Class XII
Physics (Theory)
(CBSE 2019)

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

GENERAL INSTRUCTIONS :

1. All questions are compulsory. There are 27 questions in all.

2. This question paper has four sections: Section A, Section B, Section C and Section D.

3. Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, and Section D contains three questions of five marks each.

4. There is no overall choice. However, internal choices have been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

5. You may use the following values of physical constants wherever necessary.

    $c = 3 \times 10^8$ m/s

    $h = 6.63 \times 10^{-34}$ Js

    $e = 1.6 \times 10^{-19}$ C

    $\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}

    $\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}

    $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^{2}C^{-2}

    Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg

    Mass of neutron $= 1.675 \times 10^{-27}$ kg

    Mass of proton $= 1.673 \times 10^{-27}$ kg

    Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

    Boltzmann constant $= 1.38 \times 10^{-28}$ JK^{-1}

Section-A

1. Distinguish between unpolarized and linearly polarized light.   1

2. Define the term "threshold frequency", in the context of photoelectric emission.   1

OR

Define the term "Intensity" in photon picture of electromagnetic radiation.

3. How is the drift velocity in a conductor affected with the rise in temperature?   1

4. In sky wave mode of propagation, why is the frequency range of transmitting signals restricted to less than 30 MHz?   1

OR

On what factors does the range of coverage in ground wave propagation depend?

5. Draw the pattern of electric field lines when a point charge +q is kept near an uncharged conducting plate.   1

Section-B

6. (a) Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect.   2

    (b) Plot a graph of photocurrent versus anode potential for a radiation of frequency ν and intensities I_1 and $I_2 (I_1 < I_2)$

7. Why a signal transmitted from a TV tower cannot be received beyond a certain distance? Write the expression for the optimum separation between the receiving and the transmitting antenna.   2

8. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Bracket series and state to which part of the electromagnetic spectrum does it belong.   2
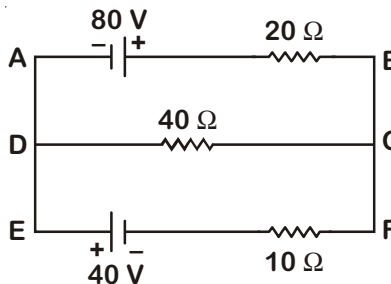
OR

Calculate the orbital period of the electron in the first excited state of hydrogen atom.

9. Why is wave theory of electromagnetic radiation not able to explain photo electric effect? How does photon picture resolve this problem?   2

10. Two bulbs are rated (P_1, V) and (P_2, V). If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2.   2

11. Obtain the expression for the ratio of the de-Broglie wavelengths associated with the electron orbiting in the second and third excited states of hydrogen atom.   2

12. A charged particle q is moving in the presence of a magnetic field B which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path.   2
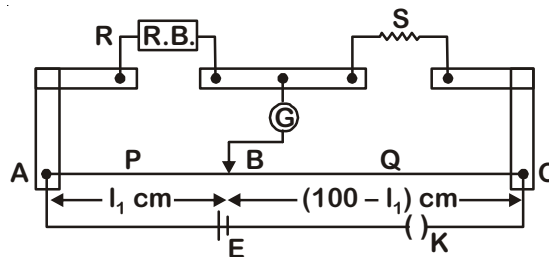
13. (a) Explain briefly how Rutherford scattering of α-particle by a target nucleus can provide information on the size of the nucleus. **3**

    (b) Show that density of nucleus is independent of its mass number A.

14. State the underlying principal of a cyclotron. Explain its working with the help of a schematic diagram. Obtain the expression for cyclotron frequency. **3**

15. Two infinitely long straight wires A_1 and A_2 carrying currents I and 2I flowing in the same directions are kept 'd' distance apart. Where should a third straight wire A_3 carrying current 1.5 I be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2? Does the net force acting on A_3 depend on the current flowing through it? **3**

16. (a) Draw the equipotential surfaces due to an electric dipole. **3**

    (b) Derive an expression for the electric field due to a dipole of dipole moment $\vec{p}$ at a point on its perpendicular bisector.

17. Using Kirchhoff's rules, calculate the current through the 40 Ω and 20 Ω resistors in the following circuit. **3**

OR

What is end error in a metre bridge? How is it overcome? The resistances in the two arms of the metre bridge are R = 5 Ω and S respectively.

When the resistance S is shunted with an equal resistance, the new balance length found to be 1.5 l_1, where l_1 is the initial balancing length. Calculate the value of S.

18. (a) Describe briefly the functions of the three segments of n-p-n transistor. **3**

    (b) Draw the circuit arrangement for studying the output characteristics of n-p-n transistor in CE configuration. Explain how the output characteristics is obtained.

OR

Draw the circuit diagram of a full wave rectifier and explain its working. Also, give the input and output waveforms.

19. Define the term wavefront. Using Huygen's wave theory, verify the law of reflection. 3

OR

Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium.

20. (a) Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range. 3

(b) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

21. Draw a labelled ray diagram of an astronomical telescope in the near point adjustment position.

A giant refracting telescope at an observatory has an objective lens of focal length 15 m and an eyepiece of focal length 1.0 cm. If this telescope is used to view the Moon, find the diameter of the image of the Moon formed by the objective lens. The diameter of the Moon is 3.48×10^6 m, and the radius of lunar orbit is 3.8×10^8 m. 3

22. (a) If A and B represent the maximum and minimum amplitudes of an amplitude modulated wave, write the expression for the modulation index in terms of A and B. 3

(b) A message signal of frequency 20 kHz and peak voltage 10 V is used to modulate a carrier of frequency 2 MHz and peak voltage of 15 V. Calculate the modulation index. Why the modulation index is generally kept less than one?

23. (a) State Gauss's law for magnetism. Explain its significance. 3

(b) Write the four important properties of the magnetic field lines due to a bar magnet.

OR

Write three points of differences between para-, dia- and ferro- magnetic materials, giving one example for each.

24. (a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which of them will not be able to detect light of wavelength 600 nm? 3

(b) Why photodiodes are required to operate in reverse bias? Explain.

Section-D

25. (a) Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor. 5

(b) A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor.
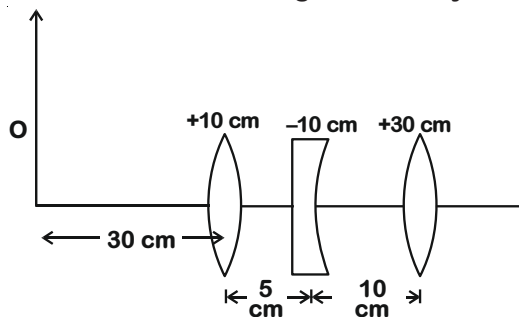
OR

(a) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

5

(b) Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

26. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.

5

(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit?

(c) When an inductor is connected to a200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.

OR

(a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device.

(b) A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electricplant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat.

27. (a) Describe any two characteristic features which distinguish between interference and diffraction phenomena. Derive the expression for the intensity at a point of the interference pattern in Young's double slit experiment.

5

(b) In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. If monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3rd order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m.

OR

(a) Under what conditions is the phenomenon of total internal reflection of light observed? Obtain the relation between the critical angle of incidence and the refractive index of the medium.

(b) Three lenses of focal lengths +10 cm, −10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.

❑ ❑ ❑

Class XII
Physics (Theory)
(CBSE 2019)

SOLUTION

GENERAL INSTRUCTIONS :

1. All questions are compulsory. There are 27 questions in all.

2. This question paper has four sections: Section A, Section B, Section C and Section D.

3. Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, and Section D contains three questions of five marks each.

