Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 3

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

General Instructions:

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

Section A

1. When a p-n diode is reverse biased, then **[1]**

a) the height of the potential barrier is reduced
b) the depletion region is increased
c) no current flows
d) the depletion region is reduced

2. How many coulombs of electricity must pass through acidulated water to liberate 22.4 litres of hydrogen at N.T.P.? **[1]**

a) 193000 C
b) $1.6 \times 10^{-19} C$
c) 96500 C
d) 19300 C

3. Which of the following is used in optical fibers? **[1]**

a) Scattering
b) Refraction
c) Diffraction
d) Total internal reflection

4. The arrangement fo two magnetic poles of equal and opposite strengths separated by a finite distance is called: **[1]**

a) Magnetic dipole
b) Magnetic current
c) Magnetic field
d) Magnetic pole

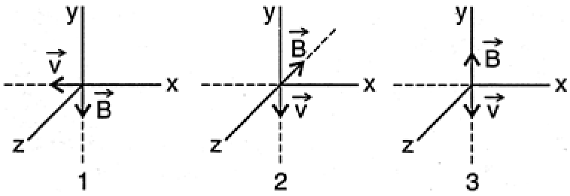
5. The dielectric constant K of an insulator will be - **[1]**

a) 0.4
b) 4

c) - 4

d) 0

6. The following figure shows three situations when an electron with velocity $\vec{v}$ travels through a uniform magnetic field $\vec{B}$. In each case, what is the direction of magnetic force on the electron? **[1]**



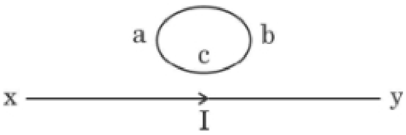
a) -ve z-axis, -ve x-axis and zero

b) -ve z-axis, +ve x-axis and zero

c) + ve z-axis, -ve x-axis, +ve y-axis

d) +ve z-axis, +ve y-axis and zero

7. The direction of induced current in the loop abc is: **[1]**



a) along abc if I is constant

b) along abc if I increases

c) along abc if I decreases

d) along acb if I increases

8. The universal property among all substances is **[1]**

a) ferromagnetism

b) non-magnetism

c) diamagnetism

d) paramagnetism

9. Phenomenon of bending of waves around corners of obstacle without a change in medium is called ________. **[1]**

a) diffraction

b) interference

c) reflection

d) refraction

10. The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object the electric field of magnitude, $16\frac{\mathrm{N}}{\mathrm{C}}$ will be at a distance of **[1]**

a) 3 m

b) 1 m

c) 6 m

d) 2 m

11. The output of the given circuit in Figure. **[1]**

a) would be like a half-wave rectifier with negative cycles in output

b) would be like a half-wave rectifier with positive cycles in output

c) would be like that of a full-wave rectifier

d) would be zero at all times

12. An equi-convex crown glass lens has a focal length 20 cm for violet rays. Here $\mu_v = 1.5$ & $\mu_r = 1.47$. Its focal length for red rays is **[1]**

a) 24.85 cm

b) 20.82 cm

c) 21.28 cm

d) 22.85 cm

13. **Assertion (A):** If the frequency of the incident light on a metal surface is doubled, the kinetic energy of emitted **[1]**

electrons is more than doubled.

Reason (R): The metal will provide additional energy to the emitted photoelectron for light of higher frequency than that for lower frequency.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

14. **Assertion (A):** Two equipotential surfaces cannot cut each other. **[1]**

Reason (R): Two equipotential surfaces are parallel to each other.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

15. **Assertion (A):** Colours are seen in thin layers of oil on the surface of the water. **[1]**

Reason (R): White light is composed of several colours.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

16. **Assertion:** An electric lamp is connected in series with a long solenoid of copper with air core and then connected to ac source. If an iron rod is inserted in solenoid, the lamp will become dim. **[1]**

Reason: If an iron rod is inserted in solenoid, the inductance of solenoid increases.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c) Assertion is correct statement but reason is wrong statement.
d) Assertion is wrong statement but reason is correct statement.

Section B

17. An e.m. wave is travelling in a medium with a velocity $v = v\hat{i}$. The electric field oscillations, of this e.m. wave, are along the y-axis. **[2]**

a. Identify the direction in which the magnetic field oscillations are taking place, of the e.m. wave.
b. How are the magnitudes of the electric field and magnetic fields in the electromagnetic wave related to each other?

18. Two identical bars, one of paramagnetic material and other of diamagnetic material are kept in a uniform external magnetic field parallel to it. Draw diagrammatically the modifications in the magnetic field pattern in each case. **[2]**

19. Describe briefly, with the help of a diagram, the role of the two important processes involved in the formation of a p-n junction. **[2]**

20. An α -particle after passing through a potential difference of 2×10^6 V falls on a silver foil. The atomic number of silver is 47. Calculate (i) the kinetic energy of the α -particle at the time of falling on the foil (ii) the kinetic energy of the α -particle at a distance of 5×10^{-14} m from the nucleus and (iii) the shortest distance from the nucleus of silver to which the α -particle reaches. **[2]**

21. The maximum torque acting on a coil of effective area 0.04 m^2 is 4×10^{-8} Nm when the current in it is 100 pA. Find the magnetic induction in which it is kept. **[2]**

OR

A long straight wire carrying a current of 30 A is placed in an external uniform magnetic field of 4.0×10^{-4} T parallel to the current. Find the magnitude of the resultant magnetic field at a point 2.0 cm away from the wire.

