Sample Question Paper 03

PHYSICS 12

Time : 3 Hrs. **Max. Marks : 70**

General Instructions

Read the following instructions carefully and follow them :

1. This question paper contains 33 questions. **All** questions are compulsory.
2. This question paper has **FIVE** sections - **Section A**, **B**, **C**, **D** and **E**.
3. **Section A** contains **16 questions, 12 MCQ and 4 Assertion-Reason** of 1 mark each.
4. **Section B** contains 5 **questions** of 2 marks each.
5. **Section C** contains 7 **questions** of 3 marks each.
6. **Section D** contains 2 **case-study based questions** of 4 marks each.
7. **Section E** contains 3 **Long Answer questions** of 5 marks each.
8. There is no overall choice. However, an internal choice has been provided in 2 questions in **Section B**, 1 question in **Section C** and all 3 questions of **Section E**.

Section A MCQs and A-R Questions

Direction *(Q.Nos. 1-16) Select the correct option out of the four given options.*

1. The phase difference between electric field **E** and magnetic field **B** in an electromagnetic wave propagating along Z-axis is [1]

(a) zero (b) π (c) $\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

2. The current flowing through an inductor of self-inductance L is continuously increasing. The graph depicting the variation of magnetic potential energy stored with the current is [1]

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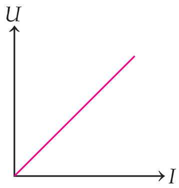

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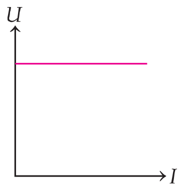

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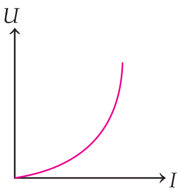

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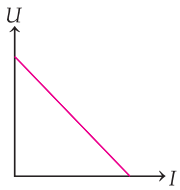


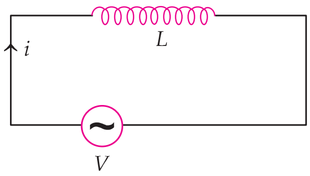
3. Two equal and opposite charges each of 2 C are placed at a distance of 0.04 m. Dipole moment of the system will be [1]

(a) 6×10^{-8} C-m (b) 8×10^{-2} C-m (c) 1.5×10^{-2} C-m (d) 8×10^{-6} C-m

4. The de-Broglie wavelength of a particle is λ. What will be the wavelength of the particle, if its kinetic energy is $\frac{K}{9}$? [1]

(a) λ (b) 2λ (c) 3λ (d) 4λ

5. Which of the following statement is true about an inductive circuit? [1]

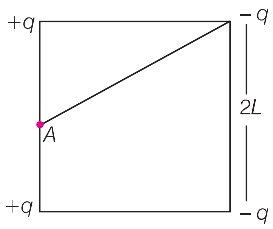


(a) In an inductive circuit, using Kirchhoff's loop rule, we get $V - L\frac{di}{dt} = 0$, where the second term is the mutual induced emf in the inductor.
(b) The quantity ωL is analogous to the conductance.
(c) The current phasor **I** is $\frac{\pi}{2}$ ahead of the voltage phasor **V**.
(d) The average power supplied to an inductor over one complete cycle is zero.

6. Charge through a conductor is given as function of time t as $q = (4t^2 + 4t + 4)$ C. At 2 s, what is the current flowing? [1]

(a) 15 A (b) 10 A (c) 20 A (d) 25 A

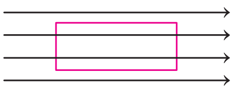
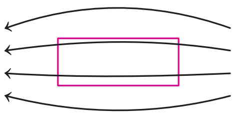
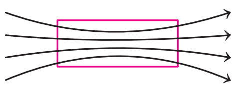
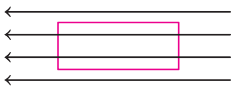
7. Four charges $-q, -q, +q$ and $+q$ are placed at the corners of a square of side $2L$ as shown in figure. The electric potential at point A mid-way between the two charges $+q$ and $+q$ is [1]



(a) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1 + \frac{1}{\sqrt{5}}\right)$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{2L}\left(1 - \frac{1}{\sqrt{5}}\right)$ (d) zero

8. A uniform magnetic field parallel to the plane of paper exists in space, initially directed from left to right. When a bar of soft iron is placed in the field parallelly, the lines of force passing through it will appear as in [1]

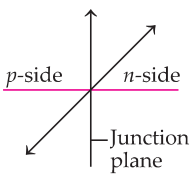
(a)  (b)  (c)  (d) 

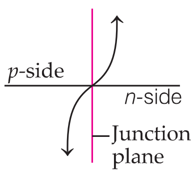
9. An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4.0$, then [1]
(a) wavelength doubled and frequency remains unchanged
(b) wavelength doubled and frequency becomes half
(c) wavelength and frequency both remain unchanged
(d) wavelength is halved and frequency remains unchanged

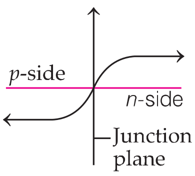
10. A current of 10A is flowing from east to west in a long straight wire kept on a horizontal table. The magnetic field developed at a distance of 10 cm due north on the table is [1]

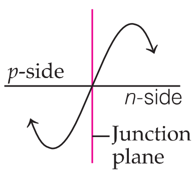
(a) 2×10^{-5} T, acting downwards (b) 2×10^{-5} T, acting upwards
(c) 4×10^{-5} T, acting downwards (d) 4×10^{-5} T, acting upwards

11. Which of these graphs shows potential difference between p-side and n-side of a p-n junction in equilibrium? [1]

(a) 

(b) 

(c) 

(d) 

12. In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits? [1]

(a) 3.4×10^{-4} m (b) 5.6×10^{-4} m (c) 6.6×10^{-4} m (d) 4.5×10^{-4} m

Directions *For questions 13 to 16, two statements are given - one labelled* ***Assertion (A)*** *and other labelled* ***Reason (R)****. Select the correct answer to these questions from the options as given below.*

(a) If both Assertion and Reason are correct and Reason is correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not correct explanation of Assertion.
(c) If Assertion is true but Reason is false.
(d) If both Assertion and Reason are false.

