

Previous IPE
SOLVED PAPERS

MARCH -2025(AP)

PREVIOUS PAPERS

IPE: MARCH-2025(AP)

Time : 3 Hours

SR. PHYSICS

Max.Marks : 60

SECTION-A**I. Answer all questions :****10 × 2 = 20**

1. Define 'power' of a convex lens. What is its unit ?
2. What is the principle of a moving coil galvanometer ?
3. Magnetic lines form continuous closed loops. Why ?
4. Define magnetic declination.
5. A transformer converts 200 V AC into 2000 V AC. Calculate the number of turns in the secondary if the primary has 10 turns.
6. What are the applications of microwaves?
7. Write down Einstein's photoelectric equation.
8. What important fact did Millikan's experiment establish ?
9. What happens to the width of the depletion layer in a p-n junction diode when it is (i) forward-biased and (ii) reverse-biased?
10. What are the basic blocks of a communication system ?

SECTION-B**II. Answer any six of the following Questions.****6 × 4 = 24**

11. Explain the formation of a mirage.
12. Does the principle of conservation of energy hold for interference and diffraction phenomena? Explain briefly.
13. Derive the equation for the couple acting on an electric dipole in a uniform electric field.
14. Derive an expression for the electric potential due to a point charge.
15. Explain how crossed E and B fields serve as a velocity selector.
16. Describe the ways in which Eddy currents are used to advantage.
17. Explain the different types of spectral series of Hydrogen atom.
18. Distinguish between half-wave and full wave rectifiers.

SECTION-C**III. Answer any two of the following Questions.****2 × 8 = 16**

19. (a) Explain the formation of stationary waves in an air column enclosed in open pipe. Derive the equations for the frequencies of the harmonics produced.
(b) A closed organ pipe 70cm long is sounded. If the velocity of sound is 331m/s, what is the fundamental frequency of vibration of the air column?
20. State the working principle of potentiometer. Explain with the help of circuit diagram how the potentiometer is used to determine the internal resistance of the given primary cell.
21. (a) Explain the principle and working of a nuclear reactor with the help of a labelled diagram.
(b) If one microgram of ${}_{92}\text{U}^{235}$ is completely destroyed in an atom bomb, how much energy will be released ?

IPPE AP MARCH-2025

SOLUTIONS

SECTION-A

1. Define 'power' of a convex lens. What is its unit ?

A: 1) **Power (P) of a Convex Lens** : Reciprocal of focal length (f) of a convex lens is called its power. Thus, $P=1/f$

2) SI Units: diopetre(D)

2. What is the principle of a moving coil galvanometer ?

A: 1) **Principle of MCG:** When a current carrying coil is placed in a uniform magnetic field, it experiences a Torque.

2) Here, Current in the coil (i) \propto deflecting angle (θ)

3. Magnetic lines form continuous closed loops. Why ?

A: The magnetic poles N and S always exist together in pairs.

So the magnetic field lines of a magnet (or a solenoid) form continuous closed loops.

4. Define magnetic declination.

A: **Magnetic Declination** : It is the angle between the 'Geographical Meridian' and the 'Magnetic meridian' at a given place.

5. A transformer converts 200 V AC into 2000 V AC. Calculate the number of turns in the secondary if the primary has 10 turns.

A: Given that $V_p = 200$ V, $V_s = 2000$ V, $N_p = 10$, $N_s = ?$

Transformer formula :
$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow N_s = \frac{V_s}{V_p} N_p = \frac{2000}{200} \times 10 = 100$$

6. What are applications of microwaves?

A: Microwaves are used in the following:

- 1) **Microwave ovens** to raise the temperature of food.
- 2) **Radar systems** for air-craft navigation.
- 3) **Speed guns** to measure the speed of fast moving balls, automobiles etc.

7. Write down Einstein's photoelectric equation.

A: 1) **Einstein's Photoelectric Equation:** $K_{\max} = h\nu - \phi_0$

where K_{\max} is maximum kinetic energy of the photoelectron, h is Planck's constant, ν is the frequency of incident light and ϕ_0 is the work function of the metal.

2) Einstein's photoelectric equation explained 'Photoelectric effect'.

8. What important fact did Millikan's experiment establish ?

A: Millikan's experiment established the following facts:

(i) Electric charge is quantised. (ii) Charge of electron is $e = 1.602 \times 10^{-19}$ C.

