Class XII Session 2026-27
Subject - Physics
Sample Question Paper - 8

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 a potential barrier in a p-n junction diode **[1]**

   a) increases
   b) remains constant
   c) first remains constant then decreases
   d) decreases

2. A student measures the terminal potential difference (V) of a cell (of emf ε and internal resistance r) as a function of the current (l) flowing through it. The slope, and intercept, of the graph between V and l, then, respectively, equal: **[1]**

   a) -r and ε
   b) ε and -r
   c) -ε and r
   d) r and -ε

3. A beaker is filled with water(refractive index $\frac{4}{3}$) upto a height H. A coin is placed at its bottom. The depth of the coin, when viewed along the near normal direction, will be **[1]**

   a) $\frac{4H}{3}$
   b) H
   c) $\frac{H}{4}$
   d) $\frac{3H}{4}$

4. Which of the following is a diamagnetic substance? **[1]**

a) Copper chloride

b) Sodium

c) Gadolinium

d) Sodium chloride

5. If the plates of a capacitor are joined together by a conducting wire, then its capacitance **[1]**

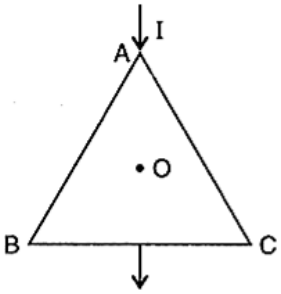
a) Remains unchanged

b) Becomes zero

c) Decreases

d) Becomes infinite

6. An equilateral triangle is made by uniform wires AB, BC, CA. A current I enteres at A and leaves from the mid-point of BC. If the lengths of each side of the triangle is L, the magnetic field B at the centroid O of the triangle is: **[1]**



a) $\frac{\mu_0}{4\pi}\left(\frac{4I}{L}\right)$

b) zero

c) $\frac{\mu_0}{2\pi}\left(\frac{4I}{L}\right)$

d) $\frac{\mu_0}{4\pi}\left(\frac{2I}{L}\right)$

7. The induction coil works on the principle of **[1]**

a) mutual induction

b) Fleming's right-hand rule

c) self-induction

d) Ampere's rule

8. A bar magnet of pole strength (m) and magnetic moment (M) is cut perpendicular to its axis in two equal halves. The new pole strength (m') and magnetic moment (M') of each part are respectively: **[1]**

a) m and $\frac{M}{2}$

b) m and M

c) 2m and $\frac{M}{2}$

d) $\frac{m}{2}$ and 2M

9. The shape of the wavefront of the portion of the wavefront of light from a distant star intercepted by the earth is **[1]**

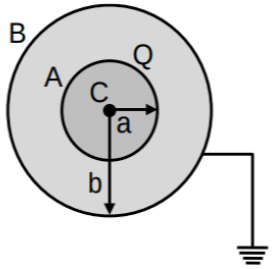
a) conical

b) hyperboloid

c) plane

d) spherical

10. A conducting sphere A of radius a, with charge Q, is placed concentrically inside a conducting shell B of radius b. B is earthed. C is the common centre of A and B. Study the following statements. **[1]**



(i) The potential at a distance r from C, where $a \leq r \leq b$ is $\frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{r}\right)$

(ii) The potential difference between A and B is $\frac{1}{4\pi\varepsilon_0}Q\left(\frac{1}{a}-\frac{1}{b}\right)$

(iii)The potential at a distance r from C, where $a \leq r \leq b$, is $\frac{1}{4\pi\varepsilon_0}Q\left(\frac{1}{r}-\frac{1}{b}\right)$

Which of the following statements are correct?

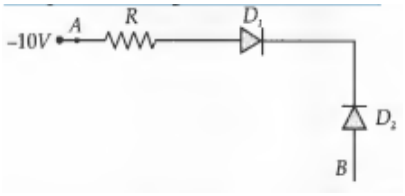
a) Only (i) and (ii)

b) Only (ii) and (iii)

c) All of these

d) Only (i) and (iii)

11. In the given Fig., assuming the diodes to be ideal, **[1]**



a) D_1 and D_2 are both forward biased and hence current flows from A to B.

b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.

c) D_1 and D_2 are both reverse biased and hence no current flows from A to B and vice versa.

d) D_1 is forward biased and D_2 is reverse biased and hence current flows from A to B

12. The minimum distance between an object and its real image formed by a convex lens of focal length f is: **[1]**

a) 3f

b) 4f

c) 2f

d) f

13. **Assertion (A):** An electron microscope is based on de Broglie hypothesis. **[1]**
Reason (R): A beam of electrons behaves as a wave that can be converted by electric and magnetic lenses.

