Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 4

with SOLUTION

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

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. In semiconductors at the room temperature **[1]**

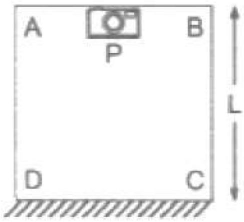
a) the valence band is partially empty and the conduction band is partially filled

b) the conduction band is completely empty

c) the valence band is completely filled and the conduction band is partially filled

d) the valence band is completely filled

2. Adjoining figure shows cubical room ABCD, with the wall CD as a plane mirror. Each side of the room is L metres in length. A camera P is placed at the mid-point of the wall AB. At what distance should the camera be focussed to photograph an object placed at A? **[1]**



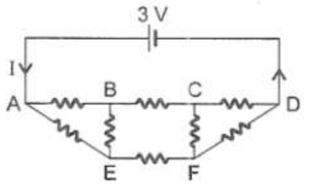
a) 2L

b) L

c) $\frac{L}{2}$

d) More than 2L

3. Following figure shows a network of eight resistors, each equal to 2 Ω, connected to a 3 V battery of negligible internal resistance. The current I in the circuit is: **[1]**



a) 1.0 A

b) 0.50 A

c) 0.75 A

d) 0.25 A

4. Which of the following is forward biased? **[1]**

a) None of these

b) 

c) 

d) 

5. An EM wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as **[1]**

a) $\frac{1}{r}$

b) $\frac{1}{r^3}$

c) remains constant

d) $\frac{1}{r^2}$

6. A moving conductor coil in a magnetic field produces an induced emf. This is in accordance with: **[1]**

a) Faraday's Law

b) Coulomb's Law

c) Lenz's Law

d) Ampere's Law

7. Rutherford's experiment on the scattering of α-particles proved that: **[1]**

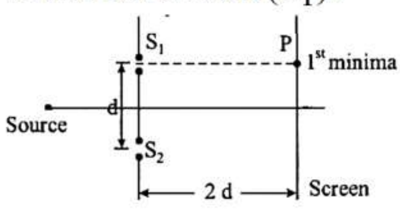
a) atom contains positrons

b) atom is mostly empty

c) positive charge is uniformly distributed in the atom

d) number of positive charges is not equal to the number of negative charges

8. Consider Young's double-slit experiment as shown in the figure. What should be the slit separation d in terms of wavelength λ such that the first minima occurs directly in front of the slit (S_1)? **[1]**



a) $\frac{\lambda}{2(\sqrt{5}-2)}$

b) $\frac{\lambda}{(5-\sqrt{2})}$

c) $\frac{\lambda}{2(5-\sqrt{2})}$

d) $\frac{\lambda}{(\sqrt{5}-2)}$

9. 6 eV of the energy of an electron striking a tungsten target is converted into X-rays. The maximum wavelength of X-rays emitted is nearly: **[1]**

a) 1×10^{-7} m

b) 2×10^{-7} m

c) 4×10^{-7} m

d) 3×10^{-7} m

10. Identify the mismatched pair from the following: **[1]**

a) germanium doped : n-type semiconductor with phosphorus

b) semiconductor : band gap > 3 eV

c) Zener diode : voltage regulator

d) p-n junction diode : rectifier

11. If σ = surface charge density, ε = electric permittivity, the dimensions of $\frac{\sigma}{\varepsilon}$ are same as **[1]**

a) pressure

b) electric force

c) electric charge

d) electric field intensity

12. Each of the two-point charges are doubled and their distance is halved. Force of interaction becomes n times, where n is **[1]**

a) 1

b) 18

c) 16

d) 4

13. The energy of a photon is E = hν and the momentum of photon p = $\frac{h}{\lambda}$, then the velocity of photon will be: **[1]**

a) $\frac{E}{p}$

b) $\left(\frac{E}{p}\right)^2$

c) 3×10^8 m/s

d) Ep

14. Which of the following radiations has the least wavelength? **[1]**

a) α-rays

b) β-rays

c) X-rays

d) γ-rays

15. **Assertion (A):** Gases become conducting only when their pressure is lowered. **[1]**
Reason (R): At low pressure, the discharge current is high.

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. Energy stored in a coil of self-inductance 40 mH carrying a steady current of 2 A is: **[1]**

a) 8 J

b) 80 J

c) 0.8 J

d) 0.08 J

17. **Assertion (A):** In a radioactive disintegration, an electron is emitted by the nucleus. **[1]**
Reason (R): Electrons are present inside the nucleus.

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):** An artificial satellite with a metallic surface is moving about the earth in a circular orbit. A current is induced when the plane of the orbit is inclined to the plane of the equator. **[1]**
Reason (R): The satellite cuts the magnetic field of the earth.

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.

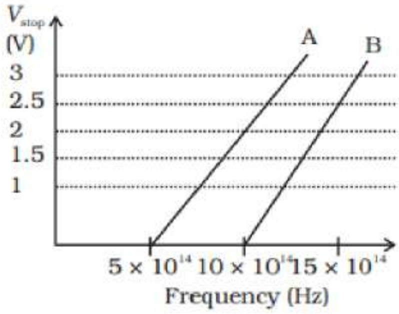
c) A is true but R is false.

d) A is false but R is true.

Section B

19. Why is it necessary to slow down the neutrons, produced through the fission of $^{235}_{92}U$ nuclei (by neutrons), to sustain a chain reaction? What type of nuclei are (preferably) needed for slowing down fast neutrons? **[2]**

20. A student performs an experiment on the photoelectric effect, using two materials A and B. A plot of V_{stop} vs ν is given in Figure. **[2]**



a. Which material A or B has a higher work function?

b. Given the electric charge of an electron = 1.6×10^{-19} C, find the value of h obtained from the experiment for both A and B. Comment on whether it is consistent with Einstein's theory:

21. Distinguish between diamagnetic and ferromagnetic materials in respect of their **[2]**

i. intensity of magnetization,

ii. behaviour in a non-uniform magnetic field and

iii. susceptibility

OR

What is meant by the terms magnetic field and magnetic field intensity?

