CLASS XII (2019-20)
PHYSICS (042)
SAMPLE PAPER-2

Time : 3 Hours **Maximum Marks : 70**

General Instructions :

(i) All questions are compulsory. There are 37 questions in all.

(ii) This question paper has four sections: Section A, Section B, Section C, Section D.

(iii) Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each and Section D contains three questions of five marks each.

(iv) There is no overall choice. However, internal choices has been provided in two question of one marks each, two question of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^8$ m/s, $h = 6.63 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C, $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1},

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}, $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^{2}C^{-2}, $m_e = 9.1 \times 10^{-31}$ kg,

Mass of neutron $= 1.675 \times 10^{-27}$ kg,

Mass of proton $= 1.673 \times 10^{-27}$ kg, Avogardro's number $= 6.023 \times 10^{23}$ per gram mole,

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}.

Section A

DIRECTION : (Q 1-Q 10) Select the most appropriate option from those given below each question

1. Nickel is **(1)**

(a) diamagnetic (b) paramagnetic

(c) ferromagnetic (d) none of these

Ans : (c) ferromagnetic

The substances which get strongly magnetised when placed in an external magnetic field are called ferromagnetic. Nickel shows the above properties so it is a ferromagnetic substance.

2. To convert mechanical energy into electrical energy one can use **(1)**

(a) D.C. dynamo (b) A.C. dynamo

(c) Motor (d) Transformer

Ans : (b) A.C. dynamo

An AC dynamo or generator produces electrical energy from mechanical work, just the opposite of what a motor does. In it a shaft is rotated by some mechanical means such as an engine or a turbine starts working and an emf is induced in the coil.

3. According to the Maxwell's displacement current law, a changing electric field is source of **(1)**

(a) an e.m.f. (b) magnetic field

(c) pressure gradient (d) all of these

Ans : (b) magnetic field

We know according to the Maxwell's displacement current law that a changing electric field is a source of magnetic field.

4. Which of the following phenomena taken place when a monochromatic light is incident on a prism? **(1)**

(a) Dispersion (b) Deviation

(c) Interference (d) All of these

Ans : (a) Dispersion

Dispersion phenomena taken place when a monochromatic light is incident on a prism.

5. When two converging lenses of same focal f are placed in contact, the focal length of the combination is. **(1)**

(a) f (b) $2f$

(c) $\frac{f}{2}$ (d) $3f$

Ans : (c) $\dfrac{f}{2}$

We know that,

Focal length of combination of lens is given by,

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

Here, $f_1 = f_2 = f$

Then, $$\frac{1}{f_{eq}} = \frac{1}{f} + \frac{1}{f}$$

$$\frac{1}{f_{eq}} = \frac{1+1}{f}$$

$$f_{eq} = \frac{f}{2}$$

6. The wave front due to a point source a finite distance from the source is- **(1)**

(a) Spherical (b) Cylindrical

(c) Plane (d) Circular

Ans : (a) Spherical

When the light source is of point type, then at any instant of finite distance, the locus of all the particles vibrating with same phase in a sphere. In this condition, the wavefront will be a spherical wave front.

7. On disintegration of one atom of U-235, the amount of energy obtained is 200 MeV. The power obtained in a reactor is 1000 kW. How many atoms are dps ? **(1)**

(a) 3.125×10^{8} (b) 3.125×10^{16}

(c) 3.125×10^{24} (d) 3.125×10^{32}

Ans : (b) 3.125×10^{16}

Given, Energy obtained per disintegration,

$$E = 200\,\text{MeV}$$
$$= 200 \times 10^{6} \times (1.6 \times 10^{-19})$$
$$= 3.2 \times 10^{-11}\,\text{J}$$

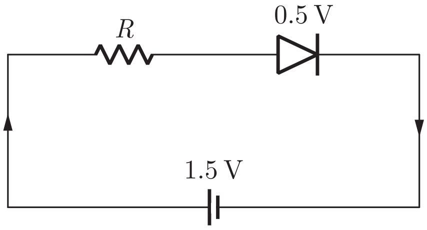
and power obtained in the reactor,

$$P = 1000\,\text{kW} = 10^{6}\,\text{W}$$
$$= 6.25 \times 10^{24}\,\text{eV-s}^{-1}$$
$$= 6.25 \times 10^{18}\,\text{MeV-s}^{-1}$$

We know that number of dps,

$$n = \frac{P}{E}$$
$$= \frac{10^{6}}{3.2 \times 10^{-11}}$$
$$= 3.125 \times 10^{16}$$

8. The p-n junction diode used in the circuit shown in the figure has a constant voltage drop at 0.5 V at all currents and a maximum power rating of 100 mW. What should be the value of the resistor R, connected in series and with p-n junction diode for obtaining maximum current? **(1)**



(a) $5\,\Omega$ (b) $10\,\Omega$

(c) $15\,\Omega$ (d) $20\,\Omega$

Ans : (a) $5\,\Omega$

Given, Voltage drop across diode,

$$V_D = 0.5\,\text{V}$$

Maximum power rating of diode,

$$P = 100\,\text{mW}$$
$$= 100 \times 10^{-3}\,\text{W}$$

and source voltage,

$$V_S = 1.5\,\text{V}$$

We know that resistance of diode

$$R_D = \frac{V_D^2}{P} = \frac{(0.5)^2}{100 \times 10^{-3}}$$
$$= 2.5\,\Omega$$

And current in diode,

$$I_D = \frac{V_D}{R_D} = \frac{0.5}{2.5} = 0.2\,\Omega$$

Therefore, total resistance in circuit,

$$R_S = \frac{V_S}{I_D} = \frac{1.5}{0.2} = 7.5\,\Omega$$

And the value of series resistor,

$$R = R_S - R_D$$
$$= 7.5 - 2.5 = 5\,\Omega$$

9. A spherical capacitor has inner sphere of radius 12 cm and an outer sphere of radius 13 cm. The outer sphere is earthed and the inner sphere has a charge of 2.5 μC. If space between the concentric spheres is filled with a liquid of dielectric constant 32, then the capacitance of the capacitor is **(1)**