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 parallel metal plates having charge +Q and -Q are facing at a distance between them. The plates are now immersed in kerosene oil and the electric potential between the plates decreases. **[1]**
Reason (R): Dielectric constant of kerosene oil is less than 1.

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):** A narrow pulse of light is sent through a medium. The pulse will retain its shape as it travels through the medium. **[1]**

Reason (R): A narrow pulse is made of harmonic waves with a large range of wavelengths.

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 (A):** The dc and ac both can be measured by a hot wire instrument. **[1]**
Reason (R): The hot wire instrument is based on the principle of magnetic effect of current.

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

17. The oscillating electric field of an electromagnetic wave is given by: **[2]**
$E_y = 30 \sin\left[2 \times 10^{11} t + 300\pi x\right] Vm^{-1}$

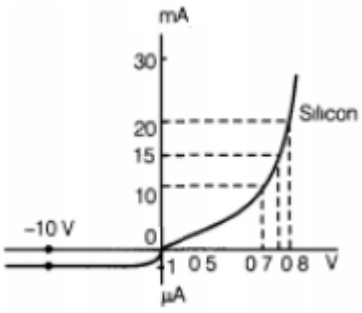
a. Obtain the value of the wavelength of the electromagnetic wave.

b. Write down the expression for the oscillating magnetic field.

18. The V-I characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at **[2]**

a. I_D = 15 mA and

b. V_D = -10V



19. Draw the energy level diagram for hydrogen atom. Mark the transitions corresponding to the series lying in the ultraviolet region, visible region and infrared region. **[2]**

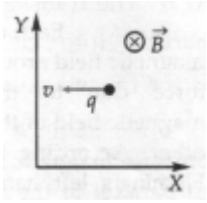
20. A magnet of magnetic moment 2.5 Am^2 weighs 66 g. If the density of the material of the magnet is 7500 kgm^{-3}, find the intensity of magnetisation. **[2]**

OR

Two equal and unlike poles placed 5 cm apart in the air attract each other with a force of 14.4×10^{-4} N. How far from each other should they be placed so that the force of attraction will be 1.6×10^{-4} N?

21. a. A point charge q moving with speed v v enters a uniform magnetic field B that is acting into the plane of the paper as shown. What is the path followed by **[2]**

the charge q and in which plane does it move?



b. How does the path followed by the charge get affected if its velocity has a component parallel to B?

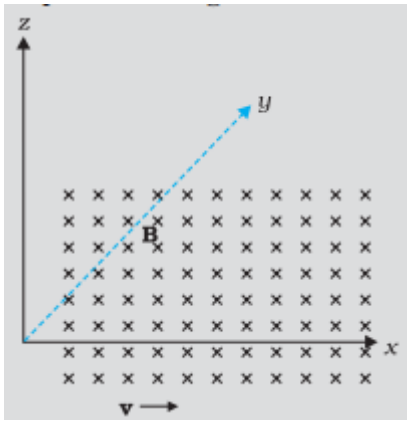
c. If an electric $\vec{E}$ is also applied such that the particle continues moving along the original straight line path, what would be the magnitude and direction of the electric field $\vec{E}$?

OR

If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis (Fig.), which way would the Lorentz force be for

a. an electron (negative charge),

b. a proton (positive charge).



Section C

22. A cell of emf ε and internal resistance r is connected across a variable resistance R. Plot graphs showing the variation of **[3]**

i. ε and R,

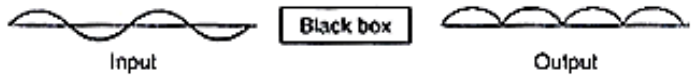
ii. terminal p.d. V with R. Predict from the second graph under which V becomes equal to ε.

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. The black box, shown here, converts the input voltage waveform into the output voltage waveform as is shown in the figure: **[3]**



Draw the circuit diagram of the circuit present in the black box and give a brief description of its working.

25. Define multiplication factor and critical size for a fissionable material. Give their **[3]**

significance.

26. Write down the expression for the radii of orbits of the hydrogen atom. Calculate the radius of the smallest orbit. **[3]**

27. 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. **[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.

28. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light? Refractive index of water is 1.33. **[3]**

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 $\varepsilon = 4$. 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.

