Class XII Session 2026-27
Subject - Physics
Sample Question Paper - 3

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

General Instructions:

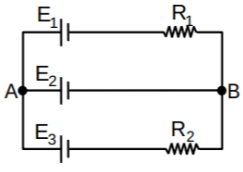
1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark 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 a p-type semiconductor, the majority carriers of current are **[1]**

   a) holes
   b) electrons
   c) protons
   d) neutrons

2. In the circuit shown here, $E_1 = E_2 = E_3 = 2\ V$ and $R_1 = R_2 = 4\Omega$. The current flowing between points A and B through battery E_2 is: **[1]**



   a) $2A$ from B to A
   b) None of these
   c) 2 A from A to B
   d) Zero

3. The layered lens is made of two kinds of glass. A point source of light is placed on its principal axis. If the reflections from the boundaries between layers are ignored, the lens will form **[1]**

   a) two images
   b) no image at all
   c) only one image
   d) infinite images

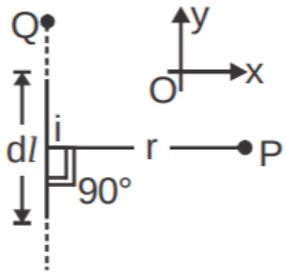
4. Which of the following pairs is that of paramagnetic materials? **[1]**

a) Copper and Aluminium
b) Lead and Iron
c) Sodium and Calcium
d) Nickel and Cobalt

5. Two neutrons are placed at some distance apart from each other. They will : **[1]**

a) Attract each other
b) Repel each other
c) Neither attract nor repel each other
d) Cannot say

6. Find the magnetic field due to a current element having $i = 10\ A$ and $dl = 2\ mm$ at P and Q. Put ($r = 1\ m$). **[1]**



a) $(0, 0)$
b) $\left(2 \times 10^{-9}\ T, 0\right)$
c) $\left(2 \times 10^{-9}\ T, 2 \times 10^{-9}\ T\right)$
d) $\left(0, 2 \times 10^{-9}\ T\right)$

7. Whenever the flux linked with a circuit changes, there is an induced emf in the circuit. This emf in the circuit lasts **[1]**

a) for a long duration
b) forever
c) as long as the magnetic flux in the circuit changes.
d) for a very short duration

8. The ratio of magnetic fields due to a small bar magnet in the end on position to the broad side on position is **[1]**

a) 1 : 4
b) 1 : 2
c) 2 : 1
d) 1 : 1

9. The intensity ratio of the maxima and minima in an interference pattern produced by two coherent sources of light is 9 : 1. The intensities of the used light sources are in the ratio: **[1]**

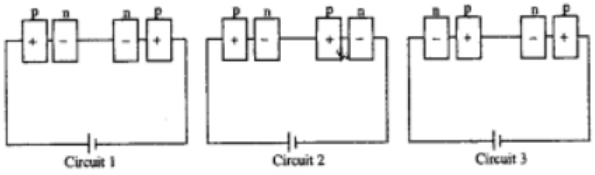
a) 3 : 1
b) 9 : 1
c) 10 : 1
d) 4 : 1

10. An electron is moving round the nucleus of a hydrogen atom in a circular orbit of radius r. The Coulomb force $\vec{F}$ between the two is: **[1]**

a) $-\kappa\frac{e^3}{r^3}\hat{r}$
b) $-\kappa\frac{e^2}{r^3}\vec{r}$
c) $\kappa\frac{e^2}{r^3}\vec{r}$
d) $\kappa\frac{e^2}{r^3}\hat{r}$

11. Two identical p-n junctions may be connected in series with a battery in three ways as **[1]**

shown. The potential drops across the two p-n junctions are equal in



a) circuit 3 only
b) circuit 1 only
c) circuit 1 and 2
d) circuit 2 and 3

12. A point object is placed in air at a distance of 4R on the principal axis of a convex spherical surface of radius of curvature R separating two mediums, air and glass. As the object is moved towards the surface, the image formed is: **[1]**

a) always real
b) first real and then virtual
c) always virtual
d) first virtual and then real

13. **Assertion (A):** The photoelectrons produced by a monochromatic light beam incident on a metal surface, have a spread in their kinetic energies. **[1]**
Reason (R): The work function of the metal varies as a function of depth from the surface.

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):** Electric field inside a conductor is zero. **[1]**
Reason (R): The potential at all the points inside a conductor is same.

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):** Coloured spectrum is seen when we look through a muslin cloth. **[1]**
Reason (R): Coloured spectrum is due to diffraction of white light passing through fine slits made by fine threads in the muslin cloth.

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):** If the frequency of the alternating current in an ac circuit consisting of an inductance coil is increased then the current gets decreased. **[1]**
Reason (R): The current is inversely proportional to the frequency of the alternating 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.