(a) $4.5 \times 10^{-9}\,\text{F}$ (b) $5.5 \times 10^{-9}\,\text{F}$

(c) $6.5 \times 10^{-9}\,\text{F}$ (d) $7.5 \times 10^{-9}\,\text{F}$

Ans : (b) $5.5 \times 10^{-9}\,\text{F}$

Given, Radius of inner sphere,

$$r_1 = 12\,\text{cm} = 0.12\,\text{m}$$

Radius of outer sphere, $r_2 = 13\,\text{cm} = 0.13\,\text{m}$

Charge of inner sphere, $q = 2.5\,\mu\text{C}$

$$= 2.5 \times 10^{-6}\text{C}$$

and dielectric constant of liquid,

$$\varepsilon = 32$$

We know that capacitance of a spherical capacitor with a dielectric,

$$C = 4\pi\varepsilon_0\varepsilon\left(\frac{r_1 r_2}{r_2 - r_1}\right)$$

Where, $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\,\text{N-m}^{-2}\text{-C}^{-2}$

$$= \frac{1}{9 \times 10^9} \times 32 \times \left(\frac{0.12 \times 0.13}{0.13 - 0.12}\right)$$

$$= 5.5 \times 10^{-9}\,\text{F}$$

10. Light passes successively through two polarimeter tubes each of length $0.29\,\text{m}$. The first tube contains dextro rotatory solution of concentration $60\,\text{kg} - \text{m}^{-3}$ and specific rotation $0.01\,\text{rad} - \text{m}^2 - \text{kg}^{-1}$. The second tube contains laevo rotatory solution of concentration $30\,\text{kg} - \text{m}^{-3}$ and specific rotation $0.02\,\text{rad} - \text{m}^2 - \text{kg}^{-1}$. The net rotation produced is **(1)**

(a) 0° (b) 10°

(c) 15° (d) 20°

Ans : (a) 0°

Given, Length of each polarimeter tube,

$$l = 0.29\,\text{m}$$

Concentration of dextro rotatory solution in first tube,

$$C_1 = 60\,\text{kg} - \text{m}^{-3}$$

Specific rotation of dextro solution

$$s_1 = 0.01\,\text{rad} - \text{m}^2 - \text{kg}^{-1}$$

Concentration of Laevo rotatory solution in second tube,

$$C_2 = 30\,\text{kg} - \text{m}^{-3}$$

and specific rotation of laevo solution,

$$s_2 = 0.02\text{rad} - \text{m}^2 - \text{kg}^{-1}$$

We know that rotation of vibration plane due to dextro rotatory solution,

$$\theta_1 = s_1 l C_1$$
$$= 0.01 \times 0.29 \times 60$$
$$= 0.17^\circ \text{ (towards right)}$$

Similarly, rotation of the vibration plane due to Laevo rotatory solution,

$$\theta_2 = s_2 l C_2$$
$$= 0.02 \times 0.29 \times 30$$
$$= 0.17^\circ \text{ (towards left)}$$

Therefore net rotation produced,

$$\theta = \theta_1 - \theta_2 = 0.17^\circ - 0.17^\circ$$
$$= 0^\circ$$

DIRECTION : (Q11-Q15) Fill in the blanks with appropriate answer.

11. The AC voltage across a resistance can be measured using a .... **(1)**

Ans : hot-wire voltmeter

The AC voltage across a resistance can be measured using a hot wire voltmeter, where deflection is proportional to square of current ($\phi \propto i^2$).

12. In the Bohr's atomic model of hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in n^{th} quantum state is .... **(1)**

Ans : -1

We know that kinetic energy of electron in n^{th} state,

$$K_n = \frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

and potential energy of electron in n^{th} state,

$$U_n = -\frac{me^4}{4\varepsilon_0^2 n^2 h^2}$$

Therefore, total energy of the electron in n^{th} state,

$$E = K_n + U_n$$
$$= \frac{me^4}{8\varepsilon_0^2 n^2 h^2} - \frac{me^4}{4\varepsilon_0^2 n^2 h^2}$$
$$= -\frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

Therefore, ratio of kinetic energy to total energy of the electron

$$= \frac{\left(\frac{me^4}{8\varepsilon_0^2 n^2 h^2}\right)}{\left(-\frac{me^4}{8\varepsilon_0^2 n^2 h^2}\right)} = -1$$

13. For a transistor working as common-base amplifier, the emitter current is $7.2\,\text{mA}$. If the current gain is 0.96, then the collector current is .... **(1)**

Ans : $6.91\,\text{mA}$

Given, Emitter current, $I_E = 7.2\,\text{mA}$

And current gain, $\alpha = 0.96$

We know that collector current in common-base amplifier,

$$I_C = \alpha I_E$$
$$= 0.96 \times 7.2 = 6.91\,\text{mA}$$

14. n identical small spherical drops, each of radius r are charged to same potential V. They are combined to form a bigger drop. The potential of the big drop will be .... **(1)**

Ans : $n^{2/3}V$

Given, Number of small drops $= n$

Radius of each small drop $= r$

andPotential of each small drop$= V$

Since, volume of n small drops remains same after forming the big drop.

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

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

We also know that, charge on big drop,

$$q_2 = nq_1$$

We also know that, potential of a spherical drop,

$$V = k \cdot \frac{q}{r} \propto \frac{q}{r}$$

Therefore, $$\frac{V_1}{V_2} = \frac{q_1}{q_2} \times \frac{r_2}{r_1}$$

$$= \frac{q_1}{nq_1} \times \frac{n^{1/3} r}{r} = \frac{1}{n^{2/3}}$$

$$V_2 = n^{2/3} V_1 = n^{2/3} V$$

where, $V_2 =$ Potential of big drop

$q_1 =$ Charge on small drop

$R =$ Radius of big drop

15. Two wires of the same dimensions but resistivities ρ_1 and ρ_2 are connected in series. The equivalent resistivity of the combination is .... **(1)**

Ans : $\dfrac{\rho_1 + \rho_2}{2}$

Given, Resistivity of first wire $= \rho_1$

Resistivity of second wire $= \rho_2$

Length of each wire, $l = l_1 = l_2$

And area of cross-section of each wire,

$$A = A_1 = A_2$$

We know that resistance of first wire,

$$R_1 = \rho_1 \frac{l_1}{A_1} = \rho_1 \frac{l}{A}$$

Similarly, resistance of second wire,

$$R_2 = \rho_2 \frac{l_2}{A_2} = \rho_2 \frac{l}{A}$$

Since, the wires are connected in series, therefore equivalent resistance of the combination,

$$R = R_1 + R_2$$
$$= \rho_1 \frac{l}{A} + \rho_2 \frac{l}{A}$$
$$= (\rho_1 + \rho_2)\frac{l}{A} \qquad ...(1)$$

