Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 7

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. In the middle of the depletion layer of reverse biased p-n junction, the: **[1]**

a) potential is maximum
b) potential is zero
c) electric field is zero
d) electric field is maximum

2. Two bulbs each marked 100 W, 220 V are connected in series across 220 V supply. The power consumed by them, when lit, is **[1]**

a) 220 W
b) zero
c) 100 W
d) 50 W

3. In a compound microscope, maximum magnification is obtained when the final image **[1]**

a) coincides with the objective
b) is formed at the least distance of distinct vision
c) coincides with the object
d) is formed at infinity

4. The magnetic moment (μ) of a revolving electron around the nucleus varies with principal quantum number n as **[1]**

a) $\mu \propto n$
b) $\mu \propto \frac{1}{n}$
c) $\mu \propto \frac{1}{n^2}$
d) $\mu \propto n^2$

5. The capacitors, each of $4\mu\text{F}$ are to be connected in such a way that the effective capacitance of the combination **[1]**

is $6\mu F$. This can be achieved by connecting

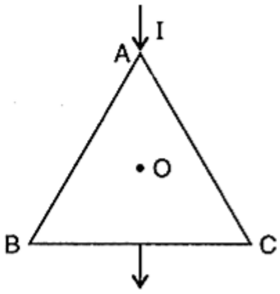
a) Two of them connected in parallel and the combination in series to the third.

b) Two of them connected in series and the combination in parallel to the third.

c) All three in series

d) All three in parallel

6. An equilateral triangle is made by uniform wires AB, BC, CA. A current I enteres at A and leaves from the mid-point of BC. If the lengths of each side of the triangle is L, the magnetic field B at the centroid O of the triangle is: **[1]**



a) $\frac{\mu_0}{4\pi}\left(\frac{4I}{L}\right)$

b) $\frac{\mu_0}{4\pi}\left(\frac{2I}{L}\right)$

c) $\frac{\mu_0}{2\pi}\left(\frac{4I}{L}\right)$

d) zero

7. A coil of wire of a certain radius has 100 turns and a self-inductance of 15 mH. The self-inductance of a second similar coil of 500 turns will be: **[1]**

a) 15 mH

b) 375 mH

c) 45 mH

d) 75 mH

8. Consider the two idealised systems: (i) a parallel plate capacitor with large plates and small separation and (ii) a long solenoid of length L > > R, radius of cross-section. In (i), E is ideally treated as a constant between plates and zero outside. In (ii), magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below: **[1]**

a) case (ii) contradicts Gauss's law for magnetic fields.

b) case (i) contradicts Gauss's law for electrostatic fields.

c) case (ii) contradicts en $\oint H.d1 = I_{en}$

d) case (i) agrees with $\oint E.d1 = 0$

9. In Huygens' theory, light waves **[1]**

a) are transverse waves and require no medium to travel.

b) are longitudinal waves and require a medium to travel.

c) are transverse waves and require a medium to travel.

d) are longitudinal waves and require no medium to travel.

10. An electric dipole placed in a non-uniform electric field can experience **[1]**

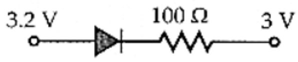
a) always a force and a torque.

b) neither a force nor a torque.

c) a force but not a torque.

d) a torque but not a force.

11. The current in the circuit shown in the figure considering ideal diode is **[1]**



a) 200 A

b) 2×10^{-4} A

c) 20 A

d) 2×10^{-3} A

12. A microscope is focused on a mark. Then a glass slab of refractive index 1.5 and thickness 6 cm is placed on the mark. To get the mark again in focus the microscope should be moved **[1]**

a) 9 cm upward

b) 2 cm downward

c) 4 cm upward

d) 2 cm upward

13. **Assertion (A):** In the process of photoelectric emission, all emitted electrons have the same kinetic energy. **[1]**

Reason (R): According to Einstein's equation $E_k = h\nu - \phi_0$.

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 but R is true.

14. **Assertion (A):** Two adjacent conductors of unequal dimensions, carrying the same positive charge have a potential difference between them. **[1]**

Reason (R): The potential of a conductor depends upon the charge given to it.

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 but R is true.

15. **Assertion (A):** To observe diffraction of light, the size of the obstacle/aperture should be of the order of 10^{-7} m. **[1]**

Reason (R): 10^{-7} is the order of the wavelength of visible light.

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 but R is true.

16. **Assertion (A):** If the frequency of the applied AC is doubled, then the power factor of a series R-L circuit decreases. **[1]**

Reason (R): Power factor of series R-L circuit is given by $\cos\phi = \frac{2R}{R^2+\omega^2L^2}$.

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 but R is true.

Section B

17. Poynting vectors $\vec{S}$ is defined as a vector whose magnitude is equal to the wave intensity and whose direction is along the direction of wave propogation. Mathematically, it is given by $\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$. Show the nature of S vs t graph. **[2]**

18. Distinguish between diamagnetic and ferromagnetic materials in terms of **[2]**

i. susceptibility and

ii. their behaviour in a non-uniform magnetic field

19. Determine the number density of donor atoms which have to be added to an intrinsic germanium semiconductor to produce an n-type semiconductor of conductivity 5 Ω^{-1} cm^{-1}, given that the mobility of electron in n-type Ge is 3900 cm^2 /Vs. Neglect the contribution of holes to conductivity. **[2]**

20. An α-particle moving with initial kinetic energy K towards a nucleus of atomic number Z approaches a distance d at which it reverses its direction. Obtain the expression for the distance of closest approach d in terms of the kinetic energy of α-particle K. **[2]**

21. A proton and an alpha particle having the same kinetic energy are, in turn, passed through a region of the uniform magnetic field, acting normal to the plane of the paper and travel in circular paths. Deduce the ratio of the radii of the circular paths described by them. **[2]**

OR

Which one of the following will describe the smallest circle when projected with the same velocity v perpendicular to the magnetic field B: (i) α-particle, and (ii) β-particle?