13. **Assertion** (A) The goggle have zero power.

Reason (R) Radius of curvature of both sides of lens of goggle is same. [1]

14. **Assertion** (A) The graph of de-Broglie wavelength *versus* stopping potential is a rectangular hyperbola.

Reason (R) de-Broglie wavelength of a particle is inversely proportional to square root of the stopping potential. [1]

15. **Assertion** (A) An electron on p-side of a p-n junction moves to n-side just after diffusion of charge carriers across junction.

Reason (R) Drifting of charge carriers reduces the concentration gradient across junction. [1]

16. **Assertion** (A) Substances which at room temperature retain their ferromagnetic property for a long period of time are called permanent magnets.

Reason (R) Permanent magnet can be made by placing a ferromagnetic rod in a solenoid and passing current through it. [1]

Section B 2 Marks Questions

17. Derive the expression for the resistivity of a good conductor in terms of the relaxation time of electrons. [2]

18. When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons.

(i) Is the frequency of reflected and refracted light same as the frequency of incident light? [1]

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave. [1]

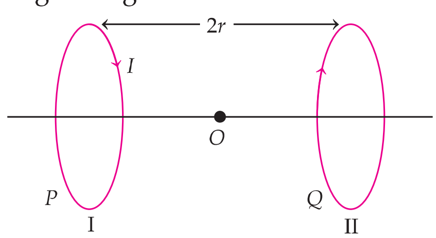
Or (i) Show analytically from the lens equation that when the object is at the principal focus, the image is formed at infinity. [1]

(ii) A magician during a show makes a glass lens $n = 1.47$ disappear in a trough of liquid. What is the refractive index of the liquid? Can the liquid be water? [1]

19. Draw the energy band diagrams of conductors and insulators. [2]

Or What is the difference between hole current and electron current? [2]

20. Two identical circular loops P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O.



The direction of current in P is clockwise and in Q is anti-clockwise as seen from O which is equidistant from the loops P and Q. Find the magnitude of the net magnetic field at O. [2]

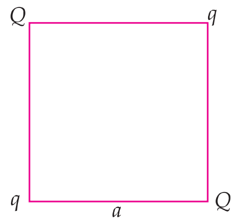
21. Work function of a certain metal is 2 eV. When light of frequency 5×10^{15} Hz is incident on the metal surface, emission of electrons take place. Find

(i) maximum kinetic energy of emitted electrons [1]

(ii) stopping potential. [1]

Section C 3 Marks Questions

22. Four point charges Q, q, Q and q are placed at the corners of a square of side a as shown in figure.Find the



(i) resultant electric force on a charge Q [2]

(ii) potential energy of this system [1]

23. Two monochromatic radiations, blue and violet, of the same intensity are incident on a photosensitive surface and cause photoelectric emission. Would the number of electrons emitted per second and the maximum kinetic energy of the electrons be equal in the two cases?
Justify your answer. [3]

24. A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flows through it in clockwise direction, then find the magnitude and direction of the magnetic field produced at its centre. [3]

25. (i) Why are coherent sources necessary to produce a sustained interference pattern? [1]

(ii) In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen, where path difference is λ, is K unit. Find out the intensity of light at a point, where path difference is $\lambda/3$. [2]

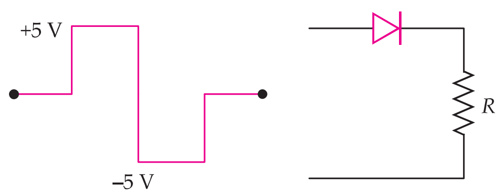
Or Explain the following giving reasons.

(i) When light of frequency less than the threshold frequency is incident on a metal surface, photoelectrons are not emitted.

(ii) The kinetic energy of photoelectrons increases with the increase in frequency of incident light but not with intensity.

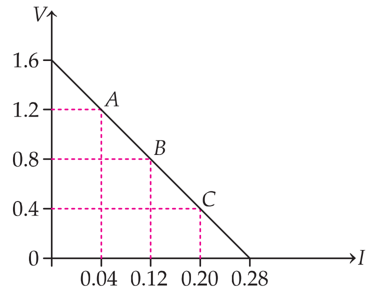
(iii) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light? [3]

26. (i) Draw and explain the output waveform across the load resistor R, if the input waveform is as shown below



(ii) Why is a semiconductor damaged by strong current? [3]

27. The potential difference across terminal of a cell were measured (in volt) against different current (in ampere) flowing through the cell. A graph is drawn which is a straight line *ABC* as shown below.



Determine from the graph [3]

(i) Emf of the cell

(ii) Maximum current obtained from the cell

(iii) Internal resistance of the cell.

28. (i) State Gauss's law for electrostatics. [1]

(ii) Prove Gauss's law for spherically symmetric surface. [2]

Section D Case Based Questions *(4 Marks Each)*

Direction *Question number 29 and 30 are case study based questions. Read the following paragraph and answer the questions that follows.*

29. Atomic masses and the concentration of the atomic nucleus are fundamental concepts in the field of atomic and nuclear physics. The atomic mass of an atom is primarily determined by the mass of its protons, neutrons and electrons. The number of protons in the nucleus determines the element's identity, while the number of neutrons can vary, leading to different isotopes of the same element.

Atomic masses are not whole numbers because they are calculated based on the weighted average of the masses of all naturally occurring isotops of an element.