We also know that resistance of two wires in series combination,

$$R = \rho_{eq} \frac{(l_1 + l_2)}{A}$$
$$= \rho_{eq} \frac{l + l}{A} = 2\rho_{eq} \frac{l}{A} \qquad ...(2)$$

Equating equations (1) and (2),

$$2\rho_{eq} = \rho_1 + \rho_2$$

or, $$\rho_{eq} = \frac{\rho_1 + \rho_2}{2}$$

where, ρ_{eq} = Equivalent resistivity of the combination.

or

An electron of mass 9.1×10^{-31} kg under the action of a uniform magnetic field moves in a circle of radius 2 cm at a velocity of $3 \times 10^6\,\text{m} - \text{s}^{-1}$. If a proton of mass 1.67×10^{-27} kg were to move in a circle of the same radius in the same magnetic field, then its speed would be ....

Ans : $1.6 \times 10^3\,\text{m} - \text{s}^{-1}$

Given, Mass of electron,

$$m_e = 9.1 \times 10^{-31}\,\text{kg}$$

Radius of electron, $r_e = 2\,\text{cm} = 0.02\,\text{m}$

Velocity of electron, $v_e = 3 \times 10^6\,\text{m} - \text{s}^{-1}$

Mass of proton, $m_p = 1.67 \times 10^{-27}\,\text{kg}$

and, Radius of proton, $r_p = 0.02\,\text{m}$

We know that velocity of charged particle in circular path when it moves in uniform magnetic field,

$$v = \frac{Bqr}{m} \propto \frac{1}{m}$$

Therefore, $$\frac{v_e}{v_p} = \frac{m_p}{m_e}$$

$$v_p = \frac{m_e}{m_p} \times v_e$$

$$= \frac{9.1 \times 10^{-31}}{1.67 \times 10^{-27}} \times (3 \times 10^6)$$

$$= 1.6 \times 10^3\,\text{m} - \text{s}^{-1}$$

where, $v_p =$ Velocity of proton

DIRECTION : (Q16-Q20) Answer the following:

16. The lab instructor told a student that in a galvanometer a coil has been wrapped on a conducting frame. Why? Which value is shown by the lab instructor?

Ans :

Eddy currents in conducting frame help in stopping the coil soon, i.e. in making the galvanometer dead beat. Value shown by lab instructor is 'Imparting knowledge to students'. **(1)**

17. The horizontal component of earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of earth's magnetic field at this place?

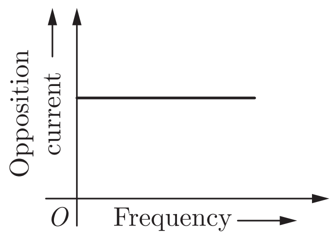
Ans :

Vertical component of earth's magnetic field,

$$B_v = B\sin\theta = B\sin 60^\circ$$

$$= \frac{\sqrt{3}}{2}B \qquad \textbf{(1)}$$

18. The graph given below represents the variation of the opposition offered by the circuit element to the flow of alternating current with the frequency of the applied emf. Identify the circuit element.



Ans :

From graph, it is clear that resistance (opposition to current) is not changing with frequency, i.e. resistance does not depend on frequency of applied voltage, so the circuit element here is pure resistance. **(1)**

19. A converging lens is kept coaxially in contact with a diverging lens both the lenses being of equal focal lengths. What is the focal length of the combination?

Ans :

Let f and $-f$ be focal lengths of the converging and the diverging lenses, respectively.

Then, focal length of the combination is given by

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{-f}$$

or $\qquad \frac{1}{F} = 0$

$$F = \infty$$

The focal length of the combination is infinite. **(1)**

20. A 10 m long horizontal straight wire extending from East to West is falling with a speed of 5m/s at right angles to the horizontal component of the Earth's magnetic field of 0.30×10^{-4} Wbm^{-2}. What is the instantaneous value of the emf induced in the wire?

Ans :

Given, $\qquad l = 10$ m

$$V = 5 \text{ ms}^{-1}$$

$$B_H = 0.30 \times 10^{-4} \text{ Wbm}^{-2}$$

Instantaneous value of the emf induced in the wire,

$$e = B_H lV$$

$$= 0.30 \times 10^{-4} \times 10 \times 5$$

$$= 1.5 \times 10^{-3} \text{ V} \qquad \textbf{(1)}$$

or

An alternating current in a circuit is given by, $I = 20\sin(100\pi t + 0.05\pi)$ A. What is the rms value of current?

Ans :

Given, $\qquad I = 20\sin(100\pi t + 0.05\pi)$ A

rms value of current is,

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

Here, $\qquad I_0 = 20$

$$I_{\text{rms}} = \frac{20}{\sqrt{2}} = 10\sqrt{2} \text{ A}$$

Section B

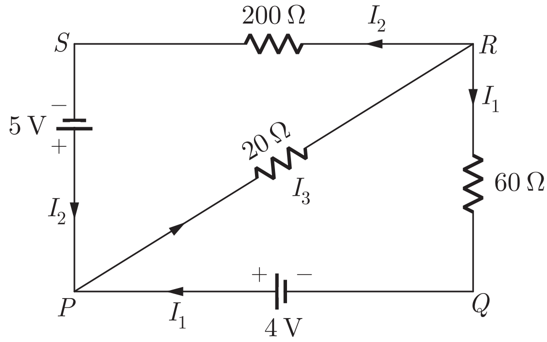
21. Guess a possible reason, why water has a much greater dielectric constant than mica?

Ans :

Dielectric constant of water is much greater than that of mica because of the following reasons

1. Water has a symmetrical shape as compared to mica
2. Water has permanent dipole moment. **(1+1)**

22. Apply Kirchhoff's laws to the loops *PRSP* and *PRQP* to write the expressions for the currents I_1, I_2 and I_3 in the given circuit.