9. What happens to the width of the depletion layer in a p-n junction diode when it is (i) forward-biased and (ii) reverse-biased?

A: i) In **forward bias**, the width of the depletion layer of a diode **decreases**

ii) In **reverse bias**, the width of the depletion layer of a diode **increases**.

10. What are the basic blocks of a communication system ?

A: **Basic Blocks of Communication System:**

1) Transmitter

2) Medium/Channel

3) Receiver

SECTION-B

11. Explain the formation of a mirage.

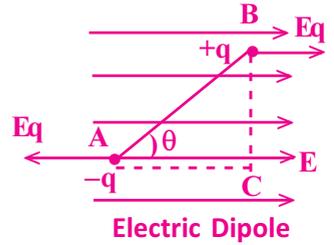
- A:**
- 1) **Mirage:** Mirage is an optical phenomenon in which light rays are bent to produce a displaced image of distant objects
 - 2) Mirages are formed due to total internal reflection of light.
 - 3) On hot summer days the density of air is less near the ground due to heat.
 - 4) Hotter air is less dense and smaller refractive index than cooler air
 - 5) When the air is stationary, the optical density at different layers of air increases with height.
 - 6) Hence the light rays coming from a tall body such as tree, bends away from normal and under goes total internal reflection.

12. Does the principle of conservation of energy hold for interference and diffraction phenomena? Explain briefly.

- A:**
- 1) Yes. The principle of conservation of energy 'holds good' for both 'interference and diffraction'.
 - 2) Patterns of bright and dark fringes are formed in interference and diffraction.
 - 3) These patterns obey the principle of conservation of energy.
 - 4) In interference and diffraction, light energy is redistributed.
 - 5) If it reduces in one region producing a dark fringe, it increases in another region producing bright fringe.
 - 6) Thus there is no gain or loss of energy.
 - 7) Hence, total energy remains constant.

13. Derive the equation for the couple acting on an electric dipole in a uniform electric field.

A : 1) **Electric Dipole:** Consider an electric dipole consisting of two equal and opposite charges q & $-q$ separated by a distance $2a$. The dipole is placed in a uniform electric field of intensity E at an angle θ to the direction of electric field.



2) **Couple:** The electrostatic forces acting on the charges q and $-q$ are Eq and E_{-q} respectively.

They form a torque or couple which tends to rotate the dipole into the direction of the electric field.

Torque = Force \times Perpendicular distance between the forces.....(1)

Here, Force = Eq and perpendicular distance between the forces is BC .

From ΔABC , $\sin \theta = \frac{BC}{2a} \Rightarrow BC = 2a \sin \theta$(2)

\therefore Torque $\tau = (Eq) 2a \sin \theta = 2aEq \sin \theta$. But $q(2a) = p =$ dipole moment

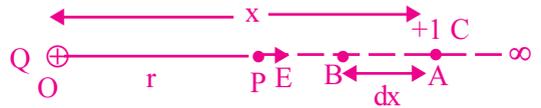
\therefore Torque $\tau = pE \sin \theta$(3). In vector form, $\vec{\tau} = \vec{p} \times \vec{E}$

Direction of the torque $\vec{\tau}$ is perpendicular to the plane containing \vec{p} and \vec{E} .

14. Derive an expression for the electric potential due to a point charge.

A : **Potential due to a Point Charge:**

Let us suppose that a point charge Q which is positive is at the origin. P is a point at position vector \vec{r} . The work done in bringing a unit positive charge from infinity to the point P is the electric potential at the point P .



The electrostatic force on unit positive charge ($+1 C$) when it is at an intermediate point A is

$$F = \frac{Q \times 1}{4\pi\epsilon_0 x^2} = \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2}$$

If dW is the work done in moving the unit positive charge against the force through a distance

$$dx, \text{ then } dW = -F dx \Rightarrow dW = -\frac{1}{4\pi\epsilon_0} \frac{Q}{x^2} dx$$

Total work done (W) is obtained by integrating this between the limits from ∞ to r .

$$W = - \int_{\infty}^r \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2} dx \text{ or } W = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

This is the work done in bringing a unit positive charge from infinity to the point P .

This gives potential at the point.