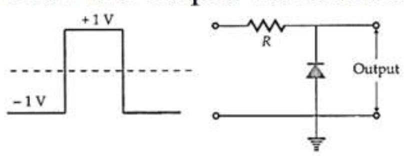
22. A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flows through it in a clockwise direction, find the magnitude and direction of the magnetic field produced at its centre. **[2]**

OR

Show that the magnetic field along the axis of a current carrying circular coil of radius r at a distance x from the centre of the coil is smaller by the fraction $\frac{3x^2}{2r^2}$ than the field at the centre of the coil carrying current.

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

24. A square wave (-1V to 1V) is applied to the p-n junction diode as shown below. Draw the output waveform. **[2]**



25. A laser beam has a wavelength of 7×10^{-7} m and aperture 10^{-2}m. The beam is sent to the moon, the distance of which from earth is 4×10^5 km. Find **[2]**
   i. the angular spread and
   ii. areal spread when the beam reaches the moon.

Section C

26. A pendulum of mass 80 milligram carrying a charge of 2×10^{-8} C is at rest in a horizontal uniform electric field of 2×10^4 Vm^{-1}. Find the tension in the thread of the pendulum and the angle it makes with the vertical. **[3]**

27. In an iron bar (5 cm × 1cm × 1cm) the magnetic moment of an atom is 1.8×10^{-23} Am^2. **[3]**
   i. What will be the magnetic moment of the bar in the state of magnetic saturation?
   ii. What torque will have to be applied to keep the bar perpendicular to an external magnetic field of 15,000 gauss? Density of iron = 7.8 g cm^{-3}, its atomic mass = 56.

28. **[3]**
   i. It is necessary to use satellites for long distance TV transmissions. Why?
   ii. If the earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now?
   iii. Some scientists have predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth. What might be the basis of this prediction?

OR

Name the laws associated with the following equations :

i. $\oint \vec{E} \cdot \overrightarrow{dS} = \frac{q}{\varepsilon_0}$

ii. $\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{d}{dt} \oint \vec{B} \cdot \overrightarrow{dS}$

iii. $\oint \vec{B} \cdot \overrightarrow{dS} = \mu_0 \varepsilon_0 \frac{d}{dt} \oint \vec{E} \cdot \overrightarrow{dS}$

29. i. Write two points to distinguish between interference and diffraction fringes. **[3]**

ii. In Young's double-slit experiment, fringes are obtained on a screen placed at a certain distance away from the slits. If the screen is moved by 5 cm towards the slits, the fringe width changes by 30 μm. Given that the slits are 1 mm apart, calculate the wavelength of the light used.

OR

What is diffraction of light? Draw a graph showing the variation of intensity with angle in a single slit diffraction experiment. Write one feature which distinguish the observed pattern from the double slit interference pattern. How would the diffraction pattern of a single slit be affected when:

i. the width of the slit is decreased?

ii. the monochromatic source of light is replaced by a source of white light?

30. Consider the motion of a charged particle of mass m and charge q moving with velocity v in a magnetic field B. **[3]**

i. If v is perpendicular to B, then show that it describes a circular path having angular frequency $\omega = \frac{qB}{m}$.

ii. If the velocity v has a component parallel to the magnetic field B, then trace the path described by the particle. Justify your answer.

Section D

31. Deuterium was discovered in 1932 by Harold Urey by measuring the small change in wavelength for a particular transition in ^{1}H and ^{2}H. This is because the wavelength of transition depends to a certain extent on the nuclear mass. If the nuclear motion is taken into account then the electrons and nucleus revolve around their common center of mass. Such a system is equivalent to a single particle with a reduced mass μ, revolving around the nucleus at a distance equal to the electron-nucleus separation. Here μ = me M/(me +M) where M is the nuclear mass and me is the electronic mass. Estimate the percentage difference in wavelength for the 1st line of the Lyman series in ^{1}H and ^{2}H. (Mass of ^{1}H nucleus is 1.6725 $\times$ 10^{-27} kg, Mass of ^{2}H nucleus is 3.3374 $\times 10^{-27}$ kg, Mass of electron = 9.109 $\times$ 10^{-31} kg.) **[5]**

OR

The inverse square law in electrostatics is $|\vec{F}| = \frac{e^2}{(4\pi\varepsilon_0)\cdot r^2}$ for the force between an electron and a proton. The $\left(\frac{1}{r}\right)$ dependence of $|\vec{F}|$ can be understood in quantum theory as being due to the fact that the particle of light (photon) is massless. If photons had a mass m_p, force would be modified to $|\vec{F}| = \frac{e^2}{(4\pi\varepsilon_0)r^2}\left[\frac{1}{r^2} + \frac{\lambda}{r}\right]$.exp (-$\lambda$r) where $\lambda = \frac{m_p c}{h}$

and $h = \frac{h}{2\pi}$. Estimate the change in the ground state energy of an H-atom if m_p were 10^{-6} times the mass of an electron.

32. A parallel plate capacitor is charged by a battery. After some time the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. What change, in any will take place in **[5]**

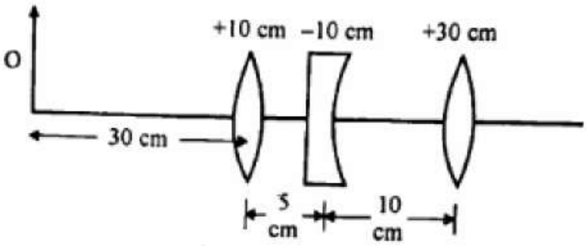
i. charge on the plates
ii. electric field intensity between the plates
iii. the capacitance of the capacitor,
iv. a potential difference between the plates and
v. the energy stored in the capacitor? Justify your answer in each case.

OR

a. Deduce the expression for the energy stored in a charged capacitor
b. Show that the effective capacitance C of a series combination of three capacitors C_1, C_2 and C_3 is given by $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

33. i. Under what conditions is the phenomenon of total internal reflection of light observed? Obtain the relation between the critical angle of incidence and the refractive index of the medium. **[5]**

ii. Three lenses of focal lengths +10 cm, -10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.



