Physics (Theory) [Official]
CISCE
ISC (Science)
Academic Year: 2023-2024
Date & Time: 4th March 2024, 2:00 pm

Duration: 3h **Marks: 70**

- Candidates are allowed an additional 10 minutes for only reading the paper.
- They must NOT start writing during this time.
- This question paper is divided into four Sections: A, B, C and D.
- Answer all questions.
- **Section A** consists of one question having sub-parts of one mark each.
- **Section B** consists of seven questions of two marks each.
- **Section C** consists of nine questions of three marks each.
- **Section D** consists of three questions of five marks each.
- Internal choices have been provided in two questions each in Section B, Section C and Section D.
- The intended marks for questions are given in brackets [].
- All work, including rough work, should be done on the Same sheet as and adjacent to the rest of the answer.
- Answers to sub-parts of the same question must be given in one place only.
- A list of useful physical constants is given at the end of this paper.
- A simple scientific calculator without a programmable memory may be used for calculations.

SECTION A - 14 MARKS

Q1.

1. (a) In questions (i) to (vii) given below, choose the correct alternative (a), (b), (c) or (d) for each of the questions.

1. (a) (i) If potential difference between the two ends of a metallic wire is doubled, drift speed of free electrons in the wire ______.

1. Remains same.
2. Becomes double.
3. Becomes four times
4. Becomes half

Solution

If potential difference between the two ends of a metallic wire is doubled, drift speed of free electrons in the wire becomes double.

Explanation:

$$\text{Drift velocity} = v_d = \frac{eV\tau}{ml}$$

When V is Potential difference

According to question, V = 2V

$$\text{Then } v_d = \frac{2eV\tau}{ml}$$

$= 2v_d$

Hence, drift velocity also becomes double.

1. (a) (ii) A meter bridge is balanced with a known resistance (R) in the left hand gap and an unknown resistance (S) in the right hand gap. Balance point is found to be at a distance of 1 cm from the left hand side. When the battery and the galvanometer are interchanged, balance point will ______.

1. Shift towards left.
2. Shift towards right.
3. **Remain same.**
4. Shift towards left or right depending on the values of R and S.

Solution

A meter bridge is balanced with a known resistance (R) in the left hand gap and an unknown resistance (S) in the right hand gap. Balance point is found to be at a distance of 1 cm from the left hand side. When the battery and the galvanometer are interchanged, balance point will remain same.

Explanation:

The balance point remains constant even if the galvanometer and batteries are switched out.

1. (a) (iii) Lorentz force in vector form is ______.

1. F = Bq v sin θ
2. $\overrightarrow{F} = q\left(\overrightarrow{v} \times \overrightarrow{B}\right)$
3. $\overrightarrow{F} = q\left(\overrightarrow{B} \times \overrightarrow{v}\right)$
4. $\overrightarrow{F} = \overrightarrow{v}\left(\overrightarrow{q} \times \overrightarrow{B}\right)$

Solution

Lorentz force in vector form is $\underline{\overrightarrow{\mathbf{F}} = \mathbf{q}\left(\overrightarrow{\mathbf{v}} \times \overrightarrow{\mathbf{B}}\right)}$.

1. (a) (iv) **Assertion:** When an electric current is passed through a moving coil galvanometer, its coil gets deflected.

Reason: A circular coil produces a uniform magnetic field around itself when an electric current is passed through it.

1. Both Assertion and Reason are true and Reason is the correct explanation for Assertion.
2. Both Assertion and Reason are true but Reason is not the correct explanation for Assertion.
3. Assertion is true and Reason is false.
4. Assertion is false and Reason is true.

Solution

Assertion is true and Reason is false.

Explanation:

A magnetic field generated by a circular coil carrying current is not a constant magnetic field.

1. (a) (v) When a ray of white light is incident obliquely on the first surface of a prism, then ______.

1. Red colour is deviated most.
2. Green colour is deviated most.
3. Yellow colour is deviated most.
4. **Violet colour is deviated most.**

Solution

When a ray of white light is incident obliquely on the first surface of a prism, then violet colour is deviated most.

Explanation:

Shorter wave lengths (like violet) deviate more in a prism due to increased refraction, whereas longer wavelengths (like red) deviate least. The deviation of light in a prism is dependent on its wavelength.

1. (a) (vi) The de-Broglie wavelength (λ) associated with a moving electron having kinetic energy (E) is given by ______.

1. $\frac{2h}{\sqrt{2mE}}$
2. $\frac{2\left(\sqrt{2mE}\right)}{h}$
3. **$\frac{h}{\sqrt{2mE}}$**
4. $\sqrt{2mhE}$

Solution

The de-Broglie wavelength (λ) associated with a moving electron having kinetic energy (E) is given by

$$\frac{\mathbf{h}}{\sqrt{\mathbf{2mE}}}.$$

Explanation:

Kinetic energy, $E = \frac{1}{2} mv^2$

or $mv = \sqrt{2mE}$

de-Broglie wavelength $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

1. (a) (vii) The majority charge carriers in a P-type semiconductor are ______.

