CBSE Sample Paper 1

Class XII Exam 2025-26

Physics

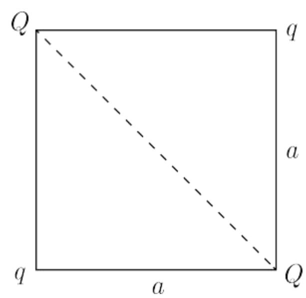
Time: 3 Hours **Max. Marks: 70**

General Instructions:

1. There are 35 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

SECTION-A

1. In the figure, if net force on Q is zero then value of $\frac{Q}{q}$ is:



(a) $\sqrt{2}$

(b) $2\sqrt{2}$

(c) $\frac{1}{2\sqrt{2}}$

(d) $\frac{1}{\sqrt{2}}$

2. Two plates of a parallel plate capacitor are 1 cm apart and potential difference between them is 10 V. The electric field between the plates is

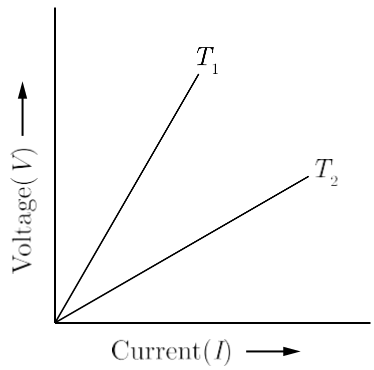
(a) 10 $N\text{-}C^{-1}$

(b) 250 $N\text{-}C^{-1}$

(c) 500 $N\text{-}C^{-1}$

(d) 1000 $N\text{-}C^{-1}$

3. The voltage V and current I graphs for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is



(a) $T_1 > T_2$ (b) $T_1 - T_2$

(c) $T_1 = T_2$ (d) $T_1 < T_2$

4. A circular coil of radius r carries a current I. The magnetic field at its center is B. At what distance from the centre, on the axis of the coil, the magnetic field will be $B/8$

(a) $\sqrt{2}R$ (b) $2R$

(c) $\sqrt{3}R$ (d) $3R$

5. An electric current passes through a long straight copper wire. At a distance 5 cm from the straight wire, the magnetic field is B. The magnetic field at 20 cm from the straight wire would be

(a) $\frac{B}{6}$ (b) $\frac{B}{4}$

(c) $\frac{B}{3}$ (d) $\frac{B}{2}$

6. If a bar magnet is dropped down in an infinitely long vertical copper tube, then the magnet will move continuously

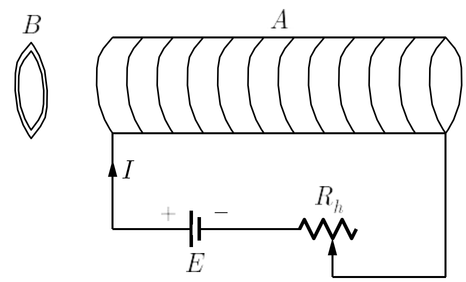
(a) increasing velocity and acceleration

(b) increasing velocity but constant acceleration

(c) decreasing velocity and ultimately comes to rest

(d) increasing velocity and ultimately acquires a constant terminal velocity

7. An aluminium ring B faces an electromagnet A. Which of the following statement is correct?



(a) if I increases, A will repel B

(b) if I decreases, A will repel B

(c) if I increases, A will attract B

(d) whether I increases or decreases B will not experience any force

8. Which scientist experimentally proved the existence of electromagnetic waves?

(a) Marconi

(b) Heinrich Rudolf Hertz

(c) James Clerk Maxwell

(d) Jagdish Chander Bose

9. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon

(a) currents in the coils

(b) materials of the wires of the coils

(c) relative position and orientation of the coils

(d) rates at which the currents are changing in the coils

10. What happens if a monochromatic light used in the Young's double slit experiment is replaced by white light?

(a) no fringes are observed

(b) all bright fringes become white

(c) all bright fringes are coloured between violet and red

(d) only central fringe is white and all other fringes are coloured

11. A particle of mass m and charged q is accelerated through a potential V. The De-Broglie wavelength of the particle will be:

(a) $\frac{Vh}{\sqrt{2qm}}$ (b) $\frac{q}{\sqrt{2mV}}$

(c) $\frac{h}{\sqrt{2qmV}}$ (d) $\frac{mh}{\sqrt{2qV}}$

12. The minimum angular momentum of electron in Hydrogen atom will be

(a) $\frac{h}{\pi} Js$ (b) $\frac{h}{2\pi} Js$

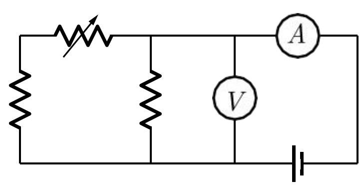
(c) $h\pi Js$ (d) $2\pi h\, Js$

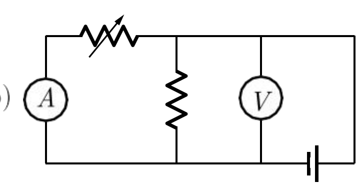
13. If elements with principal quantum $n > 4$ were not allowed in nature, the number of possible elements would have been

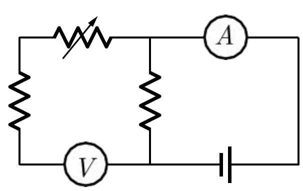
(a) 4 (b) 32

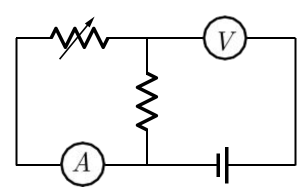
(c) 60 (d) 64

14. Which of the following set up can be used to verify the Ohm's law?

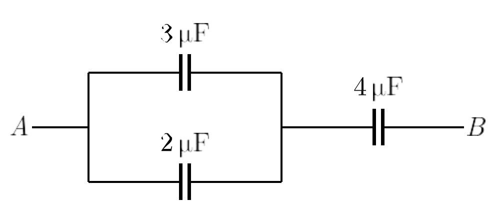
(a)


(b)


(c)


(d)


15. The equivalent capacity between A and B is



(a) $\frac{20}{9}$ μF (b) 9 μF

(c) 1 μF (d) $\frac{1}{9}$ μF

16. **Assertion :** The resistivity of a semi-conductor increases with temperature.
Reason : The atoms of semi-conductor vibrate with larger amplitude as higher temperatures thereby increasing its resistivity.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect.

17. **Assertion :** In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect.

18. **Assertion :** Photo-sensitivity of a metal is high if its work function is small.
Reason : Work function $= hf_0$ where f_0 is the threshold frequency.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

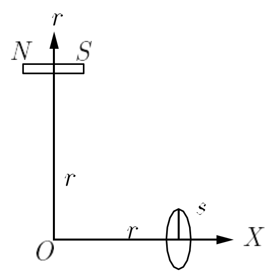
(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect.

SECTION-B

19. A capacitor of capacitance C is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit? Write the expression for the current inside the capacitor.

20. A small magnet of magnetic moment M, is placed at a distance r from the origin O with its axis parallel to X-axis as shown. A small coil, if one turn is placed on the X-axis, at the same distance from the origin, with the axis of the coil coinciding with X-axis. For what value of current in the coil does a small magnetic needle, kept at origin, remains undefiled ? What is the direction of current in the coil ?



21. What is Einstein's mass-energy equivalence? What is its importance?

or

A chain reaction dies out sometimes. Why?

22. You are given two converging lenses of focal length 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, then find out the separation between the objective and eyepiece.

23. Draw the voltage-current characteristic curve of a diode and mark its important parameter.

or

Draw $V-I$ characteristics of a $p-n$ junction diode. Answer the following questions, giving reasons:

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?

(ii) Why does the reverse current show a sudden increase at the critical voltage?

24. Draw a graph showing the variation of intensity against the position x on the screen in Young double slit experiment.

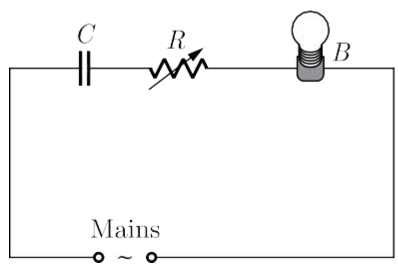
25. Two point charges having equal charges separated by 1 m distance experience a force of 8 N. What will be the force experienced by them, if they are held in water, at the same distance? (Given: $K_{\text{water}} = 80$)

SECTION-C

26. Give some points of similarities and differences between Biot-Savart law for the magnetic field and Coulomb's law for the electrostatic field.