(i) If an element *X* has three isotopes with atomic masses 10 amu, 11 amu and 12 amu, and their relative abundances are 20%, 70% and 10%. The average atomic mass of element *X* is [1]

(a) 11 amu (b) 12 amu

(c) 10 amu (d) 10.9 amu

(ii) The element which has highest number of isotopes is [1]

(a) Carbon (b) Uranium

(c) Gold (d) Sodium

(iii) The total number of protons and neutrons in an atom with atomic number 20 and mass number 40 is [1]

(a) 20 (b) 40

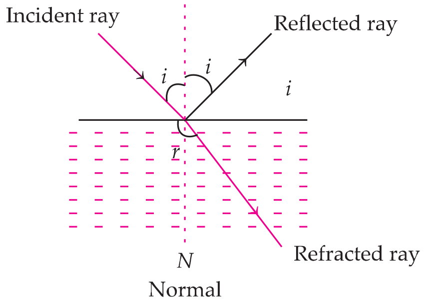
(c) 60 (d) 80

(iv) The atomic mass of an element *X* is 12.01 amu. the most abundant isotop of this element is [1]

(a) *X*-12 (mass = 12.00 amu) (b) *X*-13 (mass = 13.00 amu)

(c) *X*-14 (mass = 14.00 amu) (d) *X*-15 (mass = 15.00 amu)

30. Refraction involves change in the path of light due to change in the medium. When a beam of light encounters another transparent medium, a part of light gets reflected back into the first medium, while the rest enters the other.



The direction of propagation of an obliquely incident ray of light, that enters the other medium, changes at the interface of two media. The phenomenon is called refraction of light.

(i) A ray of light is incident from air into glass at an angle i and refracts at an angle r. What happens to the angle r, if the angle of incidence i is increased ? Explain. [1]

(ii) A ray of light is incident at same angle on three media P, Q and R. The angle of refraction are $35°, 25°$ and $15°$ respectively. Arrange the velocity of light in these media in decreasing order and justify your answer. [1]

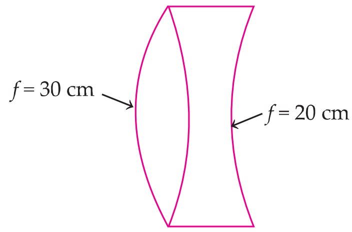
(iii) Velocity of light in glass is 2×10^8 m/s and that in air is 3×10^8 m/s. By how much would an ink dot appear to be raised when covered by a glass plate 6 cm thick? [2]

Section E Long Answer Type Questions *(5 Marks Each)*

31. (i) (a) What is the focal length of a lens combination as shown in the adjacent diagram? [1]

(b) Is the system a converging or a diverging lens? Ignore thickness of the lenses. [1]

(ii) At what angle should a ray of light be incident on the face of a prism of refracting angle 60°, so that it just suffers total internal reflection at the other face? The refractive index of the material of the prism is 1.524. [3]



Or (i) Define the power of lens. [2]

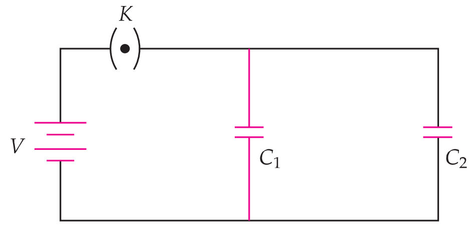
(ii) An angular magnification (magnifying power) of 24 is desired using an objective of focal length 1.25 cm and an eyepiece of focal length 5 cm. How will you set-up the compound microscope? [3]

32. (i) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d. [3]

(ii) Two parallel plate capacitors of capacitances C_1 and C_2 such that $C_1 = 2C_2$ are connected across a battery of V volt as shown in the figure. Initially, the key (K) is kept closed to fully charge the capacitors. The key is now thrown open and a dielectric slab of dielectric constant K is inserted in the two capacitors to completely fill the gap between the plates. Find the ratio of

(a) the net capacitance and [1]

(b) the energies stored in the combination before and after the introduction of the dielectric slab. [1]



Or (i) Derive an expression for the potential energy of an electric dipole placed in a uniform electric field. [3]

(ii) Discuss the conditions of stable and unstable equilibrium for above case. [2]

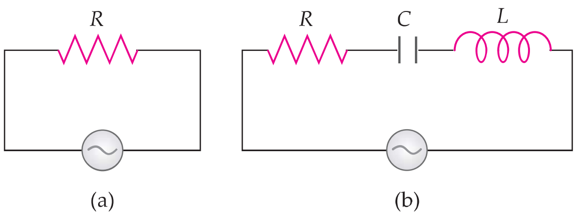
33. A series *L*-*C*-*R* circuit with $L = 0.12$ H, $C = 480$ nF, $R = 23\ \Omega$ is connected to a 230 V variable frequency supply.

(i) What is the source frequency for which current amplitude is maximum? Obtain this maximum value. [2]

(ii) What is the source frequency for which average power absorbed by the circuit is maximum? Obtain the value of maximum power. [2]

(iii) What is the quality factor (*Q*-factor) of the circuit at resonance? [1]

Or Study the circuits (a) and (b) shown in the figure and answer the following questions.



(i) Under which conditions would the rms currents in the two circuits be the same? [3]

(ii) Can the rms current in circuit (b) be larger than that in (a)? [2]

Solutions

1. (*a*) The phase difference between electric field **E** and magnetic field **B** in an electromagnetic wave propagating along *Z*-axis is zero.

2. (*c*) Magnetic potential energy stored in an inductor is given as

$$U = \frac{1}{2} LI^2$$

$$\Rightarrow \quad U \propto I^2$$

So, the correct graph is depicted in option (c).

3. (*b*) Electric dipole moment, $p = q \times d$

$$= 2 \times 0.04 = 0.08 \text{ C-m}$$
$$= 8 \times 10^{-2} \text{ C-m}$$

4. (*c*) de-Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2mK}}$$

When the KE is $\frac{K}{9}$, then

$$\lambda' = \frac{h}{\sqrt{2m\left(\frac{K}{9}\right)}} = \frac{3h}{\sqrt{2mK}} = 3\lambda$$

5. (*d*) In an inductive circuit, using Kirchhoff's loop rule, we get

$$V - L\frac{di}{dt} = 0$$

where, the second term is the self-induced emf in the inductor and L is the self-inductance of the inductor.
The quantity ωL is analogous to the resistance and is called inductive reactance denoted by $X_L (= \omega L)$.

The current phasor **I** lags $\frac{\pi}{2}$ behind the voltage phasor **V**, i.e. $\phi = \frac{\pi}{2}$.

