PHYSICS

Paper & Solution

Code : 55/3

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

General Instruction :

(i) All questions are compulsory.

(ii) There are **30** questions in total. Questions **1** to **8** are very short answer type questions and carry **one** mark each.

(iii) Questions **9** to **18** carry **two** marks each, questions **19** to **27** carry **three** marks each and questions **28** to **30** carry **five** marks each.

(iv) One of the questions carrying three marks weightage is value based question

(v) There is not overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three question of five marks each weightage. You have to attempt only one of the choices in such questions.

(vi) Use of calculators is **not** permitted. However, you may use log tables if necessary.

(vii) 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

$\mu_0 = 4\pi \times 10^{-7}$ T mA^{-1}

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

$m_e = 9.1 \times 10^{-31}$ kg

Mass of Neutrons = 1.675×10^{-27} kg

Mass of proton = 1.673×10^{-27} kg

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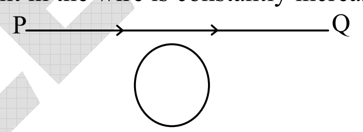
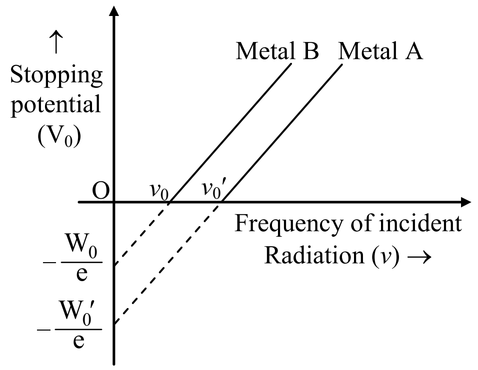
1. A conducting loop is held below a current carrying wire PQ as shown. Predict the direction of the induced current in the loop when the current in the wire is constantly increasing. **1**

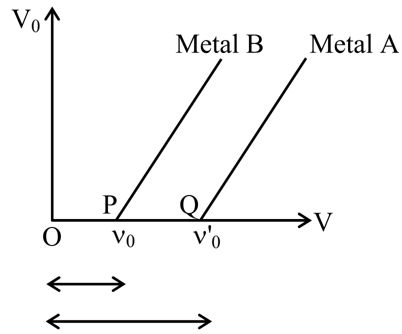


Sol. When current in wire is increased. Inward flux with loop increases. According to Lenz Law loop induces outward magnetic flux so Anti clockwise current is induced in loop.

2. The graph shows variation of stopping potential V_0 versus frequency of incident radiation ν for two photosensitive metals A and B. Which of the two metals has higher threshold frequency and why ? **1**



Sol.



As OP > OQ

$\therefore \nu'_0 > \nu_0$

$\therefore$ threshold frequency of A > Threshold frequency of B.

3. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current. **1**

Sol. One ampere is that current which if passed in each of two parallel conductors of infinite length and one meter apart in vacuum, causes each conductor to experience a force of 2×10^{-7} Newton per meter of length of conductor.

4. A biconcave lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1·33. Will the lens behave as a converging or a diverging lens ? Give reason. **1**

Sol. Biconcave lens will change its nature as refractive index of outside medium is greater than that of lens material so it will behave as converging lens

5. Why do the electric field lines never cross each other **1**

Sol. At intersection point there would be two directions of electric field which is not possible so lines of force never cross each other?

6. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{11} Hz belong ? **1**

Sol. Microwave

7. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay ? **1**

Sol. Neutrinos do not have electric charge and do not interact with other matter particles.

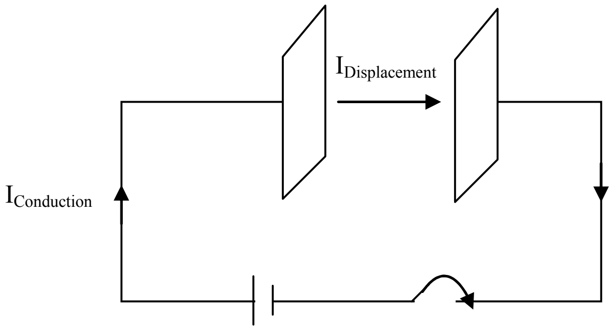
8. Why is the use of a.c. voltage preferred over d.c. voltage ? Give two reasons. **1**

Sol. (i) AC generator are simpler & cheaper than DC generator as commutator is not used in AC generator

(ii) AC Can be stepped up or down using transformer so its transmission is cheaper and efficient.

9. Considering the case of a parallel plate capacitor being charged, show how one is required to generalize Ampere's circuital law to include the term due to displacement current. **2**

Sol.



$\oint \vec{B}.\vec{d\ell} = \mu.\Sigma (I_C + I_D)$

This generalised Ampere's law is valid in conducting path as well as between plates of PPC during charging of Capacitor –

(i) In conducting path $I_C \neq 0$ but $I_D = 0$

$\Rightarrow \oint \vec{B}.\vec{d\ell} = \mu_0 \Sigma I_C \Rightarrow B \neq 0$

(ii) Between plates $I_C = 0$ but $I_D \neq 0$

$\Rightarrow \oint \vec{B}.\vec{d\ell} = \mu_0 \Sigma I_D \Rightarrow B \neq 0$

10. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 2.5×10^{-7} m^2 carrying a current of 2.7 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **2**

Sol. $I = ne\,Av_d$

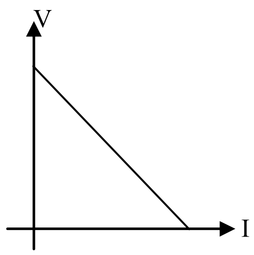
$$\therefore V_d = \frac{I}{neA} = \frac{2.7}{9\times10^{28}\times1.6\times10^{-19}\times2.5\times10^{-7}}$$

$= 7.5 \times 10^{-4}$ m/sec.

