$$n = 1.6 \times 10^{20} \text{photons } s^{-1}$$

8.5 When light of wavelength 2200Å falls on Cu, photo electrons are emitted from it. Find (i) the threshold wavelength and (ii) the stopping potential. Given: the work function for Cu is ϕ_0 = 4.65 eV.

Given: λ=2200 A^0 =2200 x $10^{-10}m$

$\phi_0 = 4.65eV = 4.65 \times 1.6 \times 10^{-19}J$

Solution :

ϕ_0 is the work function of metal

λ_0 is the threshold wavelength of metal

$$\phi_0 = h\nu_0 = h\frac{c}{\lambda_0}$$

$$\lambda_0 = \frac{hc}{\phi_0}$$

$$\lambda_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4.65 \times 1.6 \times 10^{-19}}$$

$$\lambda_0 = \frac{19.8 \times 10^{-26}}{4.65 \times 1.6 \times 10^{-19}}$$

$$\lambda_0 = \frac{19.8 \times 10^{-7}}{7.44}$$

$$\lambda_0 = \frac{19.8 \times 10^{-7}}{7.44}$$

$$\lambda_0 = \frac{198 \times 10^{-7}}{74}$$

$$\lambda_0 = 2.675 \times 10^{-7}$$

$$\lambda_0 = 2675 \times 10^{-10}$$

$$\lambda_0 = 2675\ A^0$$

Energy of photon $E = h\nu = h\frac{c}{\lambda}$

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

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{2200 \times 10^{-10} \times 1.6 \times 10^{-19}}\ eV$$

$$= \frac{19.8 \times 10^{-26}}{3520 \times 10^{-29}}\ eV$$

$$= \frac{19.8 \times 10^{3}}{3520}\ eV = \frac{19800}{3520}\ eV = \frac{1980}{352}\ eV$$

$$E = 5.65\ eV$$

By Einstein photoelectric equation

$$K_{max} = h\nu - \phi_0$$

$$K_{max} = 5.65\ eV - 4.65\ eV = 1eV$$

V_0 is the stopping potential of metal

$$eV_0 = K_{max}$$

$$V_0 = \frac{K_{max}}{e} = \frac{1eV}{e} = 1V$$

8.6 Calculate the momentum and the de Broglie wavelength in the following cases:

i) an electron with kinetic energy 2 eV.

Given: K=2eV =2 x 1.6 $\mathbf{x\ 10^{-19} J}$

Solution :

Relation between kinetic energy (K) and momentum (p) is

$$K = \frac{p^2}{2m} \qquad \mathbf{p^2 = 2\ m\ K}$$

$$\mathbf{p = \sqrt{2\ m\ K}}$$

$$= \sqrt{\mathbf{2x\ 9.11\ x\ 10^{-31} x\ 2\ x\ 1.6\ x\ 10^{-19}}}$$

$$= \sqrt{6.4 \text{ x } 9.1 \text{ x } 10^{-50}}$$

$$= \sqrt{58.24 \text{ x } 10^{-50}}$$

$$\mathbf{= 7.6\ x\ 10^{-25} kg\ m\ s^{-1}}$$

De Broglie wavelength (λ) is

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$$\boldsymbol{\lambda} = \frac{\mathbf{h}}{\mathbf{p}} = \frac{\mathbf{6.6\ x\ 10^{-34}}}{\mathbf{7.6\ x\ 10^{-25}}}$$

$$\lambda = \frac{66 \text{ x } 10^{-9}}{76} \qquad \lambda = 0.86 \text{ x } 10^{-9}\text{m}$$

$$\boldsymbol{\lambda} = \mathbf{8.6\ x\ 10^{-10} m} \qquad \boldsymbol{\lambda = 8.6\ A^0}$$

8.7 Light of wavelength 390 nm is directed at a metal electrode. To find the energy of electrons ejected, an opposing potential difference is established between it and another electrode. The current of photoelectrons from one to the other is stopped completely when the potential difference is 1.10 V. Determine i) the work function of the metal and ii) the maximum wavelength of light that can eject electrons from this metal.