Section C

22. In a Wheatstone bridge, P = 1 Ω, Q = 2 Ω, R = 2 Ω, S = 3 Ω and R_g = 4 Ω. Find the current through the galvanometer in the unbalanced position of the bridge, when a battery of 2V and internal resistance 2 Ω is used. **[3]**

23. Draw the energy band diagrams (at T > 0K) for n-type and p-type semiconductors. Using diagram, explain why in n-type semiconductor the conduction band has most electrons from the donor impurities. **[3]**

24. The energy flux of sunlight reaching the surface of the earth is 1.388×10^3 W/m^2. How many photons (nearly) per square metre are incident on the Earth per second? Assume that the photons in the sunlight have an average wavelength of 550 nm. **[3]**

25. The radionuclide ^{11}C decays according to ${}_{6}^{11}C \rightarrow {}_{5}^{11}B + e^+ + v$: $T_{1/2}$ = 20.3 min. The maximum energy of the emitted positron is 0.960 MeV. Given the mass values: m $({}_{6}^{11}C)$ = 11.011434 u and m $({}_{5}^{11}B)$ = 11.009305 u, calculate Q and compare it with the maximum energy of the positron emitted. **[3]**

26. The photon emitted during the de-excitation from the first excited level to the ground state of hydrogen atom is used to irradiate a photocathode of a photocell, in which stopping potential of 5 V is used. Calculate the work function of the cathode used. **[3]**

27. In a Young's double experiment, the slits are 1.5 mm apart. When the slits are illuminated by a monochromatic light source and the screen is kept 1 m apart from the slits, width of 10 fringes is measured as 3.93 mm. Calculate the wavelength of light used. What will be the width of 10 fringes when the distance between the slits and the screen is increased by 0.5 m. The source of light used remains the same. **[3]**

28. State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify this statement. **[3]**

OR

A metallic rod of length l and resistance R is rotated with a frequency ν, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius l, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere.

i. Derive the expression for the induced emf and the current in the rod.
ii. Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.
iii. Hence obtain the expression for the power required to rotate the rod.

Section D

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

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by c = $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(a) The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E = electric field) is

a) MLT^{-1}
b) $ML^{-1}T^{-2}$
c) ML^2T^{-2}
d) ML^2T^{-1}

(b) Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and A = electric current, then

a) $[\varepsilon_0] = ML^2T^{-1}$
b) $[\varepsilon_0] = MLT^{-2}A^{-2}$
c) $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$
d) $[\varepsilon_0] = M^{-1}L^{-3}T^2A$

(c) An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity ε = 4. Then

a) wavelength is halved and the frequency remains unchanged.
b) wavelength and frequency both remain unchanged
c) wavelength is doubled and the frequency remains unchanged
d) wavelength is doubled and the frequency becomes half

OR

The electromagnetic waves travel with

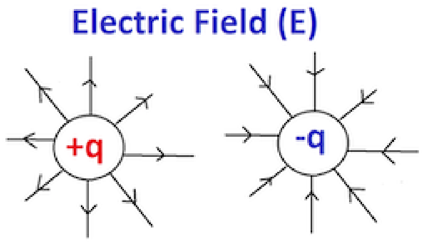
a) the speed of light c = 3×10^8 m s^{-1} in fluid medium.
b) the speed of light c = 3×10 m s^{-1} in solid medium
c) the speed of light c = 3×10^8 m s^{-1} in free space
d) the same speed in all media

(d) Which of the following are not electromagnetic waves?
cosmic rays, γ-rays, β-rays, X-rays

a) β-rays
b) X-rays
c) γ-rays
d) cosmic rays

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

Electric field intensity at any point is the strength of the electric field at that point. It is also defined as the force experienced by unit positive charge placed at that point. Electric Field Intensity is a vector quantity. It is denoted by **E**. When placed within the electric field, the test charge will experience an electric force - either attractive or repulsive.



(a) The Electric field at a point is

a) discontinuous only if there is a negative
b) always continuous

charge at that point

c) continuous if there is charge at that point

d) continuous if there is no charge at that point

(b) A charge is distributed uniformly over a ring of radius **a**. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence the points at large distances from the ring, it behaves like a point charge is:

a) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{x}$

b) $E = \frac{1}{2\pi\varepsilon_0} \cdot \frac{Q}{x^2}$

c) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{x^4}$

d) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{x^2}$

(c) Force acting on an electron in a uniform electric field of 5×10^4 N/C is:

a) 8×10^{-15} N

b) -7×10^{-15} N

c) -8×10^{-15} N

d) 7×10^{-15} N

(d) At a particular point, the electric field depends upon:

a) source charge Q only

b) both Q and q

c) test charge q_0 only

d) neither Q nor q

OR

Four charges of the same magnitude and same sign are placed at the corners of a square, of each side 0.1 m. then electric field intensity at the centre of the square is:

a) 0.01 N/C

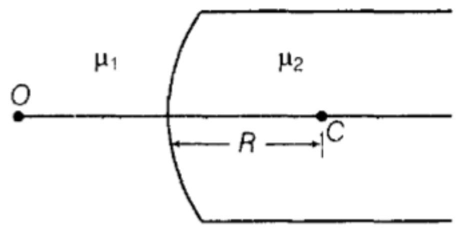
b) 0.25 N/C

c) zero

d) 0.1 N/C

Section E

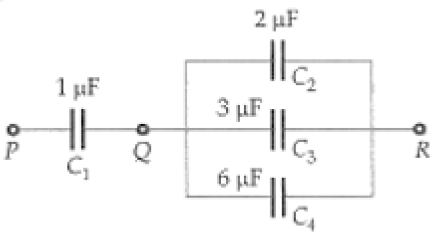
31. Figure shows a convex spherical surface with centre of curvature C separating the two media of refractive indices μ_1 and μ_2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis. Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface. **[5]**



OR

a. Use Huygen's geometrical construction to show how a plane wavefront at t = 0 propagates and produces a wavefront at a later time.
b. Verify, using Huygen's principle, Snell's law of refraction of a plane wave propagating from a denser to a rarer medium.
c. Illustrate with the help of diagrams the action of
   i. convex lens and
   ii. concave mirror, on a plane wavefront incident on it.

