SET – 3

Series : SSO/1

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Code No. **55/1/3/D**

- Please check that this question paper contains **16** printed pages.
- Code number given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
- Please check that this question paper contains **26** questions.
- **Please write down the Serial Number of the question before attempting it.**
- 15 minutes time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

PHYSICS (Theory)

Time allowed 3 hours **Maximum Marks 70**

General Instructions

1. All questions are compulsory. There are 26 questions in all.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. 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.
4. 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.
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}
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}
$m_e = 9.1 \times 10^{-31}$ kg
mass of neutron = 1.675×10^{-27} kg
mass of proton = 1.673×10^{-27} kg
Avogadro Numbers = 6.023×10^{23} per gram mole
Boltzmann constant = 1.38×10^{-23} JK^{-1}

XII PHYSICS 2015 SET-3 SOLUTION

1) 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?

SOL: The lens behaves as convex.

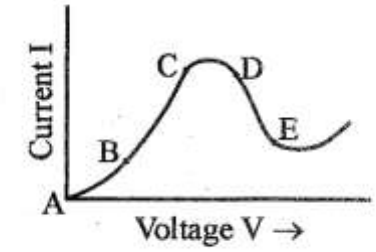
2) How are side bands produced?

SOL: During Amplitude modulation the modulating signal after superposition on carrier wave is connected to square law device and band pass filter which generates side bands from $\omega_C - \omega_m$ *to* $\omega_C + \omega_m$. Which contain the information.

3) 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.



SOL: (i) DE (ii) BC (linear part)

4) Define capacitor reactance. Write its S.I. units.

SOL: Is the resistance offered by a capacitor to the flow of a.c. ($X_C = 1/\omega C$). SI unit is Ω

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

SOL: zero.

6) Distinguish between 'intrinsic' and 'extrinsic'. semiconductors.

SOL: **<u>DISTINCTION BETWEEN INTRINSIC AND EXTRINSIC SEMICONDUCTORS</u>**

	Intrinsic Semiconductor	Extrinsic Semiconductor
1.	It is pure, natural semiconductor, such as pure Ge and pure Si .	It is prepared by adding a small quantity of impurity to a pure semiconductor, such as n-and p-type semiconductors.
2.	In it the concentrations of electrons and holes are equal.	In it the two concentrations are unequal. There is an excess of electrons in n-type semiconductors and an excess of holes in p-type semiconductors.
3.	Its electrical conductivity is very low.	Its electrical conductivity is significantly high.
4.	Its conductivity cannot controlled.	Its conductivity can be controlled by adjusting the quantity of the impurity added.
5.	Its conductivity increases exponentially with temperature.	Its conductivity also increases with temperature, but not exponentially.

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

SOL:

SOL: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ or $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

f < 0 (concave mirror) ; u < 0 (object on left) , For 2f < u < f implies

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

or $$-\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$$

or $$\frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < 0$$

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

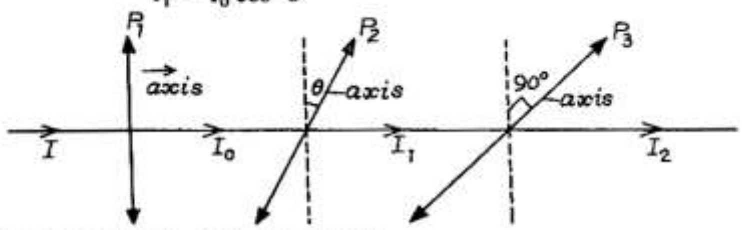
which means v < 0 (image on left ; real), the image lies beyond $2f$ The image is real because v is negative.

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 ?

SOL: The plane-polarised light is the light in which the vibrations of the electric vector occurring in a plane perpendicular to direction of propagation of light are confined to a single direction in the plane . Let intensity of light after passing through polarizer P_1 is I_0 , then intensity of light I_1 after passing through P_2, according to Malus law

$$I_1 = I_0 \cos^2 \theta \qquad ...(i)$$



further after passing through P_3 , intensity of light

$$I_2 = I_1 \cos^2\left(\frac{\pi}{2} - \theta\right)$$

i.e., $$I_2 = I_0 \cos^2 \theta \sin^2 \theta \qquad [\text{as, } I_1 = I_0 \cos^2 \theta \text{ eq. (i)}]$$

or $$I_2 = \frac{I_0}{4} \sin^2 2\theta$$

For I_2 is to be maximum $\sin^2 2\theta$ should be maximum which gives, $\theta = \frac{\pi}{4} = 45^o$

8) **Use Kirchhoff s rules to obtain conditions for the balance condition in a Wheatstone bridge.**