1. Electrons
2. Holes
3. Protons
4. Ions

Solution

The majority charge carriers in a P-type semiconductor are holes.

Explanation:

In a P-type semiconductor, holes represent the majority carrier and electrons the minority carrier.

1. (b) Answer the following questions briefly.

1. (b) (i) In an electric dipole, what is the locus of a point having zero potential?

Solution

The equatorial plane is the locus of a point having zero potential in an electric dipole.

1. (b) (ii) Three identical cells each of emf 'e' are connected in parallel to form a battery. What is the emf of the battery?

Solution

In a parallel combination, emf of the battery = emf of each cell = e.

1. (b) (iii) Three bulbs B_1 (230V, 40W), B_2 (230V, 60W) and B_3 (230V, 100W) are connected in series to a 230V supply. Which bulb glows the brightest?

Solution

The bulb B_1 (230V, 40W) will glow the brightest when connected in series with B_2 and B_3 because the resistance $\left(R = \frac{V^2}{P}\right)$ is highest for B_1.

1. (b) (iv) Explain the meaning of the following statement:

Curie temperature for soft iron is 770°C.

Solution

The temperature at which a ferromagnetic material turns paramagnetic is known as the Curie temperature. Soft iron turns paramagnetic around 770°C.

1. (b) (v) What type of wavefronts are associated with a point source of light?

Solution

Light-point sources are connected to spherical wavefronts.

1. (b) (vi) What is 'Pair production'?

Solution

An electron and a positron are produced when an intense γ-ray photon strikes a heavy material. One of the substance's nuclei is responsible for absorbing the photon. Pair creation is the term used to describe this process of energy being transformed into mass.

Equation: $$\underset{(\gamma\text{- Photon})}{\gamma} = \underset{(\text{Electron})}{{}_{-1}\beta^0} + \underset{(\text{Positron})}{{}_{+1}\beta^0}$$

1. (b) (vii) In semiconductor physics, what is the function of a rectifier?

Solution

A rectifier's job is to change an alternating current's (also known as voltage) into a direct current's (also known as voltage).

SECTION B - 14 MARKS

Q2.

2. (a)

2. (a) (i) A hollow sphere of radius R has a point charge q at its centre. Electric flux emanating from the sphere is X. How will the electric flux change, if at all, when radius of the sphere is doubled?

Solution

The electric flux remains unchanged when the sphere's radius is doubled, while the charge 'q' remains constant.

2. (a) (ii) A hollow sphere of radius R has a point charge q at its centre. Electric flux emanating from the sphere is X. How will the electric flux change, if at all, when charge q is replaced by an electric dipole?

Solution

The electric flux is zero when an electric dipole takes the place of charge 'q'.

OR

2. (b) In case of an infinite line charge, how does intensity of electric field at a point change, if at all, when.

a. charge on it is doubled?

b. distance of the point is halved?

Solution

The intensity of the electric field E at a point located at a distance r from the line charge is $E = \frac{\lambda}{2\pi \in_0 r}$ where, λ is the charge per unit length.

a. The charge on it is doubled.

Given λ = 2λ

$\therefore E' = \frac{\lambda}{2\pi \in_0 r}$

New electric field intensity

$E' = \frac{2\lambda}{2\pi \in_0 r}$

$= 2 \cdot \frac{\lambda}{2\pi \in_0 r}$

= 2E

Thus, the intensity of the electric field is doubled.

b. The distance of the point is halved:

Given, $r' = \frac{r}{2}$

$\therefore E' = \frac{\lambda}{2\pi \in_0 r'}$

New electric field intensity

$E' = \frac{\lambda}{2\pi \in_0 \left(\frac{r}{2}\right)}$

$= 2 \cdot \frac{\lambda}{2\pi \in_0 r}$

= 2E

Hence, the intensity of the electric field is also doubled in this case.

Q3.

3. (a) What is meant by the statement: "Relative permittivity of water is 81"?

Solution

Since water has a relative permittivity of 81, the force between two charges in it will be 1/81 that of the same two charges in a vacuum.

3. (b) Can a body be given a charge of 2.2×10^{-19} C? Give a reason for your answer.

Solution

No, a charge of 2.2×10^{-19} C cannot be given to a body because 2.2×10^{-19} C is not an integral multiple of the quantum of charge (1.6×10^{-19} C).

Q4.

4. (a) What type of transformer is used in a mobile phone charger?

Solution

A step-down transformer is used in mobile phone chargers.

4. (b) Why is the core of a transformer made of soft iron?

Solution

The core of a transformer is made of soft iron because it has high permeability, so, it provides complete linkage of the magnetic flux of the primary coil to the secondary coil. Secondly, the hysteresis loss of energy in soft iron is less.

Q5.

5. (a) Name the electromagnetic radiation whose frequency is 10 Hz.