\therefore Electric potential at a distance r from a point charge Q is $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$

15. Explain how crossed E and B fields serve as a velocity selector.

A : Crossed E and B fields :

When electric and magnetic fields are perpendicular to each other, they are called crossed E and B fields.

Let us consider a particle of charge q moving with velocity v along x-axis. Electric field E is along y-axis and magnetic field B is along z-axis.

The electric force on the particle will be along y-axis.

$$\therefore \vec{F}_E = qE \hat{j} \dots\dots\dots (1)$$

The magnetic force on the particle is given by $\vec{F}_B = q\vec{v} \times \vec{B}$

But $\vec{v} = v\hat{i}$ (along x-axis)

and $\vec{B} = B\hat{k}$ (along z-axis)

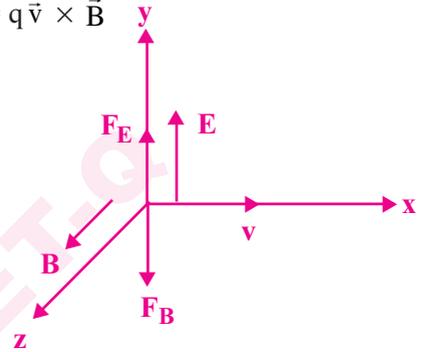
$$\therefore \vec{F}_B = qv\hat{i} \times B\hat{k} \text{ or } \vec{F}_B = qvB(\hat{i} \times \hat{k})$$

But $\hat{i} \times \hat{k} = -\hat{j}$

$$\therefore \vec{F}_B = -qvB\hat{j} \dots\dots\dots(2)$$

Th net force on the particle is $\vec{F} = \vec{F}_E + \vec{F}_B$

$$\text{or } \vec{F} = qE \hat{j} - qvB \hat{j} = q(E - vB)\hat{j}$$



The electric field E and magnetic field induction B are adjusted such that the net force on the particle $\vec{F} = \vec{0}$

$$\text{Then } (E - vB) = 0 \text{ or } vB = E \text{ or } v = \frac{E}{B}$$

Thus the crossed E and B which make the net force on the charged particle zero serve as velocity selector.

16. Describe the ways in which Eddy currents are used to advantage.

A : 1) Eddy Currents : When large pieces of conductors are subjected to changing magnetic fluxes, induced currents are produced in them. Such induced currents are called eddy currents

2) Advantages of Eddy Currents :

- i) Magnetic Brakes to Trains:** When the strong electromagnets are activated, the eddy currents induced in the rails oppose the motion of the train. As a result, **smooth braking effect** comes into play.
- ii) Electromagnetic Damping:** In galvanometers, electromagnetic damping brings the coil to rest quickly. This happens due to eddy currents produced in the core.
- iii) Induction Furnace :** A high frequency alternating current is passed through a coil which surrounds the metals to be melted. Then the eddy currents generated in the metals produce high temperatures.
- iv) Electric power meters:** The shiny **metal disc** in the 'electric power meter' **rotates** due to eddy currents.

17. Explain the different types of spectral series of hydrogen atom.

A: Hydrogen atom consists of five spectral series. They are

- 1) Lyman series 2) Balmer series 3) Paschen series 4) Brackett series 5) Pfund series.

1) Lyman series: When an electron jumps from any outer orbits to the first orbit, we get Lyman series. It is observed in the **UV** region. Here $n_1=1$ and $n_2=2,3,4,5,\dots$

$$\therefore \nu = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = R \left[\frac{1}{1^2} - \frac{1}{n_2^2} \right]$$

2) Balmer Series: When an electron jumps from any outer orbits to the second orbit, we get Balmer series. It is observed in the **Visible** region. Here $n_1=2$ and $n_2=3,4,5,\dots$

$$\therefore \nu = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = R \left[\frac{1}{2^2} - \frac{1}{n_2^2} \right]$$

3) Paschen Series : When an electron jumps from any outer orbits to the third orbit, we get Paschen series. It is observed in the **near infrared** region. Here $n_1=3$ and $n_2=4,5,6,\dots$

$$\therefore \nu = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = R \left[\frac{1}{3^2} - \frac{1}{n_2^2} \right]$$

4) Brackett Series : When an electron jumps from any outer orbits to the fourth orbit, we get Brackett series. It is observed in the **infrared** region. Here $n_1=4$ and $n_2=5,6,7,\dots$

$$\therefore \nu = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = R \left[\frac{1}{4^2} - \frac{1}{n_2^2} \right]$$