27. A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angle to the horizontal component of the Earth's magnetic field, $0.3 \# 10^{-4}$ Wb - m^{-2}. Find the instantaneous value of the emf induced in the rod.

28. A capacitor C, a variable resistor R and a bulb B are connected in series to the AC mains in the circuit as shown in the figure. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor keeping resistance R to be the same (ii) the resistance R is increased keeping the same capacitance?



or

State the condition under which the phenomenon of resonance occurs in a series LCR circuit. Plot a graph showing the variation of current with frequency of an AC source in series LCR circuit.

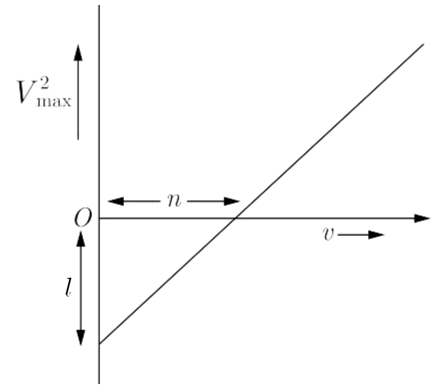
29. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy? Give reason to justify your answer.

or

(a) Give a brief description of the basic elementary process involved in the photoelectric emission in Einstein's picture.

(b) When a photosensitive material is irradiated with the light of frequency v, the maximum speed of electrons is given by V_{max}. A plot of V_{max}^2 is found to vary with frequency v as shown in the figure.

Use Einstein's photoelectric equation to find the expressions for (i) Planck's constant and (ii) work function of the given photosensitive material, in terms of the parameters l, n and mass m of the electron.



30. The electron in a given Bohr orbit has a total energy of −1.5 eV. Calculate its

(i) kinetic energy

(ii) potential energy

(iii) wavelength of radiation emitted, when this electron makes a transition to the ground state.

[Given, energy in the ground state = − 13.6 eV and Rydberg's constant = $1.09 \# 10^7\ m^{-1}$]

SECTION-D

31. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

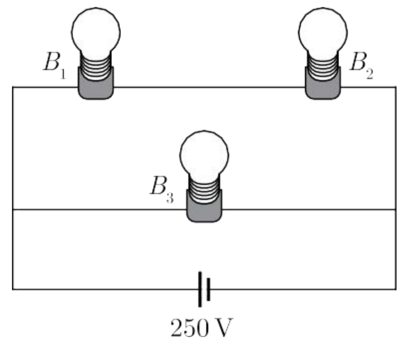
or

1. Define capacitance of a capacitor.
2. Derive expression for stored energy between plates of parallel plate capacitor. Show that energy-density between plates of the capacitor can be expressed as $1/2\ \varepsilon_0\ E^2$, when E = Electric field between plates.

32.
1. Derive an expression for the current density in terms of the drift speed of electrons.
2. Derive Ohm's law on the basis of the theory of electron drift.
3. Derive an expression for the resistivity of a conductor in terms of number density of free electrons and relaxation time.

or

A 100 W bulb B_1 and two 60 W bulbs B_2 and B_3, are connected to a 250 V source as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. What is the relation between the output powers of bulbs?



33. (a) How is a wavefront defined ? Distinguish between a plane wavefront and a spherical wavefront. Using Huygen's constructions draw a figure showing the propagation of a plane wave refracting at a plane surface separating two media. Hence verify Snell's law of refraction.

When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply reduction its energy ? Explain.

(b) When monochromatic light travels from a rarer to a denser medium, explain the following.

(i) Is the frequency of reflected and refracted light same as the frequency of incident light ?

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave ?

or

(a) In Young's double slit experiment, two slits are 1 mm apart and the screen is placed 1 m away from the slits. Calculate the fringe width when light of wavelength 500 nm is used.

(b) What should be the width of each slit in order to obtain 10 maxima of the double slits pattern within the central maximum of the single slit pattern ?

(c) The intensity at the central maxima in Young's double slit experiment is I_0. Find out the intensity at a point where the path difference is $\frac{l}{6}, \frac{l}{4}$ and $\frac{\lambda}{3}$.

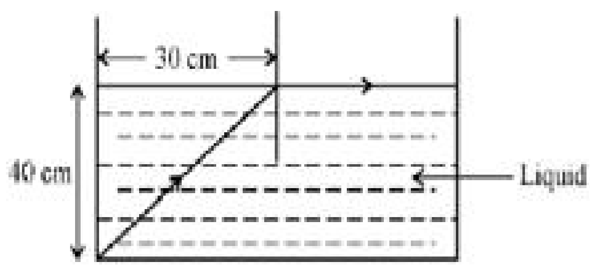
SECTION-E

34. Total internal reflection (TIR) is the optical phenomenon in which waves arriving at the interface (boundary) from one medium to another (e.g., from water to air) are not refracted into the second ("external") medium, but completely reflected back into the first ("internal") medium. It occurs when the second medium has a higher wave speed (i.e., lower refractive index) than the first, and the waves are incident at a sufficiently oblique angle on the interface. For example, the water-to-air surface in a typical fish tank, when viewed obliquely from below, reflects the underwater scene like a mirror with no loss of brightness.

TIR occurs not only with electromagnetic waves such as light and microwaves, but also with other types of waves, including sound and water waves. If the waves are capable of forming a narrow beam , the reflection tends to be described in terms of "rays" rather than waves; in a medium whose properties are independent of direction, such as air, water or glass, the "rays" are perpendicular to the associated wave fronts.

Repeated total internal reflection of a 405nm laser beam between the front and back surfaces of a glass pane. The colour of the laser light itself is deep violet; but its wavelength is short enough to cause fluorescence in the glass, which re-radiates greenish light in all directions, rendering the zigzag beam visible.

Refraction is generally accompanied by partial reflection. When waves are refracted from a medium of lower propagation speed (higher refractive index) to a medium of higher speed e.g., from water to air the angle of refraction (between the outgoing ray and the surface normal) is greater than the angle of incidence (between the incoming ray and the normal). As the angle of incidence approaches a certain threshold, called the critical angle, the angle of refraction approaches 90°, at which the refracted ray becomes parallel to the boundary surface. As the angle of incidence increases beyond the critical angle, the conditions of refraction can no longer be satisfied, so there is no refracted ray, and the partial reflection becomes total. For visible light, the critical angle is about 49° for incidence from water to air, and about 42° for incidence from common glass to air.



1. What is refractive index of a medium? (in terms of speed of light)
2. In the above diagram, calculate the speed of light in the liquid of unknown refractive index?
3 What is refractive index of a medium (in terms of real and apparent depth)?

or

4 What is the relation between refractive index and critical angle for a medium?

35. A pure semiconductor germanium or silicon, free of every impurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes). Hence its conductivity is low. When the impurity atoms of valance five or three are doped in a pure semiconductor, we get respectively n-type or p-type extrinsic semiconductor. In case of doped semiconductor $n_e n_h = n_i^2$. Where n_e and n_h are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity of extrinsic semiconductor is much higher than that of intrinsic semiconductor.

Answer the following questions :

1. What is n-type semiconductor?
2. Do pure semiconductors obey Ohm's law?
3. Why do semiconductors behave as conductors at room temperature?