When AC flows through an inductor, it generates the voltage and current as given by $V = V_m \sin \omega t$ and $i_m \sin\left(\omega t - \frac{\pi}{2}\right)$, respectively.

$\therefore$ Average power supplied to an inductor over one complete cycle,

$$P_{av} = V_{rms} \times I_{rms} \times \cos \phi$$
$$= V_{rms} \times I_{rms} \times \cos\frac{\pi}{2} = 0$$

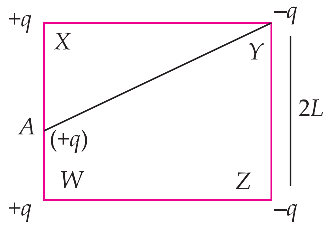
So, statement given in option (d) is true and rest are false.

6. (*c*) $I = \frac{dq}{dt} = \frac{d}{dt}(4t^2 + 4t + 4) = 8t + 4$

$$I(t = 2\text{s}) = 8 \times 2 + 4$$
$$= 16 + 4 = 20 \text{ A}$$

7. (*a*) Assuming the vertex of given square *XYZW*.

Distance of $AY = \sqrt{L^2 + (2L)^2} = \sqrt{5}L$ (by Pythagoras)



Now, electric potential is scalar quantity, $V \propto \frac{1}{r}$

Potential at A is V_A

$$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AX} + \frac{q}{AW} + \frac{(-q)}{AY} + \frac{(-q)}{AZ}\right]$$
$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L} + \frac{q}{L} + \frac{(-q)}{\sqrt{5}\,L} + \frac{(-q)}{\sqrt{5}\,L}\right]$$
$$V_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$$

8. (*c*) Since soft iron has high relative permeability, so maximum field lines will pass through it when it is placed in a uniform magnetic field. Hence, fig. (c) correctly shows the given situation.

9. (*d*) For any wave passing from one medium to another, frequency remains unchanged.

Now, $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and $v = \frac{c}{\sqrt{\varepsilon}}$

$$v = \frac{c}{\sqrt{4}} = \frac{c}{2}$$

Now, the ratio of wavelength of two media

$$\frac{\lambda_1}{\lambda_2} = \frac{c}{v} = \frac{c}{c/2} = 2$$

$$\therefore \quad \lambda_2 = \frac{\lambda_1}{2}$$

10. (*a*) Current, $I = 10$ A

Direction- East to west

Distance from wire,

$$r = 10 \text{ cm} = 0.1 \text{ m}$$

$$\therefore \quad B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.1}$$
$$= 2 \times 10^{-5} \text{ T}$$

Direction- right hand thumb rule-downward

$\Rightarrow$ 2×10^{-5} T, acting downwards

11. (*c*) In a *p-n* junction at equilibrium the potential rises smoothly from the *p*-side to the *n*-side due to the built in potential barrier. The curve is S-shaped, showing a gradual increase across the depletion region and flattening out in the neutral regions on both sides.

12. (*a*) Given, $\lambda = 600\text{ nm} = 600 \times 10^{-9}$ m

Now convert degree to radian, i.e. $\theta = 0.1° = \frac{0.1\pi}{180}$ rad

Now, $\theta = \frac{\lambda}{d}$

$\Rightarrow \quad d = \frac{\lambda}{\theta} = \frac{600 \times 10^{-9}}{0.1\pi} \times 180$

$\Rightarrow \quad d = 3.4 \times 10^{-4}$ m

13. (*a*) $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For goggle, $R_1 = R_2$

$\therefore \quad \frac{1}{f} = 0 \Rightarrow P = \frac{1}{f} = 0$

14. (*a*) The de-Broglie wavelength of a particle is given by

$$\lambda = \frac{h}{\sqrt{2mqV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{V}}$$

Hence, the graph of λ *versus* V is a rectangular hyperbola.

15. (*c*) In a *p-n* junction, due to diffusion of electrons, a positive space charge region on *n*-side of the junction and a negative space charge region on *p*-side of the junction is formed which are called immobile ions.

Due to this, an electric field directed from positive charge towards negative charge develops. (Electric field is from *n*-side to *p*-side). Due to this field, an electron on *p*-side of the junction moves to *n*-side and a hole on *n*-side of the junction moves to *p*-side. This motion of charge carriers due to the electric field is called drift. Thus, a drift current, which is opposite in direction to the diffusion current, starts flowing. However, concentration gradient is due to doping of impurities. It is not affected by drift of charge carriers.

16. (*b*) A ferromagnetic rod becomes a permanent magnet when current through a solenoid aligns its magnetic domain. This process explains how permanent magnets are formed.

17. Specific resistance or resistivity of the material of a conductor is defined as the resistance of a unit length with unit area of cross-section of the material of the conductor.

$\therefore \quad R = \rho \times \frac{l}{A}$

$\Rightarrow \quad \rho = \frac{RA}{l} \quad \ldots(i)$

Substituting the value of $R = \frac{ml}{ne^2 A\tau}$ in Eq. (i), we get

$$\rho = \frac{m}{ne^2\tau}$$

18. (i) The frequency of reflected and refracted light remains same as that of incident light because frequency only depends on the source of light.

(ii) Since, the frequency remains same, hence there is no reduction in energy because energy depends on frequency ($E = h\nu$).

Or

(i) Given, $u = -f$

Lens equation is $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\Rightarrow \quad \frac{1}{v} + \frac{1}{f} = \frac{1}{f} \Rightarrow \frac{1}{v} = 0$

$v = \frac{1}{0} =$ infinity

(ii) If $\mu_1 = \mu_2$, then $f = \infty$

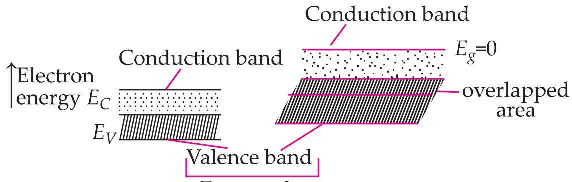
Hence, the lens in the liquid acts like a plane sheet when refractive index of the lens and the surrounding is the same. Therefore,

$$\mu_1 = \mu_2 = 1.47$$

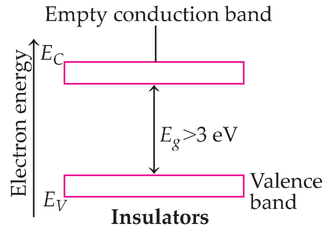
Thus, the liquid medium is not water because refractive index of water is 1.33.

