Class XII Session 2025-26
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. In forward bias the width of depletion layer **[1]**

a) independent of V
b) decreases with increase in V
c) increases with increase in V
d) dependent of V

2. According to Kirchhoff's Loop Rule, **[1]**

a) The algebraic sum of changes in potential around any closed loop must be positive.
b) The algebraic sum of changes in potential around any closed loop must be negative.
c) The absolute sum of changes in potential around any closed loop must be zero.
d) The algebraic sum of changes in potential around any closed loop must be zero.

3. If an object is placed unsymmetrically between two plane mirrors inclined at 70°, then the total number of images formed is **[1]**

a) 4
b) 5
c) 1
d) 3

4. The major contribution of magnetism in substances is due to **[1]**

a) equally due to orbital and spin motions of electrons
b) orbital motion of electrons

c) spin motion of electrons

d) hidden magnets.

5. A parallel plate capacitor has capacitance C. If it is equally filled with parallel layers of materials of dielectric constants κ_1 and κ_2, its capacity becomes C_1. The ratio of C_1 to C is **[1]**

a) $\kappa_1 + \kappa_2$

b) $\frac{\kappa_1\kappa_2}{\kappa_1+\kappa_2}$

c) $\frac{2\kappa_1\kappa_2}{\kappa_1+\kappa_2}$

d) $\frac{\kappa_1+\kappa_2}{\kappa_1\kappa_2}$

6. A thin ring of radius R metre has charge q coulomb uniformly spread on it. The ring rotates about its axis with a constant frequency of f revolutions/s. The value of magnetic induction in Wb/m^2 at the centre of the ring is: **[1]**

a) $\frac{\mu_0 q}{2\pi f R}$

b) $\frac{\mu_0 q f}{2R}$

c) $\frac{\mu_0 q f}{2\pi R}$

d) $\frac{\mu_0 q}{2 f R}$

7. A square loop of wire of each side 50 cm is kept so that its plane makes an angle θ with a uniform magnetic field of induction IT. The magnetic field is withdrawn in 0.1 s. It is found that the induced emf across the loop is 125 mV. The angle θ is: **[1]**

a) 45^o

b) 60^o

c) 90^o

d) 30^o

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

a) $\mu \propto \frac{1}{n}$

b) $\mu \propto n$

c) $\mu \propto n^2$

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

9. In a diffraction pattern due to a single slit of width a, the first minimum is observed at an angle 30^o when light of wavelength 5000 $\overset{\circ}{A}$ is incident on the slit. The first secondary maximum is observed at an angle of **[1]**

a) $\sin^{-1}\left(\frac{1}{2}\right)$

b) $\sin^{-1}\left(\frac{1}{4}\right)$

c) $\sin^{-1}\left(\frac{3}{4}\right)$

d) $\sin^{-1}\left(\frac{2}{3}\right)$

10. The magnitude of electric force, F is: **[1]**

a) directly proportional to the product of both charges.

b) constant

c) directly proportional to the distance between both charges

d) directly proportional to the square of the distance between both charges.

11. In the given Fig., V_o is the potential barrier across a p-n junction, when no battery is connected across the junction **[1]**

a) 3 and 1 both correspond to reverse bias of junction.

b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction

c) 1 corresponds to forward bias and 3 corresponds to reverse bias of junction.

d) 1 and 3 both correspond to forward bias of junction

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

a) Refraction

b) Scattering

c) Total internal reflection

d) Diffraction

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

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):** The potential of earth is assumed zero. **[1]**

Reason (R): Earth is insulator and so earth can not hold any charge.

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):** When a light wave travels from rarer to denser medium, its speed decreases. Due to this reduction of speed the energy carried by the light wave reduces. **[1]**

Reason (R): Energy of wave is proportional to the 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.

16. A resistor, a capacitor and an inductor are connected in series. The combination is connected across an ac source of frequency 50 Hz. **[1]**

Assertion: Peak current through each remains same.

Reason: Average power delivered by source is equal to average power developed across resistance.

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. The magnetic field of a beam emerging from a filter facing a floodlight is given by $B_0 = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t)$ T. What is the average intensity of the beam? **[2]**

18. A straight solenoid of length 50 cm has 1000 turns and a mean cross-sectional area of 2×10^{-4} m^2. It is placed with its axis at 30°, with a uniform magnetic field of 0.32 T. Find the torque acting on the solenoid when a current of 2A is passed through it. **[2]**

OR

Two similar bars, made from two different materials P and Q, are placed, one-by-one, in a non-uniform magnetic field. It is observed that

i. bar P tends to move from the weak to the strong field region.
ii. bar Q tends to move from the strong to the weak field region.