or

4. Why does a semiconductor behaves as an insulator at very low temperature?

Sample Paper 1 Solutions

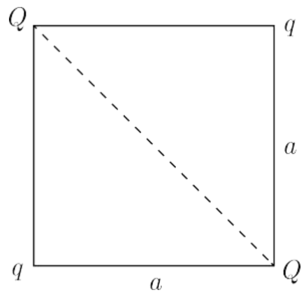
Class XII 2022-23

Physics

Time: 3 Hours **Max. Marks: 70**

SECTION-A

1. In the figure, if net force on Q is zero then value of $\frac{Q}{q}$ is:

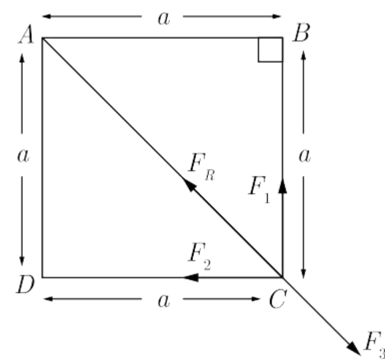


(a) $\sqrt{2}$ (b) $2\sqrt{2}$

(c) $\frac{1}{2\sqrt{2}}$ (d) $\frac{1}{\sqrt{2}}$

Ans : (b) $2\sqrt{2}$

According to the question,



In TABC,

According to Pythagorean theorem,

$$AC^2 = AB^2 + BC^2$$

$$AC = \sqrt{a^2 + a^2} = \sqrt{2}\,a$$

We know that,

Resultant force,

$$F_R = \sqrt{F_1^2 + F_2^2} \quad ...(1)$$

According to coulomb's law,

$$F_1 = \frac{KQq}{a^2}$$

Similarly, $$F_2 = \frac{KQq}{a^2}$$

$$F_3 = \frac{KQQ}{(\sqrt{2}\,a)^2} = \frac{KQ^2}{2a^2}$$

From equation (1),

$$F_R = \sqrt{\left(\frac{KQq}{a^2}\right)^2 + \left(\frac{KQq}{a^2}\right)^2}$$

$$= \sqrt{\left(\frac{KQq}{a^2}\right)^2 (1+1)}$$

$$= \frac{KQq\sqrt{2}}{a^2}$$

Since, $F_R - F_3 = 0$

$$F_R = F_3$$

$$\frac{KQq\sqrt{2}}{a^2} = \frac{KQ^2}{2a^2}$$

$$\frac{Q}{q} = 2\sqrt{2}$$

2. Two plates of a parallel plate capacitor are 1 cm apart and potential difference between them is 10 V. The electric field between the plates is

(a) 10 N-C^{-1} (b) 250 N-C^{-1}

(c) 500 N-C^{-1} (d) 1000 N-C^{-1}

Ans : (d) 1000 N-C^{-1}

Given,

Distance between plates,

$$d = 1\text{cm}$$

$$= 0.01\text{ m}$$

and potential difference between them,

$$V = 10\text{ Volt}$$

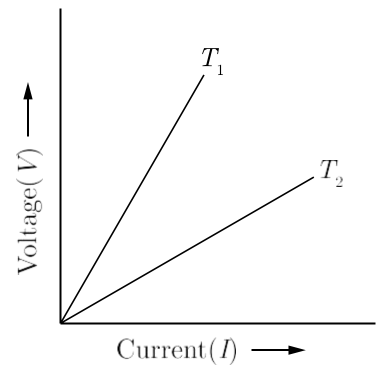
We know that electric field between the plates in a parallel plate capacitor,

$$E = \frac{V}{d}$$

$$= \frac{10}{0.01}$$

$$= 1000\text{ N-C}^{-1}$$

3. The voltage V and current I graphs for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is



(a) $T_1 > T_2$ (b) $T_1 \approx T_2$

(c) $T_1 = T_2$ (d) $T_1 < T_2$

Ans : (a) $T_1 > T_2$

We know from the Ohm's law that resistance of a conductor,

$$R = \frac{V}{I}$$

We also know from given figure that $\frac{V}{I}$ is the slope of the $V - I$ graph.

Since, $\left(\frac{V}{I}\right)_1 > \left(\frac{V}{I}\right)_2$

Therefore, $R_1 > R_2$ ...(1)

We also know that the resistance at a temperature T,

$$R = R_0(1 + \alpha T)$$

or, $R \propto T$ ...(2)

From equation (1) and (2), we get

$$T_1 > T_2$$

4. A circular coil of radius r carries a current I. The magnetic field at its center is B. At what distance from the centre, on the axis of the coil, the magnetic field will be $B/8$

(a) $\sqrt{2}R$ (b) $2R$

(c) $\sqrt{3}R$ (d) $3R$

Ans : (c) $\sqrt{3}R$

According to the question,

Magnetic field at distance x from the centre,

$$B_{axis} = \frac{\text{magnetic field at center}(B)}{8}$$

$$B_{axis} = \frac{B}{8}$$

$$\frac{\mu_0 NiR^2}{2(R^2 + x^2)^{3/2}} = \frac{\mu_0 Ni}{8 \# 2R}$$

$$8R^3 = (R^2 + x^2)^{3/2}$$

This is possible only when $x = ! \sqrt{3}R$.

Hence, $\sqrt{3}R$ distance from the centre magnetic field is equal to magnetic field at centre.

5. An electric current passes through a long straight copper wire. At a distance 5 cm from the straight wire, the magnetic field is B. The magnetic field at 20 cm from the straight wire would be

(a) $\frac{B}{6}$ (b) $\frac{B}{4}$

(c) $\frac{B}{3}$ (d) $\frac{B}{2}$

Ans : (b) $\frac{B}{4}$

Given,

Distance of first point from the wire,

$$r_1 = 5 \text{ cm}$$

Magnetic field at first point,

$$B_1 = B$$

and distance of second point from the wire,

$$r_2 = 20 \text{ cm}$$

We know that magnetic field due to current-carrying long straight wire at the point,

$$B = \frac{\mu_0}{2\pi} \# \frac{I}{r} \text{ o } \frac{1}{r}$$

Therefore, $\frac{B_1}{B_2} = \frac{r_2}{r_1}$

$$= \frac{20}{5} = 4$$

$$B_2 = \frac{B_1}{4}$$

$$= \frac{B}{4}$$

where, B_2 = magnetic field at second point

6. If a bar magnet is dropped down in an infinitely long vertical copper tube, then the magnet will move continuously

(a) increasing velocity and acceleration

(b) increasing velocity but constant acceleration

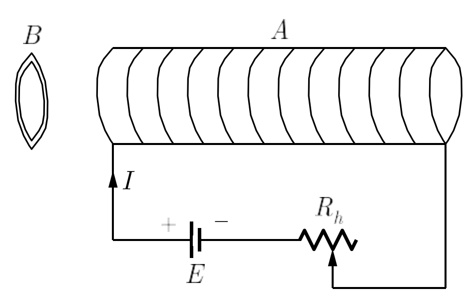
(c) decreasing velocity and ultimately comes to rest

(d) increasing velocity and ultimately acquires a constant terminal velocity

Ans : (b) increasing velocity but constant acceleration

We know that when a bar magnet is dropped down in an infinitely long vertical copper tube, its velocity continuously increases due to the gravitational attraction. As a result of this, the velocity of bar magnet continuously goes on increasing but having constant acceleration due to free fall under gravity.

7. An aluminium ring B faces an electromagnet A. Which of the following statement is correct?



(a) if I increases, A will repel B

(b) if I decreases, A will repel B
(c) if I increases, A will attract B
(d) whether I increases or decreases B will not experience any force

Ans : (a) if I increases, A will repel B
We know that when circuit is closed, increasing current in the coils of electromagnet A produces time varying magnetic flux which magnetised it.
We also know from lenz's law that when time varying magnetic flux links with a nearby ring, then direction of induced current (or E.M.F.) in the ring will be such that it opposes the cause which produces it.

8. Which scientist experimentally proved the existence of electromagnetic waves?
(a) Marconi
(b) Heinrich Rudolf Hertz
(c) James Clerk Maxwell
(d) Jagdish Chander Bose

Ans : (b) Heinrich Rudolf Hertz
We know that Heinrich Rudolf Hertz was the first scientist to produce and detect the existence of electromagnetic waves experimentally in 1887.

9. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon
(a) currents in the coils
(b) materials of the wires of the coils
(c) relative position and orientation of the coils
(d) rates at which the currents are changing in the coils

Ans : (c) relative position and orientation of the coils.
We know that mutual inductance of the pair of coils depends upon the geometry of the coils, distance between the coils, relative position and orientation of the coils, no. of turns in the coils, permeability of the medium in which the coils wounded and degree of coupling i.e., the extent to which the magnetic flux primary current links the secondary.

10. What happens if a monochromatic light used in the Young's double slit experiment is replaced by white light?
(a) no fringes are observed
(b) all bright fringes become white
(c) all bright fringes are coloured between violet and red
(d) only central fringe is white and all other fringes are coloured

Ans : (d) only central fringe is white and all other fringes are coloured
We know that if white light is used in Young's double slit experiment, we get a central white fringe, because all wavelengths of white light have zero path difference. And all other points on both sides of central white fringe have different path differences for different wavelengths of white light. Therefore no condition of brightness or darkness is satisfied.
As a result of this, coloured fringes are observed on both sides of central white fringe.

11. A particle of mass m and charged q is accelerated through a potential V. The De-Broglie wavelength of the particle will be:

(a) $\frac{Vh}{\sqrt{2qm}}$ (b) $\frac{q}{\sqrt{2mV}}$
(c) $\frac{h}{\sqrt{2qmV}}$ (d) $\frac{mh}{\sqrt{2qV}}$

Ans : (c) $\frac{h}{\sqrt{2qmV}}$

A particle of mass m and charged q is accelerated through a potential V.
Kinetic energy gained by the particle,

$$K = \frac{1}{2}mv^2 = \frac{P^2}{2m}$$

Work done on electron $= qV$.

