Previous IPE

SOLVED PAPERS

MARCH-2024 (TS)

PREVIOUS PAPERS

IPE: MARCH-2024(TS)

Time : 3 Hours **SR.PHYSICS** Max.Marks : 60

SECTION-A

I. Answer all questions : **$10 \times 2 = 20$**

1. What is sky wave propagation ?
2. What are intrinsic and extrinsic semi-conductors?
3. Write down deBroglie's relation and explain the terms therein.
4. Write down Einstein's photoelectric equation.
5. What are the applications of microwaves?
6. What is the phenomenon involved in the working of a transformer?
7. What are the laws of reflection through curved mirrors ?
8. What is the principle of a moving coil galvanometer ?
9. Define Magnetic inclination or angle of dip.
10. Write the truth table of NAND gate. How does it differ from AND gate ?

SECTION-B

II. Answer any six of the following Questions. **$6 \times 4 = 24$**

11. Define critical angle. Explain total internal reflection using a neat diagram.
12. How do you determine the resolving power of your eye?
13. Derive the equation for the couple acting on an electric dipole in a uniform electric field.
14. Explain the behaviour of dielectrics in an external field.
15. Derive an expression for the magnetic dipole moment of a revolving electron.
16. Describe the ways in which Eddy currents are used to advantage.
17. Describe Rutherford atom model. What are the draw backs of this model ?
18. Distinguish between half-wave and full wave rectifiers.

SECTION-C

III. Answer any two of the following Questions. **$2 \times 8 = 16$**

19. (a) How are stationary waves formed in closed pipes ? Explain the various modes of vibration and obtain relations for their frequencies.
    (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 Kirchoff's law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge.
21. (a) Explain the principle and working of a nuclear reactor with the help of a labelled diagram.
    (b) Calculate the energy equivalent of 1g of substance.

IPE TS MARCH-2024

SOLUTIONS

SECTION-A

1. What is sky wave propagation ?

A : **Sky Wave Propagation:** The communication between two long distance points on the earth achieved by the reflection of radio waves (3 MHz to 30 MHz) from the ionosphere is called sky wave propagation. Radios work on sky wave propagation.

---

2. What are intrinsic and extrinsic semi-conductors?

A : 1) **Intrinsic Semiconductor:** Pure semiconductor like Silicon is called Intrinsic semiconductor. In an intrinsic semiconductor, number of electrons(n_e) = number of holes(n_h).

2) **Extrinsic Semiconductor :** A semiconductor doped with Trivalent or Pentavalent impurity is called Extrinsic semiconductor. They are of two types.

i) **n-type** semiconductors have **more electrons** than holes.

i) **p-type** semiconductors have **more holes** than electrons .

---

3. Write down deBroglie's relation and explain the terms therein.

A : 1) **De Broglie's Relation :** $\lambda = \frac{h}{p} = \frac{h}{mv}$ where, λ is the de Broglie wavelength associated with a particle of momentum p = mv and h is Planck's constant.

2) De Broglie relation explains the wave nature of matter.

---

4. 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'.

---

5. 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.

6. What is the phenomenon involved in the working of a transformer?

A : **Mutual induction** is involved in the working of a transformer.

---

7. What are the laws of reflection through curved mirrors ?

A : **Laws of Reflection at Curved Mirrors :**

1) **The law of reflection:** Angle of incidence = Angle of reflection.

$$\angle i = \angle r$$

2) It is true only when the incident ray, the reflected ray and the normal to the reflecting surface are in the same plane.

---

8. 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)

---

9. Define magnetic inclination or angle of dip.

A : **Magnetic Inclination:** It is the angle between 'Total Earth's field' and it's 'Horizontal line in magnetic meridian' at a given place.

---

10. Write the truth table of NAND gate. How does it differ from AND gate ?

A:

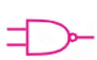
NAND gate-Truth Table

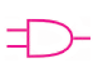
Input		Output
A	B	$Y = \overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

AND gate-Truth Table

Input		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

In NAND gate, the output becomes zero only when both the inputs are 1. It is opposite to AND gate. In AND gate the output becomes 1 only when both the inputs are 1.