OR

a. Draw the ray diagram showing the refraction of light through a glass prism and hence obtain the relation between the refractive index μ of the prism, angle of prism and angle of minimum deviation.
b. Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = \sqrt{2}$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation.

Section E

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

According to Ohm's law, the current flowing through a conductor is directly proportional to the potential difference across the ends of the conductor i.e., $I \propto V \Rightarrow \frac{V}{I} = R$, where R is resistance of the conductor. Electrical resistance of a conductor is the obstruction posed by the conductor to the flow of electric current through it. It depends upon length, area of cross-section, nature of material and temperature of the conductor. We can write, $R \propto \frac{l}{A}$ or $R = \rho\frac{l}{A}$, where ρ is electrical resistivity of the material of the conductor.

(i) Dimensions of electric resistance is

a) $[M^{-1}L^{-2}T^{-1}A]$
b) $[M^{-1}L^{2}T^{2}A^{-1}]$
c) $[ML^{2}T^{-2}A^{-2}]$
d) $[ML^{2}T^{-3}A^{-2}]$

(ii) If 1 μA current flows through a conductor when potential difference of 2 volt is applied across its ends, then the resistance of the conductor is

a) $5 \times 10^7\ \Omega$
b) $1.5 \times 10^5\ \Omega$
c) $2 \times 10^6\ \Omega$
d) $3 \times 10^5\ \Omega$

(iii) Specific resistance of a wire depends upon

a) mass
b) none of these
c) cross-sectional area
d) length

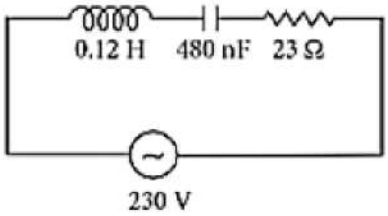
OR

The slope of the graph between potential difference and current through a conductor is

a) first straight line then curve
b) curve
c) a straight line
d) first curve then straight line

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

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.
A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.



(i) Find the value of source frequency for which current amplitude is maximum.

(ii) What will be the value of maximum current?

(iii) Find the value of maximum power.

OR

What is the Q-factor of the given circuit?

SOLUTION

Section A

1. **(a)** the valence band is partially empty and the conduction band is partially filled
   Explanation: In semiconductors at room temperature, the valence band is partially empty and the conduction band is partially filled.
2. **(d)** More than 2L
   Explanation: The image of A is at a distance of
   $\sqrt{(2L)^2 + \left(\frac{L}{2}\right)^2}$ from P
3. **(a)** 1.0 A
   Explanation: Because of symmetry, BE and CF are ineffective
   $\therefore$ AB, BC and CD are in series. Total resistance $R_1 = 6\ \Omega$
   AE, EE and FD are in series. Total resistance $R_2 = 6\ \Omega$
   When they are in parallel, total resistance = 3 Ω
   $\therefore$ Current = $\frac{3V}{3\Omega}$ = 1.0 A
4. **(d)**

   Explanation: The circuit is forward biased, as the p-side is at a higher potential than the n-side.
5. **(a)** $\frac{1}{r}$
   Explanation: A diode antenna radiates the electromagnetic waves outwards.
   The amplitude of electric field vector (E_0) is inversely proportional as the distance (r) from the antenna,
   i.e., $E_0 \propto \frac{1}{r}$
6. **(a)** Faraday's Law
   Explanation: Faraday's law of induction is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force.
7. **(b)** atom is mostly empty
   Explanation: Rutherford's alpha-particle scattering experiment proved that the atom was mainly empty space, which cannot be allowed by the Thompson mode. Thomson's model stated that atoms are positive spheres with electrons studded in them.
8. **(a)** $\frac{\lambda}{2(\sqrt{5}-2)}$
   Explanation: Here, $x_1 = 2d$ and $x_2 = \sqrt{5}\ d$
   For, first minima, $\Delta x = \frac{\lambda}{2}$
   $\therefore \Delta x = x_2 - x_1 = \sqrt{5}\ d - 2\ d = \frac{\lambda}{2} \Rightarrow d = \frac{\lambda}{2(\sqrt{5}-2)}$
9. **(b)** 2×10^{-7} m
   Explanation: $\frac{hc}{\lambda_{\max}} = 6\ eV$
   $\therefore \lambda_{\max.} = \frac{hc}{6eV} = \frac{6.6\times10^{-34}\times3\times10^{8}}{6\times1.6\times10^{-19}} = 2.06 \times 10^{-7}$ m
10. **(b)** semiconductor : band gap > 3 eV
   Explanation: In semiconductors, the energy gap between the conduction band and valence

band is very small i.e., < 3 eV

11. **(d)** electric field intensity

Explanation: The relation between E, σ and E is E = $\frac{\sigma}{\varepsilon}$

12. **(c)** 16

Explanation: F = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

F' = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2q_1 \times 2q_2}{(r/2)^2}$ = 16 F

$\therefore$ n = 16

13. **(a)** $\frac{E}{p}$

Explanation: Velocity of light (photon) is 3 × 10^8 m/s only in vacuum. Hence, let v be velocity of photon in any given medium then,

v = $\nu\lambda$

$\nu = \frac{E}{h}$ ...(i)

$\lambda = \frac{\mathrm{h}}{p}$ ...(ii)

From (i) and (ii). we get,

$\upsilon = \frac{E}{\mathrm{h}} \times \frac{\mathrm{h}}{p}$

$= \frac{E}{p}$

14. **(d)** γ-rays

Explanation: γ-rays have got the least wavelength.

15. **(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.

When the pressure of a gas is lowered, the number of gas atoms become very small. Hence, the positive ions and the electrons are able to move over a long distance under the action of the electric field without any collision. Their mean free path becomes longer. The electrons rush towards the anode and ionise by collision with other gas atoms coming in their path. The positive ions move towards the cathode and eject more electrons from the atoms of the cathode. These fresh electrons also rush towards the anode, i. e., the flow of electrons and positive ions is maintained in the gas. On reducing the pressure of the gas, the discharge current increases further.

