Solved Paper 2015
Physics
Class-XII

Time : 3 Hours | *Max. Marks : 70*

General Instructions :

(i) There are ***26*** *questions in* ***all. All*** *questions are compulsory.*

(ii) This question paper has ***five*** *sections : Section* ***A****, Section* ***B****, Section* ***C****, Section* ***D*** *and Section* ***E****.*

(iii) Section ***A*** *contains* ***five*** *questions of* ***one*** *mark each, Section* ***B*** *contains* ***five*** *questions of* ***two*** *marks each, Section* ***C*** *contains* ***twelve*** *questions of* ***three*** *marks each, Section* ***D*** *contains* ***one*** *value based question of* ***four*** *marks and Section E contains* ***three*** *questions of* ***five*** *marks each.*

(iv) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary:

$$c = 3 \times 10^{8} \text{ m/s}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$e = 1.6 \times 10^{-19} \text{ C}$$
$$\mu_o = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$
$$\varepsilon_o = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$
$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$$
$$m_e = 9.1 \times 10^{-31} \text{ kg}$$
$$\text{Mass of Neutron} = 1.675 \times 10^{-27} \text{ kg}$$
$$\text{Mass of Proton} = 1.673 \times 10^{-27} \text{ kg}$$
$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$
$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

Delhi Set | **Code No. 55/1/1**

SECTION - A

1. Define capacitor reactance. Write its S.I. units.

Ans. It is defined as the opposition to the flow of current in ac circuits offered by a capacitor.

Alternatively:

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

= S.I Unit : ohm

2. What is the electric flux through a cube of side 1 cm which encloses an electric dipole ?

Ans. Zero **[CBSE Marking Scheme, 2015]**

Detailed answer:

Cube is enclosing a dipole. Hence, the total charge enclosed is 0.

$$\text{Flux} = \frac{q}{\varepsilon_0}$$

Since, $q = 0$, then flux = 0

3. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens ?

Ans. Converging (Convex Lens),(Also accept if a student writes it as a diverging Lens or Concave lens (Since, hindi translation does not match with English version)

[CBSE Marking Scheme, 2015]

Detailed answer:

When the refractive index of the matériel of concave lens is less than the refractive index of the surrounding medium, then the lens behaves opposite in nature i.e., convex lens.

*** 4. How are side bands produced ?**

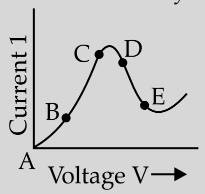
5. Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of

(i) negative resistance

(ii) where Ohm's law is obeyed.

* *Out of Syllabus*

Ans. DE: Negative resistance region
AB: Where Ohm's law is obeyed. (Also accept BC)



[CBSE Marking Scheme, 2015]

Detailed answer:

(i) In DE portion of the graph, the current decreases as voltage increases. Hence, this is the negative resistance region.

(ii) In AC region of the graph, the current increases as the voltage increases. This region follows Ohm's law.

SECTION - B

6. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.

Ans. Determination of ratio (i) accelerating potential **1**
(ii) speed **1**

(i)
$$\lambda = \frac{h}{\sqrt{2mqV}}$$
$$V = \frac{h^2}{2mq\lambda^2}$$
$$m_\alpha = 4m_p, q_\alpha = 2q_p$$
$$\Rightarrow \quad \frac{V_p}{V_\alpha} = \frac{m_\alpha q_\alpha}{m_p q_p}$$
$$= \frac{4m_p \times 2q_p}{m_p q_p}$$
$$= 8 : 1$$

(ii)
$$\lambda = \frac{h}{mv}$$
$$\Rightarrow \quad v = \frac{h}{m\lambda}$$
$$\Rightarrow \quad \frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p} = 4$$

7. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Ans. Showing that the radius of orbit varies as n^2
$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$
or
$$mv^2r = \frac{1}{4\pi\varepsilon_0}e^2 \quad \ldots(i)$$
$$mvr = \frac{nh}{2\pi}$$
$$m^2v^2r^2 = \frac{n^2h^2}{4\pi^2} \quad \ldots(ii)$$
Divide (ii) by (i)
$$mr = \frac{n^2h^2}{4\pi^2} \times \frac{4\pi\varepsilon_0}{e^2}$$
$$\therefore \quad r = \frac{n^2h^2}{4\pi^2me^2}.4\pi\varepsilon_0$$
$$\therefore \quad r \propto n^2$$
(Give full credit to any other correct alternative method)

8. Distinguish between 'intrinsic' and 'extrinsic' semiconductors.

Ans. Distinction between intrinsic & extrinsic semiconductor

	Intrinsic Semiconductor	Extrinsic Semiconductor
(i)	Without any impurity atoms.	Doped with trivalent/ pentavalent impurity atoms.
(ii)	$n_e = n_h$	$n_e \neq n_h$

(Any other correct distinguishing features.)