32. In Fig. the energy stored in C_4 is 27 J. Calculate the total energy stored in the system. **[5]**



OR

i. A. Why does the electric field inside a dielectric slab decrease when kept in an external electric field?

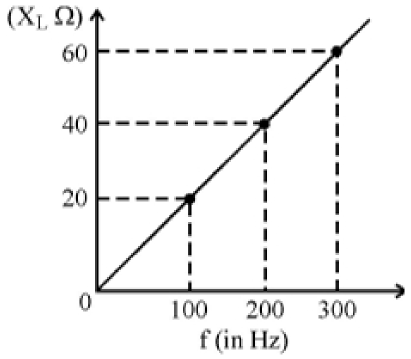
B. Derive an expression for the capacitance of a parallel plate capacitor filled with a medium of dielectric constant K.

ii. A charge q = 2 μC is placed at the centre of a sphere of radius 20 cm. What is the amount of work done in moving 4 μC from one point to another point on its surface?

iii. Write a relation for polarisation $\vec{P}$ of a dielectric material in the presence of an external electric field.

33. a. Show that an ideal inductor does not dissipate power in an ac circuit. **[5]**

b. The variation of inductive reactance (X_L) of an inductor with the frequency (f) of the ac source of 100 V and variable frequency is shown in the fig.



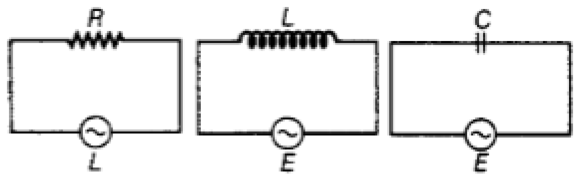
i. Calculate the self-inductance of the inductor.

ii. When this inductor is used in series with a capacitor of unknown value and a resistor of 10Ω at 300 s^{-1}, maximum power dissipation occurs in the circuit. Calculate the capacitance of the capacitor.

OR

i. What do you understand by the sharpness of resonance in a series L-C-R circuit? Derive an expression for Q-factor of the circuit.

ii. Three electrical circuits having AC sources of variable frequency are shown in the figures. Initially, the current flowing in each of these is same. If the frequency of the applied AC source is increased, how will the current flowing in these circuits be affected? Give the reason for your answer.



Solution

Section A

1.

(b) the depletion region is increased

Explanation: When a p-n junction is reverse biased, its depletion region is widened.

2. **(a)** 193000 C

Explanation: Reduction equation taking place at the cathode is as follow:

$2H^{+} + 2e^{-} \rightarrow H_2(g)$

It implies that 2 moles of electrons are required to produce 1 mole (= 22.4 liters) of Hydrogen. Hence,

1 mole of electron is = 1 Faraday

and 1 Faraday = 96500 Coulombs of charge

$\therefore$ 2 moles of electrons = 193000 Coulombs of charge.

3.

(d) Total internal reflection

Explanation: When light travelling in an optically dense medium hits a boundary at a steep angle, the light is completely reflected. This is called total internal reflection. This effect is used in optical fibres to confine light in the core.

4. **(a)** Magnetic dipole

Explanation: Magnetic dipole

5.

(b) 4

Explanation: Dielectric constant of air is 1. All dielectrics generally have a value of the dielectric constant greater than 1.

$K = \frac{F}{F_m}$

where Fm is the force between two charged particles in a medium of dielectric constant K and F is the force between the two charges when placed in air.The force between two charges is greatest in air or vacuum and it decreases when any medium is placed between the charges. K cannot have negative, fractional or zero values.

6. **(a)** -ve z-axis, -ve x-axis and zero

Explanation: -ve z-axis, -ve x-axis and zero

7.

(b) along abc if I increases

Explanation: In accordance with Lenz law.

8.

(c) diamagnetism

Explanation: Diamagnetism is a universal property among all substances.

9. **(a)** diffraction

Explanation: The phenomenon of bending of waves around corners of obstacle without a change in medium is known as diffraction.

10. **(a)** 3 m

Explanation: 3 m

11. **(a)** would be like a half-wave rectifier with negative cycles in output

Explanation: When the positive cycle is at A, the diode will be in forwarding bias, and resistance due to diode is approximately zero the current in the circuit is maximum so potential across the diode will be about zero.

Similarly, when there is a negative half cycle at A, the diode will be in reverse bias and resistance will be maximum so potential difference across the diode is $V_m \sin \omega t$ with negative at A.

So we get only negative output at A so it behaves like a half-wave rectifier with the negative cycle at A in output.

12.

(c) 21.28 cm

Explanation: $\frac{1}{f}=(\frac{\mu_2}{\mu_1}-1)(\frac{1}{R_1}-\frac{1}{R_2})$

For violet light,

$\frac{1}{f_v}=(1.5-1)(\frac{1}{R_1}-\frac{1}{R_2})=0.5(\frac{1}{R_1}-\frac{1}{R_2})$

For red light,

$\frac{1}{f_r}=(1.47-1)(\frac{1}{R_1}-\frac{1}{R_2})=0.47(\frac{1}{R_1}-\frac{1}{R_2})$

Hence, $f_r=\frac{0.5}{0.47}f_v=1.064\times 20=21.28cm$

13. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation: Yes, because the metal will provide additional energy to the emitted photoelectron for light of higher frequency than that for lower frequency.