Section C

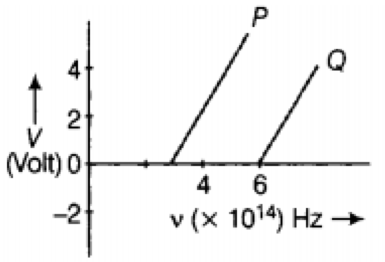
22. A homogeneous poorly conducting medium of resistivity ρ fills up the space between two thin coaxial ideally conducting cylinders. The radii of the cylinders are equal to a and b with a < b, the length of each cylinder is l. Neglecting the edge effects, find the resistance of the medium between the cylinders. **[3]**

23. Draw a circuit diagram of a transistor amplifier in CE configuration. Under what condition does the transistor act as an amplifier? **[3]**

Define the terms:

i. Input resistance and
ii. Current amplification factor. How are these determined using typical input and output characteristics?

24. In the study of a photoelectric effect, the graph between the stopping potential V and frequency ν of the incident radiation on two different metals P and Q is shown below. **[3]**



i. Which one of the two metals has higher threshold frequency?
ii. Determine the work function of the metal which has greater value.

25. We are given the following atomic masses: **[3]**

$^{238}_{92}U$ = 238.05079 u
$^{4}_{2}He$ = 4.00260 u
$^{234}_{90}Th$ = 234.04363 u
$^{1}_{1}H$ = 1.00783 u
$^{237}_{91}Pa$ = 237.05121 u

Here the symbol Pa is for the element protactinium (Z = 91).

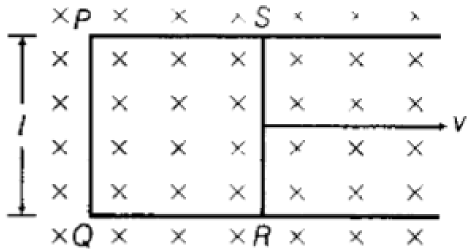
i. Calculate the energy released during the alpha decay of $^{238}_{92}U$.
ii. Calculate the kinetic energy of the emitted α-particles.
iii. Show that $^{238}_{92}U$ can not spontaneously emit a proton.

26. **[3]**
a. Using the Bohr's model, calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels.
b. Calculate the orbital period in each of these levels.

27. Define the term wavefront. State Huygen's principle. Consider a plane wavefront incident on a thin convex lens. Draw a proper diagram to show how the incident wavefront traverses through the lens and after refraction **[3]**

focusses on the focal point of the lens, giving the shape of the emergent wavefront.

28. Figure shows a rectangular conducting loop PQRS in which arm RS of length I is movable. The loop is kept in a uniform magnetic field B directed downward perpendicular to the plane of the loop. The arm RS is moved with a uniform speed v. **[3]**



Deduce an expression for

i. the emf induced across the arm RS

ii. the external force required to move the arm and

iii. the power dissipated as heat.

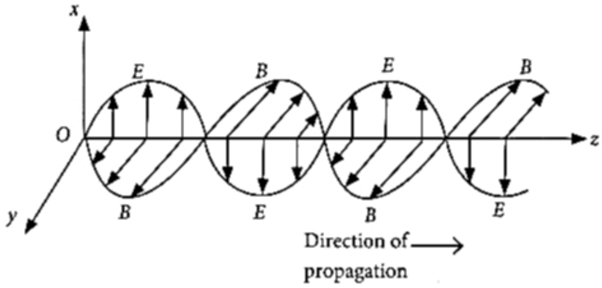
OR

Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it.

Section D

29. **Read the text carefully and answer the questions:** **[4]**

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(a) Magnetic field in a plane electromagnetic wave is given by $\vec{B} = B_0 \sin(kx + \omega t)\hat{j}$ T

Expression for corresponding electric field will be (Where c is speed of light.)

a) $\vec{E} = B_0 c \sin(kx + \omega t)\,\hat{k}$ V/m

b) $\vec{E} = -B_0 c \sin(kx - \omega t)\,\hat{k}$ V/m

c) $\vec{E} = -B_0 c \sin(kx + \omega t)\,\hat{k}$ V/m

d) $\vec{E} = \frac{B_0}{c} \sin(kx + \omega t)\,\hat{k}$ V/m

(b) The electric field component of a monochromatic radiation is given by $\vec{E} = 2E_0\hat{i} \cos kz \cos \omega t$. Its magnetic field $\vec{B}$ is then given by

a) $-\frac{2E_0}{c}\,\hat{j} \sin kz \sin \omega t$

b) $\frac{2E_0}{c}\,\hat{j} \sin kz \sin \omega t$

c) $\frac{2E_0}{c}\,\hat{j} \sin kz \cos \omega t$

d) $\frac{2E_0}{c}\,\hat{j} \cos kz \cos \omega t$

(c) A plane em wave of frequency 25 MHz travels in a free space along x-direction. At a particular point in space and time, E = (6.3 $\hat{j}$) V/m. What is magnetic field at that time?

a) 0.089 μT

b) 0.124 μT

c) 0.021 μT

d) 0.095 μT

OR

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^{-1}. The magnetic induction (B) along z-axis is

a) 3.1×10^{-8} T

b) 3×10^{-5} T

c) 3×10^{-6} T

d) 9.3×10^{-6} T

(d) A plane electromagnetic wave travelling along the x-direction has a wavelength of 3 mm. The variation in the electric field occurs in the y-direction with an amplitude 66 V m^{-1}. The equations for the electric and magnetic fields as a function of x and t are respectively

a) $E_y = 11 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_y = 11 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

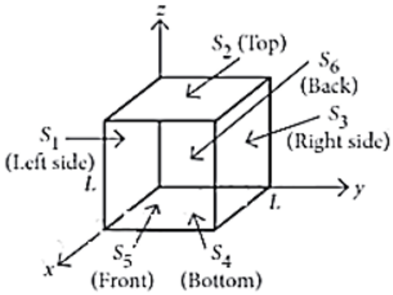
b) $E_y = 66 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_z = 2.2 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

c) $E_x = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_x = 11 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

d) $E_y = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_z = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

30. **Read the text carefully and answer the questions:** **[4]**

Net electric flux through a cube is the sum of fluxes through its six faces. Consider a cube as shown in figure, having sides of length L = 10.0 cm. The electric field is uniform, has a magnitude E = 4.00×10^{3} NC^{-1} and is parallel to the xy plane at an angle of 37^{o} measured from the +x -axis towards the +y -axis.