What is the nature of the magnetic materials used for making these two bars?
Show, with the help of a diagram, the behaviour of the field lines, due to an external magnetic field, near each of these two bars.

19. An a.c. supply of 230 V is applied to a half wave rectifier circuit through a transformer of turn ratio 10 : 1. Find the output d.c. voltage. Assume the diode to be ideal. **[2]**

20. The ground state energy of hydrogen atom is -13.6 eV . What are the kinetic and potential energies of the electron in this state? **[2]**

21. Answer the following: **[2]**

a. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why?
b. Does a bar magnet exert a torque on itself due to its own field? Justify your answer.
c. When an electron revolves around a nucleus, obtain the expression for the magnetic moment associated with it.

Section C

22. **[3]**

a. State Ohm's Law. Represent it mathematically.
b. Define 1 ohm.
c. What is the resistance of a conductor through which a current of 0.5 A flows when a potential difference of 2V is applied across its ends?

23. Ultra-violet light of wavelength 200 nm from a source is incident on a metal surface. If the stopping potential is -2.5 V, **[3]**

a. Calculate the work function of the metal, and
b. How would the surface respond to a high intensity red light of wavelength 6328 A produced by a laser?

24. What is a Zener diode? Draw its V-I characteristic. Explain with the help of a circuit diagram how a Zener diode can be used as a voltage regulator. **[3]**

25. **[3]**

i. The density of the nuclear matter is tremendously larger than the physical density of the material. Explain.
ii. The nuclear forces are not coulomb forces between nucleons. Explain.
iii. Draw a plot of the potential energy between a pair of nucleons as a function of distance between them inside a nucleus.

26. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Bracket series and state to which part of the electromagnetic spectrum does it belong. **[3]**

27. In single slit diffraction, explain why the maxima at $\theta = \left(\mathrm{n} + \frac{1}{2}\right)\left(\frac{\lambda}{\mathrm{a}}\right)$ becomes weaker and weaker as n increases. State two important differences between interference and diffraction pattern. **[3]**

28. A coil of number of turns N, area A, is rotated at a constant angular speed ω , in a uniform magnetic field B, and connected to a resistor R. **[3]**

Deduce expressions for: (i) maximum emf induced in the coil. (ii) power dissipation in the coil.

OR

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

Section D

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

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

(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) $[\varepsilon_0] = MLT^{-2}A^{-2}$
b) $[\varepsilon_0] = ML^2T^{-1}$
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 doubled and the frequency becomes half
b) wavelength and frequency both remain unchanged
c) wavelength is doubled and the frequency remains unchanged
d) wavelength is halved and the frequency remains unchanged.

OR

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

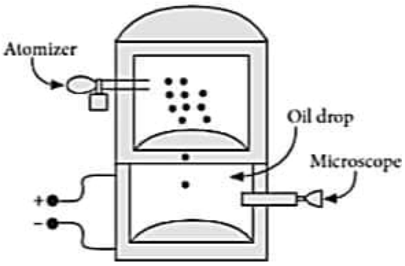
a) γ-rays
b) β-rays
c) X-rays
d) cosmic rays

(d) The electromagnetic waves travel with

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

30. In 1909, Robert Millikan was the first to find the charge of an electron in his now-famous oil-drop experiment. **[4]**
In that experiment, tiny oil drops were sprayed into a uniform electric field between a horizontal pair of oppositely charged plates. The drops were observed with a magnifying eyepiece, and the electric field was adjusted so that the upward force on some negatively charged oil drops was just sufficient to balance the downward force of gravity. That is, when suspended, upward force qE just equaled Mg. Millikan accurately

measured the charges on many oil drops and found the values to be whole number multiples of 1.6×10^{-19} C the charge of the electron. For this, he won the Nobel prize.



i. If a drop of mass 1.08×10^{-14} kg remains stationary in an electric field of 1.68×10^{5} NC^{-1}, then calculate the charge of this drop.

ii. A negatively charged oil drop is prevented from falling under gravity by applying a vertical electric field 100 V m^{-1}. Then what will be the number of electrons carried by the drop, if the mass of the drop is 1.6×10^{-3} g? (g = 10 ms^{-2})

iii. The important conclusion given by Millikan's experiment about the charge is that charge is ________.

iv. If in Millikan's oil drop experiment, charges on drops are found to be $8\mu\mathrm{C}, 12\mu\mathrm{C}, 20\mu\mathrm{C}$, then what is the quanta of charge?