It might be glycerine.

19. The energy band diagrams of conductors and insulators are as given below



For metals
Conductors



Insulators

Or

Hole current occurs in a *p*-type semiconductor, when electron jump into holes, causing the holes to move.

Electron current occurs in an *n*-type semiconductor due to the movement of free electrons.

20. To calculate net magnetic field at point *O*, first of all, calculate the magnetic field at point *O* due to both coils separately, with direction. By vector addition of these two magnetic fields, net magnetic field can be obtained.

Magnetic field at *O* due to two rings will be in same direction ($Q \to P$, along the axis) and of equal magnitude.

$$B = B_1 + B_2 \text{ but } B_2 = B_1$$

$$\Rightarrow \quad B = 2B_1 = 2\left[\frac{\mu_0 Ir^2}{2(r^2+r^2)^{3/2}}\right]$$

$$B = \frac{\mu_0 Ir^2}{(2r^2)^{3/2}} = \frac{\mu_0 Ir^2}{2^{3/2}r^3} = \frac{\mu_0 I}{2^{3/2}r} \text{ T}$$

21. Given, $\phi_0 = 2\text{ eV} = 2\times 1.6\times 10^{-19}$ J

$\nu = 5\times 10^{15}$ Hz

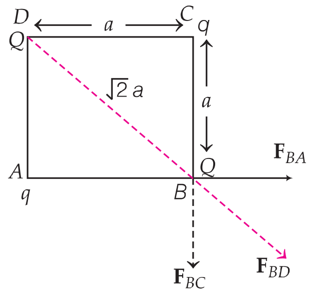
(i) Maximum kinetic energy of emitted electrons,

$$E_K = h\nu - \phi_0$$
$$= 6.63\times 10^{-34}\times 5\times 10^{15} - 2\times 1.6\times 10^{-19}$$
$$= 33.15\times 10^{-19} - 3.2\times 10^{-19} = 29.95\times 10^{-19}\text{ J}$$
$$= \frac{29.95\times 10^{-19}}{1.6\times 10^{-19}}\text{ eV}$$
$$E_K = 18.7\text{ eV}$$

(ii) Stopping potential V_0 is given by $E_K = eV_0$

$$V_0 = \frac{E_K}{e} = \frac{18.7\text{eV}}{e} = 18.7\text{ V}$$

22. (i) Force acting on charge Q placed at point B, is due to charges placed at points A, C and D.



Here, magnitude of force on charge at point B due to charge at point A,

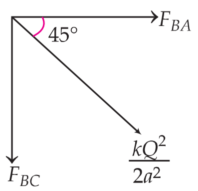
$$F_{BA} = \frac{kQq}{a^2}$$

Similarly, magnitude of force on charge at point B due to charge at point C,

$$F_{BC} = \frac{kQq}{a^2}$$

Also, the magnitude of force on charge at point B due charge at point D,

$$F_{BD} = \frac{kQ^2}{(\sqrt{2}a)^2} = \frac{kQ^2}{2a^2}$$



Let F be the resultant of F_{BA} and F_{BC}.

$$\therefore \quad F = \sqrt{2}\cdot\frac{kQq}{a^2} \quad \left[\text{as } F_{BA} = F_{BC} = \frac{kQq}{a^2}\right]$$

$\therefore$ The resultant electric force on charge Q,

$$F_{net} = F + \frac{kQ^2}{2a^2} = \sqrt{2}\frac{kQq}{a^2} + \frac{kQ^2}{2a^2}$$
$$= \frac{kQ}{a^2}\left(\sqrt{2}q + \frac{Q}{2}\right)\text{N}$$

(ii) The potential energy of the system is given by

$$U = U_{AB} + U_{BC} + U_{CD} + U_{DA} + U_{AC} + U_{BD}$$
$$= \frac{kQq}{a} + \frac{kQq}{a} + \frac{kQq}{a} + \frac{kQq}{a} + \frac{kq^2}{\sqrt{2}a} + \frac{kQ^2}{\sqrt{2}a}$$
$$= \left[4\left(\frac{kQq}{a}\right) + \frac{kq^2}{\sqrt{2}a} + \frac{kQ^2}{\sqrt{2}a}\right]$$

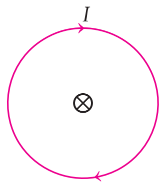
23. The intensities for both the monochromatic radiations are same but their frequencies are different. It represents the number of electrons ejected in two cases are same because it depends on the number of incident photons.

As, $KE_{max} = h\nu - \phi_0 = hc/\lambda - \phi_0$

[Einstein's photoelectric equation]

$\therefore$ The KE_{max} of violet radiation will be more.

24. When a straight wire is bent into the form of a circular coil of N turns, then the length of the wire is equal to circumference of the coil multiplied by the number of turns. Let the radius of coil be r.



As, the wire is bent round in the form of a coil having N turns.

$\therefore$ $N\times$circumference of the coil = length of the wire

$$\Rightarrow \quad N\times(2\pi r) = L$$

$$\Rightarrow \quad r = \frac{L}{2\pi N} \quad \text{...(i)}$$

Magnetic field at the centre of coil due to N turns of a coil is given by

$$B = \frac{\mu_0(NI)}{2r} = \frac{\mu_0(NI)}{2\left(\frac{L}{2\pi N}\right)} \quad \text{[from Eq. (i)]}$$
$$= \frac{\mu_0 \pi N^2 I}{L}$$

The direction of magnetic field is perpendicular to the plane of loop and entering into it.

25. (i) Coherent sources are necessary to produce a sustained interference pattern because they

(a) maintain constant phase difference.

