SAMPLE PAPER - 8

Class 12 - Physics

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

General Instructions:

1. There are 35 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. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. Hole is **[1]**

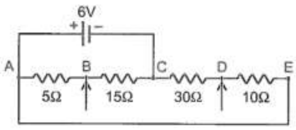
a) Gap between valence band and conduction band

b) Particle similar to that of electron

c) A vacancy created when an electron leaves a covalent bond.

d) An anti-particle of electron.

2. Four resistors are connected as shown in the following figure. A 6 V battery of negligible resistance is connected across terminals A and C. The potential difference across terminals B and D will be: **[1]**



a) 1.5 volt

b) 0 volt

c) 3 volt

d) 2 volt

3. A concave mirror of focal length f in air is used in a medium of refractive index 2. What will be the focal length of the mirror in the medium? **[1]**

a) $\frac{f}{2}$

b) 2f

c) 4f

d) None of these

4. At 0 K temperature, a p-type semiconductor: **[1]**

a) does not have any charge carriers

b) has few holes but no free electrons

c) has few holes and few free electrons

d) has equal number of holes and free electrons

5. If in a parallel plate capacitor, which is connected to a battery, we fill dielectrics in the whole space of its plates, then which of the following increases? **[1]**

a) V and E

b) Q and C

c) Q and V

d) E and C

6. Consider two straight parallel conductors A and B separated by a distance x and carrying individuals currents i_A and i_B respectively. If the two conductors attract each other, it indicates that: **[1]**

a) the magnetic lines of induction are parallel

b) the two currents are parallel in direction

c) the two currents are anti-parallel in direction

d) the magnetic lines of induction are parallel to length of conductors

7. A coil having an area A_0 is placed in a magnetic field which changes from B_0 to $4B_0$ in time interval t. The emf induced in the coil will be: **[1]**

a) $\frac{3B_0}{A_0 t}$

b) $\frac{4A_0 B_0}{t}$

c) $\frac{4B_0}{A_0 t}$

d) $\frac{3A_0 B_0}{t}$

8. Energy E of a hydrogen atom with principal quantum number n is given by: E = - (13.6/ n^2) eV. The energy of a photon ejected when the electron jumps from n = 3 state to n = 2 state of hydrogen is approximately: **[1]**

a) 3.4 eV

b) 0.85 eV

c) 1.5 eV

d) 1.9 eV

9. By a monochromatic wave, we mean: **[1]**

a) a single ray of a single colour

b) a wave having a single wavelength

c) a single ray

d) many rays of a single colour

10. The electrical potential on the surface of a sphere of radius r due to a charge 3×10^{-6} C is 500 V. The intensity of electric field 1 on the surface of the sphere is: $\left[\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \mathrm{Nm^2C^{-2}}\right]$ (in NC^{-1}) **[1]**

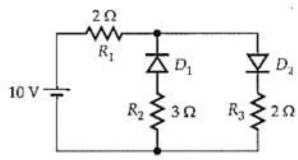
a) > 20

b) < 10

c) between 10 and 20

d) < 5

11. The given circuit has two ideal diodes connected as shown in the figure below. The current flowing through the resistance R_1 will be **[1]**



a) 2.5 A

b) 10.0 A

c) 1.43 A

d) 3.13 A

12. The diameter of the objective of a telescope is a, its magnifying power is m and wavelength of light is λ. The resolving power of the telescope is: **[1]**

a) $\frac{a}{1.22\lambda m}$

b) $\frac{\lambda m}{1.22a}$

c) $\frac{1.22\lambda}{a}$

d) $\frac{a}{1.22\lambda}$

13. The cathode of a photoelectric cell is changed such that the work function changes from W_1 to W_2 ($W_2 > W_1$). If the currents before and after changes are I_1 and I_2, all other conditions remaining unchanged, then (assuming $h\nu > W_2$), **[1]**

a) $I_1 = I_2$

b) $I_1 < I_2$

c) $I_1 < I_2 < 2I_1$

d) $I_1 > I_2$

14. A charge Q is kept at the centre of a circle of radius r. If permittivity of free space is $\in_0$ then the work done in carrying a charge q along the diameter of the circle will be: **[1]**

a) $\frac{qQ}{(8\pi\varepsilon_0 r)}$

b) zero

c) $\frac{qQ}{(4\pi\varepsilon_0\varepsilon_r r)}$

d) $\frac{qQ}{(2\pi\varepsilon_0)}$

15. The wavelength of light diminishes μ times in the medium. A diver from inside water (μ = 1.33) looks at an object whose natural colour is green. He sees the object as: **[1]**

a) Red

b) Blue

c) Green

d) Yellow

16. **Assertion (A):** Density of all the nuclei is same. **[1]**
Reason (R): Radius of nucleus is directly proportional to the cube root of mass number.

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.

17. **Assertion (A):** When cooking in microwave ovens, metal containers are used. **[1]**
Reason (R): The energy of microwaves can be easily transferred to the food through metal.

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.

18. **Assertion (A):** The net magnetic flux coming out of a closed surface is always zero. **[1]**
Reason (R): Unlike poles of equal strength exist together.

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

19. The energy of a hole is higher, the farther below it is from the top of the valence band. Give reason. **[2]**

20. In a head-on collision between an α - particle and a gold nucleus, the minimum distance of approach is 3.95×10^{-14} m. Calculate the energy of the α-particle. **[2]**

21. Show that the magnetic field B at a point in between the plates of a parallel-plate capacitor during charging is $\frac{\varepsilon_0\mu_0 r}{2}\frac{dE}{dt}$ (symbols having usual meaning). **[2]**

OR

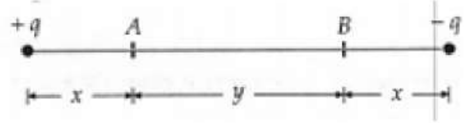
Which of the following belong to the electromagnetic spectrum : α-rays, β-rays, cathode rays, X-rays, ultraviolet rays, microwaves, ultrasonic waves, radiowaves, infrared rays? Arrange them in the order of increasing frequency.

