Class : XII || AHSEC || Pre Board Examination , 2024-25

Subject : Physics ||Full marks : 70||Time : 3hours|| Set - 05

(The figures in the margin indicate full marks for the questions)

Section A :: Each question carries 1 mark

1. A p-type semiconductor can be obtained by adding
   a) phosphorus to pure germanium
   b) gallium to pure silicon
   c) arsenic to pure silicon
   d) antimony to pure germanium

Answer- (b)

2. When a current flows in a wire, there exists an electric field in the direction of:
   a) flow of current b) opposite to the flow of current c) perpendicular to the flow of current
   d) at an angle of 45° to the flow of current

Answer- (a)

3. Which of the following is used in optical fibers?
   a) Scattering b) Refraction
   c) Diffraction d) Total internal reflection

Answer- (d)

4. If we carry a charge once around an equipotential path, then work done by the charge is
   a) infinity b) negative c) zero d) positive

Answer- (c)

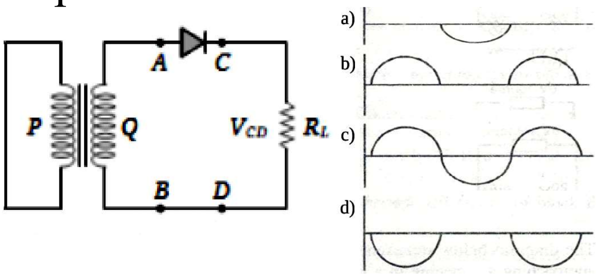
5. When a charged particle enters in a uniform magnetic field, its kinetic energy.

a) decreases b) becomes zero

c) remains constant d) increases

Answer- (c)

6. In the half wave rectifier circuit shown which one of the following wave forms is true for V_{CD}, the output across C and D?



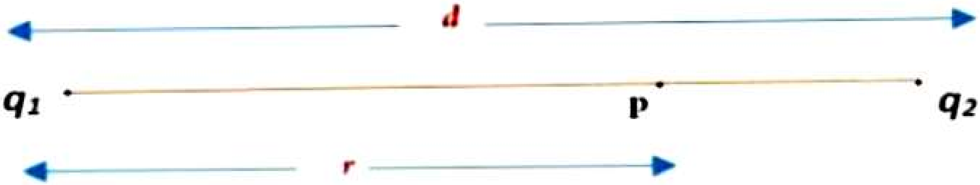
Answer- (b)

7. What is Lorentz force ? Write an expression for it .

<u>Section B :: Each question carries 2 marks</u>

8.Two charges 5×10^{-8} C and -3×10^{-8} C are located 16 cm apart. At what point (s) on the line joining the two charges is the electrical potential zero? Take the potential at infinity to be zero. [2]

Consider a point P on the line joining the two charges,



$$\therefore V = \frac{1}{4\pi\varepsilon_0}.\frac{q_1}{r} + \frac{1}{4\pi\varepsilon_0}.\frac{q_2}{(d-r)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For V = 0, equation (i) reduces to

$$0 = \frac{1}{4\pi\varepsilon_0}.\frac{q_1}{r} + \frac{1}{4\pi\varepsilon_0}.\frac{q_2}{(d-r)}$$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}.\frac{q_1}{r} = -\frac{1}{4\pi\varepsilon_0}.\frac{q_2}{(d-r)}$$

$$\Rightarrow \frac{q_1}{r} = -\frac{q_2}{(d-r)} \Rightarrow \frac{5\times10^{-8}}{r} = -\frac{(-3\times10^{-8})}{(0.16-r)}$$

$$\Rightarrow 5(0.16-r) = 3r$$

$\Rightarrow 0.8 = 8r \Rightarrow = 0.1\text{m} = 10\text{cm}$

Therefore, the potential is zero at a distance of 10 cm from the positive charge between the charges.

9. Explain the formation of depletion layer in a PN junction diode with the help of drift and diffusion method. [2]

10. Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier.

