CBSE 2014

PHYSICS (Theory)

Time allowed: ***3*** *hours* *Maximum Marks*: *100*

General Instructions:

1. *All questions are compulsory.*

2. *The question paper consists of 30 questions in total. Question Nos. 1–8 are very short answer type questions and carry one mark each.*

3. *Question Nos. 9–18 carry two marks each. Question Nos. 19–27 carry three marks each and question nos. 28–30 carry five marks each.*

4. *One of the questions carrying three marks weightage is value based question.*

5. *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 three questions of five marks each weightage. You have to attempt only one of the choices in such questions.*

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

7. *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}

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

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

1. Define the term "drift velocity" of charge carriers in a conductor and write its relationship with the current flowing through it.

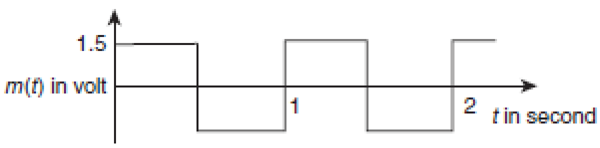
Solution

Under the action of electric field across the free ends of a wire, the electrons have a mass motion (in addition to random thermal motion) parallel to the axis of conductor with a very small velocity called drift velocity. In terms of current, it is expressed as

$$V_d = \frac{I}{nae}$$

and in terms of average relaxation time, it is given by $V_d = \frac{eE}{m} \cdot y$.

2. The carrier wave of a signal is given by $C(t) = 3 \sin (8\pi t)$ V. The modulating signal is a square wave as shown. Find its modulation index. 1



Solution

Modulation index is defined as the ratio of amplitude of modulating signal (A_m) to amplitude of carrier wave (A_c)

$$\mu = \frac{A_m}{A_c} \Rightarrow \frac{1.5}{3.0} = 0.5$$

3. Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{V}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force?

Solution

Magnetic force on a charge q moving with velocity $\vec{v}$ is a magnetic field of induction $\vec{B}$ is given by

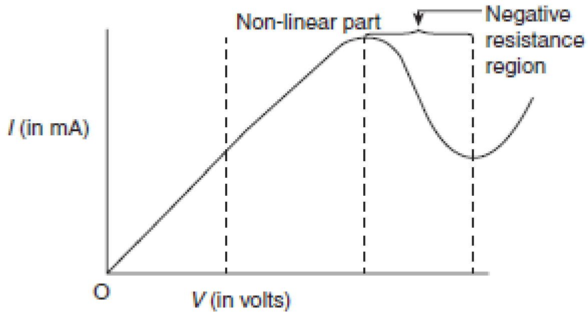
$$\vec{F} = q(\vec{v} \times \vec{B})$$

The direction of magnetic force is perpendicular to $\vec{v}$ as well as $\vec{B}$ or perpendicular to plane containing $\vec{v}$ and $\vec{B}$.

4. Plot a graph showing variation of current versus voltage for the material GaAs.

Solution

Figure shows the variation of current with potential difference for Gallium arsenide.

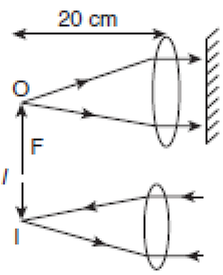


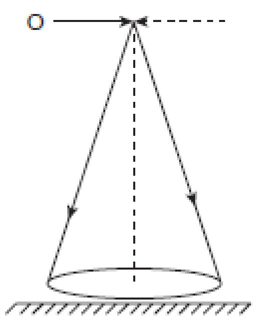
So the answer is 20 cm.

5. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?

Solution

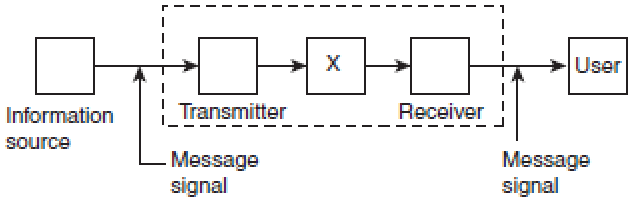
As object lies at principal focus ray will be parallel after reflection,





After reflection parallel beam will form image at I.

6. The figure given below shows the block diagram of a generalized communication system. Identify the element labeled “X” and write its function.



Solution

“X” stands for channel. It is a physical medium which connects transmitter and receiver. It may be in the form of wire or cables or may be wireless. It helps in sending signal from transmitter to receiver.

7. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?

Solution

Under the action of magnetic field of earth, eddy currents can be set up in a metallic ball, which will oppose the cause, that is, motion of ball downwards. In glass bob eddy currents are not set up as it is insulator.

Therefore, glass bob will reach the ground earlier.

8. “For any charge configuration, equipotential surface through a point is normal to the electric field.” Justify.

Solution

By definition, we know that

$$dV = -\vec{E} \cdot \overrightarrow{dr}$$

In an equipotential surface $dV = 0$

Therefore,

$$\vec{\varepsilon} \cdot \overrightarrow{ds} = 0 \;\Rightarrow\; \varepsilon\, ds \cos\theta = 0$$

$\varepsilon\, ds \cos 90° = 0;\ \theta = 90°$

$\vec{\varepsilon}$ is perpendicular to equipotential surface.

9. An electric dipole of length 1 cm, which placed with its axis making an angle of 60° with uniform electric field, experiences a torque of $6\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge ± 2 nC.

Solution

We know that

$$T = pE \sin\theta$$

$$T = 9.2l{\cdot}\varepsilon{\cdot}\sin\theta$$

$$6\sqrt{3} = 2\times10^{-9}\times1\times10^{-2}\cdot E\cdot\sin 60°$$

or $$E = 6 \times 10^{11}\ \text{NC}^{-1}.$$

$$U = -p{\cdot}\varepsilon = -2\times10^{-9}\times1\times10^{-2}\times6\times10^{11}\cos 60° = -12\times\frac{1}{2} \Rightarrow -6\,\text{J}$$

10. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.

Solution

A cyclotron is used to accelerate positively charged particle such as protons, deuterons and α-particles. It is based on the principle of resonance between electric and magnetic fields. The time taken by the particle to complete a semicircle is equal to the time in which polarity is reversed.