9. Use the mirror equation to show that an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$.

OR

*** Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum ?**

Ans. Derivation of the required condition
$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$
For concave mirror $f < 0$ and $u < 0$
As object lies between f and $2f$

(i) At $u = -f$
$$\frac{1}{v} = -\frac{1}{f} + \frac{1}{f}$$
$$\Rightarrow \quad v = \infty$$
At $\quad u = -2f$
$$\Rightarrow \quad \frac{1}{v} = -\frac{1}{f} + \frac{1}{2f} = -\frac{1}{2f}$$
$$\Rightarrow \quad v = -2f$$
$\Rightarrow$ Hence, image distance $v \geq -2f$
Since, v is negative therefore the image is real.

* *Out of Syllabus*

Alternative Method

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

For concave mirror $f < 0, u < 0$

$\because$ $2f < u < f$

$\Rightarrow$ $$\frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$$

$$\frac{1}{2f}-\frac{1}{f} > \frac{1}{u}-\frac{1}{f} > \frac{1}{f}-\frac{1}{f}$$

$\Rightarrow$ $$-\frac{1}{2f}-\frac{1}{v} > 0 \qquad \left(\because \frac{1}{u}-\frac{1}{f}=\frac{1}{-v}\right)$$

$\Rightarrow$ $$\frac{1}{2f} < \frac{1}{v} < 0$$

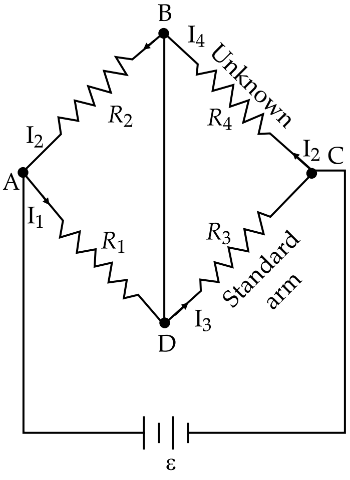
$\Rightarrow$ $v < 0$

$\therefore$ Image is real

Also $v > 2f$ image is formed beyond $2f$.

10. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge.

Ans. Obtaining condition for the balance Wheatstone bridge



Applying Kirchoff's loop rule to closed loop ADBA

$$-I_1R_1 + 0 + I_2R_2 = 0(I_g = 0) \qquad \ldots\text{(i)}$$

For loop CBDC

$$-I_2R_4 + 0 + I_1R_3 = 0 \qquad \ldots\text{(ii)}$$

$\Rightarrow$ from equation (i)

$$\frac{I_1}{I_2} = \frac{R_1}{R_2}$$

From equation (ii)

$$\frac{I_1}{I_2} = \frac{R_4}{R_3}$$

$\therefore$ $$\frac{R_1}{R_2} = \frac{R_4}{R_3}$$

SECTION - C

11. Name the parts of the electromagnetic spectrum which is

(a) suitable for radar systems used in aircraft navigation.

(b) used to treat muscular strain.

(c) used as a diagnostic tool in medicine.

Write in brief, how these waves can be produced.

Ans. Name of the parts of e.m. spectrum for *a*, *b*, *c* Production

(a) Microwave

Production: Klystron/magnetron/Gunn diode (any one)

(b) Infrared Radiation

Production: Hot bodies / vibrations of atoms and molecules **(any one)**

(c) X-Rays

Production: Bombarding high energy electrons on metal target/ x-ray tube/inner shell electrons(any one).

12. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of focal length 1.0 cm is used, what is the angular magnification of the telescope ?

(ii) If this telescope is used to view the moon, what is 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.

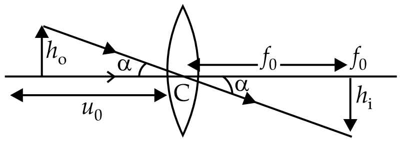
Ans. (i) Calculation of angular magnification

(ii) Calculation of image of diameter of Moon

Angular Magnification

$$m = \frac{f_o}{f_e}$$

$$= \frac{15}{10^{-2}} = 1500$$



Angular size of the moon $= \left(\frac{3.48\times10^6}{3.8\times10^8}\right)$

$$= \frac{3.48}{3.8}\times10^{-2} \text{ radian}$$

Angular size of the image

$$= \left(\frac{3.48}{3.8}\times10^{-2}\times1500\right) \text{ radian}$$

Diameter of the image

$$= \frac{3.48}{3.8}\times15\times\text{focal length of eye peice}$$

$$= \frac{3.48}{3.8} \times 15 \times 1 \text{ cm}$$

$$= 13.7 \text{ cm}$$

(Also accept alternative correct method.)