[2]

11. If Bohr's quantisation postulate (angular momentum $= \frac{nh}{2\pi}$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why then do we never speak of quantisation of orbits of planets around the sun? [2]

Answer -

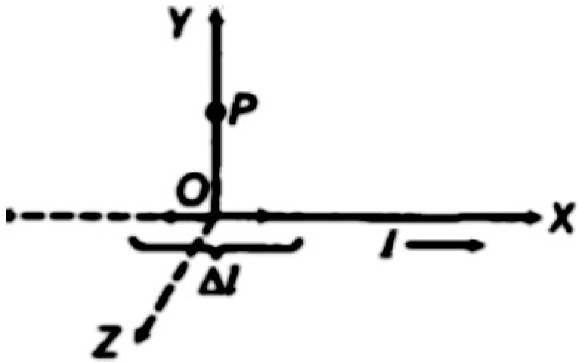
The momentum associated with planetary motion is largely relative to the value of Planck's constant (h). The angular momentum of the Earth in its orbit is of the order of 10^{70}h.

This leads to a very high value of quantum levels n of the order of 10^{70}.

For large values of n, successive energies and angular momenta are relatively very small. Hence, the quantum levels for planetary motion are considered continuous.

12. An element $M = \Delta l = \Delta x\,\hat{i}$ is placed at the origin (as shown in figure) and carries a current I = 2 A. Find out the magnetic field at a point P on the Y-axis at a distance Δx = 1.0 cm due to the element . Also, give

the direction of the field produced.

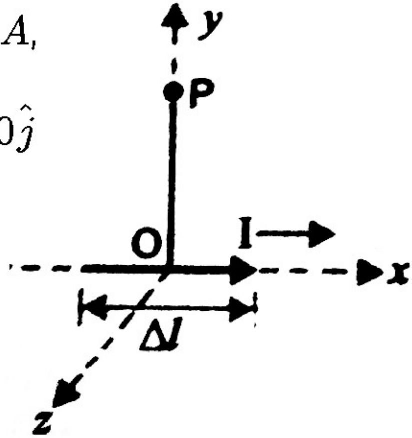


[2]

Here, $Id\vec{l} = I\Delta x\hat{i}$, where $I = 2A$,

$\Delta x = 1cm = 10^{-2}m$

$r = 1\cdot 0\,m$ and $\vec{r} = 1\cdot 0\hat{j}$



$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$$

$$= \frac{\mu_0}{4\pi}\frac{I\Delta x\hat{i}\times\left(1\cdot 0\,\hat{j}\right)}{r^3}$$

$$= \frac{\mu_0}{4\pi}\frac{(I\Delta x\times 1\cdot 0)}{r^3}\left(\hat{i}\times\hat{j}\right) = 10^{-7}\times\frac{2\times 10^{-2}\times 1\cdot 0}{1^3}\hat{k}$$

$= 2\times 10^{-9}T$ in +z direction.

OR

A horizontal overhead power line carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line? **[2]**

Current in the power line, $I = 90$ A

Point is located below the power line at distance,

$$r = 1.5 \text{ m}$$

Hence, magnetic field at that point is given as

$$B = \frac{\mu_0}{4\pi}\frac{2I}{r} = 10^{-7}\frac{2 \times 90}{1.5} = 1.2 \times 10^{-5} \text{ T}$$

The current is flowing from East to West.

The point is below the power line.

Hence, according to right-hand thumb rule, the direction of the magnetic field is towards the South.

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13. A closely wound solenoid of 800 turns and area of cross $2.5\times10^{-4}m^2$ section carries a current of 3.0 A. What is its associated magnetic moment? [2]

Number of turns in the solenoid, $n = 800$

Area of cross-section, $A = 2.5 \times 10^{-4} \text{ m}^2$

Current in the solenoid, $I = 3.0$ A

A current-carrying solenoid behaves as a bar magnet because a magnetic field develops along its axis, i.e., along its length. The magnetic moment associated with the given current-carrying solenoid is calculated as:

$M = n I A$

$= 800 \times 3 \times 2.5 \times 10^{-4} = 0.6 \text{ J T}^{-1}$

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14. A plane electromagnetic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3 V/m. Find the magnitude and direction magnetic induction (B) .s [2]

Velocity of light $C = \frac{E}{B} \Rightarrow B = \frac{E}{C} = \frac{9.3}{3 \times 10^8} = 3.1 \times 10^{-8}$ T

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15. Write down the expression for wave number .
A hydrogen atom initially in the ground level absorbs a photon, which excites it to the **n = 4** level. Determine the wavelength and frequency of photon. [2]

We know that ground state energy of hydrogen atom is eg= -13.6 eV.