22. A potential barrier of 0.60 V exists across a p-n junction, **[2]**

i. If the depletion region is 6.0×10^{-7} m thick, what is the intensity of the electric field in this region?

ii. If an electron with speed 5.0×10^{5} ms^{-1} approaches the p-n junction from the n-side, with what speed will it enter the p-side?

23. In Fig. the potentials at points A and B are V_A and V_B respectively. Calculate V_A - V_B for the given arrangement. **[2]**



OR

A point charge q moves from a point P to a point S along the path PQRS in a uniform electric field $\vec{E}$ acting along the positive direction of the X-axis. The coordinates of the points P, Q, R and S are (a, b, 0), (2a, 0, 0), (a, -b, 0) and (0, 0, 0) respectively. Find the work done by the field in the process.

24. Monochromatic radiation of wavelength 640.2 nm (1nm = 10^{-9}m) from a neon lamp irradiates a photosensitive material made of caesium on tungsten. The stopping voltage is measured to be 0.54 V. The source is replaced by an iron source and its 427.2 nm line irradiates the same photocell. Predict the new stopping voltage. **[2]**

25. Give reasons for **[2]**

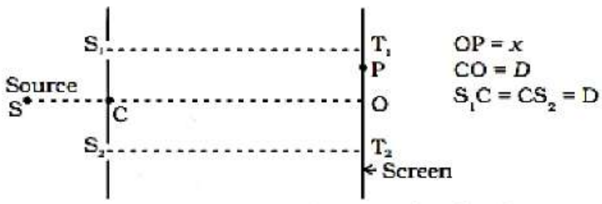
i. Lighter elements are better moderators for a nuclear reactor than heavier elements,

ii. Very high temperatures as those obtained in the interior of the sun are required for fusion reaction to take place.

Section C

26. Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when the atom makes a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number $n_f(n_f < n_i)$. **[3]**

27. Consider a two-slit interference arrangements (Figure) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen fall at a distance D from the center O. **[3]**



28. The current through two inductors of self-inductance 12 mH and 30 mH is increasing with time at the same rate. Draw graphs showing the variation of the **[3]**

i. emf induced with the rate of change of current in each inductor.

ii. energy stored in each inductor with the current flowing through it.

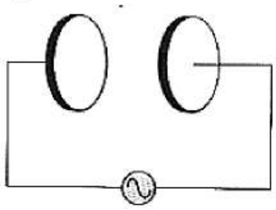
iii. compare the energy stored in the coils, if the power dissipated in the coils is the same.

OR

i. Define self-inductance. Write its SI unit.

ii. A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, then what is the induced emf in the loop while the current is changing?

29. A parallel plate capacitor made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with an angular frequency of 300 rad s^{-1}. **[3]**



a. What is the rms value of the conduction current?

b. Is the conduction current equal to the displacement current?

c. Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

OR

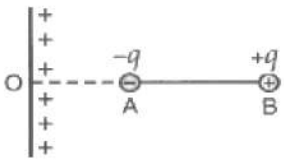
Name the type of EM waves having a wavelength range of 0.1 m to 1 mm. How are these waves generated? Write their two uses.

30. A domain in ferromagnetic iron is in the form of a cube of side length 1μm. Estimate the number of iron atoms in the domain and the maximum possible dipole moment and magnetization of the domain. The atomic mass of iron is 55 g/mole and its density is 7.9 g/cm^3. Assume that each iron atom has a dipole moment of 9.27×10^{-24} A m^2. **[3]**

Section D

31. a. Using Gauss' theorem, obtain an expression for the electric field intensity at a point at a distance r from an infinitely long uniformly charged straight wire. **[5]**

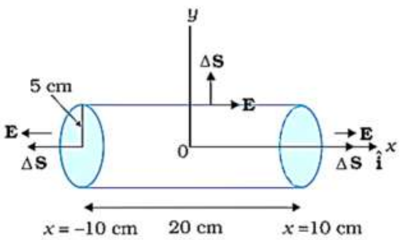
b. An electric dipole AB consists of charges ± 5 nC and separated by a distance of 2×10^{-3} m [Fig].



The dipole is placed near a long line charge having linear charge density 4.5×10^{-4} Cm^{-1}, such that the negative charge is at a distance OA = 2·5 cm from the line charge. Find the force acting on the dipole.

OR

An electric field is a uniform, and in the positive x-direction for positive x, and uniform with the same magnitude but in the negative x-direction for negative x. It is given that $\vec{E} = 200\ \hat{i}$ N/C for x > 0 and $\vec{E} = -200\ \hat{i}$ N/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one face is at x = +10 cm and the other is at x = -10 cm (Fig).



a. What is the net outward flux through each flat face?

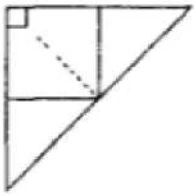
b. What is the flux through the side of the cylinder?

c. What is the net outward flux through the cylinder?

d. What is the net charge inside the cylinder?

32. i. Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism. **[5]**

ii. A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in figure. What must be the minimum value of refractive index of glass? Give relevant calculations.



OR

i. Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power.

ii. You are given three lenses of power 0.5 D, 4D and 10 D to design a telescope.

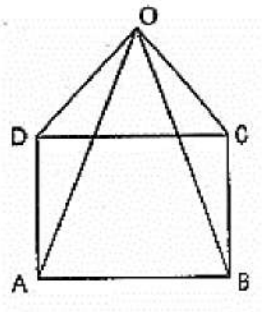
a. Which lenses should be used as objective and eyepiece? Justify your answer.

b. Why is the aperture of the objective preferred to be large?

33. Eight identical resistors 'r', each are connected along the edges of a pyramid having square base ABCD as shown in figure below. Calculate equivalent resistance between A and B. Solve the problem: **[5]**

i. Without using Kirchhoff's laws

ii. By using Kirchhoff's laws.