Solution

Microwaves or short radio waves.

5. (b) What is the speed of radio waves in vacuum?

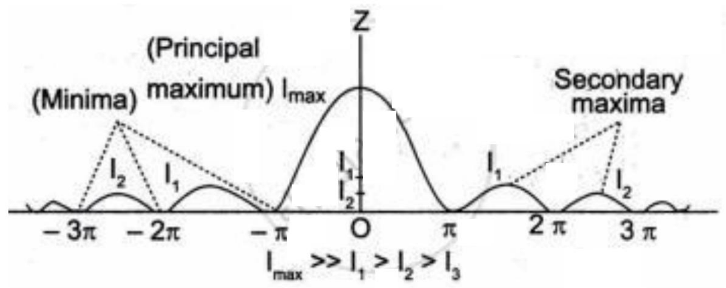
Solution

$3 \times 10^8\ ms^{-1}$

Q6. Draw a labelled graph showing the variation in intensity of diffracted light with diffracting angle in a single slit Fraunhofer diffraction experiment.

Solution

Intensity distribution for Fraunhofer diffraction at a single slit.



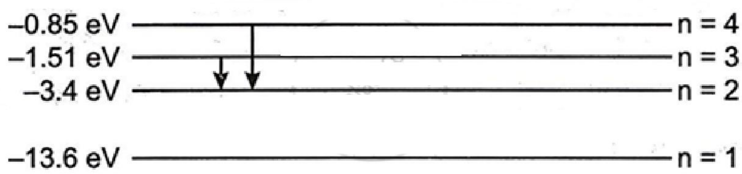
Q7.

7. (a)

7.1. (a) The figure below is the Energy level diagram for the Hydrogen atom. Study the transitions shown and answer the following question:

a. State the type of spectrum obtained.

b. Name the series of spectrum obtained.



Solution

a. It is a visible spectrum for the hydrogen atom.

b. The name of the series is Balmer series.

OR

7. (b)

7.1. (b) (i) In a nuclear reactor, state the use of graphite rods.

Solution

In order to slow down neutrons to thermal energy, graphite rods serve as moderators.

7.1. (b) (ii) In a nuclear reactor, state the use of cadmium rods.

Solution

Cadmium rods, used to control the fission rate, absorb the additional neutrons.

Q8.

8. (a) With reference to a semiconductor diode, define the depletion region.

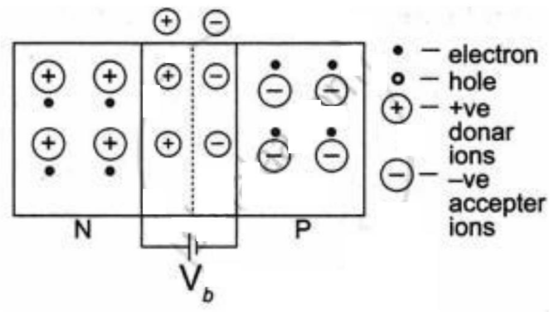
Solution

A semiconductor diode's depletion zone is the area surrounding the p-n junction where there are no mobile charge carriers, this area generates an electric field that allows the diode to conduct in one direction while blocking in another.

8. (b) With reference to a semiconductor diode, define the potential barrier.

Solution

The barrier that the repelling forces use to stop the mobile charge carriers (at the PN junction) is known as the potential barrier.



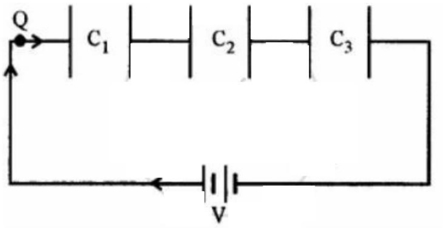
This results from the concentration of immobile charges close to the junction after electrons and holes diffuse across the function.

SECTION C - 27 MARKS

Q9. Obtain an expression for equivalent capacitance when three capacitors C_1, C_2 and C_3 are connected in series.

Solution

All the capacitors are connected in series, In the fig. are shown three capacitors of capacity C_1, C_2, C_3 connected in series. The charge Q flowing through each of the capacitors is the same but potential difference across them will be different. If V_1, V_2, and V_3 are the potential difference across them, then



$$V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}, V_3 = \frac{Q}{C_3}$$

If C is the capacitance of the combination, then

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

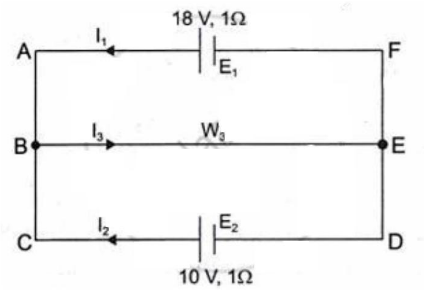
Also, $V = V_1 + V_2 + V_3$

$$\text{or } \frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$, which is the required relation.