Now if atom is excited to $n = 4$ level, then we have

$$E_4 = -\frac{13 \cdot 6}{4^2} = -\frac{13 \cdot 6}{16} = -0 \cdot 85 \text{ ev} \qquad \left(\because\ E_n = -\frac{E_g}{n^2}\right).$$

Now if v is the frequency of photon then

$$hv = E_4 - E_g \quad \text{OR} \quad v = \frac{E_4 - Eg}{h}$$

$$\text{OR} \quad v = \frac{[-0.85 - (-13.6)]\ ev}{6.63 \times 10^{-34} \text{ J-s}} = \frac{12.75 \times 1.6 \times 10^{-19} \text{ Jule}}{6.63 \times 10^{-34} \text{ Jule - sec}}$$

$$\boxed{v = 3.08 \times 10^{15}\ Hz}$$

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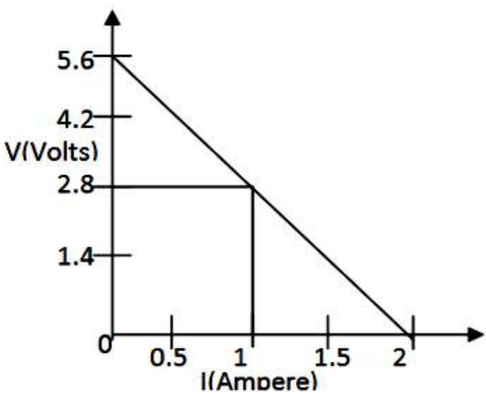
16. From the relation $\boldsymbol{R = R_0A^{1/3}}$, where $\boldsymbol{R_0}$ is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant [2]

17. Draw the ray diagram of the Cassegrain telescope . What are the types of mirrors used ? Name them . [2]

Section c :: Each question carries 3 marks

18. 4 cells of identical emf E and internal resistance r are connected in series to a variable resistor. The following graph shows the variation of terminal voltage of the combination with the current output.
(i)What is the emf of each cell used?
(ii)For what current from the cells, does maximum power dissipation occur in the circuit?



[3]

(i) Total emf of 4 cells in series = $5.6\ \mathrm{V}$

EMF of each cell $= \frac{5.6\ \mathrm{V}}{4} = 1.4\ \mathrm{V}$

(ii) When $i = 1.0A,\ V = \frac{2.8\ \mathrm{V}}{4} = 0.7\ \mathrm{V}$

Internal resistance of a cell

$$r = \frac{\varepsilon - V}{i} = \frac{1.4 - 0.7}{1.0} = 0.7\ \Omega$$

The output power is maximum when external

resistance = internal resistance = $4\ r = 4 \times 0.7\ \Omega = 2.8\ \Omega$

$$I_{max} = \frac{\text{total emf}}{\text{total resistance}} = \frac{4\,\varepsilon}{R + 4\,r} = \frac{4\,\varepsilon}{4r + 4\,r}$$

$$= \frac{\varepsilon}{4\,r} = \frac{\varepsilon}{4\,r} = \frac{1.4}{2.8} = 0.5\ \mathrm{A}$$

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19. A bar magnet is placed in a uniform magnetic field with its magnetic moment making an angle θ with the field.

(i) Find an expression for the torque acting on the magnet and hence define its magnetic moment.

(ii) Write an expression for potential energy of the magnet in this orientation. When is this energy minimum? [3]

20. Ultra-violet light of wavelength 200 nm from a source is incident on a metal surface. Stopping potential is **-2.5** V

(i) Calculate the work function of the metal, and

(ii) How would the surface respond to a high intensity red light of wavelength 6328 Å produced by a laser? **3**

The energy of the incident UV light using the formula: $E = hf = \frac{hc}{\lambda}$

$$E = \frac{(6.626 \times 10^{-34}\mathrm{J \cdot s})(3.00 \times 10^{8}\mathrm{m/s})}{200 \times 10^{-9}\mathrm{m}} \approx 9.939 \times 10^{-19}\mathrm{J}$$

The work function of the metal using the photoelectric effect equation:

$$E = \Phi_0 + eV_s => \Phi_0 = E - eV_s$$

$$\Phi_0 = 9.939 \times 10^{-19}\mathrm{J} - (1.602 \times 10^{-19}\mathrm{C})(-2.5\mathrm{V}) \approx 13.944 \times 10^{-19}\mathrm{J}$$

$$\Phi \approx 13.944 \times 10^{-19}\mathrm{J}/1.602 \times 10^{-19}\mathrm{C} \approx 8.7\mathrm{eV}$$

