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SAMPLE PAPER TEST 02 (2020-21)

SUBJECT: PHYSICS | **MAX. MARKS : 70**
CLASS : XII | **DURATION : 3 HRS**

General Instruction:

(i) *All questions are compulsory. There are **33** questions in all.*
(ii) *This question paper has five sections: Section A, Section B, Section C, Section D and Section E.*
(iii) ***Section A** contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, **Section B** has two case based questions of 4 marks each, **Section C** contains nine short answer questions of 2 marks each, **Section D** contains five short answer questions of 3 marks each and **Section E** contains three long answer questions of 5 marks each.*
(iv) *There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.*
(v) *You may use the following values of physical constants wherever necessary :*

$c = 3\times10^{8} m/s,\quad h = 6.63\times10^{-34} Js,\quad e = 1.6\times10^{-19} C,\quad \mu_0 = 4\pi\times10^{-7} TmA^{-1},$

$\varepsilon_0 = 8.854\times10^{-12} C^2N^{-1}m^{-2},\quad m_e = 9.1\times10^{-31} kg,\quad \frac{1}{4\pi\varepsilon_0} = 9\times10^{9} Nm^2C^{-2},$

Mass of neutron $= 1.675\times10^{-27} kg$, Mass of proton $= 1.673\times10^{-27} kg$,

Avogadro's number $= 6.023\times10^{23}$ per gram mole, Boltzmann constant $= 1.38\times10^{-23} JK^{-1}$

SECTION – A
Questions 1 to 14 carry 1 mark each.

1. What is the forbidden energy gap (in joule) for a germanium crystal?
Ans: E = 0.7 eV = 0.7 x 1.6 x 10^{-19} J = 1.12 x 10^{-19}J

2. What is the purpose of heavy water in nuclear reactors?
Ans: Heavy water is used as a moderator in some reactors to slow down the fast moving neutrons.

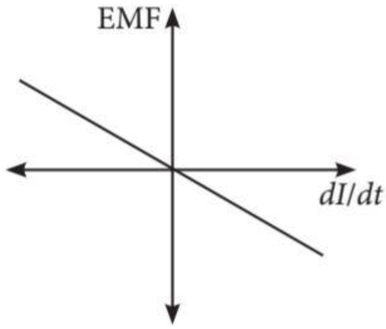
OR

Compare the radii of two nuclei with mass numbers 1 and 27 respectively.
Ans:

As $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$

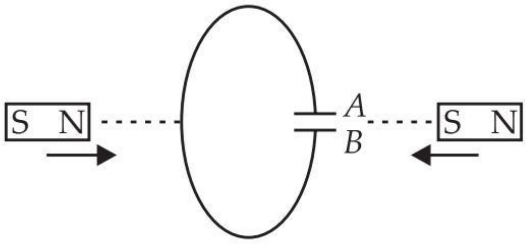
3. Define the term 'current sensitivity' of a moving coil galvanometer.
Current sensitivity : It is defined as the deflection of coil per unit current flowing in it, *i.e.*,
$I_S = \frac{\theta}{I} = \frac{NAB}{k}$

4. Plot a graph showing variation of induced e.m.f. with the rate of change of current flowing through a coil.
Ans:



OR

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



Ans: Polarity of plate A will be positive with respect to plate B in the capacitor, as induced current is in clockwise direction

5. Two metals A and B have work functions 2 eV and 6 eV respectively. Which of the two metals have larger threshold frequency?
$W_0 = h\upsilon_0$
So metal B of larger work function 6 eV has larger threshold frequency υ_0.

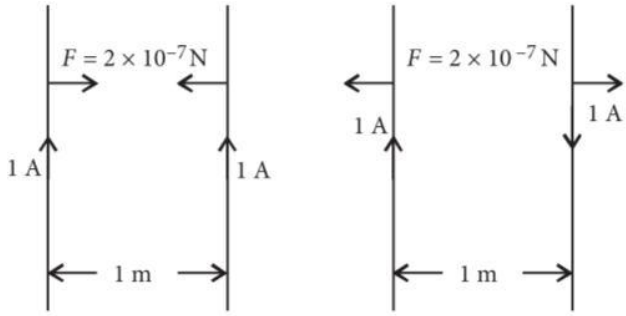
6. Give any one advantage of LEDs over conventional incandescent low power lamps.
LEDs are extremely energy efficient. They consume upto 90% less power than conventional incandescent low power lamps.

7. What is the frequency of electromagnetic waves produced by oscillating charge of frequency λ?
Frequency of the electromagnetic waves produced will be equal to the frequency λ of the oscillating charge.

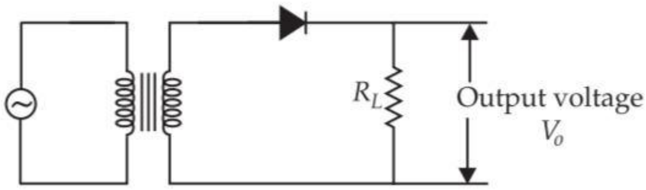
OR

Name the part of electromagnetic spectrum whose wavelength lies in the range of 10^{-10} m. Give its one use.
The wavelength range of 10^{-10} m, lies in X-ray region of the electromagnetic spectrum. X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

8. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.
One ampere is the value of steady current which when maintained in each of the two very long, straight, parallel conductors of negligible cross-section and placed one metre apart in vacuum, would produce on each of these conductors a force of attractive or repulsive nature of magnitude 2×10^{-7} N m^{-1} on their unit length.
Force between two straight parallel current carrying conductors,
$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$
when $I_1 = I_2 = 1$ A, $r = 1$ m, then $F = 2 \times 10^{-7}$ N m^{-1}

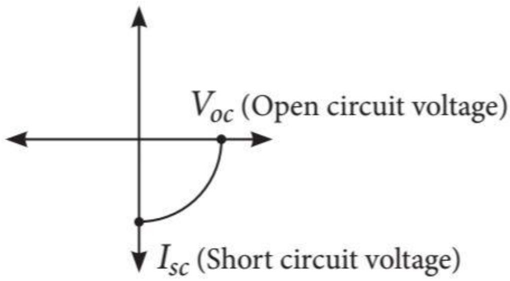


9. Draw circuit diagram of a half wave rectifier.



OR

Draw I-V characteristic of a solar cell.



10. What is the Bohr's quantization condition for the angular momentum of an electron in the second orbit?

$mvr = 2h/2\pi$ or $mvr = h/\pi$

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

11. Assertion (A): If a convex lens is kept in water its convergent power decreases.

Reason (R): Focal length of convex lens in water increases.