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

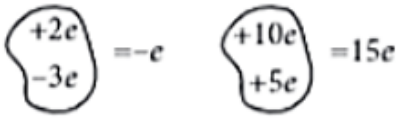
a) γ-rays

b) β-rays

c) X-rays

d) cosmic rays

30. The smallest charge that can exist in nature is the charge of an electron. During friction, it is only the transfer of electrons that makes the body charged. Hence net charge on anybody is an integral multiple of the charge of an electron [1.6×10^{-19} C] i.e. **[4]**



$q = \pm ne$

where n = 1, 2, 3, 4,...

Hence nobody can have a charge represented as 1.1e, 2.7e, $\frac{3}{5}$e, etc.

Recently, it has been discovered that elementary particles such as protons or neutrons are composed of more elemental units called quarks.

i. If a charge on a body is 1 nC, then how many electrons are present on the body? (1)

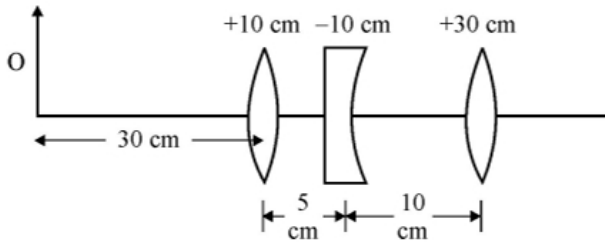
ii. If a body gives out 10^9 electrons every second, how much time is required to get a total charge of 1 C from it? (1)

iii. A polythene piece rubbed with wool is found to have a negative charge of 3.2×10^{-7} C. Calculate the number of electrons transferred. (2)

Section E

31. a. 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]**

b. 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. Sketch the refracted wavefront for the incident plane wavefront of light from a distant object passing through a convex lens.

b. Using Huygens' principle, verify the laws of refraction when light from a denser medium is incident on a rarer medium.

c. For yellow light of wavelength 590 nm incident on a glass slab, the refractive index of glass is 1.5. Estimate the speed and wavelength of yellow light inside the glass slab.

32. a. If two similar large plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance d in air, then find the expression for **[5]**

i. the field at points between the two plates and on the outer side of the plates. Specify the direction of the field in each case.

ii. the potential difference between the plates.

iii. the capacitance of the capacitor so formed.

b. Two metallic spheres of radii R and 2R are charged so that both of these have the same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why?

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. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wirelines carrying power is 0.5 Ω per km. The town gets power from the line through a 4000 - 220 V step-down transformer at a sub-station in the town. **[5]**

a. Estimate the line power loss in the form of heat.

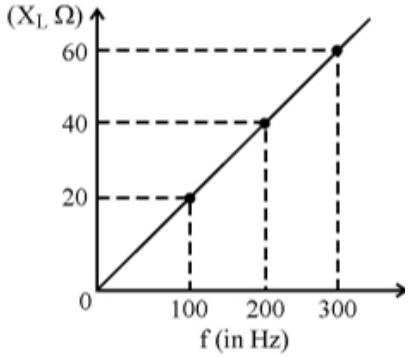
b. How much power must the plant supply, assuming there is negligible power loss due to leakage?

c. Characterize the step-up transformer at the plant.

OR

a. Show that an ideal inductor does not dissipate power in an ac circuit.

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.

Solution

Section A

1.

(d) decreases

Explanation:

In forward biasing, the width of the potential barrier decreases.

2. **(a)** -r and ε

Explanation:

$V = \varepsilon - Ir$

or $V = -rI + \varepsilon$

On comparing with $y = mx + c$, we get slope = -r and intercept = ε

3.

(d) $\frac{3H}{4}$

Explanation:

$\frac{3H}{4}$

4.

(d) Sodium chloride

Explanation:

Sodium chloride

5.

(d) Becomes infinite

Explanation:

When the plates of a capacitor are connected by a conducting wire, they effectively become a single conductor. This means there is no potential difference between the plates, as they are at the same electric potential. In this scenario, the capacitance, which is defined as the ability to store charge per unit voltage, becomes infinite because any amount of charge can be stored without any voltage across the plates.

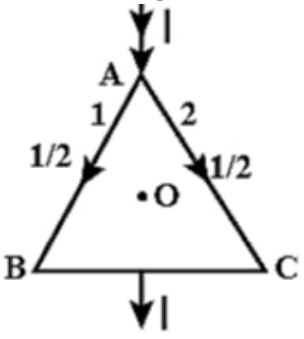
Thus, the correct answer is that the capacitance becomes infinite.

6.