14.
(c) A is true but R is false.
Explanation: The reason is false because the work done in bringing a unit positive charge from infinity to a point in the equatorial plane is equal and opposite for the two charges of the dipole.

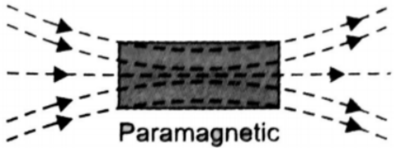
15.
(b) Both A and R are true but R is not the correct explanation of A.
Explanation: Both assertion and reason true but the reason is not the correct explanation of assertion. Colours are seen due to interference between light waves reflected by the upper and lower surfaces of the thin oil film.

16. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

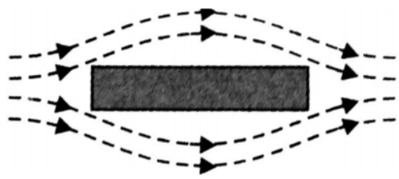
Section B

17. a. Here e.m. wave travels in x-direction and electric field oscillates along y-direction. But the e.m. wave propagates in the direction of $\vec{E}\times\vec{B}$. Hence magnetic field must oscillate along z-direction because $(+\hat{j})\times(+\hat{k})=+\hat{i}$
b. $\frac{E_0}{B_0}=c$, the speed of light.

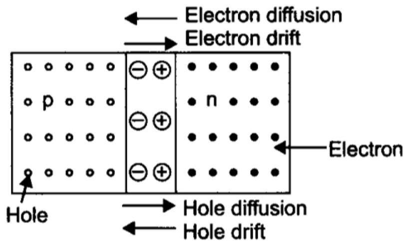
18. Inside a paramagnetic bar, field concentrates slightly in the bar, figure.



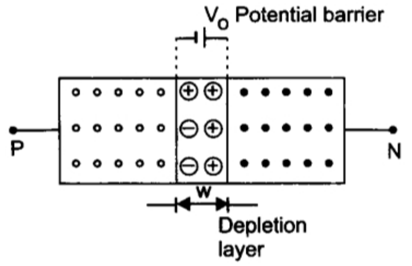
Inside a Diamagnetic bar, magnetic field lines are repelled or expelled and the field inside the material is reduced. This is shown in the figure.



19. Two important processes occurring during the formation of a p-n junction are (i) diffusion and (ii) drift.
i. **Diffusion:** In n-type semiconductor, the concentration of electrons is much greater as compared to concentration of holes; while in p-type semiconductor, the concentration of holes is much greater than the concentration of electrons. When a p-n junction is formed, then due to concentration gradient, the holes diffuse from p-side to n-side (p $\rightarrow$ n) and electrons diffuse from n-side to p-side (n $\rightarrow$ p). This motion of charge carriers gives rise diffusion current across the junction.



ii. **Drift:** The drift of charge carriers occurs due to electric field. Due to build in potential barrier, an electric field directed from n-region to p-region is developed across the junction. This field causes motion of electrons on p-side of the junction to n-side and motion of holes on n-side of junction to p-side. Thus a drift current starts. This current Depletion is opposite to the direction of **diffusion current.**



20. i. Charge on a-particle, q = 2e, V = 2 × 10^6 V

K.E. of α-particle,

K = qV = 2 × 1.6 × 10^{-19} × 2 × 10^6=6.4 × 10^{-13} J

ii. Charge on silver nucleus = Ze = 47 e

P.E. of the a-particle at a distance of 5 × 10^{-14} m from the silver nucleus

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{47e \times 2e}{5 \times 10^{-14}}$

$= \frac{9\times10^9\times94\times(1.6\times10^{-19})^2}{5\times10^{-14}} = 4.3 \times 10^{-13}$ J

So, 4.3 × 10^{-3} J of K.E. gets converted into P.E.

∴K.E. of the a-particle at a distance of 5 x 10~14 m from the silver nucleus

= 6.4 × 10^{-13} - 4.3 × 10^{-13}

= 2.1 × 10^{-13} J.

iii. Distance of closest approach,

$r_0 = \frac{2kZe^2}{K} = \frac{2\times9\times10^9\times47\times(1.6\times10^{-10})^2}{6.4\times10^{-13}}$

= 3.4 × 10^{-14} m

21. A = 0.04 m^2, τ_{max} =4 × 10^{-8} Nm

I = 100 μ A= 10^{-4} A, N=1

As τ_{max} = NIBA

∴ Magnetic induction,

$B = \frac{\tau_{max}}{NIA}$

$= \frac{4\times10^{-8}}{1\times10^{-4}\times0.04}$

=10^{-2} Wb m^{-2}

OR

Here I = 30 A, r = 2.0 cm = 2.0 × 10^{-2} m

Field due to straight current carrying wire is

$B_1 = \frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times30}{2\pi\times2.0\times10^{-2}}$ = 3.0 × 10^{-4} T

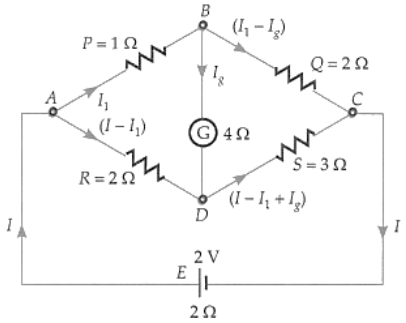
This field will act perpendicular to the external field B_2 = 4.0 × 10^{-4} T. Hence the magnitude of the resultant field is

B = $\sqrt{B_1^2 + B_2^2} = \sqrt{(3 \times 10^{-4})^2 + (4.0 \times 10^{-4})^2}$