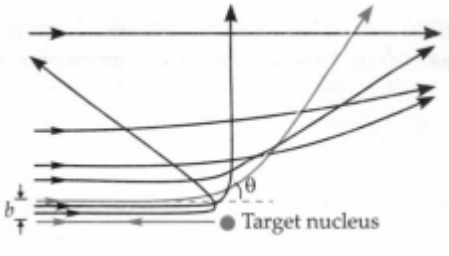
Section B

17. Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. **[2]**

Give its two applications.

18. 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]**

19. The trajectories, traced by different α-particles, in Geiger-Marsden experiment were observed as shown in Fig. **[2]**



What names are given to the symbols **b** and θ shown here?

What can we say about the values of b for (i) $\theta = \mathbf{0^o}$ and (ii) $\theta \simeq \pi$ radians?

20. Find the percent increase in the magnetic field B when the space within a current-carrying toroid is filled with aluminium. The susceptibility of aluminium is 2.1×10^{-5}. **[2]**

OR

Assume that each iron atom has a permanent magnetic moment equal to 2 Bohr magnetons (1 Bohr magneton = 9.27×10^{-24} Am^2). The number density of atoms in iron is 8.52×10^{28} m^{-3}.

i. Find the maximum magnetisation M in a long iron bar.

ii. Find the maximum magnetic induction B in the bar.

21. Two long, straight, parallel conductors carry steady currents in opposite directions. Explain the nature of the force of interaction between them. Obtain an expression for the magnitude of the force between the two conductors. Hence define one ampere. **[2]**

OR

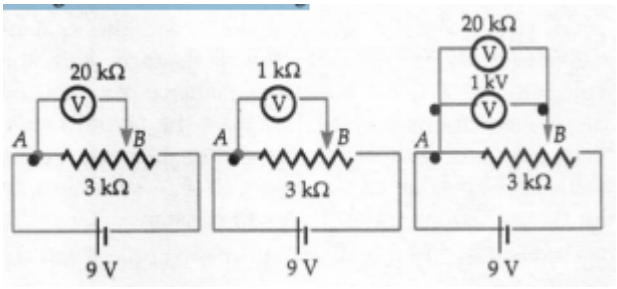
a. battery of emf 9 V and negligible internal resistance is connected to a 3k Ω resistor. The potential drop across a part of the resistor (between points A and B in Fig. is measured by

i. a 20 k Ω voltmeter;

ii. a 1 kΩ voltmeter.

iii. both the voltmeters are connected across AB. In which case would you get the

1. highest,
2. lowest reading?



b. Do your answers to this problem alter if the potential drop across the entire resistor is measured ? What if the battery has non-negligible resistance?

Section C

22. a. Differentiate between electrical resistance and resistivity of a conductor. **[3]**

b. Two metallic rods, each of length L, area of cross A_1 and A_2, having resistivities ρ_1 and ρ_2 are connected in parallel across a d.c. battery. Obtain the expression for the effective resistivity of this combination.

23. The maximum kinetic energy of the photoelectrons emitted is doubled when the wavelength of light incident on the photosensitive surface changes from λ_1 to λ_2. Deduce expressions for the threshold wavelength and work function for the metal surface in terms of λ_1 and λ_2. **[3]**

24. Draw a circuit diagram of a p-n junction diode under forward bias and explain its working. **[3]**

25. a. Differentiate between nuclear fission and fusion. **[3]**

b. The fission properties of ${}_{94}Pu^{239}$ are very similar to those of ${}_{92}U^{235}$. How much energy (in MeV), is released if all the atoms in 1 g of pure ${}_{94}Pu^{239}$ undergo fission? The average energy released per fission is 180 MeV.

26. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What are the radii of the n = 2 and n = 3 orbits? **[3]**

27. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of the same length wound one over the other. **[3]**

OR

Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns.

28. a. Define a wavefront. Using Huygens' geometrical construction, explain with the help of a diagram how the plane wavefront travels from the instant t_1 to t_2 in air. **[3]**

b. A plane wavefront is incident on a convex lens. Explain, with the help of the diagram, the shape of the refracted wavefront formed.