11. A cell of emf 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined. **2**

Sol. $V = E - Ir$

plot between V and I is straight line of positive intercept and negative slop



(i) value of potential difference corresponding to zero current gives emf of cell

(ii) Maximum current is drawn when terminal voltage is zero so

$V = E - Ir$

$0 = E - I_{max}.\, r$

$$\Rightarrow r = \frac{E}{I_{max}}$$

12. A parallel plate capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor having the same capacitance. Find out the ratio of the energy stored in the combined system to that stored initially in the single capacitor. **2**

Sol. $U_{Initial} = \frac{1}{2}CV^2 + 0 = \frac{1}{2}CV^2$

After connecting common potential

$$V_{Common} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{V}{2}$$

$$\therefore U_{final} = \frac{1}{2}C\left(\frac{V}{2}\right)^2 + \frac{1}{2}C\left(\frac{V}{2}\right)^2 = \frac{1}{4}CV^2$$

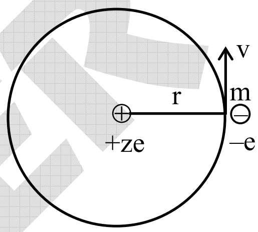
$$\therefore \frac{U_{final}}{U_{initial}} = \frac{\frac{1}{4}CV^2}{\frac{1}{2}CV^2} = 1:2$$

13. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron ?

OR

Using Bohr's postulates of the atomic model, derive the expression for radius of n^{th} electron orbit. Hence obtain the expression for Bohr's radius. **2**

Sol. electron revolves around nucleus and required centripetal force is provided by attractive force between electron and nucleus



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

$$\therefore mv^2 = \frac{kze^2}{r}$$

$$\therefore KE = \frac{1}{2}mv^2 = \frac{kze^2}{2r}$$

And potential energy

$$U = -\frac{kze^2}{r}$$

$\therefore$ Total energy

E = KE + U

$$\therefore E = -\frac{kze^2}{2r}$$

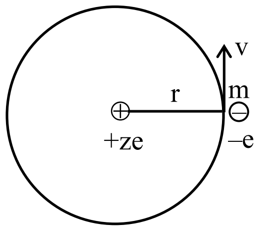
Negative sign of total energy shows that electron is bound to revolve around nucleus

OR

Electron revolves around nucleus and required centripetal force is provided by electrostatic force of attraction between nucleus and electron

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

$$\therefore \quad mv^2 = \frac{kze^2}{r} \quad .....(i)$$



By Bohr's postulate

$$mvr = \frac{nh}{2\pi} \quad ...(ii)$$

$$\therefore \quad v = \frac{nh}{2\pi mr}$$

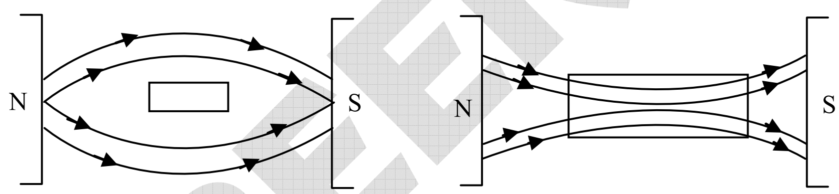
on putting value of v in equation (i)

$$r = \frac{n^2}{z}\left[\frac{h^2}{4\pi^2 kme^2}\right]$$

$$r = \frac{n^2}{z}(0.53Å)$$

14. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature ? **2**

Sol.

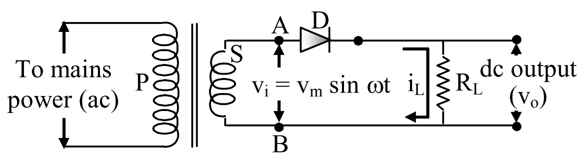


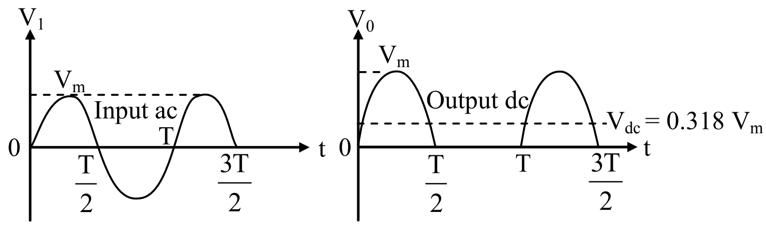
(Diamagnetic Material) (Paramagnetic Material)

Magnetic Permeability of paramagnetic is more than air so it allows more lines to pass through it while permeability of diamagnetic is less than air so it does not allow lines to pass through it -

15. Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier. **2**

Sol. Half-wave rectifier

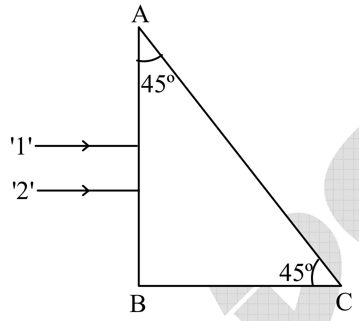




During the positive half cycle of the input voltage, end A of the secondary is positive and end B is negative. This polarity makes the diode D to be forward biased. The diode conducts and a current i_L flows through the load resistance R_L. Since a forward biased diode offers a very low resistance, the voltage drop across the diode is also very small. Therefore, the voltage across R_L is almost equal to the voltage v_i at every instant of time.