4. There is no overall choice. However, internal choices have been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

5. You may use the following values of physical constants wherever necessary.

    $c = 3 \times 10^8$ m/s

    $h = 6.63 \times 10^{-34}$ Js

    $e = 1.6 \times 10^{-19}$ C

    $\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}

    $\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}

    $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^{2}C^{-2}

    Mass of electron (m_e) = 9.1×10^{-31} kg

    Mass of neutron = 1.675×10^{-27} kg

    Mass of proton = 1.673×10^{-27} kg

    Avogadro's number = 6.023×10^{23} per gram mole

    Boltzmann constant = 1.38×10^{-28} JK^{-1}

1. Distinguish between unpolarized and linearly polarized light. [1]

Sol.

Unpolarized light	Polarized light
• The light in which Electric field oscillations are in every direction perpendicular to propagation of light.	• The light in which Electric field oscillations are confined in a specific direction perpendicular to propagation of light.

2. Define the term "threshold frequency", in the context of photoelectric emission. [1]

Sol. **Threshold frequency** → The minimum frequency of incident light below which the photoelectric phenomenon does not occur.

OR

Define the term "Intensity" in photon picture of electromagnetic radiation.

Sol. **Intensity of Radiation** → Intensity is defined as the radiation energy incident per unit area per unit time. The SI unit of intensity is Wm^{-2}.

3. How is the drift velocity in a conductor affected with the rise in temperature? [1]

Sol. Drift velocity in a conductor is related as $\vec{v}_d = \left(\dfrac{e\vec{E}}{m}\right)\tau$, where τ is relaxation time.

Due to rise in temperature, relaxation time decreases, hence drift velocity decreases.

4. In sky wave mode of propagation, why is the frequency range of transmitting signals restricted to less than 30 MHz? [1]

Sol. In sky wave mode of propagation, the ionospheric layer of atmosphere acts as a reflector for range frequencies below 30 MHz. Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.
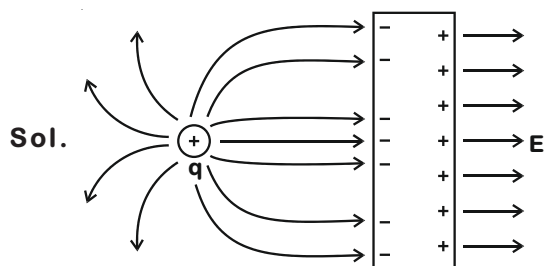
OR

On what factors does the range of coverage in ground wave propagation depend?

Sol. The range of coverage in ground wave propagation depends on following factors.

(i) Transmitted power [½]

(ii) Frequency of signal [½]

5. Draw the pattern of electric field lines when a point charge +q is kept near an uncharged conducting plate. [1]
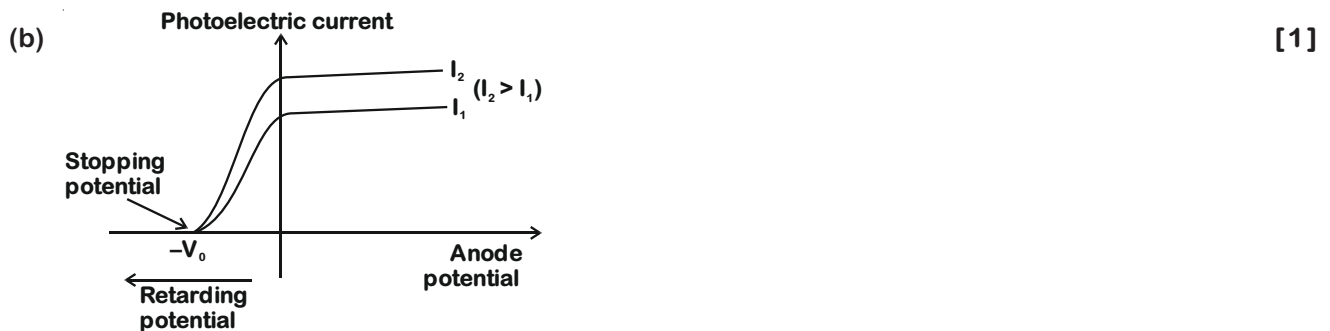
Sol.

6. **(a)** Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect. **[2]**

(b) Plot a graph of photocurrent versus anode potential for a radiation of frequency ν and intensities I_1 and $I_2 (I_1 < I_2)$
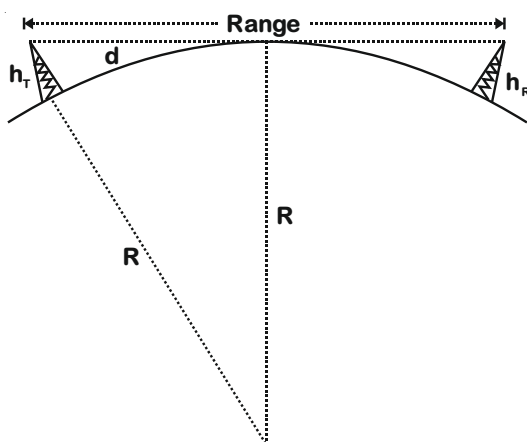
Sol. **(a)** In the photoelectric effect the term,

(i) Threshold frequency → The minimum frequency of incident radiation below which the photoelectric phenomenon does not take place, for a given metallic surface. **[½]**

(ii) Stopping potential → The minimum negative potential of anode terminal due to which the highest kinetic energy photoelectron will stop before reaching anode, therefore photoelectric current becomes zero.

i.e., $K_{max} = eV_0$ **[½]**

(b) **[1]**

7. Why a signal transmitted from a TV tower cannot be received beyond a certain distance? Write the expression for the optimum separation between the receiving and the transmitting antenna. **[2]**

Sol. At frequencies above 40 MHz, communication is essentially limited to the path of line of sight. These direct waves get blocked at some point by the curvature of earth. **[1]**

R = Radius of earth

h = Height of antenna

$\text{Range} = \sqrt{2Rh_T} + \sqrt{2Rh_R}$ **[1]**

8. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Brackett series and state to which part of the electromagnetic spectrum does it belong. **[2]**

OR

Calculate the orbital period of the electron in the first excited state of hydrogen atom.

Sol. (i) According to Bohr's quantization condition.

The angular momentum of orbiting electron is integral multiple of $\dfrac{h}{2\pi}$, where 'h' is the Plank's constant. Thus the angular momentum (L) of the orbiting electron is quantised.

$$L = n\left(\dfrac{h}{2\pi}\right)$$ **[1]**

n = number of orbit.

(ii) In Brackett series for minimum wavelength.