Section D

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

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(a) The electromagnetic waves propagated perpendicular to both $\vec{E}$ and $\vec{B}$. The electromagnetic waves travel in the direction of

a) $\vec{E} \cdot \vec{B}$ b) $\vec{B} \times \vec{E}$

c) $\vec{B} \cdot \vec{E}$ d) $\vec{E} \times \vec{B}$

(b) Fundamental particle in an electromagnetic wave is

a) proton b) photon

c) phonon d) electron

(c) Electromagnetic waves are transverse in nature is evident by

a) polarisation b) diffraction

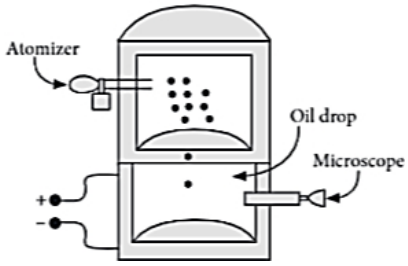
c) reflection d) interference

(d) For a wave propagating in a medium, Name the property that is independent of the others.

a) wavelength b) all these depend on each other

c) velocity d) frequency

30. In 1909, Robert Millikan was the first to find the charge of an electron in his now-famous oil-drop experiment. 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. **[4]**



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. (1)

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? ($g = 10\ ms^{-2}$) (2)

iii. If in Millikan's oil drop experiment, charges on drops are found to be $8\mu C, 12\mu C, 20\mu C$, then what is the quanta of charge? (1)

Section E

31. a. Draw the ray diagram showing the refraction of light through a glass prism and hence obtain the relation between the refractive index μ of the prism, angle of prism and angle of minimum deviation. **[5]**

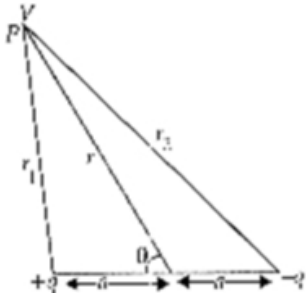
b. Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = \sqrt{2}$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation.

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. Derive an expression for potential due to a dipole for distances large compared to the size of the dipole. How is the potential due to dipole different from that due to a single charge? **[5]**



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

i. Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary to primary voltage in terms of the number of turns and currents in the two coils.
ii. A power transmission line feeds input power at 2200 V to a step-down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary to get the power output at 220 V.

Solution

Section A

1. **(a)** holes
   Explanation:
   In a p-type semiconductor, holes are the majority charge carriers.
2. **(d)** Zero
   Explanation:
   The solution is correct because the voltages from the batteries are equal, and the resistances are also equal. This means that the potential difference across the circuit is balanced, resulting in no net current flow between points A and B. Since the currents from the batteries cancel each other out, the current through battery E2 is zero.
3. **(c)** only one image
   Explanation:
   It is like a combination of two Plano – convex lenses. Therefore only one image is formed.
4. **(c)** Sodium and Calcium
   Explanation:
   Sodium and Calcium
5. **(a)** Attract each other
   Explanation:
   Neutrons are **neutral particles**, meaning they carry **no electric charge**, so:
   - **No electrostatic repulsion or attraction** occurs between them.

   However, neutrons are made of quarks and are subject to the **strong nuclear force**, which:
   - Acts between nucleons (protons and neutrons or two neutrons) when they are **very close** to each other - on the order of **femtometers (10^{-15} m)**.
   - Is a **short-range attractive force** that is stronger than any repulsive electromagnetic force in this range.

   So, when two neutrons are placed **very close together**, the **strong nuclear force causes an attraction**. However, if they are far apart (beyond the range of the strong nuclear force), **this attraction becomes negligible**. But since the question states they are at **some distance** (not infinitely far), and no repulsion is present, the best choice is:
6. **(b)** $\left(2 \times 10^{-9}\ T, 0\right)$
   Explanation:
   The solution is correct because it applies the Biot-Savart law, which states that the magnetic field $\mathbf{B}$ due to a current element $i\,dl$ at a point in space is proportional to the current, the length of the current element, and the sine of the angle between the current element and the line connecting the element to the point. In this case, the current $i = 10\,A$ and the length of the current element $dl = 2\,mm = 2 \times 10^{-3}\,m$. The distance $r = 1\,m$ is given, and the geometry of the setup indicates that the angle between the current element and the line to points P and Q is such that the sine function can be evaluated. Calculating the magnetic field at points P and Q using the appropriate components leads to a magnetic field of $(2 \times 10^{-9}\,T, 0)$ at point P, which matches the solution provided. The direction and

magnitude are consistent with the right-hand rule and the geometry of the current element. Thus, the answer is validated by the application of the Biot-Savart law and the specific conditions of the problem.

7.

(c) as long as the magnetic flux in the circuit changes.
Explanation:
as long as the magnetic flux in the circuit changes.

8.

(c) 2 : 1
Explanation:
2 : 1

9.

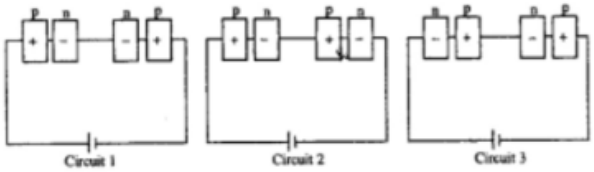
(d) 4 : 1
Explanation:
$\frac{I_{max}}{I_{min}} = \left(\frac{r+1}{r-1}\right)^2 = \frac{9}{1}$
$\Rightarrow \frac{r+1}{r-1} = 3$
$\Rightarrow$ r + 1 = 3r - 3
$\Rightarrow$ r = 2
$\therefore \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = r^2 = 4 : 1$

10.