16. **(d)** 0.08 J

Explanation: Energy stored in a self-inductance coil is given by,

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

= $\frac{1}{2}$× 40 × 10^{-3} × 4 = 0.08 J

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

Explanation: Electrons are emitted as β particles when a neutron decays into a proton during a radioactive disintegration.

18. **(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.

Section B

19. It is necessary to slow down the neutrons, produced through the fission of ${}^{235}_{92}U$ nuclei (by neutrons), to sustain a chain reaction since slow neutrons have a much higher intrinsic probability of inducing fission in ${}^{235}_{92}U$ than fast neutrons.

Any substance which is used to slow down fast moving neutrons to thermal energies is called a moderator. Moderators are provided along with the fissionable nuclei for slowing down fast neutrons. The commonly used moderators are water, heavy water (D_2D) and graphite.

20. a. Here threshold frequency of, $\nu_{0A} = 5 \times 10^{14}$Hz and of B, is given by
$\nu_{OB} = 10 \times 10^{14} Hz$
The work function is given by $\phi_0 = h\nu_o$ or $\phi_0 \propto \nu_0$
$\therefore \frac{\phi_{0A}}{\phi_{0B}} = \frac{5\times10^{14}}{10\times10^{14}} < 1$ or $\phi_{0A} < \phi_{0B}$
Therefore, the work function is higher for material B than A.

b. For metal A,
slope $= \frac{h}{e} = \frac{2}{(10-5)\times10^{14}}$ or $h = \frac{2\times e}{5\times10^{14}} = \frac{2\times1.6\times10^{-19}}{5\times10^{14}} = 6.4 \times 10^{-34}$Js
For metal B,
Slope $= \frac{h}{e} = \frac{2}{(15-10)\times10^{14}}$ or $h = \frac{2.5\times e}{5\times10^{14}} = \frac{2.5\times1.6\times10^{19}}{5\times10^{14}} = 8 \times 10^{-34} Js$
Since the value of h from the experiment for metals A and B is different. Hence, the experiment is not consistent with the theory.

21. i. Intensity of magnetization is small negative for a diamagnetic substance and large positive for a ferromagnetic substance.

ii. In a non uniform magnetic field, a diamagnetic substance tends to move from stronger to weaker part while the ferromagnetic substance tends to move from weaker to stronger part of the field.

iii. For a diamagnetic substance, susceptibility is small negative while for a ferromagnetic substance, susceptibility is large positive.

OR

Magnetic field: The space around a magnet within which its influence can be experienced is called its magnetic field.
Magnetic field intensity: The magnetic field intensity at any point in a magnetic field is defined as the force experienced by a unit north pole placed at that point. It is a vector quantity whose direction is same as the direction in which unit north pole would tend to move if free to do so.

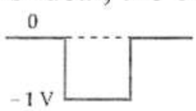
22. If r is the radius of the coil, then
$N \times 2\pi r = L$ or $r = \frac{L}{2\pi N}$
Magnetic field produced at the centre of the coil due to current I,
$B = \frac{\mu_0 NI}{2r} = \frac{\mu_0 NI}{2(L/2\pi N)} = \frac{\mu_0 \pi N^2 I}{L}$
As the current flows clockwise throughout coil, the direction of the magnetic field will be out of the plane of the coil.

OR

$B_{\text{centre}} = \frac{\mu_0 NI}{2r}$ and $B_{\text{axial}} = \frac{\mu_0 NIr^2}{2(r^2+x^2)^{3/2}}$
$\therefore \quad \frac{B_{\text{axial}}}{B_{\text{centre}}} = \frac{r^3}{(r^2+x^2)^{3/2}} = \frac{r^3}{r^3}\left[1+\frac{x^2}{r^2}\right]^{-3/2}$
$= \left[1 - \frac{3}{2}\frac{x^2}{r^2} + \ldots\right] \simeq 1 - \frac{3}{2}\frac{x^2}{r^2}$
The fractional decrease in magnetic field is $\frac{B_{\text{centre}} - B_{\text{axial}}}{B_{\text{centre}}} = 1 - \frac{B_{\text{centre}}}{B_{\text{axial}}}$
$= 1 - \left(1 - \frac{3}{2}\frac{x^2}{r^2}\right) = \frac{3}{2}\frac{x^2}{r^2}$

23. 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.

24. The p-side of the diode is earthed, it is at zero potential. So the diode conducts current when the input level is - 1V and does not conduct when the input level is +1V. As the diode is ideal, the output across it will be either 0 or - 1V, as shown in the figure.



25. Here $\lambda = 7 \times 10^{-7}$m, a = 10^{-2}m, D = 4×10^5 km = 4×10^8m

For the circular aperture, we have

i. Angular spread,

$\theta = \frac{1.22\lambda}{a} = \frac{1.22\times7\times10^{-7}}{10^{-2}} = 8.54 \times 10^{-5}$ rad

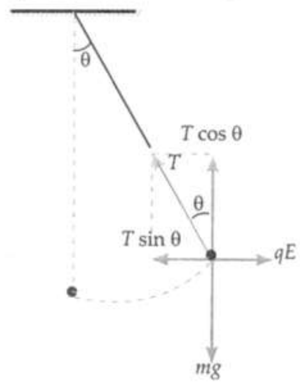
ii. Areal spread

$= (D\theta)^2 = (4 \times 10^8 \times 8.54 \times 10^{-5})^2 = 1.197 \times 10^9$ m^2

Section C

26. Here m = 80 mg = 80×10^{-6} kg

q = 2×10^{-8} C, E = 2×10^4 Vm^{-1}



Let T be the tension in the thread and θ be the angle it makes with vertical, as shown in Fig. When the bob is in equilibrium,

T sin θ = qE; T cos θ = mg

$\therefore \tan\theta = \frac{T\sin\theta}{T\cos\theta} = \frac{qE}{mg}$

$= \frac{2\times10^{-8}\times2\times10^4}{80\times10^{-6}\times9.8} = 0.51$

$\theta = 27^o$

Also, T = $\frac{qE}{\sin\theta} = \frac{2\times10^{-8}\times2\times10^4}{\sin 27^\circ}$

$= 8.81 \times 10^{-4}$ N.