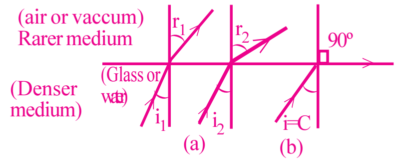
The symbol of NAND gate is 

The symbol of AND gate is 

SECTION-B

11. Define critical angle. Explain Total internal reflection using a neat diagram.

A: **1) Critical Angle:** When a light ray is passing from denser medium to rarer medium, the angle of incidence in denser medium for which the angle of refraction becomes 90º in rarer medium is called critical angle (i_C).



Critical Angle

Equation for critical angle is $n_{21} = \dfrac{1}{\sin i_C}$

where, n_{21} = refractive index of the denser medium w.r.to rarer medium.

2) Total Internal Reflection(TIR): When a light ray is passing from denser medium to rarer medium if the angle of incidence is greater than its critical angle ($i > i_C$), it gets reflected into the same denser medium without any refraction. This phenomenon is called Total Internal Reflection.

TIR

An **optical fibre** works on the principle of Total Internal Reflection.

---

12. How do you determine the resolving power of your eye?

A: **1) Resolving Power of Eye:** It is the ability to see the fine details in the viewed objects .

2) We can estimate the resolving power of our eye with a simple experiment.

3) Let us take a pattern of black stripes of equal width (each 5 mm) separated by white stripes of increasing width (0.5mm, 1mm,1.5 mm....)

from left to right as shown in the figure and paste it on a wall of the room.

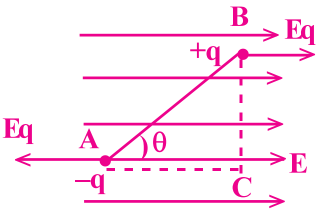
4) Now, let us watch the pattern with one eye. By moving our eye away or closer to the wall, we have to find the white stripe where we can just see some two black stripes as separate stripes. All the black stripes to the left of white stripe would merge into one another and would not be distinguishable.

5) On the other hand, the black stripes on the right of the white stripe would be more and more clearly visible. If d is the width of the white stripe which separates the two regions and D is the distance between the eye and the wall, the resolving power of the eye is given by d/D.

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

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.



Electric Dipole

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 × Perpendicular distance between the forces.........(1)

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

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

∴ Torque τ = (Eq) 2a sin θ = 2aEq sin θ. But q(2a) = p = dipole moment

∴ Torque τ = pE sin θ.........(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. Explain the behaviour of dielectrics in an external field.

A : 1) Dielectrics are non-conducting substances. The molecules of a dielectric may be polar or non-polar.

2) Polarization: When a dielectric with non-polar molecules is placed in an external electric field, the positive and negative charges of a non-polar molecules are displaced in opposite directions. Thus induced dipole moments are developed in the dielectric by the external field. Hence the dielectric is said to be polarised by the external field. All the induced dipole moments of the non-polar molecules add up to give a net dipole moment to the dielectric.

3) In dielectric with polar molecules, in the absence of external electric field, the different permanent dipoles are oriented randomly due to thermal agitation. Hence, the total dipole moment becomes zero. When an external electrical field is applied, the individual dipole moments tend to align with the field. As a result, a net dipole moment comes to the dielectric in the direction of external field. Hence the dielectric is polarised.

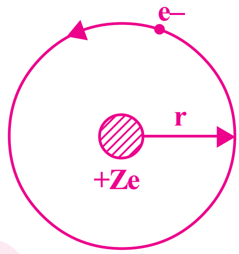
4) Thus in either case, whether polar or non-polar, a dielectric develops a net dipole moment in the presence of an external field. The dipole moment per unit volume is called polarisation (P).

5) For linear isotropic dielectrics, $P = \chi_e E$ where χ_e is electric susceptibility and E is intensity of external field.

15. Derive an expression for the magnetic dipole moment of a revolving electron.

A: Magnetic Dipole Moment due to Revolving Electron:

Let us suppose that an electron is revolving in a circular orbit of radius r with a speed v and time period T.