$n_1 = 4$, $n_2 = \infty$

$$\dfrac{1}{\lambda_{min}} = R\left(\dfrac{1}{4^2} - \dfrac{1}{\infty}\right)$$

$$\dfrac{16}{R} = \lambda_{min}$$ **[½]**

R = Rydberg constant $\approx 1.09 \times 10^7 m^{-1}$

$$R = \dfrac{1}{912\text{Å}}$$

Then,

$$\lambda_{min} = 14,592\text{Å}$$

This is associated with infrared region of electromagnetic spectrum. **[½]**

OR

In the first excited state n = 2

$$\boxed{T_n = \dfrac{2\pi r_n}{v_n}}$$ **[½]**

$$= \dfrac{2\pi \times \left(0.53 \times \dfrac{n^2}{z}\right) \times 10^{-10}}{2.19 \times 10^6 \left(\dfrac{z}{n}\right)} s$$ **[½]**

$$T_{n^{th}} = 1.5 \times 10^{-16} \times \dfrac{n^3}{z^2} s$$

$$= 1.5 \times 10^{-16} \times \dfrac{8}{1} s$$

$$T_{2^{nd}} = 1.2 \times 10^{-15} s$$ **[1]**

9. Why is wave theory of electromagnetic radiation not able to explain photoelectric effect? How does photon picture resolve this problem? **[2]**

Sol. The wave theory of electromagnetic radiation is not able to explain photoelectric effect due to the following reasons

(1) According to wave theory, electromagnetic wave of any frequency should be able to cause photoelectric effect over a sufficient time. However, it is observed that there is a threshold frequency below which photoelctric effect is not observed.

(2) It is observed that even with low intensity radiation of frequency above threshold frequency, emission of photoelectrons is almost immediate. This is contrary to prediction of wave theory.

According to the photon picture if frequency of photon f is greater than $\dfrac{\phi}{h}$ (ϕ = work function) the

photoelectric emission will happen almost instantaneously even if intensity is low.

10. Two bulbs are rated (P_1, V) and (P_2, V). If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2. **[2]**

Sol. Let (P_1, V) is rating of bulb B_1 and (P_2, V) is for bulb B_2.
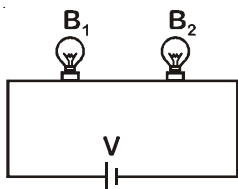
Then, from relation

$$P = \dfrac{V^2}{R}$$

$$R_1 = \dfrac{V^2}{P_1} \qquad\qquad ...(i)$$

$$R_2 = \dfrac{V^2}{P_2} \qquad\qquad ...(ii)$$

In series combination,

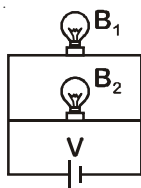$$R_{eq} = R_1 + R_2 = \dfrac{V^2}{P_1} + \dfrac{V^2}{P_2}$$

$$P_{Series} = \dfrac{V^2}{R_{eq}} = \dfrac{V^2}{V^2\left(\dfrac{1}{P_1} + \dfrac{1}{P_2}\right)} \qquad\qquad \textbf{[½]}$$

$$P_{Series} = \dfrac{1}{\left(\dfrac{P_1 + P_2}{P_1 P_2}\right)} = \dfrac{P_1 P_2}{P_1 + P_2}$$

$$\boxed{P_{Series} = \dfrac{P_1 P_2}{P_1 + P_2}} \qquad\qquad \textbf{[½]}$$

In Parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$ [½]

$$P_{Parallel} = \frac{V^2}{R_{eq}} = \frac{V^2}{\dfrac{V^2}{P_1}} + \frac{V^2}{\dfrac{V^2}{P_2}} = P_1 + P_2$$

$$\boxed{P_{Parallel} = P_1 + P_2}$$ [½]

11. Obtain the expression for the ratio of the de-Broglie wavelengths associated with the electron orbiting in the second and third excited states of hydrogen atom.   **[2]**

Sol. The de-Broglie wavelength associated with the momentum P is given as

$$\lambda = \frac{h}{P} \qquad ...(i)$$ [½]

Since momentum associated with electron revolving in n^{th} orbit is given as

$$P = \frac{P_0}{n} \qquad ...(ii)$$ [½]

Now for 2nd excited state, n = 3

Hence $$\lambda_{(n=3)} = \frac{h}{\left(\dfrac{P_0}{3}\right)} = 3\frac{h}{P_0} \qquad ...(iii)$$

For 3rd excited state, n = 4

Hence $$\lambda_{(n=4)} = \frac{h}{\left(\dfrac{P_0}{4}\right)} = 4\frac{h}{P_0} \qquad ...(iv)$$ [½]
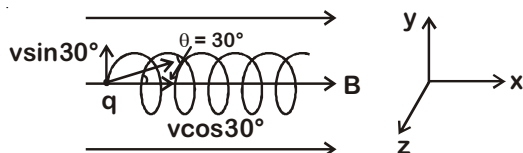
From equation (iii) and (iv)

$$\frac{\lambda_{(n=3)}}{\lambda_{(n=4)}} = \frac{3\left(\dfrac{h}{P_0}\right)}{4\left(\dfrac{h}{P_0}\right)} = \frac{3}{4}$$

$$\boxed{\frac{\lambda_{(n=3)}}{\lambda_{(n=4)}} = \frac{3}{4}}$$ [½]

12. A charged particle q is moving in the presence of a magnetic field B which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path. **[2]**

Sol. Let magnetic field B is along x-direction as shown in figure. Now charge particle enters in magnetic field at an angle 30°. Hence velocity component $v\cos 30°$ will be along the magnetic field and $v\sin 30°$ will be perpendicular to the magnetic field.

[½]

Now, from equation of force

$$\frac{m(v\sin 30°)^2}{R} = qBv\sin 30° \, n$$

$$\boxed{R = \frac{m\,v\sin 30°}{qB}} \Rightarrow \text{where R is radius of circle made by the charge particle called as radius of helix.} \quad \textbf{[½]}$$

Now, time taken to complete one cycle is

$$t = \frac{2\pi R}{(v\sin 30°)} = \frac{2\pi m}{qB}$$

[½]

Then distance travelled along the x – axis (called as pitch) is given as

$$\boxed{\text{Pitch} = v\cos 30° \times t = \frac{2\pi m\, v\cos 30°}{qB}}$$

Hence, path traced by the particle will be helical. **[½]**

Section-C

13. (a) Explain briefly how Rutherford scattering of α-particle by a target nucleus can provide information on the size of the nucleus. **[3]**

(b) Show that density of nucleus is independent of its mass number A.

Sol. (a) On the basis of Rutherford scattering experiment following observations were made:

(1) Most of the α-particles passed through the foil without any deviation.

(2) About 0.14% of incident α-particles scattered by more than 1°

(3) Deflection of more than 90° was observed in about 0.0125% of the incident α-particles. **[1]**

On the basis of above observation, it was concluded that

(1) Most of the space in an atom is unoccupied.

(2) There must be an extremely small region of concentrated positive charge at the centre of atom. This small region is called nucleus. **[1]**

(b) The volume of the nucleus is directly proportional to the number of nucleons (mass number) constituting the nucleus

$$r = r_0 A^{1/3} \qquad \qquad \text{... (i)} \qquad \textbf{[½]}$$

As nuclear density

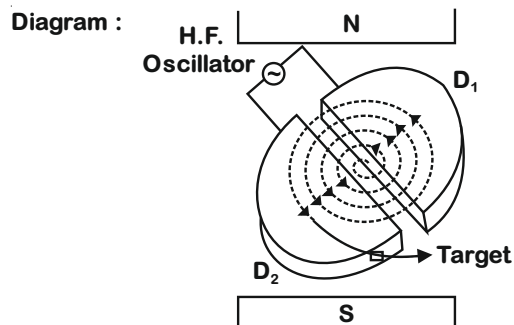$$\rho \propto \frac{A}{r^3} \qquad \qquad \text{...(ii)} \qquad \textbf{[½]}$$

From equation (i) & (ii)

∴ Density of nucleus is independent of its mass number A

14. State the underlying principle of a cyclotron. Explain its working with the help of a schematic diagram. Obtain the expression for cyclotron frequency. **[3]**

Sol. **Cyclotron :** It is a device by which charged particles like protons, deuterons etc. can be accelerated to high speed.