(a): The focal length of a lens in a medium of refractive index μ_m is given by

$$\frac{1}{f_m} = \left(\frac{\mu - \mu_m}{\mu_m}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where μ is the refractive index of glass.

In air $\frac{1}{f_a} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

From these two expressions it is dear that $f_m > f_a$. That is the focal length of the convex lens in water increases thereby reducing its convergent power.

12. Assertion (A): In a cavity within a conductor, the electric field is zero.

Reason (R): Charges in a conductor reside only at its surface.

(a): Both the assertion and reason are true and the reason is the correct explanation. It is because the charges are only at the surface of a conductor, the charge enclosed in the Gaussian surface in the cavity is zero. The field is therefore zero.

13. Assertion (A): The electromagnetic waves are transverse in nature.

Reason (R): Waves of wavelength 10 mm are radiowave and microwave.

(c): Wavelength of 10 mm lies in infrared region.

14. Assertion (A): A copper sheet is placed in a magnetic field. If we pull it out of the field or push it into the field, we experience an opposing force.

Reason (R): According to Lenz's law eddy current produced in sheet opposes the motion of the sheet.

(a): When we pull a copper plate out of the magnetic field or push it into the magnetic field, magnetic flux linked with the plate changes. As a result of this eddy currents are produced in the plate which oppose its motion (according to Lenz's law).

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. In physics, an electric power measure of the rate of electrical energy transfer by an electric circuit per unit time. Denoted by P and measured using the SI unit of power is the watt or one joule per second. Electric power is commonly supplied by sources such as electric batteries and produced by electric generators.

The formula for electric power is given by $P = VI$

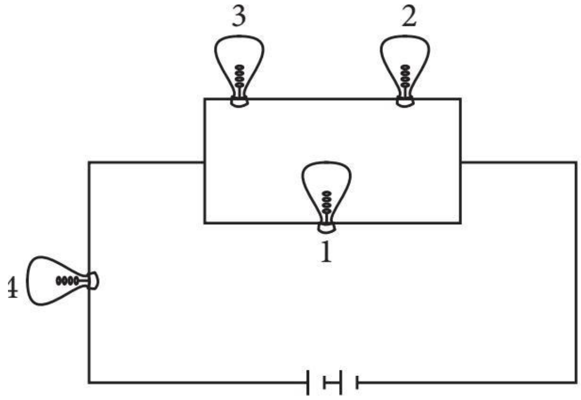
where, P is the power, V is the potential difference in the circuit, I is the electric current

Power can also be written as $P = I^2R$ and $P = V^2/R$

The above two expressions are got by using Ohms law, Where, Voltage, current, and resistance are related by the following relation

$V = IR$ Where, R is the resistance in the circuit, V is the potential difference in the circuit, I is the electric current

The given figure shows four bulbs 1, 2, 3 and 4, consume same power. The resistance of bulb 1 is 36 Ω.



(i) What is the resistance of the bulb 3?

(a) 4 Ω (b) 9 Ω (c) 18 Ω (d) 12 Ω

(b) : The Bulbs 2 and 3 are in series, current through them is same.

$\therefore \quad I_2 = I_3 = I_b(\text{say})$

Now, Bulb 1 and combination of 2 and 3 are in parallel,

$\therefore \quad V_1 = (V_2 + V_3) = V(\text{say})$

Since, all bulbs consumes same power.

$\therefore \quad P_2 = P_3 \Rightarrow I_b^2 R_2 = I_b^2 R_3 \Rightarrow R_2 = R_3$

So, $V_2 = V_3 = \dfrac{V}{2}$

Now, $P_1 = \dfrac{V_1^2}{R_1} = \dfrac{V^2}{36}$ and $P_3 = \dfrac{V_3^2}{R_3} = \dfrac{V^2}{4R_3}$

$\because \quad P_1 = P_3$

$\therefore \quad \dfrac{V^2}{36} = \dfrac{V^2}{4R_3} \Rightarrow R_3 = 9\Omega$

(ii) What is the resistance of bulb 4?

(a) 4 Ω (b) 8 Ω (c) 9 Ω (d) 18 Ω

(a) : Total current through R_1, $I_a = \dfrac{R_2 + R_3}{R_1 + (R_2 + R_3)} I = \dfrac{18}{36+18} = \dfrac{18}{54} I = \dfrac{I}{3}$

Also, $I_4 = I$

Since, $P_1 = P_4 \Rightarrow I_a^2 R_1 = I_4^2 R_4 \Rightarrow \left(\dfrac{I}{3}\right)^2 \times 36 = I^2 R_4$

Which implies sign $R_4 = 4\ \Omega$

(iii) If power of each bulb is 4 W, then the total current flowing through the circuit is

(a) 1 A (b) 2 A (c) 4 A (d) 12 A

(a) : Gives that $P_4 = 4\text{W}$

$P_4 = I_4^2 R_4$

or $\quad P_4 = I^2 R_4 \quad (\because I_4 = \text{I})$

or $\quad I = 1\text{A}$

(iv) What is the equivalent resistance of the circuit?

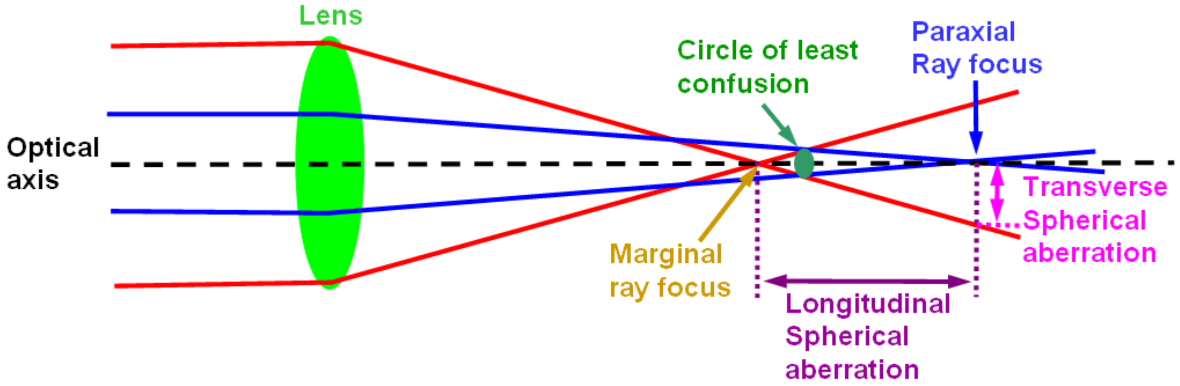
(a) 12 Ω (b) 8 Ω (c) 18 Ω (d) 16 Ω

(d) : $R_{eq.} = R_4 + \dfrac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3} = 4 + \dfrac{36(9+9)}{36+9+9} = 16\Omega$

(v) What is the voltage output of the battery, if the power of each bulb is 4 W?
(a) 16 V (b) 12V (c) 24V (d) 18V

(a) : $\varepsilon = I R_{eq.} = 16$ V

16. Image of a white object is coloured and blurred because μ (hence f) of lens is different for different colours. This defect is called chromatic aberration. As $\mu_0 > \mu_r$, therefore, $f_r > f_v$. The difference $(f_r - f_v)$ is a measure of longitudinal chromatic aberration of the lens. Focal length for mean colour is $f = \sqrt{f_r \times f_v}$. Using lens maker formula, for mean colour of light, we have $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ where f is focal length of mean colour and m is the refractive index of mean colour.