Ans :

Apply Kirchhoff's Ist law,

$$I_3 = I_2 + I_1 \qquad \textbf{(1/2)}$$

Applying Kirchhoff's IInd law to loop $PRSP$,

$$-20I_3 - 200I_2 + 5 = 0$$

$$40I_2 + 4I_3 = 1 \qquad \textbf{(1/2)}$$

Applying Kirchhoff's IInd law to loop $PRQP$
,

$$-20I_3 - 60I_1 + 4 = 0 \qquad \textbf{(1)}$$

$$15I_1 + 5I_3 = 1$$

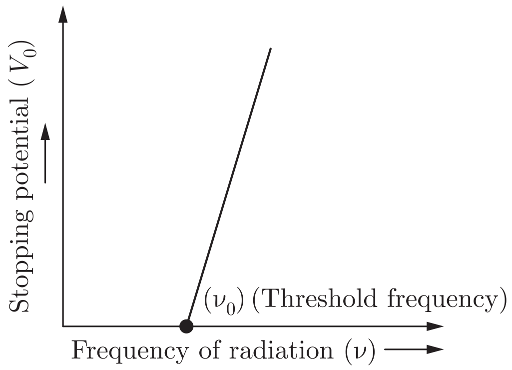
23. Write Einstein's photoelectric equation. Plot a graph showing the variation of stopping potential versus the frequency of incident radiation.

Ans :

Einstein's photoelectric equation is

$$h(v - v_0) = eV_0 \qquad \textbf{(1)}$$

Where, v_0 is the threshold frequency, v is the frequency of incident radiation, h is Plank's constant and V_0 is the stopping potential $v_0 - v$ graph is shown below



(1)

24. An electron and a proton have the same kinetic energy. Which of the two has a greater wavelength? Explain.

Ans :

We know that de-Broglie wavelength is given by

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}} \qquad \textbf{(1)}$$

As, $m_p > m_e$, thus it is clear that for same kinetic energy,

$$\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$$

$\lambda_e > \lambda_p$, i.e. de-Broglie wavelength of electron will be greater than that of a proton. **(1)**

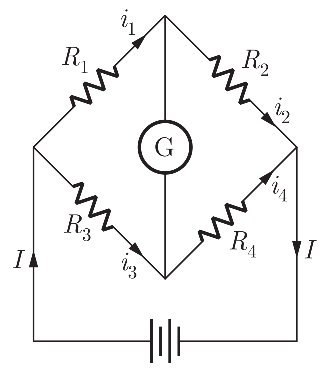
25. (i) State Kirchhoff's loop rule for an electrical network.

(ii) State principle of working of a meter bridge.

Ans :

(i) Kirchhoff's loop rule: In an electric circuit, the algebraic sum of change in potential differences across the circuit elements of any closed loop is zero. **(1)**

(ii) Meter bridge works on the principle of a balanced wheatstone bridge.
According to this,



When the bridge is in the balance condition, i.e.,

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

No current flows in the galvanometer. This can be used to find the unknown resistance, when the galvanometer shows zero deflection. **(1)**

26. Calculate the distance of an object of height (h) from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification 2.

Ans :

Given, $\qquad f = -10\,\text{cm},\ m = -2$

$$m = -\frac{v}{u}$$

$$-2 = -\frac{v}{u}$$

$$v = 2u \qquad \textbf{(1)}$$

Using mirror formula,

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

$$\frac{1}{2u}+\frac{1}{u} = \frac{1}{-10}$$

$$\frac{3}{2u} = -\frac{1}{10}$$

$$u = -15\,\text{cm}$$

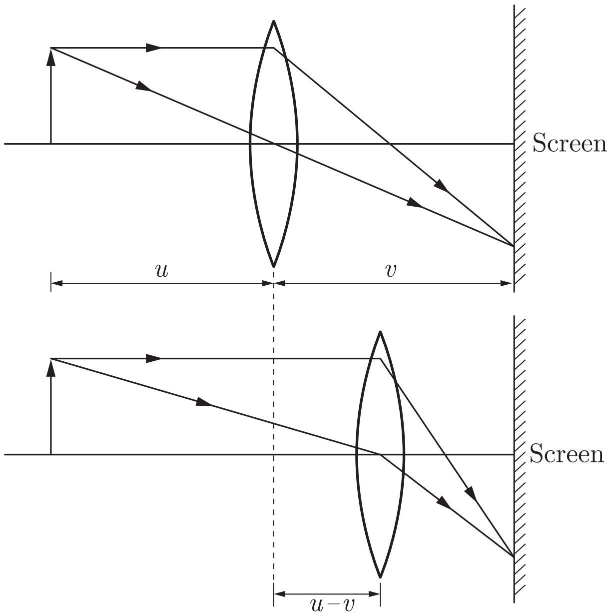
Thus, the object is placed in front of concave mirror at a distance of 15 cm **(1)**

or

A screen is placed 90 cm from an object. The image is obtained on the screen by a convex lens at two different locations separated by 20 cm. Determine the focal length of lens.

Ans :

The two situation can be drawn as below.



From question, it is given that,

$$u + v = 90 \qquad \text{...(i)}$$

and $u - v = 20$ ...(ii)

Solving eqs. (i) and (ii), we get

$$u = 55 \text{ cm and } v = 35 \text{ cm} \qquad \textbf{(1)}$$

Using sign convension and lens formula, the focal length of lens is

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

$$= \frac{1}{35} - \frac{1}{(-55)}$$

$$= \frac{90}{35 \times 55}$$

$$\Rightarrow \quad f = 21.39 \text{ cm} \qquad \textbf{(1)}$$

27. Calculate the binding energy per nucleon of nucleus ${}_{20}\text{Ca}^{40}$. Given m_n and m_p are 1.008665 u and 1.007825 u respectively and $m({}_{20}\text{Ca}^{40}) = 39.962589\,\text{u}$.

Ans :

In ${}_{20}\text{Ca}^{40}$ nucleus, number of protons, $P = 20$ and number of neutrons $N = 40 - 20 = 20$

Mass of 20 neutrons and 20 protons

$$= 20\,(m_n + m_p)$$

$$= 20 \times 1.008665 + 20 \times 1.007825$$

$$= 40.3298\,\text{u}$$

Mass defect, $\Delta\, m = 40.3298 - 39.962589$

$$= 0.367211\,\text{u}$$

Total binding energy

$$= 0.367211 \times 931$$

$$= 341.873441\,\text{MeV}$$

Binding Energy per nucleon,

$$E_{bn} = \frac{341.873441}{40}$$

$$= 8.547 \text{ MeV/nucleon} \qquad \textbf{(2)}$$

or

Using the Bohr's model, calculate the speed of the electron in a H-atom in the $n = 1$ and 2 levels.