Principle : A charged particle can be accelerated by making it to cross the same electric field repeatedly with the help of magnetic field. **[½]**

Diagram :

[1]

Working and theory : Cyclotron consists of two semi-circular disc D_1 and D_2 (called Dee's) enclosed in an evacuated chamber as shown in figure. The magnetic field, acts on the particle and makes it go round in a circular path inside a dee. Every time the particle moves from one dee to the other it is speeded up by the electric field. The sign of the electric field is changed alternately in tune with the circular motion of the particle. At a certain instant, let D_1 be positive and D_2 be negative. The radius of the circular path is given by **[½]**

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$ **[½]**
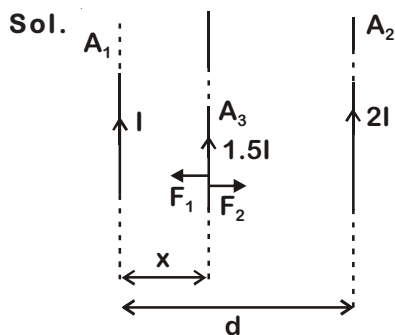
As frequency of revolutions,

$$v = 2\pi rf$$

$$\therefore \quad v = \frac{2\pi mvf}{qB}$$

$$\therefore \quad f = \frac{qB}{2\pi m}$$

f is independent of both v and r. **[½]**

15. Two infinitely long straight wires A_1 and A_2 carrying currents I and 2I flowing in the same directions are kept 'd' distance apart. Where should a third straight wire A_3 carrying current 1.5I be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2? Does the net force acting on A_3 depend on the current flowing through it? **[3]**

Sol.

Magnetic field due to wire A_1 at a perpendicular distance x is

$$\vec{B_1} = \frac{\mu_0 I}{2\pi x} \otimes$$

Force per unit length on wire A_3 due to wire A_1 is

$$\left|\vec{F_1}\right| = 1.5 I B_1$$

$$\vec{F_1} = \frac{1.5 I \mu_0 I}{2\pi x} \qquad\qquad …(i) \qquad\qquad\qquad\qquad [½]$$

Magnetic field due to wire A_2 at a perpendicular distance (d – x) is

$$\vec{B_2} = \frac{\mu_0 2I}{2\pi(d-x)} \odot$$

Force per unit length on wire A_3 due to wire A_2 is

$$\left|\vec{F_2}\right| = 1.5 I B_2$$

$$= \frac{1.5 I \mu_0 2I}{2\pi(d-x)} \qquad\qquad …(ii) \qquad\qquad\qquad\qquad [½]$$

As net force on wire A_3 is zero.

$$\therefore \quad \left|\vec{F_1}\right| = \left|\vec{F_2}\right|$$

$$\frac{1.5 I \mu_0 I}{2\pi x} = \frac{1.5 I \mu_0 2I}{2\pi(d-x)}$$

$$\frac{1}{x} = \frac{2}{d-x}$$

$$d - x = 2x$$

$$\therefore \quad x = \frac{d}{3} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad [1]$$

$\therefore$ Distance is $\dfrac{d}{3}$ from wire A_1.

Since net force per unit length on wire A_3 is given as

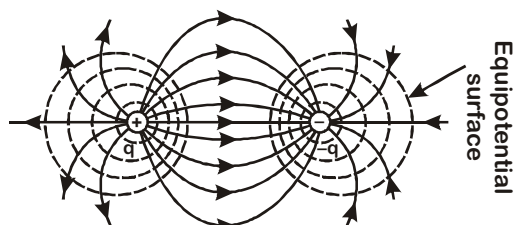$$\vec{F}_{net} = I_3\left(\vec{B_1} + \vec{B_2}\right) \qquad\qquad\qquad\qquad\qquad\qquad [½]$$

Hence net force acting on wire A_3 depends on the current flowing through it and it will be independent only when net magnetic field is zero. [½]

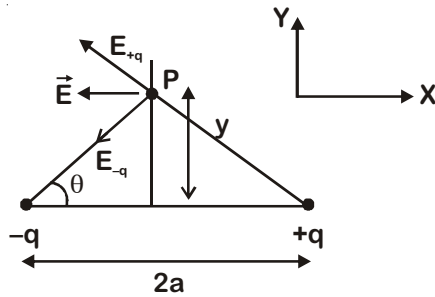16. (a) Draw the equipotential surfaces due to an electric dipole. [1]

(b) Derive an expression for the electric field due to a dipole of dipole moment $\vec{p}$ at a point on its perpendicular bisector. [2]

Sol. (a) [1]

Equipotential surfaces due to an electric dipole

(b) Let distance of point P where field has to be calculate be y from axial line.

$$\left|\vec{E}_{-q}\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(y^2 + a^2\right)}$$

$$\left|\vec{E}_{+q}\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(y^2 + a^2\right)}$$ [1]

$$\vec{E} = \vec{E}_{-q} + \vec{E}_{+q}$$

Due to symmetry electric field in y direction will cancel out.

$$\vec{E} = 2\left|\vec{E}_{-q}\right|\cos\theta\,(-\hat{i})$$

$$\vec{E} = \frac{2qa\,(-\hat{i})}{4\pi\varepsilon_0\,(a^2 + y^2)^{3/2}}$$

for y >> a

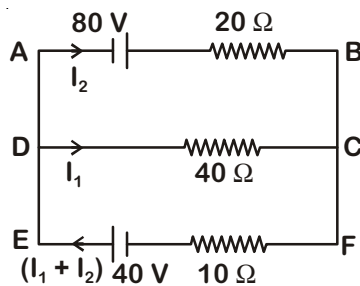$$\vec{E} = \frac{2qa}{4\pi\varepsilon_0 y^3}\,(-\hat{i})$$

$$\vec{E} = -\frac{\vec{p}}{4\pi\varepsilon_0 y^3}$$ [1]

17. Using Kirchhoff's rules, calculate the current through the 40 Ω and 20 Ω resistors in the following circuit.   **[3]**

Sol.

Apply KVL in FEDC

$$-10(I_1 + I_2) + 40 - 40I_1 = 0$$

$$\Rightarrow \quad 4 - 5I_1 = I_2$$ [1]

Apply KVL in CDAB

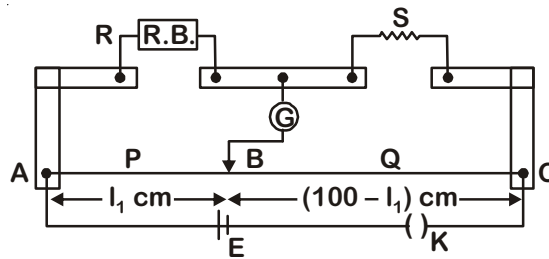$40\,I_1 + 80 - 20I_2 = 0$

$\Rightarrow\quad 2I_1 + 4 = I_2$ [1]

Solving we get $I_1 = 0$, $I_2 = 4$ A [1]

So, current through 20 Ω resistor is 4 A and current through 40 Ω resistor is zero

OR

What is end error in a metre bridge? How is it overcome? The resistances in the two arms of the metre bridge are R = 5 Ω and S respectively.

When the resistance S is shunted with an equal resistance, the new balance length found to be $1.5l_1$, where l_1 is the initial balancing length. Calculate the value of S.