(b) zero

Explanation:

Equal current flows in part 1 and 2 of triangular loop as shown in the figure. As both part of the triangular loop is symmetric about point O, so magnetic field at O due to both parts is equal and opposite to each other. Thus magnitude of magnetic field at O due to part 1 cancel out the magnitude of magnetic field at O due to part 2. Hence net magnetic field at O is zero.



7. **(a)** mutual induction
Explanation:
The induction coil works on the principle of mutual induction.

8. **(a)** m and $\frac{M}{2}$
Explanation:
M = m(2l)
M' = ml
M' = $\frac{M}{2}$
So, pole strength will be m and $\frac{M}{2}$.

9. **(c)** plane
Explanation:
Stars are very far away from earth. Near the star the shape is spherical but by the time its light reaches earth, the portion of the wavefront is plane due to increase in radius.

10. **(b)** Only (ii) and (iii)
Explanation:
The solution identifies statements (ii) and (iii) as correct based on the principles of electrostatics and the behavior of conductors. For statement (i), the potential at a distance r from the center C for $a \leq r \leq b$ is incorrectly stated. The potential in this region is influenced by both the charge Q on sphere A and the induced charge on the conducting shell B. The correct expression should account for the potential due to both the inner sphere and the outer shell, which is not represented in statement (i). Statement (ii) correctly calculates the potential difference between the conducting sphere A and the conducting shell B. The formula reflects the contributions from both conductors, taking into account their respective distances from the center. Statement (iii) also correctly describes the potential at a distance r from C in the region between the two conductors. It includes the effect of the induced charge on the shell, which is necessary for an accurate representation of the potential in that region.
Thus, statements (ii) and (iii) are valid, while statement (i) is not, leading to the conclusion that only (ii) and (iii) are correct.

11. **(b)** D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.
Explanation:
In circuit, A is at -10V and B is at 0V. So B is positive than A. So D_2 is in forward bias and D_1 is in reverse bias so no current flows from A to B or B to A.

12. **(b)** 4f
Explanation:
4f

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

Assertion and reason both are correct statements and reason is correct explanation for assertion.

14.

(c) A is true but R is false.

Explanation:

Electric field for parallel plate capacitor in vacuum $= E = \frac{\sigma}{\varepsilon_0}$

Electric field in dielectric $= E' = \frac{\sigma}{\kappa\varepsilon_0}$

Since, the value of κ for Kerosene oil is greater than 1, then $E' < E$ and hence $V' < V$. Hence, the assertion is true.

Dielectric constant of Kerosene oil is greater than 1. Hence, the reason is false.

15.

(d) A is false but R is true.

Explanation:

A narrow pulse is made of harmonic waves with a large range of wavelengths. As speed of propagation is different for different wavelengths, the pulse cannot retain its shape while travelling through the medium.

16.

(c) A is true but R is false.

Explanation:

Both ac and dc produce heat, which is proportional to the square of the current. The reversal of direction of current in ac is immaterial so far as production of heat is concerned.

Section B

17. $E_y = 30\sin\left[2\times10^{11}t + 300\pi x\right]Vm^{-1}$

a. On comparing the given equation with $E_y = E_0 \sin(\omega t + kx)$, we get

$k = 300\pi = \frac{2\pi}{\lambda}$

$\Rightarrow \lambda = \frac{1}{150} = 6.7\times10^{-3}m$

b. The wave is propagating along X-axis, electric field is oscillating along Y-axis, so according to right hand system of (vector E, vector B, vector K), the magnetic field must oscillate along Z-axis.

On comparing the given equation with $E = E_0 \sin(\omega t + kx)$, we get,

$E_0 = 30$ V/m

Now, $B_0 = \frac{E_o}{c} = \frac{30}{3\times10^8} = 10^{-7}$ T

Thus, equation of oscillating magnetic field is

$B_z = B_0 \sin(\omega t + kx)$

$\Rightarrow B_z = (10^{-7})\sin\left[2\times10^{11}t + 300\pi x\right]T$

18. a. From the given curve, V = 0.8 volt for current 20 mA and V = 0.7 volt for current 10 mA,