Ans :

Let V_1 be the orbital speed of the electron in a H-atom in the ground state level, $n_1 = 1$. For charge (e) of an electron, V_1 is given by the relation

$$V_1 = \frac{e^2}{n_1 4\pi\varepsilon_0\left(\frac{h}{2\pi}\right)} = \frac{e^2}{2\varepsilon_0 h}$$

where, $e = 1.6 \times 10^{-19}\,\text{C}$

$\varepsilon_0 =$ permittivity of free space

$= 8.85 \times 10^{-12}\,\text{N}^{-1}\,\text{C}^2\text{m}^{-2}$

$h =$ Plank's constant

$= 6.63 \times 10^{-34}$ J-s

$$V_1 = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 6.63 \times 10^{-34}}$$

$$= 0.0218 \times 10^8$$

$$= 2.18 \times 10^6\,\text{m/s}$$

We know that, $V_n = V_1/n$

For level, $n_2 = 2$, we can write the relation for the corresponding orbital speed as,

$$V_2 = \frac{V_1}{2} = \frac{2.18 \times 10^6}{2}$$

$$= 1.09 \times 10^6\,\text{m/s}$$

Hence, the speed of the electron in a H-atom in $n = 1$ and $n = 2$ is 2.18×10^6 m/s and 1.09×10^6 m/s, respectively. **(2)**

Section C

28. In a single slit diffraction pattern, how does the angular width of central maximum changes when

1. Slit width is decreased?
2. Distance between the slit and screen is increased?
3. Light of smaller visible wavelength is used? Justify your answer in each case.

Ans :

We know that angular width of central maximum of diffraction pattern of a single slit is given by,

$$2\theta = \frac{2\lambda}{a}$$

1. If slit width a is decreased, the angular width will increases because $2\theta \propto \frac{1}{a}$. **(1)**
2. If the distance between the slit and the screen increases, then it does not affect the angular width of diffraction maxima. **(1)**
3. If the light of smaller visible wavelength is used, the angular width is decreased because $2\theta \propto \lambda$. **(1)**

29. A circular coil of N-turns and radius R is kept normal to a magnetic field given by $B = B_0 \cos \omega t$. Deduce an expression for the emf induced in this coil. State the rule which helps to detect the direction of induced current.

Ans :

Induced emf in the coil,

$$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA\cos\theta) \qquad [\phi = BA\cos\theta]$$

$$= -N\frac{d}{dt}(BA\cos 0^\circ)$$

$$= -NA\frac{dB}{dt} \qquad [\cos 0^\circ = 1] \textbf{ (1)}$$

$$= -N\pi R^2 \frac{d}{dt}(B_0 \cos \omega t) \quad [A = \pi R^2]$$

$$= N\pi R^2 \omega B_0 \sin \omega t$$

$$\left[\frac{d}{dt}(\cos \omega t) = -\omega \sin \omega t\right]$$

(1)

The direction of induced current is given by Lenz's law which states the direction of induced current is always in such a way that it opposes the cause due to which it is produced. **(1)**

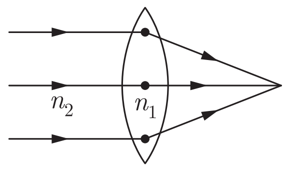
30. A convex lens made of a material of refractive index n_1 is kept in a medium of refractive index n_2. A parallel beam of light is incident on the lens. Complete the path of rays of light emerging from the convex lens, if

1. $n_1 > n_2$
2. $n_1 = n_2$
3. $n_1 < n_2$.

Ans :

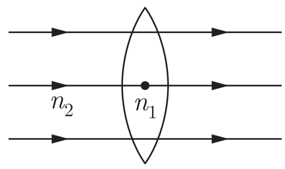
The path of rays of light emerging from the convex lens in different cases is shown below.

1. $n_1 > n_2$



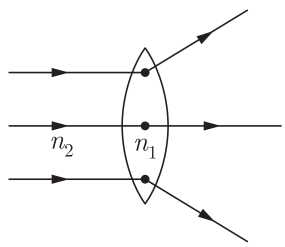
(1)

2. $n_1 = n_2$



(1)

3. $n_1 < n_2$



(1)

31. (i) What will be the effect on the fringe width, if the entire Young's double slit experiment's apparatus is immersed in water?

(ii) Draw a diagram showing the formation of primary rainbow and explain at what angles the primary rainbow is visible.

Ans :

(i) We have, $\lambda_w = \dfrac{\lambda_a}{\mu_w}$

i.e. the wavelength of light decreases in water.

Therefore, the fringe width $\beta = \dfrac{D\lambda}{d}$, also decreases in water as $\beta \propto \lambda$. **(1)**

(ii) Formation of primary rainbow

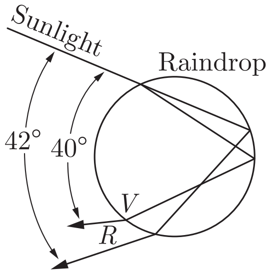


Figure: (a) Primary rainbow

The primary rainbow is formed by those rays which suffer one internal reflection and two refractions and come out of the raindrop at angle of minimum deviation.

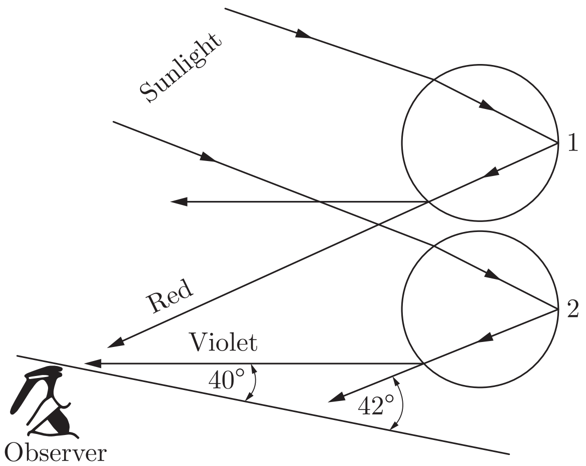
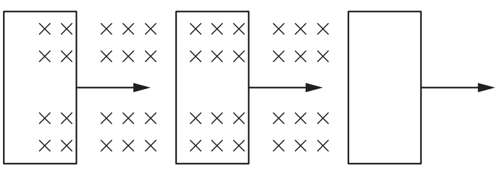


Figure: (b) Angles of primary rainbow

The violet and red light colours emerge at 40° and 42°, respectively and can be viewed by observer. **(2)**

32. (i) Steel is preferred for making permanent magnets, whereas soft iron is preferred for making electron magnets. Why?