Sol. End Error : Shifting of zero of scale at different points as well as the stray resistance give rise to the end error in meter bridge wire. [½]

It can be overcome by interchanging resistance in resistance box or can be overcome by using end correction in measurement [½]

$\dfrac{R}{S} = \dfrac{\ell_1}{100 - \ell_1}$ [½]

$\dfrac{2R}{S} = \dfrac{1.5\ell_1}{100 - 1.5\ell_1}$ [½]

$\Rightarrow \dfrac{1.5\ell_1}{2(100 - 1.5\ell_1)} = \dfrac{\ell_1}{(100 - \ell_1)}$

$\Rightarrow 150 - 1.5\ell_1 = 200 - 3\ell_1$

$1.5\ell_1 = 50$

$\Rightarrow S = 2R = 10\ \Omega$ [1]

18. (a) Describe briefly the functions of the three segments of n-p-n transistor. [3]

(b) Draw the circuit arrangement for studying the output characteristics of n-p-n transistor in CE configuration. Explain how the output characteristics is obtained.

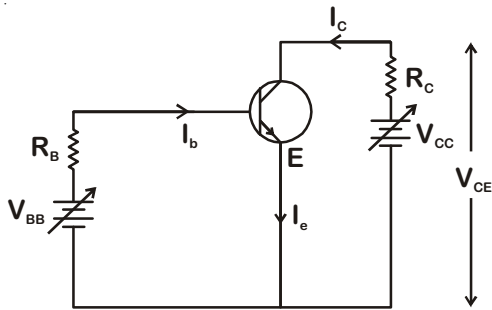**Sol.** (a) The function of three segments of a transistor are :

Emitter : Emits the majority charge carriers.

Collector : Collects the majority charge carriers.

Base : Base provides the interaction between the collector and emitter. [1]
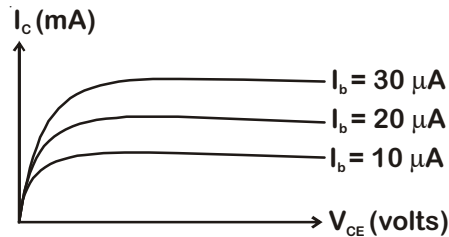
(b)

Output characteristics :

A graph showing the variation of collector current (I_c) with collector emitter voltage V_{CE} at constant base current I_b is called the output characteristic of transistor. **[1]**

A study of these curve reveals the following

(i) Initially the collector current I_c increases rapidly with increase in V_{CE} and becomes constant afterwards.

(ii) Saturation collector current depends entirely on base current I_b.
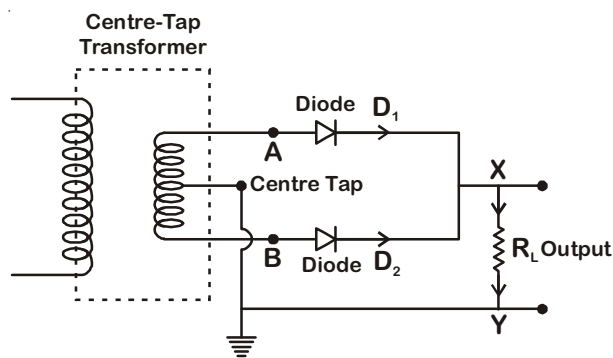

Output resistance (r_o) :

This is defined as the ratio of change in collector emitter voltage to the change in collector current at constant base current.

$$r_o = \left[\frac{\Delta V_{CE}}{\Delta I_c} \right]_{I_b}$$

[1]

OR

Draw the circuit diagram of a full wave rectifier and explain its working. Also, give the input and output waveforms.
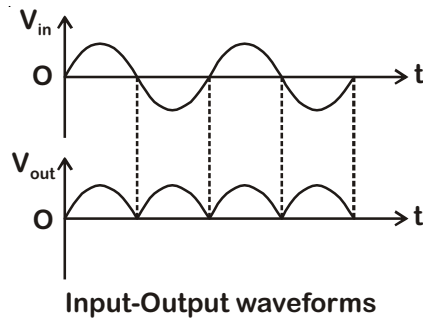
Sol. Full wave rectifier

[1]

A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a centre tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between A and B as shown in the circuit. **[½]**

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So, diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So, diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y. **[½]**
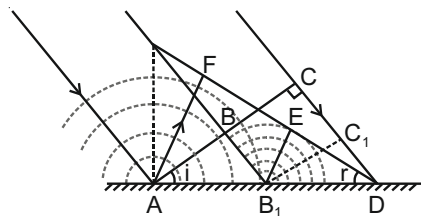

Input-Output waveforms

Since, in both the half cycles of input a.c., electric current through load R_L flows in the same direction, so d.c. is obtained across R_L. Although direction of electric current through R_L remains same, but its magnitude changes with time, so it is called pulsating d.c. **[1]**

19. Define the term wavefront. Using Huygen's wave theory, verify the law of reflection. **[3]**

Sol. In a region where wave is propagating, geometrical structure formed by joining all the points which are vibrating in same (absolute) phase are said to be wavefront. **[1]**
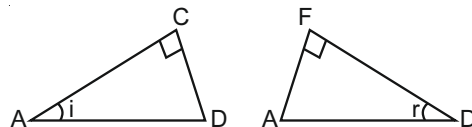
Reflection of plane wave :

[½]

Consider a plane wave ABC incident at an angle 'i' on a reflecting surface 'AD'. If v represents the speed of the wave in medium Δt is the time taken to move from ABC to B_1C_1 and also from B_1C_1 to point 'D'.

So, at the time when disturbance of point 'C' reaches to point 'D' disturbance of point 'A' must have formed a hemispherical shape of radius $2v\Delta t$ and at point 'B_1' it must have formed a hemispherical shape of radius $v\Delta t$. Drawing a common tangent from point 'D' to both of the above mentioned spherical envelope we shall have DEF as reflected wavefront. **[½]**

Now in ΔACD and in ΔDFA

Side AD = AD and side CD = AF = $2v\Delta t$

And $\angle ACD = \angle DFA = 90°$

so by RHS rule both the triangles are congruent.

Hence each corresponding parameters must be same.

Hence $\angle CAD = i$ (angle of incidence)

Must be same as $\angle FDA = r$ (angle of reflection)

$\Rightarrow \angle i = \angle r$ **[1]**

OR

Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium.

Sol. The factor by which speed of light gets reduced with respect to the "speed of light in vacuum" is said to be the refractive index for the medium.

$$\mu = \frac{c}{v} \quad \text{or} \quad v = \frac{c}{\mu}$$

Here v is the speed of light in medium, c is the speed of light in vacuum and μ is the defined refractive index for the medium. **[1]**

[½]

In the figure above

Let B_1B_2 is the incident wavefront and A_1A_2 is the refracted wavefront in other medium with V_2 as the wave speed. When the point B_1 traverse a distance $B_1A_1 = V_1T$ in medium I, the wavefront originated from point B_2 must have travelled a distance of V_2T in medium II.