(b) $-\kappa\frac{e^2}{r^3}\vec{r}$
Explanation:
Charge on an electron = -e
Charge on nucleus of hydrogen = +e
$\therefore \vec{F} = \kappa\frac{(-e)\times e}{r^2}\hat{r} = -\frac{ke^2}{r^3}\vec{r}$
Here $\hat{r} = \frac{\vec{r}}{r}$ is unit vector along the line joining electron to the nucleus. The negative sign shows that the force is of attraction.

11.

(d) circuit 2 and 3
Explanation:
The potential drop across the two p-n junctions, connected in series, are equal in circuit 2 and circuit 3. These two circuits are either forward biased or reverse biased in terms of the p-n junctions.



In circuit 1, the two p-n junctions are such that one is forward biased and the other is reverse biased.

12.

(b) first real and then virtual

Explanation:
First real and then virtual

13. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
Electrons being emitted as photoelectrons have different velocities. Actually, all the electrons do not occupy the same level of energy but they occupy continuous band and levels. So, electrons being knocked off from different levels come out with different energies. The work function is the energy required to pull the electron out of the metal surface. Naturally, electrons on the surface will require less energy to be pulled out hence will have lesser work function as compared with those deep inside the metal.
So, Both A and R are true and R is the correct explanation of A.

14. **(b)** Both A and R are true but R is not the correct explanation of A.
Explanation:
Both A and R are true but R is not the correct explanation of A.

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

16. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
When the frequency of the alternating current is increased, the effective resistance of the inductive coil increases. Current $X_L = \omega L = 2\pi f L$. As the inductive resistance of the inductor increases, the current in the circuit decreases.

Section B

17. Here it is given that, $\nu = 5 \times 10^{19}$ Hz
Now, we know that the wavelength is given by:
$\lambda = \frac{c}{v} = \frac{3\times10^8}{5\times10^{19}} = 6 \times 10^{-12}$ m
This wavelength corresponds to either gamma rays or X-rays. These are used:
i. For causing certain nuclear reactions, and
ii. For treatment of cancer

18. 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 $= I_{dc} \times R_L$
$= \frac{I_0}{\pi} \times R_L = \frac{V_{ms}}{\pi}$
$= \frac{32.53}{3.14} = 10.36V$

19. The symbol b represents impact parameter and θ represents the scattering angle.
i. When $\theta = 0^\circ$ the impact parameter b is large and the α -particle passes almost undeflected.
ii. When $\theta = \pi$ radians, the impact parameter b = 0 and the α -particle is reversed back along its original path.

20. In the absence of aluminium,
$B_0 = \mu_0 H$
In the presence of aluminium,

B = $\mu H = \mu_0 (1 + \chi_m) H$

Increase in magnetic field induction

= B - B_0 = $\mu_0 \chi_m H$

Percentage increase = $\frac{B - B_0}{B_0} \times 100$

= $\frac{\mu_0 \chi_m H}{\mu_0 H} \times 100$

= 2.1 $\times$ 10^{-5} $\times$ 100 = 2.1 $\times$ 10^{-3}

OR

i. Number of atoms per unit volume,

n = 8.52 $\times$ 10^{28} m^{-3}

The magnetic moment of each iron atom

= $2\mu_B$ = 2 $\times$ 9.27 $\times$ 10^{-24} Am^2

As magnetisation M is the magnetic moment per unit volume, so the maximum value of magnetisation is

$M_{max} = n \times 2\mu_B$ (when all the dipoles get aligned)

= $8.52 \times 10^{28} \times 2 \times 9.27 \times 10^{-24}$

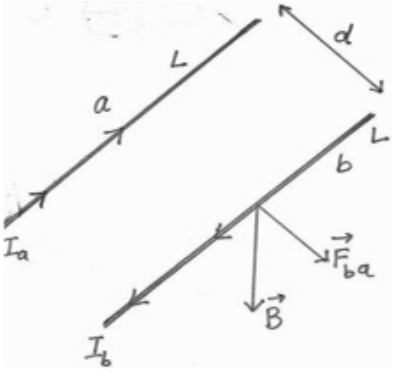
= 1.58 $\times$ 10^6 Am^{-1}

ii. Magnetic induction, B = μ_0(H + M)

As no magnetising field is applied, so H = 0. Hence

B = μ_0 M = $4\pi \times 10^{-7} \times 1.58 \times 10^6$ = 1.985 T

21. Nature of force is repulsive.



Magnetic field due to current I_a at all points of conductor b

$B_{ab} = \frac{\mu_0 I_a}{2\pi d}$ directed downwards

Force experienced by conductor b on its segment of length l

$F_{ab} = I_b l B_{ab}$

$= \frac{\mu_0 I_a I_b}{2\pi d} l$ directed towards left

Similarly

Force experienced by conductor a on its segment of length l

$F_{ba} = \frac{\mu_0 I_a I_b}{2\pi d} l$ directed towards right

One ampere is that steady current which when maintained in each of two very long straight parallel conductors of negligible cross- section, placed one metre apart in vacuum produces a force of 2×10^{-7} N/m on each conductor.