5) Pfund Series : When an electron jumps from any outer orbits to the fifth orbit, we get Pfund series. It is observed in the **far infrared** region. Here $n_1=5$ and $n_2=6,7,8,\dots$

$$\therefore \nu = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = R \left[\frac{1}{5^2} - \frac{1}{n_2^2} \right]$$

18. Distinguish between half-wave and full wave rectifiers.

A:

Half wave rectifier	Full wave rectifier
1) A single diode is used in half wave rectifier.	1) Two diodes are used in full wave rectifier.
2) A transformer without centre tap is used in it.	2) A transformer with centre tap is used in it.
3) Half wave rectifier converts only one half of AC into DC.	3) Full wave rectifier converts both the half cycles of AC into DC.
4) Its maximum efficiency is 40.6%.	4) Its maximum efficiency is 81.2 %.

SECTION-C

19. a) Explain the formation of stationary waves in an air column enclosed in open pipe. Derive the equations for the frequencies of the harmonics produced.

A: 1) **Open pipe:** A pipe open at 'both the ends' is called 'open pipe'.

2) **Formation of Stationary wave:** When a sound wave is sent to an open pipe, the wave reflects back at the other end of the pipe. The incident wave and reflected wave 'travelling in opposite directions' **super impose each other** to produce Stationary waves.

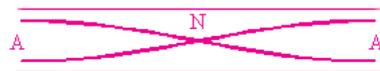
3) Antinodes (A) are formed at the open ends.

4) **Notation:** l = length of air column, V = Velocity of sound in air, $\lambda_1, \lambda_2, \lambda_3$ are the wave lengths of waves in respective harmonics.

5) **First Harmonic:** Here, 1 node and 2 antinodes are formed.

Length of the air column = Half of the wavelength

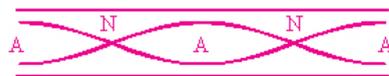
$$\Rightarrow l = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2l$$



$$\therefore \text{Frequency of first harmonic } n_1 = \frac{V}{\lambda_1} = \frac{V}{2l} \quad \therefore n_1 = \frac{V}{2l} \quad \dots\dots\dots(i)$$

6) **Second Harmonic:** Here, 2 nodes and 3 antinodes are formed.

$$\text{Length of the air column } l = \frac{\lambda_2}{2} + \frac{\lambda_2}{2} = \lambda_2 \Rightarrow \lambda_2 = l$$



$$\therefore \text{Frequency of the second harmonic } n_2 = \frac{V}{\lambda_2} = \frac{V}{l} = 2\left(\frac{V}{2l}\right) = 2n_1 \quad \dots\dots\dots(ii)$$

7) **Third Harmonic:** Here, 3 nodes and 4 antinodes are formed.

$$\text{The length of the air column } l = \frac{3\lambda_3}{2} \Rightarrow \lambda_3 = \frac{2l}{3}$$



$$\therefore \text{Frequency of the third harmonic } n_3 = \frac{V}{\lambda_3} = V\left(\frac{3}{2l}\right) = 3n_1 \quad \dots\dots\dots(iii)$$

8) From (i), (ii) & (iii) we have $n_1 : n_2 : n_3 : \dots = \cancel{n_1} : 2\cancel{n_1} : 3\cancel{n_1} : \dots = 1 : 2 : 3 : \dots$

b) A closed organ pipe 70cm long is sounded. If the velocity of sound is 331m/s, what is the fundamental frequency of vibration of the air column?

Sol: Given length of closed pipe $l = 70 \text{ cm} = 0.7 \text{ m}$, $V = 331 \text{ m/s}$, $n = ?$

$$\text{Fundamental frequency } n = \frac{V}{4l} = \frac{331}{4 \times 0.7} = 118.2 \text{ Hz}$$

20. State the working principle of potentiometer. Explain with the help of circuit diagram how the potentiometer is used to determine the internal resistance of the given primary cell.

A : 1) **Potentiometer** : Potentiometer is a device used to measure emf of a cell without drawing any current from it.

2) **Construction**: Potentiometer consists of a wooden board on which a uniform manganin wire of length 4 m is fixed in parallel rows between two binding screws A and C, by the side of a metre scale. A jockey is provided to make a contact at any point of the wire.