= 5 × 10^{-4} T

Section C

22. The circuit for the given Wheatstone bridge is shown in Figure. Let I, I_1 and I_g, be the currents as shown.



Applying Kirchhoff's second law to loop ABDA, we get,

$I_1 \times 1 + I_g \times 4 - (I - I_1) \times 2 = 0$

or $3I_1 - 2I + 4I_g = 0$ ...(i)

Applying Kirchhoff's second law to loop BCDB, we get

$(I_1 - I_g) \times 2 - (I - I_1 + I_g) \times 3 - I_g \times 4 = 0$

$5I_1 - 3I - 9I_g = 0$ ...(ii)

Applying Kirchhoff's second law to loop ADCEA, we get

$2(I - I_1) + 3(I - I_1 + I_g) + 2I = 2$

or $-5I_1 + 7I + 3I_g = 2$ ...(iii)

Adding (ii) and (iii),

$4I - 6I_g = 2$ ...(iv)

Multiplying (i) by 5 and (ii) by 3 and Subtracting, we get

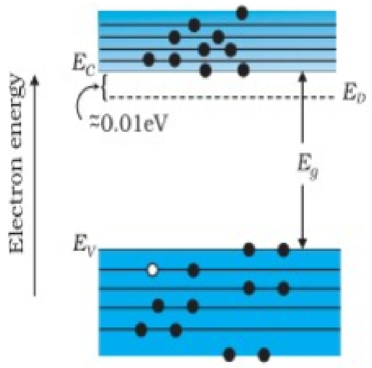
$-I + 47I_g = 0$ or $I = 47I_g$

From (iv),

$4 \times 47 I_g - 6 I_g, = 2$ or $182 I_g = 2$

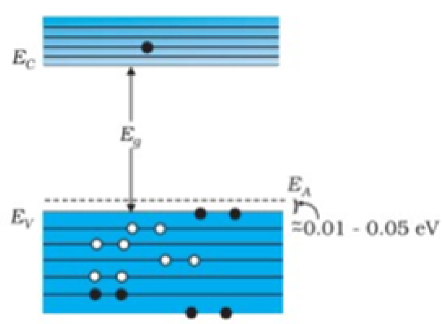
$\therefore I_g = \frac{2}{182} = \frac{1}{91}$ **A**

23. Energy Band Diagram of n-type



(a) $T > 0K$

Energy Band Diagram of p-type



(b) $T > 0K$

In the energy band of n-type semiconductors, donor energy level E_D is

formed slightly below the bottom of E_C of the conduction band. Hence electrons from this level move into the conduction band easily.

24. Energy flux of sunlight reaching the surface of earth, $\phi = 1.388 \times 10^3 \text{W/m}^2$

Hence, power of sunlight per square metre, $P = 1.388 \times 10^3$W

Speed of light, $c = 3 \times 10^8$ m/s

Planck's constant, $h = 6.626 \times 10^{-34}$ Js

Average wavelength of photons present in sunlight, $\lambda = 550$ nm

$= 550 \times 10^{-9}$m

Number of photons per square metre incident on earth per second = n

Hence, the equation for power can be written as:

$P = nE$

Number of photos incident on earth's surface per second per square metre is given by:-

$\therefore n=\frac{P}{E}=\frac{P\lambda}{hc}$

$=\frac{1.388\times10^{3}\times550\times10^{-9}}{6.626\times10^{-34}\times3\times10^{8}}=3.84\times10^{21}$ photons m^2/s

Therefore, every second, 3.84×10^{21} photons are incident per square metre on earth.

25. Important: We must consider electron mass in β decays, this mass is no more negligible.

The nuclear reaction is given by:

${}^{11}_{6}C\rightarrow{}^{11}_{5}B+e^{+}+v:T_{1/2}=20.3$ min

Hence Q value for this reaction is given by = $[11.011434-(11.009305+2\times m_e)]\times c^2$

We know, $m_e=0.000548$ u

$Q=[11.011434-(11.009305+2\times0.000548)]\times c^2$

$=0.001033\ u\times c^2$, as($1u=931.5\ MeV/c^2$)

= 0.962 MeV maximum energy of emitted positron.

Hence the Q value is comparable with the maximum energy of the positron emitted.

26. Energy of incident photon = $E_2-E_1=-3.4-(13.6)=10.2$ eV

K.E. of photo electron = eV_0=5 eV

By conservation of energy,

Energy of incident photon = K.E. of photo electron + Work function

10.2 eV = 5 eV + W_0

$\therefore W_0=5.2$ eV

27. In first case :

d = 1.5 mm = 1.5×10^{-3} m, D = 1 m

Width of 10 fringes = 3.93 mm

$\therefore$ Fringe width,

$\beta=\frac{3.93}{10}$ = 0.393 mm = 0.393×10^{-3} m

Wavelength,

$\lambda=\frac{\beta d}{D}=\frac{0.393\times10^{-3}\times1.5\times10^{-3}}{1}$

$=5.895\times10^{-7}$ m

In second case :

D' = 1 + 0.5 = 1.5 m,

d = 1.5×10^{-3} m, $\lambda=5.895\times10^{-7}$ m

Width of 10 fringes = 10 $\beta'=\frac{10D'\lambda}{d}$

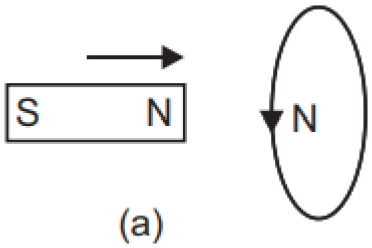
$=\frac{10\times1.5\times5.895\times10^{-7}}{1.5\times10^{-3}}=5.895\times10^{-3}$ m

28. According to Lenz's law, the direction of the induced current (caused by induced emf) is always such as to oppose the change causing it.