Section E

31. i. Draw a ray diagram showing the formation of a real image of an object placed at a distance **u** in front of a concave mirror of radius of curvature **R**. Hence, obtain the relation for the image distance **v** in terms of u and R. **[5]**

ii. A 1.8 m tall person stands in front of a convex lens of focal length 1 m, at a distance of 5 m. Find the position and height of the image formed.

OR

A narrow monochromatic beam of light of intensity I is incident on a glass plate. Another identical glass plate is kept close to the first one and parallel to it. Each plate reflects 25% of the incident light and transmits the remaining. Calculate the ratio of minimum and maximum intensity in the interference pattern formed by two beams obtained after reflection from each plate.

32. a. Deduce the expression for the energy stored in a charged capacitor **[5]**

b. Show that the effective capacitance C of a series combination of three capacitors C_1, C_2 and C_3 is given by $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

OR

A capacitor of capacitance C_1 is charged to a potential V_1 while another capacitor of capacitance C_2 is charged to a potential difference V_2. The capacitors are now disconnected from their respective charging batteries and connected in parallel to each other.

i. Find the total energy stored in the two capacitors before they are connected.

ii. Find the total energy stored in the parallel combination of two capacitors.

iii. Explain the reason for the difference of energy in parallel combination in comparison to the total energy before they are connected

33. i. Describe, with the help of a suitable diagram, the working principle of a step-up transformer. Obtain the relation between input and output voltages in terms of the number of turns of primary and secondary windings and the currents in the input and output circuits. **[5]**

ii. Given the input current 15 A and the input voltage of 100 V for a step-up transformer having 90% efficiency, find the output power and the voltage in the secondary if the output current is 3 A.

OR

A series L-C-R circuit is connected to an AC source. Using the phasor diagram, derive the expression for the impedance of the circuit. Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation.

Solution

Section A

1.

(b) decreases with increase in V

Explanation:

The width of the depletion layer decreases with the increase in forward bias voltage.

2.

(d) The algebraic sum of changes in potential around any closed loop must be zero.

Explanation:

Kirchhoff's loop rule is based on the principle of conservation of energy. Since work done in transporting a charge in a closed loop is zero. The algebraic sum (since potential differences can be both positive and negative) of potential differences around any closed loop is always zero.

3.

(b) 5

Explanation:

Two plane mirrors places asymmetrically at 70 degrees.

Number of images $\frac{360}{70}$ = 5 (highest integral value)

4.

(c) spin motion of electrons

Explanation:

spin motion of electrons

5.

(c) $\frac{2\kappa_1\kappa_2}{\kappa_1+\kappa_2}$

Explanation:

For the original capacitor, $C = \frac{\varepsilon_0 A}{d}$

The new arrangement is equivalent to a series combination of two capacitors, each with plate area A and separation $\frac{d}{2}$

The new capacitance C_1 is given by

$\frac{1}{C_1} = \frac{1}{C} + \frac{1}{C'} = \frac{1}{\frac{\varepsilon_0 A_\kappa 1}{(\frac{d}{2})}} + \frac{1}{\frac{\varepsilon_0 A_\kappa}{(\frac{d}{2})}}$

$= \frac{d}{2\varepsilon_0 A}\left(\frac{1}{k_1} + \frac{1}{\kappa_2}\right)$

or $C_1 = \frac{2\varepsilon_0 A}{d}\left(\frac{\kappa_1\kappa_2}{\kappa_1+\kappa_2}\right)$

$\therefore \frac{C_1}{C} = \frac{2k_1k_2}{\kappa_1+\kappa_2}$

6.

(b) $\frac{\mu_0 qf}{2R}$

Explanation:

Current,$I = \frac{q}{T} = qf$

$B = \frac{\mu_0 I}{2R} = \frac{\mu_0 qf}{2R}$

7.

(d) 30^o

Explanation:

$\varepsilon = -\frac{\phi_2 - \phi_1}{t}$

$125 \times 10^{-3} = -\frac{0 - 1 \times 0.5 \times 0.5 \times \cos(90^\circ - \theta)}{0.1}$

$125 \times 10^{-3} = 0.50 \times 0.50 \times \sin\theta$

$\sin\theta = \frac{125 \times 10^{-3}}{0.50 \times 0.50} = \frac{1}{2}$

$\theta = 30^\circ$

8.

(b) $\mu \propto n$

Explanation:

$L = n \cdot \frac{h}{2\pi}$ and $\mu = \frac{e}{2m} \cdot L$

$\therefore \mu = \frac{e}{2m} \cdot \frac{nh}{2\pi}$ $\therefore$ u $\propto$ n.

9.