27. i. Mass of iron bar = volume × density

$= 5$ cm$^3 \times 7.8$ gcm^{-3} = 39 g

Number of atoms in 56 g of iron = 6.02×10^{23}

$\therefore$ Number of atoms in 39 g of iron = $\frac{6.02\times10^{23}\times39}{56} = 4.19 \times 10^{23}$

Magnetic moment of each atom = 1.8×10^{-23} Am^2

Magnetic moment of the iron bar in the state of magnetic saturation is

m = $1.8 \times 10^{-23} \times 4.19 \times 10^{23}$ = 7.54 Am^2

ii. Here $\theta = 90^o$, B = 15,000 G = 15000×10^{-4} T

$\therefore$ Required torque, τ = mB sin θ

$= 7.54 \times 15000 \times 10^{-4} \times \sin 90^o$ = 11.3 Nm

28.

i. TV waves have frequency range 47 MHz-940 MHz. These frequencies are not reflected by the ionosphere. As space wave, they can cover a distance of 50-60 km only. Therefore, for long distance TV transmission, we make use of satellites which reflect the TV signal back towards the earth.
ii. If the earth did not have an atmosphere, then its average surface temperature will be lesser than what it is now because in that case, the greenhouse effect will be absent.
iii. The prediction is based on the assumption that the large dust clouds produced by global nuclear war would perhaps cover substantial part by the global nuclear war would perhaps cover a substantial part of the sky and solar radiations will not be able to reach the earth. It may cause a severe winter on the earth with a devastating effect on life on earth.

OR

i. Gauss law of electrostatics.
ii. Faraday's law of electromagnetic induction.
iii. Modified Ampere's law, the term on the right-hand side is Maxwell's displacement current.

29. i. Any two points of difference

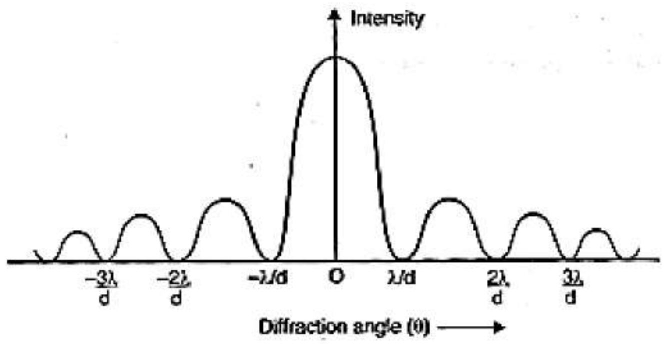
Interference	**Diffraction**
Fringes are equally spaced.	Fringes are not equally spaced.
Intensity is same for all maxima.	Intensity falls as we go to successive maxima away from the centre.
Superposition of two waves originating from two narrow slits.	Superposition of a continuous family of waves originating from each point on a single slit.

ii. Let D be the distance of the screen from the plane of the slits.

We have d= 1mm =10^{-3} m.
Fringe width, $\beta = \frac{\lambda D}{d}$
In the first case $\beta = \frac{\lambda D}{d}$ or $\beta d = \lambda D$ ...(i)
In the second case $\left(\beta - 30 \times 10^{-6}\right) = \frac{\lambda(D-0.05)}{d}$
or $\left(\beta - 30 \times 10^{-6}\right) d = \lambda(D - 0.05)$ ...(ii)
Subtracting (ii) from (i) we get
$30 \times 10^{-6} \times d = \lambda \times 0.05$
$\therefore \lambda = \frac{30 \times 10^{-6} \times 10^{-3}}{5 \times 10^{-2}}$ m
$\therefore \lambda = 6 \times 10^{-7}$m = 600 nm

OR

Diffraction of light: Phenomenon of bending of light around the corners of an obstacle or aperture is called diffraction.
The intensity distribution wave for diffraction is shown in the diagram below:



In interference, by 2 slits all bright fringes are of same intensity. In diffraction, the intensity of bright fringes decreases with the increase in distance from the central bright fringe.

i. The diffraction pattern becomes narrower if the width of the slit is decreased.

ii. When the monochromatic source is replaced by a white light source, we get a coloured diffraction pattern. The central band is white, but the other bands are coloured. As bandwidth is proportional to λ, the red band of higher wavelength is wider than the violet band with smaller wavelength.

30. i. Force acting on the charged particle, moving with a velocity v, in magnetic field B.

$\vec{F} = q(\vec{v} \times \vec{B})$

As, $\mathbf{v} \perp \mathbf{B}, |\text{ Force }| = qvB$

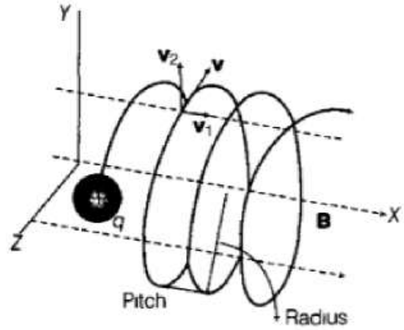
Since, $\mathbf{F} \perp \mathbf{v}$, it acts as a centripetal force and makes the particle move in a circular path, in the plane, perpendicular to the magnetic field.

Now, $qvB = \frac{mv^2}{r}$ (as the magnetic force supplies the required centripetal force)

$\therefore \quad r = \frac{mv}{qB}$

Now, $\omega = \frac{v}{r}$

$\therefore \quad \omega = \frac{qB}{m}$

ii. 

Component of velocity, v parallel to magnetic field, will make the particle move along the field.

Perpendicular component of velocity, v, will cause the particle to move along circular path in the plane perpendicular to the magnetic field. That means the particle will revolve in a circular path and will shift in the forward direction as shown in the figure above. Hence, the particle will travel the helix path.