(i) Focal length of a equiconvex lens of glass μ = 3/2 in air is 20 cm. The radius of curvature of each surface is
(a) 10 cm (b) –10 cm (c) 20 cm (d) –20 cm

(c) : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For equiconvex lens, $R_1 = R$, $R_2 = -R$

$$\frac{1}{20} = \left(\frac{3}{2} - 1\right)\left(\frac{2}{R}\right) = \frac{1}{R}$$

$\therefore \quad R = 20$ cm

(ii) Focal length of the lens in water would be
(a) 20 cm (b) 80 cm (c) –20 cm (d) –80 cm

(b) : $\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$= \left(\frac{3/2}{4/3} - 1\right)\left(\frac{1}{20} + \frac{1}{20}\right) = \frac{1}{8} \times \frac{1}{10} = \frac{1}{80}$$

$\therefore \quad f_w = 80$ cm

(iii) If $\mu_v = 1.6$, $\mu_r = 1.5$, $R_1 = 20$ cm and $R_2 = -20$ cm, then the chromatic aberration of the lens would be
(a) 3 cm (b) 3.3 cm (c) –3 cm (d) –3.3 cm

(b): $\frac{1}{f_v} = (\mu_v - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1.6 - 1)\left(\frac{2}{20}\right) = \frac{6}{100}$

$\therefore \quad f_v = \frac{100}{6} = 16 \cdot 7$ cm

$\frac{1}{f_r} = (\mu_r - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1 \cdot 5 - 1)\left(\frac{2}{20}\right) = \frac{1}{20}$

$f_r = 20$ cm

Chromatic aberration $= f_r - f_v = 20 - 16.7 = 3.3$ cm

(iv) A given convex lens of glass (μ = 3/2) can behave as concave when it is held in a medium of μ equal to

(a) 1 (b) 3/2 (c) 2/3 (d) 7/4

(d) : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

The given lens would behave as concave when f_m becomes negative, for which $\mu_m > \mu_g$.

(v) Chromatic aberration of a lens can be corrected by

(a) providing different suitable curvature to its two surfaces

(b) proper polishing of its two surfaces

(c) Suitably combining it with another lens

(d) reducing its aperture.

(c) Suitably combining it with another lens

SECTION – C

Questions 17 to 25 carry 2 marks each.

17. Answer the following questions:

(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

(b) If the Earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.

(a) Microwaves are suitable for the radar system used in aircraft navigation. Range of frequency of microwaves is 10^8 Hz to 10^{11} Hz.

(b) If the Earth did not have atmosphere, then there would be absence of green house effect of the atmosphere. Due to this reason, the temperature of the earth would be lower than what it is now.

OR

What are the radio waves? How are these waves produced?

Radio waves are the electromagnetic waves of frequency ranging from 500 kHz to about 1000 MHz. These waves are produced by oscillating electric circuits having inductor and capacitor.

18. In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?

In double slit experiment, an interference pattern is observed by waves from two slits but as each slit provide a diffraction pattern of its own, thus the intensity of interference pattern in Young's double slit experiment is modified by diffraction pattern of each slit.

19. Write the four important properties of the magnetic field lines due to a bar magnet.

Properties of magnets

(i) Attractive property: When a magnet is dipped into iron filings, it is found that the concentration of iron filings is maximum at the ends. It means attracting power of the magnet is maximum at two points near the ends and minimum at the centre. The places in a magnet where its attracting power is maximum are known as poles while the place of minimum attracting power is known as the neutral region.

(ii) Directive property: When a magnet is suspended, its length becomes parallel to N-S direction. The pole at the end pointing north is known as north pole while the other pointing south is known as south pole.

(iii) Magnetic poles always exist in pairs i.e., an isolated magnetic pole does not exist.

(iv) Like poles repel each other and unlike poles attract each other.

OR

A conducting rod of length 2 m is placed on a horizontal table in north-south direction. It carries a current of 5 A from south to north. Find the direction and magnitude of the magnetic force acting on the rod. Given that the Earth's magnetic field at the place is 0.6×10^{-4} T and angle of dip is $\pi/6$.

Given Earth's magnetic field,

$B = 0.6 \times 10^{-4}$ T,

$\theta = \frac{\pi}{6} = 30°, I = 5$ A and $l = 2$ m.

The horizontal component of earth's magnetic field,

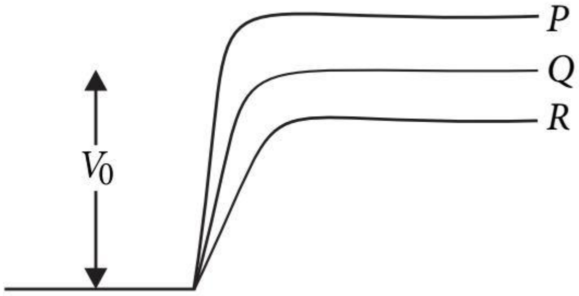
$B_H = B\cos\theta$

$= 0.6 \times 10^{-4} \times \frac{\sqrt{3}}{2} = 3\sqrt{3} \times 10^{-5}$ T

$\therefore$ Magnetic force $= BIl = 3\sqrt{3} \times 10^{-5} \times 5 \times 2$

$= 3\sqrt{3} \times 10^{-4}$ N

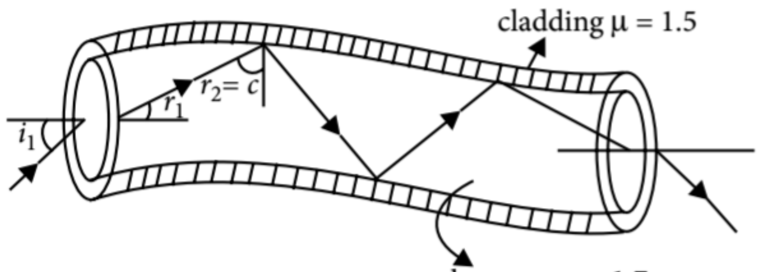
20. In figure, V_0 is the potential barrier across a p-n junction, when no battery is connected across the junction. Which of P, Q and R corresponds to forward and reverse bias of junction?