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

SOL: From de-Broglie matter wave equation

$$\lambda = \frac{h}{p}$$

But $p = \sqrt{2mK}$ and $K = qV$

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

where, m = mass of charge particle ; q = charge of charge particle ; V = potential difference.

$$\lambda^2 = \frac{h^2}{2mqV}$$

$$V = \frac{h^2}{2mq\lambda^2}$$

(a) Ratio of **accelerating potentials** of proton and α -particles for same wavelength.

$$\frac{V_p}{V_\alpha} = \frac{\left(\frac{h^2}{2m_p q_p \lambda^2}\right)}{\left(\frac{h^2}{2m_\alpha q_\alpha \lambda^2}\right)} = \frac{m_\alpha q_\alpha}{m_p q_p} = 4 \times 2 = 8$$

(b) $\lambda = \frac{h}{m\text{v}}$; Ratio of velocities for same wavelength

$$\frac{h}{m_\alpha \text{v}_\alpha} = \frac{h}{m_p \text{v}_p}$$

$$\frac{\text{v}_p}{\text{v}_\alpha} = \frac{m_\alpha}{m_p} = \frac{4}{1}$$

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

11) 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 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 2 V Also find the resistance G of the galvanometer in terms of R_1 and R_2.

SOL: For voltmeter of range V,

$$R_1 = \frac{V}{I_g} - R_g \quad \text{or} \quad \frac{V}{I_g} = R_1 + R_g \qquad ...(1)$$

For voltmeter of range $V/2$

$$R_2 = \frac{V}{2I_g} - R_g \quad \text{or} \quad \frac{V}{2I_g} = R_2 + R_g \qquad ...(2)$$

Dividing (1) by (2), we get

$$2 = \frac{R_1 + R_g}{R_2 + R_g} \quad \text{or} \quad R_g = R_1 - 2R_2$$

For conversion of galvanometer into a voltmeter of range 2 V, we have

$$R = \frac{2V}{I_g} - R_g = 2(R_1 + R_2) - R_g$$

$$= 2R_1 + R_g = 2R_1 + (R_1 - 2R_2)$$

$$R = 3R_1 - 2R_2.$$

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

Eventhough 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?

13) Draw a circuit diagram of a transistor amplifier in CE configuration.

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

14) 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 0.1^0. Find the spacing between the two slits.

b) Light of wavelength 5000 $\overset{o}{A}$ 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 ?

SOL: (a) The angular fringe width, $\theta = \frac{\lambda}{d}$

spacing between the slits, $d = \frac{\lambda}{\theta}$,

But λ = 600 nm = 6 × 10^{-7}m, θ = 0.1° = $\frac{0.1 \times \pi}{180}$ *Radian*

$$d = \frac{6 \times 10^{-7}}{(0.1 \times \pi / 180)} = \frac{180 \times 6 \times 10^{-7}}{0.1 \times 3.14} = 3.44 \times 10^{-4} m$$

(b) In vacuum and or air $\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{5000 \times 10^{-10}} = 6 \times 10^{14} Hz$ = frequency of incident wave = frequency of reflected or refracted wave.

In water wavelength of refracted ray = $\frac{\lambda}{\mu_w} = \frac{5000 \times 10^{-10}}{\frac{4}{3}} = 3750 \times 10^{-10} = 3750 \overset{0}{A}$

15) 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.

SOL: (i) On reducing the number of turns in the inductor, the inductance $L\ (\propto N^2)$ and hence the inductive reactance $X_L\ (= \omega\ L)$ decreases. So, the current in the circuit increases and the bulbs glows more brightly.

(ii) Iron rod inserted L increases X_L increases Z increases I_{rms} Decreases Brightness of bulb Decreases.

(iii) When $X_L = X_C$, the impedance of the circuit is minimum (equal to R). Hence the current is maximum and the bulb glows with maximum brightness.

16) 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.

SOL: a) Microwave, **source :** Oscillating currents in special vacuum tubes like klytrons, magnetrons, & gunn diodes.

b) Infrared , **source:** Vibrations of atoms & molecules in hot bodies.

c) X- Rays, **source:**When fast moving electrons strike a metal target with high atomic mass in X ray tubes.

17) (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.

SOL: $f_o = 15\ m, f_e = 10^{-2}\ m$

(a) Angular magnification of the telescope = $-\frac{f_o}{f_e} = -\frac{15}{10^{-2}} = -1500$

(b) Let d be the diameter of the image.

Angle subtended by image = $\frac{d}{f_o} = \frac{d}{15}$

Angle subtended by diameter of Moon = $\frac{3.48\times10^6 m}{3.8\times10^8 m}$

Equating , $\frac{d}{15} = \frac{3.48\times10^6 m}{3.8\times10^8 m}$

$d = 13.73cm.$

18) 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.