Section E

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

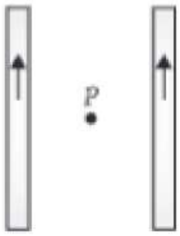
A magnetic field can be produced by moving, charges or electric currents. The basic equation governing the magnetic field due to a current distribution is the Biot-Savart law. Finding the magnetic field resulting from a current distribution involves the vector product, and is inherently a calculus problem when the distance from the current to the field point is continuously changing. According to this law, the magnetic field at a point due to a current element of length $d\vec{l}$ carrying current I, at a distance r from the element is dB = $\frac{\mu_0}{4\pi}\frac{I(d\vec{l}\times\vec{r})}{r^3}$.

Biot-Savart law has certain similarities as well as differences with Columb's law for electrostatic field e.g., there is an angle dependence in Biot-Savart law which is not present in the electrostatic case.

(i) What is the direction of magnetic field $d\vec{B}$ at a distance r due to a current element Idl when current I passes through a long conductor ?

(ii) What happens to the magnetic field due to a current carrying wire if the distance of the point from the current carrying wire is reduced to half?

(iii) Two long straight wires are set parallel to each other. Each carries a current i in the same direction and the separation between them is 2r. What will be the intensity of the magnetic field midway between them?

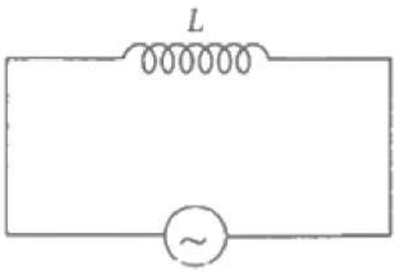


OR

A long straight wire carries a current along the z-axis. What will be the magnetic field along the Z axis.

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

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a circuit containing a pure inductance L. If I is the value of instantaneous current in the circuit, then $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The inductive reactance limits the current in a purely inductive circuit and is given by $X_L = \omega L$.



(i) A 100 hertz a.c. is flowing in a 14 mH coil. What will be the reactance in the coil?

(ii) In an inductive circuit, by what value of phase angle does alternating current lags behind e.m.f.?

(iii) How much inductance should be connected to 200 V, 50 Hz a.c. supply so that a maximum current of 0.9 A flows through it?

OR

What will be the maximum value of current when the inductance of 2 H is connected to 150 volts, 50 Hz supply?

Solution

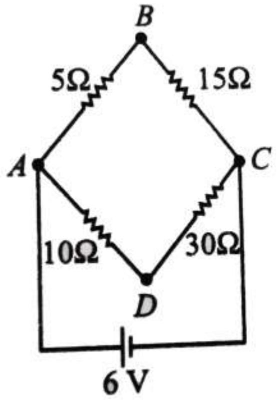
SAMPLE PAPER - 8

Class 12 - Physics

Section A

1. **(c)** A vacancy created when an electron leaves a covalent bond.
   Explanation: A **hole** is the absence of an electron in a particular place in an atom.

2. **(b)** 0 volt
   Explanation: The given figure is a circuit of balanced Wheatstone bridge as shown in the figure.
   Point B and D would be at the same potential. i.e. VB − VD = 0 volt



3. **(d)** None of these
   Explanation: The focal length of a mirror is independent of the medium from which the light is incident. So, it remains equal to f.

4. **(b)** has few holes but no free electrons
   Explanation: We know that at 0 K temperature, a pure semiconductor behaves as an insulator because it has a few holes in its valence band. But there is no free electron in this state.

5. **(b)** Q and C
   Explanation: By using,
   C = $\frac{\varepsilon_0 KA}{d}$ and q = CV

6. **(b)** the two currents are parallel in direction
   Explanation: If two straight parallel conductors carrying currents attract each other, the two currents are in the same direction.

7. **(d)** $\frac{3A_0B_0}{t}$
   Explanation: e = $\frac{d\phi}{dt} = \frac{dB}{dt}$ A = $A_0\frac{dB}{dt}$
   = $A_0\left[\frac{4B_0 - B_0}{t}\right] = \frac{3A_0B_0}{t}$

8. **(d)** 1.9 eV
   Explanation: ΔE = E_3 - E_2
   $= \frac{-13.6}{3^2} + \frac{13.6}{2^2}$
   = 13.6 $\left[\frac{1}{4} - \frac{1}{9}\right]$
   eV = 1.9 eV

9. **(b)** a wave having a single wavelength
   Explanation: Monochromatic wave means a single wavelength, not a single colour.

10. **(b)** < 10
    Explanation: Given that; $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$ = 500
    or r = $\frac{(9 \times 10^9)(3 \times 10^{-6})}{500}$
    $\therefore E = \frac{V}{r} = \frac{250}{27}$ < 10

11. **(a)** 2.5 A

Explanation: D_1 is reverse biased and D_2 is forward biased. D_1 blocks current. Hence, Current will flow through 10 V cell, R_1, D_2 and R_3.

$\therefore I = \frac{\varepsilon}{R_1+R_3}$

$= \frac{10\text{ V}}{(2+2)\Omega} = 2.5$ A

12. **(d)** $\frac{a}{1.22\lambda}$

Explanation: $\frac{a}{1.22\lambda}$

13. **(a)** $I_1 = I_2$

Explanation: Photoelectric current $\propto$ Intensity of incident radiation. So long as the frequency of incident radiation is greater than the threshold frequency, the photocurrent remains the same.

Therefore, $I_1 = I_2$.

14. **(b)** zero

Explanation: zero

15. **(b)** Blue

Explanation: We know that on entering the water, the wavelength decreases. Hence, the green colour appears blue.

16. **(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.

17. **(d)** A is false but R is true.

Explanation: The atoms of the metallic container are set into forced vibrations by the microwaves. Hence, the energy of the microwaves is not efficiently transferred to the metallic contain. Hence food in metallic containers cannot be cooked in a microwave oven. Normally in a microwave oven, the energy of waves is transferred to the kinetic energy of the molecules. This raises the temperature of any food.