(ii) A uniform magnetic field exists normal to the plane of the paper over a small region of space. A rectangular loop of wire is slowly moved with a uniform velocity across the field as shown in the figure.

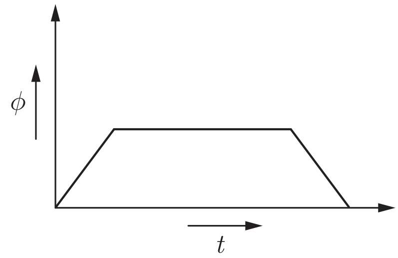


Draw the graph showing the variation of
(a) Magnetic flux linked with the loop and
(b) The induced emf in the loop with time.

Ans :

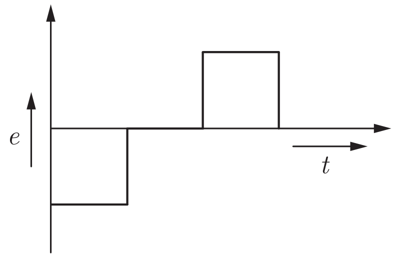
(i) Steel is preferred for making permanent magnets on account of its high retentivity and high coercivity. Soft iron is preferred for making electromagnets on account of low retentivity, low corecivity and low hysteresis loss. **(1)**

(ii) (a) Variation of magnetic flux linked with the loop



(1)

(b) Variation of induced emf in the loop with time



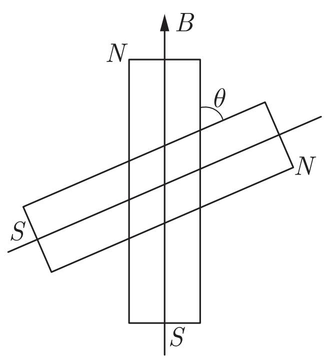
(1)

or

A small compass needle of magnetic moment m and moment of inertia I is free to oscillate in a magnetic field B. It is slightly disturbed from its equilibrium position and then released. Show that it executes simple harmonic motion. Hence, write the expression for its time period.

Ans :

Let a small magnetic needle of magnetic moment m be freely suspended in a uniform magnetic field B, so that in equilibrium position, magnet comes to rest along the direction of B.



Hence, Restoring torque,

$$\tau = \mathrm{m} \times \mathrm{B} = - mB\sin\theta \qquad \textbf{(1/2)}$$

If I is the moment of inertia of magnetic needle about the axis of suspension, then

$$\tau = I\alpha = I\frac{d^2\theta}{dt^2} \qquad \textbf{(1/2)}$$

Hence, in equilibrium state, we have

$$I\frac{d^2\theta}{dt^2} = -mB\sin\theta$$

If θ is small, then $\sin\theta = \theta$, we get

$$I\frac{d^2\theta}{dt^2} = -mB\theta$$

$$\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta \quad \textbf{(1/2)}$$

But angular acceleration is directly proportional to angular displacement and directed towards the equilibrium position, motion of the magnetic needle is simple harmonic motion.

Angular frequency of SHM,

$$\omega = \sqrt{\frac{mB}{I}} \quad \textbf{(1)}$$

Time period of oscillation,

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{mB}} \quad \textbf{(1/2)}$$

33. Find the half-life period of a radioactive material, if its activity drops to (1/16)th of its initial value in 30 yr.

Ans :

Activity $\propto$ Number of atoms present

Hence, $N = \frac{N_0}{16}$, if $t = 30$yr **(1)**

Let half-life period of sample be T.

Number of atoms left after n half-lives is given by,

$$N = N_0\left(\frac{1}{2}\right)^n$$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{16} = \left(\frac{1}{2}\right)^n$$

$\Rightarrow$ $2^n = 16 = 2^4$

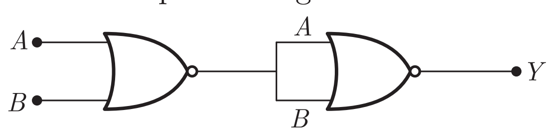
$\Rightarrow$ $n = 4$

Hence, Half-life period,

$$T = \frac{t}{n} = \frac{30}{4}$$

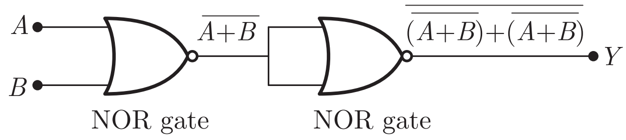
$$= 7.5 \text{ yr} \quad \textbf{(2)}$$

34. Write the truth table for circuit given in figure below consisting of NOR gates and identify the logic operation (OR, AND, NOT) which this circuit is performing.



Ans :

A and B are the inputs of the given circuit. The output of the first NOR gate is $\overline{A+B}$. It can be observed from the figure, that the outputs of the first NOR gate becomes the input of the second one.



(1)

Hence, the output of the combination is given as,

$$Y = \overline{\overline{(A+B)}+\overline{(A+B)}}$$
$$= \overline{\overline{(A+B)}} \cdot \overline{\overline{(A+B)}}$$
$$= (A+B)\cdot(A+B)$$
$$= A+B \quad \textbf{(1)}$$

The truth table for this operation is given as,

A	B	$Y = A+B$
0	0	0
0	1	1
1	0	1
1	1	1

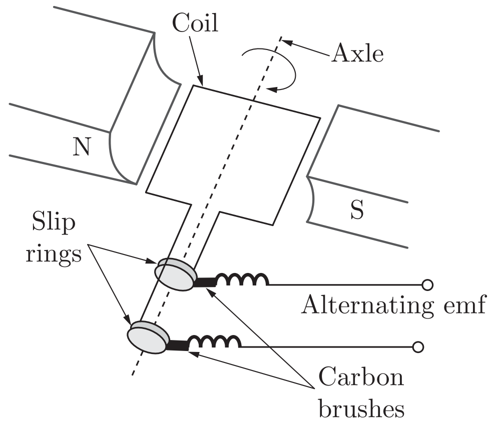
This is the truth table of an OR gate. Hence, this circuit functions as an OR gate. **(1)**

Section D

35. Explain with the help of diagram, the principle and working of an AC generator. Write the expression for the emf generated in the coil in terms of its speed of rotation.