OR

a. The voltmeter, which has maximum resistance, will draw minimum current and allow maximum current to flow through resistor AB. Consequently, there will be maximum potential difference across AB.

In case (i), resistance of voltmeter, $R_y = 20\text{k}\Omega$

In case (ii), $R_V = 1\text{k}\Omega$

In case (iii), $\frac{1}{R_V} = \frac{1}{20} + \frac{1}{1} = \frac{1+20}{20}$ or $R_V = \frac{20}{21}\text{k}\Omega$

1. As the resistance of voltmeter is maximum in case (i), it will show maximum reading.
2. As the resistance of voltmeter is minimum in case (iii), it will show lowest reading.

b. In all cases, the voltmeter reading will be same if the battery has negligible internal resistance. But if the internal resistance is non-negligible, then the answers will be similar to those in (a).

Section C

22. a.

Electrical resistance	Resistivity
It is the property of material due to which it opposes the flow of electricity through the conductor.	The resistivity is defined as the resistance of a material of 1 metre length and 1 square metre area of cross section.
Unit : Ohm	Unit : Ohm-metre
Symbol : R	Symbol : ρ
Depends on length, cross-section area of conductor and temperature.	Depends on temperature and material of the conductor.

b. For resistor R_1,

Resistivity = ρ_1
Length = L
Area = A_1
$\therefore R_1 = \rho_1 \times \frac{L}{A_1}$

For resistor R_2,

Resistivity = ρ_2
Length = L
Area = A_2
$\therefore R_2 = \rho_2 \times \frac{L}{A_2}$

For the equivalent resistor,
Resistivity = ρ
Length = L
Area = A = $A_1 + A_2$
$\therefore R = \rho \times \frac{L}{A}$

Since, the resistors are connected in parallel,
Equivalent resistance $= R = \frac{R_1 R_2}{R_1 + R_2}$

or, $\rho \times \frac{L}{A} = \frac{\frac{\rho_1 L}{A_1} \times \frac{\rho_2 L}{A_2}}{\frac{\rho_1 L}{A_1} + \frac{\rho_2 L}{A_2}}$

$\therefore \rho$ = Effective resistivity $= \frac{\rho_1 \rho_2 (A_1 + A_2)}{\rho_1 A_2 + \rho_2 A_1}$

23. Given that
Initial kinetic energy of photoelectrons is given by = K_1

Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$

Wavelength of light changes from λ_1 to λ_2

Let the threshold frequency is ν_0 and work function is ϕ_0

Now, we know that:-

$\frac{hc}{\lambda} = \phi_0 + KE$

$\frac{hc}{\lambda_1} = \phi_0 + K_1$ ...(i)

$\frac{hc}{\lambda_2} = \phi_0 + K_2$ ...(ii)

$K_2 = 2K_1$

$\frac{hc}{\lambda_2} = \phi_0 + 2K_1$ ...(iii)

$\frac{2hc}{\lambda_1} = 2\phi_0 + 2K_1$ (eq (i) $\times$ 2)

$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \phi_0$

$\Rightarrow \phi_0 = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

We know

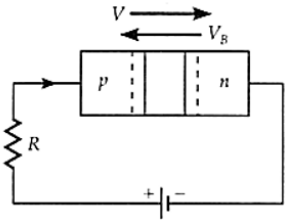
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$

$\frac{hc}{\lambda_0} = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

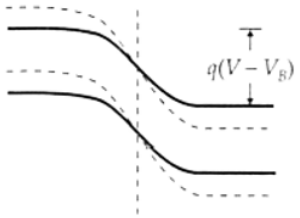
$\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

24. **Forward biasing:** If the positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the p-n junction is said to be forward-biased. As shown in figure(a), here the applied voltage V opposes the barrier voltage V_B. As a result of this



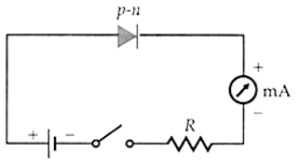
i. the effective barrier potential decreases to (VB - V) and hence the energy barrier across the junction decreases, as shown in the figure,



ii. the majority charge carries i.e., holes from the p-side and electrons from the n-side begin to flow towards the junction,

iii. the diffusion of electrons and holes into the depletion layer decreases its width, and

iv. the effective resistance across the p-n junction decreases.