(a) Electric flux passing through surface S_6 is

a) -24 Nm^2 C^{-1}

b) 32 Nm^2 C^{-1}

c) -32 Nm^2 C^{-1}

d) 24 Nm^2 C^{-1}

(b) Electric flux passing through surface S_1 is

a) -32 Nm^2 C^{-1}

b) -24 Nm^2 C^{-1}

c) 32 Nm^2 C^{-1}

d) 24 Nm^2 C^{-1}

(c) The surfaces that have zero flux are

a) S_2 and S_4

b) S_3 and S_6

c) S_1 and S_2

d) S_1 and S_3

(d) The total net electric flux through all faces of the cube is

a) 24 Nm^2 C^{-1}

b) 8 Nm^2 C^{-1}

c) -8 Nm^2 C^{-1}

d) zero

OR

The dimensional formula of surface integral $\oint \vec{E} \cdot d\vec{S}$ of an electric field is

a) $[M^{-1} L^3 T^{-3} A]$

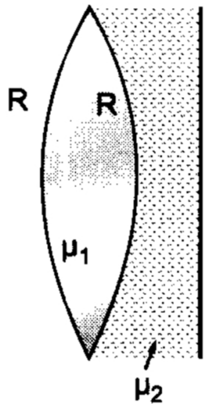
b) $[M L^2 T^{-2} A^{-1}]$

c) $[M L^3 T^{-3} A^{-1}]$

d) $[M L^{-3} T^{-3} A^{-1}]$

Section E

31. A biconvex lens with its two faces of equal radius of curvature R is made of a transparent medium of refractive index μ_1. It is kept in contact with a medium of refractive index μ_2 as shown in the figure. **[5]**



a. Find the equivalent focal length of the combination.

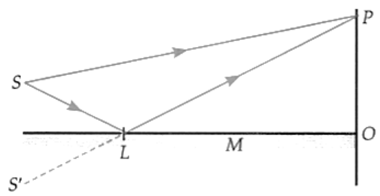
b. Obtain the condition when this combination acts as a diverging lens.

c. Draw the ray diagram for the case $\mu_1 > \frac{(\mu_2+1)}{2}$, when the object is kept far away from the lens. Point out the nature of the image formed by the system.

OR

Figure shows an outline of Lloyd's mirror experiment. M is a plane mirror; S is a narrow slit illuminated by some source of light (not shown) and S' is the image of S in M. M, S and S' are in a plane perpendicular to the paper. O is the line of intersection of the mirror and the screen.

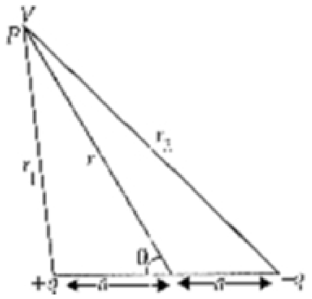
a. What is the origin of fringes observed on the screen?



b. Why is the slit S placed so as to have very oblique angle of incidence of light striking the mirror?

c. The two path lengths PS and PS' are equal when P coincides with O. Yet the fringe at O is found in the experiment to be dark not bright. What does this observation imply?

32. Derive an expression for potential due to a dipole for distances large compared to the size of the dipole. How is the potential due to dipole different from that due to a single charge? **[5]**



OR

Two point charges q and -q are located at points (0, 0,- a) and (0, 0, a) respectively.

i. Find the electrostatic potential at (0, 0, z) and (x, y, 0).
ii. How much work is done in moving a small test charge from the point (5, 0, 0) to (-7, 0, 0) along the X-axis?
iii. How would your answer change if the path of the test charge between the same points is not along the x-axis but along any other random path?
iv. If the above point charges are now placed in the same positions in a uniform external electric field $\vec{E}$, what would be the potential energy of the charge system in its orientation of unstable equilibrium? Justify your answer in each case.

33. a. Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device. **[5]**

b. A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5Ω per km. The town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat

OR

i. With the help of a diagram, explain the principle and working of a device which produces current that reverses its direction after regular intervals of time.
ii. If a charged capacitor C is short-circuited through an inductor L, the charge and current in the circuit oscillate simple harmonically.
    a. In what form the capacitor and the inductor store energy?
    b. Write two reasons due to which the oscillations become damped.

Solution

Section A

1.

(c) electric field is zero

Explanation: When a p-n junction is reverse biased, the width of the depletion region increases. As a result, the electric field is greatly reduced. Practically, it becomes zero.

2.

(d) 50 W

Explanation: 50 W

3.

(b) is formed at the least distance of distinct vision

Explanation: Magnification of compound microscope is given by

m = $\left(\frac{v_o}{u_o}\right)\left(1+\frac{D}{f_e}\right)$ when final image is formed at near point

Whereas, m = $\left(\frac{v_o}{u_o}\right)\left(\frac{D}{f_e}\right)$, when final image is formed at infinity.

Hence, magnification is maximum when final image is formed at near point (least distance of distinct vision).

4. **(a)** $\mu \propto n$

Explanation: Orbital magnetic moment of an electron,

$\mu = n\frac{eh}{4\pi m_e}$ i.e., $\mu \propto n$

5.

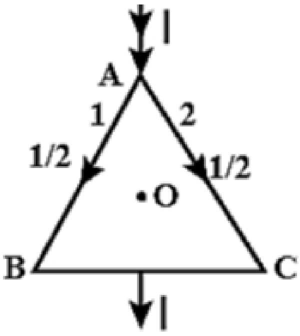
(b) Two of them connected in series and the combination in parallel to the third.

Explanation: Two of them connected in series and the combination in parallel to the third.

6.

(d) zero

Explanation: Equal current flows in part 1 and 2 of triangular loop as shown in the figure. As both part of the triangular loop is symmetric about point O, so magnetic field at O due to both parts is equal and opposite to each other. Thus magnitude of magnetic field at O due to part 1 cancel out the magnitude of magnetic field at O due to part 2. Hence net magnetic field at O is zero.



7.

(b) 375 mH

Explanation: $L \propto N^2$

$\therefore L_2 = \left(\frac{N_2}{N_1}\right)^2 L_1$

$= \left(\frac{500}{100}\right)^2 \times 15\text{mH}$ = 375 mH

8. **(a)** case (ii) contradicts Gauss's law for magnetic fields.

Explanation: case (ii) contradicts Gauss's law for magnetic fields.

9.

(b) are longitudinal waves and require a medium to travel.

Explanation: According to Huygens, light waves are longitudinal waves and require a material medium to travel. For this reason Huygens assumed the existence of a hypothetical medium called luminiferous aether.

