

ISC Solved Paper 2023

Physics

Class-XII

(Maximum Marks : 70)

(Time allowed : Three hours)

(Candidates are allowed **additional 15 minutes** for **only** reading the paper. They must **NOT** start writing during this time.)

This 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, and

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 working, 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

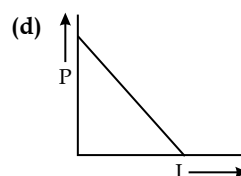
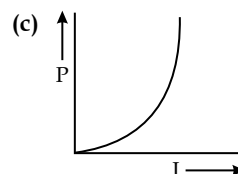
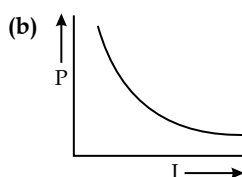
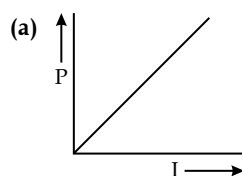
[14 Marks]

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

(i) A hollow sphere of radius **R** has a point charge **Q** at its centre. **Electric flux** emanating from it is ϕ . If both the charge and the radius -of the sphere be doubled, **electric flux** emanating from the sphere will: [1]

- (a) remain the same. (b) become 2ϕ
(c) become 4ϕ (d) become 8ϕ

(ii) An electric current (**I**) flowing through a metallic wire is gradually increased. The graph of heating power (**P**) developed in it **versus** the current (**I**) is: [1]



(iii) A circular coil has radius ' r ', number of turn ' N ' and carried a current ' I '. **Magnetic flux density** ' B ' at its centre is: [1]

- (a) $B = \mu_0 NI$ (b) $B = \frac{\mu_0 NI}{2r}$
(c) $B = \frac{\mu_0 NI}{4\pi r}$ (d) $B = \frac{\mu_0 NI}{4r}$

(iv) If an object is placed at a distance of 10 cm in front of a **concave mirror** of focal length 20 cm, the image formed will be: [1]

- (a) real and 20 cm in front of the mirror.
(b) real and 6.67 cm in front of the mirror.
(c) virtual and 20 cm behind the mirror.
(d) virtual and 6.67 cm behind the mirror.

(v) What type of wavefronts are associated with a source at **infinity**? [1]

- (a) Cylindrical wavefronts
- (b) Plane wavefronts
- (c) Spherical wavefronts
- (d) All types of wavefronts

(vi) **Matter waves** are: [1]

- (a) waves associated with moving particles.
- (b) waves associated with stationary particles.
- (c) waves associated with any charged particles.
- (d) waves associated with electrons only.

(vii) With an increase in the temperature, electrical **conductivity** of a semiconductor: [1]

- (a) decreases.
- (b) increases.
- (c) does not change.
- (d) first increases and then decreases.

(B) Answer the following questions **briefly**.

(i) What is meant by an **equipotential** surface? [1]

(ii) In case of metals, what is the relation between **current density** (J), **electrical conductivity** (σ) and **electric field intensity** (E)? [1]

(iii) What is meant by "**Motional emf**"? [1]

(iv) What is meant by a **microscope** in normal use? [1]

(v) In a single slit **Fraunhofer diffraction experiment**, how does the **angular width** of central maximum change when the slit width is **increased**? [1]

(vi) Name the type of **nuclear reaction** that takes place in the core of the Sun. [1]

(vii) What **type** of semiconductor is obtained when a crystal of silicon is doped with a **trivalent** element? [1]

Ans.(A) (i) **Option (b)** is correct.

Explanation: The electric flux $\phi = \frac{q}{\epsilon_0}$

Thus, when charge gets doubled, the electric flux gets doubled. It has no dependency on radius of the surface. Thus, the flux becomes 2ϕ .

(ii) **Option (a)** is correct.

Explanation: Since the heating power $P = VI$, When current increases the power P also increases.

(iii) **Option (b)** is correct.

Explanation: For a circular coil, the magnetic flux density at centre, $B = \frac{\mu_0 NI}{2r}$

(iv) **Option (c)** is correct.

Explanation: Using mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Given $f = -20$ cm

$u = -10$ cm

Thus, using above formula v is obtained as $+20$ cm.

Since v is positive, then the image is formed behind the mirror. The image is hence virtual. Virtual image formed by mirror is erect.

The image formed is virtual and 20 cm behind the mirror.

(v) **Option (b)** is correct.

Explanation: Source at infinity produces plane wavefronts.

(vi) **Option (a)** is correct.

Explanation: Matter waves are associated with moving particles.

(vii) **Option (b)** is correct.

Explanation: With the increase in the temperature, the electrical conductivity of semiconductor increases.

(B) (i) The surface where all the points are at same electric potential is said to be an equipotential surface. Since the charge experiences same potential energy throughout the equipotential surface, the work done to take a charge from one point to another remains zero.