Section D

31. Total energy of electron in n^{th} stable orbit in H or like atom is given by:

$E_n = \frac{\mu Z^2 e^4}{8\varepsilon_0^2 h^2 n^2}$

μ = reduced mass of electron, proton and neutron (mass defect)

$E_H = \frac{\mu_H (1)^2 e^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = \frac{\mu_H e^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{1} - \frac{1}{2^2}\right] = \frac{\mu_M e^4}{8\varepsilon_0^2 h^2}\left[\frac{3}{4}\right]$

$E = h\nu = \frac{h}{\lambda}$ or $\lambda_H = \frac{h}{E_H}$

$\therefore h\nu_H = \frac{\mu_H e^4}{8\varepsilon_0^2 h^2}\frac{3}{4}$

$\nu_H = \frac{\mu_H e^4}{8\varepsilon_0^2 h^3}\cdot\frac{3}{4}$

The percentage difference in the wavelength is given by = $\frac{(\lambda_D - \lambda_H)}{\lambda_H} \times 100$

Percentage change in wavelength is given by:

or change $\Delta E = \left[\frac{\lambda_D}{\lambda_H} - 1\right] \times 100$ ($\because \Delta E = E_1 - E_2$) ...(i)

$h\nu = \frac{\mu e^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_2^2} - \frac{1}{n_2^2}\right]$

$\nu = \frac{\mu e^4}{8\varepsilon_0^2 h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\frac{c}{\lambda} = \frac{\mu e^4}{8\varepsilon_0^2 h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\frac{1}{\lambda} = \frac{\mu e^4}{8\varepsilon_0^2 c h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

as μ= mass defect, e, ε, c, and h are constants for an atom.

$\therefore \lambda \propto \frac{1}{h}$

So eqn. 1st can be written as the percentage change in the wavelength is given by =

$\left[\frac{\mu_H}{\mu_D} - 1\right] \times 100$

$\because \mu = \frac{m_e M}{(M + m_e)}$ (Given)

$\therefore$ Percentage change in wavelength = $\left[\frac{\frac{m_e M_H}{(M_H + m_e)}}{\frac{m_e + M_D}{(M_D + m_e)}} - 1\right] 100$

$\frac{\Delta\lambda}{\lambda_H} \times 100 = \left[\frac{M_H}{M_D}\frac{(M_D + m_e)}{(M_H + m_e)} - 1\right] \times 100$

$= \left[\frac{M_H}{M_D}\frac{M_D\left(1 + \frac{m_e}{M_D}\right)}{M_H\left(1 + \frac{m_e}{M_H}\right)} - 1\right] \times 100$

$= \left[\left(1 + \frac{m_e}{M_D}\right)\left(1 + \frac{m_e}{M_H}\right)^{-1} - 1\right] \times 100$

$= \left[\left(1 + \frac{m_e}{M_D}\right)\left(1 - \frac{m_e}{M_H}\right) - 1\right] \times 100$

Me << M_D so neglecting the higher degree term

$\frac{\Delta\lambda}{\lambda_H} \times 100 = \left[1 - \frac{m_e}{M_H} + \frac{m_e}{M_D} - \frac{m_e m_e}{M_D \cdot M_H} - 1\right] \times 100$

$= m_e\left[\frac{1}{M_D} - \frac{1}{M_H}\right] \times 100$

$= 9.1 \times 10^{-31}\left[\frac{1}{3.3374 \times 10^{-27}} - \frac{1}{1.6725 \times 10^{-27}}\right] \times 100$

$= \frac{9.1 \times 10^{-31+2}}{10^{-27}}\left[\frac{1.6725 - 3.3374}{3.3374 \times 1.6725}\right]$

$\frac{\Delta\lambda \times 100}{\lambda_H} = \frac{-9.1 \times 10^{-3.27} \times 0.6649}{3.3374 \times 1.6725} = \frac{-6.05059 \times 10^{-2}}{5.5180}$

$\frac{\Delta\lambda \times 100}{\lambda_H} = -1.084 \times 10^{-2}$ Decrease in wavelength

(-) sign shows that $\lambda_D < \lambda_H$

OR

Here, we suppose mass of photon is given by, $m_p = 10^{-6}$ electronic mass

i.e., $m_p = 10^{-6}(0.5)$ MeV $= 5 \times 10^{-7} \times 1.6 \times 10^{-13}$J $= 0.8 \times 10^{-19}$J.

Now, $\frac{1}{\lambda}=\frac{h}{m_p c}=\frac{hc}{m_p c^2}=\frac{10^{-34}\times3\times10^{8}}{0.8\times10^{-19}}$ $=4\times10^{-7}$ m, which is much larger than the Bohr radius.

As $|\vec{F}|=\frac{e^2}{4\pi\epsilon_0}\left[\frac{1}{r^2}+\frac{\lambda}{r}\right]\exp.(-\lambda r)$ ...(i) where $\lambda^{-1}=\frac{h}{m_p c}=4\times10^{-7}m$ >> r_B

$\therefore \lambda << \frac{1}{r_B}$ or $\lambda_B << 1$

Now, $U(r)=\frac{-e^2}{4\pi\epsilon_0}\frac{\exp(-\lambda r)}{r}$ ...(ii)

As mvr = $\frac{h}{2\pi}$ =h or v= $\frac{h}{mr}$. As exp(-λr) $\rightarrow$ 1, therefore, form (i)

$\frac{mv^2}{r}=F=\frac{e^2}{4\pi\epsilon_0}\left[\frac{1}{r^2}+\frac{\lambda}{r}\right]$

$\therefore \frac{m}{r}\left(\frac{h}{mr}\right)^2=\frac{e^2}{4\pi\epsilon_0}\left[\frac{1}{r^2}+\frac{\lambda}{r}\right]$

$\frac{h^2}{m}=\frac{e^2}{4\pi\epsilon_0}r+\lambda r^2$ ...(iii)

If $\lambda=0$, r_B, then $\frac{h^2}{m}=\frac{e^2}{4\pi\epsilon_0}r_B$

As $\lambda^{-1} >> r_B$, put $r = r_B + \delta$

Form (iii), $r_B = (r_B+\delta)+\lambda(r_B+\delta)^2 = r_B+\delta+\lambda\left(r_B^2+\delta^2 2\delta r_B\right)$

by Neglecting δ^2, we get $0=\lambda r_B^2+\delta\left(1+2\lambda r_B^2\right)$

$=-\lambda r_B^2\,(As\lambda r_B << 1)$

form (ii),

$V(r)=\frac{-e^2}{4\pi\epsilon_0}\frac{\exp.(-\lambda\delta-\lambda r_B)}{r_B+\delta}=\frac{-e^2}{4\pi\epsilon_0}\frac{1}{r_B}\left[\left(1-\frac{\delta}{r_B}\right)(1-\lambda r_B)\right]$ = -27.2 eV

hence, V(r) remains unchanged.