10. **(a)** always a force and a torque.

Explanation: always a force and a torque.

11.

(d) 2×10^{-3} A

Explanation: I = $\frac{(3.2-3)V}{100\Omega}$ = 2×10^{-3} A

12.

(d) 2 cm upward

Explanation: Shift S = $t\left(\frac{1-1}{\mu}\right)$

Substituting the given data we get,

S = $6\left(\frac{1-1}{1.5}\right)$

or, S = $6\left(\frac{1-2}{3}\right)$ = 2cm upward

13.

(d) A is false but R is true.

Explanation: A is false but R is true.

14.

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

Explanation: Both A and R are true but R is not the correct explanation of A.

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

Explanation: Both A and R are true and R is the correct explanation of A.

Diffraction is prominent when the size of the obstacle or the aperture is comparable to the wavelength of light used.

16.

(c) A is true but R is false.

Explanation: $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+\omega^2L^2}}$

When ω is doubled, power factor ($\cos\phi$) decreases.

So, A is true but R is false.

Section B

17. Poynting vectors S is defined as a vector whose magnitude is equal to the wave intensity and whose direction is along the direction of wave propagation. In an electromagnetic wave, let $\vec{E}$ be varying along y-axis, $\vec{B}$is along z-axis and propagation of wave be along x-axis. Then $\vec{E} \times \vec{B}$ will tell the direction of propagation of energy flow in electromagnetic wave, along x-axis.

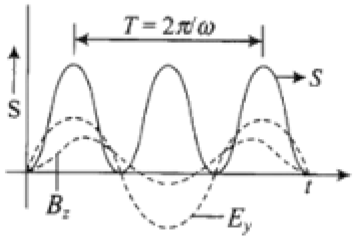
Let $\vec{E}$ = E_0 sin (ωt - kx) $\hat{j}$

$\vec{B}$ = B_0 sin (ωt - kx) $\hat{k}$

$S = \frac{1}{\mu_0}(\vec{E} \times \vec{B}) = \frac{1}{\mu_0}E_0B_0\sin^2\ (\omega t - kx)(\hat{j} \times \hat{k})$

$\Rightarrow S = \frac{E_0B_0}{\mu_0}\sin^2\ (\omega t - kx)\hat{i}$ (As $\hat{j} \times \hat{k} = \hat{i}$)

Since $\sin^2$ (ωt - kx) is never negative, $\vec{S}$ (x, t) always points in the positive X-direction, i.e, in the direction of wave propagation. The variation of $|S|$ with time T will be as given in the figure below:



18. i. **Susceptibility for diamagnetic material:**

It is independent of magnetic field and temperature (except for bismuth at low temperature).

Susceptibility for ferromagnetic material:

The susceptibility of ferromagnetic materials decreases steadily with increase in temperature. At the Curie temperature, the ferromagnetic materials become paramagnetic.

ii. **Behaviour in non-uniform magnetic field:**

Diamagnetic substances are feebly repelled, whereas ferromagnets are strongly attracted by non-uniform field.

19. Here $\sigma = 5\Omega^{-1}\ \text{cm}^{-1}$, μ_e = 3900 cm^2 V^{-1} s^{-1}, n_e = ?

If we neglect the contribution of holes to conductivity, then

$\sigma = \frac{1}{\rho} = en_e\mu_e$

$\therefore$ Electron density,

$n_e = \frac{\sigma}{e\mu_e} = \frac{5}{1.6\times10^{-19}\times3900}$ cm^{-3}

$= 8.01 \times 10^{15}$ cm^{-3}

20. When alpha particle approaches Nucleus,Kinetic energy of alpha particle will be converted into potential energy of the system.

Kinetic energy of α-particle is given as,

$K = \frac{1}{4\pi\varepsilon_0}\frac{2e.Ze}{d}$

where d is the distance of closest approach.

Or $d = \frac{2Ze^2}{4\pi\varepsilon_0 K}$

This is the required expression for the distance of closest approach d in terms of kinetic energy K.

21. Derivation of ratio of the radii of the circular paths r = $\frac{mv}{qB}$

But $\frac{p^2}{2m} = k \Rightarrow p = \sqrt{2mk}$ = mv

$\Rightarrow \quad \frac{r_\alpha}{r_p} = \frac{\sqrt{2m_\alpha k_\alpha}/q_a B}{\sqrt{2m_p k_p}/q_p B}$

But $k_\alpha = k_p$

$\frac{r_\alpha}{r_p} = \frac{q_p}{q_\alpha}\sqrt{\frac{m_\alpha}{m_p}}$

Since, charge of alpha particle $q_\alpha = 2q_p$

mass of alpha particle $m_\alpha = 4m_p$

$\Rightarrow \quad \frac{r_\alpha}{r_p} = \frac{q_p}{2q_p}\sqrt{\frac{4m_p}{m_p}}$ = 1:1

OR

Radius, $r = \frac{mv}{qB}$

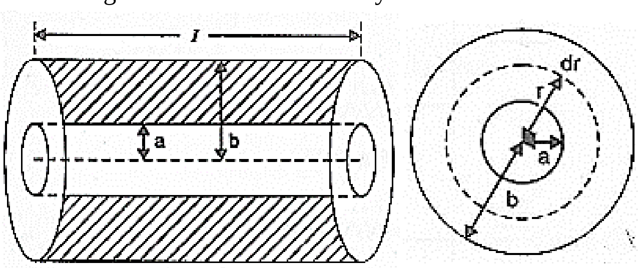
$\frac{r_\alpha}{r_\beta} = \frac{m_\alpha v}{q_\alpha B}\cdot\frac{q_\beta B}{m_\beta v} = \frac{m_c q_\beta}{m_\beta q_\alpha} = \frac{4m_p\cdot e}{m_e\cdot 2e}$

$= \frac{4\times1.67\times10^{-27}}{2\times9.1\times10^{-31}} = \frac{1835}{2} = 917.5$

Thus β-particle will describe the circle of smallest radius.

Section C

22. The current will be conducted radially outwards from the inner conductor (say) to the outer. The area of cross section for the conduction of the current is, therefore, the area of an elementary cylindrical shell and which varies with radius. The length of the conducting shell is measured radially from radius a to radius b.