Hence, $\frac{P^2}{2m} = qV$

$$P = \sqrt{2mqV}$$

Hence, the de-Broglie wavelength of the particle,

$$\lambda = \frac{h}{P}$$

$$= \frac{h}{\sqrt{2mqV}}$$

12. The minimum angular momentum of electron in Hydrogen atom will be

(a) $\frac{h}{\pi} Js$ (b) $\frac{h}{2\pi} Js$

(c) $h\pi Js$ (d) $2\pi h\, Js$

Ans : (b) $\frac{h}{2\pi} Js$

According to Bohr's atomic model, the electrons are permitted to circulate only in those orbits in which the angular momentum of an electron is an integral multiple of $\frac{h}{2\pi}$, h being plank's constant

$$L = \frac{nh}{2\pi}$$

When, $n = 1$

$$L = \frac{h}{2\pi}$$

Hence, the minimum angular momentum of electron in Hydrogen atom will be $\frac{h}{2\pi}$.

13. If elements with principal quantum $n > 4$ were not allowed in nature, the number of possible elements would have been

(a) 4 (b) 32

(c) 60 (d) 64

Ans : (c) 60

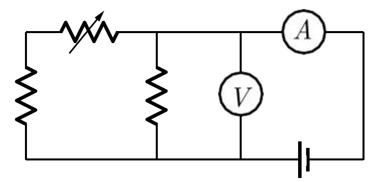
Given,
Principal quantum number allowed in nature, $n = 4$.
We know that number of possible elements for principal quantum number,

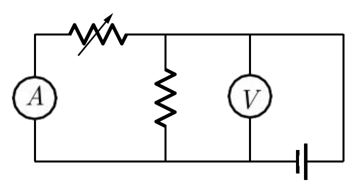
$$N = \sum_{n=1}^{4} 2n^2$$

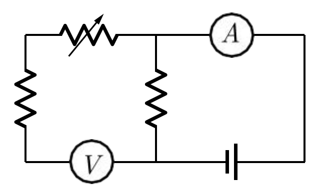
$$= 2[(1)^2 + (2)^2 + (3)^2 + (4)^2]$$

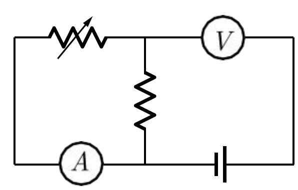
$$= 2[30] = 60$$

14. Which of the following set up can be used to verify the Ohm's law?

(a)


(b)


(c)


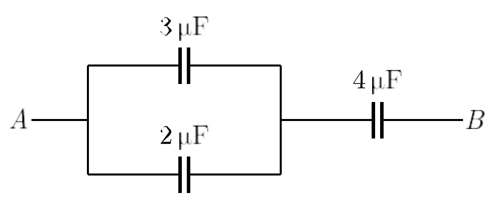
(d)


Ans : (a)

We know that Ohm's law gives the resistance offered by a conductor by measuring steady current I flowing through the conductor

and voltage drop across the ends of the conductor.
We also know that ammeter is always connected in series with the cell to measure current flowing through the conductor and voltmeter is always connected in parallel to the cell to measure voltage drop across the conductor.
Therefore, option (a) is used to verify the Ohm's law.

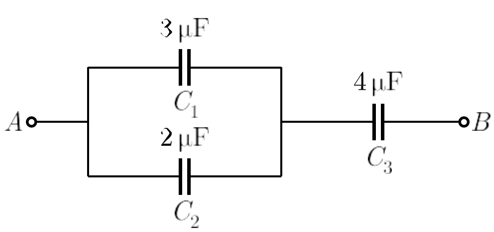
15. The equivalent capacity between A and B is



(a) $\frac{20}{9}$ μF (b) 9 μF

(c) 1 μF (d) $\frac{1}{9}$ μF

Ans : (a) $\frac{20}{9}$ μF



In the given circuit C_1 and C_2 are connected in parallel combination Hence, equivalent capacitance,

$$Cl = C_1 + C_2$$
$$= 3 + 2 = 5 \text{ μF}$$

Cl and C_3 are connected in series combination Now, equivalent capacitance between A and B,

$$C_{AB} = \frac{Cl \# C_3}{Cl + C_3}$$
$$= \frac{5 \# 4}{5 + 4}$$
$$= \frac{20}{9} \text{ μF}$$

16. **Assertion :** The resistivity of a semi-conductor increases with temperature.
Reason : The atoms of semi-conductor vibrate with larger amplitude as higher temperatures thereby increasing its resistivity.
(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) The Assertion is correct but Reason is incorrect.
(d) Both the Assertion and Reason are incorrect.

Ans : (d) Both the Assertion and Reason are incorrect.

The resistivity of semiconductor decreases with increase in temperature as more electrons jump into conduction band increasing its conductivity.

17. **Assertion :** In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed.
(a) Both Assertion and Reason are

correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect.

Ans : (d) Both the Assertion and Reason are incorrect.

In Young's experiment, fringe width of dark and white fringes are equal. If white light is used as source, coloured fringes are observed representing bright band of different colours.

18. **Assertion :** Photo-sensitivity of a metal is high if its work function is small.
Reason : Work function $= hf_0$ where f_0 is the threshold frequency.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect.

Ans : (b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

The photo-sensitivity of a metal is high when its work function is small. Work function of a metal depends not on the threshold frequency but on the nature of the metal.

SECTION-B

19. A capacitor of capacitance C is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit? Write the expression for the current inside the capacitor.

Ans :

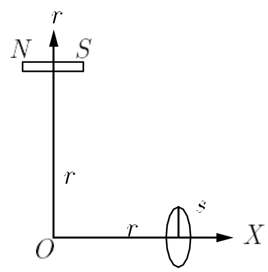
The ammeter will show the momentary deflection.
This momentary deflection occurs due to the fact that the conduction current flows through connection wires during the charging of capacitor. This lead to gathering of charge at two plated and hence varying electric field of increasing nature is produced between the plated which in turn produce displacement current in space between two plates. This maintains the continuity with the conduction current.

$$I_c = I_d$$

The current inside the capacitor,

Displacement current I_c and $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$.

20. A small magnet of magnetic moment M, is placed at a distance r from the origin O with its axis parallel to X-axis as shown. A small coil, if one turn is placed on the X-axis, at the same distance from the origin, with the axis of the coil coinciding with X-axis. For what value of current in the coil does a small magnetic needle, kept at origin, remains undefiled ? What is the direction of current in the coil ?



Ans :

This happens when magnetic field of bar magnet is equal and opposite to the magnetic field of coil

$$|\ddot{B}_m| = |\ddot{B}_c|$$

$$\frac{\mu_0 M}{4\pi r^3} = \frac{\mu_0 I a^2}{2r^3}$$

$$I = \frac{2M}{4\pi a^2}$$

Current is in anti-clockwise sense, an seen from the origin.

21. What is Einstein's mass-energy equivalence? What is its importance?

Ans :

In his special theory of relativity, Einstein showed that,

$$E = mc^2$$

This equation expresses equivalence between mass and energy. Thus the energy content of an object is its mass times the square of the speed of light. This principle is central to our understanding of nuclear energy and harnessing it as a source of power. Using this principle, the Q -value of nuclear process can be expressed in terms of initial and final masses.

or

A chain reaction dies out sometimes. Why?

Ans :

A chain reaction may die out due to any of the following causes:

1. Excessive neutron leakage if the size of the fissionable material is smaller than the critical size.
2. Fast neutrons may escape the fissionable material without causing further fissions.
3. Some neutrons may suffer non-fission capture by ${}^{238}_{92}U$ nuclei.

22. You are given two converging lenses of focal length 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, then find out the separation between the objective and eyepiece.