Magnetic force = Centrifugal force

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

$$v = \frac{qBr}{m}$$

r goes on increasing and ultimately equals radius of dee ($r = R$), maximum velocity

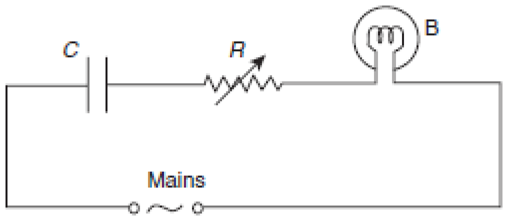
$$V_{\max} = \frac{qBR}{2m}$$

$$(\text{K.E})_{\max} = \frac{1}{2}m\left(\frac{qBR}{2m}\right)^2$$

$$(\text{K.E})_{\max} = \frac{q^2B^2R^2}{2m}$$

Energy impact depends upon magnetic field strength and radius of dee.

11. A capacitor "C", a variable resistor "R" and a bulb "B" are connected in series to the AC mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same, (ii) the resistance R is increased keeping the same capacitance?



Solution

In a C-R circuit, the impedance is given by $Z = \sqrt{R^2 + X_c^2}$

where,

$$X_C = \frac{1}{c\omega} = \frac{1}{2\pi bc}$$

$$Z = \left[R^2 + \frac{1}{4\pi^2 b^2 c^2}\right]^{\frac{1}{2}}$$

(i) On introduction of dielectric sheet, capacity will increase K times, $I' = KC$

Impedance Z will decrease

$$I_V = \frac{\varepsilon V}{Z}$$ will increase, Glow will be more.

(ii) Increase of R will increase value of Z. Current will decrease. Glow will be less.

12. A deuteron and an alpha particle are accelerated with the same accelerating potential. Which one of the two has

(1) greater value of de-Broglie wavelength, associated with it

(2) less kinetic energy? Explain

Solution

We know that deBroglie wavelength is given by

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

(i) from $\frac{1}{2}mv^2 = eV$

$$mv^2 = 2ev \text{ or } m^2v^2 = 2 \text{ meV}$$

$$mv = \sqrt{2meV}$$

Therefore,

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

As h, 2, e and V are constant

$$\lambda \propto \frac{1}{\sqrt{m}}$$

Smaller the mass more will be deBroglie wavelength. Deutron has more deBroglie wavelength associated with it.

(ii) Kinetic energy

$$\frac{1}{2}mv^2 = eV$$

For deuteron $q = e$

$$(\text{K.E})_d = eV$$

For α particle,

$$q = 2e$$

$$(\text{K.E})_\alpha = (2e)V$$

Therefore, α particle will have more K.E. and deuteron has less kinetic energy.

13. Out of the two magnetic materials, "A" has relative permeability slightly greater than unity while "B" has less than unity. Identify the nature of the materials "A" and "B". Will their susceptibilities be positive or negative?

Solution

We know that relative magnetic permeability μ_r is related to magnetic susceptibility x_m is

$$\mu_r = (1 + x_m)$$

(i) For material A, μ_r is slightly more than one. x_m is slightly positive. The material is paramagnetic.

(ii) For material B, μ_r is less than one, which implies x_m is slightly negative, therefore, material B is diamagnetic.

14. State Kirchhoff's rules. Explain briefly how these rules are justified.

Solution

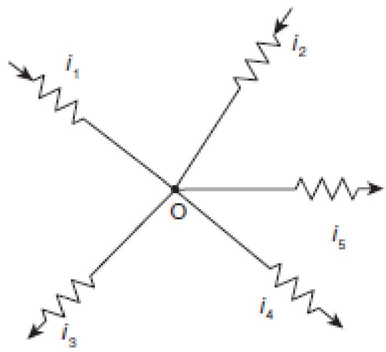
According to Kirchhoff

(a) The algebraic sum of all the currents meeting at a point is zero.

$$i_1 + i_2 - i_3 - i_4 - i_5 = 0$$

$$i_1 + i_2 = i_3 + i_4 + i_5$$

Total current entering 0 = Total current leaving 0

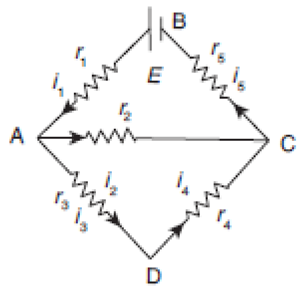


(b) In a closed mesh or circuit, sum of products of currents and resistances is equal to total emf in the circuit.

In mesh BACB,

$$i_1r_1 + i_2r_2 + i_5r_5 = E \qquad (1)$$

In mesh ADCA,



$$i_3r_3 + i_4r_4 - i_2r_2 = 0 \qquad (2)$$

From Eqs. (1) and (2), we see that sum of all the emfs in closed mesh is zero.

$$i_1r_1 + i_2r_2 + i_5r_5 - E = 0$$

15. Given a uniform electric field $\vec{E} = 4\times10^3\hat{i}$ N/C. Find the flux of this field through a square of 5 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square if the plane makes a 30° angle with the *X*-axis?

Solution

(i) In first case, angle between $\vec{\varepsilon}$ and $\vec{A}$ is 0°. The total flux is given by

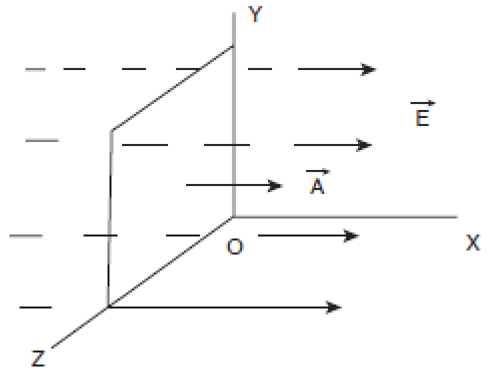
$$\phi = \vec{\varepsilon}\cdot\vec{A}$$

$$\phi = \varepsilon A\cos 0°$$

$$\phi = \varepsilon A$$

$$\phi = (4\times10^3)\times(5\times10^{-2})^2$$

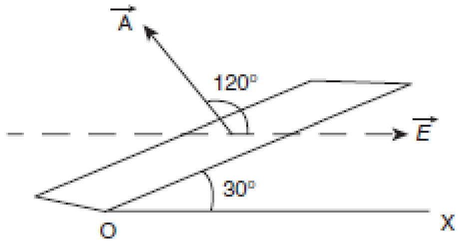
$$\phi = 4\times10^3\times25\times10^{-4} = 10 \text{ Nm}^2\text{c}^{-1}$$