The energy of the red light ($\lambda = 6328\text{Å} = 632.8 \times 10^{-9}\mathrm{m}$)

$$E_{red} = \frac{(6.626 \times 10^{-34}\mathrm{J \cdot s})(3.00 \times 10^{8}\mathrm{m/s})}{632.8 \times 10^{-9}\mathrm{m}} \approx 3.14 \times 10^{-19}\mathrm{J}$$

$$E_{red} \approx 3.14 \times 10^{-19}\mathrm{J}/1.602 \times 10^{-19}\mathrm{C} \approx 1.96\mathrm{eV}$$

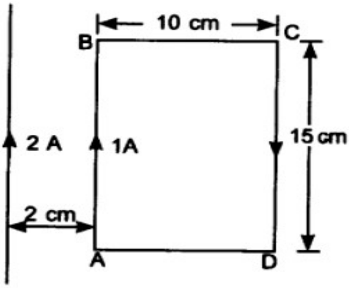
Since the energy of the red light is lower than the work function, the surface would not respond to the red light with photoemission

21. Name the process involved in the sun for the production of energy . Describe how energy is produced . **[3]**

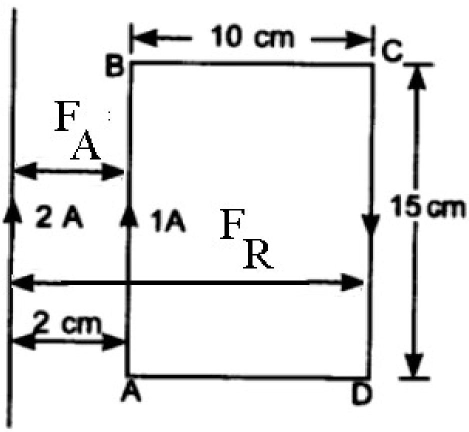
22. Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is

(i) attractive, (ii) repulsive.Write two important conclusions which you can draw regarding the nature of the nuclear forces.
[3]

23. Find the force on the rectangular coil Give its direction



[3]



$I_1 = 2\,A$

$I_2 = 1A$

$a = 10\ cm$

$r = 2\ cm$

$b = 15\ cm$

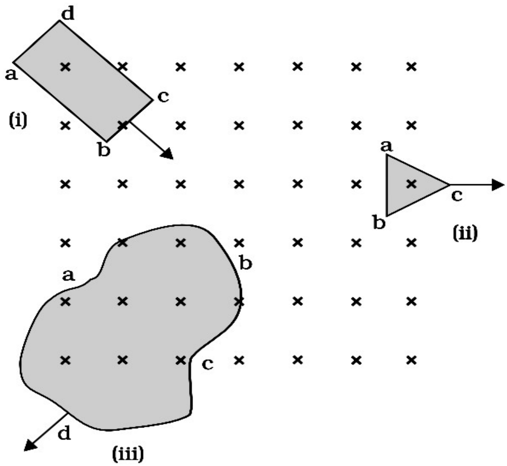
$$F_A = \frac{\mu_o}{4\pi}\frac{2I_1I_2}{r}b = 10^{-7}\frac{2 \times 1}{0.02} \times 0.15 = 15 \times 10^{-7}\ N$$

$$F_R = \frac{\mu_o}{4\pi}\frac{2I_1I_2}{r+a}b = 10^{-7}\frac{2 \times 1}{0.12} \times 0.15 = 2.5 \times 10^{-7}\ N$$

$F_A > F_R$, so net force on the loop

$$F = F_A - F_R = (15 - 2.5) \times 10^{-7} = 12.5 \times 10^{-7}\ N$$

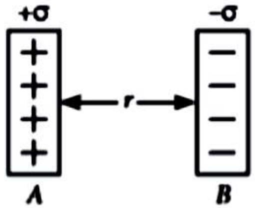
23. State Lenz's law .
Following figure shows planar loops of different shapes moving out of or into a region of a magnetic field which is directed normal to the plane of the loop away from the reader. Determine the direction of induced current in each loop using



Lenz's law. [3]

(i) The magnetic flux through the rectangular loop abcd increases,due to the motion of the loop into the region of magnetic field, The induced current must flow along the path bcdab .
(ii) Due to the outward motion, magnetic flux through the triangular loop abc decreases due to which the induced current flows along bacb.
(iii) As the magnetic flux decreases due to motion of the irregular shaped loop abcd out of the region of magnetic field, the induced current flows along cdabc, so as to oppose change in flux.

25. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17×10^{-22} Cm^{-2} as shown.



(i) Find electric field in the outer region of the first plate

(ii) Find electric field in between the two plates .

(iii) Find the force acting on an alpha particle placed in between the two plates .

Surface charge density of plate A = $+17.7 \times 10^{-22}$ C/m^2

Surface charge density of plate B = -17.7×10^{-22} C/m^2

(i) In the outer region of plate I, electric field intensity E is zero.

(ii) Electric field intensity E in between the plates is given by relation

$$E = \frac{\sigma}{\epsilon_0}$$

Where, ϵ_0 = Permittivity of free space = 8.85×10^{-12} N^{-1} C^2 m^{-2}

$$\therefore E = \frac{17.7 \times 10^{-22}}{8.85 \times 10^{-1}} = 2.0 \times 10^{-10} \text{ N/C}$$

Therefore, electric field between the plates is 2.0×10^{-10} N/C.

(iii) Force on the alpha particle placed in between the two plates

$$F = q E = + 3.2 \times 10^{-19} \times 2 \times 10^{-10} = 6.4 \times 10^{-29} \text{N}$$

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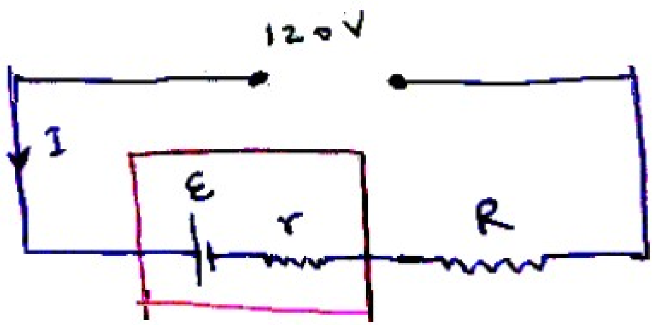
26. Define internal resistance of a cell .

A storage battery of emf 8.0 V and internal resistance 0.5 Ω is being charged by a 120 V dc supply using a series resistor of 15.5 Ω. What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?



Effective voltage, $E_{eff} = 120 - 8 = 112$ v

Equivalent resistance, Req = r + R = 0.5 + 15.5 = 16 Ω

$\therefore I = \frac{E_{eff}}{R_{eq}} = \frac{112}{16} = 7A$

∴ Terminal voltage of battery during charging,

$V = E + Ir \quad = 8 + 7 \times 0.5 \quad = 11.5\ V$

Series resistance controls the current drawn from external supply. In its absence, the current during the charging will be dangerously high.

<u>Section D :: Each question carries 5 marks</u>

27. (i) Obtain the refraction formula for a convex spherical surface , with object in the rarer medium .
(ii) A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate its magnifying power . **[5]**

Given $f_o = 4cm$, $f_e = 10cm$ $u_o = -6cm$

Magnifying power of microscope

$$M = -\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$$

From lens formula $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$= \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o} = \frac{1}{4} - \frac{1}{6} = \frac{3-2}{12}$$

$\Rightarrow$ $v_o = 12$ cm

$$\therefore\ m = -\frac{12}{6}\left(1+\frac{25}{10}\right) = -2\times 3.5 = -7$$

OR

(i) In Young's double slit experiment,

monochromatic light of wavelength λ illuminates the pair of slits separated by a small distance of b and produces an interference pattern in a screen at a distance of L from the sources . Find the phase difference in the experiment . Prove that the central bright fringe forms at the centre of the screen .
(ii) The intensity at the central maxima in Young's double-slit experiment is I_o. Find out the intensity at a point where the path difference is **λ/6** . **[5]**

The resultant intensity of two waves of intensity, I_o

$I = 4I_o \cos^2(\frac{\phi}{2})$, where φ is phase difference

1) Path difference of $\frac{\lambda}{6}$

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{6} = \frac{\pi}{3}$$

$$I' = 4I_o \cos^2(\frac{\pi}{6}) = 3I_o$$

28.(i) Describe briefly the process of loss of energy when two parallel plate capacitor are connected parallely to each other . Derive an expression for the loss of energy in the process .
(ii) A 600pF capacitor is charged by a 200V supply. It is then disconnected from the supply and is

connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the process?