Ans: Height of potential barrier decreases when p-n junction is forward biased and it increases when junction is reverse biased. So, curve R corresponds to forward biasing and P corresponds to reverse biasing.

21. Explain briefly how the phenomenon of total internal reflection is used in fibre optics.

Optical fibre is made up of very fine quality glass or quartz of refractive index about 1.7. A light beam incident on one end of an optical fibre at appropriate angle refracts into the fibre and undergoes repeated total internal reflection. This is because the angle of incidence is greater than critical angle. The beam of light is received at other end of fibre with nearly no loss in intensity. To send a complete image, the image of different portion is send through separate fibres and thus a complete image can be transmitted through an optical fibre.



22. Show that the capacitance of a spherical conductor is $4\pi\varepsilon_0$ times the radius of the spherical conductor.

The potential at any point on the surface of the conductor having radius r and charge q is given by

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

where $\varepsilon_0 = 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

The capacitance of the spherical conductor situated in vaccum is given by

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

$$C = 4\pi\varepsilon_0 r$$

Hence, the capacitance of an isolated spherical conductor situated in vaccum is $4\pi\varepsilon_0$ times its radius.

OR

Two charges 2 µC and –2 µC are placed at points A and B 6 cm apart.

(a) Identify an equipotential surface of the system.

(b) What is the direction of the electric field at every point on this surface?

(a) Since it is an electric dipole, so a plane normal to AB and passing through its mid-point has zero potential everywhere.

(b) Normal to the plane in the direction AB.

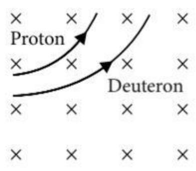
23. A proton and a deuteron, each moving with velocity $\vec{v}$ enter simultaneously in the region of magnetic field $\vec{B}$ acting normal to the direction of velocity. Trace their trajectories establishing the relationship between the two.

Charge on deuteron (q_d) = charge on proton (q_p)

Radius of circular path $r \propto m \left(\because qvB = \frac{mv^2}{r} \right)$

(For constant velocity v)

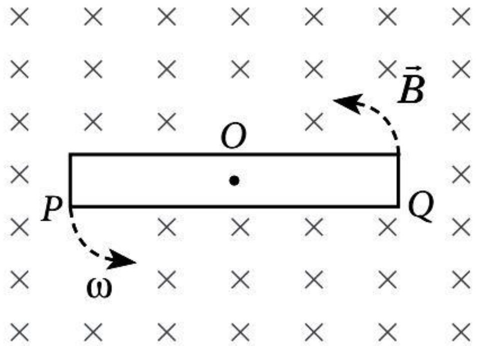
$$\frac{r_d}{r_p} = \frac{m_d}{m_p}$$



$\because\ m_d = 2m_p$

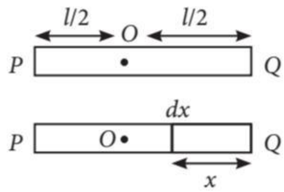
$\Rightarrow\ r_d = 2r_p$ or $r_d : r_p = 2 : 1$

24. A metallic rod PQ of length l is rotated with an angular velocity w about an axis passing through its midpoint (O) and perpendicular to the plane of the paper, in uniform magnetic field $\vec{B}$, as shown in the figure. What is the potential difference developed between the two ends of the rod, P and Q?



Consider a small element 'dx' on the rod, then the induced EMF on the element 'dx',

$$d\varepsilon = (\vec{v} \times \vec{B})dx = vBdx = B\omega x dx$$



$\therefore$ The total EMF induced,

$$\varepsilon = \int d\varepsilon = \int_{-\frac{l}{2}}^{\frac{l}{2}} B\omega x dx = \frac{B\omega}{2}[x^2]_{-\frac{l}{2}}^{\frac{l}{2}} = \frac{1}{2}B\omega l^2$$

25. When an electric field is applied across a semiconductor what happens to electrons and holes?

Ans: Electrons in conduction band get accelerated and acquire energy by the application of electric field and move from lower energy level to higher energy level. While holes in valence band move from higher energy level to lower energy level.

SECTION – D

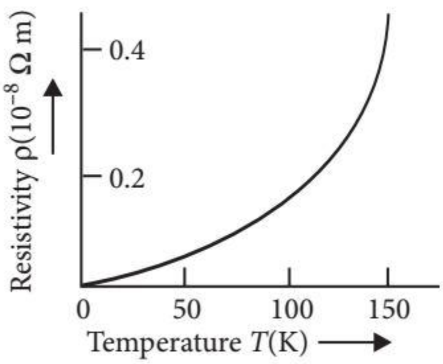
Questions 26 to 30 carry 3 marks each.

26. Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material?

Ans:

$$R = \rho\frac{l}{A}$$

If $l = 1,\ A = 1 \Rightarrow \rho = R$



Resistivity ρ of metallic conductor as a function of temperature T

Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area.
The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperature. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by,

$$\rho_T = \rho_0 [1 + \alpha(T - T_0)] \text{ .....(i)}$$

where ρ_T is the resistivity at a temperature T and ρ_0, is the same at a reference temperature T_0. α is called the temperature coefficient of resistivity.
The relation in eqn. (i) implies that a graph of T plotted against T would be a straight line. At temperatures much lower than 0°C, the graph, however, deviates considerably from a straight line.

OR

Derive an expression for the drift speed of electrons in a good conductor in terms of the relaxation time of electrons.
Ans: In the absence of an external field, the free electrons in a metal are moving randomly in all directions due to thermal agitation. There is no overall drift and the average velocity is zero.
In the presence of an external electric field E, each electron experience an acceleration
$a = eE/m$
opposite to the field direction. However, this acceleration is momentary, since the electrons are continuously colliding with vibrating ions and other electrons. After each collision, the electron makes a fresh start and accelerates only to be deflected randomly again. If t is the relaxation time, i.e., the average time between two successive collisions, then the drift velocity of the electrons is given by

$$v_d = a\tau = \frac{eE\tau}{m}$$

In vector notation, $\vec{v}_d = \frac{e\vec{E}\tau}{m}$

27. Write three characteristic properties of nuclear force.
Properties of nuclear force are :
(i) Nuclear forces are short range forces and are strongly attractive within a range of 1 fermi to 4.2 fermi.
(ii) Nuclear forces above 4.2 fermi are negligible, whereas below 1 fermi, they become repulsive in nature. It is this repulsive nature below 1 fermi, which prevents the nucleus from collapsing under strong attractive force.
(iii)Nuclear forces are charge independent. The same magnitude of nuclear force act between a pair of protons, pair of proton and neutron and pair of neutrons. The attractive nuclear force is due to exchange of π mesons (π^0, π^+, π^-) between them.