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

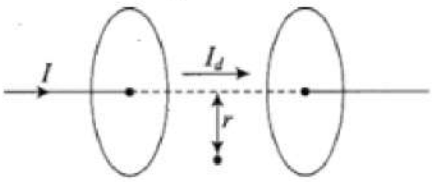
Explanation: The assertion is Gauss's theorem in magnetism. A magnet has always two equal and opposite poles. Monopoles do not exist.

Section B

19. Imagine an electron being removed from the filled valence band to the bottom of the conduction band. This removal creates a vacancy or a hole in the valence band. Clearly, it requires more energy to remove an electron that is farther from the top of the valence band. Thus a valence hole state, farther from the top of the valence band, has higher energy just as a conduction electron farther from the bottom of the conduction band has higher energy.

20. $K = \frac{2kZe^2}{5_0} = \frac{2\times9\times10^9\times79\times(1.6\times10^{-19})^2}{3.95\times10^{-14}\times1.6\times10^{-13}}\text{MeV} = 6$ MeV

21. Let the assume I_d be the displacement current in the region between two plates of parallel plate capacitor, in the figure.



The magnetic field at a point between two plates of capacitor at a perpendicular distance r from the axis of plates is given by

$B = \frac{\mu_0 2I_d}{4\pi r} = \frac{\mu_0}{2\pi r}\ I_d = \frac{\mu_0}{2\pi r} \times \varepsilon_0 \frac{d\phi_E}{dt}\ \left[\because I_d = \frac{\epsilon_0 d\phi_E}{dt}\right]$

$\Rightarrow B = \frac{\mu_0\varepsilon_0}{2\pi r}\frac{d}{dt}\left(E\pi r^2\right) = \frac{\mu_0\varepsilon_0}{2\pi r}\pi r^2\frac{dE}{dt}$

$\Rightarrow B = \frac{\mu_0\varepsilon_0 r}{2}\frac{dE}{dt}\ \left[\because \phi_E = E\pi r^2\right]$ this is the required result.

OR

Arranged in the order of their increasing frequency, the following radiations belong to the electromagnetic spectrum :

Raidowaves, infrared rays, visible light, ultraviolet rays, X-rays and λ-rays.

22. Electric field, E = $\frac{v}{d} = \frac{0.60}{6.0\times10^{-7}}$

$= 1.0 \times 10^6\ \text{Vm}^{-1}$

Let v_1 = velocity of the electron when enters the depletion layer. V_2 be the velocity of the electron emerging out of the depletion layer. Barrier voltage, V = 0.60V, $v_1 = 5.0 \times 10^5$ m/s According to Principle of conservation of energy

$\frac{1}{2}mv_1^2 = eV + \frac{1}{2}mv_2^2$

or $\frac{1}{2} \times \left(9.1 \times 10^{-31}\right) \times \left(5.0 \times 10^5\right)^2$

$= (1.6 \times 10^{-19}) \times 0.6 + \frac{1}{2} \times \left(9.1 \times 10^{-31}\right) \times v_2^2$

or $1.375 \times 10^{-19} = 0.96 \times 10^{-19} + 4.55 \times 10^{-31} v_2^2$

On solving, we get,

$v^2 = 1.975 \times 10^5\ ms^{-1}$

23. The net potential at A due to the two charges is

$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x} - \frac{q}{x+y}\right] = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qy}{x(x+y)}$

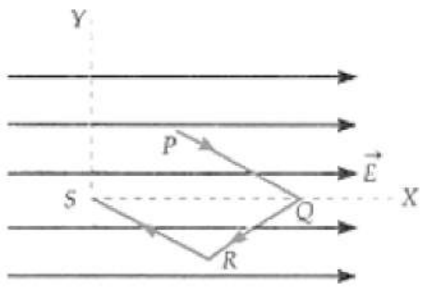
The net potential at B due to the two charges is

$V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x+y} - \frac{q}{x}\right] = -\frac{1}{4\pi\varepsilon_0} + \frac{qy}{x(x+y)}$

$\therefore V_A - V_B = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2qy}{x(x+y)}$

OR

As the electric field is a conservative field, so the work done depends only on the initial and final points.



Displacement of charge q,

$\overrightarrow{PS}$ = (0, 0, 0) - (a, b, 0)

$= (0-a)\hat{i} + (0-b)\hat{j} + (0-0)\hat{k} = -a\hat{i} - b\hat{j}$

Force on charge q,

$\vec{F} = q\vec{E} = qE\hat{i}$

$W = \vec{F} \cdot \overrightarrow{PS} = qE\hat{i} \cdot (-a\hat{i} - b\hat{j}) = -qEa$

24. Here, for neon lamp,

$\lambda = 640.2nm = 640.2 \times 10^{-9}m$

V = 0.54 Volt

As, $eV_1 = \frac{hc}{\lambda_1} - \phi_0$

$eV_2 = \frac{hc}{\lambda_2} - \phi_0$

Thus, $eV_2 - eV_1 = hc\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]$

$V_2 - V_1 = \frac{hc}{e}\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]$

$V_2 = V_1 + \frac{hc}{e}\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]$

$V_2 = 0.54 + \frac{6.63\times10^{-34}\times3\times10^8}{1.6\times10^{-19}}\left[\frac{1}{427.2\times10^{-9}} - \frac{1}{640.2\times10^{-9}}\right]$

= 0.54 + 0.97

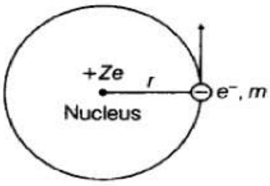
V_2 = 1.51 V

25. i. The nucleus of a lighter element contains a relatively larger number of protons. When fast neutrons are passed through such an element, they make elastic collisions with their protons, which have smaller velocities. After few interactions, the final velocities of the neutrons become equal to the low velocities of protons and hence they get slowed down.

ii. To overcome coulomb repulsion, the fusing nuclei are given enough thermal energy by raising their temperature to 10^6 - 10^7 K. Such a high temperature is available in the interior of the sun.