(c) $\sin^{-1}\left(\frac{3}{4}\right)$

Explanation:

The condition for first minimum is

a $\sin\theta = \lambda$

$\Rightarrow$ a sin $30^o = \lambda$

$\Rightarrow$ a = 2λ

The condition for first secondary maximum is

a $\sin\theta_1 = \frac{3\lambda}{2}$

$\Rightarrow \sin\theta_1 = \frac{3\lambda}{2a} = \frac{3\lambda}{2 \times 2\lambda} = \frac{3}{4}$

$\therefore \theta_1 = \sin^{-1}\left(\frac{3}{4}\right)$

10. **(a)** directly proportional to the product of both charges.

Explanation:

The magnitude of the electric force F is directly proportional to the amount of an electric charge, q_1, multiplied by the other, q_2, and inversely proportional to the square of the distance 'r' between their centres.

11.

(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction

Explanation:

When p-n junction is forward biased, it opposes the potential barrier across junction. When p-n junction is reverse biased, it supports the potential barrier junction, resulting increase in potential barrier across the junction.

12.

(c) 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.

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:
A is true but R is false.

15.
(d) A is false but R is true.
Explanation:
When a light wave travels from rarer to denser medium, its speed decreases. But this reduction of speed does not imply the loss of energy carried by the light wave. So, the assertion is false.
Energy of wave is proportional to the frequency of the wave which remains same in very medium. Hence there is no loss of energy. So, the reason is true.

16.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
Explanation:
Assertion and reason both are correct statements but reason is not correct explanation for assertion.

Section B

17. The standard equation of magnetic field can be expressed as $B = B_0 \sin \omega t$.

We are given equation

$B = 12 \times 10^{-8} \sin (120 \times 10^7 z - 3.60 \times 10^{15} t)T$

On comparing this equation with standard equation, we get

$B_0 = 12 \times 10^{-8}$ T and

The average intensity of the beam is given by :-

$I_{\text{av}} = \frac{1}{2} \frac{B_0^2}{\mu_0} \cdot c = \frac{1}{2} \times \frac{(12 \times 10^{-8})^2 \times 3 \times 10^8}{4\pi \times 10^{-7}}$

$= 1.71 \text{ W/m}^2$

18. Torque of solenoid is given by

$\tau = MB \sin \theta$

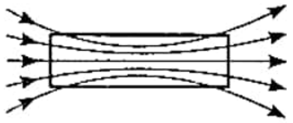
$= (NIA) B \sin \theta$

$= 1000 \times 2 \times 2 \times 10^{-4} \times 0.32 \times \frac{1}{2}$

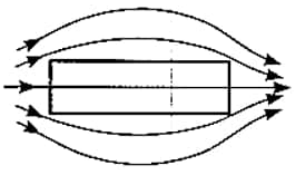
$= 0.064$ Nm

OR

i. P is a paramagnetic bar. The lines of force get concentrated inside the material as shown in figure.



ii. Q is a diamagnetic bar. The lines of force get expelled from it as shown in figure.



19. Here, $\frac{n_p}{n_s} = 10$

R.M.S. primary voltage, $V_{rms} = 230V$

Maximum primary voltage, $V_{m_p} = \sqrt{2} \times V_{rms} = \sqrt{2} \times 230 = 325.3$ V

Maximum secondary voltage, $V_{m_s} = V_{m_p} \times \frac{n_s}{n_p} = 325.3 \times \frac{1}{10} = 32.53$ V

Half wave rectified current, $I_{dc} = \frac{I_0}{\pi}$

Output dc voltage $= I_{dc} \times R_L$

$= \frac{I_0}{\pi} \times R_L = \frac{V_{m_s}}{\pi}$

$= \frac{32.53}{3.14} = 10.36V$

20. Here, ground state energy, E = -13.6 eV

Kinetic energy, $E_k = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{2r}$

and Potential energy, $E_p = -\frac{1}{4\pi\varepsilon_0} \frac{e^2}{r} [\because E_p = -2E_k]$

Total energy, E = E_k + E_p

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

$E = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}\right)$

$-13.6 = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}\right)$

$\therefore \frac{1}{4\pi\varepsilon_0} \frac{e^2}{r} = 27.2$

$\therefore E_k = \frac{1}{4\pi\varepsilon_0} \frac{e^2}{2r} = \frac{27.2}{2} eV = 13.6 eV$

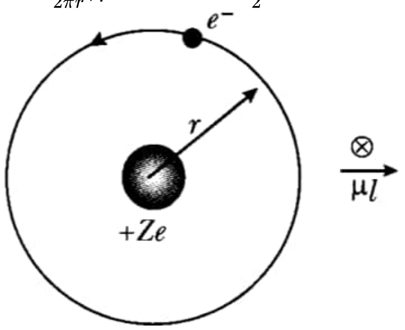
$E_p = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r} = -27.2 \ eV$