28. Radiations of frequency 10^{15} Hz are incident on two photosensitive surfaces A and B. Following observations are recorded. Surface A: No photo-emission takes place. Surface B: Photo-emission takes place but photo-electrons have zero energy. Explain the above observations on the basis of Einstein's photoelectric equation. How will the observation with surface B change when the wavelength of incident radiation is decreased?
By Einstein's photoelectric equation

$$\frac{1}{2}mv_{\max}^2 = h\text{v} - W_0$$

So, no emission of photo-electrons takes place at surface A, because the work function W_0 of surface A is more than the energy $h\upsilon$ of photons of incident radiations of frequency 10^{15} Hz.
However, for surface B, photoemission takes place but photoelectrons have zero energy,

So, $\frac{1}{2}mv_{\max}^2 = 0$ or $h\upsilon - W_0 = 0$

$W_0 = h\upsilon$

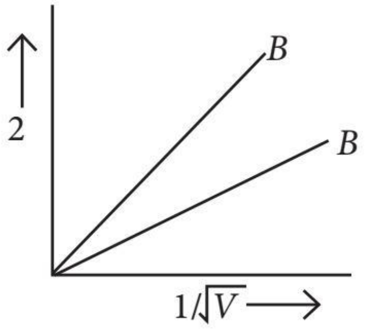
or $h\nu_0 = h\upsilon$

or $\upsilon_0 = \upsilon = 10^{15}$ Hz

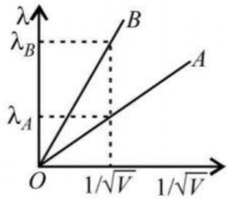
i.e., 10^{15} Hz is the threshold frequency for surface B. If the wavelength of incident radiation is decreased, then the frequency and hence energy $h\upsilon$ of photons of incident radiations will increase, due to which photo electrons emitted will have same kinetic energy.

OR

The two lines A and B shown in the graph represent the de-Broglie wavelength (λ) as a function of 1/√V (V is the accelerating potential) for two particles having the same charge. Which of the two represents the particle of heavier mass?



As $\lambda = \frac{12.27}{\sqrt{V}}$ Å,



So $\lambda \propto \frac{1}{\sqrt{V}}$

At same V, $\lambda_B > \lambda_A$

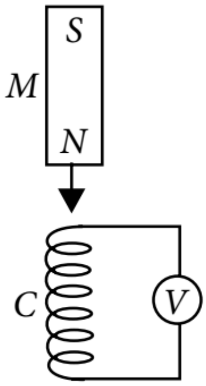
or $\frac{h}{m_B v_B} > \frac{h}{m_A v_A}$ or $m_A v_A > m_B v_B$

or $m_A\sqrt{\frac{2qV}{m_A}} > m_B\sqrt{\frac{2qV}{m_B}}$ or $\sqrt{m}_A > \sqrt{m}_B$

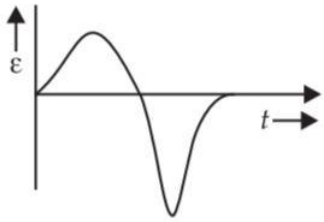
or $m_A > m_B$

So line A represents particle of heavier mass.

29. Figure shows a bar magnet M falling under gravity through an air cored coil C. Plot a graph showing variation of induced emf (e) with time (t). What does the area enclosed by the e-t curve depict?



Induced emf ∝ rate of change of magnetic flux. Therefore, as the magnet approaches coil, the induced emf first increases, becomes maximum and then decreases to zero.



When the bar magnet crosses the coil, then the induced emf changes direction, increases, becomes maximum and finally decreases to zero. The graph is shown in figure.

As $\varepsilon = -\dfrac{d\phi}{dt}$

$d\phi = \varepsilon dt$ (numerically)

$\phi = \int \varepsilon dt$

Accordingly, the area under ε-t curve represents the change in flux.

30. Using the relevant Bohr's postulates, derive the expression for the speed of the electron in the nth orbit.

Ans: Speed of the electron in the nth orbit: The centripetal force required for revolution is provided by the electrostatic force of attraction between the electron and the nucleus.

$$\therefore \quad \frac{mv^2}{r} = \frac{KZe^2}{r^2} \left[\text{where, } K = \frac{1}{4\pi\varepsilon_0}\right] \Rightarrow r = \frac{KZe^2}{mv^2} \qquad \text{...(i)}$$

The angular momentum for any permitted (stationary) orbit is

$mvr = \dfrac{nh}{2\pi}$ where n is any positive integer.

$r = \dfrac{nh}{2\pi mv}$ ...(ii)

From (i) and (ii), we get

$$\frac{KZe^2}{mv^2} = \frac{nh}{2\pi mv} \quad \therefore \quad v = \frac{2\pi KZe^2}{nh}$$

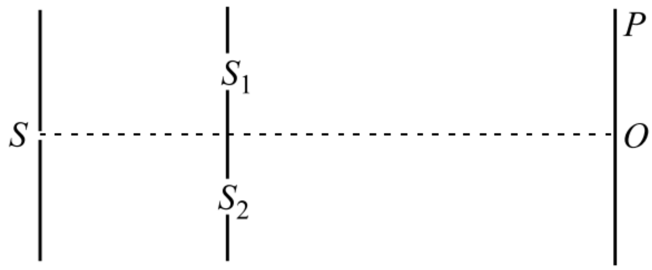
For hydrogen atom, $Z = 1$

$$\therefore \quad v = \frac{2\pi Ke^2}{nh}$$

SECTION – E

Questions 31 to 33 carry 5 marks each.

31. Figure shows an experiment setup similar to Young's double slit experiment to observe interference of light.



Here $SS_2 - SS_1 = \lambda/4$

Write the condition of (i) constructive, (ii) destructive interference at any point P in terms of path difference, $\Delta = S_2P - S_1P$

Does the central fringe observed in the above setup lie above or below O? Give reason in support of your answer. Yellow light of wavelength 6000Å produces fringes of width 0.8 mm in Young's double slit experiment. What will be the fringe width if the light source is replaced by another monochromatic source of wavelength 7500Å and separation between the slits is doubled?