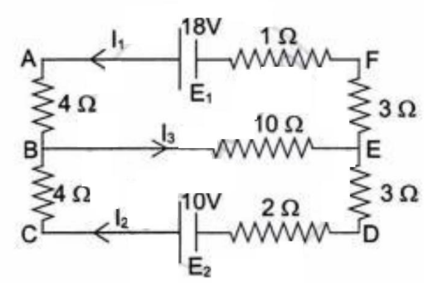
Q10.

10. (a) The figure below shows two batteries, E1 and E2, having emfs of 18V and 10V and internal resistances of 1 Ω and 2 Ω, respectively. W_1, W_2 and W_3 are uniform metallic wires AC, FD and BE having resistances of 8 Ω, 6 Ω and 10 Ω respectively. B and E are midpoints of the wires W_1 and W_2. Using Kirchhoff's laws of electrical circuits, calculate the current flowing in the wire W_3:



Solution

Since B and E are the mid-points of AC and FD respectively, so resistance between AB, BC, DE and EF will be 4 Ω, 4 Ω, 3 Ω and 3 Ω respectively as shown in the diagram.



Using Kirchhoff's law in the closed-loop ABEFA, we have:

$4 I_1 + 10 I_1 + 10 I_2 + 3 I_1 + 1 I_1 = 18$

$18 I_1 + 10 I_2 = 18$

$9 I_1 + 5 I_2 = 9$ ...(i)

For the closed-loop BEDCB, we have.

$4 I_2 + 10 I_1 + 10 I_2 + 3 I_2 + 2I_2 = 10$

$10 I_1 + 19 I_2 = 10$ ...(ii)

Solving equation (i) and (ii),

$9 I_1 + 5 I_2 = 9$ ...(i) × 10

$10 I_1 + 19 I_2 = 10$ ...(ii) × 9

$90 I_1 + 50 I_2 = 90$

$90 I_1 + 171 I_2 = 90$

(-) (-) (-)

$\Rightarrow -121 I_2 = 0$

$\Rightarrow I_2 = 0$

Putting $I_2 = 0$ in equation (i),

$9 I_1 + 5 \times 0 = 9$

$9 I_1 = 9$ or $I_1 = 1A$

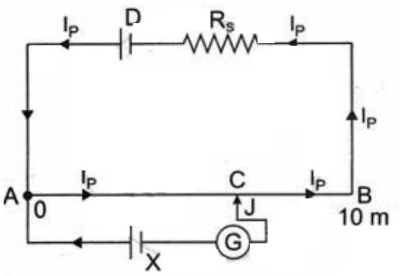
$\therefore I_1 = 1A, I_2 = 0$

and $I_3 = I_1 + I_2$

$= 1A$

OR

10. (b) The Figure below shows a potentiometer circuit in which the driver cell D has an emf of 6 V and internal resistance of 2 Ω. The potentiometer wire AB is 10 m long and has a resistance of 28 Ω. The series resistance R_S is of 2 Ω.



a. The current I_p flowing in the potentiometer wire AB when the jockey (J) does not touch the wire AB.

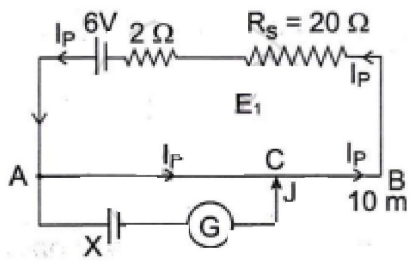
b. emf of the cell X if the balancing length AC is 4.5 m.

Solution

Resistance of 10 m wire AB = 28 Ω

Rs = 20 Ω

r = 2 Ω



∴ Total resistance (R) = (28 + 20 + 2) Ω = 50 Ω

$$I_p = \frac{V}{R}$$
$$= \frac{6}{50}\ A$$
$$= 0.12\ A$$

$V_{AB} = I_P \times R_{AB}$

= 0.12 × 28 V

= 3.36 V

emf of cell

$$X = Kl\ \ldots\left(\begin{array}{c}\text{Here } K = \frac{3.36}{10}\ Vm^{-1} = 0.336\ Vm^{-1} \\ \text{and } l = 4.5\ m\end{array}\right)$$

X = 0.336 × 4.5 V

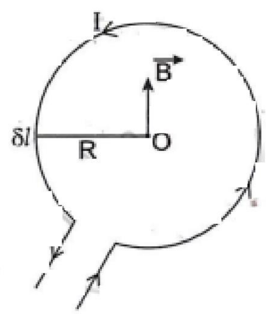
X = 1.512 V

Q11. Using Biot-Savart law, show that magnetic flux density 'B' at the centre of a current carrying circular coil of radius R is given by:

$B = \frac{\mu_0 I}{2R}$ where the terms have their usual meaning.

Solution

Let a circular coil of radius R carry a current I and O be its centre.