21. a. If field lines were extremely confined between two ends of a straight solenoid, the flux through the cross section at each end would be non zero. But the flux of field B through any closed surface must always be zero, For a toroid this difficulty is absent.

b. No, there is no force on torque on an element due to the field produced by that element itself.

c. $I = \frac{e}{T}, T = \frac{2\pi r}{v}$

$I = \frac{ev}{2\pi r}, \mu = I\pi r^2 = \frac{evr}{2}$



Section C

22. a. Ohm's law state that keeping the physical conditions (temperature, pressure and material) constant, potential difference across the conductor is directly proportional to the current flowing through the two ends of the conductor.

$\vee \alpha I$

$\frac{V}{I}$ = constant = R (where } R is called as resistance)

b. Resistance offered by a conductor is said to be 1ohm when a potential difference of 1 V is set up between the ends of the conductor and 1 A current flows through the ends of the conductor.

c. I = 0.5 A

V = 2 V

R = ?

$R = \frac{V}{I} = \frac{2}{0.5} = 4\Omega$

23. a. λ = 200 nm, stopping potential = -2.5 V

K.E. = 2.5 $\times$1.6 $\times$ 10^{-19} J = 4 $\times 10^{-19}$ J

E = hv =h$\frac{c}{\lambda}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{200 \times 10^{-9}}$

= 9.945 $\times$ 10^{-19} J

Work function = E - eV

= (9.945 $\times$ 10^{-19} - 4 $\times 10^{-19}$)J

= 5.595 $\times$ 10^{-19} J

b. Wavelength of red light = 6328 $\mathring{A}$

E = hv = h$\frac{c}{\lambda}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6328 \times 10^{-10}}$

$= 0.00314 \times 10^{-16}$ J

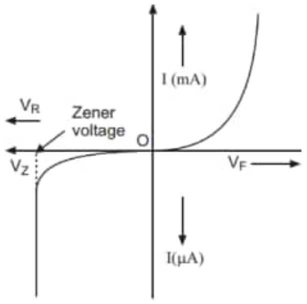
$= 3.14 \times 10^{-19}$ J

Energy of red light < work function of metal surface

$\therefore$ No emission of photoelectrons takes place.

24. **Zener diode:** A junction diode specially designed to operate only in the reverse breakdown region continuously (without getting damaged) is called a Zener diode.

I-V characteristics

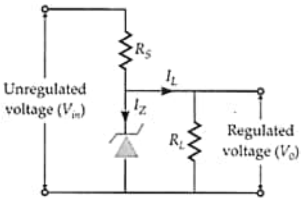


Zener diode as a Voltage Regulator

The Zener diode makes its use as a voltage regulator due to the following property:

When a Zener diode is operated in the breakdown region, the voltage across it remains practically constant for a large change in the current.

A simple circuit of a voltage regulator using a Zener diode is shown in the figure. The Zener diode is connected across load such that it is reverse biased.

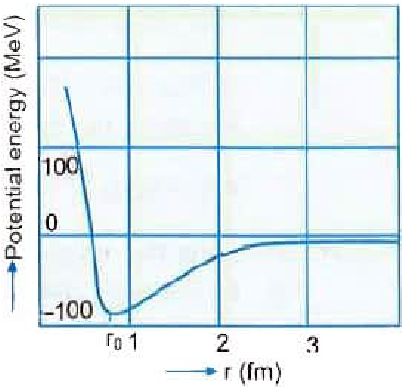


The series resistance R absorbs the output voltage fluctuations so as to maintain a constant voltage across the load. If the input dc voltage increases, the current through the R and Zener diode also increases. So, the voltage drop across R increases, without any change in the voltage across the Zener diode.

25. i. The density of nuclear matter is approximately $2.3\times10^{17}kgm^{-3}$ which is tremendously larger than the density of ordinary material, say water, which is 10^3kgm^{-3}. This is due to the fact that most of an atom is empty and its whole mass is concentrated at its nucleus. Ordinary material, consisting of atoms, has a large amount of empty space and consequently its density is small.

ii. Coulombian force between two protons is repulsive. However, within a nucleus a number of protons and neutrons exist together within a very small space. So it is clear that nuclear force is not coulomb force but is an extremely short range force which is attractive in nature and is responsible for maintaining all the nucleons together.

iii.



26. <u>Bohr's quantization condition of angular momentum:</u> According to Bohr, the electron can revolve in certain discrete orbits called stationary orbits. The total angular momentum (L) of the revolving electron is an integral multiple of $\frac{h}{2\pi}$.