$\Rightarrow \Delta I = (20-10)\text{mA}$

$\Rightarrow \quad \Delta I = 10mA = 10\times10^{-3}\text{A}$

$\Rightarrow \quad \Delta I = 10^{-2}\text{A}$

and $\Delta V = (0.8-0.7) = 0.1\text{V}$

Resistance of the diode is given by, $R = \frac{\Delta V}{\Delta I}$

$\Rightarrow R = \frac{0.1}{10^{-2}}$

$\Rightarrow R = 10\Omega$

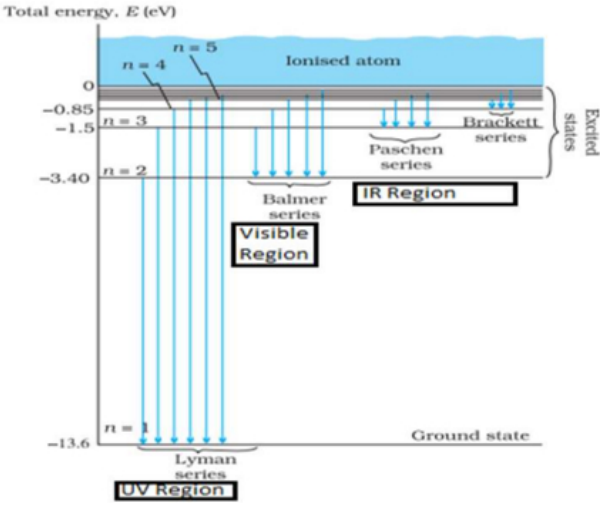
b. For V = -10V, we have

$I = -1\mu A = -1 \times 10^{-6} A$

resistance of diode is given by, R = $\frac{V}{I}$

$\Rightarrow \quad R = \frac{-10}{-1\times10^{-6}} = 1.0 \times 10^{7}\Omega$

19.



The above energy level diagram shows transitions corresponding to the series lying in the ultraviolet region, visible region and infrared region.

20. Volume,

V = $\frac{\text{Mass}}{\text{Density}} = \frac{66\times10^{-3}\text{ kg}}{7500\text{kgm}^{-3}} = \frac{66\times10^{-5}}{75}\text{ m}^3$

Magnetisation,

M = $\frac{m}{V} = \frac{\frac{2.5}{66\times10^{-5}}}{75} = \frac{2.5\times75\times10^{5}}{66}$

= 2.84×10^{5} Am^{-1}

OR

Distance between the poles = 5 cm

Force of attraction = 14.4×10^{-4} N

The force of attraction between two magnetic poles is given by the formula

F = $\frac{\mu_0}{4\pi}\frac{q_{m_1}q_{m_2}}{r^2}$ i.e., $F \propto \frac{1}{r^2}$

$\therefore \frac{F_1}{F_2} = \frac{r_2^2}{r_1^2}$

$r^2 = \sqrt{\frac{F_1}{F_2}} \cdot r_1 = \sqrt{\frac{14.4\times10^{-4}}{1.6\times10^{-4}}} \times 5 \times 10^{-2}$

= 0.15 m

21. a. The charge q moves in the XY plane describing a circular path in the anticlockwise sense.

b. The path of the charged particle will become helical.

c. By Fleming's left hand rule, the magnetic Lorentz force acts on charge q in -Y direction

∴Applied electric field should be in the + Y direction to make the charged particle move along the original straight line path.

$F_e = F_m$

$qE = qvB\sin 90^\circ \quad \text{or} \quad E = vB$

OR

The velocity v of the particle is along the x-axis, while B, the magnetic field is along the y-axis, so v × B is along the z-axis (screw rule or right-hand thumb rule). So, depending upon the charge force is given by:

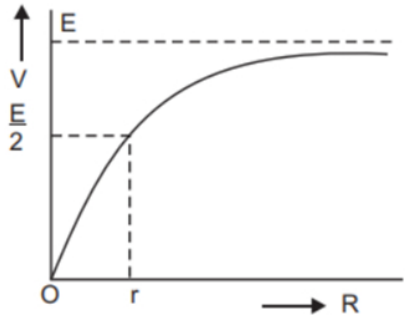
a. for electron it will be along –z axis.

b. for a positive charge (proton) the force is along +z axis.

Section C

22. When R $\rightarrow$ 0, V = 0 When R = r, V = $\frac{E}{2}$ When R = ∞, V = E

The graph is shown in fig.