$\varepsilon=-k\frac{d\phi}{dt}$

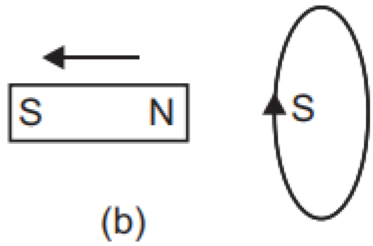
where k is a positive constant. The negative sign expresses Lenz's law. It means that the induced emf is such that, if the circuit is closed, the induced current opposes the change in flux.

Example: When the north pole of a coil is brought near a closed coil, the direction of current induced in the coil is such as to oppose the approach of north pole. For this the nearer face of coil behaves as north pole. This necessitates an anticlockwise current in the coil, when seen from the magnet side [fig. (a)]



(a)

Similarly when north pole of the magnet is moved away from the coil, the direction of current in the coil will be such as to attract the magnet. For this the nearer face of coil behaves as south pole. This necessitates a clockwise current in the coil, when seen from the magnet side (fig. b).



(b)

Thus, in each case whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore to maintain the relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus Lenz's law is based on conservation of energy.

OR

i. In the one revolution, change of area,
$dA = \pi l^2$
$\therefore$ Change of magnetic flux in one revolution of the rod,
$d\phi_B = \vec{B} \cdot d\vec{A} = BdA\cos 0^\circ = B\pi l^2$
(Given, magnetic field intensity, $\vec{B}$ is parallel to change in area, $d\vec{A}$)
If period of revolution is T,
   a. Induced emf (e) = $\frac{d\phi}{dt} = \frac{B\pi l^2}{T} = B\pi l^2\nu$ $(\because \nu = \frac{1}{T})$
   b. Induced current in the rod,
   $I = \frac{e}{R} = \frac{\pi\nu Bl^2}{R}$
   (Given R = resistance of the rod)

ii. Magnitude of force acting on the rod,
$|\vec{F}| = |I(\vec{l} \times \vec{B})| = BIlsin90^0 = \frac{\pi\nu B^2 l^3}{R}$
The external force required to rotate the rod opposes the Lorentz force acting on the rod, i.e external force acts in the direction opposite to the Lorentz force.

iii. Power required to rotate the rod,
$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

Section D

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

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by c = $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(i) **(b)** $ML^{-1}T^{-2}$

Explanation: $\frac{1}{2}\varepsilon_0 E^2$ = energy density = $\frac{\text{Energy}}{\text{Volume}}$

$\therefore \left[\frac{1}{2}\varepsilon_0 E^2\right] = \frac{ML^2T^{-2}}{L^3}$ = $[ML^{-1}T^{-2}]$

(ii) **(c)** $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$

Explanation: As $\varepsilon_0 = \frac{q_1 q_2}{4\pi FR^2}$ (from Coulomb's law)

$\varepsilon_0 = \frac{C^2}{Nm^2} \frac{[AT]^2}{MLT^{-2}L^2} = M^{-1}L^{-3}T^4A^2$

(iii) **(a)** wavelength is halved and the frequency remains unchanged.

Explanation: The frequency of the electromagnetic wave remains same when it passes from one medium to another.

Refractive index of the medium, n = $\sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{\frac{4}{1}} = 2$

Wavelength of the electromagnetic wave in the medium,

$\lambda_{\text{med}} = \frac{\lambda}{n} = \frac{\lambda}{2}$

OR

(c) the speed of light c = 3 × 10^8 m s^{-1} in free space

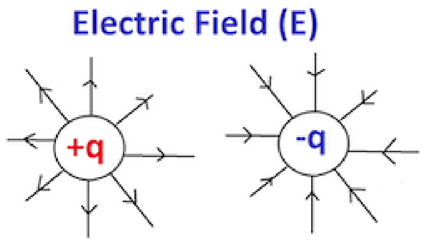
Explanation: The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (i.e., 3 × 10^8 m s^{-1}).

(iv) **(a)** β-rays

Explanation: β-rays consists of electrons which are not electromagnetic in nature.

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

Electric field intensity at any point is the strength of the electric field at that point. It is also defined as the force experienced by unit positive charge placed at that point. Electric Field Intensity is a vector quantity. It is denoted by **E**. When placed within the electric field, the test charge will experience an electric force - either attractive or repulsive.



(i) **(d)** continuous if there is no charge at that point

Explanation: continuous if there is no charge at that point

(ii) **(d)** E = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{x^2}$

Explanation: E = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{x^2}$

(iii) **(a)** 8 × 10^{-15} N

Explanation: 8 × 10^{-15} N

(iv) **(a)** source charge Q only

Explanation: source charge Q only

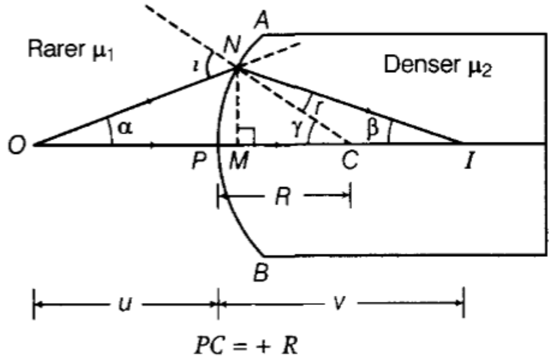
OR

(c) zero

Explanation: zero

Section E

31. The ray diagram is shown in the figure.



Let, NM = h

The convex spherical refracting surface forms the image of object O at I. The radius of curvature is R

Here $PI = +v \text{ and } PO = -u$

In $\triangle NCO,\ i = \gamma + \alpha$ ...(i)

In $\triangle NCI,\ \gamma = r + \beta$

$\Rightarrow \quad r = \gamma - \beta$ ...(ii)