Thus, angular momentum, L = mvr = $\frac{nh}{2\pi}$

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

Brackett series is obtained when an electron jumps to fourth orbit ($n_1 = 4$) from any outer orbit ($n_2 = 5, 6, 7.....$) of the hydrogen atom.

The wavelength of a spectral line is given as

$\frac{1}{\lambda}$ = RZ$\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

where R is Rydberg's constant (1.097×10^7 m^{-1}) and Z is the atomic number (Z = 1 for hydrogen atom). For Brackett series, n_1 = 4 and n_2 = 5, 6, 7…

Therefore,

$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n_2^2}\right)$

For the shortest wavelength, $n_2 = \infty$. Therefore,

$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{\infty^2}\right] = R\left(\frac{1}{4^2} - 0\right)$

$\frac{1}{\lambda} = \frac{R}{16} = \frac{1.097 \times 10^7}{16}$

$\Rightarrow \lambda = \frac{16}{1.097 \times 10^7}$ = 14.585×10^{-7}

or λ = 1458.5 nm.

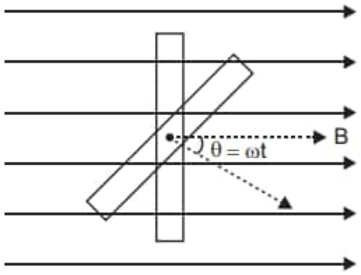
The shortest wavelength of the Brackett series is 1458.5 nm.

This wavelength belongs to infrared range of electromagnetic spectrum.

27. As n increases. deviation of light from straight direction increases thus the light spread out more and which result in decreasing intensity of bright fringes.

In interference pattern the fringes are of equal width (dark and bright) and are of equal intensity and in diffraction the central maxima is brightest and its width is wider twice as compare to the other maxima and intensity of bands goes on decreasing as we move away from the Centre.

28. i. Suppose initially the plane of coil is perpendicular to the magnetic field B. When coil rotates with angular speed ω, then after time t, the angle between magnetic field vector B and normal to plane of coil is



$\theta = \omega$t

$\therefore$ At this instant magnetic flux linked with the coil $\phi = \mathrm{BA}\cos\omega\mathrm{t}$. If coil contains, N-turns, then emf induced in the coil.

If coil contains, N-turns, then emf induced in the coil

$\varepsilon = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA\cos\omega t)$

$= +NBA\omega\sin\omega t$

$\therefore$ For maximum value of emf ε,

sin ωt = 1

$\therefore$ Maximum emf induced, $\varepsilon_{\max} = NBA\omega$

ii. If R is resistance of coil, the current induced, $I = \frac{\varepsilon}{R}$

$\therefore$ Instantaneous power dissipated,

$P = \varepsilon I = \varepsilon\left(\frac{\varepsilon}{R}\right) = \frac{\varepsilon^2}{R}$

$= \frac{N^2B^2A^2\omega^2\sin^2\omega t}{R}$

but, $\left(\sin^2\omega t\right)_{av} = \frac{1}{2}$ (Average power dissipated in a complete cycle is obtained by taking average value of $\sin^2\omega$t over a complete cycle which is $\frac{1}{2}$)

$\therefore$ Average power dissipated $P_{av} = \frac{N^2B^2A^2\omega^2}{2R}$

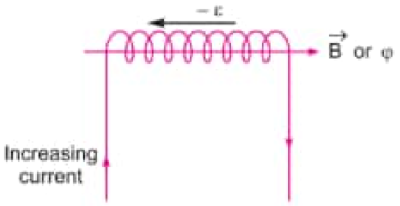
OR

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

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

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

Expression for magnetic energy:



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

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

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

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

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

From work-energy theorem,

dU = LIdI

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

Section D

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

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

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 ε_0 = $\frac{q_1q_2}{4\pi FR^2}$ (from Coulomb's law)

ε_0 = $\frac{C^2}{Nm^2}\frac{[AT]^2}{MLT^{-2}L^2}$ = $M^{-1}L^{-3}T^4A^2$

(iii) **(d)** 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

(b) β-rays

Explanation:

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

(iv) **(a)** 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}).