Ans:

Given $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between the two waves from slits S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$ or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$

(i) For constructive interference at point P, path difference

$$\Delta x = n\lambda \text{ or } \frac{\lambda}{4} + \frac{yd}{D} = n\lambda \text{ or } \frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda \qquad ...(i)$$

where $n = 0, 1, 2, 3, \ldots\ldots$

(ii) For destructive interference at point P, path difference

$$\Delta x = (2n-1)\frac{\lambda}{2} \text{ or } \frac{\lambda}{4} + \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$$

$$\text{or } \frac{yd}{D} = \left(2n - 1 - \frac{1}{2}\right)\frac{\lambda}{2} = (4n-3)\frac{\lambda}{4} \qquad ...(ii)$$

where $n = 1, 2, 3, 4, \ldots\ldots$

For central bright fringe, putting $n = 0$ in equation (i), we get

$$\frac{yd}{D} = -\frac{\lambda}{4} \text{ or } y = \frac{-\lambda D}{4d}$$

The –ve sign indicates that central bright fringe will be observed below centre O of screen, at distance $\frac{\lambda d}{4d}$ below it.

Given for $\lambda_1 = 6000$ Å, fringe width $\beta_1 = 0.8$ mm, then for $\lambda_2 = 7500$Å, fring width $\beta_2 = ?$

Also, $d_2 = 2d_1$

$$\text{So, } \frac{\beta_2}{\beta_1} = \frac{\lambda_2 D / d_2}{\lambda_1 D / d_1} = \frac{\lambda_2}{\lambda_1} \times \frac{d_1}{d_2}$$

$$\text{or } \beta_2 = \frac{7500}{6000} \times \frac{d_1}{2d_1} \times 0.8 \text{ or } \beta_2 = 0.5 \text{ mm}$$

OR

(a) What are coherent sources of light? State two conditions for two light sources to be coherent.

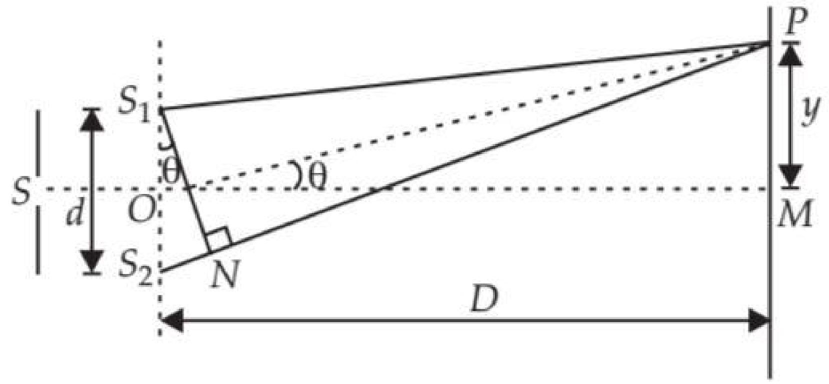
(b) Derive a mathematical expression for the width of interference fringes obtained in Young's double slit experiment with the help of a suitable diagram.

Ans: (a) Coherent sources are those which have exactly the same frequency and are in the same phase or have a constant difference in phase.

Conditions : (i) The sources should be monochromatic and originating from common single source.

(ii) The amplitudes of the waves should be equal.

(b) Expression for fringe width : Let S_1 and S_2 be two coherent sources separated by a distance d. Let the distance of the screen from the coherent sources be D. Let M be the foot of the perpendicular drawn from O, the midpoint of S_1 and S_2 on the screen. Obviously point M is equidistant from S_1 and S_2. Therefore, the path difference between the two waves at point M is zero. Thus, the point M has the maximum intensity. Consider a point P on the screen at a distance y from M. Draw S_1N perpendicular from S_1 on S_2P.



The path difference between two waves reaching at P from S_1 and S_2 is $\Delta = S_2P - S_1P \approx S_2N$

As $D >> d$, therefore $\angle S_2S_1N = \theta$ is very small

$\therefore \quad \angle S_2S_1N = \angle MOP = \theta$

In ΔS_1S_2N, $\sin\theta = \frac{S_2N}{S_1S_2}$

In ΔMOP, $\tan\theta = \frac{MP}{OM}$

As θ is very small

$\therefore \quad \sin\theta = \theta = \tan\theta$

$$\therefore \quad \frac{S_2N}{S_1S_2} = \frac{MP}{OM} \quad \therefore \quad S_2N = S_1S_2\frac{MP}{OM} = d\cdot\frac{y}{D}$$

$$\therefore \quad \text{Path difference } \Delta = S_2P - S_1P = S_2N = \frac{yd}{D}$$

(i) Positions of bright fringes (or maxima) : For bright fringe or maximum intensity at P, the path difference must be an integral multiple of wavelength (X) of light used. i.e., $\Delta = n\lambda$

$$\therefore \quad \frac{yd}{D} = n\lambda, n = 0, 1, 2, 3, ...$$

$$\therefore \quad y = \frac{nD\lambda}{d}$$

This equation gives the distance of *nth* bright fringe from the point M. Therefore, writing y_n for y, we get

$$y_n = \frac{nD\lambda}{d}$$

(ii) Position of dark fringes (or minima) : For dark fringe or minimum intensity at P, the path difference must be an odd number multiple of half wavelength

$$i.e.\ \Delta = (2n-1)\frac{\lambda}{2}$$

$$\therefore \quad \frac{y\cdot d}{D} = (2n-1)\frac{\lambda}{2} \quad \text{where } n = 1, 2, 3, ...$$

$$\text{or} \quad y = \frac{(2n-1)\lambda D}{2d} = \left(n - \frac{1}{2}\right)\frac{\Delta\lambda}{d}$$

This equation gives the distance of n^{th} dark fringe from point M. Therefore writing y_n for y, we get

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

(iii) Fringe width : The distance between any two consecutive bright fringes or any two consecutive dark fringes is called the fringe width. It is denoted by β. For bright fringes : If y_{n+1} and y_n denote the distances of two consecutive bright fringes from M, then we have

$$y_{n+1} = (n+1)\frac{D\lambda}{d} \text{ and } y_n = \frac{nD\lambda}{d}$$

∴ Fringe width,

$$\beta = y_{n+1} - y_n = (n+1)\frac{D\lambda}{d} - \frac{nD\lambda}{d} = \frac{D\lambda}{d}$$

For dark fringes : If y_{n+1} and y_n are the distances of two consecutive dark fringes from M, then we have

$$y_{n+1} = \left(n+\frac{1}{2}\right)\frac{D\lambda}{d}, \quad y_n = \left(n-\frac{1}{2}\right)\frac{D\lambda}{d}$$

∴ Fringe width,

$$\beta = y_{n+1} - y_n = \left(n+\frac{1}{2}\right)\frac{D\lambda}{d} - \left(n-\frac{1}{2}\right)\frac{D\lambda}{d} = \frac{D\lambda}{d}\left(n+\frac{1}{2}-n+\frac{1}{2}\right) = \frac{D\lambda}{d}$$

Thus, fringe width is the same for bright and dark fringes and is equal to

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

32. (a) A lamp is connected in series with a capacitor. Predict your observations for d.c. and a.c. connections. What happens in each case if the capacitance of the capacitor is reduced?