By Biot-Savart's law, the magnitude of the magnetic field at O due a small element δ l of the loop is,

$$\delta B = \frac{\mu_0}{4\pi}\frac{I\delta l \sin\theta}{R^2}$$

Where θ is the angle between the length of the element (δ l) and the line joining the element to the point O. Here, θ = 90° because every element of. a circle is perpendicular to the radius.

$$\therefore \delta B = \frac{\mu_0}{4\pi} \frac{I \delta l}{R^2}$$

Every component of the coil will have the same field direction.

Because of the complete coil, the field $\vec{B}$ magnitude at O is:

$$B = \frac{\mu_0}{4\pi} \frac{I}{R^2} \sum \delta l$$

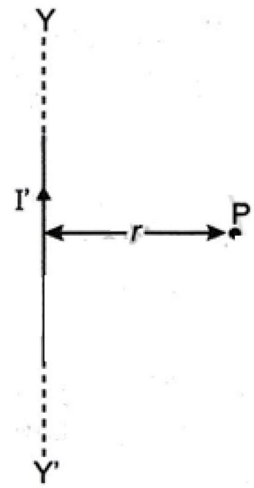
But $\sum \delta l = 2\pi R$

$$\therefore B = \frac{\mu_0}{4\pi} \cdot \frac{I}{R^2} \times 2\pi R$$

or $B = \dfrac{\mu_0 I}{2R}$

Q12. The Figure below shows an infinitely long metallic wire YY' which is carrying a current I'.

P is a point at a perpendicular distance r from it.



i. What is the direction of magnetic flux density B of the magnetic field at the point P?

ii. What is the magnitude of magnetic flux density B of the magnetic field at the point P?

iii. Another metallic wire MN having length l and carrying a current I is now kept at point P. If the two wires are in vacuum and parallel to each other, how much force acts on the wire MN due to the current I' flowing in the wire YY'?

Solution

(i) The magnetic flux density B at point P will be directed perpendicularly inside the paper plane according to right-hand palm rule no. 2.

(ii) $B = \frac{\mu_0 I}{4\pi} \cdot \frac{2I}{r}$

(iii) $F = \frac{\mu_0}{4\pi} \cdot \frac{2II}{r} \times l$ (l is the length of the wire)

Q13.

13. (a) Using Huygen's wave theory, show that (for refraction of light):

$$\frac{\sin i}{\sin r} = \text{constant}$$

where terms have their usual meaning. You must draw a neat and labelled diagram.

Solution

Let SS' represent the surface separating media 1 and 2 of refractive indices n_1 and n_2, respectively. Let c_1 and c_2 be the velocities of light in the two media. The second medium is optically denser than the first, hence $c_1 > c_2$.

APB is the incident wavefront. By the time the disturbance at B reaches C, the secondary wavelet from A has travelled a distance of AD = c_2t, where t is the time, it took the waves to travel the distance of BC. Therefore, BC= c_1 t and AD= c_2t.· With A as the centre and radius AD(= c_2t), we draw a sphere and a tangent CD to the sphere is also drawn from the point C. Thus, CD represents the refracted plane wavefront. To prove that CD is the common wavefront, it is enough to show that in the time the disturbance travels from B to C or A to D, the disturbance at P reaches L. With M as the centre, we draw a sphere such that CD happens to be the tangent of the sphere.

From the similar triangles ACD and MCL,

$$\frac{AD}{ML} = \frac{AC}{MC} \quad ...(i)$$

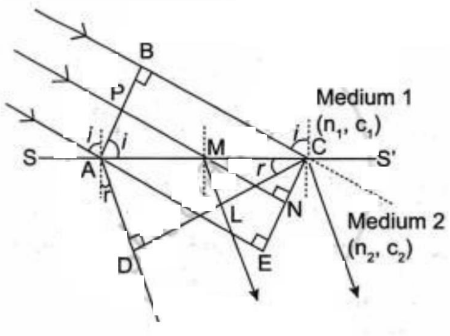
Similarly, from similar triangles (ACE and MCN),

$$\frac{\text{AE}}{\text{MN}} = \frac{\text{AC}}{\text{MC}} \quad ...(ii)$$

From (i) and (ii),

$$\frac{\text{AD}}{\text{ML}} = \frac{\text{AE}}{\text{MN}}$$

$$\text{or } \frac{\text{AE}}{\text{AD}} = \frac{\text{MN}}{\text{ML}}$$



∵ AE = BC = c_1t and AD = c_2t, we can write,

$$\frac{\text{AE}}{\text{AD}} = \frac{c_1t}{c_2t} = \frac{\text{MN}}{\text{ML}}$$

$$\text{or } \frac{\text{BC}}{\text{AD}} = \frac{\text{MN}}{\text{ML}} = \frac{c_1}{c_2} \quad ...(iii)$$

The radius of the secondary wavefront for point A is therefore AD, while the radius of the secondary wavefront for point M is ML.

Let r and i represent the angles of refraction and incidence, respectively.