Given: λ=390nm =390 $\mathbf{x\ 10^{-9}} \boldsymbol{m}$

Stopping potential $\boldsymbol{V_0} = \mathbf{1.1V}$

Solution :

By Einstein photoelectric equation

$$K_{max} = h\nu - \phi_0$$

$$\phi_0 = h\frac{c}{\lambda} - K_{max}$$

If V_0 is the stopping potential of metal, then $\quad e\,V_0 = K_{max}$

$$\boldsymbol{\phi_0} = \frac{\mathbf{hc}}{\boldsymbol{\lambda}} - \mathbf{e\ V_0}$$

$$\boldsymbol{\phi_0} = \frac{\mathbf{6.6\ x\ 10^{-34} x\ 3\ x\ 10^8}}{\mathbf{390\ x\ 10^{-9}}} - \mathbf{1.6x\ 10^{-19} x\ 1.1}$$

$$\phi_0 = \frac{19.6 \text{ x } 10^{-26}}{390 \text{ x } 10^{-9}} - 1.76 \text{ x } 10^{-19}$$

$$\phi_0 = \frac{19.6 \text{ x } 10^{-17}}{390} - 1.76 \text{ x } 10^{-19}$$

$$\phi_0 = \frac{196 \text{ x } 10^{-19}}{39} - 1.76 \text{ x } 10^{-19}$$

$$\phi_0 = 5\text{x } 10^{-19} - 1.76 \text{ x } 10^{-19}$$

$$\boldsymbol{\phi_0} = \mathbf{3.24\ x\ 10^{-19} J}$$

ii) the maximum wavelength

$$\phi_0 = h\nu_0, \qquad \phi_0 = h\nu_{min} \qquad \phi_0 = h\frac{c}{\lambda_{max}}$$

$$\boldsymbol{\lambda}_{\mathbf{max}} = \frac{\mathbf{hc}}{\boldsymbol{\phi_0}}$$

$$\boldsymbol{\lambda}_{\mathbf{max}} = \frac{\mathbf{6.6\ x\ 10^{-34} x\ 3\ x\ 10^8}}{\mathbf{3.24\ x\ 10^{-19}}}$$

$$\lambda_{max} = \frac{19.8 \text{ x } 10^{-7}}{3.24} = \frac{198 \text{ x } 10^{-7}}{32}$$

$$\lambda_{max} = \frac{198 \text{ x } 10^{-7}}{32} \qquad \lambda_{max} = 6 \text{ x } 10^{-7} m$$

$$\lambda_{max} = 6000 \text{ x } 10^{-10} m \qquad \boldsymbol{\lambda}_{\mathbf{max}} = \mathbf{6000}\ \boldsymbol{A^0}$$

8.8 Find the de Broglie wavelength associated with an alpha particle which is accelerated through a potential difference of 400 V. Given that the mass of the proton is 1.67 × 10^{-27} kg.

Given: $\boldsymbol{m_p}$ = 1.67 $\mathbf{x\ 10^{-27}} \boldsymbol{kg}$

mass *M* of the alpha particle is 4 times that of a proton

charge q of the alpha particle is 2 times that of a proton

Solution :

$$\boldsymbol{\lambda} = \frac{\mathbf{h}}{\sqrt{\mathbf{2}\ \boldsymbol{M\ q\ V}}} = \frac{h}{\sqrt{2 \text{ x } 4\ m_p \text{x } 2eV}}$$

$$\boldsymbol{\lambda} = \frac{\mathbf{h}}{\sqrt{\mathbf{2\ x\ 4\ m_p x\ 2\ e\ V}}}$$

$$\boldsymbol{\lambda} = \frac{\mathbf{6.6\ x\ 10^{-34}}}{\mathbf{4x}\sqrt{\mathbf{1.67\ x\ 10^{-27} x\ 1.67\ x\ 10^{-19}\ x400}}}$$

$$\lambda = \frac{6.6 \text{ x } 10^{-34}}{4 \text{ x } 20 \text{ x} \sqrt{1.6 \text{ x } 10^{-27} \text{x } 1.6 \text{ x } 10^{-19}}}$$

$$\lambda = \frac{6.6 \text{ x } 10^{-34}}{80\text{x } 1.6\sqrt{10^{-46}}} = \frac{6.6 \text{ x } 10^{-34}}{80\text{x } 1.6 \text{ x} 10^{-23}}$$

$$\lambda = \frac{6.6 \text{ x } 10^{-11}}{128} \qquad \lambda = 0.051\text{x } 10^{-11}$$

$$\lambda = 0.0051\text{x } 10^{-10} m \qquad \boldsymbol{\lambda} = \mathbf{0.0051}\ \boldsymbol{A^0}$$

JAYA PHYSICS

9.Atomic and nuclear physics

9.1 The radius of the 5th orbit of hydrogen atom is 13.25 Å. Calculate the de broglie wavelength of the electron orbitting in the 5th orbit.