For small angles $\alpha,\ \beta$ and γ and assuming M is very close to P, we have

$\alpha \approx \tan\alpha = \frac{MN}{MO} = \frac{MN}{PO} = \frac{+h}{-u}$

$\beta \approx \tan\beta = \frac{MN}{MI} = \frac{MN}{PI} = \frac{h}{v}$

$\gamma \approx \tan\gamma = \frac{MN}{MC} = \frac{MN}{PC} = \frac{h}{+R}$

By Snell's law,

$\frac{\mu_2}{\mu_1} = \mu = \frac{\sin i}{\sin r}$

For small i and r,

$\frac{\mu_2}{\mu_1} = \frac{i}{r}$ or $r\mu_2 = i\mu_1$

$\mu_2(\gamma - \beta) = (\alpha + \gamma)\mu_1$ [From Eqs. (i) and (ii)]

$(\mu_2 - \mu_1)\gamma = \mu_1\alpha + \mu_2\beta$

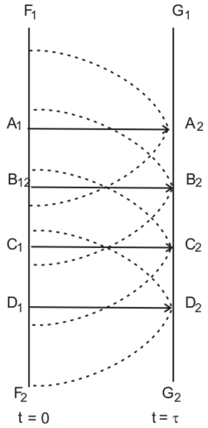
$(\mu_2 - \mu_1)\left(\frac{h}{R}\right) = \mu_1\left(\frac{h}{-u}\right) + \mu_2\left(\frac{h}{v}\right)$

$\Rightarrow \quad \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

This is the required relation.

OR

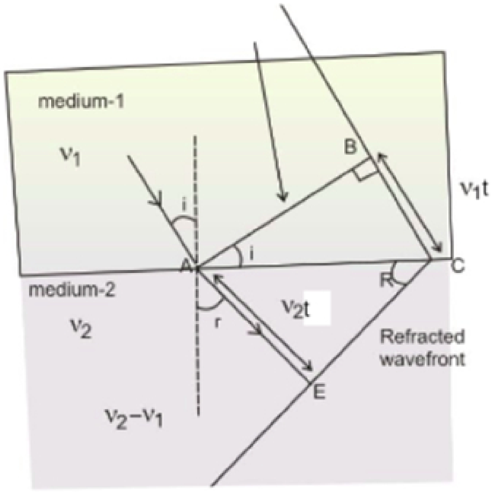
a. The surface of constant phase is known as a wavefront.



The Geometrical construction of wavefront:

To determine the wavefront at t = τ draw spheres of radius vτ from each point on F_1F_2 and draw a common tangent to these spheres to obtain the new position of the wavefront.

b.



The ratio of the speed of light in vaccum to the speed of light in the medium is termed as refractive index of medium.

Let us consider the medium I, which is optically denser than medium 2.

Let the speed of light be v_1 in medium I and v_2 in medium II.

Always, note that $v_2 > v_1$

A plane wave AB propagates and hits the interface at an angle i. and can be the time taken be the wavefront to travel the distance BC.

Now, we want to draw the refracted wavefront.

We can draw a sphere of radius v_2 with A as centre. Let the surface tangent to the sphere passing through point C, as the refracted wavefront.

Now,

Let the surface be tangent to the sphere at E.

In $\triangle$ABC

sin i = $\frac{v_1 t}{AC}$ and,

In △ AEC ι

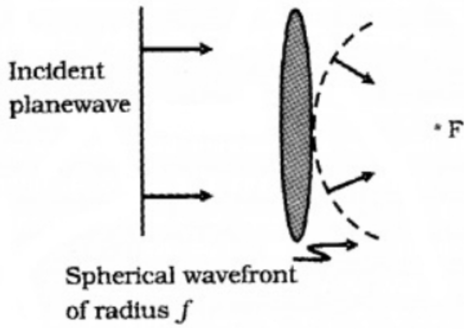
$\sin r = \frac{v_2 t}{AC}$

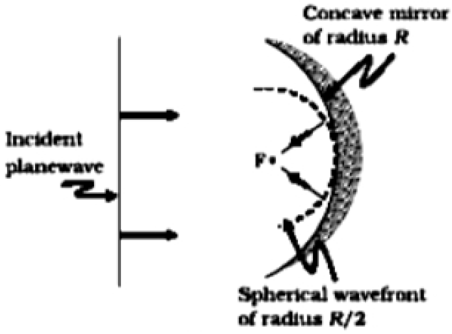
On dividing both the equations, we finally have,

$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\frac{c}{v_2}}{\frac{c}{v_1}}$

Hence, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

This is the verified Snell's law.

c. 



32. Energy stored in C_4 is

$U_4 = \frac{1}{2} C_4 V^2 = 27J$

or $\frac{1}{2} \times 6 \times 10^{-6} \times V^2 = 27$

or $V^2 = \frac{27 \times 2}{6 \times 10^{-6}} = 9 \times 10^6$

Energy stored in C_2

$U_2 = \frac{1}{2} \times 2 \times 10^{-6} \times 9 \times 10^6 = 9J$

Energy stored in C_3,

$U_3 = \frac{1}{2} \times 3 \times 10^{-6} \times 9 \times 10^6 = 13.5$ J

Energy stored in C_2, C_3 and C_4

$= U_2 + U_3 + U_4 = 9 + 13.5 + 27 = 49.5$ J

Equivalent capacitance of C_2, C_3 and C_4 connected in parallel

$= 2 + 3 + 5 = 11\ \mu$F

$\therefore \frac{q^2}{2 \times 11 \times 10^{-6}} = 49.5$ J $\left[u = \frac{q^2}{2C}\right]$

Energy stored in C_1

$U_1 = \frac{q^2}{2C_1} = \frac{49.5 \times 2 \times 11 \times 10^{-6}}{2 \times 1 \times 10^{-6}} = 544.5$ J

Total energy stored in the arrangement

$= 544.5 + 49.5 = 594.0$ J

OR

i. A. A dielectric material gets polarized when it is placed in an external electric field. The field produced due to the polarization of material reduces the effect of external electric field. Hence, the electric field inside a dielectric decreases.