Section C

26. Let an electron revolves around the nucleus of hydrogen atom. The necessary centripetal force is provided by electrostatic force of attraction.



$\therefore \quad \frac{mv^2}{r} = \frac{ke^2}{r^2} \Rightarrow r = \frac{ke^2}{mv^2}$ ....(i)

By Bohr's second postulates,

$mvr = nh/2\pi$ where, n = 1, 2, 3....

$r = nh/2\pi mv$ ....(ii)

On comparing Eqs. (i) and (ii), we get

$\frac{ke^2}{mv^2} = \frac{nh}{2\pi mv} \Rightarrow v = \frac{2\pi ke^2}{nh}$

Substituting in Eq. (ii), we get

$r = \frac{n^2h^2}{4\pi^2mke^2}$ ....(iii)

Now, kinetic energy of electron

$\mathbf{KE} = 1/2mv^2 = ke^2/2r$

Also, potential energy, PE= - ke^2 /2r

Energy of electron in n^{th} orbit,

$E_n = -\frac{ke^2}{2r} = -\frac{ke^2}{2} \cdot \frac{4\pi^2mke^2}{n^2h^2}$

$\Rightarrow \quad E_n = -\frac{2\pi^2mk^2e^4}{n^2h^2}$ ....(iv)

where, $R = \frac{2\pi^2mk^2e^4}{ch^3} \Rightarrow E_n = -\frac{Rhc}{n^2}$ ....(v)

where, n = 1, 2, 3....

For $n = n_i \Rightarrow E_n \propto \frac{1}{n^2}$

$E_{n_i} = -\frac{Rhc}{n_i^2}$ and $E_{n_f} = -\frac{Rhc}{n_f^2}$

By Bohr's postulates,

$E_{n_f} - E_{n_t} = h\nu \Rightarrow Rhc\left[1/n_i^2 - 1/n_f^2\right] = h\nu$

$\nu = Rc\left[n/n_i^2 - 1/n_f^2\right]$

This is required expression for frequency associated with photon.

27. According to θ

d = D (Given) ...(i)

$D = \frac{1}{2}d$ (Given) ...(ii)

d = 2D

Path difference at P = S_2P - S_1P

Path difference $p = \sqrt{D^2 + \left(x + \frac{d}{2}\right)^2} - \sqrt{D^2 + \left(x - \frac{d}{2}\right)^2}$

Substitute the value of d and x from (i) and (ii)

$= \sqrt{D^2 + (D) + D)^2} - \sqrt{D^2 + (D - D)^2}$

$= \sqrt{5D^2} - \sqrt{D^2}$

$p = D(\sqrt{5} - 1)$

The path difference for nth dark fringe from central maxima O is $(2n-1)\frac{\lambda}{2}$

$\therefore$ For 1st minima $p = \frac{\lambda}{2}$

Put the value of p in (iii)

$\frac{\lambda}{2} = D(\sqrt{5} - 1)$

$D = \frac{\lambda}{2(\sqrt{5}-1)}$

Rationalizing the denominator, we get,

$D = \frac{\lambda}{2(\sqrt{5}-1)} \times \frac{(\sqrt{5}+1)}{(\sqrt{5}+1)} = \frac{(2.236+1)}{2\times(5-1)}\lambda = \frac{3.236}{2\times 4}\lambda$

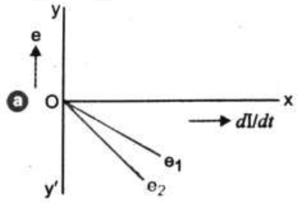
$= \frac{3.236}{8}\lambda = 0.404\lambda$

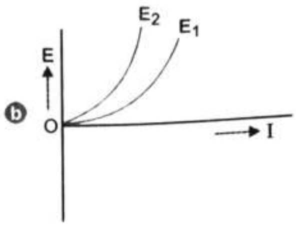
28. Here, L_1 = 12mH = 12 × 10^{-3}H

L_2 = 30mH = 30 × 10^{-3}H

i. As current is increasing at the same rate ($\frac{dI}{dt}$), e.m.f. induced opposes the increase.
$e_1 = L_1\frac{dI}{dt} = 12 \times 13^{-3}(\frac{dI}{dt})$
$e_2 = L_2\frac{dI}{dt} = 30 \times 10^{-3}(\frac{dI}{dt})$
The variation of either $d\frac{I}{dt}$ is as shown in fig.

ii. Energy stored E = $\frac{1}{2}LI^2$
For given L, E ∝ I^2, therefore, the variation of energy stored with the current is as shown in fig.
Power dissipated,
P = $\frac{dE}{dt} = \frac{d}{dt}\left(\frac{1}{2}LI^2\right)$
= $LI\frac{dI}{dt} = \left(\frac{LdI}{dt}\right)I$ = e.I = const.
As $e_2 > e_1$
$\therefore e_2 > e_1$
$\therefore I_2 < I_1$
$\therefore \frac{E_2}{E_1} = \frac{\frac{1}{2}L_2I_2^2}{\frac{1}{2}L_1I_1^2} = \frac{L_2}{L_1}\left(\frac{I_2}{I_1}\right)^2 = \frac{30}{12}\left(\frac{12}{30}\right)^2$
$= \frac{12}{30} = \frac{2}{2}$ = 0.4





OR

i. When the current in a coil is changed, a back emf is induced in the same coil. This phenomenon is called self-induction. And self-inductance is the magnetic flux linked with the coil when a unit current flows through it. If L is self-inductance of coil, then net magnetic flux,
$N\phi \propto I \Rightarrow N\phi = LI \Rightarrow \quad L = \frac{N\phi}{I}$
The SI unit of self-inductance is Henry (H).