(ii) Angle between $\vec{\varepsilon}$ and $\vec{A}$ will be 120°,

$$\phi = \varepsilon A \cos 120° = 4\times10^{3}\times25\times10^{-4}\times\left(-\frac{1}{2}\right)$$

$$\phi = -5\ \text{Nm}^2\text{c}^{-1}$$



16. (i) Monochromatic light of frequency 5.0×10^{14} Hz is produced by a laser. The power emitted is 3.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

Solution

(i) Given data, $v = 5 \times 10^{14}$ Hz

$$P = 3.0 \times 10^{-3}\ \text{W}$$

$$P = \eta(hv)$$

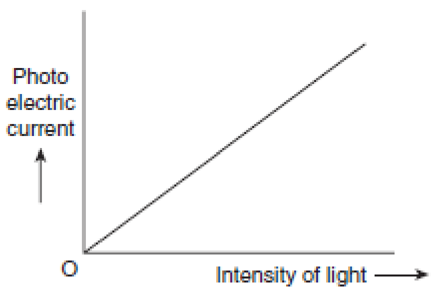
where η is number of photons per second.

$$3 \times 10^{-3} = \eta \times 6.26 \times 10^{-34} \times 5 \times 10^{14}$$

$$3 \times 10^{-3} = \eta \times 33.130 \times 10^{-20}$$

$$\eta = \frac{3\times10^{-3}}{33.13\times10^{-20}} = 9.055\times10^{15}$$

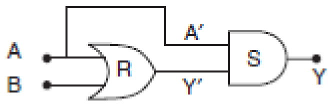
(ii) Figure shows the graph between intensity of light and photoelectric current. It comes out to be a straight line.



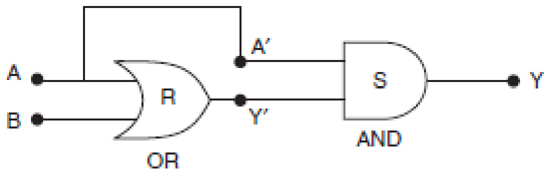
Keeping the frequency accelerating potential fixed, when intensity of light is increased, photoelectric current also goes on increasing, increase in intensity means more number of photons will be incident on surface more will be the number of photo electrons given out.

(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.

17. Write the truth table for the combination of the gates shown. Name the gates used.



Solution



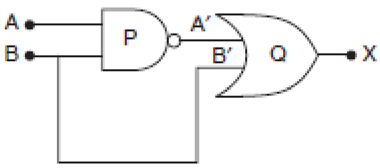
R is OR gate

S is AND gate

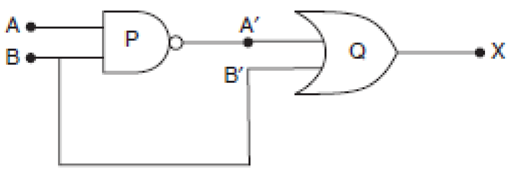
A	*B*	*A′*	*Y′*	*Y*
0	0	0	0	0
1	0	1	1	1
0	1	0	1	0
1	1	1	1	1

OR

Identify the logic gates marked “P” and “Q” in the given circuit. Write the truth table for the combination.



Solution



P is NAND gate

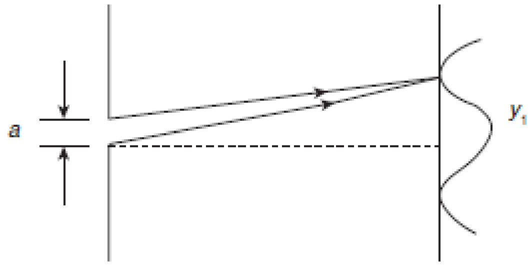
Q is OR gate

A	B	A′	B′	X
0	0	1	0	1
1	0	1	0	1
0	1	1	1	1
1	1	0	1	1

18. For a single slit of width *a*, the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance *a*. Explain.

Solution

For diffraction at single slit, the condition for minimum is given by



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

$$a\sin\theta = \lambda \quad (n = 1) \text{ for first minima.}$$

$\sin\theta = \frac{l}{a}$ If θ is small $\sin\theta = \theta$, therefore,

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

In YDSE, the condition for maxima is given by

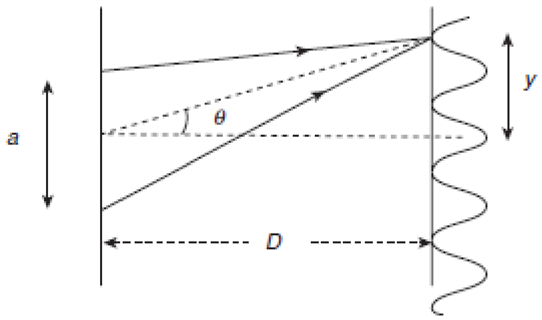
$$y = \frac{Dx}{d} \quad x = n\lambda$$

$$y = n\frac{D\lambda}{d} \text{ or } \frac{y}{D} = n\frac{\lambda}{d}$$

$\frac{y}{D} = \tan\theta = \theta$; $d = a$; $n = 1$, therefore,

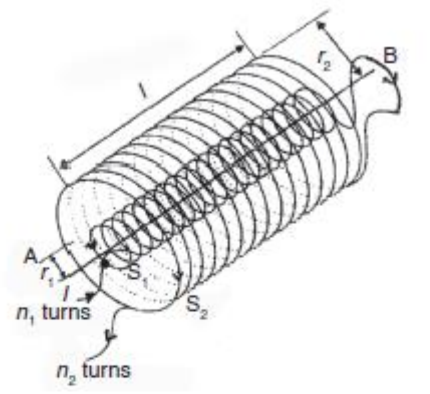
$$\theta = 1\cdot\frac{\lambda}{a}$$

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



19. (a) State Ampere's circuital law, expressing it in the integral form.

(b) Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current I flow through the inner solenoid S_1 to the other end B, which is connected to the outer solenoid S_2 through which the same current I flows in the opposite direction so as to come out at end A. If n_1 and n_2 are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system.

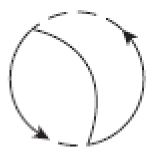


Solution

(a) Ampere's circuital rule: According to this low line integral of magnetic field over a closed surface is μ_0 times the current threading the circuit, where μ_0 is permeability of free space having value $4\pi \times 10^{-7}$ TA^{-1} m or $wbA^{-1}\,m^{-1}$.

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

(b) (i) Near end A, current in inner solenoid is anticlockwise direction. The solenoid will behave like a bar magnet with north pole at A and south pole at B.