During the negative half cycle of the input voltage end A of the secondary is negative and end B is positive. Thus, the diode is in reverse bias. The diode does not conduct. No current flows through R_L. Hence, no voltage is developed across R_L. All the input voltage appears across the diode itself. This explains the output waveform.

16. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1·38 and 1·52. Trace the path of these rays after entering through the prism. **2**



Sol. $\sin i = \sin 45° = \frac{1}{\sqrt{2}} = \frac{1}{1.414}$

$$\sin i = \frac{1}{1.414} > \frac{1}{1.52}$$

$\therefore$ sin i > sin i_c for ray (2)

$\therefore$ i > i_c for ray (2)

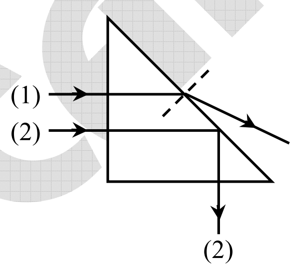
$\therefore$ ray (2) will suffer T.I.R.

While sin i < sin i_c

as $\frac{1}{1.414} < \frac{1}{1.38}$

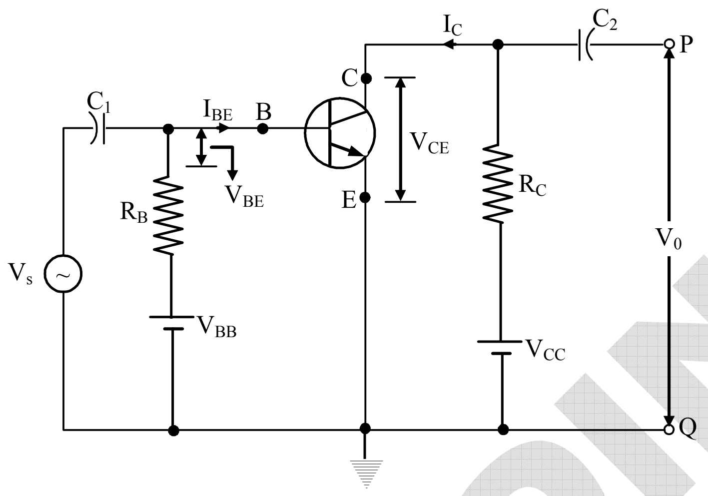
$\therefore$ i < i_c for ray (1)

$\therefore$ ray (1) got refracted.



17. Draw a circuit diagram of n-p-n transistor amplifier in CE configuration. Under what condition does the transistor act as an amplifier ? **3**

Sol.



The condition necessary for the amplifier to work is that the base emitter junction should be forward biased and collctor base junction should be reverse biased.

18. Write the functions of the following in communication systems : **3**

(i) Receiver

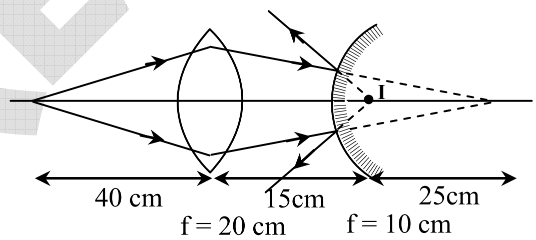
(ii) Demodulator

Sol. **Receiver** : Receiver separates the message signal from the carrier signal. It reconstructs actual signal using output transducers.

Demodulator : The process of retrieval of information from the carrier wave at the receiver is called demodulation and Electronic Circuit used for it is called demodulator.

19. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15 cm apart. A point object is placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation. **3**

Sol.



'O' is at 2f of lens so it will form image at 2f i.e. 40 cm from lens so position of object for mirror is at (40 – 15) cm = 25 cm behind the mirror

For mirror

f = +10 cm

u = +25 cm

v = ?

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

$$\frac{1}{v}+\frac{1}{25}=\frac{1}{+10}$$

$\therefore\ v=+\frac{50}{3}\text{cm}$ i.e. $\frac{50}{3}\text{cm}$ behind the mirror

20. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons. Taking other factors, such as numerical aperture etc. to be same, how does the resolving power of an electron microscope compare with that of an optical microscope which uses yellow light ? **3**

Sol. $\lambda=\frac{12.27\text{Å}}{\sqrt{V}}$

$\lambda=\frac{12.27\text{Å}}{\sqrt{50000}}$

$\lambda=\frac{12.27\text{Å}}{233}$

$\lambda = 0.0526$ Å

Resolving Power (RP) $\propto\frac{1}{\lambda}$

as wavelength of moving electron is very small as compared to that of yellow light so it has high **Resolving Power** than optical microscope .

21. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. **3**

Sol.

	Conductors	Semiconductors	Insulators
(i)	Conduction band is completely filled	Conduction and valance bands are partially filled	Conduction band is empty & valance band is completely filled
(ii)	Conduction and valance bands overlap	Forbidden energy gap is of the order of 1 eV	Forbidden energy gap is very large i.e more than 5 eV.