ii. Mutual inductance of solenoid coil system, $M = \frac{\mu_0 N_1 N_2 A}{l}$
Here, $N_1 = 15, N_2 = 1, l = 1\text{cm} = 10^{-2}\text{m}$
$A = 2\text{cm}^2 = 2 \times 10^{-4}\text{m}^2$
$\therefore M = \frac{4\pi\times10^{-7}\times15\times1\times2\times10^{-4}}{10^{-2}}$
$= 120\pi \times 10^{-9}\text{H}$
Induced emf in the loop,
$|e_2| = M\frac{dI}{dt} = 120\pi \times 10^{-9} \times \frac{(4-2)}{0.1}$
$= 120 \times 3.14 \times 10^{-9} \times \frac{2}{0.1}$
$= 7.5 \times 10^{-6}\text{V} = 7.5\mu\text{V}$

29. a. Here, a = 6.0 cm
C = 100 pF = $100 \times 10^{-12}F$
$\omega = 300\ rads^{-1}$
E_{rms} = 230V
$I_{rms} = \frac{E_{rms}}{X_C} = \frac{E_{rms}}{\frac{1}{\omega C}} = E_{rms} \times \omega C$

$\therefore I_{rms} = 230 \times 300 \times 100 \times 10^{-12}$
$= 6.9 \times 10^{-6} A = 6.9 \mu A$

b. I = I_D whether I is steady d.c. or a.c. This is shown below:

$I_D = \varepsilon_0 \frac{d(\phi_E)}{dt} = \varepsilon_0 \frac{d}{dt}(EA) \; (\because \phi_E = EA)$
Or $I_D = \varepsilon_0 A \frac{dE}{dt}$
$= \varepsilon_0 A \frac{d}{dt}\left(\frac{Q}{\varepsilon_0 A}\right) \left(\because E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}\right)$
$I_D = \varepsilon_0 A \times \frac{1}{\varepsilon_0 A} \frac{dQ}{dt} = \frac{dQ}{dt} = I$

c. We know that,
$B = \frac{\mu_0}{2\pi} \frac{r}{R^2} I_D$
This formula goes through even if I_D (and therefore B) oscillates in time. The formula shows that they oscillate in phase. Since I_D = I, we have
$B = \frac{\mu_0 r I}{2\pi R^2}$
If I = I_0, the maximum value of current, then amplitude of B = maximum value of B
$= \frac{\mu_0 r I_0}{2\pi R^2} = \frac{\mu_0 r \sqrt{2}\, I_{rms}}{2\pi R^2} \; (\because I_0 = \sqrt{2}\, I_{rms})$
$= \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2 \times 3.14 \times (0.06)^2} T$
$= 1.63 \times 10^{-11} T$

OR

i. Microwaves: Wavelength 10^{-4}m - 10^{-1}m, frequency 10^{13} Hz - 10^{9} Hz
ii. Generation: Microwaves are produced by valves like magnetron, using a maser or Klystron valve. They are detected with crystal detectors, Point contact diodes or solid-state diodes.
iii. Uses:
   a. Used in radar
   b. Used in telemetry
   c. Used in electron spin resonance studies
   d. Used in microwave ovens for heating food

30. The volume of the cubic domain is

V = $(10^{-6}\ m)^3 = 10^{-18}\ m^3 = 10^{-12}\ cm^3$

Its mass is volume × density = 7.9 g cm^{-3} × 10^{-12} cm = 7.9 × 10^{-12}g

It is given that Avagadro number (6.023 × 10^{23}) of iron atoms have a mass of 55 g. Hence, the number of atoms in the domain is
$N = \frac{7.9 \times 10^{-12} \times 6.023 \times 10^{23}}{55}$
= 8.65 × 10^{10} atoms

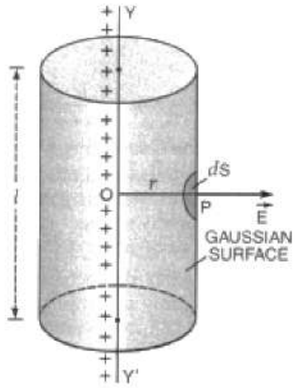
The maximum possible dipole moment m_{max} is achieved for the (unrealistic) case when all the atomic moments are perfectly aligned.

Thus,
$m_{\max} = \left(8.65 \times 10^{10}\right) \times \left(9.27 \times 10^{-24}\right)$
$= 8.0 \times 10^{-13} \mathrm{Am}^2$

The maximum intensity of magnetization is given by ;-
$M_{max} = \frac{m_{max}}{Domain\ volume}$
= 8.0 × 10^{-13} $Am^2/10^{-18}$ m^3
= 8.0 × 10^5 Am^{-1}

Section D

31. a. Consider a thin infinitely long straight line charge having a uniform linear charge density λ placed along YY'. Draw a cylindrical surface of radius r and length l about the line charge as its axis.



If E is the magnitude of electric field at point P, then electric flux through the gaussian surface is given by

$\phi = \mathrm{E} \times$ area of the curved surface of a cylinder of cylinder radius r and length l

or

$\phi = \mathrm{E} \times 2\pi\, r\, l$

According to Gauss' theorem, we have $\phi = \frac{q}{\varepsilon_0}$

Now, charge enclosed by the gaussian surface, q = λ l

$\therefore \quad \phi = \frac{\lambda l}{\varepsilon_0}$

Thus,

$\mathrm{E} \times 2\,\pi\, r\, l = \frac{\lambda l}{\varepsilon_0}$

or $\mathrm{E} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}$

b. Electric field at a distance r from the line charge,

$\mathrm{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\lambda}{r}$

To calculate force on charge -q at point A:

Here, OA = 2·5 cm = $2{\cdot}5 \times 10^{-2}$ m

Electric field at point A,

$\mathrm{E}_1 = \frac{1}{2\pi \times 8.854 \times 10^{-12}} \times \frac{4.5 \times 10^{-4}}{2.5 \times 10^{-2}}$