K.E. $=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{h}{mr}\right)^2=\frac{h^2}{2m(r_B+\delta)^2}=\frac{h^2}{2mr_B^2}\left(1-\frac{2\delta}{r_B}\right)$ = (13.6eV)[1 + 2λr_B]

Thus, the Total energy is given by = $\frac{-e^2}{4\pi\epsilon_0 r_B}+\frac{h^2}{2mr_B^2}(1+2\lambda r_B)$ = -27.2 + 13.6(1 + 2λr_B) eV.

Change in ground state energy of hydrogen atom is given by = 13.6 $\times$ 2λ_BeV = 27.2 λr_BeV

32. i. The charge q_0 on the capacitor plates remains the same because the battery has been disconnected, before placing the dielectric slab.

ii. The surface charges induced on the dielectric slab reduce electric field intensity to a new value given by $E=\frac{E_0}{\kappa}$

iii. The reduction in the electric field induces the potential difference $V=Ed=\frac{E_0 d}{k}=\frac{V_0}{k}$

iv. Due to the decrease in p.d., the capacitance increases k times

$C=\frac{q_0}{V}=\frac{q_0}{V_0/\mathrm{k}}=\mathrm{K}\frac{q_0}{V_0}=\kappa\mathrm{C}_0$

v. Energy stored decreases by a factor of κ:

$U=\frac{1}{2}CV^2=\frac{1}{2}(\kappa C_0)\left(\frac{V_0}{K}\right)^2=\frac{1}{\kappa}\cdot\frac{1}{2}C_0V_0^2=\frac{U_0}{\kappa}$

OR

a. During charging of the capacitor, work is done by the battery which is stored in the form of potential energy inside the capacitor.

Consider a capacitor which is to be charged by charge Q with the help of a battery. Let at any instant charge on the capacitor is q and the potential difference between the two plates of the capacitor is V.

We know that,

q = CV $\Rightarrow$ V = q/C

Now small work done to charge the capacitor by small charge dq,

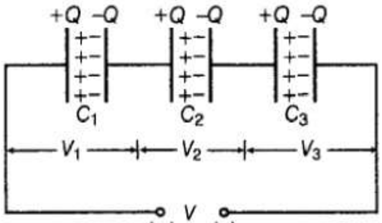
$dW = Vdq = \frac{q}{C}dq$

where, q = instantaneous charge, C = capacitance and V = voltage

∴ Total work done in storing charge from 0 to Q(total charge) is given by

$\Rightarrow W = \int_0^Q \frac{q}{C}dq = \frac{Q^2}{2C}$

b. In a series combination of capacitors, the same charge lie on each capacitor for any value of capacitances.



Capacitors in series combination

Also, the net potential difference across the combination is equal to the algebraic sum of potential differences across each capacitor

i.e. $V = V_1 + V_2 + V_3$ ....(i)

where V_1 , V_2, V_3 and V are the potential differences across C_1, C_2, C_3 and equivalent capacitor, respectively.

Again $q_1 = C_1V_1 \Rightarrow V_1 = \frac{q_1}{C_1}$

Similarly, $V_2 = \frac{q}{C_2}$ *and* $V_3 = \frac{q}{C_3}$

∴ Total potential difference [From Eq.(i)]

$\Rightarrow V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$

$\Rightarrow \frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$\Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ [$\frac{V}{q} = \frac{1}{C}$, where C is equivalent capacitance]

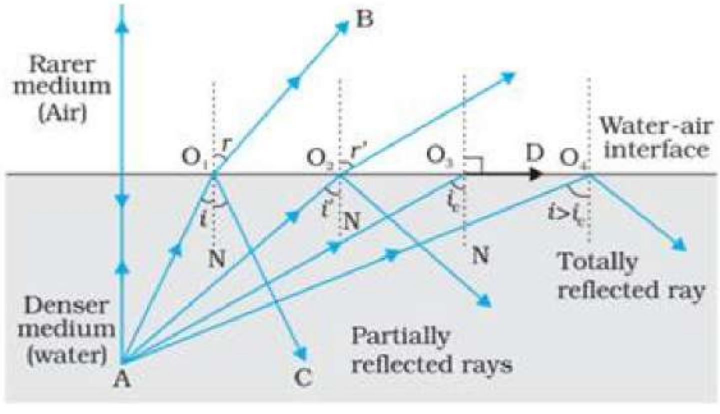
33. i. The conditions for total internal reflection are:

(i) Light must be trying to travel from optically denser medium to optically lighter medium.

(ii) The angle of incidence must be greater than a certain angle known as critical angle.

Derivation:

Suppose light is travelling from medium 1 to medium 2. When light strikes the surface separating the media, some of it refracts and some of it reflects. If we keep increasing the angle of incidence, the refracted ray becomes parallel to the surface. This value of angle of incidence is known as the critical angle. If we increase the angle of incidence, even further, we will have a reflected ray and no refracted ray. Thus, we will have total internal reflection.