Anticlockwise

↓

North

$$B_1 = \mu_0 n_1 I$$

where n_1 is number of turns per unit length

For outer solenoid current at end A is clockwise. So south pole will be established at end A. The direction of magnetic induction is reversed.

$$B_2 = \mu_0 n_2 I$$

The net magnetic induction will be

$$B = B_1 - B_2$$

$$B = \mu_0 (n_1 - n_2) I$$

Net magnetic induction will depend on $(n_1 - n_2)$. If $n_1 > n_2$. Net magnetic dipole moment will along BA.

(ii) Outside the combined system: There is no significant magnetic field outside the solenoid. So total magnetic induction will be zero.

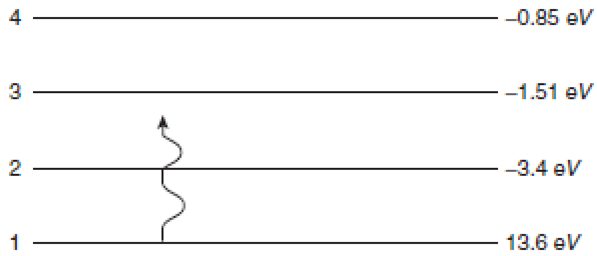
$$B = B_1 + B_2 = 0$$

20. A 12.3 eV electron beam is used to bombard gaseous hydrogen at room temperature. Up to which energy level, the hydrogen atoms would be excited?

Calculate the wavelengths of the second member of Lyman series and second member of Balmer series.

Solution

$$W_3 - W_1 = -1.51 - (-13.6) = +\ 12.3 \text{ eV}$$



Due to energy absorption of 12.3 eV, electrons from K shell will be excited to M-shell.

We know that wavelength of photon is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{\eta_1^2} - \frac{1}{\eta_2^2}\right]$$

For first member of Lyman series $n_1 = 1$; $n_2 = 3$, therefore,

$$\therefore \ \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \Rightarrow R\left[\frac{9-1}{9}\right] = \frac{8}{9}R$$

$$\lambda = \frac{9}{8R} \Rightarrow \frac{9}{8 \times 1.09678 \times 10^7}$$

$$\lambda = \frac{9 \times 10^{-7}\text{m}}{8.77424} = 1.028 \times 10^{-7} \text{ m}$$

$$\lambda = 1028 \text{ Å}$$

For second number of Balmer series

$$n_1 = 2;\ n_2 = 4$$

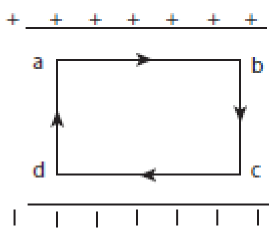
$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] \Rightarrow R\left[\frac{1}{4} - \frac{1}{6}\right] \Rightarrow R\left(\frac{4-1}{16}\right)$$

$$\frac{1}{4^2} \Rightarrow \frac{3R}{16} \text{ or } \frac{1}{4^2} \Rightarrow \frac{16}{3R}$$

$$\lambda_{42} = \frac{16 \times 10^{-7}}{3 \times 1.0967678}\text{m} = 4868 \text{ Å}$$

21. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor. 3

(b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop a b c d a.



Solution

(a) We know that energy stored in a capacitor is given by

$$U = \frac{1}{2}cv^2$$

Energy density is defined as p.e. per unit volume

$$C = \frac{\varepsilon_0 A}{d};\ V = E \cdot d$$

Therefore,

$$\frac{\text{p.e.}}{\text{Volume}} = \frac{1}{2} \cdot \frac{\varepsilon_0 A}{d} E^2 d^2 \cdot \frac{1}{A \cdot d}$$

Since, volume of specimen $V = A \cdot d$

$$\text{P.e. density} = \frac{1}{2}\varepsilon_0 E^2$$

(b) Zero. The electric field inside a capacitor is $E = \frac{v}{d}$, electrostatic field is conservative in nature. Work done in a closed path inside conservative field is zero.

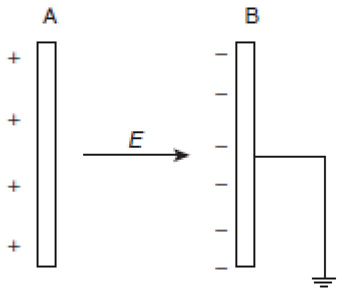
OR

(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area *A* and plate separation *d*.

(b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2, respectively. Find the ratio of their surface charge densities in terms of their radii.

Solution

(a) Capacity of a parallel plate condenser, consider a parallel plate condenser having two plates, each of area *A*, the separation between the plates is *d*.



Charge on capacitor = q …(1)

Potential drop $v = E \cdot d$

where $E = \frac{\phi}{A}$

From Gauss theorem $\phi = \frac{q}{\varepsilon_0}$

Therefore,

$$E = \frac{q}{\varepsilon_0 A}$$

or $$V = \frac{q}{\varepsilon_0 A} \cdot d \quad \text{…(2)}$$

$$\text{Capacity} = \frac{\text{Charge}}{\text{Potential}}$$

$$C = \frac{q}{\frac{qd}{\varepsilon_0 A}}$$

$$C = \frac{\varepsilon_0 A}{d}$$

(b) We know that $\sigma = \frac{q}{4\pi R^2}$

Therefore,

$$\sigma_1 = \frac{q_1}{4\pi R_1^2} \quad (1)$$

$$\sigma_2 = \frac{q_2}{4\pi R_2^2} \quad (2)$$

Dividing Eq. (1) by Eq. (2), we get

$$\frac{\sigma_1}{\sigma_2} = \frac{q_1}{4\pi R_1^2} \times \frac{4\pi R_2^2}{q_2}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2} \quad (3)$$

As the two spheres are connected to each other

$$V_1 = V_2$$

$$\frac{q_1}{4\pi\varepsilon_0 R_1} = \frac{q_2}{4\pi\varepsilon_0 R_2}$$

or $$\frac{q_1}{q_2} = \frac{R_1}{R_2} \quad (4)$$

From Eqs. (3) and (4), we get

$$\frac{\sigma_1}{\sigma_2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

22. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.

(b) Suppose the lower half of the concave mirror’s reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain.