Ans :

Given, $f_0 = 1.25$ cm

$f_e = -5$ cm

Magnification, $M = 30,$

$D = 25$ cm

If the objective is very close to the principal focus of the objective and the image formed by the objective is very close to eyepiece, then magnifying power of a microscope is given by

$$M = -\frac{1}{f_0} \cdot \frac{D}{f_2}$$

$$30 = \frac{1}{1.25} \cdot \frac{25}{5}$$

$$L = \frac{1.25 \times 30 \times 5}{25 \times 100}$$

$$L = \frac{25 \times 30}{100}$$

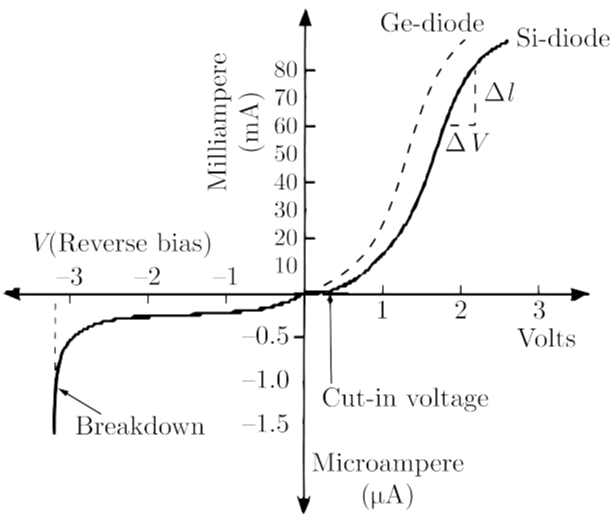
$$L = \frac{30}{4}$$

$$L = 7.5 \text{ cm}$$

This is a required separation between the objective and the eyepiece.

23. Draw the voltage-current characteristic curve of a diode and mark its important parameter.

Ans :



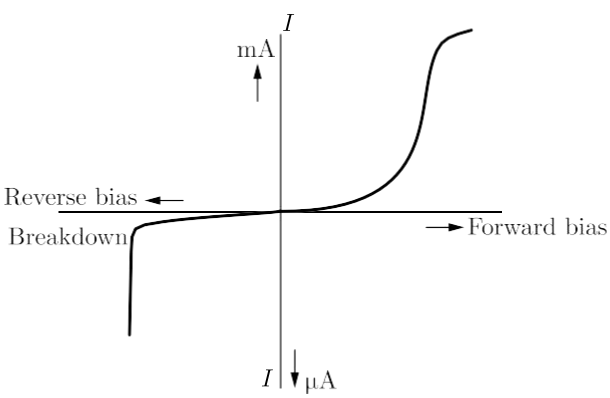
or

Draw $V-I$ characteristics of a $p-n$ junction diode. Answer the following questions, giving reasons:

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?

(ii) Why does the reverse current show a sudden increase at the critical voltage?

Ans :



(i) In the reverse biasing, the current of order of μA is due to movement/ drifting of minority charge carriers from one region to another through the junction.

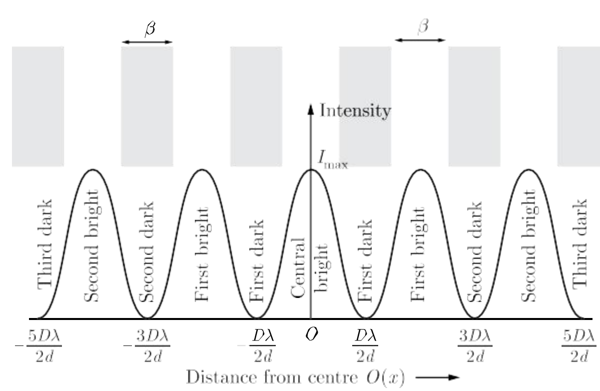
A small applied voltage is sufficient to sweep the minority charge carriers through the junction. So, reverse current is almost independent of critical voltage.

(ii) At critical voltage (or breakdown voltage), a large number of covalent bonds break, resulting in the increase of large number of charge carriers. Hence, current increases at critical voltage.

24. Draw a graph showing the variation of intensity against the position x on the screen in Young double slit experiment.

Ans :

On plotting the intensities of bright and dark fringes against distance x from O, we get a curve as shown in figure. The intensity is maximum at the central point O. Then it becomes zero and maximum alternately on either side of O, depending on x is odd multiple of $\frac{D\lambda}{2d}$ and integral multiple of $\frac{D\lambda}{d}$, respectively.



Intensity Distribution Curve for an Interference Pattern

25. Two point charges having equal charges separated by 1 m distance experience a force of 8 N. What will be the force experienced by them, if they are held in water, at the same distance? (Given: $K_{\text{water}} = 80$)

Ans :

Two point charges system is taken from air to water keeping other variables (e.g. distance, magnitude of charge) unchanged. So, the only factor which may affect the interacting force is dielectric constant of medium.

Force acting between two point charges.

$$F = \frac{1}{4\pi\varepsilon_0 K}\frac{|q_1 q_2|}{r^2}$$

or $$F \propto \frac{1}{K}$$

$$\frac{F_{\text{air}}}{F_{\text{Medium}}} = K$$

$$\frac{8}{F_{\text{water}}} = 80$$

$$F_{\text{water}} = \frac{8}{80} = \frac{1}{10}\text{ N}$$

SECTION-C

26. Give some points of similarities and differences between Biot-Savart law for the magnetic field and Coulomb's law for the electrostatic field.

Ans :

According to Coulomb's law, the electric field produced by a charged element is,

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

According to Biot-Savart law, the magnetic field produced by a current element $I\,dl$ is,

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2}$$

On comparing the above two equations, we can note the following points:

Points of Similarity

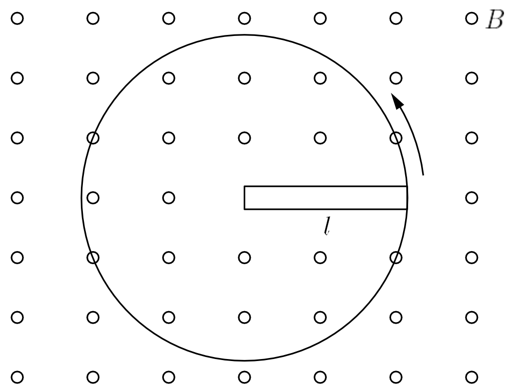
1. Both fields depend inversely on the square of the distance from the source.
2. Both are long range fields.
3. The principle of superposition is applicable to both fields.

Points of Difference

1. The magnetic field is produced by a vector source: the current element $I\,d\vec{l}$. The electrostatic field is produced by a scalar source: the electric charge dg.
2. The direction of the electrostatic field is along the displacement vector joining the source and the field point. The direction of the magnetic field is perpendicular to the plane containing the displacement vector $\vec{r}$ and the current element $I\,d\vec{l}$.
3. In Bio-Savart law, the magnitude of the magnetic field is proportional to the sine of the angle between the current element $I\,d\vec{l}$ and displacement vector $\vec{r}$ while there is no such angle dependence in the Coulomb's law for the electrostatic field.

27. A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angle to the horizontal component of the Earth's magnetic field, 0.3×10^{-4} Wb − m^{-2}. Find the instantaneous value of the emf induced in the rod.

Ans :



Given, $B = 0.3 \# 10^{-4}$ Wb-m^{-2}

$v = 5$ m/s

$\theta = 90c$

$l = 10$ m

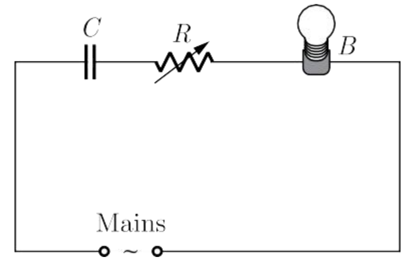
$e = B\,vl\,\sin\theta$

$= 0.3 \# 10^{-4} \# 10 \# 5 \# \sin 90c$

$= 15 \# 10^{-4}$V

Hence, $e = 1.5 \# 10^{-3}$V $= 1.5$ mV

28. A capacitor C, a variable resistor R and a bulb B are connected in series to the AC mains in the circuit as shown in the figure. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor keeping resistance R to be the same (ii) the resistance R is increased keeping the same capacitance?



Ans :

(i) As, the dielectric slab is introduced between the plates of the capacitor, its capacitance will increase. Hence, the potential drop across the capacitor will decrease, i.e., $V = \frac{Q}{C}$. As a result, the potential drop across the bulb will increase as they are connected in series. Thus its brightness will increase.