13. Write Einstein's photoelectric equation and mention which important features in photoelectric effect can be explained with the help of this equation.

The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light incident on the surface changes from λ_1 to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface.

Ans. (i) Einstein's Photoelectric equation

(ii) Important features

(iii) Derivation of expressions for λ_0 and work function

$$hv = \phi_0 + k_{max}$$

or

$$h_v = hv_0 + \frac{1}{2}mv^2 \max$$

Important features

(i) k_{max} depends linearly on frequency v.

(ii) Existence of threshold frequency for the metal surface. (Any other two correct features.)

$$hv = \phi_0 + k_{max}$$

$$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_0} + k_{max} \quad \text{...(i)}$$

$$\frac{hc}{\lambda_2} = \frac{hc}{\lambda_0} + 2k_{max} \quad \text{...(ii)}$$

From (i) and (ii)

$$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \frac{hc}{\lambda_0}$$

$$\frac{1}{\lambda_0} = \left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$$

$$\text{Work function } \phi_0 = \frac{hc}{\lambda_0} = \frac{hc(2\lambda_2 - \lambda_1)}{\lambda_1\lambda_2}$$

14. In the study of Geiger-Marsdon experiment on scattering of α particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

OR

Distinguish between nuclear fission and fusion. Show how in both these processes energy is released.

Calculate the energy release in MeV in the deuterium-tritium fusion reaction:

$$^2_1H + ^3_1H \rightarrow ^4_2He + n$$

Using the data:

$$m(^2_1H) = 2.014102 \text{ u}$$

$$m(^3_1H) = 3.016049 \text{ u}$$

$$m(^4_2He) = 4.002603 \text{ u}$$

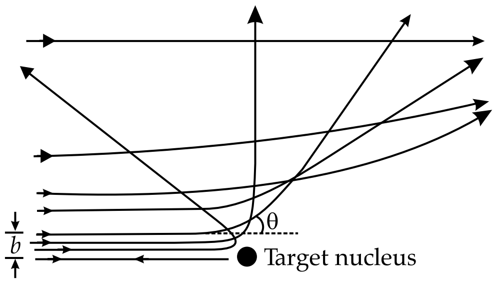
$$m_n = 1.008665 \text{ u}$$

$$1u = 931.5 \text{ MeV}/c^2$$

Ans. (i) Drawing of trajectory

(ii) Explanation of information on the size of nucleus

(iii) Proving that nuclear density is independent of A



Only a small fraction of the incident α – particles rebound. This shows that the mass of the atom is concentrated in a small volume in the form of nucleus and gives an idea of the size of nucleus.

Radius of nucleus

$$R = R_0A^{1/3}$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{mA}{\frac{4}{3}\pi R^3}$$

where, m: mass of one nucleon

A: Mass number

$$= \frac{mA}{\frac{4}{3}\pi(R_0A^{1/3})^3}$$

$$= \frac{3m}{4\pi R_0^3}$$

$\Rightarrow$ Nuclear matter density is independent of A

OR

Distinction between nuclear fission and nuclear fusion

Showing release of energy in both processes

Calculation of release of energy

The breaking of heavy nucleus into smaller fragments is called nuclear fission; the joining of lighter nuclei to form a heavy nucleus is called nuclear fusion.

Binding energy per nucleon, of the daughter nuclei, in both processes, is more than that of the parent nuclei. The difference in binding energy is released in the form of energy. In both processes some mass gets converted into energy.

Alternatively:

In both processes, some mass gets converted into energy.

Energy Released

$$Q = [m(^2_1H) + m(^3_1H) - m(^4_2He) - m(n)] \times 931.5 \text{ MeV}$$
$$= [2.014102 + 3.016049 - 4.002603 - 1.008665] \times 931.5 \text{ MeV}$$
$$= 0.018883 \times 931.5 \text{ MeV}$$
$$= 17.59 \text{ MeV}$$

*** 15. Draw a block diagram of a detector for AM signal and show, using necessary processes and the waveforms, how the original message signal is detected from the input AM wave.**

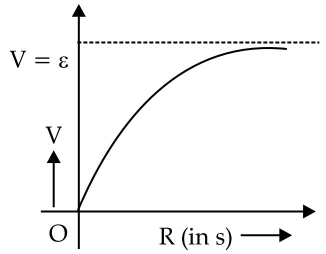
16. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.

It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance *r*.