(b) have the same frequency and wavelength.

Without coherence, the phase difference between wave varies randomly with time causing the interference pattern fluctuate and disappear.

(ii) Intensity of light at a point on the screen is given by

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

For the path difference λ, phase difference is 2π.

As, sources are coherent and taken out of the same source in Young's double slit experiment,

$$I_1 = I_2 = I \Rightarrow \quad I_R = 2I + 2I\cos 2\pi$$

$$\Rightarrow \quad I_R = 4I$$

$$\Rightarrow \quad 4I = K \text{ unit} \qquad \ldots\text{(i)}$$

For the path difference, $\frac{\lambda}{3}$ corresponding phase difference is $\frac{2\pi}{3}$, so

$$I_R = 2I + 2I\cos\frac{2\pi}{3} = 2I - I = I \qquad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we conclude

$$I_R = \frac{K}{4}\text{ unit}$$

Or (i) Photoelectrons are emitted only if the energy of the incident phton is equal to or greater than the metal's work function. Since, energy of a photon is $E = h\nu$, if the frequency is less than the threshold, the energy is insufficient of eject electrons. Therefore, no photoemission occurs regardless of the intensity of light.

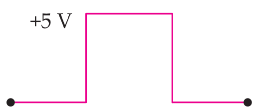
(ii) The kinetic energy of photoelectrons is given by KE $= h\nu - \phi_0$ where ν is the frequency and ϕ_0 is the work function. Since intensity only affects the number of photons and not their energy, it does not influence kinetic energy. Hence, kinetic energy depends solely on the frequency of incident light.

(iii) In the photon picture of light, intensity of a light is determined by the number of photons incident per unit area. For a given frequency, intensity of light in the photon picture is determined by

$$I = \frac{\text{Energy of photons}}{\text{Area} \times \text{Time}} = \frac{n \times h\nu}{A \times t}$$

26. (i) When the input voltage of $+5$V is applied across diode, it get forward biased and hence a output of $+5$V is obtained across R, while when the input voltage of -5V is applied across the diode, it gets reversed biased. So, no output is obtained across R.

The output waveform is



(ii) When a strong current passes through a semiconductor, a large amount of heat is produced which break the covalent bonds in the semiconductor due to which it gets damaged.

27. (i) The emf of cell is the potential difference for zero current.

From the graph, the potential difference, $V = 1.6$ V.

$\therefore$ emf of cell, $\varepsilon = 1.6$ V

(ii) Maximum current is obtained from the cell when the terminal potential difference of the cell is zero.

i.e. $\quad I_{max} = 0.28$ A

(iii) Internal resistance of cell,

$$r = \frac{\varepsilon}{I_{max}} = \frac{1.6}{0.28} = 5.71\,\Omega$$

28. (i) **Gauss's Law** The surface integral of the electric field intensity over any closed surface (called Gaussian surface) in free space is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed within the surface.

$$\phi_E = \oint_S \mathbf{E}\cdot d\mathbf{S} = \frac{1}{\varepsilon_0}\sum_{i=1}^{n} q_i = \frac{q}{\varepsilon_0}$$

where, $q = \sum_{i=1}^{n} q_i$ is the algebraic sum of all the charges inside the closed surface.

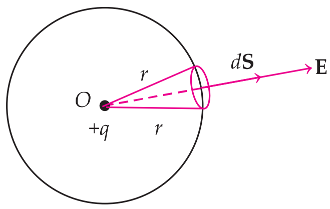
(ii) Electric flux through a surface element $d\mathbf{S}$ is given by

$$d\phi_E = \mathbf{E}\cdot d\mathbf{S} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}\hat{\mathbf{r}}\cdot(dS\hat{\mathbf{n}})$$

$$\Rightarrow \quad d\phi_E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q\,dS}{r^2}\hat{\mathbf{r}}\cdot\hat{\mathbf{n}}$$

Here, $\hat{\mathbf{r}}\cdot\hat{\mathbf{n}} = 1\cdot 1\cdot\cos 0° = 1$

$$\therefore \quad d\phi_E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q\,dS}{r^2}$$



Total electric flux through the spherical surface,

$$\phi_E = \oint_S d\phi_E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}\oint_S dS$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}\cdot 4\pi r^2 = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \quad \phi_E = \frac{q}{\varepsilon_0}$$

If there is no net charge within the closed surface, i.e. when $q = 0$, then $\phi_E = 0$.

$\therefore$ The total electric flux through a closed surface is zero, if no charge is enclosed by the surface.

Mistake Alert
Don't confuse between enclosed charge and total charge.

29. (i) (*d*) Average atomic mass

$= (0.20 \times 10) + (0.70 \times 11) + (0.10 \times 12) = 10.9$ amu

(ii) (*c*) Carbon have 14 isotopes, Uranium have 3 isotopes, Gold have 32 isotopes and sodium have 20 isotopes.

(iii) (*b*) Total number of protons and neutrons is mass number of element.

(iv) (*a*) The most abundant isotope is the isotope whose mass is closest to 12.01 amu.

30. (i) From Snell's law of refraction,

$$^{a}\mu_{g} = \frac{\sin i}{\sin r} = \text{constant}$$

Since, angle of incidence increases, so the angle of refraction will increase, so that the ratio $\left(\frac{\sin i}{\sin r}\right)$ is constant.

(ii) According to Snell's law, $\mu = \frac{\sin i}{\sin r}$ or $\mu \propto \frac{1}{\sin r}$

μ is maximum for R, since r is minimum.

Also, $\mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu}$

Therefore, if μ is maximum, v is minimum, i.e. velocity of light is minimum in medium R and order of velocity will be $v_P > v_Q > v_R$.