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$\frac{c}{\lambda}$

= $\frac{6.63\times10^{-34}\times3\times10^{8}}{200\times10^{-9}}$

= 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$\frac{c}{\lambda}$

= $\frac{6.63\times10^{-34}\times3\times10^{8}}{6328\times10^{-10}}$

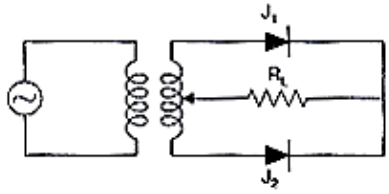
= 0.00314 $\times 10^{-16}$ J

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

Energy of red light < work function of metal surface

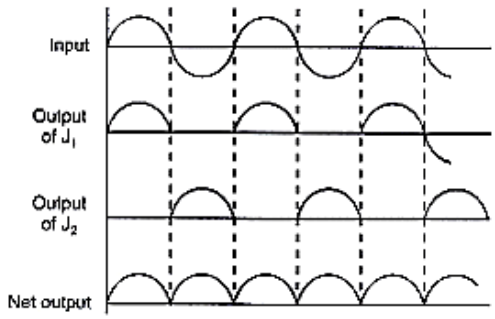
$\therefore$ No emission of photoelectrons takes place.

24. Circuit diagram present in black box is drawn in figure.



It is full wave rectifier. For half cycle of the applied input a.c., one junction diode conducts and other does not conduct to work as half wave rectifier. Similarly for another half cycle, the other junction diode conducts and the first one does not conduct to work is another half wave rectifier, hence the complete applied a.c. input is rectified which is drawn across the load resistance R_L.

The input and output waveform diagram is shown in the given figure.



25. **Multiplication factor:** Whether a chain reaction, once started in a fissionable mass, will remain steady, increase or decrease, depends on a parameter called multiplication factor. The

multiplication factor of a fissionable mass is defined as the ratio of the number of neutrons present at the beginning of a particular generation to the number of neutrons present at the beginning of the previous generation. Thus

$$k = \frac{\text{Number of neutrons present at the beginning of one generation}}{\text{Number of neutrons present at the beginning of previous generation}}$$

The multiplication factor k gives a measure of the growth rate of the neutrons in a fissionable mass.

If k > 1, the chain reaction grows.

If k = 1, the chain reaction remains steady.

If k < 1, the chain reaction gradually dies out.

Critical size and critical mass. Whether the mass of a fissionable material can sustain a chain reaction or not, depends on its multiplication factor. This, in turn, depends on the size of the material. The size of the fissionable material for which the multiplication factor k = 1, is called **critical size** and its mass is called critical mass. The chain reaction in this case remains steady or sustained.

If k > 1, the neutron population increases exponentially with time and the size of the material is said to be supercritical. The chain reaction builds up at a fast rate and results in an explosion.

If k < 1, the neutrons population decreases exponentially with time and the size of the material is said to be subcritical. The chain reaction gradually comes to an end.

26. The radius of the nth orbit of a hydrogen atom is given by $r = \frac{n^2h^2}{4\pi^2mke^2}$

Radius of the innermost orbit, called Bohr's radius, is obtained by putting n = 1 It is denoted by r_0

$$\therefore \quad r_0 = \frac{h^2}{4\pi^2mke^2}$$

$$= \frac{\left(6.6\times10^{-34}\right)^2}{4\pi^2\times9.1\times10^{-31}\times9\times10^9\times\left(1.6\times10^{-19}\right)^2}\ \text{m}$$

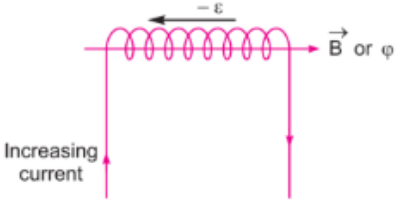
- 0.53×10^{10} m = 0.53 $\dot{A}$.

27. 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

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

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) = {tex}\frac {d\phi}{dt} = \frac {B\pi l^2}{T} = B\pi l^2 \nu{/tex} ($\because \nu = \frac{1}{T}$)

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,

$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

28. Given, $\lambda = 589nm$

$c = 3 \times 10^8 m/s, \mu = 1.33$

a. For reflected light,

Wavelength $\lambda = 589nm = 589 \times 10^{-9}m$

$\nu = \frac{c}{\lambda} = \frac{3\times10^8}{589\times10^{-9}}$

$= 5.09 \times 10^{14} Hz$

Hence, the speed, frequency, and wavelength of the reflected light are 3×10^8 m/s, 5.09×10^{14} Hz, and 589 nm respectively.

b. Frequency of light does not depend on the property of the medium in which it is travelling. Hence, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

$v = \frac{c}{\mu}$

$v = \frac{3\times10^8}{1.33} = 2.26 \times 10^8 \text{m/s}$

Wavelength of light in water is given by the relation,

$\lambda = \frac{c}{\nu}$

$= \frac{2.26\times10^8}{5.09\times10^{14}}$

$= 444.007 \times 10^{-9}\text{m} = 444.01\ nm$

Hence the speed, frequency and wavelength of refracted light are 2.26×10^8 m/s, 5.09×10^{14} Hz and 444.01 nm respectively.