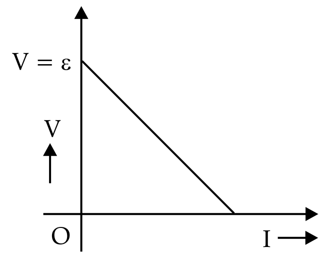
Ans. Drawing of Plots of Part (i) & (ii)

Finding the values of emf and internal resistance

(i)



(ii)



(If the student just writes the relations $V = \varepsilon - IR$ and $V = \frac{\varepsilon R}{R+r}$ but does not draw the plots, award ½ mark.)

$$I = \frac{E}{R+r}$$

$$I = \frac{E}{4+r}$$

$$\Rightarrow \quad E = 4 + r \quad \ldots(i)$$

Also, $$0.5 = \frac{E}{9+r}$$

$$E = 4.5 + 0.5r \quad \ldots(ii)$$

From equation (i) & (ii)

$$4 + r = 4.5 + 0.5r$$

$$\therefore \quad r = 1\Omega$$

Using this value of r, we get

$$E = 5V$$

17. Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel across a battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, determine the value of C_1 and C_2. Also calculate the charge on each capacitor in parallel combination.

Ans. Determination of C_1 and C_2

Determination of Charge on each capacitor in parallel combination

Energy stored in a capacitor

$$E = \frac{1}{2}CV^2$$

In series combination

$$0.045 = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(100)^2$$

$$\Rightarrow \quad \frac{C_1C_2}{C_1+C_2} = 0.09 \times 10^{-4} \quad \ldots(i)$$

In Parallel combination

$$0.25 = \frac{1}{2}(C_1+C_2)(100)^2$$

$$\Rightarrow \quad C_1 + C_2 = 0.5 \times 10^{-4} \quad \ldots(ii)$$

On simplifying (i) & (ii)

$$C_1C_2 = 0.045 \times 10^{-8}$$
$$(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$$
$$= (0.5 \times 10^{-4})^2 - 4 \times 0.045 \times 10^{-8}$$
$$= 0.25 \times 10^{-8} - 0.180 \times 10^{-8}$$
$$(C_1 - C_2)^2 = 0.07 \times 10^{-8}$$
$$(C_1 - C_2) = 2.6 \times 10^{-5}$$
$$= 0.26 \times 10^{-4} \quad \ldots(iii)$$

From (ii) and (iii) we have

$$\Rightarrow \quad C_1 = 0.38 \times 10^{-4} \text{ F}$$

and $$C_2 = 0.12 \times 10^{-4} \text{ F}$$

Charges on capacitor C_1 and C_2 in Parallel combination

$$Q_1 = C_1V = (0.38 \times 10^{-4} \times 100)$$
$$= 0.38 \times 10^{-2} \text{ C}$$
$$Q_2 = C_2V = (0.12 \times 10^{-4} \times 100)$$
$$= 0.12 \times 10^{-2} \text{ C}$$

[Note: If the student writes the relations/ equations

$$E = \frac{1}{2}CV^2$$

and $$0.045 = \frac{1}{2}\left(\frac{C_1C_2}{C_1+C_2}\right)(100)^2$$

$$0.25 = \frac{1}{2}(C_1 + C_2)(100)^2$$

But is unable to calculate C_1 and C_2, award him/her full 2 marks.

* *Out of Syllabus*

Also if the student just writes

$Q_1 = C_1V = C_1(100)$ and $Q_2 = C_2V = C_2(100)$

Award him/her one mark for this part of the question.]

18. State the principle of working of a galvanometer.

A galvanometer of resistance G is converted into a voltmeter to measure upto V volts by connecting a resistance R_1 in series with the coil. If a resistance R_2 is connected in series with it, then it can measure upto $\frac{V}{2}$ volts. Find the resistance, in terms of R_1 and R_2, required to be connected to convert it into a voltmeter that can read upto 2V. Also find the resistance G of the galvanometer in terms of R_1 and R_2.

Ans. Working Principle

Finding the required resistance

Finding the resistance G of the Galvanometer

Working Principle: A current carrying coil experiences a torque when placed in a magnetic field which tends to rotate the coil and produces an angular deflection.

$$V = I_g(G + R_1)$$

$$\frac{V}{2} = I_g(G + R_2)$$

$$\Rightarrow \quad 2 = \frac{G+R_1}{G+R_2}$$

$$\Rightarrow \quad G = R_1 - 2R_2$$

Let R_3 be the resistance required for conversion into voltmeter of range 2V

$$\therefore \quad 2V = I_g(G + R_3)$$

$$\text{Also} \quad V = I_g(G + R_1)$$

$$\therefore \quad 2 = \frac{G+R_3}{G+R_1}$$

$$\therefore \quad R_3 = G + 2R_1$$

$$= R_1 - 2R_2 + 2R_1$$

$$= 3R_1 - 2R_2$$

*** 19. With what considerations in view, a photodiode is fabricated ? State its working with the help of a suitable diagram.**

Even though the current in the forward bias is known to be more than in the reverse bias, yet the photodiode works in reverse bias. What is the reason ?