(ii) For a conductor,

$$J = \sigma E$$

where, J is the current density

σ is the conductivity

E is the electric field

(iii) Motional emf(e) is the emf generated in a conductor because of its motion in a region having magnetic field B.

$$e = vBl$$

where,

v is the velocity with which conductor is moving (perpendicular to length l)

B is the intensity of magnetic field

l is the length of the conductor.

(iv) Microscope is a laboratory instrument used to produce enlarged images of the small objects. With the help of microscope one can see tiny objects that are too small to be seen by the naked eye.

(v) The angular width of the central maxima in Fraunhofer diffraction will decrease when the slit width is increased

The angular width is given by $2 \sin \theta = \frac{2\lambda}{b}$

Where b is the slit width.

(vi) In the core of the sun, the hydrogen gets converted to helium by the nuclear reaction process called nuclear fusion.

(vii) When a pure Si is doped with trivalent impurity, we get *p*-type semiconductor due to deficiency of electron. Holes will be the charge carriers in the case of trivalent impurity doping.

SECTION-B **[14 Marks]**

2.(i) Calculate **equivalent capacitance** of the circuit shown in *Figure 1* given below: [2]

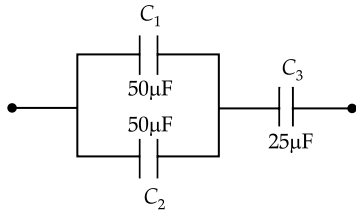


Figure 1
OR

(ii) Calculate **electric potential** at a point P which is at a distance of 9 cm from a point charge of 50 μC.

Ans. (i) In the given figure two capacitors C_1 and C_2 are connected parallelly

$$C_1 = 50 \mu\text{C}$$

$$C_2 = 50 \mu\text{C}$$

Thus, net capacitance ' C ' can be calculated using the formula.

$$C = C_1 + C_2$$

$$C = 50 + 50 = 100$$

Thus, net capacitance $C = 100 \mu\text{C}$

This, net capacitance C is connected in series with C_3 . Thus, equivalent capacitance can be calculated using the formula.

$$\frac{1}{C_{(\text{equivalent})}} = \frac{1}{C} + \frac{1}{C_3} = \frac{1}{100} + \frac{1}{25}$$

$$\frac{1}{C_{(\text{equivalent})}} = \frac{1}{100} + \frac{4}{100} = \frac{5}{100}$$

$$C_{(\text{equivalent})} = \frac{100}{5} = 20 \mu\text{C}$$

This equivalent capacitance of the circuit = 20 μC

(ii) The electric potential at point P because of charge q is given by

$$V = \frac{Kq}{x}$$

where, $K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ and x

is the distance in meter from the point charge
From the question $q = 50 \mu\text{C} = 50 \times 10^{-6}\text{C}$
 $x = 9 \text{ cm} = 9 \times 10^{-2} \text{ m}$

3.(i) Write **balancing condition** of a **Wheatstone bridge**.

(ii) Current ' I ' flowing through a metallic wire is related to drift speed V_d of free electrons as follows: [2]

$$I = nAev_d$$

State what the symbol ' n ' stands for.

Ans. (i) The balancing condition of wheatstone bridge is:

$$\frac{P}{Q} = \frac{R}{S}$$

(ii) The formula $I = neAV_d$ stands for the current flowing through the conductor. Here n stands for the number density of free electrons (charge carriers) present in the conductor.

4. When an **electric current** is passed through a wire or a coil, a **magnetic field** is produced. Is the reverse phenomenon possible *i.e.*, can a **magnetic field** produce an **electric current**? Explain with the help of an **appropriate example**. [2]

Ans. Yes, the reverse phenomenon is also possible. That is, the magnetic field is also capable to produce electric current in the circuit, just like the current flowing through the coil produces magnetic field.

For example,

Consider a circular metallic wire connected to a galvanometer. When a bar magnet is moved in and out of the coil, there will be a generation of magnetic field. At the same time one can see a deflection in the galvanometer as well. This is because of the current produced in the circular metallic wire as a result of magnetic field produced.

5.(i) A long straight wire **AB** carries a current of 5A. **P** is a proton travelling with a velocity of 2×10^6 m/s, parallel to the wire, 0.2 m from it and in a direction opposite to the current, as shown in *Figure 2* below. Calculate the **force** which magnetic field of the current carrying conductor AB exerts on the proton. [2]

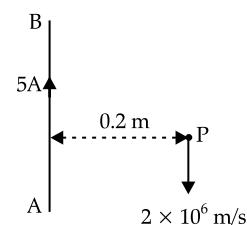


Figure 2

OR

- (ii) A moving coil galvanometer of resistance 55 Ω produces a **full scale deflection** for a current of 250 mA. How will you convert it into an **ammeter** having a range of 0 – 3A?