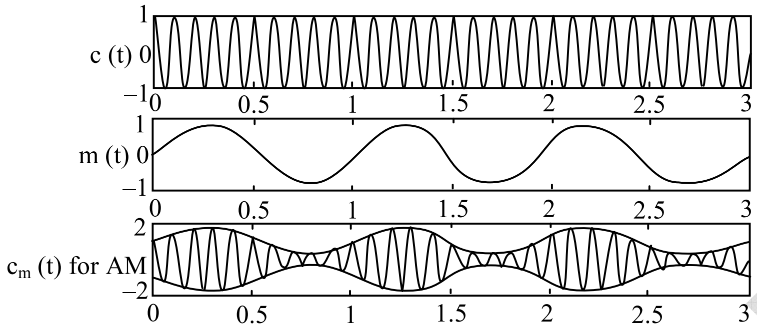
22. Write two basic modes of communication. Explain the process of amplitude modulation. Draw a schematic sketch showing how amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave. **3**

Sol. There are two basic modes of communication : point-to-point and broadcast.

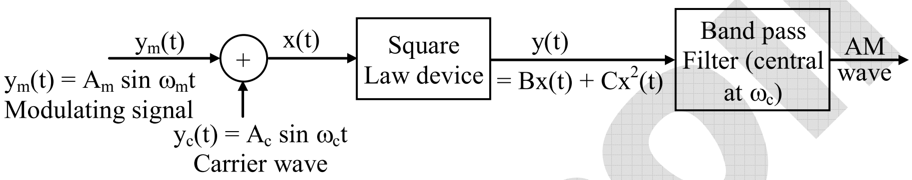
In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver. Telephony is an example of such a mode of communication.

In broadcast mode, there are a large number of receivers for a single transmitter. Radio and television are examples of broadcast mode of communication.

If the amplitude of the carrier wave is varied in accordance with the amplitude of the signal, it is called amplitude modulation. Frequency and phase are kept constant.



A conceptually simple method of production of amplitude modulated wave is shown in the block diagram below.



23. Answer the following : **3**

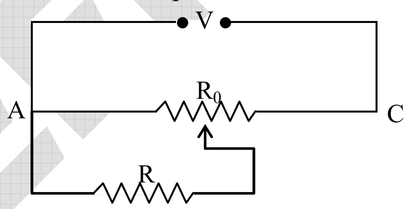
(a) Why are the connections between the resistors in a meter bridge made of thick copper strips ?

(b) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire ?

(c) Which material is used for the meter bridge wire and why ?

OR

A resistance of R Ω draws current from a potentiometer as shown in the figure. The potentiometer has a total resistance R_o Ω. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer.



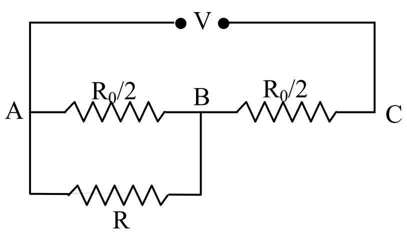
Sol. (a) For making gaps thick copper strips are used due to their negligible resistance.

(b) Meter bridge is most sensitive when all four resistances are of same order.

(c) Alloy Magnanin or Constantun are used for making meter bridge wire due to low temperature Coefficient of resistance & high resistivity.

OR

Equivalent Circuit is as shown



So equivalent resistance of circuit

R_{eq} =

$$\frac{R_o}{2} + \frac{\frac{RR_o}{2}}{R + \frac{R_o}{2}}$$

$$\therefore\ I_{circuit} = \frac{V}{R_{eq}}$$

$$\therefore\ \text{PD across R} = I\left(\frac{R\frac{R_o}{2}}{R + \frac{R_o}{2}}\right) = \frac{VR}{2(R + \frac{R_o}{4})}$$

24. For the past some time, Aarti had been observing some erratic body movement, unsteadiness and lack of coordination in the activities of her sister Radha, who also used to compain of severe headache occasionally. Aarti suggested to her parents to get a medical check-up of Radha. The doctor thoroughly examined Radha and diagnosed that she has a brain tumour. **3**

(a) What, according to you, are the values displayed by Aarti ?

(b) How can radioisotopes help a doctor to diagnose brain tumour ?

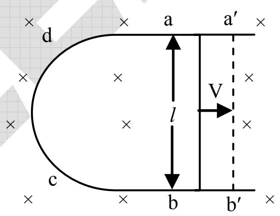
Sol. (a) Arti shows good awareness towards health and care for her sister.

(b) Certain radio isotopes are injected to body and they are absorbed by brain tumour and by detecting intensity of radiations we can measure location and severity of tumour.

25. (a) A rod of length l is moved horizontally with a uniform velocity 'v' in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod.

(b) How does one understand this motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor ? Explain. **3**

Sol. **(a)** Consider a straight conductor moving with velocity V on U shaped Conductor placed in perpendicular magnetic field as shown.