*** 20. Draw a circuit diagram of a transistor amplifier in CE configuration.**

Define the terms: (i) Input resistance and (ii) Current amplification factor. How are these determined using typical input and output characteristics ?

21. Answer the following questions:

(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(b) Light of wavelength 5000 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected ?

Ans. Finding the spacing between two slits

Effect on wavelength and frequency of reflected and refracted light

(a) Angular width of fringes

$$\theta = \frac{\lambda}{d},$$

where d = separation between two slits

Here $\theta = 0.1° = 0.1\times\frac{\pi}{180}$ radian

$$\therefore \quad d = \frac{600\times10^{-9}\times180}{0.1\times\pi} \text{ m}$$

$$= 3.43 \times 10^{-4} \text{ m}$$

$$= 0.34 \text{ m}$$

(b) For Reflected light: Wavelength remains same Frequency remains same

For Refracted light: Wavelength decreases Frequency remains same

22. An inductor L of inductance X_L is connected in series with a bulb B and an ac source.

How would brightness of the bulb change when (i) number of turn in the inductor is reduced, (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case.

Ans. Change in the Brightness of the bulb in cases (i), (ii) & (iii) Justification

(i) Increases

$X_L = \omega L$ As number of turns decreases, L decreases, hence current through bulb increases. / Voltage across bulb increases.

(ii) Decreases

Iron rod increases the inductance which increases X_L, hence current through the bulb decreases./ Voltage across bulb decreases.

(iii) Increases

Under this condition ($X_C = X_L$) the current through the bulb will become maximum / increase.

SECTION - D

23. A group of students while coming from the school noticed a box marked "Danger H.T.

2200 V" at a substation in the main street. They did not understand the utility of a such a high voltage, while they argued, the supply was only 220 V. They asked their teacher this question the next day. The teacher thought it to be an important question and therefore explained to the whole class.

Answer the following questions:

(i) What device is used to bring the high voltage down to low voltage of a.c. current and what is the principle of its working ?

* *Out of Syllabus*

(ii) Is it possible to use this device for bringing down the high dc voltage to the low voltage ? Explain.

(iii) Write the values displayed by the students and the teacher.

Ans. (i) Name of device and Principle of working

(ii) Possibility and explanation

(iii) Values displayed by students and teachers

(i) Transformer

Working Principle: Mutual induction. Whenever an alternative voltage is applied in the primary windings, an emf is induced in the secondary windings.

(ii) No, There is no induced emf for a dc voltage in the primary

(iii) Inquisitive nature/ Scientific temperament

(any one)

Concern for students / Helpfulness / Professional honesty(any one) (Any other relevant values)

[CBSE Marking Scheme, 2015]

Detailed answer:

(i) Transformer is used to bring down high voltage ac to low voltage.

Working principle: Mutual induction.

Transformers have two coils - primary and secondary. When ac voltage is applied to the primary an emf is induced in the secondary coil.

(ii) No. Continuous change is voltage level in the primary coil is required for emf to be induced in the secondary coil. But in dc, there is no change in voltage level. Hence, no emf is induced in the secondary coil.

(iii) Values displayed by students: Inquisitive nature, scientific temperament.

Values displayed by the teacher: Concern for students, helpfulness, professional honesty.

SECTION - E

24. (a) State Ampere's circuital law. Use this law to obtain the expression for the magnetic field inside an air cored toroid of average radius 'r', having 'n' turns per unit length and carrying a steady current I.

(b) An observer to the left of a solenoid of N turns each of cross section area 'A' observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic moment $m = NIA$.

OR

(a) Define mutual inductance and write its S.I. units.

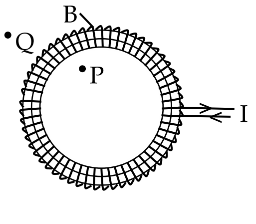
(b) Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.

(c) In an experiment, two coils c_1 and c_2 are placed close to each other. Find out the expression for the emf induced in the coil c_1 due to a change in the current through the coil c_2.

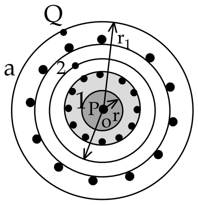
Ans. (a) Line integral of magnetic field over a closed loop is equal to the μ_0 times the total current passing through the surface enclosed by the loop.

Alternatively

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$



(a)



(b)

Let the current flowing through each turn of the toroid be I. The total number of turns equals $n.(2\pi r)$ where n is the number of turns per unit length. Applying Ampere's circuital law, for the Amperian loop, for interior points.