Ans. (i) The magnetic field produced by the long straight wire is given

$$B = \frac{\mu_0 2I}{4\pi a} = \frac{10^{-7} \times 2 \times 5}{0.2} = \frac{10 \times 10^{-7}}{0.2} = 5 \times 10^{-6} \text{ T}$$

Magnitude of force acting,

$$F = qvB$$

$$\text{Or, } F = 1.6 \times 10^{-19} \times 2 \times 10^6 \times 5 \times 10^{-6}$$

$$\therefore F = 16 \times 10^{-19} \text{ N}$$

Both the currents are in same direction. So, the force on proton will be repulsive and it will be towards right *i.e.* away from the current carrying wire.

- (ii) Given, the resistance of galvanometer $G = 55 \Omega$
The current for which, full scale deflection is observed in the galvanometer, $i = 250 \text{ mA}$.

Range of ammeter is thus 250 mA which needs to be converted to 3A Thus, $I = 3\text{A}$

In order to convert the moving coil galvanometer into ammeter in the range of 0-3A, we need to connect a shunt S parallel to the galvanometer.

The value of S can be obtained using the equation

$$S = \frac{iG}{(I-i)} = \frac{0.25 \times 55}{3 - 0.25} = \frac{13.75}{2.75} = 5 \Omega$$

- 6.(i) State how vectors \vec{E}, \vec{B} and \vec{c} are oriented in an

electromagnetic wave.

[2]

- (ii) Name the electromagnetic wave/radiation which is used to **study** crystal structure.

Ans. (i) The electric vector \vec{E} , the magnetic vector \vec{B} and the velocity vector \vec{c} are mutually perpendicular to each other.

- (ii) X-rays whose frequency lies in the range of 10^{17} Hz to 10^{19} Hz is used to analyse the crystal structure.

7. Name **any two** phenomena which take place in the formation of a **rainbow**. [2]

Ans. The phenomenon such as total internal reflection and dispersion are responsible for the formation of rainbow.

8. With reference to semiconductor physics, answer the following questions. [2]

- (i) What is meant by "**Forbidden band**" of energy levels?

- (ii) In which material "**Forbidden band**" is absent?

Ans. (i) The difference between the top most energy level of valence band and bottom level of conduction band is called forbidden band energy. This forbidden energy gap usually lies in the range of few eV.

- (ii) The forbidden band is absent in the case of metals. In this case, there is overlapping between the valence band and the conduction band leaving no energy gap between them.

SECTION-C

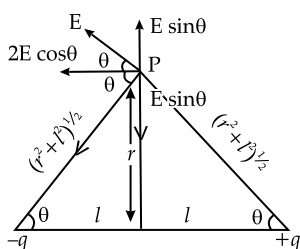
[27 Marks]

9. Show that **intensity of electric field** at a point in **broadside position** of an **electric dipole** is given by:

$$E = \left(\frac{1}{4\pi\epsilon_0} \right) \frac{p}{(r^2 + l^2)^{3/2}}$$

Where the terms have their usual meaning. [3]

Ans. Consider a point P at on broadside position of an electric dipole having a distance of 'r' meter from the middle point of the dipole. The length of the dipole be 2l.



Let E_1 be the electric field intensity generated at P due to $+q$ and E_2 be the electric field generated at point P due to $-q$. From the figure using Pythagoras theorem, the distance to point P from each charge of dipole is given as $\sqrt{r^2 + l^2}$.

The intensity of Electric Field E_1 due to $+q =$

$$\frac{q}{4\pi\epsilon_0(r^2 + l^2)}$$

The intensity of the Electric Field E_2 due to $-q =$

$$\frac{-q}{4\pi\epsilon_0(r^2 + l^2)}$$

The magnitude of E_1 and E_2 are equal.

On resolving E_1 and E_2 the components perpendicular to the dipole gets cancel while the components parallel to the dipole AB gets added up.

That is, the component $E_1 \sin \theta$ and $E_2 \sin \theta$ cancel each other because of their opposite direction while the components $E_1 \cos \theta$ and $E_2 \cos \theta$ are added up since they are in same direction.