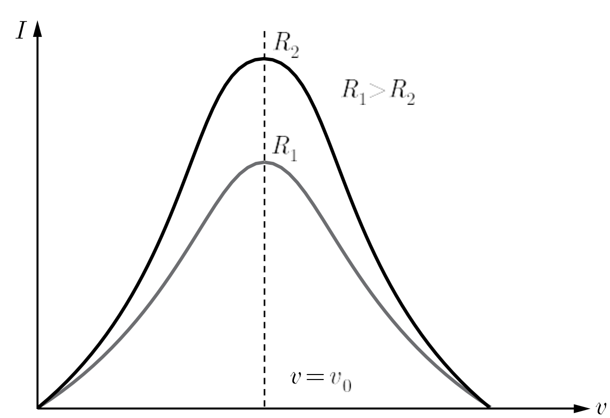
(ii) As the resistance R is increased, the potential drop across the resistor will increase. As a result, the potential drop across the bulb will decrease as they are connected in series. Thus, its brightness will decrease.

or

State the condition under which the phenomenon of resonance occurs in a series LCR circuit. Plot a graph showing the variation of current with frequency of an AC source in series LCR circuit.

Ans :

The condition for series resonance is,



$$X_L = X_C$$

$$\omega_0 L = \frac{1}{\omega_0 C}$$

$$\omega_0^2 = \frac{1}{LC}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$2\pi\nu_0 = \frac{1}{\sqrt{LC}}$$

(where ν_0 is resonance frequency)

$$\nu_0 = \frac{1}{2\pi\sqrt{LC}}$$

The graph between I and ν is as shown in figure.

29. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy? Give reason to justify your answer.

Ans :

1. De-Broglie wavelength,

Since, $\lambda = \frac{h}{p}$

$$= \frac{h}{\sqrt{2mqV}}$$

For same V,

$$\lambda \text{ O } \frac{1}{\sqrt{mq}}$$

Hence, $\frac{l_p}{l_a} = \sqrt{\frac{m_a q_a}{m_p q_p}}$

$$= \sqrt{\frac{4m_p}{m_p} \cdot \frac{2e}{e}}$$

$$= \sqrt{8}$$

$$= 2\sqrt{2}$$

Clearly, λ_p 2 λ_a

Hence, proton has a greater de-Broglie wavelength.

2. Kinetic energy,

$$E_K = qV$$

For same V,

$$E_K \text{ O } q$$

$$\frac{E_{K_p}}{E_{K_a}} = \frac{q_p}{q_a}$$

$$= \frac{e}{2e} = \frac{1}{2}$$

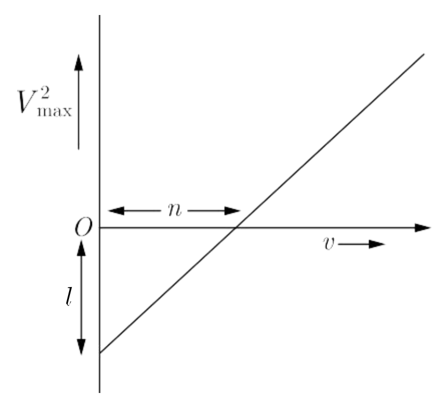
Clearly, E_{K_p} 1 E_{K_a}

or

(a) Give a brief description of the basic elementary process involved in the photoelectric emission in Einstein's picture.

(b) When a photosensitive material is irradiated with the light of frequency v, the maximum speed of electrons is given by V_{max}. A plot of V_{max}^2 is found to vary with frequency v as shown in the figure.

Use Einstein's photoelectric equation to find the expressions for (i) Planck's constant and (ii) work function of the given photosensitive material, in terms of the parameters l, n and mass m of the electron.



Ans :

(a) According to Einstein, packets of energy called photons, which are absorbed completely by electrons. This absorbed energy is used to reject the electron and also provide kinetic energy to the emitted electron.

(b) $$\frac{1}{2} m V_{max}^2 = h\nu - \varphi_0$$

$$V_{max}^2 = \left(\frac{2h}{m}\right)\nu - \left(\frac{2\varphi_0}{m}\right)$$

Hence, $$\text{Slope} = \frac{2h}{m} = \frac{l}{n}$$

$$h = \frac{ml}{2n}$$

$$\text{Intercept} = \frac{2\varphi_0}{m} = l$$

Hence, $$\varphi_0 = \frac{ml}{2}$$

30. The electron in a given Bohr orbit has a total energy of -1.5 eV. Calculate its

(i) kinetic energy

(ii) potential energy

(iii) wavelength of radiation emitted, when this electron makes a transition to the ground state.

[Given, energy in the ground state $= -13.6$ eV and Rydberg's constant $= 1.09 \times 10^7\ \text{m}^{-1}$

Ans :

(i) The kinetic energy (K_K) of the electron in an orbit is equal to negative of its total energy (E).

$$E_K = -E$$

$$= -(-1.5) = 1.5\ \text{eV}$$

(ii) The potential energy (U) of the electron in an orbit is equal to twice its total energy (E)

i.e., $$U = 2E$$

$$= -1.5 \times 2 = -3\ \text{eV}$$

(iii) As, a result of transition of electron from excited state of ground state.

Energy of radiation $= -1.5 - (-13.6)$

(Since, Ground state energy of H-atom $= -13.6$ eV)

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

$$\frac{hc}{\lambda} = 12.1\ \text{eV}$$

= energy of radiation

Hence, $$\frac{1}{\lambda} = \frac{12.1 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34} \times 3 \times 10^8}$$

$$\lambda = 1.025 \times 10^{-7}\ \text{m}$$

$$= 1025\ \text{Å}$$

SECTION-D

31. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

Ans :

Initially when there is vacuum between the two plates, the capacitance of the two-parallel plates is,

$$C_0 = \frac{\varepsilon_0 A}{d}$$

where, A is the area of parallel plates.

Suppose that the capacitor is connected to a battery, an electric field E_0 is produced.

Now, if we insert the dielectric slab of thickness $t = d/2$, the electric field reduces to E.

Now, the gap between plates is divided in two parts, for distance t there is electric field E and for the remaining distance $(d - t)$ the electric field is E_0.

If V be the potential difference between the plates of the capacitor, then

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

$$= \frac{Ed}{2} + \frac{E_0 d}{2} = \frac{d}{2}(E + E_0)$$

$$\left(\text{at } t = \frac{d}{2}\right)$$

$$= \frac{d}{2}\left(\frac{E_0}{K} + E_0\right)$$

$$= \frac{dE_0}{2K}(K + 1)$$

$$\left(\text{As}, \frac{E_0}{E} = K\right)$$

$$E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$$

$$V = \frac{d}{2K} \cdot \frac{q}{\varepsilon_0 A}(K + 1)$$

$$C = \frac{q}{V}$$

$$= \frac{2K\varepsilon_0 A}{d(K + 1)}$$

or

1. Define capacitance of a capacitor.
2. Derive expression for stored energy between plates of parallel plate capacitor. Show that energy-density between plates of the capacitor can be expressed as $1/2\, \varepsilon_0 E^2$, when E = Electric field between plates.

Ans :

1. Capacitance

The capacitance of capacitor may be defined as the charge required to be supplied to either of the conductors of the capacitor so as to increase the potential difference between them by unit amount.

Capacitance,

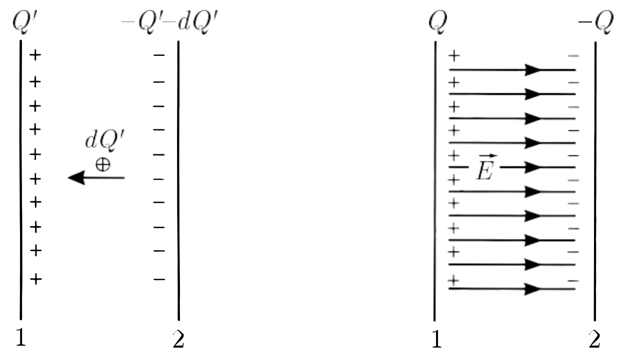
$$C = \frac{\text{Charge on either plate(Q)}}{\text{Potential difference between the two plates } (V)}$$

SI unit of capacitance is farad (F).