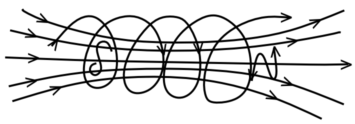
$$\oint \vec{B}.\vec{dl} = \mu_0(n\, 2\pi rl)$$

$$\oint Bdl\cos 0 = \mu_0 n\, 2\pi rl$$

$$\Rightarrow \quad B \times 2\pi r = \mu_0 n\, 2\pi rl$$

$$B = \mu_0 nI$$

(b)



The solenoid contains N loops, each carrying a current I. Therefore, each loop acts as a magnetic dipole. The magnetic moment for a current I, flowing in loop of area (vector) A is given by m = IA

The magnetic moments of all loops are aligned along the same direction.

Hence, net magnetic moment equals NIA

OR

(a) $\phi = MI$

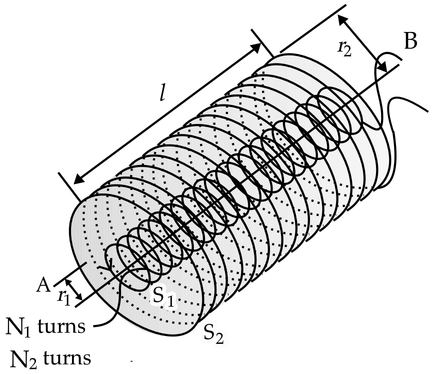
Mutual inductance of two coils is equal to the magnetic flux linked with one coil when a unit current is passed in the other coil. Alternatively,

$$e = -M\frac{dI}{dt}$$

Mutual inductance is equal to the induced emf set up in one coil when the rate of change of current flowing through the other coil is unity.

SI unit: henry / (Weber ampere^{-1}) / (volt second ampere^{-1}) (Any one)

(b)



Let a current I_2 flow through S_2. This sets up a magnetic flux ϕ_1 through each turn of the coil S_1. Total flux linked with S_1

$$N_1\phi_1 = M_{12}I_2 \quad \ldots\text{(i)}$$

where M_{12} is the mutual inductance between the two solenoids

Magnetic field due to the current I_2 in S_2 is $\mu_0 n_2 I_2$. Therefore, resulting flux linked with S_1.

$$N_1\phi_1 = [(n_1\ell)\pi r_1^2](\mu_0 n_2 I_2) \quad \ldots\text{(ii)}$$

Comparing (i) & (ii),we get

$$M_{12}I_2 = (n_1\ell)\pi r_1^2(\mu_0 n_2 I_2)$$

$$\therefore \quad M_{12} = \mu_0 n_1 n_2 \pi r_1^2 \ell$$

(c) Let a magnetic flux be (ϕ_1) linked with coil C_1 due to current (I_2) in coil C_2:

We have: $\phi_1 \propto I_2$

$\Rightarrow \quad \phi_1 = MI_2$

$\therefore \quad \dfrac{d\phi_1}{dt} = M\dfrac{dI_2}{dt}$

$\Rightarrow \quad e = -M\dfrac{dI_2}{dt}$

25. (a) Using Huygens's construction of secondary wavelets explain how a diffraction pattern is obtained on a screen due to a narrow slit on which a monochromatic beam of light is incident normally.

(b) Show that the angular width of the first diffraction fringe is half that of the central fringe.

(c) Explain why the maxima at $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ become weaker and weaker with increasing n.

OR

(a) A point object 'O' is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature R which separates the second medium of refractive index n_2 from the first one, as shown in the figure.

Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1, n_2 and R.

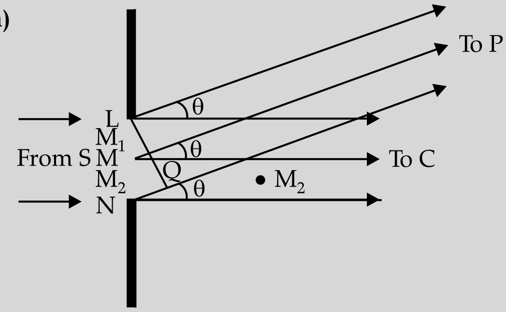
(b) When the image formed above acts as a virtual object for a concave spherical surface separating the medium n_2 from n_1($n_2 > n_1$), draw this ray diagram and write the similar (similar to (a)) relation. Hence obtain the expression for the lens maker's formula.

Ans. (a) Explanation of diffraction pattern using Huygen's construction

(b) Showing the angular width of first diffraction fringe as half of the central fringe

(c) Explanation of decrease in intensity with increasing n

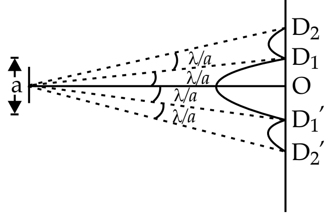
(a)



We can regard the total contribution of the wavefront LN at some point P on the screen, as the resultant effect of the superposition of its wavelets like LM, MM_2, M_2N. These have to be superposed taking into account their proper phase differences. We, therefore, get maxima and minima, i.e., a diffraction pattern, on the screen.