Thus, net electric field E at the point $P = E_1 \cos \theta + E_2 \cos \theta$

$$E = \frac{q \cos \theta}{4\pi\epsilon_0(r^2 + l^2)} + \frac{q \cos \theta}{4\pi\epsilon_0(r^2 + l^2)} = \frac{2q \cos \theta}{4\pi\epsilon_0(r^2 + l^2)}$$

From the Figure

$$\cos \theta = \frac{l}{\sqrt{r^2 + l^2}}$$

$$\text{Hence, } E = \frac{2q \frac{l}{\sqrt{r^2 + l^2}}}{4\pi\epsilon_0(r^2 + l^2)} = \frac{2ql}{4\pi\epsilon_0(r^2 + l^2)^{\frac{3}{2}}}$$

Since $2ql = p$ (dipole moment)

$$\text{Net Electric Field at point } P = \frac{1}{4\pi\epsilon_0} \frac{p}{(r^2 + l^2)^{\frac{3}{2}}}$$

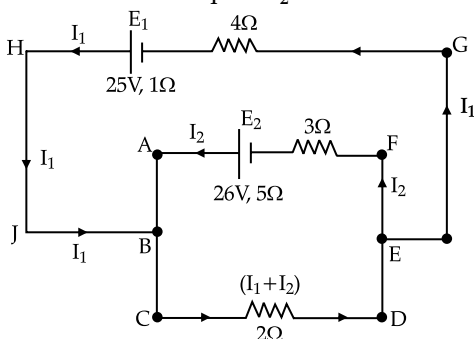
Hence, the proof.

- 10.(i) Eight **identical** cells, each of emf 2V and internal resistance 3Ω , are connected in **series** to form a row. **Six** such rows are connected in **parallel** to form a battery. This battery is now connected to an external resistor R of resistance 6Ω . Calculate:

- (a) emf of the battery.
- (b) internal resistance of the battery.
- (c) current flowing through R . [3]

OR

- (ii) In the circuit shown in *Figure 3* below, E_1 and E_2 are batteries having **emfs** of 25V and 26V. They have an internal resistance of 1Ω and 5Ω respectively. Applying **Kirchhoff's laws** of electrical networks, calculate the currents I_1 and I_2 .



- Ans. (i) (a) The emf of each row is
 $E = 8 \times 2 = 16V$
 Equivalent emf of the combination,
 $E_{eq} = 16V$
 (b) Internal resistance of each row = $3 \times 8 = 24\Omega$
 6 such rows are in parallel.

If r_{eq} is the equivalent internal resistance of the battery, then

$$\frac{1}{r_{eq}} = \frac{6}{24} = \frac{1}{4}$$

$$\therefore r_{eq} = 4\Omega$$

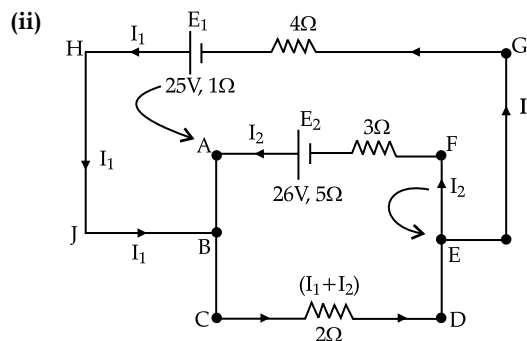
- (c) From part (b) solution, total internal resistance, $r_{eq} = 4\Omega$

When the battery is connected to an external resistance $R = 6\Omega$ then the total resistance of the circuit = $r_{eq} + R = 4\Omega + 6\Omega = 10\Omega$

Now, the current flowing through external resistance R can be obtained using Ohm's law $V = IR$

$$I = \frac{V}{R} = \frac{16}{10} = 1.6\text{ A}$$

OR



In loop HJBAFEFH

$$26 - 5I_2 - 3I_2 + 4I_1 + 1 \times I_1 - 25 = 0$$

$$\text{Or, } 8I_2 - 5I_1 = 1 \quad \dots(1)$$

In loop ABCDEFA

$$2(I_1 + I_2) + 3I_2 + 5I_2 - 26 = 0$$

$$\text{Or, } I_1 + 5I_2 = 13 \quad \dots(2)$$

$$\text{Solving (1) and (2) } \begin{aligned} I_1 &= 3\text{ A} \\ I_2 &= 2\text{ A} \end{aligned}$$

Figure 3

11. Using **Ampere's circuital law**, obtain an expression for **magnetic flux density 'B'** at a point near an **infinitely long and straight conductor**, carrying a current I . [3]

Ans. According to ampere's circuital law, the "line integral of the magnetic field surrounding closed-loop equals to the number of times the algebraic sum of currents passing through the loop".

Thus mathematically, it can be expressed as

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \sum i$$

$$B \oint dl = \mu_0 \sum i$$

Considering the small elemental length of the straight wire, we have $\oint dl = 2\pi r$

Where r is the radius of the wire.