Let conductor shifts from ab to a'b' in time dt then change in magnetic flux

$d\phi = B \times$ change in area

$= B \times (\text{Area a'b' ab})$

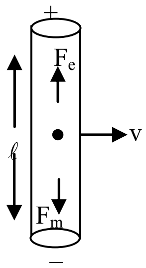
$= B \times (\ell \times v\,dt)$

$$\therefore\ \frac{d\phi}{dt} = Bv\ell$$

$$\therefore\ \text{Induced emf } |e| = \frac{d\phi}{dt} = B\underline{v}\ell$$

$$\therefore\ \text{Induced emf } |e| = \frac{d\phi}{dt} = Bv\ell$$

(b) During motion free e^- are shifted at one end due to magnetic force so due to polarsation of rod electric field is produced which applies electric force on free e^- in opp. direction –



At equilibrium of Lorentz force

$\vec{F}_e + \vec{F}_m = 0$

$q\vec{E} + q(\vec{V} \times \vec{B}) = 0$

$\vec{E} = -\vec{V} \times \vec{B} = \vec{B} \times \vec{V}$

$|E| = |BV \sin 90)$

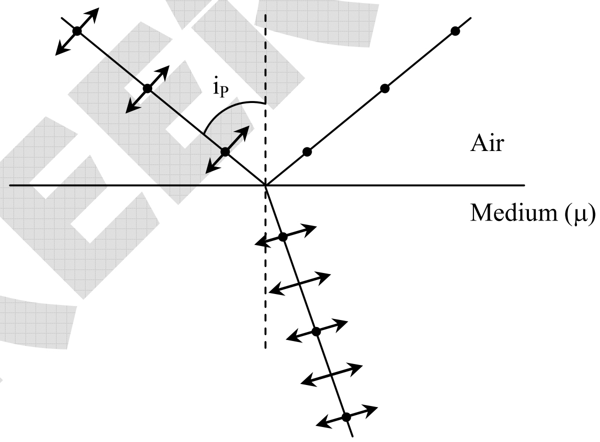
$\dfrac{dv}{dr} = Bu$

$\therefore \quad \boxed{P_D = Bv\ell}$

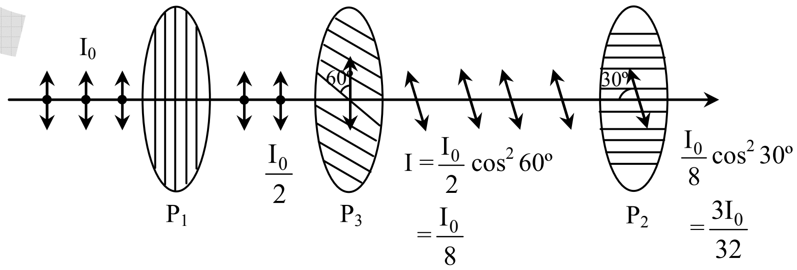
26. (a) Show, giving a suitable diagram, how unpolarized light can be polarized by reflection.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_o is incident on P_1. A third Polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60º with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **4**

Sol. **(a)** If light incidents at Brewster angle $i_P = \tan^{-1}(\mu)$ then reflected light is plane polarised where μ is refraction index of medium and refracted light is partially polarised.



(b)



Intensity through $P_1 = \dfrac{I_0}{2}$

Intensity through $P_3 = \frac{I_0}{8}$

Intensity through $P_2 = \frac{3I_0}{32}$

27. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for the average power dissipated over a cycle.
Under what condition is (i) no power dissipated even though the current flows through the circuit, (ii) maximum power dissipated in the circuit ? **5**

Sol. Let the Alternating voltage is

$V = V_0 \cos \omega t$

Let $\omega L > \frac{1}{\omega C}$ then current lags by angle ϕ

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

and $\tan \phi = \dfrac{\omega L - \frac{1}{\omega c}}{R}$

$\therefore$ Average power $= \dfrac{\int_0^T EI\,dt}{T}$

$= \frac{1}{T}\int_0^T (E_o \cos \omega t)(I_o \cos(\omega t - \phi))dt$

$= \frac{E_o I_o}{T}\int_0^T (\cos^2 \omega t \cos\phi + \cos \omega t \sin \omega t \sin\phi)dt$

$= \frac{1}{2} E_o\, I_o \cos \phi$

$\boxed{P_{average} = E_{rms}\, I_{rms} \cos\phi}$

(i) if $\phi = 90$ $\Rightarrow$ $P_{average} = 0$

$\because$ $\tan \phi = \dfrac{\omega L - \frac{1}{\omega C}}{R} = \infty$

$\Rightarrow$ $R = 0$

(ii) if $\phi = 0$ $\Rightarrow$ $P_{average}$ = Max.

$\tan \phi = \dfrac{\omega L - \frac{1}{\omega C}}{R} = 0$

$\Rightarrow$ $X_L = X_C$ (Resonance)

28. (a) In Young's double slit experiment, describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit. Hence obtain the expression for the fringe width.

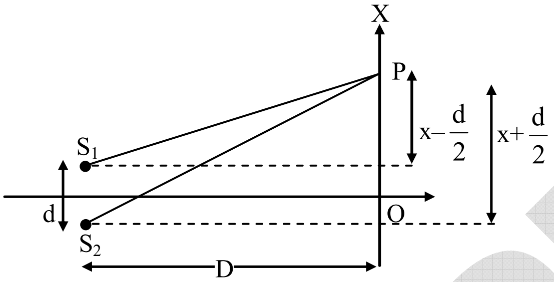
(b) The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9 : 25. Find the ratio of the widths of the two slits.

OR

(a) Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

(b) Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-6} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases. **5**

Sol. **(a)** The path difference between two rays coming from holes S_1 and S_2 is $(S_2P - S_1P)$. If point P corresponds to a maximum.