Consider an elementary cylindrical shell of radius r and thickness dr. Its area of cross section (normal to flow of current) $= 2\pi rl$ and its length = dr.

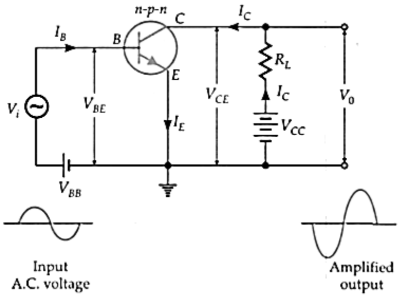
Hence, the resistance of the elementary cylindrical shell of the medium is

$dR = \frac{\rho dr}{2\pi rl} = \frac{\rho}{2\pi l}\left[\frac{dr}{r}\right]$

The resistance of the medium is obtained by integrating for r from a to b.

Hence required resistance

$R = \frac{\rho}{2\pi l}\int_a^b \frac{dr}{r} = \frac{\rho}{2\pi l}[\log_e]_a^b = \left(\frac{\rho}{2\pi l}\right)\log_e \frac{b}{a}$

23. 

Condition: For a transistor to act as an amplifier, it must be operated close to the centre of its active region.

Input resitance:

$R_i = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE} = \text{constant}}$

Its value is determined from the slope of I_B versus V_{BE} curve at constant V_{CE}.

Current amplification factor,

$\beta_{ac} = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE} = \text{constant}}$

Its value is determined from the I_C vs. V_{CE} curves plotted with different values of I_B.

24. i. Einstein's photoelectric equation is given by,

$h\nu = \phi + eV$

$V = \frac{h\nu}{e} - \frac{\phi}{e}$ ....(i)

Eq. (1) represents a straight line given by line P and Q, $\frac{\phi}{e}$ represents negative intercept on the Y-axis. Since Q has greater negative intercept, it will have greater ϕ (work function) and hence higher threshold frequency.

ii. To know work function of Q, we put V = 0 in (i),

$0 = \frac{h\nu}{e} - \frac{\phi}{e} \Rightarrow \phi = h\nu$

$\therefore \quad \phi = 6.6 \times 10^{-34} \times 6 \times 10^{14}\text{J}$

$= \frac{6.6 \times 6 \times 10^{-20}}{1.6 \times 10^{-19}}\text{eV} = 25\text{eV}$

25. i. The alpha decay of ${}^{238}_{92}U$. The energy released in this process is given by:-

$Q = (M_U - M_{Th} - M_{He})\ c^2$

$Q = (238.05079 - 234.04363 - 4.00260)u \times c^2$

$= (0.00456\ u)\ c^2$

= (0.00456 u) (931.5 MeV/u)

= 4.25 MeV

ii. The kinetic energy of the α-particle

$E_\alpha \approx \left(\frac{A-4}{A}\right)Q = \frac{238-4}{238} \times 4.25\text{MeV}$

= 4.18 MeV

iii. If ${}^{238}_{92}U$ spontaneously emits a proton, the decay process would be ${}^{238}_{92}U \rightarrow {}^{237}_{91}Pa + {}^{1}_{1}H$

The Q for this process to happen is

$= (M_U - M_{Pa} - M_H)\ c^2$

$= (238.05079 - 237.05121 - 1.00783)\ u \times c^2$

$= (-0.00825\ u)\ c^2$

= – (0.00825 u)(931.5 MeV/u)

= – 7.68 MeV

Thus, the Q of the process is negative and therefore it cannot proceed spontaneously. We will have to supply an energy of 7.68 MeV to a ${}^{238}_{92}U$ nucleus to make it emit a proton.

26. a. Now, $v = \frac{c}{n}\alpha$,

where $\alpha = \frac{2\pi Ke^2}{ch}$ = 0.0073

$v_1 = \frac{3 \times 10^8}{1} \times 0.0073 = 2.19 \times 10^6 m/s$

$v_2 = \frac{3\times10^8}{3} \times 0.0073 = 1.095 \times 10^6 m/s$

$v_3 = \frac{3\times10^8}{3} \times 0.0073 = 7.3 \times 10^5 m/s$

b. Orbital period, $T = \frac{2\pi r}{v}$

As $r_1 = 0.53 \times 10^{-10} m$

$T_1 = \frac{2\pi\times0.53\times10^{-10}}{2.19\times10^6} = 1.52 \times 10^{-16} s$

As $r_2 = 4\, r_1$ and $v_2 = \frac{1}{2} v_1$

$T_2 = 8\ T_1 = 8 \times 1.52 \times 10^{-16} s = 1.216 \times 10^{-15} s$

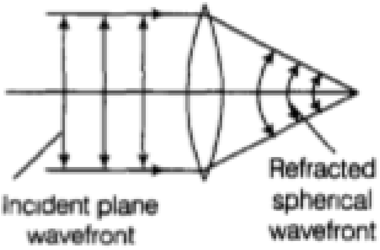
As $r_3 = 9 r_1$ and $v_3 = \frac{1}{3} v_1$

$\therefore T_3 = 27\ T_1 = 27 \times 1.52 \times 10^{-16} s = 4.1 \times 10^{-15} s$

27. When light is emitted from a source, then the particles present around it begins to vibrate. The locus of all such particles which are vibrating in the same phase is termed as wavefront.

Huygens' principle: Every point on a wave-front may be considered a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets.

Now when a plane wavefront (parallel rays) is incident on a thin convex lens, the emergent rays are focused on the focal point of the lens. Thus the shape of emerging wavefront is spherical.



28. i. Let RS moves with speed v rightward and also RS is at distances x_1 and x_2 from PQ at instants t_1 and t_2, respectively.