Now, $B \cdot 2\pi r = \mu_0 I$ where $\sum i = I$ (total current in the circuit)

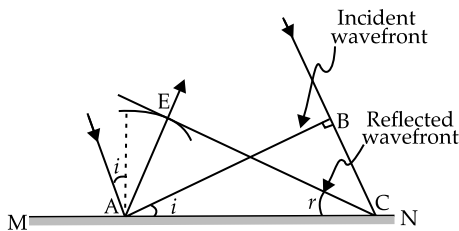
Thus, the intensity of magnetic flux density B at a point near infinitesimally long straight wire can be given as

$$B = \frac{\mu_0 I}{2\pi r}$$

12. Using Huygen's wave theory of light, show that the angle of incidence is equal to the angle of reflection. Draw a neat and labelled diagram. [3]

Ans. Huygens principle states that each point of a wave acts as a source for secondary wave fronts.

In order, to prove the laws of reflection
With reference to the figure shown below,
Let us consider that,
MN be the reflecting side of the mirror.



Consider a wave front AB incident on MN side of the mirror

i be the angle of incidence

r be the angle of reflection

Let τ be the time taken by the wave front to travel from the point B to C, then distance $BC = v\tau$

The reflected wave front can be constructed by drawing a sphere of radius $v\tau$ and centre A as shown in the figure.

Let CE represents the tangent plane drawn from the point C to this sphere. Then $AE = BC = v\tau$,

Considering triangle EAC, and BAC

$\angle ABC = \angle CEA = 90^\circ$ and AC is common side.

The triangle EAC and BAC are congruent.

Thus, $i = r$

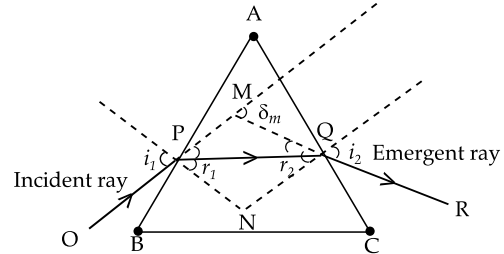
Hence the laws of reflection that angle of incidence is equal to angle of reflection is proved by Huygens principle.

13. (i) For any prism, obtain a relation between angle of the prism (A), angle of minimum deviation (δ_m) and refractive index of its material (μ or n). [3]

OR

- (ii) Obtain an expression for refraction at a single convex spherical surface i.e, the relation between μ_1 (rarer medium), μ_2 (denser medium), object distance u , image distance v and the radius of curvature R .

Ans. (i) With reference to the figure,



OP is the incidence ray, which is making the angle i_1 , with the normal, and QR is the emergent ray which makes angle i_2 with the normal.

Let A and n be the angle of prism and refractive index respectively.

In the case of minimum deviation, $\angle r_1 = \angle r_2 = \angle r$

The angle $A = r_1 + r_2$

$$A = \angle r + \angle r = 2\angle r$$

Thus $\angle r = \frac{A}{2}$

Also, $A + \delta = i_1 + i_2$

However, for minimum deviation we have $i_1 = i_2 = 2i$

$$A + \delta_m = 2i$$

$$i = \frac{A + \delta_m}{2}$$

According to snell's law, the refractive index of a

$$\text{medium } n = \frac{\sin i}{\sin r} = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}$$

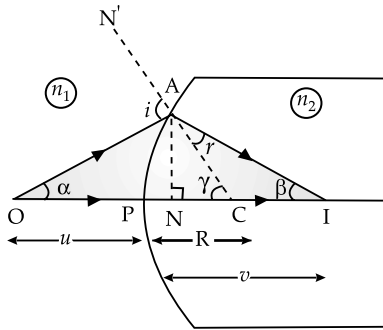
$$\text{Thus, } n = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}$$

Hence the relation between angle of incidence, angle of minimum deviation and refractive index of the material is obtained.

OR

- (ii) Let the object be kept at a point O in the rarer medium of refractive index μ_1 .

The image of the object is formed at I as a result of refraction of convex spherical surface in another medium having refractive index μ_2 . Consider that the convex surface have small aperture.



From the figure,

$$\angle AOP = \alpha$$

$$\angle AIP = \beta$$

$$\angle ACP = \gamma$$

Now a perpendicular AN is drawn to the principal axis,

By Snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

Since i and r are small

We have $\mu_1 i = \mu_2 r$

From triangle AOC, $i = \alpha + \gamma$

From triangle IAC, $r = \gamma - \beta$

Thus,

$$\mu_1(\alpha + \gamma) = \mu_2(\gamma - \beta)$$

Since α , β and γ are small, their tangents can be taken.

$$\mu_1(\tan \alpha + \tan \gamma) = \mu_2(\tan \gamma - \tan \beta)$$

$$\mu_1 \left(\frac{AN}{NO} + \frac{AN}{NC} \right) = \mu_2 \left(\frac{AN}{NC} - \frac{AN}{NI} \right)$$

$$\frac{\mu_1}{NO} + \frac{\mu_1}{NC} = \frac{\mu_2}{NC} - \frac{\mu_2}{NI}$$

Since the lens has small aperture, N lies close to P

Thus, $NO = OP = -u$

$$NI = IP = v$$

$$NC = R$$

Thus, we can obtain the equation

$$\frac{-\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

14. (i) What is the essential condition for obtaining a sustained interference? [3]

(ii) In Young's double slit experiment, the distance of the 4th bright fringe from the centre of the interference pattern is 1.5 mm. The distance between the slits and the screen is 1.5 m and the wavelength of light used is 500 nm. Calculate the distance between the two slits.