Solution

(a)

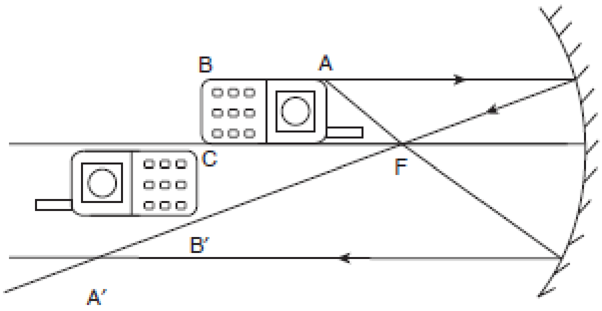


Figure shows the image formed by concave mirror. $BC = B'C$; if $u = 2f$; $v = 2f$, $m = \frac{v}{u} = \frac{2f}{2f} = 1$. For A', v is greater than u, therefore magnification is more than one. For each section magnification is different.

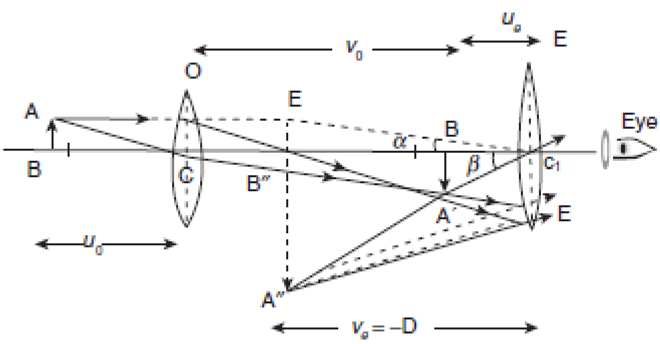
(b) On covering lower half of the mirror by opaque material, the size of image formed will not be affected. The image will be full in size but intensity of image will be reduced.

23. (a) Draw a labeled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision. 3

(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.

Solution

(a) Compound microscope:



(b) $M = m_0 \times m_e$ $\quad m_e = 5$

$m_0 = \frac{m}{m_e}$ $\quad m = 20$

$= \frac{20}{5}$ $\quad v_e = -20$ cm

$m_0 = 4$

From $m_e = \left(1 + \frac{D}{fe}\right) \Rightarrow 5 = 1 + \frac{20}{fe} \Rightarrow b_c = 5\,cm$

$$-\frac{1}{u_e} + \frac{1}{v_e} = \frac{1}{f_e} \Rightarrow -\frac{1}{u_e} + \frac{1}{-20} = \frac{1}{6}$$

$$-\frac{1}{u_e} = \frac{1}{5} + \frac{1}{20} \Rightarrow \frac{4+1}{20} \Rightarrow \frac{5}{20} \Rightarrow \frac{1}{4}$$

$$u_e = -4 \text{ cm}$$

$$L = u_0 + u_e \Rightarrow 14 \text{ cm or } v_0 = 14 - 4$$

$$v_0 = 10 \text{ cm}$$

From $m = \dfrac{f - v}{b}$, we get

For objective $m = -4$; $f = ?$; $v = 10$ cm

$$-4 = \frac{f - 10}{f}$$

$$-4f = b - 10$$

$$5f = 10 \text{ or } b_0 = 2 \text{ cm}$$

24. Answer the following questions:

(a) Name the em waves which are produced during radioactive decay of a nucleus. Write their frequency range.

(b) Welders wear special glass goggles while working. Why? Explain.

(c) Why are infrared waves often called as heat waves? Give their one application.

Solution

(a) During radioactivity α, β and γ rays are given out. Out of three γ-rays lie in electromagnetic spectrum. Their frequency range is 10^{19} h_3 to 10^{23} h_3.

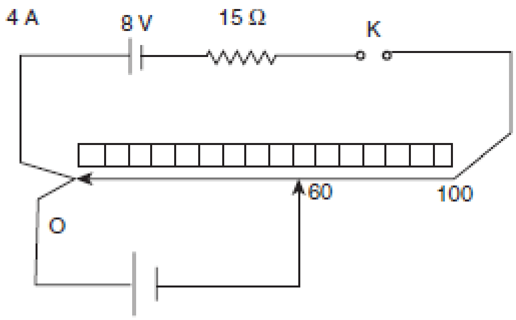
(b) Welders use goggles during welding, because ultraviolet light emitted during welding is harmful for eye. Glasses protect our eyes against ultraviolet light. The range of *u* – *v* light is between 0.6*n* – *m* to 400 *n* – *m*. It is produced by very hot bodies. It causes sun burn or tanning.

(c) They are termed as heat waves, as water molecules present in most materials absorb infrared rays. Due to absorption, thermal agitation of molecules increases and they heat up. They are also used in physiotherapy. They are used in remote switches of house hold electronic systems like TV sets, video recorders and other hi-fi systems.

25. A potentiometer wire of length 1 m has a resistance of 5 Ω. It is connected to a 8 V battery in series with a resistance of 15 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm.

Solution

$$I = \frac{V}{(R_1 + R_2)} = \frac{8}{5 + 25} \Rightarrow \frac{8}{20} \Rightarrow 0.4\text{A}$$



Resistance of wire of length 60 cm

$$r = \frac{5}{100} \times 60 = 3\Omega$$

Emf. of cell $V = Ir = 0.4 \times 3 = 12$ V

26. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.

(b) (i) Write symbolically the process expressing the β^+ decay of $^{22}_{11}\text{Na}$. Also write the basic nuclear process underlying this decay.

(ii) Is the nucleus formed in the decay of the nucleus $^{22}_{11}\text{Na}$, an isotope or isobar?

Solution

(a) From the law of radioactive disintegration, rate of disintegration of nuclei $\left(\frac{dN}{dt}\right)$ is directly proportional to number of nuclei present at that instant

$$\frac{dN}{dt} \propto N$$

$$\frac{dN}{dt} = -\lambda N$$

Where λ is called radioactive disintegration constant. Negative sign indicates decrease in remaining nuclei

$$\frac{dN}{N} = -\lambda \cdot dt \qquad (1)$$

Integrating this equation, we get

$$\log_e N = -\lambda t + c \qquad (2)$$

where C is called constant of integration.

To find C.

At $t = 0$; N = No, Eq. (1) becomes

$$\log_e N_0 = -\lambda \times 0 + C$$

$$\log_e N_0 = C \qquad (3)$$

From Eqs. (2) and (3), we get

$$\log_e N = -\lambda t + \log_e N_0$$

$$\log_e N - \log_e N_0 = -\lambda t$$

$$\log_e \frac{N}{N_0} = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t} \text{ or}$$

$$V = N_0 e^{-\lambda t} \qquad (4)$$

Equation (4) is called radioactive disintegration law.