2. Expression for the Energy Stored in a Capacitor

Consider a capacitor of capacitance C. Initially, its two plates are uncharged. Suppose the positive charge is transferred from plate 2 to plate 1 bit by bit. In this process, external work has to be done because at any stage plate 1 is at higher potential than the plate 2. Suppose at any instant the plates 1 and 2 have charges Q' and $-Q'$ respectively, as shown in Figure a. Then the potential difference between the two plates will be

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



(a) (b)

Suppose now a small additional charged dQ' be transferred from plate 2 to plate 1. The work done will be,

$$dW = V' \cdot dQ' = \frac{Q'}{C} \cdot dQ'$$

The total work done in transferring a charge Q from plate 2 to plate 1 (Figure b) will be,

$$W = \int dW = \int_0^Q \frac{Q'}{C} \cdot dQ'$$

$$= \left[\frac{Q'^2}{2C}\right]_0^Q = \frac{1}{2} \cdot \frac{Q^2}{C}$$

This work done is stored as electrical potential energy U of the capacitor.

$$U = \frac{1}{2} \cdot \frac{Q^2}{C} = \frac{1}{2} \cdot CV^2$$

$$= \frac{1}{2}QV \quad (\text{Since}, Q = CV)$$

Energy Density between Plates of Capacitor

Capacitance of the parallel plate capacitor is given by,

$$C = \frac{\varepsilon_0 A}{d} \quad ...(1)$$

If σ is the surface charge density on the capacitor plates, then electric field between the capacitor plates will be,

$$E = \frac{\sigma}{\varepsilon_0}$$

$$\sigma = \varepsilon_0 E$$

Charge on either plate of capacitor is,

$$Q = \sigma A = \varepsilon_0 EA \quad ...(2)$$

Hence, Energy stored in the capacitor is,

$$U = \frac{Q^2}{2C} = \frac{(\varepsilon_0 EA)^2}{2 \cdot \frac{\varepsilon_0 A}{d}}$$ [From Eq. (1) and (2)]

$$= \frac{1}{2}\varepsilon_0 E^2 Ad$$

But $Ad =$ volume of the capacitor between its two plates. Therefore, the energy stored per unit volume or the energy density of the electric field is given by,

$$\boxed{u = \frac{U}{Ad} = \frac{1}{2}\varepsilon_0 E^2}$$

32. 1. Derive an expression for the current density in terms of the drift speed of electrons.
2. Derive Ohm's law on the basis of the theory of electron drift.
3. Derive an expression for the resistivity of a conductor in terms of number density of free electrons and relaxation time.

Ans :

1. **Relation between Electric Current and Drift Velocity :** Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by

$$E = \frac{V}{l}$$

Under the influence of field $\vec{E}$, the free electrons begin to drift in the opposite direction $\vec{E}$ with an average drift velocity v_d.

Let the number of electrons per unit volume or electron density $= n$

Charge on an electron $= e$

Number of electrons in length l of the conductor $= n \#$ volume of the conductor $= nAl$

Total charge contained in length l of the conductor is $q = enAl$

All the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d}$$

Hence, Current, $I = \frac{q}{t} = \frac{enAl}{l/v_d}$

$$I = enAv_d$$

The equation relates the current I with the drift velocity v_d.

The current density j is given by,

$$j = \frac{I}{A} = env_d$$

2. **Deduction of Ohm's law :** If m is the mass of an electron and τ is the relaxation time, then drift velocity,

$$v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

:since $E = \frac{V}{l}$D

Hence, Current, $I = enAv_d$

$$= enA \cdot \frac{eV\tau}{ml}$$

$$\frac{V}{I} = \frac{ml}{ne^2\tau A}$$

At a fixed temperature, the quantities m, l, n, e, τ and A, all have constant value for a given conductor.

Therefore, $\frac{V}{I}$ = a constant R

This proves Ohm's law for a conductor and here

$$R = \frac{ml}{ne^2\tau A}$$

is the resistance of the conductor.

3. **Resistivity in Terms of Electron Density and Relaxation Time :** The resistance R of a conductor of length l, area of cross-section A and resistivity ρ is given by,

$$R = \rho\frac{l}{A}$$

But, $$R = \frac{ml}{ne^2\tau A}$$

where, τ is the relaxation time. Comparing the above two equations, we get

$$\rho = \frac{m}{ne^2\tau}$$

Obviously, ρ is independent of the dimensions of the conductor but depends on its two parameters :

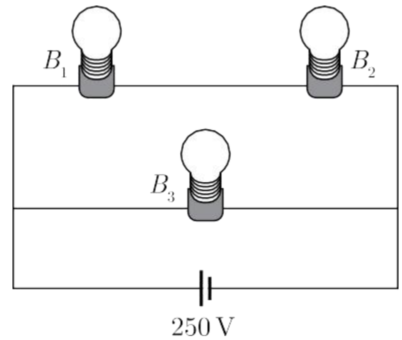
(a) Number of free electrons per unit volume or electron density of the conductor.

(b) The relaxation time τ, the average time between two successive collisions of an electron.

or

A 100 W bulb B_1 and two 60 W bulbs B_2 and B_3, are connected to a 250 V source as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively.

What is the relation between the output powers of bulbs?



Ans :

Given,

Power of bulb B_1, $P_1 = 100$ W

Power of bulb B_2, $P_2 = 60$ W

Power of bulb B_3, $P_3 = 60$ W

Source voltage, $V = 250$ Volt

Output power of bulb, $B_1 = W_1$

Output power of bulb, $B_2 = W_2$

Output power of bulb, $B_3 = W_3$

We know that resistance of bulb B_1,

$$R_1 = \frac{V^2}{P_1} = \frac{(250)^2}{100} = 625\,\Omega$$

Similarly, resistance of bulb B_2,

$$R_2 = \frac{V^2}{P_2} = \frac{(250)^2}{60} = 1042\,\Omega$$

and resistance of bulb B_3,

$$R_3 = \frac{V^2}{P_3} = \frac{(250)^2}{60} = 1042\,\Omega$$

We also know that as the resistance R_1 and R_2 are connected in series. Therefore, output power of bulb B_1,

$$W_1 = \frac{V^2}{(R_1 + R_2)} \# R_1$$

$$= \frac{(250)^2}{(625 + 1042)^2} \# 625$$

$$= 14.1 \text{ W}$$

Similarly, output power of bulb B_2,

$$W_2 = \frac{V^2}{(R_1 + R_2)^2} \# R^2$$

$$= \frac{(250)^2}{(625 + 1042)^2} \# \ 1042$$

$$= 23.4 \text{ W}$$

and output power of bulb B_3,

$$W_3 = \frac{V^2}{R_3^2} \# R_3$$

$$= \frac{(250)^2}{(1042)^2} \# \ 1042 = 60 \text{ W}$$

Therefore, $W_1 < W_2 < W_3$

33. (a) How is a wavefront defined ? Distinguish between a plane wavefront and a spherical wavefront. Using Huygen's constructions draw a figure showing the propagation of a plane wave refracting at a plane surface separating two media. Hence verify Snell's law of refraction. When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply reduction its energy ? Explain.

(b) When monochromatic light travels from a rarer to a denser medium, explain the following.

(i) Is the frequency of reflected and refracted light same as the frequency of incident light ?

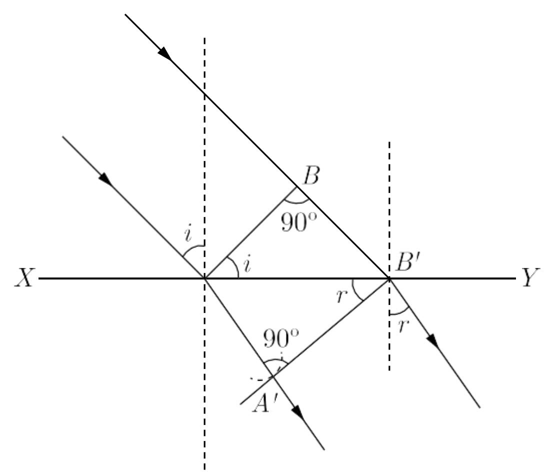
(ii) Does the decrease in speed imply a reduction in the energy carried by light wave ?

Ans :

(a) **Wavefront :** A wavefront is a locus of all particles of medium vibrating in the same phase.

Huygen's Principle : When a wavefront strikes to the corner of an obstacle, light wave bends around the corner because every point on wavefront again behaves like a light source and emit secondary wavelets in all directions (Huygen's wave theory) including the region of geometrical shadow. This explains diffraction.

Proof of Snell's law of Refraction using Huygen's wave theory : When a wave starting from one homogeneous medium enters the another homogeneous medium, it is deviated from its path. This phenomenon is called refraction. In transversing from first medium to another medium, the frequency of wave medium to another medium, the frequency of wave remains unchanged but its speed and the wavelength both are changed. Let XY be a surface separating the two media 1 and 2. Let v_1 and v_2 be the speeds of waves in these media.



Suppose a plane wavefront AB in first medium is incident obliquely on the boundary surface XY and its end A touches the surface at A at time $t = 0$ while the other end B reaches the surface at point B after time-interval t. Clearly $BB1 = v_1 t$. As the wavefront AB advances, it strikes the points between A and $B1$ of boundary surface. According to Huygen's principle, secondary spherical wavelets originate from these points, which travel with speed v_1 in the first medium and speed v_2 in the second medium.