Now $(S_2P)^2 - (S_1P)^2 =$

$$\left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(x - \frac{d}{2}\right)^2\right]$$

$= 2xd$, where $S_1S_2 = d$ and $OP = x$

$(S_2P + S_1P)(S_2P - S_1P) = 2xd$

$$S_2P - S_1P = \frac{2xd}{S_2P + S_1P}$$

If x, d << D, then negligible error will be introduced if $(S_2P + S_1P)$ in the denominator is replaced by 2D.

$$S_2P - S_1P = \frac{xd}{D}$$

For maximum, $S_2P - S_1P = n\lambda$

Thus, $n\lambda = \frac{xd}{D}$

Or, $x = x_n = \frac{n\lambda D}{d}$,

$n = 0, \pm 1, \pm 2, \pm 3, \ldots$ [For maxima]

Now, for minimum, $S_2P - S_1P = (2n - 1)\frac{\lambda}{2}$

Thus $(2n - 1)\frac{\lambda}{2} = \frac{xd}{D}$

or $x = x_n = (2n - 1)\frac{\lambda D}{2d}$,

$n = \pm 1, \pm 2, \pm 3, \ldots$ [For minima]

Thus, bright and dark bands appear on the screen, as shown in Figure. Such bands are called 'fringes'. These dark and bright fringes are equally spaced.

Expression for fringewidth (β)

Let n^{th} order bright fringe is at a distance x_n and $(n + 1)^{th}$ order bright fringe is at x_{n+1} from O. Then

$x_n = \frac{n\lambda D}{d}$ and $x_{n+1} = \frac{(n+1)\lambda D}{d}$ … [from eq,, (2)]

Now the fringewidth is

$\beta = x_{n+1} - x_n = \dfrac{\lambda D}{d}$

Thus, the expression for fringwidth is $\beta = \dfrac{\lambda D}{d}$

(b) $\dfrac{I_{min}}{I_{max}} = \dfrac{9}{25}$

$\left[\dfrac{\sqrt{I_1} - \sqrt{I_2}}{\sqrt{I_1} + \sqrt{I_2}}\right]^2 = \dfrac{9}{25}$

$\dfrac{\sqrt{I_1} - \sqrt{I_2}}{\sqrt{I_1} + \sqrt{I_2}} = \dfrac{3}{5}$

$5\sqrt{I_1} - 5\sqrt{I_2} = 3\sqrt{I_1} + 3\sqrt{I_2}$

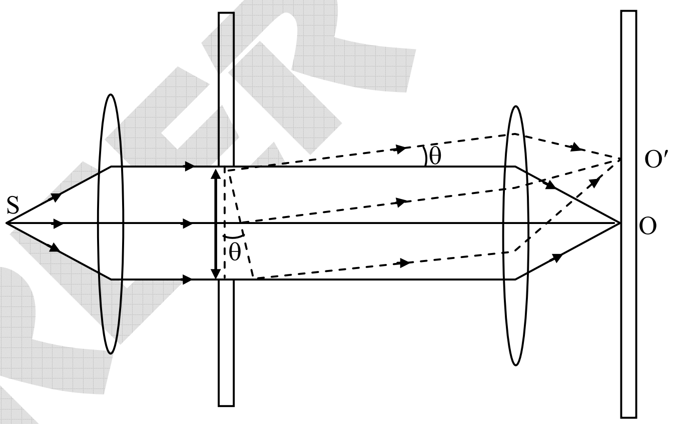
$2\sqrt{I_1} = 8\sqrt{I_2}$

$\sqrt{\dfrac{I_1}{I_2}} = \dfrac{4}{1}$

$\dfrac{I_1}{I_2} = \dfrac{16}{1}$ = Ratio of intensities

OR

(a)



A point source S is placed at the focus of a converging lens. The source-lens arrangement provides a plane wavefront which is then diffracted. Another converging lens is introduced between the diffracting slit and the observation screen such that the screen is in the focal plane of the lens. Plane wavefront emerging from the slit at different angles are brought to focus on the screen using the second lens, as shown in the Fig.

Condition for minima

Divide the slit into two equal halves AC and CB, each of size $\dfrac{a}{2}$. For every point M_1 in AC, there exists a point M_2 in CB such that $M_1M_2 = \dfrac{a}{2}$. The path difference between secondary waves from M_1 and M_2 reaching P is

$M_2P - M_1P = \dfrac{a}{2}\sin\theta$

Point P on the screen would be a **first minimum** if this path difference is λ between the secondary waves from extreme points A and B. Thus, path difference between waves from A and C or between waves from M_1 and M_2 will be $\frac{\lambda}{2}$.

Hence, $\frac{a}{2}\sin\theta = \frac{\lambda}{2}$ or $a \sin\theta = \lambda$ for P to be first minimum.

P is a second minimum if

Path difference, $a \sin\theta = 2\lambda$

Proceeding in the same manner, we can show that the intensity at P is zero if

Path difference, $a \sin \theta = n\lambda$ (condition for minima)

where n = 1, 2, 3, ……

Condition for secondary maxima

Imagine the slit to be divided into three parts AM_1, M_1M_2 and M_2B. Let the secondary waves reaching P from the extreme points A and B be $\frac{3\lambda}{2}$. The secondary waves reaching P from the corresponding points of the parts AM_1 and M_1M_2 will have path difference of $\frac{\lambda}{2}$ and interfere destructively. The secondary waves reaching P from points in the third part M_2B will contribute to the intensity at P. Therefore, only one-third of the slit contributes to the intensity at point P between two minima. This will be much weaker than the central maximum. This is the first secondary maximum. The condition for first secondary maximum is

Path difference, $a \sin \theta = \frac{3\lambda}{2}$,

The condition for second secondary maximum is

Path difference, $a \sin \theta = \frac{5\lambda}{2}$.