Now, consider the incident wavefront B_1B_2 and refracted wavefront A_1A_2 **[½]**

$$\sin i = \frac{B_1A_1}{A_1B_2}$$

$$\sin r = \frac{A_2B_2}{A_1B_2}$$

$$\frac{\sin i}{\sin r} = \frac{V_1T}{V_2T} = \frac{V_1}{V_2}$$

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \qquad \textbf{[1]}$$

20. (a) Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range. **[1]**

(b) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field. **[2]**

Sol. (a) (i) Microwaves are used for 'Radar' system. Frequency range of microwaves are from 1 GHz to 2 GHz. **[½]**

(ii) Ultraviolet rays (UV rays) are used in eye surgery. Frequency range of UV rays are from 10^{15} to 10^{17} Hz **[½]**

(b) For a travelling electromagnetic wave equations can be written as

$E = E_0 \sin(kx - \omega t)$ and

$B = B_0 \sin(kx - \omega t)$

Two important results are

$$C = \frac{E_0}{B_0} \text{ and } C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad \textbf{[½]}$$

Now electric field energy density

$$\rho_E = <\frac{1}{2}\varepsilon_0 E^2>$$

$$\rho_E = \frac{1}{2}\varepsilon_0 < E_0^2 \sin^2(kx - \omega t)>$$

Average of $\sin^2(kx - \omega t)$ will come out to be $\frac{1}{2}$ over a long time.

so $\rho_E = \frac{1}{4}\varepsilon_0 E_0^2$ ...(1) [½]

Now magnetic field energy density (Average)

$$\rho_B = \frac{1}{2\mu_0}<B^2> = \frac{1}{2\mu_0}<B_0^2 \sin^2(kx - \omega t)>$$

$$\Rightarrow \quad \rho_B = \frac{1}{2\mu_0}\cdot\frac{B_0^2}{2} = \frac{B_0^2}{4\mu_0}$$ ...(2) [½]

As $B_0 = \dfrac{E_0}{C}$

$$\therefore \quad \rho_B = \frac{E_0^2}{4\mu_0 C^2} = \frac{\mu_0 \varepsilon_0 \cdot E_0^2}{4\mu_0}$$
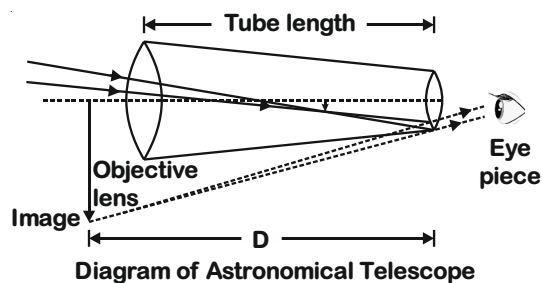
$$\Rightarrow \quad \rho_B = \frac{1}{4}\varepsilon_0 E_0^2$$ ...(3)

So from equation (1) & (3) avarage electric field energy density and average magnetic field energy density are equal. [½]

21. Draw a labelled ray diagram of an astronomical telescope in the near point adjustment position.

A giant refracting telescope at an observatory has an objective lens of focal length 15 m and an eyepiece of focal length 1.0 cm. If this telescope is used to view the Moon, find the diameter of the image of the Moon formed by the objective lens. The diameter of the Moon is 3.48 × 10⁶ m, and the radius of lunar orbit is 3.8 × 10⁸ m. [3]
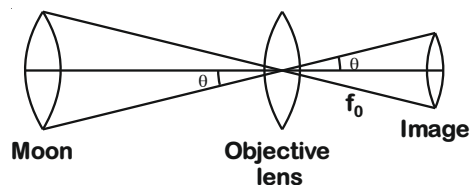
Sol. [1]

Diagram of Astronomical Telescope

Now, f_0 = focal length of objective lens = 15 m

f_e = focal length of eyepiece lens = 1 cm

Now, the image formed by objective lens is in its focal plane.

$$\therefore \quad \frac{d_{moon}}{r_{moon}} = \frac{d_{image}}{r_{focal\ plane}}$$ [1]

$$\Rightarrow \quad \frac{3.48 \times 10^6}{3.8 \times 10^8} = \frac{d_{image}}{15}$$

$\Rightarrow \quad d_{image} = 13.74 \times 10^{-2}$ m

$\Rightarrow \quad d_{image} = 13.74$ cm [1]

22. **(a)** If A and B represent the maximum and minimum amplitudes of an amplitude modulated wave, write the expression for the modulation index in terms of A and B. **[1½]**

Sol. **(a)** Let the amplitude modulated signal be

$$C_m(t) = (A_c + A_m \sin\omega_m t) \sin\omega_c t$$

$\Rightarrow \quad A = A_c + A_m$ ...(I)

$B = A_c - A_m$ ...(II) **[½]**

From equations (I) and (II)

$$\frac{A+B}{2} = A_c$$

$$\frac{A-B}{2} = A_m$$ **[½]**

The modulation index μ is given as

$$\Rightarrow \quad \mu = \frac{A_m}{A_c} = \frac{A-B}{A+B}$$ **[½]**

(b) A message signal of frequency 20 kHz and peak voltage 10 V is used to modulate a carrier of frequency 2 MHz and peak voltage of 15 V. Calculate the modulation index. Why the modulation index is generally kept less than one? **[1½]**

Sol. **(b)** Modulation index, $\mu = \dfrac{A_m}{A_c}$

Here, $A_m = 10$ V

$A_c = 15$ V

$$\Rightarrow \quad \mu = \frac{10}{15} = \frac{2}{3}$$ **[1]**

Modulation index, μ is generally kept less than one to avoid distortion. When μ is greater than one, over modulation occurs and the modulating signal being of greater amplitude, a part of its information is lost in the process of modulation. **[½]**

23. **(a)** State Gauss's law for magnetism. Explain its significance. **[1]**

Sol. **(a)** Gauss's law of magnetism states that net magnetic flux through a closed surface (Gaussian surface) is zero.

Mathematically

$$\oint \vec{B} \cdot d\vec{s} = 0$$ **[1]**

Gauss's Law for magnetism tells us that magnetic monopoles do not exist.

(b) Write the four important properties of the magnetic field lines due to a bar magnet. **[2]**

Sol. (b) Important properties of magnetic field lines due to a bar magnet:

(i) Field lines form close loop **[½]**

(ii) Field lines do not intersect **[½]**

(iii) Degree of closeness of lines represents relative strength of field in regions **[½]**

(iv) Direction of magnetic field at a point is along the tangent to a line at that point **[½]**

OR

Write three points of differences between para-, dia- and ferro- magnetic materials, giving one example for each. **[3]**

Sol.

S. No.	Paramagnetic Material	Diamagnetic Material	Ferromagnetic Material
(i)	The materials which get weakly attracted by a magnet are called Paramagnetic materials.	The materials which get weakly repelled by a magnet are called Diamagnetic materials.	The materials which gets strongly mangetised when placed in external magnetic field (strongly attracted) are called Ferromagnetic materials.
(ii)	The magnetic susceptibility of paramagnetic material is positive and small. Field lines concentration increases inside the material.	The magnetic susceptibility of diamagnetic material is negative and small. The concentration of field lines inside the material decreases.	The magnetic susceptibility of ferromagnetic material is positive and very large. The concentration of magnetic field lines increases very much inside the material.
(iii)	Paramagnetic nature decreases with increase in temperature. Ex. Aluminium, calcium, sodium, etc.	Diamagnetism is found in every material. At low temperature, they behave as super conductors. Ex : Bismuth, Copper, Silicon, etc.	Ferromagnetism also decreases with temperature. At Curie temperature, they become paramagnetic. Ex : Iron, Cobalt, Nickel

24. (a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which of them will not be able to detect light of wavelength 600 nm? **[1½]**

Sol. (a) Given that:

Band gap of diode D_1 = 2.5 eV

Band gap of diode D_2 = 2 eV

Band gap of diode D_3 = 3 eV

Wavelength of light incidented = 600 nm

∴ Energy associated with a photon of incident light,

$$E = \frac{hc}{\lambda} = \frac{1240}{600} \, eV$$ **[1]**
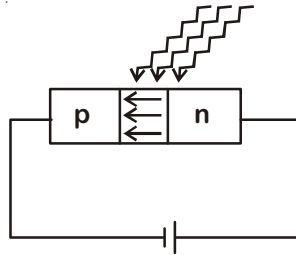
⇒ E = 2.1 eV

To detect the light, the band gap should be less than E

⇒ Band gap < E

∴ Only diode D_2 will be able to detect the light. **[½]**

(b) Why photodiodes are required to operate in reverse bias? Explain. [1½]

Sol. (b) The photodiodes are operated in reverse biased. In this case, the depletion region is large, electric field strength is very high and current through the circuit is very small. All these things, facilitate the easy detection of light. [1]

When light photons get incidented on depletion region, they generate new pairs of holes and electrons. Due to strong electric field, they separate out and constitute rise in electric current in the circuit, which indicates detection.
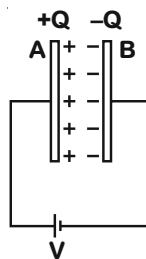
[½]

<div align="center">

Section-D

</div>

25. (a) Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor.

[2½]

Sol. (a) When plates A and B of a parallel plate capacitor are connected to the terminals of a battery, the battery sets up electric field in the connecting wires. The electric field drives charge Q from plate B, connected to the negative terminal of the battery to plate A connected to the positive terminal. The charge transfer takes place till the potential difference across the capacitor plates equals the emf of the battery.

$$\Rightarrow \quad V = \frac{Q}{C}$$ [1]

or   Q = CV

Energy stored in the capacitor

$$U = \int V dq = \int_0^Q \frac{q}{C} dq = \frac{Q^2}{2C}$$

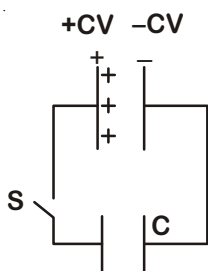$$\left[V = \frac{q}{C} \right]$$ [1½]

$$\Rightarrow \quad U = \frac{Q^2}{2C}$$

(b) A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor. [2½]

Sol. **(b)** Let charge q be transferred from one capacitor to the other. Then equating potential difference across the two capacitors,
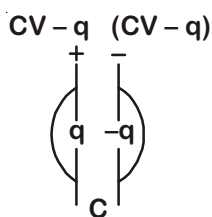
$$\frac{CV - q}{C} = \frac{q}{C}$$

+CV –CV

S

C

[½]

$$\Rightarrow \quad q = \frac{CV}{2}$$

Now, Energy stored in the combination,

$$U_f = 2\frac{1}{2}\frac{q^2}{C} = \frac{CV^2}{4}$$

[1]

Initial energy, $U_i = \frac{1}{2}CV^2$

CV – q (CV – q)

q –q

C

$$\Rightarrow \quad \boxed{\frac{U_f}{U_i} = \frac{CV^2}{4}\frac{2}{CV^2} = \frac{1}{2}}$$
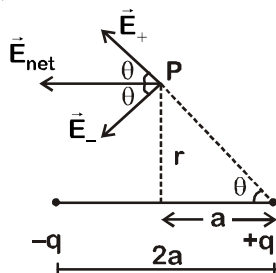
[1]

OR

(a) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

Sol. **(a)** Let P be an equatorial point for a dipole consisting of charges –q and +q with a separation 2a (see figure). Then

$\vec{E}_+$ = Electric field due to the charge +q

$\vec{E}_{net}$ $\vec{E}_+$ θ   P   θ $\vec{E}_-$ r   θ

–q   2a   +q   a

$$E_+ = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{a^2 + r^2}$$

[½]

$\vec{E}_-$ = Electric field due to the charge –q

$$E_- = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{a^2 + r^2}$$

$$\vec{E}_{net} = \vec{E}_+ + \vec{E}_-$$

By symmetry the electric field in y-direction will cancel out. **[½]**

$$\left|\vec{E}_{net}\right| = 2E_+ \cos\theta = \frac{2}{4\pi\varepsilon_0} \cdot \frac{q}{(a^2+r^2)} \cdot \frac{a}{\sqrt{a^2+r^2}}$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{2qa}{(a^2+r^2)^{3/2}}$$ **[½]**

In vector form, $\boxed{\vec{E}_{net} = \frac{1}{4\pi\varepsilon_0}\frac{-\vec{p}}{(a^2+r^2)^{3/2}}}$ **[1]**
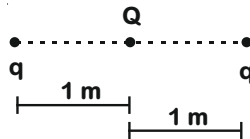
For a short dipole, r >> a then

$$\boxed{\vec{E}_{net} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-\vec{p}}{r^3}}$$

(b) Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

Sol. (b) To overcome the electrostatic repulsion between the point charges q each, Q must be at the centre of the line segment joining the two. The sign of Q must be opposite to that of q. **[1]**
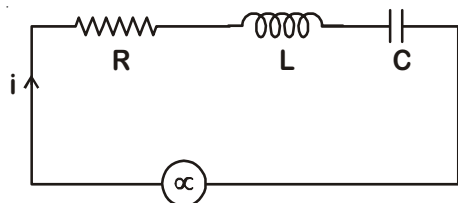
Also $\dfrac{kq^2}{2^2} + \dfrac{kqQ}{1^2} = 0$

$$\Rightarrow \quad Q = \frac{-q}{4}$$ **[1½]**

Q must be at a distance of 1 m from each charge q.

26. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source. **[5]**

Sol. (a)

as source of variable
frequency

(i) In series current will be same across all components.

(ii) Voltage drop across resistance $V_R = iR$

Voltage drop across inductor $V_L = iX_L$
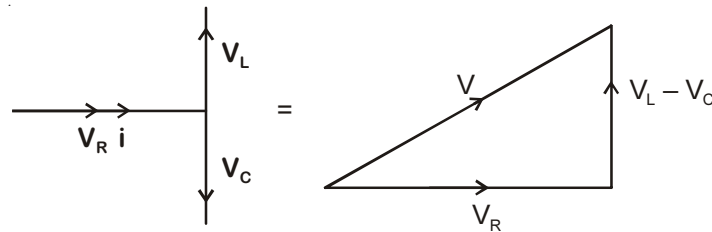
Voltage drop across capacitor $V_C = iX_C$ **[½]**

(iii) Voltage across resistance is in phase with current

Voltage across inductor leads current by $\pi/2$

Voltage across capacitor lags current by $\pi/2$
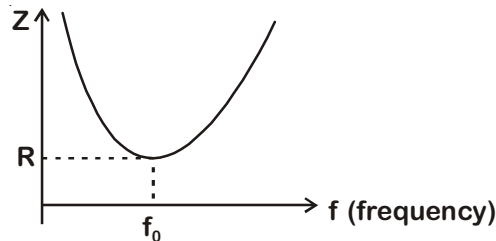
So phasor diagram

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$ [½]

$$iZ = \sqrt{i^2 R^2 + (iX_L - iX_C)^2}$$

$$\Rightarrow Z = \sqrt{R^2 + (X_L - X_C)^2}$$ [½]

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Variation of impedance (Z) with frequency of source

$f_0 \rightarrow$ Resonance frequency at this frequency impedance will be minimum and equal to the resistance in the circuit. [½]

(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit?

Sol. **(b)** Phase difference between voltage across inductor and capacitor is π in series LCR circuit. [1]

(c) When an inductor is connected to a 200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.