Given: r=13.25 Å =13.25 x $10^{-10} m$

The circumference of an electron's orbit of radius *r* must be an integral multiple of de Broglie wavelength

Solution :

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$$2\pi r = n\lambda$$

$$\lambda = \frac{2\pi r}{n}$$

$$\lambda = \frac{2 \times 3.14 \times \cancel{13.25}^{2.65} \times 10^{-10}}{\cancel{5}}$$

$$\lambda = 6.28 \times 2.65 \times 10^{-10} = 16.642 \times 10^{-10} \text{m}$$

$$\lambda = 16.642\ A^0$$

9.2 Find the (i) angular momentum (ii) velocity of the electron revolving in the 5th orbit of hydrogen atom. (h = 6.6 × 10^{-34} Js, m = 9.11 × 10^{-31} kg)

The angular momentum of an electron must be an integral multiple of nh/2π

Solution :

Angular momentum of electron] $\ell = \frac{n h}{2\pi} = \frac{5 \times 6.6 \times 10^{-34}}{2 \times 3.14}$

$$\ell = \frac{33 \times 10^{-34}}{6.28} = \frac{3300 \times 10^{-34}}{628}$$

$$\ell = 5.25 \times 10^{-34} \text{ kg m}^2\text{s}^{-1}$$

Radius of nth orbit] $r_n = n^2 \times 0.529\ A^0$

$$r_5 = 5^2 \times 0.53\ A^0 = 25 \times 0.53\ A^0$$

$$r_5 = 13.25\ A^0$$

Angular momentum of a circulating particle

$$\ell = m v r$$

$$v = \frac{\ell}{m r} = \frac{5.25 \times 10^{-34}}{9.11 \times 10^{-31} \times 13.25 \times 10^{-10}}$$

$$v = \frac{5.25}{9.11 \times 13.25} \times 10^7$$

$$v = \frac{5.25}{9.1 \times 13.3} \times 10^7$$

$$v = \frac{5.3}{121.03} \times 10^7$$

$$v \approx \frac{5300}{121} \times 10^4 \qquad v = 43.8 \times 10^4 \text{ m s}^{-1}$$

9.3 Calculate the radius of $^{197}_{79}Au$ ucleus

Nuclear radius

$$R = R_0 A^{\frac{1}{3}}$$

$$R = 1.2 \times 10^{-15} (197)^{\frac{1}{3}}$$

$$R = 1.2 \times 10^{-15} \times 5.8$$

$$R = 6.96 \times 10^{-15} \text{ m}$$

$$R = 6.96 \text{ F}$$

For you to understand

R_0 = 1.2 fermi

$R_0 = 1.2 \times 10^{-15}$m

$5^3 = 125$

$6^3 = 216$

9.4Calculate the number of nuclei of carbon-14 undecayed after 22,920 years if the initial number of carbon-14 atoms is 10,000. The half-life of carbon-14 is 5730 years.

N_o original no of nuclei, N is no of undecayed nuclei

Solution :

$$\text{number of decays} = \frac{\text{Total half life period}}{\text{half life period}}$$

$$n = \frac{T}{T_{1/2}} = \frac{22920}{5730} = 4 \text{ decays}$$

number of remaining or undecayed nuclei] $N = \left[\frac{1}{2}\right]^n N_o$

$$N = \left[\frac{1}{2}\right]^4 \times 10000$$

$$N = \frac{1}{16} \times 10000 \qquad N = 625 \text{ atoms}$$

9.5Half lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially, the samples have equal number of nuclei. Calculate the ratio of decayed numbers of A and B nuclei after 80 minutes.