25. a. In nuclear fission, a heavy nucleus splits into two or more lighter nuclei and energy is released.
In nuclear fusion, lighter nuclei combine together a form a heavy nucleus and larger amount of energy is released.

b. Number of atoms in 1 g of $_{94}Pu^{239}$

$= \frac{6.023 \times 10^{23}}{239}$

$= 2.5 \times 10^{21}$

Energy released in fission of 1 g of $_{94}Pu^{239}$,

$E = 180MeV \times 2.5 \times 10^{21}$

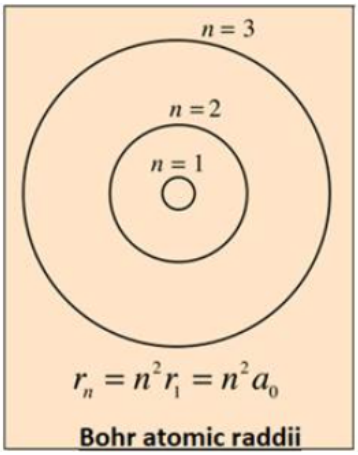
$E = 4.5 \times 10^{23} MeV$

26. Given, the radius of the innermost orbit, $r_1 = 5.3 \times 10^{-11}$ m

Then, let r_2 be the radius of an orbit at n = 2.

Then, $r_2 = (n)^2 r_1$

As shown in the diagram:



$\Rightarrow r_2 = 2^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow r_2 = 2.12 \times 10^{-10}$ m

For n = 3, we can write the corresponding electron radius as:

$\Rightarrow r_3 = (n)^2 r_1$

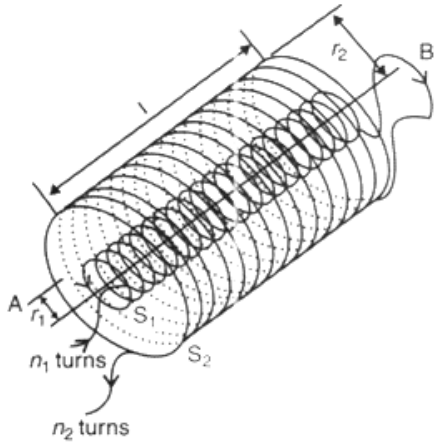
$\Rightarrow r_3 = 3^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow r_3 = 4.77 \times 10^{-10}$ m

Hence, the radii of an electron for n = 2 and n = 3 orbits are 2.12×10^{-10} m and 4.77×10^{-10} m

27. i. Mutual inductance is numerically equal to the induced emf in the secondary coil when the current in the primary coil changes by unity.

ii. in the question mutual inductance of two long coaxial solenoids of same length l wound one over the other is given by:-



Let a current l_2 flow in the secondary coil

$\therefore B_2 = \frac{\mu_0 N_2 i_2}{l}$

$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

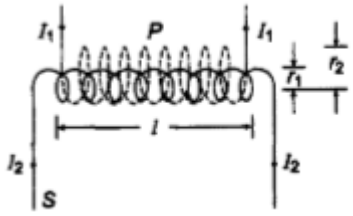
$= M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_1}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

OR

Let coaxial solenoid P is wound over an another solenoid.



Let l = length of both solenoid

r_1 and r_2 = radii of P and S

$A_2 = \pi r_2^2$ [area of secondary coil, S]

Magnetic induction in solenoid, P

$B_1 = \mu_0 n_1 I_1$

where, $n_1 = \frac{N_1}{l}$

∴Total flux linked with solenoid S,

$\phi_2 = B_1 A_2 N_2$

$\Rightarrow \quad \phi_2 = B_1 \left(\pi r_2^2\right) N_2 = \left(\mu_0 n_1 I_1\right) \pi r_2^2 N_2$

$\phi_2 = \left(\mu_0 \frac{N_1}{l} I_1\right) \pi r_2^2 N_2$

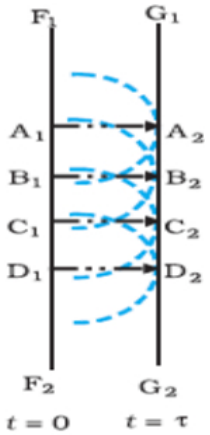
$\Rightarrow \quad \phi_2 = \frac{\mu_0 \pi I_1 N_1 N_2 r_2^2}{l}$ ...(i)

But $\phi_2 = MI_1$

were, M = coefficient of mutual induction

$\Rightarrow MI_1 = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l} I_1 \Rightarrow M = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l}$