Ans. (i) There exists several conditions under which one can obtain a sustained interference pattern. They are

1. The two light sources must be coherent with same frequency, same wavelength, same phase or with constant phase difference.
2. The two sources must be very close to each other with almost same amplitude.
3. The light source should emit the waves continuously without any delay.

(ii) The distance of n^{th} bright fringe from the central maxima of interference pattern is given by $x_n = \frac{n\lambda D}{d}$

Where λ is the wavelength of light used

D is the distance of screen from the slits

d is the distance between slits

Given,

$$x_4 = 1.5 \times 10^{-3} \text{ m}$$

$$\lambda = 500 \text{ nm}$$

$$= 500 \times 10^{-9} \text{ m}$$

$$D = 1.5 \text{ m}$$

Since $x_4 = \frac{4\lambda D}{d}$

$$= \frac{4 \times 500 \times 10^{-9} \times 1.5}{d}$$

$$1.5 \times 10^{-3} = \frac{4 \times 500 \times 10^{-9} \times 1.5}{d}$$

$$d = \frac{4 \times 500 \times 10^{-9} \times 1.5}{1.5 \times 10^{-3}}$$

$$= \frac{2000 \times 10^{-9} \times 1.5}{1.5 \times 10^{-3}}$$

$$= 2000 \times 10^{-6} \text{ m}$$

$$= 2 \times 10^{-3} \text{ m} = 2 \text{ mm}$$

Therefore, the distance between the slits is 2 mm.

15. Monochromatic light of wavelength 396 nm is incident on the surface of a metal whose work function is 1.125 eV. Calculate: [3]

(i) the energy of an incident photon in eV.

(ii) the maximum kinetic energy of photoelectrons in eV.

Ans. (i) The energy of incident light $E = \frac{hc}{\lambda}$

Where h is the Planck's constant = $6.64 \times 10^{-34} \text{ Js}$

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{396 \times 10^{-9}} = \frac{19.92 \times 10^{-26}}{396 \times 10^{-9}}$$

$$= 0.0503 \times 10^{-17} = 50.3 \times 10^{-20} \text{ J}$$

$$\text{The energy } E \text{ is eV} = \frac{50.3 \times 10^{-20}}{1.6 \times 10^{-19}} = 31.43 \times 10^{-1}$$

$$= 3.143 \text{ eV}$$

- (ii) The energy $E =$ Work function (W_0) + Kinetic Energy (E_k)
 The Kinetic energy $E_k = E - W_0$
 $E_k = E - W_0 = 3.43 - 1.125$
 $= 2.305 \text{ eV}$

16. Name *any two* essential parts of a nuclear reactor. State the function of *any one* of them. [3]

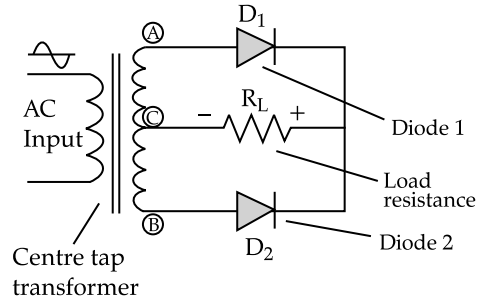
Ans. Two essential parts of a nuclear reactor are coolants and the moderator.

The function of coolant in the nuclear reactor is to remove the enormous amount of heat produced in the core of the reactor during the nuclear reaction process and to transfer them to the electrical generators. There exist gaseous coolants as well as

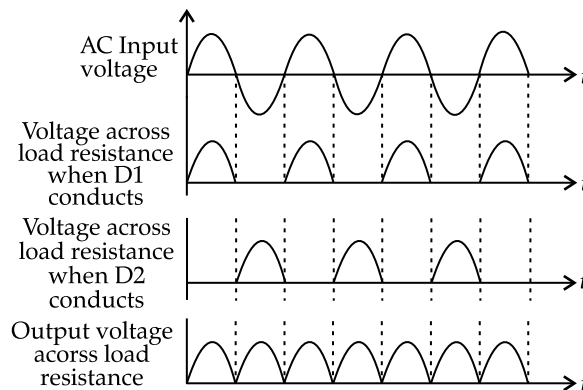
liquid coolants.