SOL: $\frac{hc}{\lambda_1} = W + KE_{max}$ ……..(i) ; $\frac{hc}{\lambda_2} = W + 2KE_{max}$ …………(ii)

$$\frac{hc}{\lambda_2} = W + 2(\frac{hc}{\lambda_1} - W)$$

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

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

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

19) In the study of Geige-Marsdon experiment on scattering of a 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_o is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

SOL:

The size of the nucleus is experimentally determined using Rutherford's α-scattering experiment and the distance of closed approach and impact parameter.

The relation between radius and mass number of nucleus is

$R = R_0A^{1/3}$, where R_o =1.2 fm

where, A = mass number, R= radius of nucleus

Nuclear density

$$\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$$

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

where, m = mass of each nucleon

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

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

From the above formula, it is clear that ρ does not depend on mass number 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

$${}_1^2H + {}_1^3H \longrightarrow {}_2^4He + n$$

Using the data :

$m({}_1^2H) = 2.014102$ u

$m({}_1^3H) = 3.016049$ u

$m({}_2^4He) = 4.002603$ u

$m_n = 1.008665$ u

$1u = 931.5\ MeV/c^2$

SOL:

Nuclear fission	*Nuclear fusion*
1. A heavy nucleus undergoes decomposition into two nuclei of much lower masses.	1. Two or more lighter nuclei are fused together to form a heavier nucleus.
2. It takes place at ordinary temperature.	2. It requires a very high initiation temperature of the order of 10^7 K.
3. Comparatively lower amount of energy is released.	3. Extraordinary huge amount of energy is liberated.
4. Controlled fission reactions are utilized to generate electricity for peaceful purpose.	4. Fusion reactions are yet to be controlled.
5. Fission products are, generally, radioactive and their disposal is a problem.	5. Fusion products are mostly non-radioactive and they can be disposed off easily.
6. Fission can be used to manufacture nuclear bombs.	6. Fusion is used for production of hydrogen bomb.
7. Fuel (uranium) is quite costly and limited in quantity.	7. Fuel (hydrogen) is cheap and available in planty.

The amount of energy released is given by

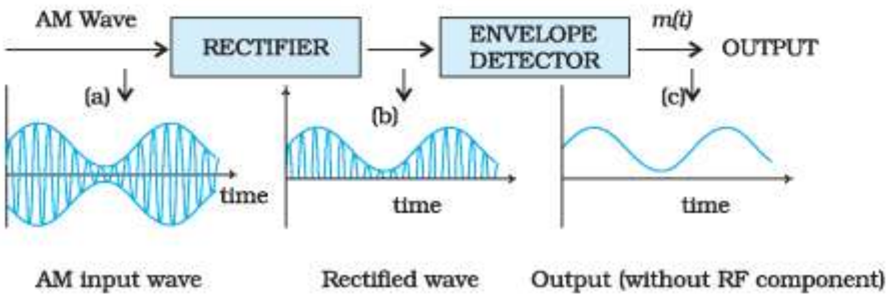
$$Q = [m({}_1H^2) + m({}_1H^3) - m({}_2He^4) - m({}_0n^1)] \times 931\cdot5 \text{ MeV}.$$

We can substitute the given *atomic* masses instead of *nuclear* masses, the masses of orbital electrons cancel out in the equation. Thus

$$Q = [2\cdot014102 + 3\cdot016049 - 4\cdot002603 - 1\cdot00867] \times 931\cdot5$$
$$= 0\cdot018796 \times 931\cdot5 = \mathbf{17\cdot508 \text{ MeV}.}$$

20) 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.

SOL: Detection is the process of recovering the modulating signal from the modulated carrier wave. We just saw that the modulated carrier wave contains the frequencies ω_c and $\omega_c \pm \omega_m$. In order to obtain the original message signal $m(t)$ of angular frequency ω_m, a simple method is shown in the form of a block diagram in Fig.



Block diagram of a detector for AM signal. The quantity on y-axis can be current or voltage.

The modulated signal of the form given in (a) of fig is passed through a rectifier to produce the output shown in (b). This envelope of signal (b) is the message signal. In order to retrieve $m(t)$, the signal is passed through an envelope detector (which may consist of a simple RC circuit).

21) 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 9Ω, the current reduces to 0.5 A. Find the values of the emf B and internal resistance r.

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.