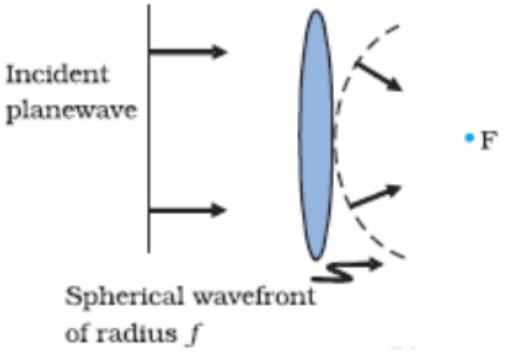
28. a. Wave front: It is the locus of the medium or points of a medium which are in the same phase of disturbance



Geometrical Construction:

The wave is propagating to the right. F_1F_2 is the plane wavefront at t = 0 & G_1G_2 is the wave front at a later time t, the lines A_1, A_2, B_1B_2...etc. are normal to both F_1F_2 and G_1G_2 represent rays. $A_1A_2 = B_1B_2 = c\tau$

b. Spherical Wave front



The central part of the incident plane wave traverses the thickest portion of the lens and is delayed the most. The emerging wavefront has a depression at the centre and hence the wavefront is spherical and converges to the point F known as the focus.

Section D

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

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(a) **(d)** $\vec{E} \times \vec{B}$

Explanation:

Electromagnetic waves propagate in the direction of $\vec{E} \times \vec{B}$.

(b) **(b)** photon

Explanation:

Photon is the fundamental particle in an electromagnetic wave.

(c) **(a)** polarisation

Explanation:

Polarisation establishes the wave nature of electromagnetic waves.

(d) **(d)** frequency

Explanation:

Frequency ν remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

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

The charge of this drop will be 6.4 $\times$ 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

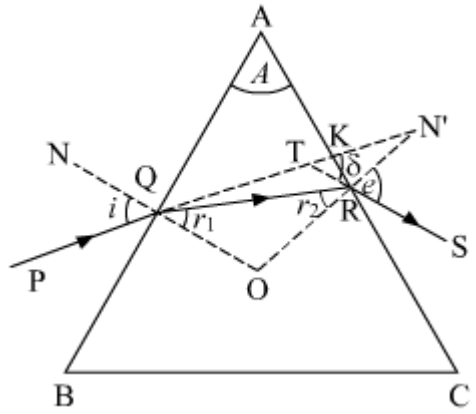
The number of electrons carried by the drop is

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

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



The angles of incidence and refraction at first face AB are $\angle i$ and $\angle r_1$

The angles of incidence at the second face AC is $\angle r_2$ and the angle of emergence $\angle e$

δ is the angle between the emergent ray RS and incident ray PQ and is called the angle of deviation.

Here, $\angle PQN = i$, $\angle SRN' = e$, $\angle RQO = r_1$, $\angle QRO = r_2$, $\angle KTS = \delta$

$\because \angle TQO = i$ and $\angle RQO = r_1$, we have

$\angle TQR = i - r_1$

$\angle TRO = e$ and $\angle QRO = r_2$

$\angle TRQ = e - r_2$

In triangle TQR, the side QT has been produced outwards. Therefore, the exterior angle δ should be equal to the sum of the interior opposite angles.

i.e., $\delta = \angle TQR + \angle TRQ = (i - r_1) + (e - r_2)$

$\delta = (i + e) - (r_1 + r_2)$ ...(i)

In triangle QRO,

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

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

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

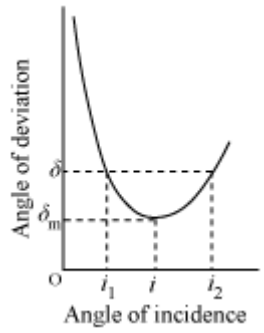
From equations (i) and (ii),

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

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

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

$A + \delta = i + e$



If the angle of incidence is increased gradually, then the angle of deviation first decreases, attains a minimum value (δ_m), and then again starts increasing.

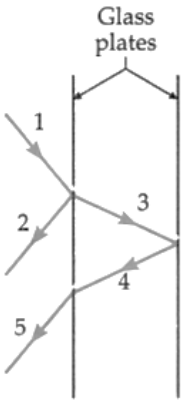
When angle of deviation is minimum, the prism is said to be placed in the minimum deviation

position.
There is only one angle of incidence for which the angle of deviation is minimum.
When
$\delta = \delta_m$ [prism in minimum deviation position],
e = i and $r_2 = r_1 = r$ ...(iv)
$\because r_1 + r_2 = A$
From equation (iv), r + r = A
$r = \frac{A}{2}$
Also, we have
$A + \delta = i + e$
Setting,
$\delta = \delta_m$ and e = i
$A + \delta_m = i + i$
$i = \frac{(A+\delta_m)}{2}$
$\because \mu = \frac{\sin i}{\sin r}$
$\therefore \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