From triangle ABC and ACD,

$$\frac{\sin i}{\sin r} = \frac{\frac{\text{BC}}{\text{AC}}}{\frac{\text{AD}}{\text{AC}}} = \frac{\text{BC}}{\text{AD}} = \frac{c_1t}{c_2t} = \frac{c_1}{c_2} = {}_1n_2$$

${}_1n_2$ is constant and is called the refractive index of the second medium with respect to the first medium. So, $\frac{\sin i}{\sin r}$ = constant

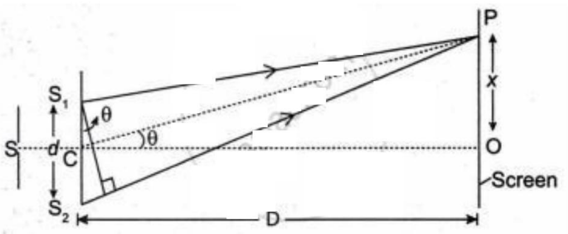
OR

13. (b) In Young's double slit experiment, show that:

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

Where the terms have their usual meaning.

Solution



Assume that S is a light source that is receiving light from another light source. Two line sources, S_1 and S_2, are equally spaced apart from light source S.

Let $S_1S_2 = d$

Path difference between waves at point P,

$S_2P - S_1P = S_2A$

ΔS_1S_2A and ΔPCO are similar to each other.

$$\therefore \frac{S_2A}{S_1S_2} = \frac{OP}{CP}$$

Since CO is very much greater than S_1S_2,

So, CP ≈ CO

$$\therefore \frac{S_2A}{S_1S_2} = \frac{OP}{CO}$$

$$\frac{S_2A}{d} = \frac{x}{D}$$

$$\therefore \text{Path difference} = \frac{x}{D}$$

For bright fringes, = mλ

$$x = m\,\frac{D\lambda}{d}$$

For m[th] and (m + 1)[th] fringe,

$$x_m = m\,\frac{D\lambda}{d} \text{ and}$$

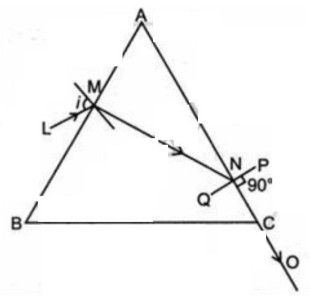
$$x_{m+1} = (m+1)\,\frac{D\lambda}{d}$$

Fringe width, $\beta = x_{m+1} - x_m$

$$= (m+1)\,\frac{D\lambda}{d} - m\,\frac{D\lambda}{d}$$

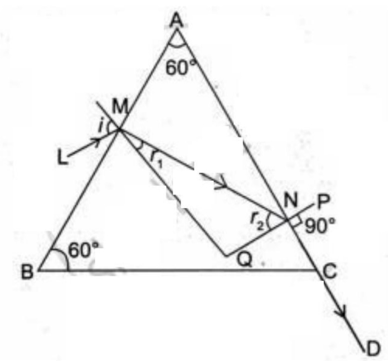
$$\beta = \frac{D\lambda}{d}$$

Q14. The Figure below shows a ray of monochromatic light LM incident on the first surface AB of a regular (equilateral) glass prism ABC. The emergent ray grazes the adjacent surface AC. Calculate the angle of incidence. (Refractive Index of glass = 1.5)



Solution

Given A = 60°, n = 1.5, At the surface AC, r_2 is the critical angle



$$\sin r_2 = \frac{1}{n}$$

$$= \frac{1}{1.5}$$

$$= \frac{2}{3}$$

= 0.6667

$\therefore r_2 = \sin^{-1}(0.6667)$

= 41.8°

Also, $r_1 + r_2 = A$

$r_1 = A - r_2$

= 60° - 41.8°

= 18.2°

At the surface AB,

$$\frac{\sin i}{\sin r_1} = n$$

sin i = 1.5 × sin 18.2°

= 1.5 × 0.31

= 0.465

$\therefore i = \sin^{-1}(0.465)$

= 27.7°

Q15. A student is performing an experiment to determine focal length of a convex lens by using lens formula i.e., by no parallax method. The examiner gives some instructions to the student. The student responds to each instruction as per her understanding of the experiment.

State whether the student's response is correct or incorrect. Give a reason for your answer.

i. EXAMINER: Image formed by the lens is magnified. Reduce the size of the image.
STUDENT moves the lens towards the object pin.

ii. EXAMINER: Plot a graph of (1/v) against (1/u).
STUDENT takes (1/v) on Y axis and (1/u) on X axis.

iii. EXAMINER: Write the relation between the optical power (P) and the focal length (f) of the convex lens.
STUDENT writes P = 2f.

Solution

i. The response of the student is incorrect because the image gets magnified, and the object distance decreases when the lens is moved in the direction of the object pin.

ii. Since a graph can only have two axes at most, the student's response is correct.

iii. The response of the student is incorrect because the relation between P and f is P = 1/f.

Q16.