Formula: $v = \frac{2\pi r}{T} \Rightarrow T = \frac{2\pi r}{v}$

Current $i = \frac{e}{T} \Rightarrow i = \frac{ve}{2\pi r}$

Magnetic dipole moment $M = iA = \frac{ve(\pi r^2)}{2\pi r}$

Magnetic dipole moment due to revolving electron is $M = \frac{evr}{2}$

---

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. Describe Rutherford atom model. What are the draw backs of this model ?

A : A) Rutherford model of Atom :

1) Rutherford discovered nucleus of atom. Nucleus contains almost all the mass of the atom.
2) Outside the nucleus, there are electrons which move around nucleus like planets revolve around the sun.
3) The space between the nucleus and the electrons is empty.

B) Drawbacks of Rutherford's Model of Atom :

1) As the electron revolving around nucleus is accelerating, radius of its orbit should decrease continuously and finally should merge with nucleus. Thus there is no stability of atom.
2) As there is continuous radiation of energy from the electron, Rutherford model of atom should emit continuous spectrum. But an atom emits line spectrum in practice.

---

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. How are stationary waves formed in closed pipes ? Explain the various modes of vibration and obtain relations for their frequencies.

A: 1) **Closed pipe:** A pipe closed at one end is called closed pipe.

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

3) A node (N) is formed at the closed end and an antinode (A) is formed at open end .

4) **Notation:** l= length of air column,

V = Velocity of sound in air, $\lambda_1, \lambda_3, \lambda_5$ are the wave lengths of waves in respective harmonics.

5) **First Harmonic:** Here, 1 node and 1 antinode is formed.

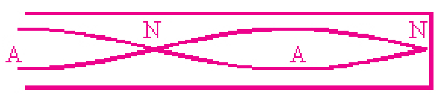
Length of the air column $l = \frac{\lambda_1}{4} \Rightarrow \lambda_1 = 4l$

$\therefore$ Frequency of first harmonic $n_1 = \frac{V}{\lambda_1}$

$$\therefore\ n_1 = \frac{V}{4l} \quad \text{..................(i)}$$

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

Length of air column $l = \frac{\lambda_3}{4} + \frac{\lambda_3}{4} + \frac{\lambda_3}{4} = \frac{3\lambda_3}{4}$



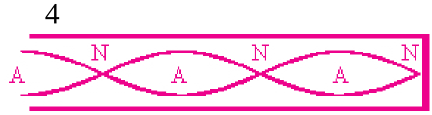
$$\therefore l = \frac{3\lambda_3}{4} \Rightarrow \lambda_3 = \frac{4l}{3}$$

$\therefore$ Frequency of third harmonic $n_3 = \frac{V}{\lambda_3} = V\left(\frac{3}{4l}\right) = 3\left(\frac{V}{4l}\right) = 3n_1$ ....(ii)

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

Length of air column $l = \frac{\lambda_5}{4} + \frac{\lambda_5}{4} + \frac{\lambda_5}{4} + \frac{\lambda_5}{4} + \frac{\lambda_5}{4} = \frac{5\lambda_5}{4}$

$$\therefore l = \frac{5\lambda_5}{4} \Rightarrow \lambda_5 = \frac{4l}{5}$$



$\therefore$ Frequency of fifth harmonic $n_5 = \frac{V}{\lambda_5} = V\left(\frac{5}{4l}\right) = 5\left(\frac{V}{4l}\right) = 5n_1$ ....(iii)

8) From (i), (ii) & (iii) we have $n_1 : n_3 : n_5 : ...... = n_1 : 3n_1 : 5n_1 : ...... = 1:3:5: ......$

TAG P) 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 $l = 70$ cm = 0.7 m , V = 331 m/s, n = ?