B. Electric field in vacuum between the plates = E0 = $\frac{\sigma}{\varepsilon_o}$

Electric field in dielectric between the plates, E = $\frac{E_0}{K}$

Potential difference between the capacitor plates

$V = Et + E_0(d - t)$

where 't' is the thickness of dielectric slab.

$V = \frac{E_0}{K}t + E_0(d - t)$

$V = \frac{\sigma}{\varepsilon_o}\left[\frac{t}{K} + (d - t)\right]$

$V = \frac{\sigma}{\varepsilon_o}\left[\frac{t+K(d-t)}{K}\right]$

As $C = \frac{Q}{V}$

$\Rightarrow C = \frac{\varepsilon_0 AK}{t+K(d-t)}$

ii. The surface of the sphere is equipotential. So, the work done in moving the charge from one point to the other is zero.

$W = q\,\Delta V$ ($\because \Delta V = 0$)

$= 0$

iii. $P = \chi E$

33. a. Power dissipation = $P = V_{rms} I_{rms} \cos\phi$

$\cos\phi = \frac{R}{Z}$

For ideal inductor R = 0

$\therefore \cos\phi = 0$

$\therefore P = V_{rms} I_{rms} \cos\phi = 0$

Thus, ideal inductor does not dissipate power in an ac circuit.

b. i. Inductive reactance = $X_L = 2\pi fL$

$\therefore L = \frac{X_L}{2\pi f}$

From graph, at f = 100 Hz

$X_L = 20\ \Omega$

$\therefore L = \frac{X_L}{2\pi f} = \frac{20}{2\pi \times 100}$

= 0.032 H = 32 mH

ii. Power dissipation is maximum when

$2\pi fL = \frac{1}{2\pi fC}$

$f = 300\ s^{-1}$

L = 0.032 H

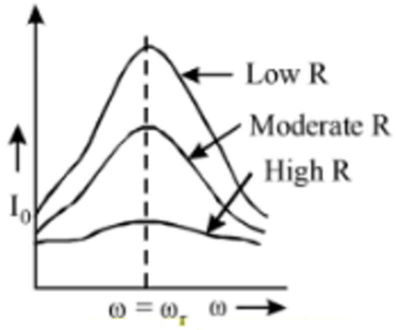
$2\pi fL = \frac{1}{2\pi fC}$

Or, $2\pi \times 300 \times 0.032 = \frac{1}{2\pi \times 300 \times C}$

$\therefore C = 8.8 \times 10^{-6}\ F = 8.8\ \mu F$

OR

i. The sharpness of resonance in series L-C-R circuit refers how quick fall of alternating current in circuit takes place when the frequency of alternating voltage shifts away from the resonant frequency. It is measured by the quality factor (Q-factor) of circuit.



The Q -factor of the series resonant circuit is defined as the ratio of the voltage developed across the capacitance or inductance at resonance to the impressed voltage which is the voltage applied.

i.e., quality factor (Q) = $\frac{\text{voltage across L or } C}{\text{applied voltage}}$

$Q = \frac{(\omega_r L)I}{RI}$

[$\because$ applied voltage = voltage across R]

or $Q = \frac{\omega_r L}{R}$ or $Q = \frac{(1/\omega_r C)I}{RI} = \frac{1}{RC\omega_r}$

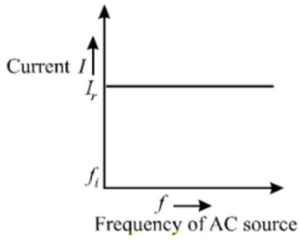
$\therefore$ Q = $\frac{L}{RC \cdot \frac{1}{\sqrt{LC}}}$ [using $\omega_r = \frac{1}{\sqrt{LC}}$]

Thus, Q = $\frac{1}{R}\sqrt{\frac{L}{C}}$

This is required expression.

ii. Let initially I_r current is flowing in all the three circuits. If the frequency of applied AC source is increased then, the change in current will occur in the following manner:

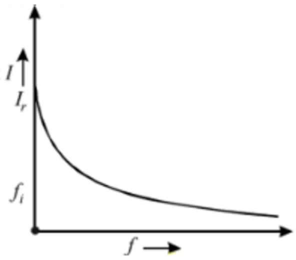
Circuit containing resistance R only:



where, f_i = initial frequency of AC source.

There is no effect on current with the increase in frequency.

AC circuit containing inductance only:



With the increase of frequency of AC source, inductive reactance increase as

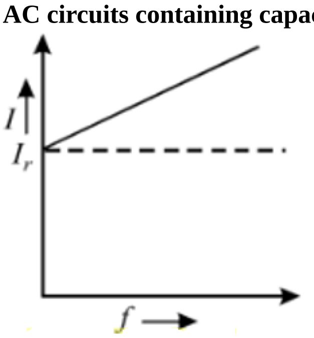
I = $\frac{V_{rms}}{X_L} = \frac{V_{rms}}{2\pi fL}$

For given circuit,

I $\propto \frac{1}{f}$

Current decreases with the increase of frequency.

AC circuits containing capacitor only:



$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

Current, I = $\frac{V_{rms}}{X_C} = \frac{V_{rms}}{\left(\frac{1}{2\pi fC}\right)}$

I = $2\pi fCV_{rms}$

For given circuit, I $\propto$ f

Current increases with the increase of frequency.