(b) $_{11}\text{Na}^{22} \rightarrow {}_{10}\text{Ne}^{22} + {}_{+1}\text{e}^0$

as in general β^+ decay is represented

$$\underset{\substack{\text{parent}\\\text{nucleus}}}{_Z\text{X}^A} \rightarrow \underset{\substack{\text{daughter}\\\text{nucleus}}}{\underbrace{_{(z-1)}\text{Y}^A}} + \underset{\text{position}}{_{+1}\text{e}^0} + \text{energy}$$

During β^+ decay, mass number of daughter nucleus remains uncharged, while atomic number decreases by one.

(c) The nucleus formed is isobar as mass number for ($_{11}\text{Na}^{22}$ and $_{10}\text{Ne}^{22}$) remains same.

27. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents that this move would be a health hazard.

Ultimately her parents agreed:

(1) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health?

(2) By objecting to this move of her parents, what value did Sunita display?

(3) Estimate the range of em waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km)

Solution

(a) Cell tower radiation has also been linked to headaches, memory loss, low sperm count, cancer, birth effects, heart conditions and Alzheimer's disease. Electromagnetic field exposure affects enzymes, DNA, metabolism, genes, hormones. Human body contains 70% water and when exposed to 950 MHz microwaves causes serious defects.

(b) By objecting to move of his parents, Sunita awakened the parents about ill effects of radiation and long-term effects on health. She shared the knowledge and gave timely advice, which was necessary for the whole community.

(c) We know that range is given by

$$d = \sqrt{2hR} = \sqrt{2 \times 20 \times 6400 \times 1000} = \sqrt{4 \times 64 \times 10^6} = 16000 \text{ m}$$

$$d = 16.0 \text{ km}$$

28. (a) State briefly the processes involved in the formation of p-n junction explaining clearly how the depletion region is formed.

(b) Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in

(i) Forward biasing

(ii) Reverse biasing

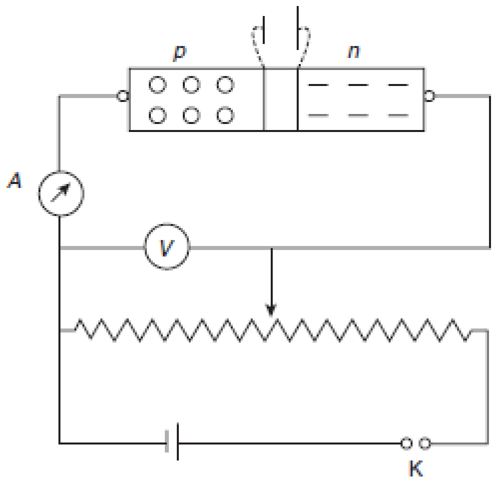
How are these characteristics made use of in rectification?

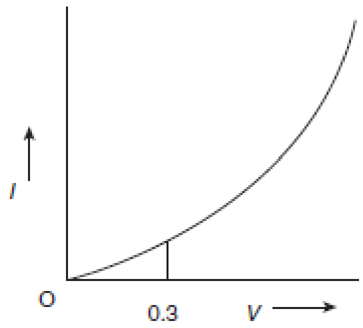
Solution

(a) Two important processes occur during the formation of a p-n junction: Diffusion and Drif. We know that concentration of electrons is more that concentration of holes in N-type semiconductor. Similarly in P-type semiconductor, concentration of holes is more than that of electrons. During formation of p-n junction holes from P-region diffuse into P-side (n → p). This gives rise to diffusion.

When an electron diffuses from N to P, it leaves behind an ionized doner on N-side. The ionized (positive charge) is immobile as it is bonded to surrounding atoms. A layer of positive space charge is developed on N-side. Similarly, a layer of negative charge or (negative space charge region) is developed on P-side. The space charge region on either side of the junction is known as depletion region.

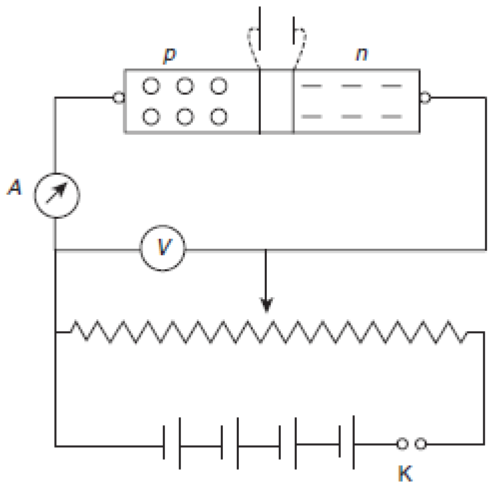
(b) (i) Forward biasing: Figure shows the circuit diagram of PN junction diode. P-region is connected to positive terminal and N-region is connected to negative terminal of battery. After the barrier voltage is crossed, current in circuit rises sharply and shows maximum current for a p.d. of one volt.

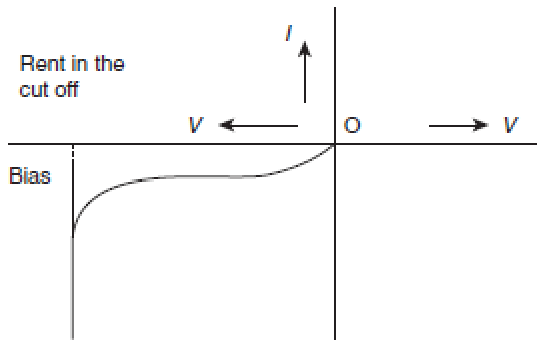




(ii) <u>Reverse bias:</u> Figure shows the circuit diagram of a p-n junction diode in reverse biased mode. All holes are pulled towards N-region and electrons are pulled towards positive terminal of battery. A current in the circuit is due to minority current carries. As we go on increasing bias current remains at (1 μA). Beyond a certain voltage. Junction diode gets damaged and cannot be used over again.

The fact that a junction diode operates only when it is forward biased and does not operate when it is reverse biased is used in diode as rectifier.





OR

(a) Differentiate between three segments of a transistor on the basis of their size and level of doping.

(b) How is a transistor biased to be in active state?

(c) With the help of necessary circuit diagram, describe briefly how n-p-n transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the AC current gain.