17. Draw a labelled circuit diagram of a **full wave rectifier**. Show graphically how the **output voltage** varies with **time**. [3]

Ans.



Circuit Diagram Of Full Wave Rectifier



Output waveform of full wave rectifier

SECTION-D

[15 Marks]

18.(i) A 60Ω resistor, a 1.0 H inductor and a $4\mu\text{F}$ capacitor are connected in **series** to an ac supply generating an emf $e = 300 \sin(500t)\text{V}$. Calculate: [5]

- (a) **impedance** of the circuit.
- (b) **peak value** of the current flowing through the circuit.
- (c) **phase difference** between the current and the supply voltage.

OR

(ii) (a) An ac generator generates an emf which is given by $e = 311 \sin(240\pi t)\text{V}$. Calculate:

- (1) **frequency** of the emf.
- (2) **r.m.s. value** of the emf.

(b) The **primary** coil of a transformer has 60 turns whereas its **secondary** coil has 3000 turns.

- (1) If a 220V ac voltage is applied to the **primary** coil, how much emf is induced in the **secondary** coil?
- (2) If a current of 5A flows in the **primary** coil, how much current will flow in a load in the

secondary coil? State the **assumption** you have made **regarding the transformer**, in this calculation.

Ans.(i) (a) In the case of LCR circuit the Impedence $Z =$

$$\sqrt{R^2 + (X_L - X_C)^2}$$

Given,

$$R = 60 \Omega$$

$$L = 1 \text{ H}$$

$$C = 4 \mu\text{F}$$

The emf $e = 300 \sin(500t)\text{V}$.

Comparing with $e = V_0 \sin\omega t$

$$\omega = 500$$

$$X_L = \omega L = 500 \times 1 =$$

$$500 \Omega$$

Similarly, $X_C = \frac{1}{\omega C} =$

$$\frac{1}{500 \times 4 \times 10^{-6}} = \frac{10^6}{2000} = 500 \Omega$$

Hence, Impedence, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$$= \sqrt{60^2 + (500 - 500)^2} = 60 \Omega$$

(b) Peak Current $I_0 = \frac{V_0}{Z}$

The peak value of voltage $V_0 = 300\sqrt{2} = 424.3 \text{ V}$

Hence $I_0 = \frac{424.3}{60} = 7.07 \text{ A}$

(c) The phase difference is given by $\tan \phi =$

$$\frac{X_L - X_C}{R}$$

Since $X_L = X_C$, there is no phase difference between the current and the supply voltage. The current is in phase with the voltage.

OR

(ii) (a) Given,

$$e = 311 \sin(240\pi)t$$

Thus $\omega = 240\pi$

We also have $\omega = 2\pi f$.

(1) Thus, frequency $f = \frac{\omega}{2\pi} = \frac{240\pi}{2\pi} = 120 \text{ Hz}$

(2) The rms voltage can be written as,

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{311}{\sqrt{2}} = \frac{311}{1.414} = 219.9 \text{ V}$$

(b) We know that for a transformer

$$\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Where,

E_s and E_p are the emf of the secondary and primary coil respectively.

N_s and N_p are number of turns in the secondary and primary coil respectively.

I_p and I_s are the currents in primary and secondary coil respectively.

(1) Given, $\frac{E_s}{E_p} = \frac{N_s}{N_p}$

$$\frac{E_s}{220} = \frac{3000}{60}$$

$$E_s = \frac{3000}{60} \times 220$$

$$= 11000 \text{ V}$$

(2) $\frac{N_s}{N_p} = \frac{I_p}{I_s}$

$$\frac{3000}{60} = \frac{5A}{I_s}$$

$$I_s = \frac{5 \times 60}{3000} = 0.1 \text{ A}$$

19. (i) (a) Name the **series** of lines of hydrogen spectrum which lies in the [5]

(1) ultraviolet region.

(2) visible region.

(b) How much is the **angular momentum** of an electron when it is orbiting in the **second Bohr orbit** of hydrogen atom?

(c) With reference to **Nuclear Physics**, answer the following questions.

(1) What is meant by "**Isotopes**"?

(2) Define **1u** (where **u** stands for unified atomic mass unit).

OR

(ii) (a) Using **Bohr's Theory** of hydrogen atom, obtain an expression for the **velocity** of an electron in n^{th} orbit of an atom.

(b) What is meant by "**binding energy per nucleon**" of a nucleus? State its **physical significance**.

Ans. (i) (a) 1. Lyman Series of hydrogen spectrum lies in UV region. The transition of electron from $n \geq 2$ to $n = 1$ results in the formation of Lyman series where n is the principle quantum number.

2. Balmer Series of hydrogen spectrum lies in visible region. The transition of electron from $n \geq 3$ to $n = 2$ results in the formation of Balmer series where n is the principle quantum number.