Change in flux, $d\phi = \phi_2 - \phi_1 = Bl\,(x_2 - x_1)$ [$\because$ magnetic flux, $\phi = \vec{B}.\vec{A} = BAcos0^0 = Blx$]

$\Rightarrow d\phi = Bldx \Rightarrow \quad \frac{d\phi}{dt} = Bl\frac{dx}{dt} = Blv \quad \left[\because v = \frac{dx}{dt}\right]$

If resistance of loop is R, then $I = \frac{vBl}{R}$

ii. Magnetic force = $BIl \sin 90^\circ$

$= \left(\frac{vBl}{R}\right) Bl = \frac{vB^2l^2}{R}$

Now, External force must be equal to magnetic force

$\therefore$ External force $= \frac{vB^2l^2}{R}$

iii. As, $P = I^2 R = \left(\frac{vBl}{R}\right)^2 \times R = \frac{v^2B^2l^2}{R^2} \times R$

$\therefore P = \frac{v^2B^2l^2}{R}$

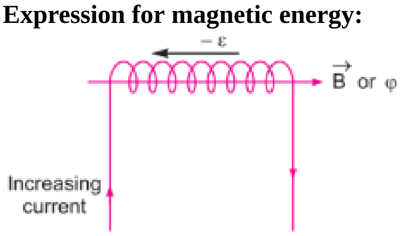
OR

Using formula, $|-\varepsilon| = L\frac{dI}{dt}$

If $\frac{dI}{dt} = 1$ A/s, then L = $|-\varepsilon|$

Self inductance of the coil is equal to the magnitude of induced emf produced in the coil itself when the current varies at rate 1 A/s.

Expression for magnetic energy:



When a time varying current flows through the coil, back emf $(-\varepsilon)$ produces, which opposes the growth of the current flow. It means some work needs to be done against induced emf in establishing a current I. This work done will be stored as magnetic potential energy.

For the current I at any instant, the rate of work done is

$\frac{dW}{dt} = (-\varepsilon)I$

Only for inductive effect of the coil $|-\varepsilon| = L\frac{dI}{dt}$

$\therefore \quad \frac{dW}{dt} = L\left(\frac{dI}{dt}\right)I \quad \Rightarrow dW = LIdI$

From work-energy theorem,

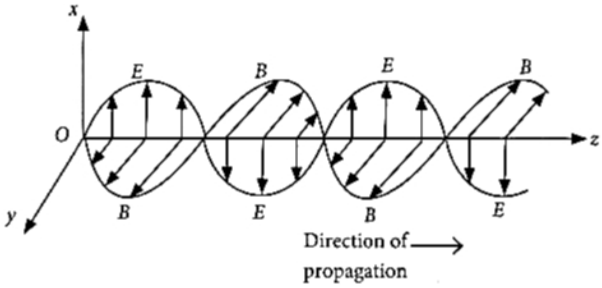
dU = LIdI

$\therefore U = \int_0^I LIdI = \frac{1}{2}LI^2$

Section D

29. **Read the text carefully and answer the questions:**

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(i) **(a)** $\vec{E}$ = B_0c sin (kx + ωt) $\hat{k}$ V/m

Explanation: Given : $\vec{B}$ = B_0 sin (kx + ωt)$\hat{j}$T

The relation between electric and magnetic field is, c = $\frac{E}{B}$ or E = cB

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along z-axis is obtained as $\vec{E}$ = cB_0 sin (kx + ωt) $\hat{k}$ V/m

(ii) **(b)** $\frac{2E_0}{c}$ $\hat{j}$ sin kz sin ωt

Explanation: $\frac{dE}{dz} = -\frac{dB}{dt}$

$\frac{dE}{dz}$ = -2 E_0k sin kz cos ωt = $-\frac{dB}{dt}$

dB = +2 E_0k sin kz cos ωt dt

B = +2 E_0k sin kz $\int$ cos ωt dt = +2 E_0 $\frac{k}{\omega}$ sin kz sin ωt

$\frac{E_0}{B_0} = \frac{\omega}{k} = c$

B = $\frac{2E_0}{c}$ sin kz sin ωt $\therefore$ $\vec{B}$ = $\frac{2E_0}{c}$ sin kz sin ωt $\hat{j}$

E is along y-direction and the wave propagates along x-axis.

$\therefore$ B should be in a direction perpendicular to both x-and y-axis.

(iii) **(c)** 0.021 μT

Explanation: Here, E = 6.3 $\hat{j}$; c = 3 $\times$ 10^8 m/s

The magnitude of B is

B_z = $\frac{E}{c}$ = $\frac{6.3}{3\times10^8}$ = 2.1 $\times$ 10^{-8} T = 0.021 μ T

OR

(a) 3.1 $\times$ 10^{-8} T

Explanation: At a particular point, E = 9.3 V m^{-1}

$\therefore$ Magnetic field at the same point = $\frac{9.3}{3\times10^8}$

= 3.1 $\times$ 10^{-8} T

(iv) **(b)** $E_y = 66\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$, $B_z = 2.2 \times 10^{-7}\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

Explanation: Here : E_0 = 66 V m^{-1}, E_y = 66 cos $\omega\left(t - \frac{x}{c}\right)$,

λ = 3 mm = 3 $\times$ 10^{-3} m, k = $\frac{2\pi}{\lambda}$

$\frac{\omega}{k}$ = c $\Rightarrow$ ω = ck = 3 $\times$ 10^8 $\times$ $\frac{2\pi}{3\times10^{-3}}$

or ω = 2π $\times$ 10^{11}

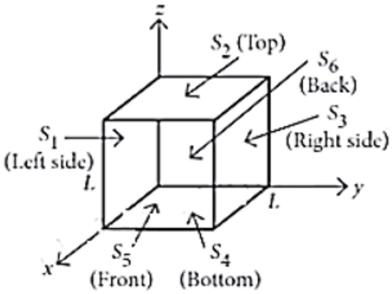
$\therefore E_y = 66 \cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

$B_z = \frac{E_y}{c} = \left(\frac{66}{3\times10^8}\right)\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

$= 2.2 \times 10^{-7} \cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

30. **Read the text carefully and answer the questions:**

Net electric flux through a cube is the sum of fluxes through its six faces. Consider a cube as shown in figure, having sides of length L = 10.0 cm. The electric field is uniform, has a magnitude $E = 4.00 \times 10^3 NC^{-1}$ and is parallel to the xy plane at an angle of 37^o measured from the +x -axis towards the +y -axis.