= $3{\cdot}24 \times 10^{8}$ NC^{-1}

Force on charge - q at point A, $F_1 = qE_1 = 5 \times 10^{-9} \times 3{\cdot}24 \times 10^{8} = 1{\cdot}62$ N (towards the line charge)

To calculate force on charge +q at point B:

Here, OB = $2{\cdot}5 \times 10^{-2} + 2 \times 10^{-3} = 2{\cdot}7 \times 10^{-2}$ m

Electric field at point B,

$E_2 = \frac{1}{2\pi \times 8.854 \times 10^{-12}} \times \frac{4.5 \times 10^{-4}}{2.7 \times 10^{-2}}$

= 3×10^{8} NC^{-1}

Force on charge + q at point B,

$F_2 = qE_2 = 5 \times 10^{-9} \times 3 \times 10^{-8} = 1{\cdot}5$ N (away from the line charge)

Hence, net force on electric dipole,

$F = F_1 - F_2 = 1.62 - 1.5 = 0{\cdot}12$ N (towards the line charge)

OR

a. We can see from the figure that on the left face E and ΔS are parallel. l = 20 cm, r = 5 cm = 0.05m. Therefore, the outward flux is

$\phi_L = \vec{E} \cdot \Delta S = -200\hat{i} \cdot \Delta S$

= + 200 ΔS, since $\hat{i} \cdot \Delta S = -\Delta S$

= + 200 $\times$ $\pi(0.05)^2$ = + 1.57 Nm^2C^{-1}

On the right face, E and ΔS are parallel and therefore

$\phi_R = E \cdot \Delta S$ = + 1.57 Nm^2 C^{-1}.

b. For any point on the side of the cylinder E is perpendicular to ΔS and hence E.ΔS = 0. This is because when dot prdouct is solved they involve cos and the angle between E and ds is 90 degree and cos 90 = 0. Therefore, the flux out of the side of the cylinder is zero.

c. Net outward flux through the cylinder

$\phi = 1.57 + 1.57 + 0 = 3.14\ Nm^2\ C^{-1}$

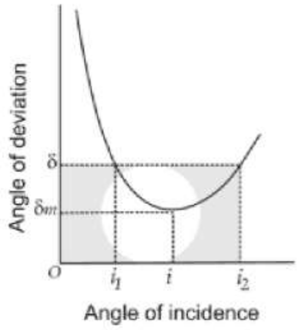
d. The net charge within the cylinder can be found by using Gauss's law which gives

$q = \epsilon_o \phi$

$= 3.14 \times 8.854 \times 10^{-12}$ C

$= 2.78 \times 10^{-11}$ C

32. i.



If the angle of incidence is increased gradually, then the angle of deviation first decreases, attains a minimum value (δ_m) and then again starts increasing. When angle of deviation is minimum, the prism is said to be placed in the minimum deviation position. There is only one angle of incidence for which the angle of deviation is minimum.

When $\delta = \delta_m$ [prism in minimum deviation position]

$e = i$ and $r_2 = r_1 = r$

$\because r_1 + r_2 = A$ .....(i)

From (i), we get r + r = A

$r = \frac{A}{2}$

Also, we have

$A + \delta = i + e$

Substituting $\delta = \delta_m$ and e = i,

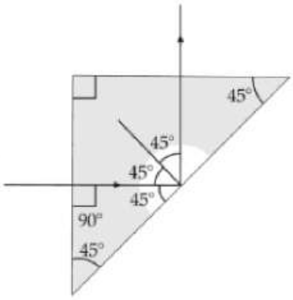
$A + \delta_m = i + i$

$i = \frac{(A+\delta_m)}{2}$

$\because \mu = \frac{sin\, i}{sin\, r}$

$\because \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

ii.



We know that light incident normally on one face of a right isosceles prism is totally reflected.

$\mu = \frac{1}{sinC}$ (Total Internal Reflection)

C is that critical angle, which is 45^o.

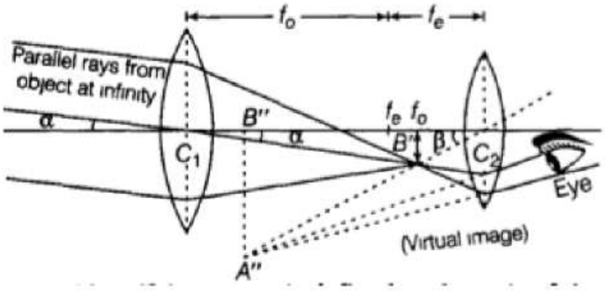
$\mu = \frac{1}{sin\ 45^o} = \sqrt{2} = 1.41$

So, the minimum value of the refractive index of the glass is 1.41.

OR

i. In astronomical telescope for normal adjustment, final image is formed at infinity and it is virtual.

The labelled ray diagram to obtain one of the real image formed by the astronomical telescope is shown below:

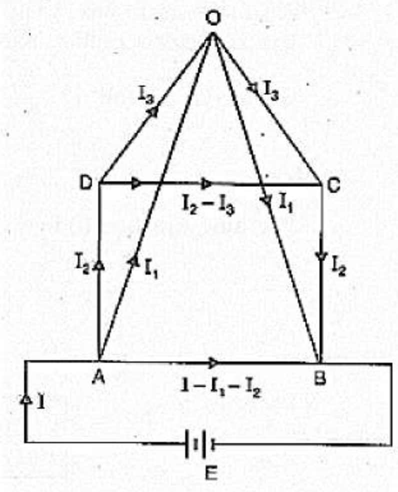


Magnifying power is defined as the ratio of the angle subtended at the eye by the focal image as seen through the telescope to the angle subtended at the eye by the object seen directly, when both the image and the object lies at infinity.

ii. a. We know the objective lens of a telescope should have larger focal length and eyepiece lens should have smaller focal length. And focal length is inverse of power, so lens of power (P = 1/f).
Thus, 10D can be used as eyepiece and lens of power 0.5 D can be used as objective lens.
b. The objective lens of a telescope should have larger aperture, in order to form bright image of distant objects, so that it can gather sufficient light rays from the distant objects.