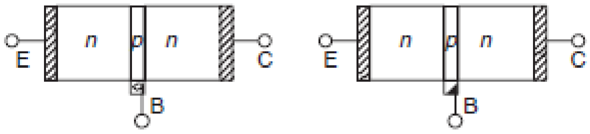
Solution

(a) A transistor has three doped regions facing two p-n junctions between them. A brief description of three segments of a transistor is given below:

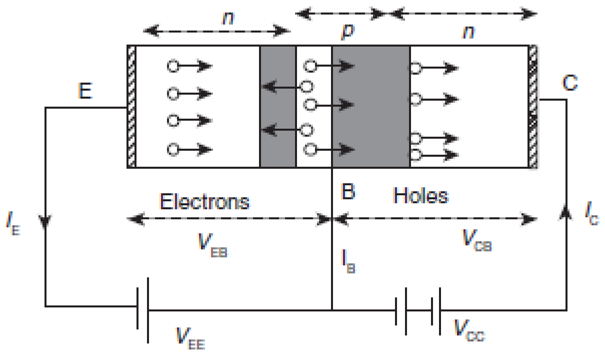
Emitter: This is a segment on one side of transistor. It is of moderate size and heavily doped. It supplies a large number of majority carriers for the current flow through transistor.

Base: It is central segment which is very thin and lightly doped.

Collector: This segment collects a majority of current carriers supplied by emitter. It is moderately doped and is larger size as compared to emitter. Transistors are of two types.



(b) For a transistor to be in active stage emitter-base section is forward biased and base collector section is reverse biased.



(c) Transistor as an amplifier:

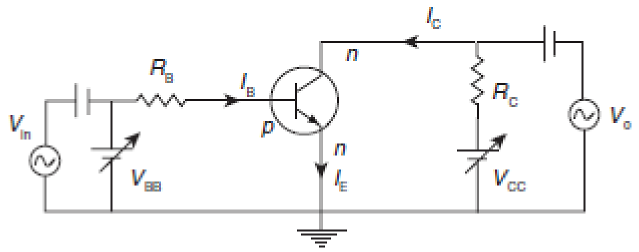


Figure shows transistor as an amplifier. The slope of linear part of the curve represents the rate of change of output with input.

Output voltage

$$V_0 = V_{CC} - I_C R_C$$

$$\Delta V_0 = 0 - R_C\, \Delta I_C$$

Similarly, $V_i = I_B R_B + V_{BE}$

$$\Delta V_i = R_B \Delta I_B + \Delta V_{BE}$$

ΔV_{BE} is very small in comparison to $\Delta I_B R_B$

Voltage again

$$A_V = -\frac{R_C \Delta I_C}{R_B \Delta I_B}$$

$$A_V = -\beta_{ac} \frac{R_C}{R_B}$$

<u>Current gain β_{AC}</u>: It is defined as the ratio of change in collector current ΔI_C to change in base current ΔI_B.

$$\beta_{AC} = \frac{\Delta I_C}{\Delta I_B}$$

29. (a) (i) "Two independent monochromatic sources of light cannot produce a sustained interference pattern". Give reason.

(ii) Light waves each of amplitude a and frequency ω, emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a\cos(\omega x + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(b) In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

Solution

(a) (i) Two independent sources of light cannot produce sustained interference as they are Not Coherent, that is, waves from two sources do not have zero or constant phase difference. A photon of light is produced by jumping of electrons from higher orbit to lower orbit in time of 10^{-8}s (coherent time). Jumping of electrons in two sources is not simultaneous or synchronous.

(ii) $y_1 = a\sin\omega t$

$$y_2 = a\cos(\omega t + \phi)$$

From principle of super position

$$y = y_1 + y_2$$

$$y = a\cos\omega t + a\cos(\omega t + \phi)$$

$$y = a[\cos\omega t + \cos(\omega t + \phi)]$$

Using $\cos C + \cos D = 2\cos\left(\frac{C - D}{2}\right)\cos\left(\frac{C + D}{2}\right)$, we get

$$y = 2a\cos\frac{\phi}{2}\cos\left(\omega t + \frac{\phi}{2}\right) \qquad (1)$$

Equation (1) represents S.H.M of amplitude

$$A = 2a\cos\frac{\phi}{2}$$

As Intensity $\propto$ (Amplitude)^2

$$I \propto 4a^2\cos^2\frac{\phi}{2} \qquad (2)$$

$$I_m \propto 4a^2 \qquad (3)$$

Dividing Eqs. (2) by (3), we get

$$\frac{I}{I_m} = \cos^2\frac{\phi}{2}$$

or $$I = I_m\cos^2\frac{\phi}{2}$$

(b) We know that resultant amplitude is given by

$$A^2 = (a_1^2 + a_2^2 + 2a_1a_2\cos\phi)$$

where ϕ is phase difference.

$$I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$$

If $I_1 = I_2$, the resultant intensity is given by

$$I' = I + I + 2\sqrt{II}\cos\phi$$

$$I' = 2I + 2I\cos\phi \qquad (1)$$

At path difference λ,

Phase difference $= \frac{2\pi x}{\lambda}$

$$\phi_1 = \frac{2\pi\lambda}{\lambda} \Rightarrow 2\pi$$

At path difference $\frac{\lambda}{3}$

Phase difference, $\phi_2 = \frac{2\pi}{\lambda}\frac{\lambda}{3} \Rightarrow \frac{2\pi}{3}$

From Eq. (1)

$$I_1 = 2I + 2I\cos 2\pi \text{ } (\cos 360° = \text{I})$$

$$I_1 = 2I + 2I\cdot 1 = 4I$$

$$K = 4I \qquad (2)$$

$$I_2 = 2I + 2I\cos\frac{2\pi}{3} = 2I + 2I\cos 120° = 2I - I$$

$$I_2 = I = \frac{K}{4} \qquad (3)$$

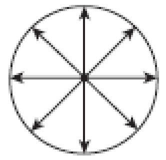
OR

(a) How does one demonstrate, using a suitable diagram, the unpolarised light when passed through a polarizer gets polarized?