[CBSE Marking Scheme, 2015]

(b)



Condition for first minimum on the screen

$$a \sin\theta = \lambda$$

$$\Rightarrow \quad \theta = \frac{\lambda}{a}$$

$\therefore$ angular width of the central fringe on the screen (from figure)

$$= 2\theta = \frac{2\lambda}{a}$$

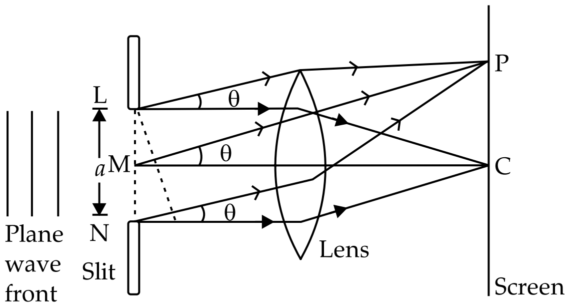
Angular width of first diffraction fringe (From fig) $= \frac{\lambda}{a}$

Hence angular width of central fringe is twice the angular width of first fringe.

(c) Maxima become weaker and weaker with increasing n. This is because the effective part of the wavefront, contributing to the maxima, becomes smaller and smaller, with increasing n.

Detailed answer:

(a)



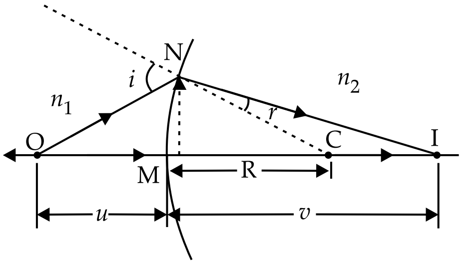
A plane wavefront from a monochromatic source S is incident on the slit LN. According to Huygens' principle each point of the incident wavefront becomes the source of secondary wavelet. These wavelets emerge with the same phase. These wavelets reach point C with same phase. Due to constructive interference central maximum is formed at C.

The wavelets which meet at point P (other than point C) have different phases since they traverse different paths to reach P and accordingly they produce either maxima or minima.

Thus a diffraction pattern is generated.

OR

(a)



(Deduct ½ mark for not showing direction of propagation of ray)

For small angles

$$\angle NOM \simeq \tan \angle NOM = \frac{MN}{OM}$$

$$\angle NCM \simeq \tan \angle NCM = \frac{MN}{MC}$$

$$\angle NIM \simeq \tan \angle NIM = \frac{MN}{MI}$$

In ΔNOC, $\angle i = \angle NOM + \angle NCM$

$$\therefore \quad \angle i = \frac{MN}{OM} + \frac{MN}{MC} \quad ...(i)$$

Similarly, $\angle r = \angle NCM - \angle NIM$

$$= \frac{MN}{MC} - \frac{MN}{MI} \quad ...(ii)$$

Using Snell's Law

$$n_1 \sin i = n_2 \sin r$$

For small angles

$$n_1 i = n_2 r$$

Substituting for i and r, we get

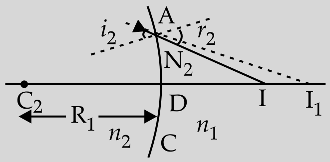
$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

Here, $OM = -u$, $MI = +v$, $MC = +R$

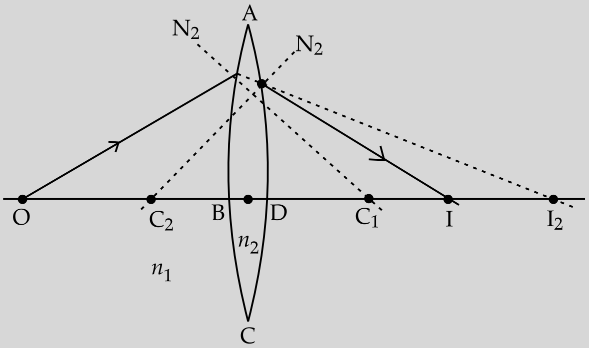
Substituting these, we get

$$\Rightarrow \quad \frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

(b)



(Alternatively accept this Ray diagram)



Similarly relation for the surface ADC.

$$\frac{-n_2}{DI_1} + \frac{n_1}{DI} = \frac{n_2 - n_1}{DC_2} \quad ...(i)$$

Refraction at the first surface ABC of the lens.