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.

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

Explanation:

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

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

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

Explanation:

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

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

(c) **(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,

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

(d) **(b)** β-rays

Explanation:

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

30. i. Charge on the body is q = ne

$\therefore$ No. of electrons present on the body is $n = \frac{q}{e} = \frac{1\times10^{-9}C}{1.6\times10^{-19}C} = 6.25 \times 10^9$

ii. Here, $n = 10^9$ electrons per second

The charge given per second, $q = ne = 10^9 \times 1.6 \times 10^{-19}$ C

$q = 1.6 \times 19^{-10}$ C

Total charge, Q = 1 C ...(given)

$\therefore$ Time required = $\frac{Q}{q} = \frac{1}{1.6\times10^{-10}} s = 6.25 \times 10^9$ s

$\therefore \frac{6.25\times10^9}{3600\times24\times365}$ year = 198.19 years

iii. As q = ne, $n = \frac{3.2\times10^{-7}}{1.6\times10^{-19}}$

$\Rightarrow n = 2 \times 10^{12}$ electrons

$\therefore$ the number of electrons transferred will be 2×10^{12}

Section E

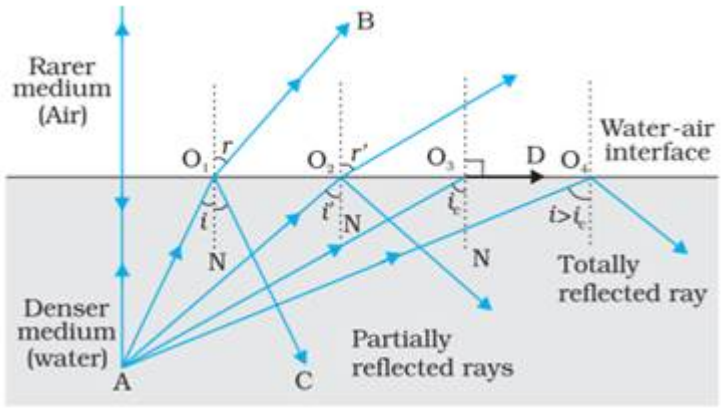
31. a. The conditions for total internal reflection are:

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.

b. 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

$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$

$\frac{1}{-10} = \frac{1}{v_2} - \frac{1}{10}$

$\Rightarrow v_2 = \infty$

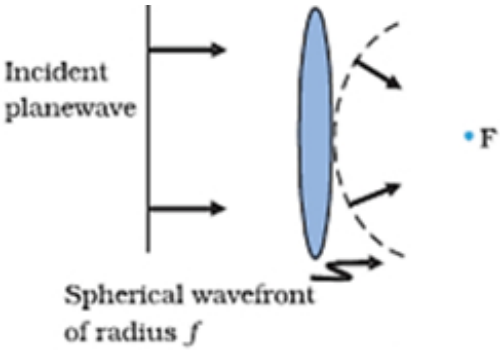
For third lens,

$\frac{1}{f_3} = \frac{1}{v_3} - \frac{1}{u_3}$

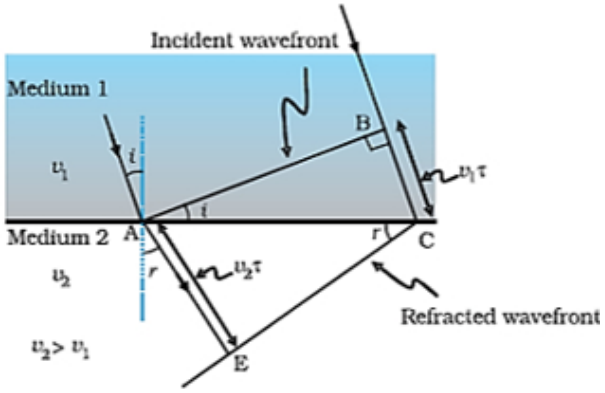
$\frac{1}{30} = \frac{1}{v_3} - \frac{1}{\infty} \Rightarrow v_3 = 30$ cm

OR

a.



b.