30. i. As, qE = mg $\Rightarrow$ q = $\frac{1.08\times10^{-14}\times9.8}{1.68\times10^5}$ = 6.4×10^{-19} C

The charge of this drop will be 6.4×10^{-19} C.

ii. For the drop to be stationary,

Force on the drop due to electric field = Weight of the drop

qE = mg

q = $\frac{mg}{E} = \frac{1.6\times10^{-6}\times10}{100}$ = 1.6 $\times$ 10^{-7} C

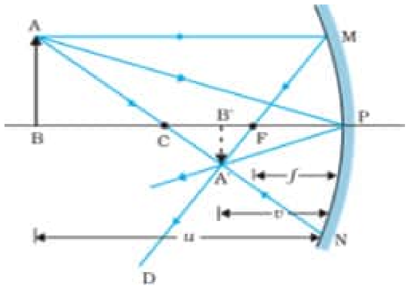
The number of electrons carried by the drop is

n = $\frac{q}{e} = \frac{1.6\times10^{-7}\text{C}}{1.6\times10^{-19}\text{C}}$ = 10^{12}

iii. quantized

iv. Millikan's experiment confirmed that the charges are quantized, i.e., charges are small integer multiples of the base value which is a charge on the electron. The charges on the drops are found to be multiple of 4. Hence, the quanta of charge are 4 μC.

Section E

31. i. 

From Fig. the two right-angled triangles A′B′F and MPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.) Therefore,

$\frac{\text{B}'\text{A}'}{\text{PM}} = \frac{\text{B}'\text{F}}{\text{FP}}$

or $\frac{\text{B}'\text{A}'}{\text{BA}} = \frac{\text{B}'\text{F}}{\text{FP}}$ ($\because$ PM = AB) ...(i)

Since $\angle$APB = $\angle$A′PB′, the right angled triangles A′B′P and ABP are also similar. Therefore,

$\frac{\text{B}'\text{A}'}{\text{BA}} = \frac{\text{B}'\text{P}}{\text{BP}}$ ...(ii)

Comparing equations (i) and (ii)

$\frac{\text{B}'\text{F}}{\text{FP}} = \frac{\text{B}'\text{P}-\text{FP}}{\text{FP}} = \frac{\text{B}'\text{P}}{\text{BP}}$ ...(iii)

B'P = -v, FP = -f, BP = -u;

Using these in Eq. (iii) we get $\frac{1}{\text{v}} + \frac{1}{u} = \frac{1}{f} = \frac{2}{R}$

ii. For lens: $\frac{1}{\text{v}} - \frac{1}{u} = \frac{1}{f}$

u = -5m; f = +1m

$\frac{1}{v} - \frac{1}{-5} = \frac{1}{(+1)}$

$\Rightarrow$ v = $\frac{5}{4}$m = 1.25m

hence, the position of the image formed is at 1.25m behind the lens.

$m = \frac{I}{O} = \frac{\text{v}}{u} = \frac{(+\frac{5}{4})}{(-5)}$

I = (-0.25) $\times$ (1.8)

I = -0.45 m

OR

Let I be the intensity of beam 1 incident on the first glass plate. Each plate reflects 25% of light incident on it and transmits 75%. Therefore,

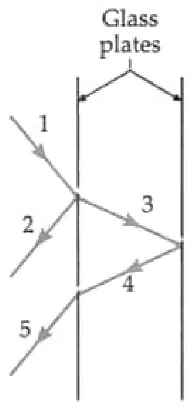
I_1 = I;

$I_2 = \frac{25}{100}$ I = $\frac{I}{4}$

$I_3 = \frac{75}{100}$ I = $\frac{3}{4}$I

$I_4 = \frac{25}{100} I_3 = \frac{1}{4} \times \frac{3}{4}$ I = $\frac{3}{16}$ I

$I_5 = \frac{75}{100} I_4 = \frac{3}{4} \times \frac{3}{16}$ I = $\frac{9}{64}$ I



∴ Amplitude ratio of beams 2 and 5 is

r = $\sqrt{\frac{I_2}{I_5}} = \sqrt{\frac{I}{4} \times \frac{64}{9I}} = \frac{4}{3}$

$\frac{I_{\min}}{I_{\max}} = \left[\frac{r-1}{r+1}\right]^2 = \left[\frac{\frac{4}{3}-1}{\frac{4}{3}+1}\right]^2 = \frac{1}{49}$ = 1 : 49

32. 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 ⇒ V = q/C

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

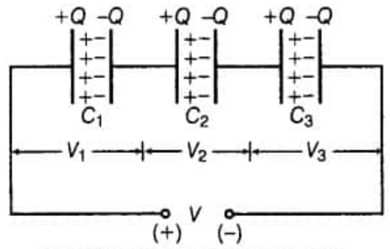
dW = Vdq = $\frac{q}{C}dq$

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]

OR

i. Total energy stored in the two capacitors before they are connected,

$u_i = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

ii. After the two capacitors are connected in parallel, the common potential is

$V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1+q_2}{C_1+C_2} = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