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1} \quad ...(ii)$$

Adding (i) and (ii) and taking $BI_1 \simeq DI_1$, we get

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

Here, $OB = -u$

$DI = +v$

$$BC_1 = +R_1$$

$$\Rightarrow \quad DC_2 = -R_2$$

$$\Rightarrow \quad \frac{n_1}{-u} + \frac{n_1}{v} = (n_2 - n_1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow \quad n_1\left(\frac{1}{v} + \frac{1}{u}\right) = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

[CBSE Marking Scheme, 2015]

26. An electric dipole of dipole moment $\vec{p}$ consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x >> a$, $\vec{E} \to \frac{2\vec{p}}{4\pi\varepsilon_0 x^3}$.

(b) Given the electric field in the region $\vec{E}2x\hat{i}$, find the net electric flux through the cube and the charge enclosed by it.

OR

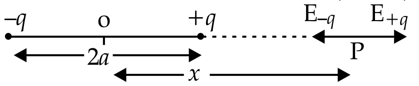
(a) Explain, using suitable diagrams, the difference in the behaviour of a (i) conductor and (ii) dielectric in the presence of external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.

(b) A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at its centre C and an other charge +2Q is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A, (ii) the electric flux through the shell.

Ans. (a) Derivation of the expression for the Electric field E and its limiting value

(b) Finding the net electric flux

(a)



Electric field intensity at point p due to charge $-q$

$$\vec{E}_{-a} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x+a)^2}(\hat{x})$$

Due to charge $+q$

$$\vec{E}_{-q} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x-a)^2}(\hat{x})$$

Net Electric field at point p

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

$$= \frac{q}{4\pi\varepsilon_0}\times\left[\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right](\hat{x})$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{4aqx}{(x^2-a^2)^2}\right](\hat{x})$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{(q\times 2a)2x}{(x^2-a^2)^2}(\hat{x})$$

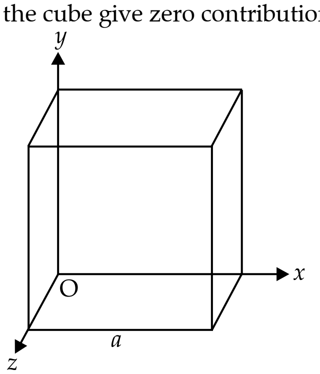
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2px}{(x^2-a^2)^2}\hat{x}$$

For $x >> a$

$$(x^2 - a^2)^2 \simeq x^4$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{x^3}\hat{x}$$

(b) Only the faces perpendicular to the direction of x-axis, contribute to the Electric flux. The remaining faces of the cube give zero contribution.



$$\text{Total flux } \phi = \phi_I + \phi_{II}$$

$$= \oint_I \vec{E}.\vec{ds} + \oint_{II} \vec{E}.\vec{ds}$$

$$= 0 + 2(a).a^2$$

$$\therefore \quad \phi = 2a^3$$

$$\phi = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

$$\text{or,} \quad 2a^3 = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

$$\therefore \quad q_{\text{enclosed}} = 2a^3\varepsilon_0$$

OR

(a) Explanation of difference in behaviour of

(i) conductor

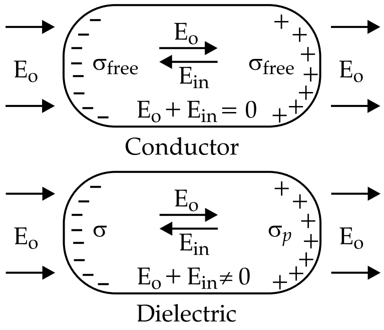
(ii) dielectric

Definition of polarization and its relation with susceptibility

(b) (i) Finding the force on the charge at centre and the charge at point A

(ii) Finding Electric flux through the shell

(a)



In the presence of Electric field, the free charge carriers, in a conductor, the charge distribution in the conductor readjusts itself so that the net Electric field within the conductor becomes zero.

In a dielectric, the external Electric field induces a net dipole moment, by stretching /reorienting the molecules. The Electric field, due to this induced dipole moment,opposes ,but does not exactly cancel, the external Electric field.

Polarisation: Induced Dipole moment, per unit volume, is called the polarization. For Linear isotropic dielectrics having a susceptibility χ_c, we have

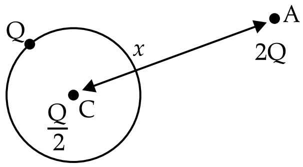
$$P = \chi_e E$$

(b) (i) Net Force on the charge $\frac{Q}{2}$, placed at the centre of the shell, is zero.

Force on charge '2Q' kept at point A

$$F = E \times 2Q$$

$$= \frac{\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_0 r^2} = \frac{(K)3Q^2}{r^2}$$



(ii) Electric flux through the shell

$$\phi = \frac{Q}{2\varepsilon_0}$$

❑❑