(iii) Given, velocity of light in glass, $v = 2 \times 10^8$ m/s

Velocity of light in air, $c = 3 \times 10^8$ m/s

$\therefore$ Refractive index of glass with respect to air,

$$^{a}\mu_{g} = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

∴Normal shift in the position of ink dot,

$$d = t\left(1 - \frac{1}{^{a}\mu_{g}}\right) = 6\left(1 - \frac{1}{1.5}\right) \quad [\because t = 6\,\text{cm}]$$

$$= \frac{6 \times 0.5}{1.5} = 2\,\text{cm}$$

31. (i) (a) Given, focal length of convex lens, $f_1 = 30$ cm

Focal length of concave lens, $f_2 = -20$ cm

Using the formula of combination of lenses,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{30} - \frac{1}{20} = \frac{2-3}{60} = -\frac{1}{60}$$

$\Rightarrow \quad f = -60$ cm

(b) Since, the focal length of combination is negative in nature, so the combination behaves like a diverging lens, i.e. as a concave lens.

(ii) Given, angle of prism, $A = 60°$

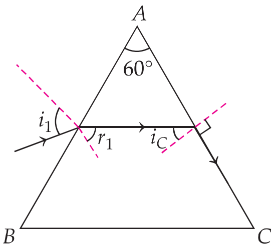
Refractive index of prism, $\mu = 1.524$

Let i be the angle of incidence. The angle of incidence at the other surface is equal to the critical angle i_c because it just suffers total internal refraction.

$$\therefore \quad \sin i_c = \frac{1}{\mu} = \frac{1}{1.524} = 0.6561 \Rightarrow i_c = 41°$$

For a prism $r_1 + r_2 = A$,

here $r_2 = i_c$



$\therefore \quad r_1 + i_c = A$

$\Rightarrow \quad r_1 + 41° = 60°$

$\Rightarrow \quad r_1 = 19°$

Using the formula,

$$\mu = \frac{\sin i_1}{\sin r_1}$$

or $\sin i_1 = 1.524 \sin 19° = 1.524 \times 0.3256$

or $i_1 = \sin^{-1}(0.4962)$

or $i_1 = 29°75'$

Thus, incident angle should be 29°75′.

Or (i) **Power of lens** It is the ability to diverge or converge the light rays incident on it. It is defined as the reciprocal of focal length.

$$P = \frac{1}{f(\text{in m})} = \frac{100}{f(\text{in cm})}$$

(ii) We assume the microscope in common usage, i.e. the final image is formed at the least distance of distinct vision, $D = 25$ cm, $f_e = 5$ cm

$\therefore$ Angular magnification of the eyepiece,

$$m_e = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 6$$

As, total magnification, $m = m_e \times m_o$

$\therefore$ Angular magnification of the objective,

$$m_o = \frac{m}{m_e} = \frac{24}{6} = 4$$

As real image is formed by the objective, therefore

$$m_o = -\frac{v_o}{u_o} = -4 \quad \text{or} \quad v_o = -4\,u_o,$$

$$f_o = 1.25\,\text{cm}$$

Now, $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$ or $\frac{1}{-4\,u_o} - \frac{1}{u_o} = \frac{1}{1.25}$

or $\frac{-5}{4\,u_o} = \frac{1}{1.25}$ or $u_o = -\frac{5 \times 1.25}{4} = -1.6$ cm

Thus, the object should be held at 1.6 cm in front of the objective lens.

Also, $v_o = -4u_o = -4 \times (-1.6) = 6.4$ cm

As, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$$\therefore \quad \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{5} \quad [\because v_e = -D = -25\,\text{cm}]$$

$$= \frac{-1-5}{25} = -\frac{6}{25}$$

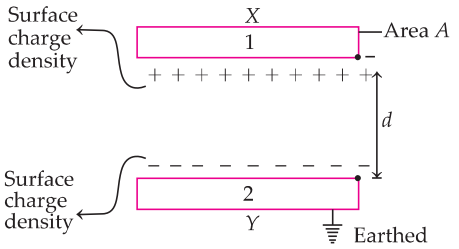
or $u_e = \frac{-25}{6} = -4.17$ cm

$\therefore$ Separation between the objective and the eyepiece

$= |u_e| + |v_o| = 4.17 + 6.4 = 10.57$ cm

32. (i) Parallel plate capacitor consists of two thin conducting plates each of area A held parallel to each other at a suitable distance d.

One of the plates is insulated and other is earthed and also there is vacuum between the plates.



Suppose the surface density of charge on each plate is σ. We know that, the intensity of electric field at a point between two plane, parallel sheets of equal and opposite charges is σ/ε_0, where ε_0 is the permittivity of free space.

The intensity of electric field between the plates will be given by $E = \frac{\sigma}{\varepsilon_0}$

The charge on each plate is q and the area of each plate is A. Thus,

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

and so, $$E = \frac{q}{\varepsilon_0 A} \quad \ldots(\text{i})$$

Now, let the potential difference between the two plates be V volt. Then, the electric field between the plates is given by

$$E = \frac{V}{d} \quad \text{or} \quad V = Ed$$

Substituting the value of E from Eq. (i), we get

$$V = \frac{qd}{\varepsilon_0 A}$$

$\therefore$ Capacitance of the parallel plate capacitor is given by

$$C = \frac{q}{V} = \frac{q}{qd/\varepsilon_0 A}$$

or $$C = \frac{\varepsilon_0 A}{d}$$

(ii) (a) Given, $C_1 = 2C_2$ ...(i)

Net capacitance before filling the gap with dielectric slab is given by

$$C_{\text{initial}} = C_1 + C_2 \quad \text{[from Eq. (i)]}$$

$$C_{\text{initial}} = 2C_2 + C_2 = 3C_2 \quad \ldots(\text{ii})$$

Net capacitance after filling the gap with dielectric slab of electric constant K,

$$C_{\text{initial}} = KC_1 + KC_2$$

$$= K(C_1 + C_2) \quad \text{[from Eq. (ii)]}$$

$$C_{\text{final}} = 3KC_2 \quad \ldots(\text{iii})$$

Ratio of net capacitance is given by

$$\frac{C_{\text{initial}}}{C_{\text{final}}} = \frac{3C_2}{3KC_2} = \frac{1}{K}$$

[from Eqs. (ii) and (iii)]

(b) Energy stored in the combination before introducing the dielectric slab,

$$U_{\text{initial}} = \frac{1}{2} \times \frac{Q^2}{3C_2} \quad \ldots(\text{i})$$