Proceeding in the same manner, we can show that the condition for a secondary maxima is Path difference, $a \sin \theta = (2n + 1)\frac{\lambda}{2}$ where n = 1, 2, 3, …

(b) For $\lambda_1 = 590$ nm

location of I[st] Maxima

$$y_1 = (2n + 1)\frac{D\lambda_1}{2a}$$

n = 1

$$y_1 = \frac{3D\lambda_1}{2a}$$

for $\lambda_2 = 596$ nm

location of I[st] Maxima

$$y_2 = (2n + 1)\frac{D\lambda_2}{2a}$$

n = 1

$$y_2 = \frac{3D\lambda_2}{2a}$$

∴ Difference

$= y_2 - y_1$

$= \frac{3D}{2a}(\lambda_2 - \lambda_1)$

$= \frac{3\times1.5}{2\times2\times10^{-6}}(6 \times 10^{-9})$

$= \frac{27}{4} \times 10^{-3}$

∴ Difference $= 6.75 \times 10^{-3}$ m

29. (a) Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle.

(b) Draw a schematic sketch of a cyclotron. Explain, giving the essential details of its construction, how it is used to accelerate the charged particles.

OR

(a) Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle and working.

(b) Answer the following :

(i) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer ?

(ii) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason. **5**

Sol. (a) If particle is performing circular motion due to magnetic force then

centripetal force = Magnetic force $\frac{mv^2}{r} = q\,v\,B \sin 90°$

$$\Rightarrow r = \frac{mv}{qB}$$

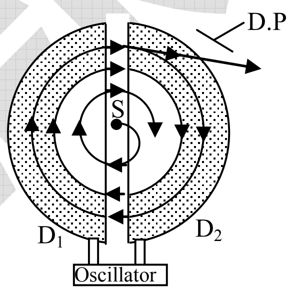
$$\therefore \text{Time period} = \frac{2\pi r}{v}$$

$$T = \frac{2\pi}{v} \cdot \frac{mv}{qB} = \frac{2\pi m}{qB}$$

$$T = \frac{2\pi m}{qB} \propto v°$$

$$\therefore \text{Frequency } f = \frac{1}{T} = \frac{qB}{2\pi m} \propto v°$$

(b) Cyclotron is a device to accelerate ions to extremely high velocities, by accelerating them repeatedly through high voltages.



Principle – A positive ion can acquire sufficiently large energy with a small alternating potential difference by making the ion cross the same electric field time and again by making use of a strong magnetic field.

Construction- It consists of a pair of hollow metal cylindrical chambers shaped like D, and called the Dees ; Both the Dees are placed under the circular pole pieces of a very strong electromagnet. The two Dees are connected to the terminals of a very high frequency and high voltage oscillator whose frequency is of the order of a few million cycles per second.

Working - Charged ion is passed through electric field again & again to be energised. Inside dee's strong ⊥ magnetic field turns the particle towards gap. So radius of semi circular path increase continuously -

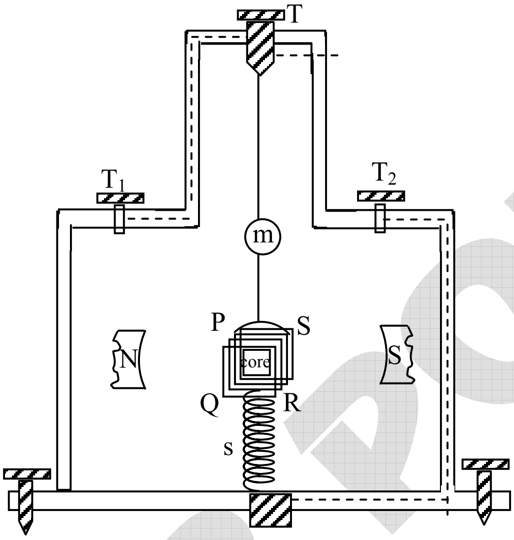
OR

(a)

Principle. When a current carrying coil is placed in magnetic field, it experiences a torque.

Construction. It consists of a narrow rectangular coil PQRS consisting of a large number of turns of fine insulated copper wire wound over a frame made of light, non-magnetic metal. A soft iron cylinder known as the core is placed symmetrically within the coil and detached from it. The coil is suspended between the two cylindrical polepieces (N and S of a strong permanent horse shoe magnet) by a thin flat phosphor bronze strip the upper end of which is connected to a movable torsion head T. The lower end of the coil is connected to a hair spring s of phosphor bronze having only a few turns.

Redial magnetic field. The magnetic field in the small air gap between the cylindrical pole pieces is radial. The magnetic lines of force within the air gap are along the radii. On account of this, the plane of the coil remains always parallel to the direction of the magnetic field



The magnetic field in the small air gap between the cylindrical pole-pieces is radial. On account of this, the plane of the coil remains always parallel to the direction of the magnetic field

Theory :

Let I = current flowing through the coil

B = magnetic field induction

l = length of the coil ; b = breadth of the coil

N = number of turns in the coil A (= $l \times b$) = area of the coil

Moment of deflecting couple = NBI$l \times b$ = NBIA

When the coil deflects, the suspension fibre gets twisted. On account of elasticity, a restoring couple is set up in the fibre. This couple is proportional to the twist. If α be the angular twist then

Moment of restoring couple = $k\alpha$

For equilibrium of the coil, NBIA = $k\alpha$ or I = $\left(\frac{k}{NBA}\right)\alpha$

or $\boxed{I = K\alpha}$

where K $\left(= \frac{k}{NBA}\right)$ is the galvanometer constant.