16. (a) In an experiment on photo electric effect, how does stopping potential change, if at all, when intensity of incident monochromatic UV radiation is increased?

Solution

An increase in the incident radiation intensity has no effect on the stopping potential. Only increases the number of emitted electrons.

16. (b) Ultraviolet light is incident on metals P, Q and R, having work functions 8 eV, 2 eV and 4 eV respectively,

a. Which metal has lowest threshold frequency for photoelectric effect?

b. For which metal is the value of E_{max} minimum?
(Note: E_{max} is maximum kinetic energy of the emitted photoelectrons.)

Solution

a. The metal (Q) with a work function of 2 eV has the lowest threshold frequency since $E_0 = hv_0$.

b. Since, $E_{max} = E - E_0$, the metal (P) having work function of 8 eV will have minimum E_{max}.

Q17.

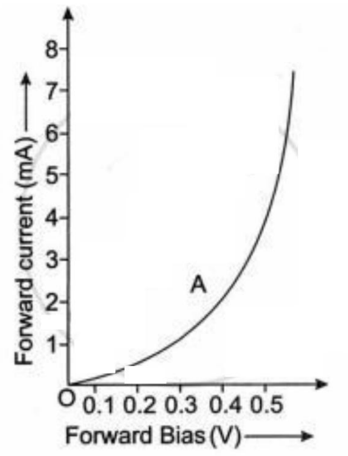
17. (a) What is meant by forward biasing of a semiconductor diode?

Solution

When the positive terminal of an external battery is connected to the n-region of the diode and the negative terminal is connected to the same n-region, the diode is said to be forward biased.

17. (b) Draw a labelled characteristic curve (I-V graph) for a semiconductor diode during forward bias.

Solution



SECTION D -15 MARKS

Q18.

18. (a) (i) A 220V, 50Hz ac source is connected to a coil having coefficient of self-induction of 1H and a resistance of 400 Ω. Calculate:

1. the reactance of the coil.
2. the impedance of the coil.
3. the current flowing through the coil.

Solution

1. Reactance of coil, $X_L = 2\pi fL$

$= 2 \times 3.14 \times 50 \times 1\ \Omega$

$= 314\ \Omega$

2. Impedance of coil,

Z = $\sqrt{R^2 + X_L^2}$

$= \sqrt{400^2 + 314^2}$

$= \sqrt{160000 + 98596}$

$= \sqrt{258596}$

$= 508.5\ \Omega$

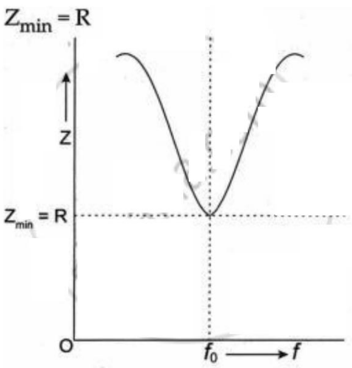
3. Current flowing in coil, $I = \dfrac{V}{Z}$

$= \dfrac{220}{508.5}\ A$

$= 0.43$ A

18. (a) (ii) Draw a labelled graph showing variation of impedance (Z) of a series LCR circuit Vs frequency (f) of the ac supply. Mark the resonant frequency as f_0.

Solution



OR

18. (b) (i) When current flowing through a solenoid decreases from 5A to 0 in 20 milliseconds, an emf of 500V is induced in it.

1. What is this phenomenon called?
2. Calculate coefficient of self-inductance of the solenoid.

Solution

1. The phenomenon is called self-induction.

2. ΔI = (5 – 0) A = 5 A, Δt = 20 × 10^{-3} sec.

$$e = L\frac{\Delta I}{\Delta t}$$

$$L = e \times \frac{\Delta t}{\Delta I}$$

$$= \frac{500 \times 20 \times 10^{-3}}{5} \text{H}$$

= 2H

18. (b) (ii)

18. (b) (ii) 1. RMS value of an alternating current flowing in a circuit is 5A. Calculate its peak value.

Solution

Peak value of ac, $I_0 = I_{rms} \times \sqrt{2} = 5\sqrt{2}A$

18. (b) (ii) 2. State any one difference between a direct current (dc) and an alternating current (ac).

Solution

While alternating current (AC) continuously changes direction at regular intervals, direct current (DC) only travels in one direction.

Q19.

19. (a)

19. (a) (i) On the basis of Bohr's theory, derive an expression for the radius of the n^{th} orbit of an electron of hydrogen atom.

Solution

Let r be the orbit's radius and e, m, and v represent the electron's charge, mass, and velocity. Ze represents the nucleus's positive charge. For an atom of hydrogen, Z = 1. The electrostatic force of attraction provides centripetal force.

Therefore,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze \times e}{r^2}$$

$$mv^2 = \frac{Ze^2}{4\pi\varepsilon_0 r} \quad ...(i)$$

By first postulate:

$$mvr = \frac{nh}{2\pi} \quad ...(ii)$$

Where n is the quantum number.