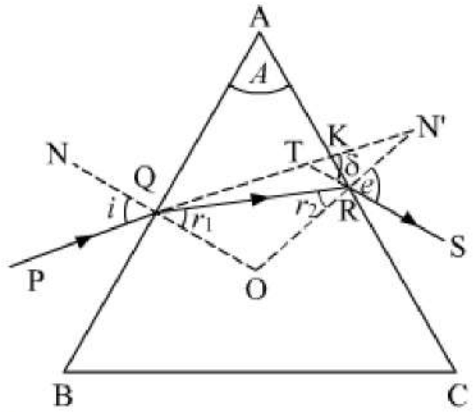


Let us consider the condition when the angle of incidence is equal to critical angle, i_c .
By Snell's law,
$\frac{\sin\ i_c}{sin\ 90} = \frac{n_2}{n_1}$
where n_1 and n_2 are the refractive indices of medium 1 and medium 2 respectively. Let n_{12} be the refractive index of 1 with respect to 2.
$\sin\ i_c = \frac{1}{n_{12}}$
$i_c = \sin^{-1}(\frac{1}{n_{12}})$
Thus, we have obtained the required relation.

ii. For convex lens of focal length 10 cm,
$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$
$\frac{1}{10} = \frac{1}{v_1} - \frac{1}{-30} \Rightarrow v_1 = 15$ cm
Object distance for cancave lens $u_2 = 15 - 5 = 10$ cm
$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$
$\frac{1}{-10} = \frac{1}{v_2} - \frac{1}{10}$
$\Rightarrow v_2 = \infty$
For third lens,
$\frac{1}{f_3} = \frac{1}{v_3} - \frac{1}{u_3}$
$\frac{1}{30} = \frac{1}{v_3} - \frac{1}{\infty} \Rightarrow v_3 = 30$ cm

OR

a. The figure below shows the passage of light through a triangular prism ABC.



The angles of incidence and refraction at first face AB are $\angle i$ and $\angle r_1$
The angles of incidence at the second face AC is $\angle r_2$ and the angle of emergence $\angle e$
δ is the angle between the emergent ray RS and incident ray PQ and is called the angle of deviation.
Here, $\angle PQN = i$, $\angle SRN' = e$, $\angle RQO = r_1$, $\angle QRO = r_2$, $\angle KTS = \delta$
$\because \angle TQO = i$ and $\angle RQO = r_1$, we have
$\angle TQR = i - r_1$
$\angle TRO = e$ and $\angle QRO = r_2$
$\angle TRQ = e - r_2$
In triangle TQR, the side QT has been produced outwards. Therefore, the exterior angle δ should be equal to the sum of the interior opposite angles.
i.e., $\delta = \angle TQR + \angle TRQ = (i - r_1) + (e - r_2)$
$\delta = (i + e) - (r_1 + r_2)$ ...(i)

In triangle QRO,

$r_1 + r_2 + \angle ROQ = 180^o$ ...(ii)

From quadrilateral AROQ, we have the sum of angles ($\angle AQO + \angle ARO = 180^o$) This means that the sum of the remaining two angles should be 180^o.

i.e., $\angle A + \angle QOR = 180^o$ [$\angle A$ is called the angle of prism]

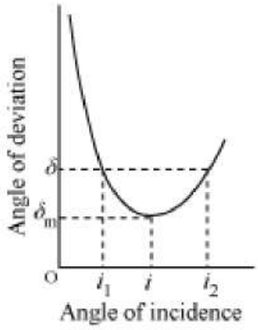
From equations (i) and (ii),

$r_1 + r_2 = A$ ...(iii)

Substituting (iii) in (i), we obtain,

$\delta = (i + e) - A$

$A + \delta = i + e$



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 $r_2 = r_1 = r$ ...(iv)

$\because r_1 + r_2 = A$

From equation (iv), $r + r = A$

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

Also, we have

$A + \delta = i + e$

Setting,

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

$A + \delta_m = i + i$

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

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

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

b. The incident ray travelling from denser medium to rarer medium grazes along the surface of the separation of the medium only when the light ray incident at the surface at an angle called critical angle (C) such that the angle of reflection is 90^o. Therefore, following Snell's law, we can write

$\frac{\mu_1}{\mu_2} = \frac{\sin 90}{\sin C}$

$\frac{\mu_1}{\mu_2} = \frac{1}{\sin C}$

$\frac{\sqrt{2}}{1} = \frac{1}{\sin C}$

Sin C = $\frac{1}{\sqrt{2}}$

C = $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$

∴ Critical angle = Angle of incidence = 45^o

Section E

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

According to Ohm's law, the current flowing through a conductor is directly proportional to the potential difference across the ends of the conductor i.e., I $\propto V \Rightarrow \frac{V}{I}$ = R, where R is resistance of the conductor. Electrical resistance of a conductor is the obstruction posed by the conductor to the flow of electric current through it. It depends upon length, area of cross-section, nature of material and temperature of the conductor. We can write, R $\propto \frac{l}{A}$ or R = $\rho\frac{l}{A}$, where ρ is electrical resistivity of the material of the conductor.

(i) **(d)** $[ML^2T^{-3}A^{-2}]$

Explanation: $[ML^2T^{-3}A^{-2}]$

(ii) **(c)** $2 \times 10^6\ \Omega$

Explanation: R = $\frac{V}{I} = \frac{2}{10^{-6}} = 2 \times 10^6\ \Omega$

(iii) **(b)** none of these

Explanation: Specific resistance depends upon the nature of material and is independent of mass and dimensions of the material.

OR

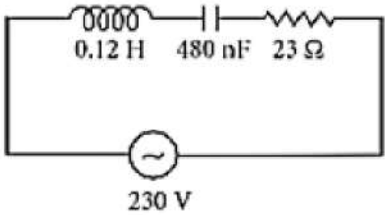
(c) a straight line

Explanation: a straight line

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

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.



(i) Here, L = 0.12 H, C = 480 nF = 480 × 10^{-9} F, R = 23Ω, V = 230 V

$V_0 = \sqrt{2} \times 230 = 325.22$ V

$I_0 = \frac{V_0}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$

At resonance, $\omega L - \frac{1}{\omega C} = 0$

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^{9}}} = 4166.67$ rad s^{-1}

$v_R = \frac{4166.67}{2 \times 3.14} = 663.48$ Hz

(ii) Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14$ A

(iii) Maximum power, $P_{max} = \frac{1}{2}(I_0)^2 R$

$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3$ W

OR

Quality factor $Q = \frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{4166.67 \times 0.12}{23} = 21.74$