CBSE Board
Class XII Physics – Set 1
Board Paper - 2010

Time: 3 hours   **[Total Marks: 70]**

General instructions:

1. All questions are compulsory.
2. There are 30 questions in total. Questions 1 to 8 are very short answer type questions and carry one mark each.
3. 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.
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 three questions of five marks each. You have to attempt only one of the given choices in such questions.
5. Use of calculators in not permitted. However, you may use log tables if necessary.
6. You may use the following values of physical constants wherever necessary.

   $c = 3 \times 10^8 \ ms^{-1}$

   $h = 6.626 \times 10^{-34} \ Js$

   $e = 1.602 \times 10^{-19} \ C$

   $\mu_o = 4\pi \times 10^{-7} \ TmA^{-1}$

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

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

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

   Boltzmann's constant $k = 1.381 \times 10^{-23} \ J \ K^{-1}$

   Avogadro's number $N_A = 6.022 \times 10^{23} \ mol^{-1}$

   Radius of earth = 6400 km

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1. In which orientation, a dipole placed in a uniform electric field is in (i) stable, (ii) unstable equilibrium?
2. Which part of electromagnetic spectrum has largest penetrating power?

3. A plot of magnetic flux ϕ versus current (I) is shown in the figure for two inductors A and B. Which of the two has larger value of self inductance?
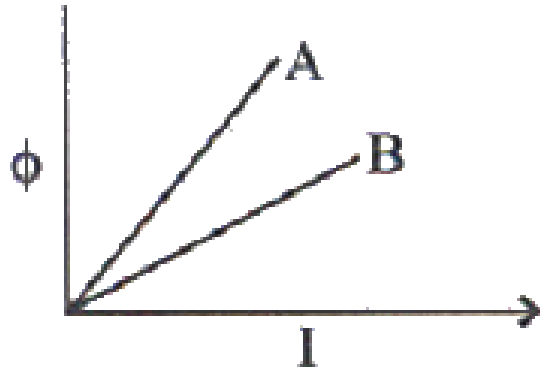
4. Figure shows three points charges, +2q, -q and +3q. Two charges +2q and –q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'?
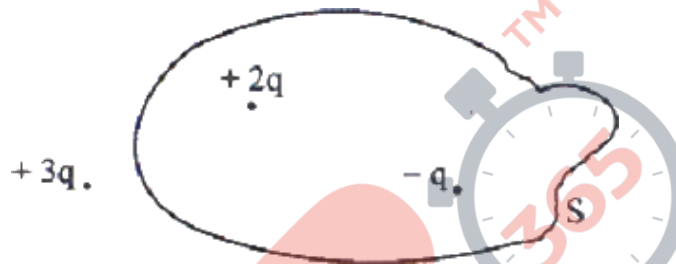
5. A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid?

6. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?

7. A wire of resistance 8R is bent in the form of a circle. What is the effective resistance between the ends of a diameter AB?
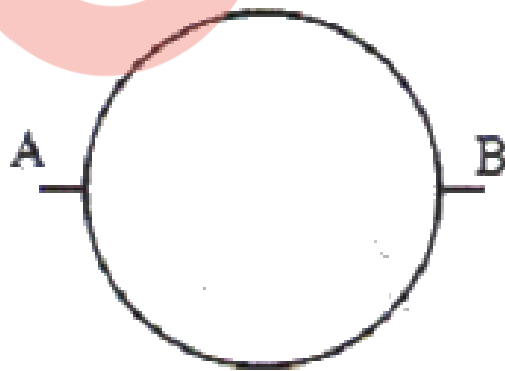

8. State the conditions for the phenomenon of total internal reflection to occur.

9. Explain the function of a repeater in a communication system.

10. (i) Write two characteristics of a material used for making permanent magnets.
(ii) Why is core of an electromagnet made of ferromagnetic materials?

OR

Draw magnetic field lines when a (i) diamagnetic, (ii) paramagnetic substance is placed in an external magnetic field. Which magnetic property distinguishes this behaviour of the field lines due to the two substances?

11. Draw the circuit diagram of an illuminated photodiode in reverse bias. How is photodiode used to measure light intensity?