Ans :

The labelled diagram of an AC generator is shown below



(1)

Principle

An AC generator is based on the principle of electromagnetic induction. If a rectangular armature rotates about its axis in a uniform magnetic field, then the magnetic flux linked with the coil changes and an emf is induced in the coil. The direction of induced current is given by Fleming right hand rule. **(1)**

Working

When an armature coil of N turns and each turn enclosing area A is placed in a uniform magnetic field of strength (B) making an angle θ with normal to the direction of magnetic field.

Magnetic flux linked with the coil is $\phi = \mathrm{B} \cdot \mathrm{A} = NBA\cos\theta$.

As, the coil is rotated about its own axis with an angular speed (ω), then value of angle $\theta = \omega t$ and hence, magnetic flux changes and an induced emf is developed across the ends of coil. **(2)**

Hence, Induced emf,

$$\varepsilon = -\frac{d\phi}{dt} = NBA\omega\sin\omega t = \varepsilon_0\sin\omega t$$

Where, $\varepsilon_0 = NBA\omega$ = maximum (peak) value of induced emf. Induced emf is sinusoidal in nature. **(1)**

or

The primary coil of an ideal step-up transformer has 100 turns and the transformation ratio is also 100. The input voltage and the power are 220 V and 1100 W. Find:

1. Number of turns in secondary
2. The current in the primary
3. Voltage across the secondary
4. The current in the secondary
5. Power in the secondary.

Ans :

Given,

$$N_P = 100,\ k = 100,$$
$$V_P = 220\text{ V},\ P_{\text{in}} = 1100\text{ W}$$

1. $$N_S = K \cdot N_P = 100 \times 100 = 10000$$ **(1)**

2. $$I_P = \frac{P_{\text{in}}}{V_P} = \frac{1100}{220} = 5\text{A}$$ **(1)**

3. $$V_s = K \cdot V_P = 100 \times 220 = 22000\text{ V}$$ **(1)**

4. $$I_s = \frac{I_P}{K} = \frac{5}{100} = 0.05\text{ A}$$ **(1)**

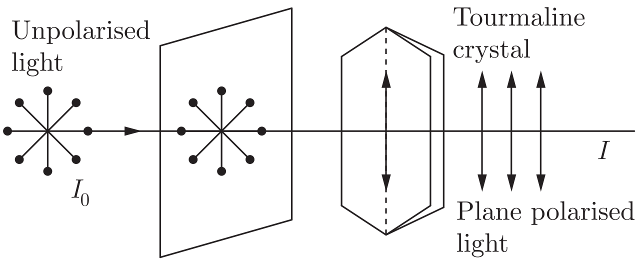
5. Output power $= V_s \times I_s = 22000 \times 0.05 = 1100\text{ W}$ **(1)**

36. (i) What do you mean by the polarisation of light? Define law of Malus and then show that the intensity of light becomes half, when ordinary light is incident on a polariser.

(ii) Two polarising sheets have their polarising direction parallel, so that the intensity of the transmitted light is maximum. Through what angle must the either sheet be turned, if the intensity is to drop by one half?

Ans :

(i) **Polarisation of light :** The ordinary light have electric vectors in all possible directions in a plane perpendicular to the direction of propagation of light waves. When it is pass through a tourmaline crystal, then in transmitted light, only those electric vectors are present which are parallel to the axis of crystal.



Polarisation of light

Such light is called plane polarised light. The phenomena of restricting the electric vectors of light into particular direction is called polarisation of light. The tourmaline crystal acts as a polariser. **(1½)**

Law of Malus:

when completely plane polarised light is incident on an analyser, the intensity of transmitted light is proportional to the square of the cosine of the angle between the plane of polariser and analyser.

$$I \propto \cos^2\theta \Rightarrow I = I_0\cos^2\theta$$ **(1)**

Where, I_0 is the intensity of incident light.

Let the intensity of the ordinary light be I_0 and it is incident on a polariser.

In ordinary light, electric vectors are in all possible directions and therefore, intensity of transmitted light is

$$I = I_0(\cos^2\theta)_{av} \quad \text{[average value of } \cos^2\theta]$$

$$\text{Here,} (\cos^2\theta)_{av} = \frac{1}{2\pi}\int_0^{2\pi}\cos^2\theta d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi}\left[\frac{1+\cos 2\theta}{2}\right]d\theta$$

$$= \frac{1}{4\pi}\left[\theta + \frac{\sin 2\theta}{2}\right]_0^{2\pi}$$

$$= \frac{1}{4\pi}\left[2\pi + \frac{\sin 4\pi}{2} - 0\right]$$

$$= \frac{1}{4\pi}\times 2\pi = \frac{1}{2}$$

Hence, $I = \frac{I_0}{2}$ **(1½)**

2. We know that, $I = \frac{I_0}{2}$

Using Malus's law,

$$I = I_0\cos^2\theta$$

$$\frac{I_0}{2} = I_0\cos^2\theta$$

$$\cos^2\theta = \frac{1}{2}$$

$$\cos\theta = \pm\frac{1}{\sqrt{2}}$$

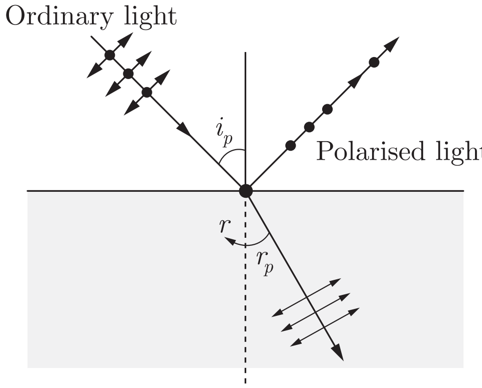
$\Rightarrow$ $\theta = \pm 45°, \pm 135°$ **(1)**

or

1. Define Brewster's law. Show that the sum of angle of polarisation and angle of refraction is 90°.
2. Discuss the intensity of transmitted light, when polaroid sheet is rotated between two crossed polaroid.