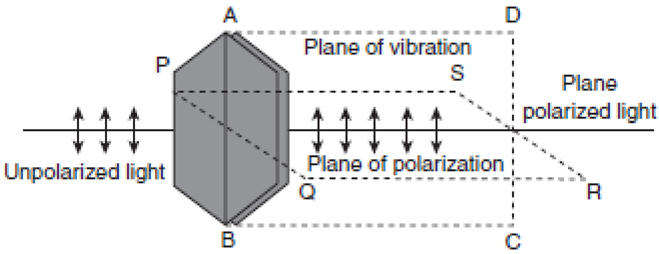
(b) A beam of unpolarised light is incident on a glass–air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarized, when $\mu = \tan i_B$, where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

Solution

(a) A unpolarised beam of light has vibrations in all possible directions. If we resolve all

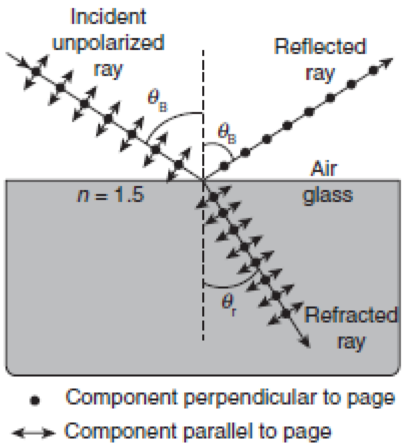


direction vibrations into two mutually perpendicular components, that is, vibrations in plane of paper (shown by arrows) and vibrations perpendicular to plane of paper (shown by dots). Unpolarised light can be shown as in figure (ii),



Consider a beam of unpolarised light is incident on a tourmaline crystal P. Vibrations of light parallel to crystallographic axis will pass through P, while vibrations perpendicular to plane of paper are cut off. P is called polarizer. Place another crystal Q with its axis parallel to that of P. Q is called analyser. After passing through Q, the polarized light will enter eye. Plane PQRS in which vibrations of light take place is called plane of vibration. Another plane ABCD perpendicular to plane of paper, in which vibrations have been cut off is called plane of polarization.

(b) It was shown that light waves can also be polarized by reflection. The amount of polarization depends upon angle of incidence. At a certain angle called polarizing angle i_B, the reflected light is completely polarized and angle between reflected and refracted beam is 90°.



For refraction of force AB from Snell's law

$$\frac{\sin i_B}{\sin i_r} = \frac{\mu}{1} \qquad (1)$$

Also

$$i_B + 90° + r = 180°$$
$$i_B + r = 90°$$
$$r = (90° - i_B)$$

Equation (1) can be written as

$$\frac{\sin i_B}{\sin(90 - i_B)} = \frac{\mu}{1}$$

$$\frac{\sin i_B}{\cos i_B} = \mu$$

or $$\mu = \tan i_B$$

This is called Brewster's law. i_B is called Brewster's angle. Glancing or grazing angle is given by $(90° – i_B)$, which the incident ray makes with the surface.

30. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.

(b) The current flowing through a inductor of self-inductance *L* is continuously increasing. Plot a graph showing the variation of

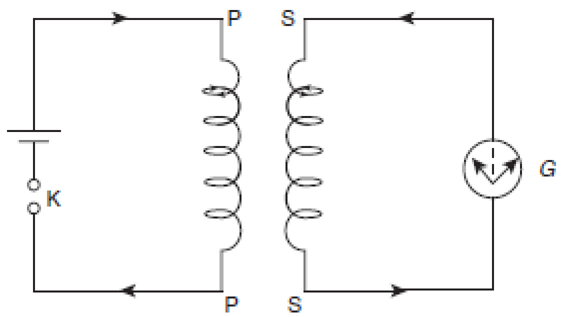
(i) Magnetic flux versus the current

(ii) Induced emf versus dI/dt

(iii) Magnetic potential energy stored versus the current.

Solution

(a)



Consider the given circuit. When plug is put in key k, current in primary coil begins to increase so flux linked with coil will also increase. It is seen that current in secondary coil is induced in anticlockwise direction.

Increase → inverse

When plug is taken out of battery, flux through, coil begins to decrease, current in secondary coil is in direction i.e. increase current.

Decrease → Direct

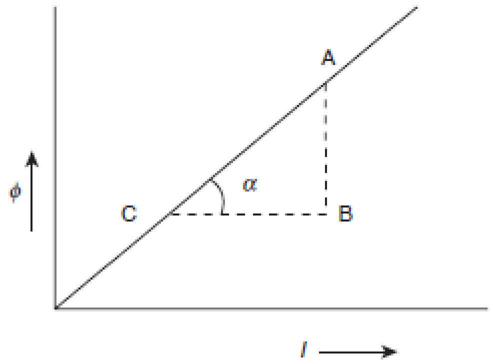
(b) (i) We know that

$$\phi \propto I$$

$$\phi = MI \qquad (1)$$

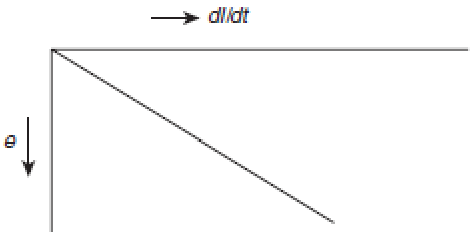
This is equation of a standard line having slope *M*, passing through origin.

$$M = \tan \alpha = \frac{AB}{CB} \Rightarrow \frac{\phi}{I} = \text{M (mutual inductive)}$$



(ii) We know that $e = -M\dfrac{dI}{dt}$

This is equation of a straight light passing through origin with negative slope.

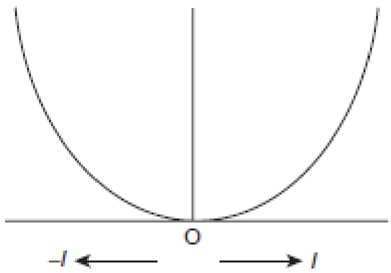


Magnetic potential energy

$$U_B = \frac{1}{2}L^0 I^2$$

where L is self inductance and I is current

The graph is a parabola with vertex downwards.



OR

(a) Draw a schematic sketch of an AC generator describing its basic elements. State briefly its working principle. Show a plot of variation of

(i) Magnetic flux

(ii) Alternating emf versus time generated by a loop of wire rotating in a magnetic field.

(b) Why is choke coil needed in the use of fluorescent tubes with AC mains?

Solution

(a) A.C. generator: It is a device which converts mechanical/heat/nuclear energy into electrical energy.

Principle: It is based on principle of electromagnetic induction.

Construction: It essentially consists of following parts.

(i) Armature: It is a coil having large number of turns capable of rotation around a fixed axis.

(ii) Field magnets N and S are two pole pieces of a horse shoe electromagnet.

(iii) Slip Rings R_1 and R_2 are two rings which rotate along with the coil.

(iv) Brushes B_1 and B_2 made of graphite are kept pressed against rings and carry electricity generated to outside circuit.