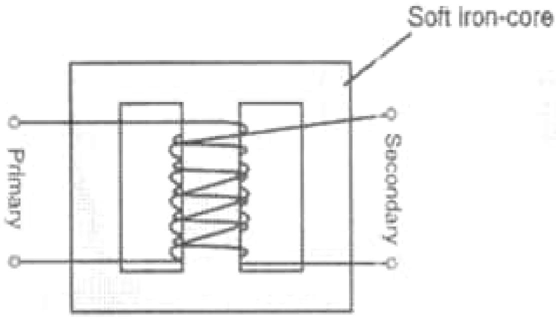
Total energy stored in the parallel combination,

$U_f = \frac{1}{2}(C_1 + C_2)V^2 = \frac{1}{2}(C_1 + C_2)\left(\frac{C_1V_1+C_2V_2}{C_1+C_2}\right)^2$

$= \frac{1}{2}\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2}$

iii. Clearly, $U_f < U_i$. Thus the total energy of the parallel combination is less than the sum of the energies stored in the two capacitors before they are connected. During sharing of charges, some energy is lost as heat due to the flow of charges in connecting wires.

33. i.



Working principle:

Step-down transformer is made up of two or more coil wound on the iron core of the transformer. It works on the principle of magnetic induction between the coils. Whenever current in one coil changes an emf gets induced in the neighboring coil (Principle of mutual induction)

Voltage across secondary

$V_s = e_s = -N_s \frac{d\phi}{dt}$

Voltage across primary

$V_p = e_p = -N_p \frac{d\phi}{dt}$

$\frac{V_s}{V_p} = \frac{N_s}{N_p}$ (here, $N_s > N_p$)

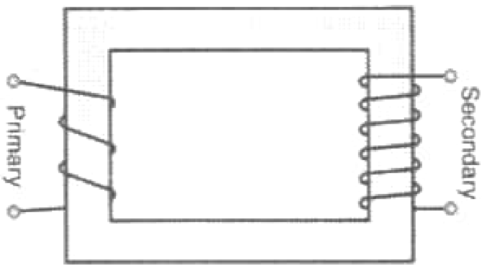
In an ideal transformer

Power Input - Power output

$I_p V_p = I_s V_s$

$\therefore \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$

ii.



Input power, $P_i = I_i \times V_i = 15 \times 100 = 1500$ W

Power output, $P_0 = P_i \times \frac{90}{100} = 1350$ W

$\Rightarrow I_0 V = 1350$ W

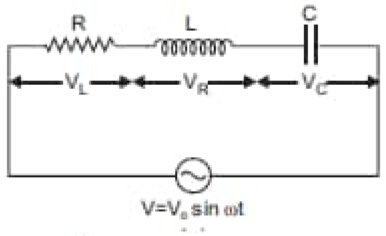
Output voltage, $V_0 = \frac{1350}{3}$ V = 450 V

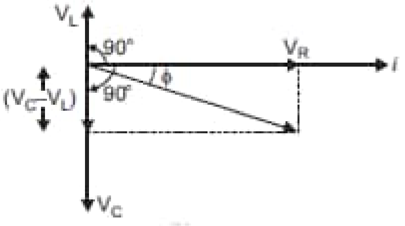
OR

Suppose a resistance R, inductance L and capacitance C in series. An alternating source of voltage $V = V_o \sin \omega t$ is applied across it. Since all the components are connected in series, the current flowing through all is same.

Voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C.

V_R and $(V_C - V_L)$ are mutually perpendicular and the phase difference between them is 90^o.





From the figure above, we have

$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2}$ ..... (i)

and V_R = Ri, V_C = X_C i and V_L = V_L i ..... (ii)

where $X_C = \frac{1}{\omega C}$ = capacitance reactance and X_L = ωL = inductive reactance

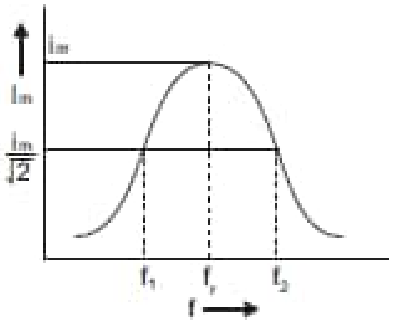
$\therefore \quad V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$

$\therefore$ Impendance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e. $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$

The phase difference between current and voltage is given by,

$\tan \phi = \frac{X_C - X_L}{R}$



From the graph, we can see that with increase in frequency, current first increases and then decreases. At resonant frequency, current amplitude is maximum.