SOL: When capacitors are connected in parallel

Equivalent capacitance, $C_P = C_1 + C_2$

The energy stored in the combination of the capacitors, $E_P = \frac{1}{2} C_P V^2$

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

$\Rightarrow (C_1 + C_2) = 5 \times 10^{-5} \quad \ldots(i)$

When capacitors are connected in series

Equivalent capacitance, $C_S = \frac{C_1 C_2}{C_1 + C_2}$

The energy stored in the combination of the capacitors, $E_S = \frac{1}{2} C_S V^2$

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

$\Rightarrow \frac{1}{2} \frac{C_1 C_2}{5 \times 10^{-5}}(100)^2 = 0.045$ J

$\Rightarrow C_1 C_2 = 0.045 \times 10^{-4} \times 5 \times 10^{-5} \times 2 = 4.5 \times 10^{-10}$

$(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1 C_2$

$\Rightarrow (C_1 - C_2)^2 = 25 \times 10^{-10} - 4 \times 4.5 \times 10^{-10} = 7 \times 10^{-10}$

$\Rightarrow (C_1 - C_2) = \sqrt{7 \times 10^{-10}} = 2.64 \times 10^{-5}$

$C_1 - C_2 = 2.64 \times 10^{-5} \quad \ldots(ii)$

Add and subtract (i) and (2)

$2C_1 = 7.64\times10^{-5}$; $C_1 = 3.82\times10^{-5}$

$2C_2 = 2.36\times10^{-5}$; $C_2 = 1.18\times10^{-5}$

When capacitor connected in parallel the charge on each of them

$Q_1 = C_1 V = 3.82\times10^{-5} \times 100 = 3.82\times10^{-4}$C

$Q_2 = C_2 V = 1.18\times10^{-5} \times 100 = 1.18\times10^{-4}$C

22) 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 ?

(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.

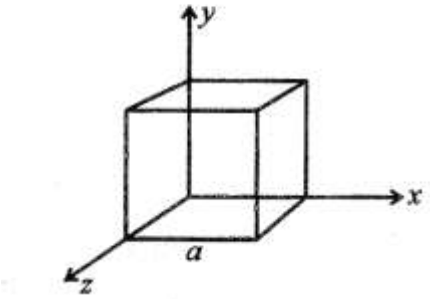
SOL: (i) Transformer

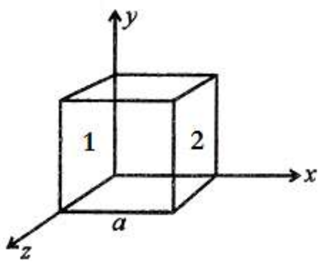
(ii) No

23) (a) 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 $x >> a$, $\vec{E} \longrightarrow 2\vec{p}/(4\pi\varepsilon_0 x^3)$.

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



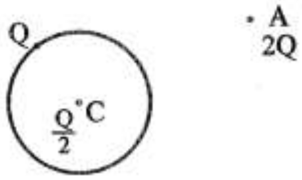


SOL: Surface (1) E = 0 at x= 0, $\phi = 0$ flux entering to the cube is zero .
Surface (2) flux entering to the cube = 2 $a \times a^2 = 2a^3$

$$\phi_{net} = \frac{q_{in}}{\varepsilon_0} = 2a^3$$

$$q_{in} = 2\varepsilon_0 a^3$$

24) (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.



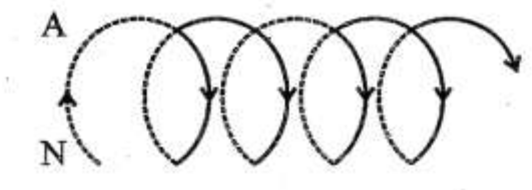
SOL: (b) (i) Force on $\frac{Q}{2}$ will be zero as E =0

(ii) Force on 2 Q will be $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2Q \cdot \frac{3Q}{2}}{x^2}$

(iii) Flux through shell $\frac{\frac{Q}{2}}{\varepsilon_0} = \frac{Q}{2\varepsilon_0}$

25) (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.



(a) Define Mutual. inductance and write its S.L 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.

26) (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.

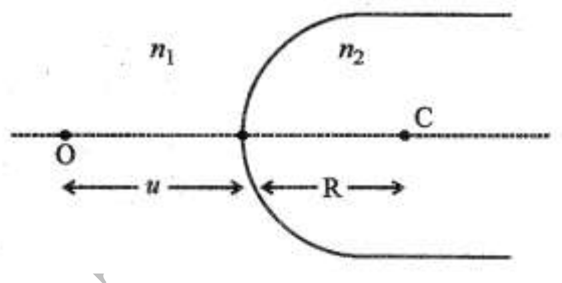
(b) Show that the angular width of the first diffraction. fringe is half that of the central fringe.

(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 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 saparating 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.