(b) A coil of 0.01 henry inductance and 1 ohm resistance is connected to 200 volt, 50 Hz ac supply. Find the impedance of the circuit and time lag between maximum alternating voltage and current.

(a) Here, combination of lamp and capacitor is a series LCR circuit. Capacitor offers infinite resistance for d.c.

For d.c.,

$$X_C = \frac{1}{2\pi\upsilon C} = 0, X_C = \infty$$

On switching d.c. on after a fraction of second the capacitor gets charged fully and then no current flows. For a.c.circuit, capacitor offers finite resistance.

$$X_C = \frac{1}{2\pi\upsilon C}, \ X_L = 2\pi\upsilon L, Z = \sqrt{R^2 + (X_L - X_C)^2}$$

reducing C will increase Z and thus reduce the current.

(b) $L = 0.01$ H, $R = 1\ \Omega$, $E = 200$ V, $\upsilon = 50$ Hz.

$X_L = 2\pi\upsilon l = 2 \times (3.14) \times 50 \times 0.01 = 3.14\ \Omega.$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{(1)^2 + (3.14)^2} = \sqrt{10.86} = 3.3\ \Omega$$

$$\tan\phi = \frac{X_L}{R} = \frac{3.14}{1} = 3.14$$

$$\phi = \tan^{-1}(3.14) = 72° = 72 \times \frac{\pi}{180}\text{ rad} = 0.4\,\pi \text{ rad}$$

Time lag, $\Delta t = \dfrac{\phi}{\omega} = \dfrac{0.4\pi}{100\pi} = 0.004$ s

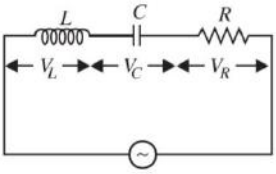
$(\omega = 2\pi\upsilon = 100\,\pi \text{ rad s}^{-1})$

OR

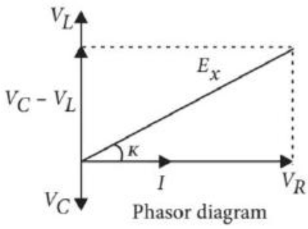
(a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.
(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit?
(c) When an inductor is connected to a 200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.

(a) AC circuit containing inductor, capacitor and resistor in series [Series LCR circuit]

If I is the current in the circuit containing inductor of inductance L, capacitor of capacitance C and resistor of resistance R in series, then the voltage drop across the inductor is
$V_L = I \times X_L$



which leads current I by phase angle of $\pi/2$, and voltage drop across the capacitor is $V_C = I \times X_C$



Phasor diagram

which lags behind current I by phase angle of $\pi/2$, and voltage drop across the resistor is $V_R = IR$,
which is in phase with current I. So the net voltage E, across the circuit is

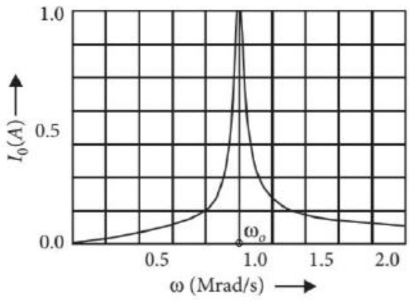
$$E = \sqrt{V_R^2 + (V_L - V_C)^2}$$

or $E = I\sqrt{R^2 + (X_L - X_C)^2}$

or $E = IZ$

where Z is the effective resistance offered by ac circuit containing inductor, capacitor and resistor in series, known as impedance in series LCR circuit. Hence in series LCR circuit, phase difference ϕ between the current I and the voltage E is

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\left(\omega L - \frac{1}{\omega C}\right)}{R}$$



With increase in ω, current first increases (upto ω_0) and then decreases.

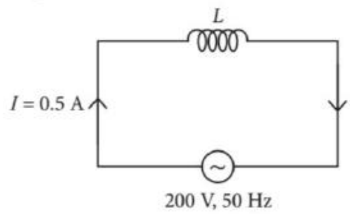
(b) At resonance, $X_L = X_C$

$\therefore \tan\phi = \frac{X_L - X_C}{R} = 0$

$\therefore \phi = 0°$

∴ There is no phase difference between voltage across inductor and capacitor at resonance in the LCR circuit.

(c) Whenever an inductor is connected to an a.c. source then it produces inductive reactance as impedance, that reduces the amount of current flowing through it. When inductor is connected to d.c. voltage, current flow in a circuit is 1 A and when in same inductor is connected to a.c. source, current will be reduced so, we can say that power consumption is more in case of d.c. circuit.

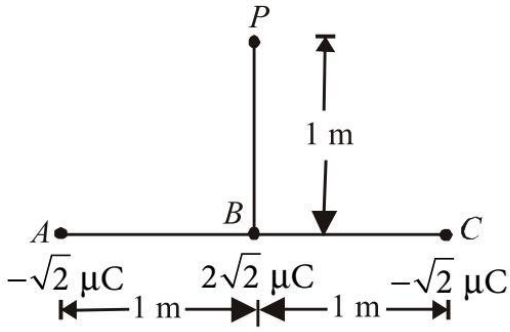


Here, $I = 0.5$ A, $V = 200$ V, $\upsilon = 50$ Hz

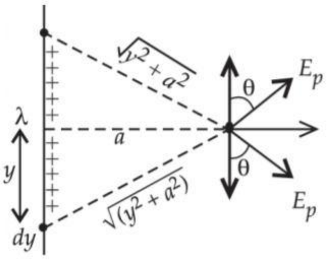
∴ Inductive reactance, $X_L = \omega L = 2\pi\upsilon L$

Also, $I = \frac{V}{X_L}$ or $0.5 = \frac{200}{2 \times 3.14 \times 50 \times L}$

33. (a) Obtain the formula for the electric field due to a long thin wire of uniform linear charge density λ without using Gauss's law.
(b) Three charges $-\sqrt{2}\mu C$, $2\sqrt{2}\mu C$ and $-\sqrt{2}\mu C$ are arranged along a straight line as shown in the figure. Calculate the total field intensity due to all three charges at the point P.