Sol. **(c)** A real inductor has some resistance

i.e.,

$\Rightarrow$ Impedance of real inductor $Z = \sqrt{R^2 + X_L^2}$, for dc source $X_L = 0$

$$i = \frac{V}{Z} = \frac{V}{R}$$

$$1 = \frac{200}{R}$$

$\Rightarrow$ R = 200 Ω [½]

for ac source

$$i = \frac{V}{Z}$$

$$0.5 = \frac{200}{Z}$$

$$\Rightarrow \quad Z = 400 \ \Omega \qquad \text{[½]}$$

so for ac source impedance is more hence current is less

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

$$400^2 = 200^2 + X_L^2$$

$$\Rightarrow \quad X_L = 200\sqrt{3} \ \Omega$$

$$X_L = \omega L$$

$$\omega L = 200\sqrt{3} \qquad \text{[½]}$$

$$2\pi f L = 200\sqrt{3}$$

$$\Rightarrow \quad L = \frac{200\sqrt{3}}{2 \times \pi \times 50}$$

$$L = \frac{2\sqrt{3}}{\pi} \text{ henry} \qquad \text{[½]}$$

OR

(a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device. **[5]**

Sol. **(a)** The device is stepdown transformer. It works on the principle of mutual Induction. **[1]**

Primary winding, Secondary winding, Laminated core, LOAD

[1]

Losses:

(i) Flux linkage loss

(ii) Copper loss in primary and secondary windings

(iii) Eddy current loss in the core

(iv) Hysteresis loss in the core **[1]**

(b) A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat.

Sol. (b) Total electric power required,

P = 1200 kW = 1200 × 10^3 W

Supply voltage V = 220 V

Voltage at which electric plant is generating power V′ = 440 V

Distance between the town and power generation station, d = 20 km

Resistance of the two wire lines carrying power = 0.5 Ω/km

Total Resistance of the wires

R = (20 + 20) × 0.5 = 20 Ω **[1]**

A step-down transformer of rating 4000 – 220 V is used in the sub-station. Input voltage V_1 = 4000 V

Output voltage V_2 = 220 V

rms current in the wire lines is given as

$$I = \frac{P}{V_1} = \frac{1200 \times 10^3}{4000} = 300 \text{ A}$$

$\Rightarrow$ Line power loss i^2R = 300^2 × 20

= 1800 kW

$\Rightarrow$ Line power loss in the form of heat = 1800 kW   **[1]**

27. (a) Describe any two characteristic features which distinguish between interference and diffraction phenomena. Derive the expression for the intensity at a point of the interference pattern in Young's double slit experiment.   **[5]**

Sol. (a) Difference between Interference and diffraction:

Interference	Diffraction
(1) Interference is caused by superposition of finite number of waves.	(1) Diffraction is caused by superposition of infinite number of waves.
(2) All fringes are of equal width.	(2) All fringes are not of equal width.

[1]

Expression for the intensity :

Let displacement produced by S_1 and S_2 are

y_1 = acos ωt and y_2 = acos (ωt + ϕ)

then amplitude of resultant displacement is

y = y_1 + y_2 = a[cos ωt + cos (ωt + ϕ)]

$$= 2a \cos\left(\frac{\phi}{2}\right) \cos\left(\omega t + \frac{\phi}{2}\right)$$ **[½]**

$$A = 2a \cos\left(\frac{\phi}{2}\right)$$

Thus intensity at any point is

$$I = 4I_0 \cos^2\left(\frac{\phi}{2}\right) \text{ (since } I_0 \propto A^2\text{)}$$ **[1]**

(b) In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. If monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3rd order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m.

Sol. (b) Given wavelength

$\lambda = 620$ nm $= 6.20 \times 10^{-7}$ m

Slit width a = 3 mm = 3×10^{-3} m

Distance of screen from slit is D = 1.5 m

Fringe width $= \beta = \dfrac{\lambda D}{a}$ [1]

Now separation between 1st minimum and 3rd order maxima is

$y = \dfrac{7}{2}\dfrac{\lambda D}{a} - \dfrac{\lambda D}{a} = \dfrac{5}{2}\dfrac{\lambda D}{a}$ [½]

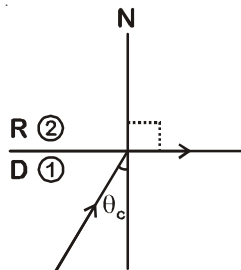$y = \dfrac{5}{2} \times \dfrac{6.20 \times 10^{-7} \times 1.5}{3 \times 10^{-3}} = 7.75 \times 10^{-4}$ m

$\boxed{y = 7.75 \times 10^{-4} \text{ m} = 0.775 \text{ mm}}$ [1]

OR

(a) Under what conditions is the phenomenon of total internal reflection of light observed? Obtain the relation between the critical angle of incidence and the refractive index of the medium.   [5]

Sol. (a) When light travel from denser medium to rarer medium it moves away from the normal. If we keep on increasing the angle of incidence then at a particular angle of incidence angle of refraction become 90°, this angle of incidence is known as critical angle. Beyond this angle of incidence light ray does not move to other medium it gets reflected to the same medium. This phenomenon known as Total Internal Reflection (TIR)   [1]

Snell's Law

[½]

$\mu_1 \sin i = \mu_2 \sin r$
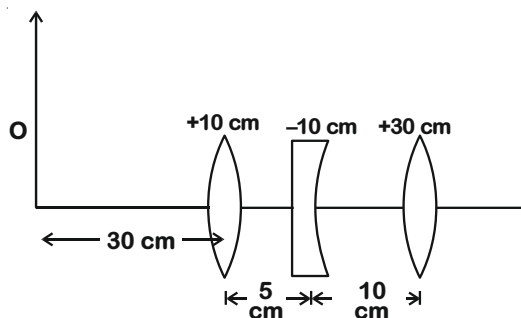
$\mu_1 \sin\theta_c = \mu_2 \sin 90°$

$\Rightarrow \quad \sin\theta_c = \dfrac{\mu_2}{\mu_1}$

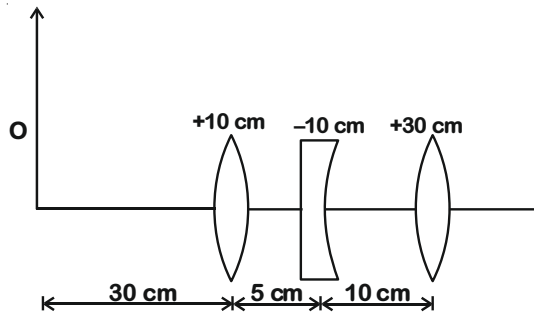$\mu_1 \rightarrow$ Refractive index of denser medium

$\mu_2 \rightarrow$ Refractive index of rarer medium   [1]

(b) Three lenses of focal lengths +10 cm, –10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.

Sol. (b)

From lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$ [½]

$$\frac{1}{v} - \frac{1}{-30} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{30}$$

$$v = 15 \text{ cm}$$ [½]

It will act as an object for middle lens

u = + 10 cm

v = ?

f = –10

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} - \frac{1}{10} = \frac{1}{-10}$$ [½]

v = ∞ ⇒ Rays will become parallel to principal axis

So for third lens object is at infinite so final image $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ [½]

$$\frac{1}{v} - 0 = \frac{1}{30} \Rightarrow v = 30 \text{ cm Right of the last lens}$$ [½]

❏ ❏ ❏