In right triangle ABC

$\sin i = \frac{BC}{AC}$

In $\triangle AEC \sin r = \frac{AE}{AC}$

$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1\tau}{v_2\tau} = \frac{v_1}{v_2} = \mu$

c. Speed of yellow light inside the glass slab

$v = \frac{c}{\mu}$

$= \frac{3\times10^8}{1.5}$ m/s

$= 2 \times 10^8$ m/s

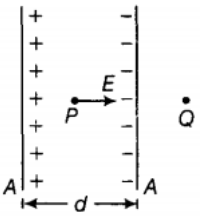
Wavelength of yellow light inside the glass slab

$\lambda' = \frac{\lambda}{\mu}$

$= \frac{590}{1.5}$ nm

= 393.33 nm

32. a. Consider the figure shown below:



i. Electric field due to the plate of the positive charge of charge density $+\sigma$ at point P, is given by

$E_1 = \sigma/2\varepsilon_0$

Magnitude of electric field due to the other plate of negative charge density $-\sigma$,is given by

$E_2 = -\sigma/2\varepsilon_0$

In , the inner region between the plates 1 and 2 , electric field due to the two charged plates add up, is given by

$E_{net} = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

Outside the plate, electric field will be equal to zero because of the opposite directions of the electric fields E_1 and E_2 there.

ii. Potential difference between the plates of the capacitor is given by

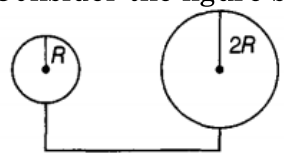
$V = Ed = \sigma d/\varepsilon_0$ ($\because E = \sigma/\varepsilon_0$)

iii. Capacitance of the capacitor is given by

($\because Q = CV$)

$C = \frac{Q}{V} = \frac{\sigma A}{\sigma d}\varepsilon_0 = \frac{\varepsilon_0 A}{d}$

b. Consider the figure shown below:



Potential at the surface of the sphere of radius R,

{tex}= \frac { k q } { R } \quad \left[\because q = \sigma \times 4πR ^ { 2 } \right]{/tex}

$= \quad \frac{k\sigma 4\pi R^2}{R} = \sigma k 4\pi R = 4k\sigma\pi R$

Potential at the surface of the second sphere of radius twice the previous one i.e. 2R,

$= \frac{kq}{2R} \quad \left[\because q = \sigma \times 4\pi(2R)^2 = 16\sigma\pi R^2\right]$

$= \frac{k16\sigma\pi R^2}{2R} = 8k\sigma\pi R$

We know that charge always flows from the higher potential surface to lower potential surface. Since the potential of the bigger sphere is more, so charge will flow from sphere of radius 2R to the sphere of radius R after connecting both the spheres by a conducting wire

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,

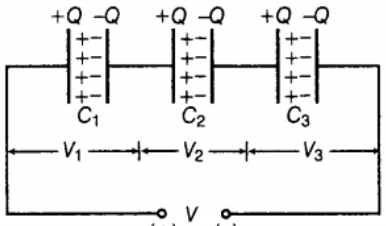
dW = Vdq = $\frac{q}{C}dq$

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

$\therefore$ 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* $V_3 = \frac{q}{C_3}$

$\therefore$ 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. Total electric power required,

Supply voltage, V = 220 V

The voltage at which electric plant is generating power, V' = 440 V

Distance between the town and power generating station, d = 15 km

The resistance of the two-wire lines carrying power = 0.5 Ω/km

Total resistance of the wires, R = (15 + 15) 0.5 = 15 Ω

A step-down transformer of rating 4000 - 220 V is used in the sub-station.

Input voltage is , V_1 = 4000 V

Output voltage is, V_2 = 220 V

Rms current in the wire lines is given as:

$I = \frac{P}{V_1}$

$= \frac{800 \times 10^3}{4000}$ = 200 A

a. Line power loss in the form of heat is given by = I^2R

$= (200)^2 \times 15$

$= 600 \times 10^3$ W

= 600 KW

b. Assuming that the power loss is negligible due to the leakage of the current:

hence Total power supplied by the plant = 800 KW + 600 KW

= 1400 KW

c. Voltage drop in the power line is given by = IR = 200 × 15 = 3000 V

Hence, total voltage transmitted by the plant = 3000 + 4000

= 7000 V

Hence, the rating of the step-up transformer situated at the power plant is 440 V - 7000 V.

OR

a. Power dissipation = P = V_{rms} I_{rms} cos ϕ

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

For ideal inductor R = 0

$\therefore$ cos ϕ = 0

$\therefore$ P = V_{rms} I_{rms} cos ϕ = 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 Ω

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

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

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