(i) **(c)** $-32\ Nm^2\ C^{-1}$

Explanation: Electric flux, $\phi = \vec{E}\cdot\vec{A} = EA\cos\theta$

where $\vec{A} = A\hat{n}$

For electric flux passing through S_6, $\hat{n}_{S_6} = -\hat{i}$ (Back)

$\therefore \phi_{S_6} = -(4 \times 10^3\ NC^{-1})(0.1\ m)^2 \cos 37^o$

$= -32\ N\ m^2\ C^{-1}$

(ii) **(b)** $-24\ Nm^2\ C^{-1}$

Explanation: For electric flux passing through S_1, $\hat{n}_{S_1} = -\hat{j}$ (Left)

$\therefore \phi_{S_1} = -(4 \times 10^3\ NC^{-1})(0.1\ m)^2 \cos 90^o = 0$

$= -24\ Nm^2\ C^{-1}$

(iii) **(a)** S_2 and S_4

Explanation: Here, $\hat{n}_{S_2} = +\hat{k}$ (Top)

$\therefore \phi_{S_2} = -(4 \times 10^3\ NC^{-1})(0.1\ m)^2 \cos 90^o = 0$

$\hat{n}_{S_3} = +\hat{j}$ (Right)

$\hat{n}_{S_4} = -\hat{k}$ (Bottom)

$\therefore \phi_{S_4} = -(4 \times 10^3\ NC^{-1})(0.1\ m)^2 \cos 90^o = 0$

And, $\hat{n}_{S_5} = +\hat{i}$ (Front)

$\therefore \phi_{S_5} = +(4 \times 10^3\ NC^{-1})(0.1\ m)^2 \cos 37^o$

$= 32\ N\ m^2\ C^{-1}$

S_2 and S_4 surface have zero flux.

(iv) **(d)** zero

Explanation: As the field is uniform, the total flux through the cube must be zero, i.e., any flux entering the cube must leave it.

OR

(c) $[M\ L^3\ T^{-3}\ A^{-1}]$

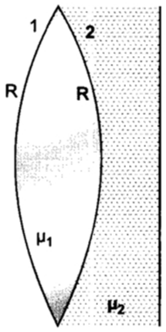
Explanation: Surface integral $\oint \vec{E}\cdot d\vec{S}$ is the net electric flux over a closed surface S.

$\therefore [\phi_E] = [M\ L^3\ T^{-3}\ A^{-1}]$

Section E

31. a. If refraction occurs at first surface

$\frac{\mu_1}{v_1} - \frac{1}{u} = \frac{(\mu_1 - 1)}{R}$ ...(i)



If refraction occurs at second surface, and the image of the first surface acts as an object

$\frac{\mu_2}{v} - \frac{u_1}{v_1} = \frac{\mu_2 - \mu_1}{-R}$ ...(ii)

On adding equation (i) and (ii), we get

$\frac{\mu_2}{v} - \frac{1}{u} = \frac{2\mu_1 - \mu_2 - 1}{R}$

If rays are coming from infinity, i.e., u = $-\infty$ then v = f

$\frac{\mu_2}{f} + \frac{1}{\infty} = \frac{2\mu_1 - \mu_2 - 1}{R} \Rightarrow f = \frac{\mu_2 R}{2\mu_1 - \mu_2}$

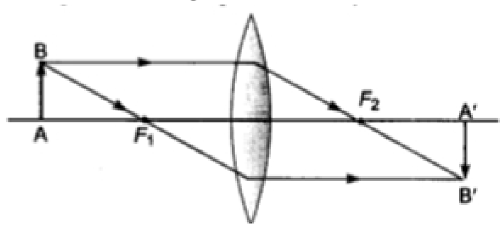
b. If the combination behave as a diverging system then f < 0. This is possible only when

$2\mu_1 - \mu_2 - 1 < 0$

$\Rightarrow 2\mu_1 < \mu_2 + 1$

$\Rightarrow \mu_1 < \frac{(\mu_2 + 1)}{2}$

Nature of the image formed is real.



c. If the combination behaves as a converging lens then > 0. Itis possible only when

$2\mu_1 - \mu_2 - 1 > 0$

$\Rightarrow \mu_1 - > \mu_2 + 1$

$\Rightarrow \mu_1 > \frac{(\mu_2 + 1)}{2}$

Nature of the image formed is real.

OR

a. S' is the virtual image of source S formed by mirror M. So S and S' act as two coherent sources of light. Light waves coming directly from the source S and the reflected waves (which appear to come from virtual source S') interfere to produce a fringe pattern.
b. Very oblique angle of incidence requires the source S to be placed very close to the mirror. In that case the separation between the coherent sources S and S' will be small, as required in Young's double-slit experiment for obtaining broad and distinct interference fringes.
c. The light wave reflected by the mirror suffers a phase change of 180^o which is equivalent to a change in the path length of $\frac{\lambda}{2}$.

Then the path difference for any point P on the screen becomes

p = S'P - sP + $\frac{\lambda}{2}$

Consequently, the condition for a dark fringe is

p = S' P - SP + $\frac{\lambda}{2}$ = (2n + 1)$\frac{\lambda}{2}$

or S' P - SP = nλ

This condition is satisfied by the central fringe for which S'P = SP. Hence the central fringe in Lloyd's mirror method is dark.

32. Consider origin at the centre of dipole. As per superposition principle, potential due to dipole will be the sum of potentials due to charges q and -q

$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r_1} - \frac{q}{r_2}\right]$

Where,

r_1 and r_2 = distances of point P from q and -q.

$r_1^2 = r^2 + a^2 - 2$ arcos θ

$r_2{}^2 = r^2 + a^2 + 2$ arcos θ

If r is greater than a, and taking terms upto first order in a/r

$r_1{}^2 = r^2 \left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

$= r^2 \left[1 - \frac{2a\cos\theta}{r}\right]$

Also, $r_2{}^2 = r^2 \left[1 + \frac{2a\cos\theta}{r}\right]$

With the help of Binomial theorem, keeping terms upto first order is shown below:

$\frac{1}{r_1} \equiv \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$

$\frac{1}{r_2} \equiv \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$

As p = qa

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

$V = \frac{p}{4\pi\varepsilon_0} \cdot \frac{\cos\theta}{r^2}$

Now, $p\cos\theta = \vec{p}.\hat{r}$

where $\hat{r}$ is unit vector along position vector.