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

20. State Kirchoff's law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge.

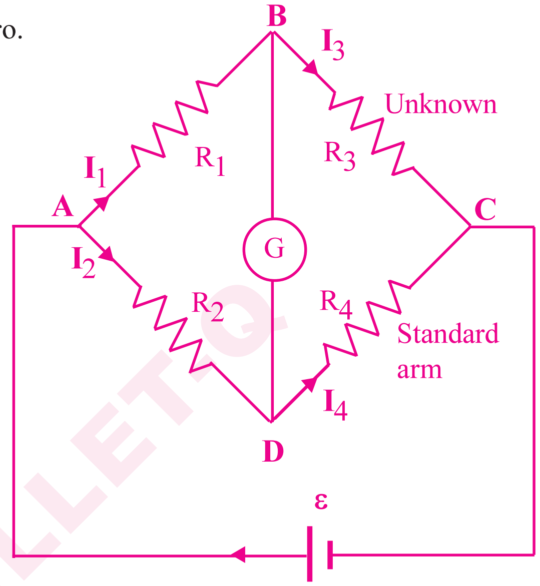
A : 1) Kirchoff's First Law : At any junction in an electric circuit, the sum of currents entering the junction is equal to the sum of currents leaving the junction.

2) Kirchoff's Second Law : The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.

3) Wheatstone's Bridge :

The circuit shown in the figure is called Wheatstone's bridge. It has four resistors R_1, R_2, R_3 and R_4. AC is battery arm, BD is galvanometer arm.

The galvanometer G detects the current. If the resistors are adjusted such that the galvanometer current $I_g = 0$, the bridge is said to be balanced.



Wheatstone bridge

Applying Kirchoff's junction rule at B, we get $I_1 = I_3$ ....(1)

Applying Kirchoff's junction rule at D, we get $I_2 = I_4$ ....(2)

Applying Kirchoff's loop rule to closed loop ABDA, we get $I_1 R_1 + 0 - I_2 R_2 = 0$

$\Rightarrow I_1 R_1 = I_2 R_2 \Rightarrow \frac{I_1}{I_2} = \frac{R_2}{R_1}$ ....(3)

Applying Kirchoff's loop rule to closed loop CBDC, we get $I_4 R_4 + 0 + -I_3 R_3 = 0$

$\Rightarrow I_3 R_3 = I_4 R_4$ From (1) & (2) $I_3 = I_1$ and $I_4 = I_2$

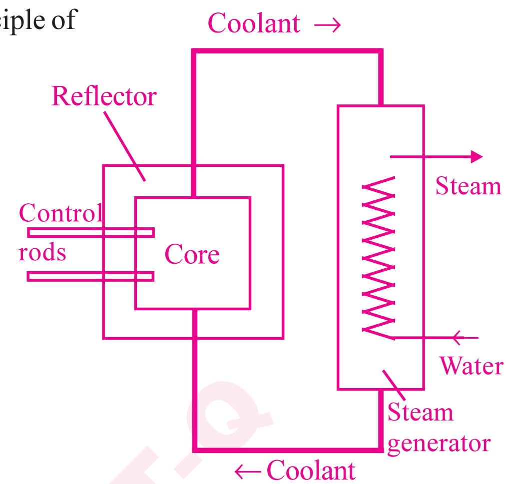
$\therefore I_1 R_3 = I_2 R_4 \Rightarrow \frac{I_1}{I_2} = \frac{R_4}{R_3}$ ....(4)

Equating the RHS of equ (3) and equ (4), we get $\frac{R_2}{R_1} = \frac{R_4}{R_3} \Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R4}$

This is the **balance condition of Wheatstone's bridge** to make $I_g = 0$.

21. 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.**



Nuclear Reactor

2) Main parts of Nuclear reactor:

i) Fuel
ii) Moderator
iii) Control rods
iv) Protective Sheilding
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*l* 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) Calculate the energy equivalent of 1g of substance(Uranium). [TS 19]

Sol: Energy released by each Uranium atom

$= 200\text{MeV}$

From Avagadro theory 235gm of Uranium contains 6.023×10^{23} atoms.

1 gm contain $\dfrac{6.023\times10^{23}}{235}$ atoms

Energy released by 1gm of substance $= \dfrac{6.023\times10^{23}}{235}\times200\text{ MeV} = 5.12\times10^{23}\text{MeV}$