ANSWER-

Capacitance of the capacitor, C = 600 pF

Potential difference, V = 200 V

Electrostatic energy stored in the capacitor is given by,

$$E_1 = \frac{1}{2}CV^2 = \frac{1}{2} \times (600 \times 10^{-12}) \times (200)^2 \text{ J} = 1.2 \times 10^{-5} \text{ J}$$

If supply is disconnected from the capacitor and another capacitor of capacitance C = 600 pF is connected to it, then equivalent capacitance (Ceq) of the combination is given by,

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{600} + \frac{1}{600} = \frac{2}{600} = \frac{1}{300}$$

$$\Rightarrow C_{eq} = 300 \text{ pF}$$

New electrostatic energy can be calculated as

$$E_2 = \frac{1}{2}C_{eq}V^2 = \frac{1}{2} \times 300 \times (200)^2 \text{ J} = 0.6 \times 10^{-5} \text{ J}$$

Loss in electrostatic energy $= E_1 - E_2 = 1.2 \times 10^{-5} - 0.6 \times 10^{-5}$ J

$= 0.6 \times 10^{-5} \text{ J} = 6 \times 10^{-6}$ J

Therefore, the electrostatic energy lost in the process is 6×10^{-6} J.

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[5]

Or

A parallel plate capacitor has a square plate of side 12cm and seperated by 2 mm. The right plate is earthed and the left plate is given a charge of 10µC.

(i) Determine the capacitance of the capacitor.

(ii)The space between the plates is filled with a liquid of dielectric constant 2 . What is the capacitance now ?

(iii) Compare the energy stored in both the cases .**[5]**

(a) Initially, the capacitance without dielectrics is :

$$C_0 = \frac{\varepsilon_0 A}{d} = \frac{(8.85 \times 10^{-12} C^2/N.m^2)(0.12 m^2)}{0.2 \times 10^{-2} m} = 89 pF$$

(b) the capacitance with dielectrics is :

$$C = \frac{K \varepsilon_0 A}{d} = K\, C_0 = 2 \times 89 pF = 178\ pF$$

$$U_0 = \frac{1}{2} C_0 V^2 \ \ldots\ldots\ldots\ldots (1)$$

$$U = \frac{1}{2} C V^2 = \frac{1}{2} K C_0 V^2 \ \ldots\ldots\ldots\ldots (2)$$

$$(2)/(1) = \frac{U}{U_0} = \frac{\frac{1}{2} K C_0 V^2}{\frac{1}{2} C_0 V^2} = K = 2$$

29: (i) Prove that RMS value of AC is about 70% of the peak value of the AC .

(ii) An inductor of 200 mH, a capacitor of 400μF and a resistor of 10 Ω are connected in series to ac source of 50 V of variable frequency. Calculate the angular frequency at which maximum power dissipation occurs in the circuit and the value of Q-factor in the circuit. **[5]**

Here, $L = 200mH = \frac{2}{10}H$

$C = 400\nu F = 400 \times 10^{-6}F = 4 \times 10^{-4}F$

$R = 10ohm, E_v = 50V$

(i) Maximum power dissipation occurs in the circuit

at resonance, i.e., when

$$\omega L = \frac{1}{\omega C}$$

$$\text{or } \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\frac{2}{10} \times 4 \times 10^{-4}}}$$

$$\omega = \frac{1}{\sqrt{80 \times 10^{-6}}} = \frac{10^3}{8.944}$$

$$\omega = 111.8rad/s$$

$$I_v = \frac{E_v}{Z} = \frac{E_v}{R} = \frac{50}{10} = 5A$$

$$\text{(ii) } Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$Q = \frac{1}{10}\sqrt{\frac{2/10}{4 \times 10^{-4}}} = \frac{1}{10} \times \frac{100}{1.47} = 2.237$$

Or

An ac voltage $V = V_0 \sin\omega t$ is applied to a pure inductor of inductance L. Obtain an expression for the current in the circuit with the help of phasor diagram .

Prove that the average power supplied to an inductor over one complete cycle is zero. **[5]**