(b) The angular momentum L is given by $\frac{nh}{2\pi}$

. For the electron orbiting in second Bohr orbit, the value of n is 2.

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

(c) 1. The atoms those have equal number of protons but different number of neutrons are called isotopes. They generally have same atomic number and different mass number.

An example is C_6^{12} and C_6^{14} . Here, the carbon C has same atomic number 6 while their mass numbers are different.

2. $1u$ is equal to the unit of mass equal to $1/12^{\text{th}}$ of the mass of one atom of C^{12} isotope. $1u$ can also be defined as 1 atomic mass unit (1 amu).

- (ii) (a) The necessary centripetal force required for the electron to revolve around the nucleus is provided by the electrostatic force between the electron and the nucleus. Thus, by equating both the forces we have

$$\frac{mv^2}{r} = \frac{ze^2}{4\pi\epsilon_0 r^2} \quad \dots(i)$$

Where Z = atomic number
 r = radius of the orbit
 m = mass of the electron

Also,

We have, the angular momentum $L = \frac{nh}{2\pi}$

i.e.,
$$mvr = \frac{nh}{2\pi} \quad \dots(ii)$$

Divide the equation (i) by (ii) we have,

$$v = \left(\frac{ze^2}{4\pi\epsilon_0} \right) \cdot \frac{2\pi}{nh}$$

Thus, the velocity of electron in the n th orbit is given by $v_n = \frac{ze^2}{2nh\epsilon_0}$

Velocity of the electron is directly proportional to atomic number z and inversely proportional to principal quantum number n .

- (b) Binding energy (B.E) per nucleon is the minimum amount of energy needed to remove a nucleon from the nucleus. Stability of the element can be estimated from the value of Binding Energy per nucleon. One has to do more work to separate a proton or neutron from the nucleus of an atom with higher binding energy per nucleon. The average B.E per nucleon will always be in the range of MeV.

20. Read the passage given below and answer the questions that follow. [5]

There are two types of lenses: Converging lenses and Diverging lenses, depending on whether they converge or diverge an incident beam of light. They are also called convex or concave lenses. Lenses are usually made of glass. Convex lenses are more popular as they form a real image of an object. They are widely used in our daily life, for instance, in microscopes, telescopes, projectors, cameras, spectacles etc. Microscopes are used to view small and nearby objects whereas telescopes are used to see distant objects.

- (i) State *any one* factor on which focal length of a lens depends.

- (ii) Give an example where a convex lens behaves like a diverging lens.

- (iii) What type of lens is used in a camera?

- (iv) Write an expression for **magnifying power** of a **compound microscope** when its final image lies at the least distance of distinct vision (D).

- (v) State *any one* difference between **reflecting** telescope and a **refracting** telescope.

Useful Constants & Relations:

1	Constant for Coulomb's law	$(1/4\pi\epsilon_0)$	9×10^9 m/F
2	Permeability of vacuum	(μ_0)	$4\pi \times 10^{-7}$ H/m
3	Speed of light in vacuum	c	3×10^8 m/s
4	Plank's Constant	h	6.6×10^{-34} Js
5	Charge of a proton	e	1.6×10^{-19} C
6		1eV	1.6×10^{-19} J
7		1 nm	1×10^{-9} m

- Ans. (i) Focal length of lens depends on, the radius of curvature of the lens.

- (ii) The convex lens gives divergent rays when it is placed in a medium whose refractive index is higher than that of lens. For example, the convex lens with refractive index 1.525 when placed in carbon disulphate having higher refractive index of 1.6 behaves as diverging lens.

- (iii) Normally, a standard lens whose focal length lies in the range of 3.5 cm to 8 cm is used in cameras. Such lenses are supposed to give a field of view similar to that of a human eye.

- (iv) The magnifying power M of compound microscope is generally given as $M = m_o m_e$

Where, m_o is the magnification due to objective

$$\left(m_o = \frac{L}{f_o} \right)$$

m_e is the magnification due to eyepiece

$$\left(m_e = 1 + \frac{D}{f_e} \right)$$

L is the length of the compound microscope

f_o is the focal length of objective

f_e is the focal length of eyepiece

D is the least distance of distinct vision

In the case of image formed at D , the magnification of the compound microscope is

$$M = \frac{v_o}{u_o} \left(1 + \frac{D}{f_e} \right) = \frac{L}{f_o} \left(1 + \frac{D}{f_e} \right)$$

- (v) The major difference between reflecting and refracting telescope lies in the material with which they are made up of. That is, in the case of reflecting telescopes mirrors are used while in the case of refracting telescopes lenses are used.

Reflecting telescopes is in size than the refracting telescopes and they suffer only less aberrations compared to that of refracting ones. Refracting telescopes are heavier than reflecting telescopes.