Now, $\boxed{I \propto \alpha}$ or $\boxed{\alpha \propto I}$

(b) (i) By using soft iorn core . magnetic field is increased so sensitivity increases and mag. field becomes radial So angle between plane of coil & magnetic line of force is zero in all orientations of coil.

(ii) Voltage sensitivity = $\frac{\text{Current Senitivity}}{\text{Resistance of Coil}}$

$$V\,S = \frac{CS}{R_{coil}}$$

If R_{coil} = constant $\Rightarrow V\,S \propto C\,S$

It means that V S increases if C S is increased

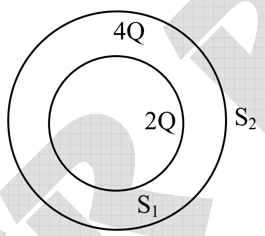
But if resistance of coil is also increases in same ratio then V S may be constant

30. Draw a labelled diagram of Van de Graaff generator. State its working principle to show how by introducing a small charged sphere into a larger sphere, a large amount of charge can be transferred to the outer sphere. State the use of this machine and also point out its limitations.

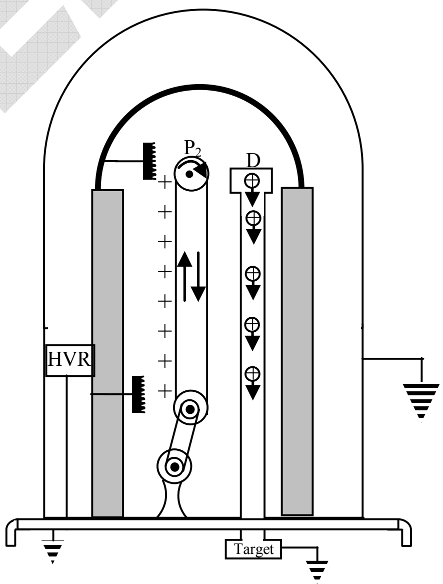
OR

(a) Deduce the expression for the torque acting on a dipole of dipole moment $\vec{p}$ in the presence of a uniform electric field $\vec{E}$

(b) Consider two hollow concentric spheres, S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in the figure (i) Find out the ratio of the electric flux through them. (ii) How will the electric flux through the sphere S_1 change if a medium of dielectric constant 'ε_r' is introduced in the space inside S_1 in place of air ? Deduce the necessary expression. **5**



Sol. **Principle**. The working of the Van de Graff generator is based on the discharging action of points and collecting action of hollow conductor. In other words, if a charged conductor is brought in electrical contact with a hollow conductor, the charge is transferred to the hollow conductor, no matter what is the potential of the hollow conductor.



Theory. Consider a large spherical conducting shell A having radius R and charge +Q. Potential inside the shell, $V_1 = \frac{1}{4\pi\in_0}\frac{Q}{R}$, Assume that a small conducting sphere B of radius r and carrying charge +q is placed at the centre of shell A.

Potential due to A at the surface of B, $V_2 = \frac{1}{4\pi\in_0}\frac{q}{R}$

Potential due to B at the surface of B, $V_3 = \frac{1}{4\pi\in_0}\frac{q}{r}$

Total potential at the surface of shell A, $V_A = V_1 + V_2 = \frac{1}{4\pi\in_0}\left(\frac{Q}{R}+\frac{q}{R}\right)$

Total potential at the surface of B, $V_B = V_1 + V_3 = \frac{1}{4\pi\in_0}\left(\frac{Q}{R}+\frac{q}{r}\right)$

Potential difference, $V = V_B - V_A = \frac{1}{4\pi\in_0}\left[\frac{Q}{R}+\frac{q}{r}-\frac{Q}{R}-\frac{q}{R}\right]$

$= \frac{q}{4\pi\in_0}\left(\frac{1}{r}-\frac{1}{R}\right)$. The potential difference is independent of charge Q on the shell. If the sphere is connected to the shell by a wire, the charge will flow to the shell because the shell is at a lower potential.

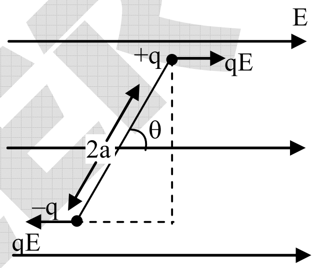
Application. It can be used to accelerate particles like protons, deuterons, α- particles and other ions. These accelerated particles are called "projectiles". These particles are used in nuclear physics for collision experiments.

Limitations of Van de

Due to very high electric field at sphere, sparking & leakage of charge takes place so high pressure gasses are used around sphere. But still leakage takes place at higher electric field so highest potential is limited.

OR

(a) Consider an electric dipole placed in uniform electric field then



τ = Force × Perpendicular distance

= (qE) (2a sinθ)

$\boxed{\begin{array}{l}\tau = \cancel{P}E\,\cancel{\sin}\,\theta \\ \tau = P \times E\end{array}}$

(b) (i) According to Gauss theorem

$$\phi_{net} = \frac{\Sigma q}{\in_0\in_r} \propto \Sigma q$$

$$\frac{\phi_{S_1}}{\phi_{S_2}} = \frac{2Q}{2Q+4Q} = \frac{1}{3}$$

(ii) If medium is filled in S_1 then

$$\phi_{S_1} = \frac{\Sigma q}{\in_0\in_r} = \frac{2Q}{\in_0\in_r}$$