b. The incident ray travelling from denser medium to rarer medium grazes along the surface of the separation of the medium only when the light ray incident at the surface at an angle called critical angle (C) such that the angle of reflection is 90^o. Therefore, following Snell's law, we can write
$\frac{\mu_1}{\mu_2} = \frac{\sin 90}{\sin C}$
$\frac{\mu_1}{\mu_2} = \frac{1}{\sin C}$
$\frac{\sqrt{2}}{1} = \frac{1}{\sin C}$
Sin C = $\frac{1}{\sqrt{2}}$
C = $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$
$\therefore$ Critical angle = Angle of incidence = 45^o

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. Consider origin at the centre of dipole. As per superposition principle, potential due to dipole will be the sum of potentials due to charges q and -q

$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r_1} - \frac{q}{r_2}\right]$

Where,

r_1 and r_2 = distances of point P from q and -q.

$r_1^2 = r^2 + a^2 - 2a\cos\theta$

$r_2^2 = r^2 + a^2 + 2a\cos\theta$

If r is greater than a, and taking terms upto first order in a/r

$r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

$= r^2\left[1 - \frac{2a\cos\theta}{r}\right]$

Also, $r_2^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right]$

With the help of Binomial theorem, keeping terms upto first order is shown below:

$\frac{1}{r_1} \equiv \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$

$\frac{1}{r_2} \equiv \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$

As p = qa

$V = \frac{1}{4\pi\varepsilon_0}\frac{q(2a)\cos\theta}{r^2}$

$V = \frac{p}{4\pi\varepsilon_0}\cdot\frac{\cos\theta}{r^2}$

Now, $p\cos\theta = \vec{p}.\hat{r}$

where $\hat{r}$ is unit vector along position vector.

Hence electric potential of dipole for distances large compared to size of dipole is given as below :

$V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}\hat{r}}{r^2}$ for r >>a

---For potential at any point on axis, $\theta = [0, \pi]$

$V = \pm\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r}$

potential is positive when θ = 0

potential is negative when $\theta = \pi$

Hence, electric potential falls at large distance, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$

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

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

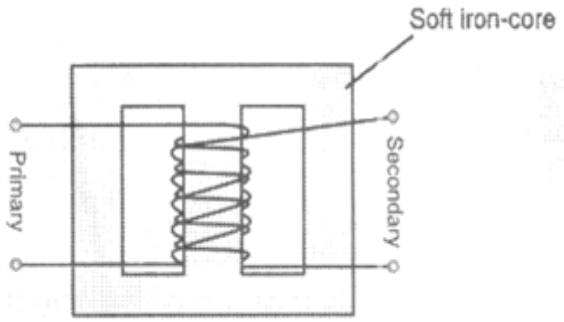
Total energy stored in the parallel combination,

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

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

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, $N_s > N_p$)

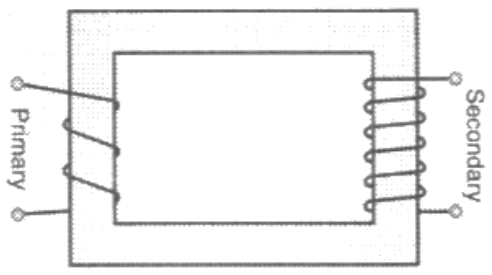
In an ideal transformer

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

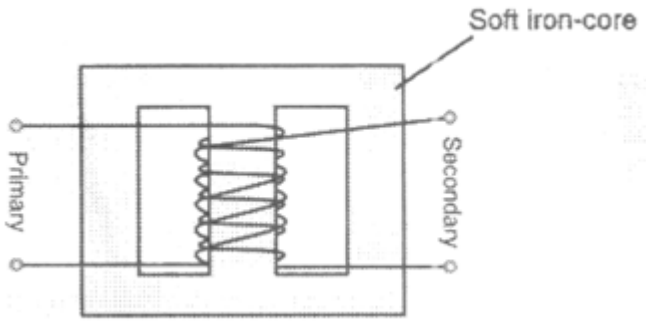
Power output, $P_0 = P_i \times \frac{90}{100} = 1350$ W

$\Rightarrow I_0 V = 1350$ W

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

OR

i.



Whenever current in one coil changes an emf gets induced in the neighbouring 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. Calculation of the number of turns in the secondary:

No. of turns in primary coil $N_p = 3000$, $V_s = 220$V, $V_p = 2200$V

$\frac{N_s}{N_p} = \frac{V_s}{V_p}$

$\frac{N_s}{3000} = \frac{220}{2200}$

$\therefore N_s = 300$