33. i. **Without using Kirchhoff's laws**
Consider a battery connected between A and B. The circuit now has a plane of symmetry. This plane of symmetry passes through the mid-points of AB and CD and the vertex O. So, the currents are same in (i) AO and OB (ii) DO and OC. Now, OA and OB can be treated as a series combination which gives resistance 25. Also DO and OC are in series combination. This gives 2r. It is in parallel with DC. This gives a resistance of $\frac{2r\times r}{2r+r}$ or $\frac{2r^2}{3r}=\frac{2r}{3}$. This is in series with resistances AD and CB. This gives $\frac{2r}{3}+2r$ i.e. $\frac{8r}{3}$. Now, $\frac{8r}{3}$, resistor AB and combination of AO and BO i.e. 2r are in parallel. If R is the equivalent resistance, then
$\frac{1}{R}=\frac{3}{8r}+\frac{1}{r}+\frac{1}{2r}=\frac{3+8+4}{8r}=\frac{15}{8r}$
$R=\frac{8r}{15}$

ii. **By using Kirchhoff's laws**
Using Kirchhoff's second law in loop DOCD, we get
$-I_3r - I_3r + (I_2 - I_3) = 0$
or, $-3I_3r + I_2r = 0$
or $I_3=\frac{I_2}{3}$ ...(i)
Again, using Kirchhoff's second law to loop AOBA, we get
$-I_1r - I_1r + (I - I_1 - I_2)r = 0$
or $3I_1 + I_2 = 1$ ...(ii)
Considering loop ADCBA, we get
$-I_2r - (I_2 - I_3)r - I_2r + (I - I_1 - I_2)r = 0$
or $Ir - I_1r - 4I_2r + I_3r = 0$
or $I = I_1 + 4I_2 - I_3$ or $I=I_1+4I_2-\frac{I_2}{3}$



Using equation (i),
$I=I_1+\frac{11}{3}I_2$

Using equation (ii),

$3I_1 + I_2 = I_1 + \frac{11}{3}I_2$ or $I_2 = \frac{3}{4}I_1$

From equation (ii),

$I = 3I_1 + \frac{3}{4}I_1 = \frac{15}{4}I_1$

Considering circuit ABEA,

E - (I - I_1 - I_2)r = 0

or E = (I - I_1 - I_2)r

$= \left(\frac{15}{4}I_1 - I_1 - \frac{3}{4}I_1\right)r$

or E = $2I_1$r

If R is the total resistance then E = I r

or $E = \frac{15}{4}I_1 R$

$2I_1 r = \frac{15}{4}I_1 R$(from (iii))

$\therefore \frac{15}{4}R = 2r$ or $R = \frac{8r}{15}$

Section E

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

A magnetic field can be produced by moving, charges or electric currents. The basic equation governing the magnetic field due to a current distribution is the Biot-Savart law. Finding the magnetic field resulting from a current distribution involves the vector product, and is inherently a calculus problem when the distance from the current to the field point is continuously changing. According to this law, the magnetic field at a point due to a current element of length $\vec{dl}$ carrying current I, at a distance r from the element is dB = $\frac{\mu_0}{4\pi}\frac{I(\vec{dl}\times\vec{r})}{r^3}$.

Biot-Savart law has certain similarities as well as differences with Columb's law for electrostatic field e.g., there is an angle dependence in Biot-Savart law which is not present in the electrostatic case.

(i) perpendicular to both $\vec{dl}$ and $\vec{r}$

According to Biot-Savart's law, the magnetic induction due to a current element is given by

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

this is perpendicular to both $\overrightarrow{dl}$ and $\vec{r}$

(ii) decreases as $\frac{1}{r^2}$, so it becomes 4 times.

From Biot-savart's law

dB = $\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$ i.e., $dB \propto \frac{1}{r^2}$

(iii) It will become zero

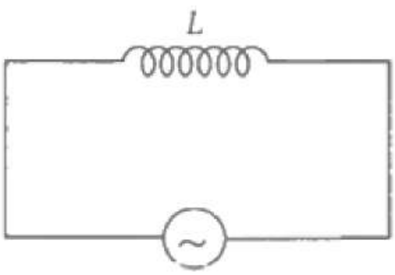
B = $\frac{\mu_0}{2\pi}\cdot\frac{i}{r} - \frac{\mu_0}{2\pi}\cdot\frac{i}{r}$ = 0

OR

The magnetic fields along the current current carrying wire is zero.

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

Let a source of alternating e.m.f. E = E_0 sin ωt be connected to a circuit containing a pure inductance L. If I is the value of instantaneous current in the circuit, then I = I_0 sin $\left(\omega t - \frac{\pi}{2}\right)$. The inductive reactance limits the current in a purely inductive circuit and is given by X_L = ωL.



(i) Inductive reactance,

X_L = ωL = $2\pi v L$ = $2\pi \times 100 \times 14 \times 10^{-3}$

X_L = 8.8 Ω

(ii) In an inductor voltage leads the current by $\frac{\pi}{2}$ or current lags the voltage by $\frac{\pi}{2}$ or by 90^o.

(iii)The current in the inductor coil is given by

$I_0 = \frac{E_0}{X_L} = \frac{\sqrt{2}E_v}{2\pi vL}$

$L = \frac{\sqrt{2}E_v}{2\pi\cup I_0} = \frac{1.414\times200}{2\times3.14\times50\times0.9}$ = 1 H

OR

Inductive reactance,

$X_L = \omega L = 2\pi vL = 2 \times 3.14 \times 50 \times 2 = 628\ \Omega$

$I_0 = \frac{E_0}{X_L} \Rightarrow I_0 = \frac{\sqrt{2}\times E_v}{X_L} = \frac{\sqrt{2}\times150}{628}$ = 0.337 A