First of all secondary wavelet starts from A which transverses a distance $AA1(= v_2t)$ in second medium in time t. In the same time-interval t, the point of wavefront transverses a distance $BB1(= v_1t)$ in first medium and reaches $B1$, from where the secondary wavelet now starts. Clearly $BB1 = v_1t$ and $AA1 = v_2t$.

Assuming A as centre, we draw a spherical arc of radius $AA1(= v_2t)$ and draw tangent $B1A1$ on this arc from $B1$. As the incident wavefront AB advances, the secondary wavelets start from points between A and $B1$, one after the other and will touch $A1B1$ simultaneously. According to Huygen's principle $A1B1$ is the new position of wavefront AB in the second medium. Hence $A1B1$ will be the refracted wavefront.

First law : As AB, $A1B1$ and surface XY are in the plane of paper, therefore the perpendicular drawn on them will be in the same plane. As the lines drawn normal to wavefront denote the rays, therefore we may say that the incident ray, refracted ray and the normal at the point of incidence all lie in the same plane. This is the first law of refraction.

Second law : Let the incident wavefront AB and refracted wavefront $A1B1$ make angles I and r respectively with refracting surface XY.

In right angled $TAB1B$,

$$+ABB1 = 90c$$

Hence,

$$\sin r = \sin +BAB1 = \frac{BB1}{AB1} = \frac{v_1t}{AB1} \quad ...(1)$$

Similarly in right-angled

$TAA1B1$, $\quad +AA1B1 = 90c$

Hence,

$$\sin r = \sin +AB1A1 = \frac{AA1}{AB1} = \frac{v_2t}{AB1} \quad ...(2)$$

Dividing equation (1) by (2), we get

$$\frac{\sin r}{\sin r} = \frac{v_1}{v_2} = \text{constant} \quad ...(3)$$

$$\overset{\$}{dB_x} = \frac{\mu_0 Idl}{4\pi r^2} \cdot \frac{R}{r} = \frac{\mu_0 IR}{4\pi r^3} dl$$

As the rays are always normal to the wavefront, therefore the incident and refracted rays make angles i and r with the normal drawn on the surface XY i.e., i and r are the angle of incidence and angle of refraction respectively. According to equation (3). The ratio of sine of angle of incidence and the sine of angle of refraction for a given pair of media is a constant and is equal to the ratio of velocities of waves in the two media. This is the second law of refraction and is called the Snell's law.

(b)

(i) If the radiation of certain frequency interact with the atoms/molecules of the matter, they start to vibrate with the same frequency under forced oscillations.
Thus, the frequency of the scattered light (under reflection and refraction) equals to the frequency of incident radiation.

(ii) No, energy carried by the wave depends on the amplitude of the wave, but not on the speed of the wave.

or

(a) In Young's double slit experiment, two slits are 1 mm apart and the screen is placed 1 m away from the slits. Calculate the fringe width when light of wavelength 500 nm is used.

(b) What should be the width of each slit in order to obtain 10 maxima of the double slits pattern within the central maximum of the single slit pattern ?

(c) The intensity at the central maxima in Young's double slit experiment is I_0. Find out the intensity at a point where the path difference is $\frac{l}{6}, \frac{l}{4}$ and $\frac{\lambda}{3}$.

Ans :

(a) Fringe width is given by

$$\beta = \frac{\lambda D}{d}$$

$$= \frac{500 \# 10^{-9} \# 1}{10^{-3}} = 0.5 \text{ mm}$$

$$= 0.5 \# 10^{-3} \text{ m} = 5 \# 10^{-4} \text{ m}$$

(b) $\beta_0 = \frac{2\lambda D}{d} = 10\beta$

$$d = \frac{2 \# 500 \# 10^{-9} \# 1}{10 \# 5 \# 10^{-4}}$$

$$= 2 \# 10^{-4} \text{ m}$$

(c) The general expression, for the intensity, at a point is

$$I = I_0 \cos^2 \frac{\varphi}{2}$$

(i) For path difference $= \frac{\lambda}{6}, \varphi = 60c$

$$I = \frac{3I_0}{4}$$

[For path difference λ, phase difference $\varphi = 2\pi$]

(ii) For path difference $= \frac{\lambda}{4}, \varphi = 90c$

$$I = \frac{I_0}{2}$$

(iii) For path difference $= \frac{\lambda}{3}, \varphi = 120c$

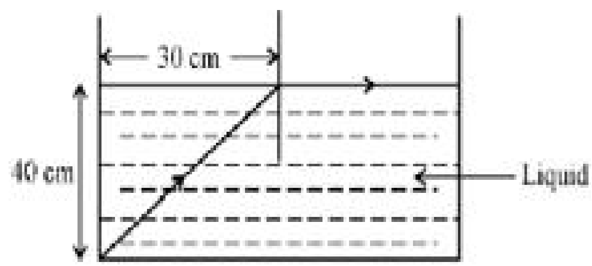
$$I = \frac{I_0}{4}$$

SECTION-E

34. Total internal reflection (TIR) is the optical phenomenon in which waves arriving at the interface (boundary) from one medium to another (e.g., from water to air) are not refracted into the second ("external") medium, but completely reflected back into the first ("internal") medium. It occurs when the second medium has a higher wave speed (i.e., lower refractive index) than the first, and the waves are incident at a sufficiently oblique angle on the interface. For example, the water-to-air surface in a typical fish tank, when viewed obliquely from below, reflects the underwater scene like a mirror with no loss of brightness. TIR occurs not only with electromagnetic waves such as light and microwaves, but also with other types of waves, including sound and water waves. If the waves are capable of forming a narrow beam , the reflection tends to be described in terms of "rays" rather than waves; in a medium whose properties are independent of direction, such as air, water or glass, the "rays" are perpendicular to the associated wave fronts.

Repeated total internal reflection of a 405nm laser beam between the front and back surfaces of a glass pane. The colour of the laser light itself is deep violet; but its wavelength is short enough to cause fluorescence in the glass, which re-radiates greenish light in all directions, rendering the zigzag beam visible.

Refraction is generally accompanied by partial reflection. When waves are refracted from a medium of lower propagation speed (higher refractive index) to a medium of higher speed e.g., from water to air the angle of refraction (between the outgoing ray and the surface normal) is greater than the angle of incidence (between the incoming ray and the normal). As the angle of incidence approaches a certain threshold, called the critical angle, the angle of refraction approaches 90°, at which the refracted ray becomes parallel to the boundary surface. As the angle of incidence increases beyond the critical angle, the conditions of refraction can no longer be satisfied, so there is no refracted ray, and the partial reflection becomes total. For visible light, the critical angle is about 49° for incidence from water to air, and about 42° for incidence from common glass to air.



1. What is refractive index of a medium? (in terms of speed of light)
2. In the above diagram, calculate the speed of light in the liquid of unknown refractive index?
3 What is refractive index of a medium (in terms of real and apparent depth)?

or

4 What is the relation between refractive index and critical angle for a medium?

Ans :

1. Speed of light in vacuum/speed of light in medium.
2. 1.8×10^8 m/s.
3. Real depth/Apparent depth.

or

4. $n = 1/\sin i_c$

35. A pure semiconductor germanium or silicon, free of every impurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes). Hence its conductivity is low. When the impurity atoms of valance five or three are doped in a pure semiconductor, we get respectively n -type or p -type extrinsic semiconductor. In case of doped semiconductor $n_e n_h = n_i^2$. Where n_e and n_h are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity of extrinsic semiconductor is much higher than that of intrinsic semiconductor.

Answer the following questions :

1. What is n-type semiconductor?
2. Do pure semiconductors obey Ohm's law?
3. Why do semiconductors behave as conductors at room temperature?

or

4. Why does a semiconductor behaves as an insulator at very low temperature?

Ans :

1. An n -type semiconductor is an intrinsic semiconductor doped with phosphorus (P), arsenic (As), or antimony (Sb) as an impurity. Silicon of Group IV has four valence electrons and phosphorus of Group V has five valence electrons.
2. Semiconductors do not obey Ohm's law because $I - V$ characteristics is a curved line instead of straight line.
3. At room temperature, a few electrons in valence band acquire energy greater than the forbidden energy gap and move to conduction band. Hence, at room temperature a pure semiconductor behaves slightly as a conductor.

or

4. Pure semiconductor is almost an insulator at low temperature because in this condition the electrons form the valence band cannot move towards the conduction band. Hence, it is almost insulator.