3) **Principle**: The potential difference (E) between any 2 points of the wire is directly proportional to the length l of the wire between the two points. $\epsilon \propto l \Rightarrow \epsilon = \phi l$

Here, ϕ is potential drop per unit length of the wire.

4) Determining Internal Resistance of a Cell:

The cell of emf ϵ , whose internal resistance r is to be determined is connected across a resistance box through a key K_2 .

First the key K_1 is closed. Then keeping K_2 open, the position of the jockey is adjusted until the galvanometer shows 'null deflection'.

Its balancing length l_1 of the wire is noted.

In the first case, the cell is in the circuit ,

$$\therefore \text{Emf of the cell } \epsilon = \phi l_1 \dots\dots\dots(1)$$

where ϕ is potential drop per unit length of the potentiometer wire.

Now the key K_2 is closed to include R in the circuit.

Again the position of the jockey is adjusted for null deflection of the galvanometer.

Balancing length of the wire l_2 is noted.

In this second case, R is in parallel to the cell.

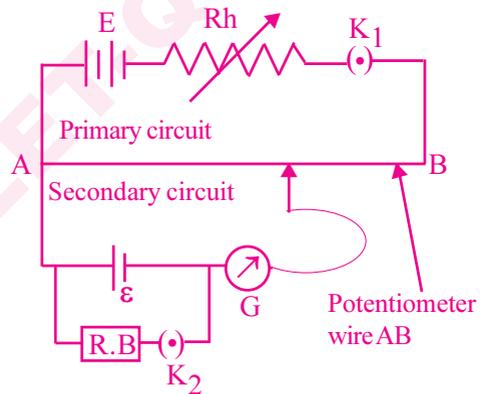
The terminal voltage is given by $V = \phi l_2 \dots\dots\dots(2)$

Dividing equation (1) by equation (2) we get, $\frac{\epsilon}{V} = \frac{l_1}{l_2} \dots\dots\dots(3)$

But $\epsilon = I(R + r)$ and $V = IR \Rightarrow \frac{\epsilon}{V} = \frac{R+r}{R} \dots\dots\dots(4)$

From (3) and (4), we get $\frac{R+r}{R} = \frac{l_1}{l_2} \Rightarrow 1 + \frac{r}{R} = \frac{l_1}{l_2} \Rightarrow \frac{r}{R} = \left(\frac{l_1}{l_2} - 1 \right) \Rightarrow r = R \left(\frac{l_1}{l_2} - 1 \right)$

Using this formula, Internal resistance r of the cell can be calculated.



21. a) Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

A: 1) **Principle:** Nuclear reactor works on the principle of **controlled chain reaction.**

2) **Main parts of Nuclear reactor:**

- (i) Fuel
- (ii) Moderator
- (iii) Control rods
- (iv) Protective Shielding
- (v) Coolant

3) **Fuel:** The material which undergoes fission is called fuel. **Ex:** U^{235} .

4) **Moderator:** The material which slows down the fast moving neutrons is called moderator. **Ex:** D_2O , Graphite

5) **Control rods:** The rods which absorb neutrons to control the chain reaction are called control rods.
Ex: Cd, B

6) **Protective Shielding:** The construction with cement and lead(Pb) around the reactor which protects from harmful radiations is called protective shielding.

7) **Coolant:** The liquid which removes the heat generated by the reactor is called circulating coolant. **Ex:** Water at high pressure, molten sodium.

8) **Working:**

- i) Uranium fuel rods are arranged in the $A/$ cylinders.
- ii) The graphite moderator is placed in between the fuel cylinders.
- iii) When U^{235} undergo fission, fast neutrons are released.
- iv) These neutrons pass through the surrounding graphite moderator and loose their energy.
- v) The heat generated here is used to produce steam.
- vi) This steam is used to rotate steam turbine then electric power is produced.

b) **If one microgram of ${}_{92}U^{235}$ is completely destroyed in an atom bomb, how much energy will be released ?**

Sol: Given that $m = 10^{-6}g = 10^{-9}kg$, $c = 3 \times 10^8 ms^{-1}$, $E = ?$

Formula: $E = mc^2$

$$\therefore E = 10^{-9} (3 \times 10^8)^2 \Rightarrow E = 9 \times 10^{-9+8+8} \quad \therefore E = 9 \times 10^7 J$$