Squaring equation (ii) and dividing by equation (i), we get:

$$\frac{m^2v^2r^2}{mv^2} = \frac{n^2h^2}{\frac{4\pi^2}{\frac{Ze^2}{4\pi\varepsilon_0 r}}}$$

Then, $r = \frac{n^2h^2\varepsilon_0}{\pi Ze^2 m}$

19. (a) (ii) Calculate the energy released in the following nuclear fusion reaction:

$${}_1^2\mathrm{H} + {}_1^2\mathrm{H} \longrightarrow {}_2^4\mathrm{He} + \text{energy}$$

Mass of ${}_1^2\mathrm{H} = 2.014102\,\mathrm{u}$

Mass of ${}_2^4\mathrm{He} = 4.002604\,\mathrm{u}$

Solution

$${}_1^2\mathrm{H} + {}_1^2\mathrm{H} \longrightarrow {}_2^4\mathrm{He} + \text{energy}$$

Mass of ${}_1^2\mathrm{H} + {}_1^2\mathrm{H} = 2\times\ (2.014102)\mathrm{u}$

= 4.028204u

Mass defect (Δm) = (4.028204 – 4.002604)u

= 0.0256u

∴ Energy released = (Δm) × c^2

= 0.0256 × 931 MeV

= 23.8336 MeV (1u × c^2 = 931 MeV)

OR

19. (b) (i)

Calculate mass defect and binding energy per nucleon of ${}^{20}_{10}Ne$, given

Mass of ${}^{20}_{10}Ne = 19.992397$ u

Mass of ${}^{1}_{0}H = 1.007825$ u

Mass of ${}^{1}_{0}n = 1.008665$ u

Solution

Mass defect (Δm) = Mass of nucleons − Mass of nucleus

= (10 × 1.007825 + 10 × 1.008665)u - 19.992397u

= 0.172503u

Binding energy ΔE = 0.1725034 × 931 MeV

= 160.600 MeV

Binding energy per nucleon $\frac{\Delta E}{A} = \frac{160.600}{20}$

= 8.03 MeV

19. (b) (ii) State the Bohr's postulate of angular momentum of an electron.

Solution

The angular momentum postulate proposed by Bohr argues that electrons can only rotate in orbits when their angular momentum is an integral multiple of h/ 2π where h is Planck's universal constant.

Given an electron with mass 'm' and orbital velocity 'v', it can be explained using Bohr's postulate.

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

Here n is an integer (n = 1, 2, 3.....) and is called the 'principal quantum number' of the orbit.

19. (b) (iii)

19. (b) (iii) 1. What is the velocity of an electron in the 3rd orbit of hydrogen atom if its velocity in the 1st orbit is v_0?

Solution

$$v \propto \frac{1}{n}$$

$$\frac{v_1}{v_3} = \frac{n_3}{n_1}$$

$$\frac{V_0}{v_3} = \frac{3}{1} (Here\ v_1 = V_0)$$

$$v_3 = \frac{V_0}{3}$$

The velocity of an electron in the 3rd orbit of a hydrogen atom is 1/3 of the velocity of an electron in the 1st orbit.

19. (b) (iii) 2. Radius of the 1st orbit of hydrogen atom is r_0. What will be the radius of the 4th orbit?

Solution

$$r \propto n^2$$

$$\Rightarrow \frac{r_1}{r_4} = \frac{1^2}{4^2}$$

$$\Rightarrow \frac{r_0}{r_4} = \frac{1}{16}$$

$$\Rightarrow r_4 = 16\ r_0$$

The radius of the 4th orbit of a hydrogen atom is 16 times the radius of the 1st orbit.

Q20. Read the passage given below and answer the question that follows.

There are two types of optical instruments: Microscopes and Telescopes. Microscopes are used to magnify very tiny objects whereas telescopes are used to study distant objects. Both of them deploy convex lenses. In his telescope, Newton used a large parabolic mirror to collect light from the stars and reduce aberrations.

i. Rohit observed the launch of Chandrayan 3 with the help of an optical instrument. Name the instrument used by him.

ii. State any one advantage of a reflecting telescope over a refracting telescope.

iii. Which instrument is used to study the structure of a virus?

iv. What is the ability of an optical instrument to form enlarged images called?

v. What is the difference between a compound microscope and an astronomical telescope (refracting type), as far as their lenses are concerned?

Useful Constants & Relations:

1	Charge of a proton	e	1.6×10^{-19} C
2	Speed of light in vacuum	c	3×10^{8} ms^{-1}
		1 u = 931 MeV	

Solution

i. Telescope

ii. When two telescopes of the same size are used for reflection and refraction, the reflecting telescope produces a brighter image. Moreover, a reflecting telescope's image is free of chromatic aberration, or colour orbit distortion.

iii. Microscope

iv. Magnifying power

v. When using an astronomical telescope, the objective lens's focal length is greater than the eyepiece; however, in a compound microscope, it is less than the eyepiece.