Ans :

1. **Brewster's Law :** When un-polarised light is incident on a transparent medium at polarising angle , the reflected light becomes completely polarised. **(1)**



(1)

If refractive index of the transparent medium is μ, then $\mu = \tan i_p$

This relation is called Brewster's law, which gives relation angle of polarisation (i_P) and angle of refraction.

According to the Brewster's law,

$$\mu = \tan i_p$$

or $$\mu = \frac{\sin i_p}{\cos i_p} \quad ...(i)$$

According to Snell's law,

Refractive index,

$$\mu = \frac{\sin i_p}{\sin r_p} \quad ...(ii) \quad \textbf{(1)}$$

From Eqs. (1) and (2), we get

$$\frac{\sin i_p}{\cos i_p} = \frac{\sin i_p}{\sin r_p}$$

$\Rightarrow$ $\cos i_p = \sin r_p$

or $\sin(90° - i_p) = \sin r_p$

$$[\cos\theta = \sin(90° - \theta)]$$

$$(90° - i_p) = r_p$$

$\Rightarrow$ $i_p + r_p = 90°$ **(1)**

2. Let I_0 be the intensity of polarised light transmitted by first polariser P_1. Then, the intensity of light transmitted by second polariser P_2 will be,

$$I = I_0(\cos^2\theta)$$

As, P_1 and P_3 are crossed, the angle between P_2 and P_3 will be $(\pi/2 - \theta)$.

The intensity of light transmitted by P_3 will be,

$$I = I_0\cos^2\theta\cos^2(\pi/2 - \theta)$$

$$= I_0\cos^2\theta\sin^2\theta - \frac{I_0}{4}\sin^2 2\theta$$

The transmitted intensity will be maximum When,

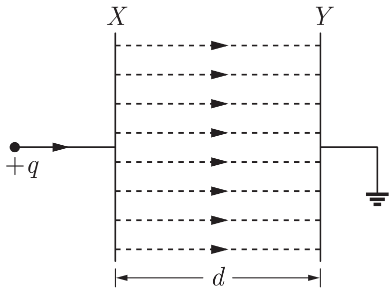
$$2\theta = \pi/2$$

$\Rightarrow$ $\theta = \pi/4$ **(1)**

37. Find an expression for the capacitance of a parallel plate capacitor. An air capacitor has a capacitance of $2\,\mu F$, which becomes $12\,\mu F$, when a dielectric medium is filled in the space between the plates. Find dielectric constant of that material.

Ans :

Suppose a parallel plate capacitor consists of two conducting parallel plates X and Y, each of cross-sectional area A and separated by a distance d consisting of material having dielectric constant K.



A parallel plate capacitor
consisting of two parallel plates

$+q$ charge is given to plate X while plate Y is connected to the earth. **(1)**

Charge density on plates,

$$\sigma = \frac{q}{A}$$

Electric field intensity between the plates,

$$E = \frac{\sigma}{K\varepsilon_0} \quad \textbf{(1)}$$

We know that potential difference between plates,

$$V = E\,d = \frac{\sigma}{K\varepsilon_0}d \quad \textbf{(1)}$$

Substituting the value of σ, we get

$$V = \frac{q}{AK\varepsilon_o}d$$

The capacitance of a parallel plate capacitor,

$$C = \frac{q}{V} = \frac{q}{\left(\frac{qd}{KA\varepsilon_0}\right)}$$

$$= \left(\frac{KA\varepsilon_0}{d}\right) \quad \textbf{(1)}$$

For air, the capacitance of the capacitor,

$$C_0 = \frac{A\varepsilon_0}{d} = 2\,\mu\text{F} \quad ...(i)$$

When a dielectric medium is placed between the plates,

then $$C = \frac{KA\varepsilon_0}{d} = 12\,\mu\text{F} \quad ...(ii)$$

Dividing Eq. (ii) by Eq. (i), we get

$$\frac{\left(\frac{KA\varepsilon_0}{d}\right)}{\left(\frac{A\varepsilon_0}{d}\right)} = \frac{12}{2}$$

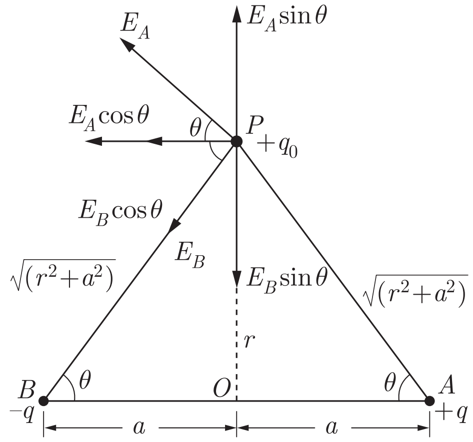
$$\Rightarrow \quad K = 6 \quad \textbf{(1)}$$

or

Find an expression for the electric field intensity at a point on equatorial line due to an electric dipole.

Ans :

Consider an electric dipole AB, consists of two charges $+q$ and $-q$ separated by a distance $2a$. We have to find electric field at a point P on equatorial line separated by a distance r from centre O.



Intensity at a point on equatorial line due to an electric dipole

(2)

Electric field at point P due to charge $+q$.

$$E_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(\sqrt{r^2+a^2})^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(r^2+a^2)}, \text{along (AP)}$$

Electric field at point P due to charge $-q$,

$$E_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(r^2+a^2)}, \text{(along PB)} \quad \textbf{(2)}$$

On resolving E_A and E_B into rectangular components, $E_A\sin\theta$ and $E_B\sin\theta$ cancel each other. $[E_A = E_B]$

Hence, Resultant electric field at point P,

$$E = E_A\cos\theta + E_B\cos\theta$$

$$= 2\times\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(r^2+a^2)}\cos\theta$$

$$\left[|E_A| = |E_B|\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{2q}{(r^2+a^2)}\times\frac{a}{\sqrt{(r^2+a^2)}}$$

$$\left[\cos\theta = \frac{OB}{BP} = \frac{a}{\sqrt{r^2+a^2}}\right]$$

But, $q\cdot 2a = p$, electric dipole moment.

Hence, $$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{(r^2+a^2)^{3/2}} \quad \textbf{(1/2)}$$

If $r > a$, then $r^2 >> a^2$

Therefore, neglecting a^2 in comparison to r^2, we get

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^3}$$

In opposite direction of electric dipole moment. **(1/2)**