(a) Consider a point P, a unit away from the long charged wire.



Electric field due to element dy, $dE_p = \dfrac{Q}{4\pi\varepsilon_0 r^2}$

$Q = \lambda dy$

$r^2 = y^2 + a^2$

$$\Rightarrow dE_p = \frac{\lambda dy}{4\pi\varepsilon_0 (y^2 + a^2)} \quad \Rightarrow \quad E_p = \int_{-\infty}^{\infty} dE_p$$

Vertical components cancel out and horizontal components are added due to symmetry.

$$\Rightarrow \; E_p = \int_0^{\infty} \frac{2\lambda dy}{4\pi\varepsilon_0 (y^2 + a^2)} \times (\cos\theta) \; = \frac{2}{4\pi\varepsilon_0} \int_0^{\infty} \frac{\lambda dy}{y^2 + a^2} \times \frac{y}{\sqrt{y^2 + a^2}}$$

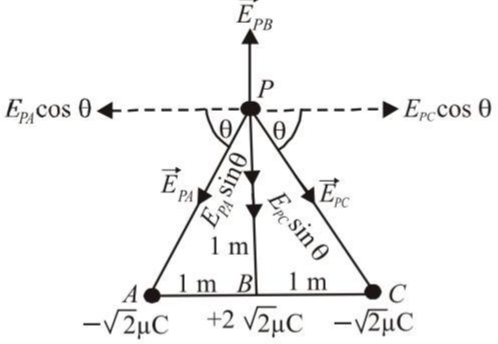
$$= \frac{2}{4\pi\varepsilon_0} \int_0^{\infty} \frac{\lambda y dy}{(y^2 + a^2)^{3/2}}$$

Take $y^2 + a^2 = x \quad \Rightarrow \quad 2ydy = dx$

Taking proper limits

$$E_p = \frac{\lambda}{4\pi\varepsilon_0} \int_{a^2}^{\infty} \frac{dx}{x^{3/2}} \Rightarrow \left[\frac{-2\lambda}{4\pi\varepsilon_0} \frac{1}{\sqrt{x}} \right]_{a^2}^{\infty} = \frac{\lambda}{2\pi\varepsilon_0 a}$$

(b) Electric field at (i) point P due to charge at A or C is



$$E_{PA} = E_{PC} = 9 \times 10^9 \times \frac{\sqrt{2} \times 10^{-6}}{(\sqrt{2})^2} = \frac{9\sqrt{2}}{2} \times 10^3 \text{ N/C}$$

(ii) Point P due to charge at B is

$$E_{PB} = 9 \times 10^9 \times \frac{2\sqrt{2} \times 10^{-6}}{1^2} = 18\sqrt{2} \times 10^3 \text{ N/C}$$

Horizontal component of net electric field at point P is

$$E_X = E_{PC} \cos\theta - E_{PA} \cos\theta = 0$$

Vertical component of net electric field at point P is

$$E_Y = E_{PB} - E_{PA} \sin\theta - E_{PC} \sin\theta$$

$$= \left(18\sqrt{2} - \frac{9\sqrt{2}}{2} \times \frac{1}{\sqrt{2}} - \frac{9\sqrt{2}}{2} \times \frac{1}{\sqrt{2}}\right) \times 10^{-3} \text{ N/C} \quad (\text{as, } \theta = 45°)$$

$$= (18\sqrt{2} - 4.5 - 4.5) \times 10^{-3} \text{ N/C}$$

$$= 16.45 \times 10^{-3} = 1.645 \times 10^{-2} \text{ N/C}$$

So resultant electric field at point P is

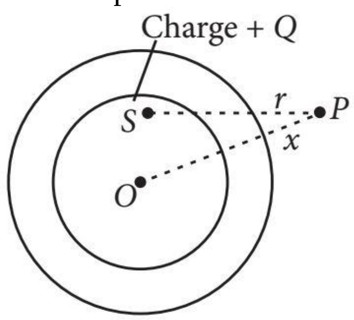
$$E = \sqrt{E_X^2 + E_Y^2} = E_Y \text{ or } E = 1.645 \times 10^{-2} \text{ N/C}$$

directed along vertical, *i.e.*, along PB.

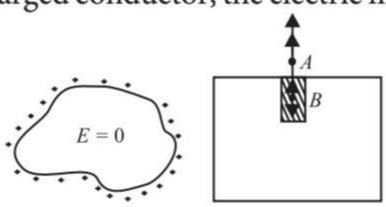
OR

(a) A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $\left(\frac{\sigma}{2\varepsilon_0}\right)\hat{n}$, where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.

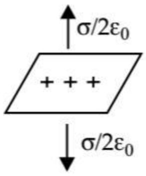
(b) The figure shows a charge + Q held on an insulating support S and enclosed by a hollow spherical conductor. O represents the centre of the spherical conductor and P is a point such that OP = x and SP = r. Find the electric field at point P.



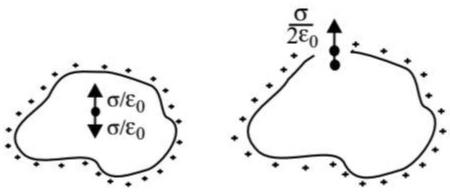
(a) Inside a charged conductor, the electric field is zero.



But a uniformly charged flat surface provide an electric field $\frac{\sigma}{2\varepsilon_0}$ normal to its plane.



If we consider a small flat part on the surface of charged conductor, it certainly provides an electric field $\frac{\sigma}{2\varepsilon_0}$ inside the conductor, which is nullified by an equal field due to rest of charged conductor.



Now if a hole is made in charged conductor, the field due to small flat part is absent but the field due to rest of charged conductor is present, *i.e.*, equal to $\frac{\sigma}{2\varepsilon_0}\hat{n}$.

(b) According to Gauss's theorem,

$$\Rightarrow \oint E.dS = \frac{Q_{in}}{\varepsilon_0} \Rightarrow E.4\pi x^2 = \frac{Q}{\varepsilon_0} \quad \text{or} \quad E = \frac{Q}{4\pi\varepsilon_0 x^2}$$