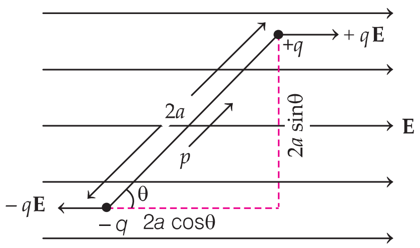
Energy stored in the combination after introducing the dielectric slab,

$$U_{\text{final}} = \frac{1}{2} \times \frac{Q^2}{3KC_2} \quad \ldots(\text{ii})$$

Ratio of energies stored,

$$\frac{U_{\text{initial}}}{U_{\text{final}}} = \frac{K}{1} \quad \text{[from Eqs. (iv) and (v)]}$$

Or (i) Let at any instant, dipole makes an angle θ with the direction of electric field **E**. Two equal and opposite forces $+q\mathbf{E}$ and $-q\mathbf{E}$ act on the two point charges of dipole.



These forces form a couple whose torque (τ) is given by

$$\tau = F \times \text{perpendicular distances between forces}$$

$$\Rightarrow \quad \tau = qE \times (2a \sin\theta)$$

$$= [q(2a)]\, E \sin\theta$$

$$\Rightarrow \quad \tau = pE \sin\theta \quad \ldots(\text{i})$$

where, $p = q(2a)$ is electric dipole moment.

If the dipole is rotated through a small angle $d\theta$ against the torque, then small work done is given by

$$dW = \tau\, d\theta$$

$$\Rightarrow \quad dW = (pE\sin\theta)\, d\theta$$

The total work done in rotating the dipole from angle θ_1 to θ_2 with the direction of electric field **E** is given by

$$W = \int dW = \int_{\theta_1}^{\theta_2} pE\sin\theta\, d\theta$$

$$W = pE[-\cos\theta]_{\theta_1}^{\theta_2} = pE[\cos\theta_1 - \cos\theta_2]$$

This work done is stored in the form of electrostatic potential energy.

$\therefore$ Electrostatic potential energy,

$$U = pE[\cos\theta_1 - \cos\theta_2]$$

If $\theta_1 = 90°$ and $\theta_2 = \theta$, then

$$U = pE(\cos 90° - \cos\theta)$$
$$= -pE\cos\theta = -\mathbf{p}\cdot\mathbf{E} \quad [\because \cos 90° = 0]$$

This is the required expression of potential energy of an electric dipole placed in a uniform electric field.

Value Point
- Draw the suitable diagram.
- Show proper orientation of electric dipole.

(ii) **For stable equilibrium**

When $\theta = 0°$, potential energy,

$$U = -pE\cos\theta = -pE\cos 0°$$
$$\Rightarrow \quad U = -pE$$

The potential energy of an electric dipole is minimum and dipole attains stable equilibrium.

For unstable equilibrium

When $\theta = 180°$, potential energy,

$$U = -pE\cos\theta$$
$$= -pE\cos 180°$$
$$= -pE(-1) = pE$$

Thus, the potential energy is maximum and in this situation, dipole is said to be in unstable equilibrium.

33. Given, $L = 0.12$ H, $C = 480$ nF $= 480 \times 10^{-9}$ F,

$R = 23\Omega$ and $V_{rms} = 230$ V

$$\Rightarrow \quad V_0 = 230\sqrt{2} \text{ V}$$

(i) Current amplitude, $I_0 = \dfrac{V_0}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$

I_0 would be maximum, if

$$\omega = \omega_r = \frac{1}{\sqrt{LC}}$$
$$= \frac{1}{\sqrt{0.12 \times 480 \times 10^{-9}}}$$
$$= 4166.7 \text{ rad/s}$$

$\therefore$ Maximum value of current,

$$I_0 = \frac{V_0}{R} = \frac{\sqrt{2} \times 230}{23} = 14.14 \text{ A}$$

(ii) Average power absorbed by the circuit is maximum, if $I = I_0$ at $\omega = \omega_r$

Source frequency,

$$\nu_r = \frac{\omega_r}{2\pi} = \frac{4166.7}{2\pi} = 663.48 \text{ Hz}$$

$$\therefore \quad P_{av} = \frac{1}{2} I_0^2 R = \frac{1}{2}(14.14)^2 \times 23$$
$$= 2299.3 \text{ W} \approx 2300 \text{ W}$$

(iii) $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}} = \dfrac{1}{23}\sqrt{\dfrac{0.12}{480 \times 10^{-9}}}$

$$= \frac{1}{23}\sqrt{2.5 \times 10^5} = \frac{1}{23} \times 500 = 21.7$$

Or

Let $(I_{rms})_a$ = rms current in circuit (a)

$(I_{rms})_b$ = rms current in circuit (b)

$$(I_{rms})_a = \frac{V_{rms}}{R} = \frac{V}{R}$$
$$(I_{rms})_b = \frac{V_{rms}}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

(i) When $(I_{rms})_a = (I_{rms})_b$

$$R = \sqrt{R^2 + (X_L - X_C)^2}$$
$$\Rightarrow \quad R^2 = R^2 + (X_L - X_C)^2$$
$$\Rightarrow \quad 0 = (X_L - X_C)^2$$
$$\Rightarrow \quad X_L = X_C$$

i.e. In resonance condition.

(ii) As, $Z \geq R$

$$\Rightarrow \quad \frac{(I_{rms})_a}{(I_{rms})_b} = \frac{\sqrt{R^2 + (X_L - X_C)^2}}{R} = \frac{Z}{R} \geq 1$$
$$\Rightarrow \quad (I_{rms})_a \geq (I_{rms})_b$$

No, the rms current in circuit (b) cannot be larger than that in (a).

My Reflection & Problem Points

Write down any difficulties, doubts, or mistakes you faced in this paper.

Discuss these points with your teacher and sort them out.

Concept (s) I got stuck on ....

....

Question (s) I couldn't complete ....

....

What confused me most ....

....

Time issue faced in ....