Solution :

$$\text{Number of decays} = \frac{\text{Total half life period}}{\text{half life period}} \qquad n = \frac{T}{T_{1/2}}$$

$$n_A = \frac{T}{T_{1/2_A}} = \frac{80}{20} = 4 \text{ decays}$$

$$n_B = \frac{T}{T_{1/2_B}} = \frac{80}{40} = 2 \text{ decays}$$

number of decayed nuclei] $= N_o - N = N_o - \left[\frac{1}{2}\right]^n N_o$

number of decayed A nuclei] $= N_o - \left[\frac{1}{2}\right]^4 N_o = N_o - \frac{1}{16} N_o = \frac{15}{16} N_o$

number of decayed B nuclei] $= N_o - \left[\frac{1}{2}\right]^2 N_o = N_o - \frac{1}{4} N_o = \frac{3}{4} N_o$

ratio of decayed numbers of A and B nuclei] $= \frac{\frac{15}{16}\cancel{N_o}}{\frac{3}{4}\cancel{N_o}} = \frac{5}{4}$

9.6 Calculate the time required for 60% of a sample of radon undergo decay. Given $T12$ /of radon =3.8 days

Given 60% of a sample of radon undergoes decay

40% of a sample of radon is remaining

Solution :

$N_o = 100\,\%$ **and** $N = 40\%$

decay constant of radioactive element radon $\left.\right]$ $\lambda = \frac{0.6931}{T_{\frac{1}{2}}}$

$$\lambda = \frac{0.6931}{3.8}/day$$

$$N = N_o \,.\, e^{-\lambda t}$$

$$\frac{N}{N_o} = e^{-\lambda t}$$

$$\frac{N}{N_o} = \frac{1}{.\,e^{\lambda t}}$$

$$e^{\lambda t} = \frac{N_o}{N}$$

$$\lambda t = \ln\left[\frac{N_o}{N}\right]$$

$$t = \frac{\ln\left[\frac{N_o}{N}\right]}{\lambda}$$

$$t = \frac{ln\left[\frac{100}{40}\right]}{\frac{0.6931}{3.8}}$$

$$t = ln[2.5]\text{ x }\frac{3.8}{0.6931}$$

$$t = 0.9162\text{ x }\frac{3.8}{0.6931}$$

$$t = 0.9162\text{ x }\frac{3.8}{0.6931}$$

$$t = 0.92\text{ x }\frac{3.8}{0.7}$$

$$t = 5.022\text{ days}$$

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9.7 Calculate the radius of the earth if the density of the earth is equal to the density of the nucleus.[mass of earth 5 .97 x 10^{24} kg].

nuclear density $= 2.3\text{ x }10^{17}\ kg\ m^{-3}$

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

$$\frac{4}{3}\pi R^3 = \frac{\text{mass}}{\text{density}}$$

$$R^3 = \frac{\text{mass}}{\text{density}}\text{ x }\frac{3}{4\,\pi}$$

$$R^3 = \frac{5.97\text{ x }10^{24}}{2.3\text{ x }10^{17}}\text{ x }\frac{3}{4\text{ x }3.14}$$

$$R^3 \approx \frac{6\text{ x }10^{24}}{2.3\text{ x }10^{17}}\text{ x }\frac{3}{4\text{ x }3}$$

$$R^3 = \frac{18\text{ x }10^7}{27.6}$$

$$R^3 = \frac{180\text{ x }10^6}{27.6}$$

$$R^3 = 6.52\text{x }10^6$$

$$R = 1.8\text{x }10^2$$

$$R \approx 180\ m$$

10 electronics and Communication

10.1Determine the wavelength of light emitted from LED which is made up of GaAsP semiconductor whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Take h = 6.6 × 10–34 Js).

Given E = 1.875 eV = 1.875 x 1.6x 10^{-19}J

Solution :

$$\lambda = \frac{h\,c}{E} = \frac{6.6\text{ x }10^{-34}\text{x }3\text{ x }10^{8}}{1.875\text{ x }1.6\text{x }10^{-19}} = 660\text{ nm}$$

10.2 In a transistor connected in the common base configuration, α=095., I_E=1mA. Calculate the values of $I_C$and I_B.

Solution :

$$\alpha = \frac{I_C}{I_E}$$

$$I_C = \alpha I_E = 0.95\text{ x}1 = 0.95\text{mA}$$

$$I_E = I_B + I_C$$

$$I_B = I_E - I_C = 1 - 0.95 = 0.05\text{mA}$$