Hence electric potential of dipole for distances large compared to size of dipole is given as below :

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p}\hat{r}}{r^2}$ for r >>a

---For potential at any point on axis, $\theta = [0, \pi]$

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

potential is positive when $\theta = 0$

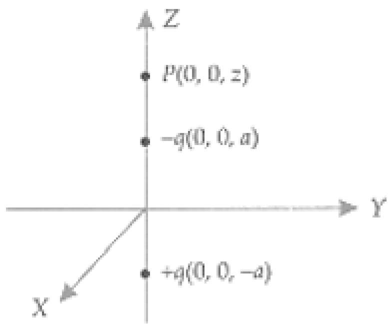
potential is negative when $\theta = \pi$

Hence, electric potential falls at large distance, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$

OR

i. Potential at point P(0, 0, 2) due to charge +q(0, 0, -a) is

   $V_+ = \frac{1}{4\pi\varepsilon_0}, \frac{q}{z-(-a)} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{z+a}$

   Potential at point P(0, 0, z) due to charge -q(0, 0, a) is $V_- = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-q}{z-a}$

   Total potential at point P(0, 0, z) is

   $V = V_+ + V_- = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{z-a} - \frac{q}{z-a}\right]$

   $= -\frac{1}{4\pi\varepsilon_0} \cdot \frac{2qa}{z^2-a^2} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{z^2-a^2}$

   Potentials at point (x, y, 0) will be

   $V_+ = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{\sqrt{x^2+y^2+a^2}}$

   $V_- = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-q}{\sqrt{x^2+y^2+a^2}}$

   The total potential at point (x, y, 0) will be

   $V = V_+ + V_- = 0$

ii. Points (5, 0, 0) and (-7, 0, 0) are the points on the X -axis i.e., these points lie on the perpendicular bisector of the dipole. The electric potential at each of these points will be zero.

Work done in moving the test charge q_0 from point & (5, 0, 0) to (7, 0, 0) is

$W = q(V_1 - V_2) = q(0 - 0) = 0$

iii. No, the work done will not change. This is because the electric field is a conservative field. Work done against this field is path independent.

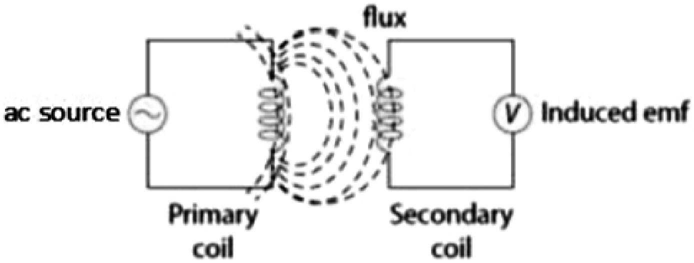
iv. The dipole will be in unstable equilibrium if its dipole moment $\vec{p}$ is antiparallel to the external field $\vec{E}$

Then its potential energy will be $U = +pE$

33. a. The device used to decrease high ac voltage into a low ac voltage is called transformer (step-down transformer).

Working principle:

Transformer works on the principle of Faraday's law of electromagnetic induction. The law of electromagnetic induction states that when magnetic flux linked with a coil changes, an emf is induced in the coil. Transformer consists of two coils called primary coil and secondary coil. The ac current in primary coil changes magnetic flux linked with the secondary coil and thus an emf is induced in the secondary coil.



Sources of energy loss in transformer

i. **Copper loss:** The coils of transformer (made of copper) have a finite resistance due to which some energy in lost as heat.
ii. **Iron loss:** Due to induced eddy currents in the iron core, some energy is lost in the bulk.
iii. **Magnetic loss:** Since all magnetic flux in primary coil does not pass through the secondary coil, there is some loss of energy due to leakage of flux.
iv. **Hysteresis loss:** alternating magnetization and demagnetization of the iron core cause some loss of energy in form of heat

b. Demand of electric power = 1200 kW

Distance of town from power station = 20 km Two wire = 20 $\times$ 2 = 40 km

Total resistance of line = 40 $\times$ 0.5 = 200

The town gets a power of 4000 volts

Power = voltage $\times$ current

$I = \frac{1200 \times 10^3}{4000} = \frac{1200}{4} = 300$ A

The line power loss in the form of heat = $I^2 \times R$

= $(300)^2 \times 2$

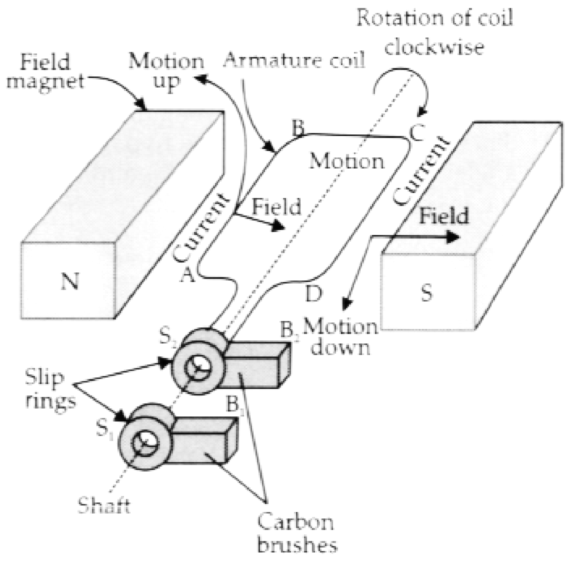
= 9000 $\times$ 20 = 1800 kW

OR

i. AC generator: it converts mechanical energy into the alternating form of electrical energy.

Basic elements of an AC generator:

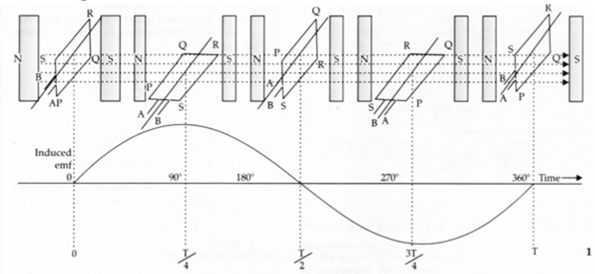
a. Rectangular coil: Also called as an armature
b. Strong permanent magnets: The magnetic field is perpendicular to the axis of rotation of the coil.
c. Slip rings
d. Brushes



AC generator

Principle: It is based on the principle of electromagnetic induction. That is, when a coil is rotated about an axis perpendicular to the direction of the uniform magnetic field, an induced emf is produced across it.

Working of AC Generator



ii.

a. The capacitor stores energy in the form of an electric field and the inductor stores energy in the form of a magnetic field.

b. Oscillation becomes damped due to :

- The resistance of the circuit
- Radiation in the form of EM waves