12. An electric lamp having coil of negligible inductance connected in series with a capacitor and an AC source is glowing with certain brightness. How does the brightness of lamp change on reducing the (i) capacitance, and (ii) the frequency? Justify your answer.
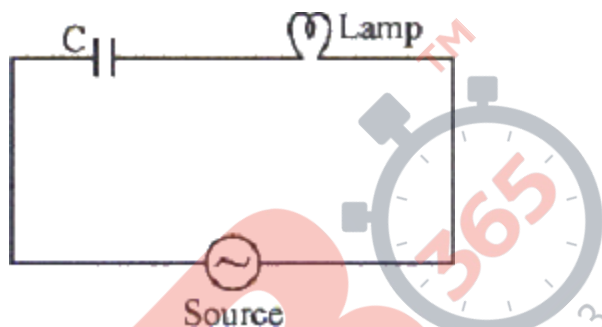
13. Arrange the following electromagnetic radiations in ascending order of their frequencies:
(i) Microwave
(ii) Radio wave
(iii) X-rays
(iv) Gamma rays
Write two uses of any one of these.

14. The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.

15. An electron is accelerated through a potential difference of 100 volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond?

16. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.85 MeV per nucleon. Calculate the energy Q released per fission in MeV.

17. (a) The bluish colour predominates in clear sky.
(b) Violet colour is seen in the bottom of the spectrum when white light is dispersed by a prims.
State reasons to explain these observations.

18. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions w_1 and w_2 ($w_1 > w_2$). On what factors does the (i) slope and (ii) intercept of the lines depend?

19. A parallel plate capacitor is charged by a battery. After sometime the battery is disconnected and a dielectric slabs its thickness equal to the plate separation is inserted between the plates. How will (i) the capacitance of the capacitor. (ii) Potential difference between the plates and (iii) the energy stored in the capacitor be affected?
Justify your answer in each case.

20. Write the principle of working of a potentiometer. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a given cell.

21. Write the expression for the magnetic moment $\vec{m}$ due to a planer square loop of side 'l' carrying a steady current I in a vector form.
In the given figure this loop is placed in a horizontal plane near a long straight conductor carrying a steady current I_1 at a distance l as shown. Give reasons to explain that the loop will experience a net force but no torque. Write the expression for this force acting on the loop.
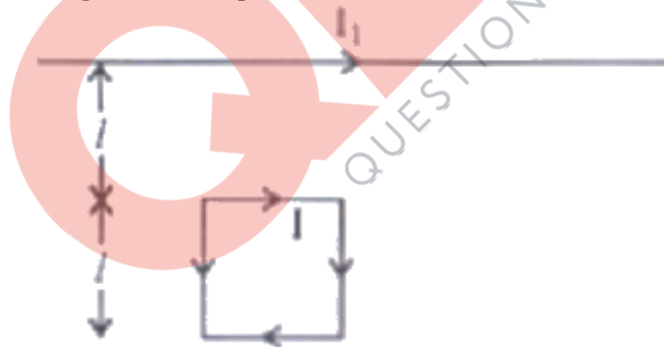
22. (a) Depict the equipotential surfaces for a system of two identical positive point charges placed a distance'd' apart.
(b) Deduce the expression for the potential energy of a system of two point charges q_1 and q_2 brought from infinity to the points $\vec{r_1}$ and $\vec{r_2}$ respectively in the presence of external electric field $\vec{E}$.

23. What is an upolarized light? Explain with the help of suitable ray diagram how an unpolarized light can be polarized by reflection from a transparent medium. Write the expression for Brewster angle in terms of the refractive index of denser medium.

24. (i) Define 'activity' of a radioactive material and write its S.I. unit.

(ii) Plot a graph showing variation of activity of a given radioactive sample with time.

(iii) The sequence of stepwise decay of a radioactive nucleus is

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta-} D_2$$

If the atomic number and mass number of D_2 are 71 and 176 respectively, what are their corresponding values for D?

25. A long straight wire of a circular cross-section of radius 'a' carries a steady current 'I'. The current is uniformly distributed across the cross-section. Apply Ampere's circuital law to calculate the magnetic field at a point 'r' in the region for (i) r < a and (ii) r > a.

OR

State the underlying principle of working of a moving coil galvanometer. Write two reasons why a galvanometer cannot be used as such to measure current in a given circuit. Name any two factors on which the current sensitivity of a galvanometer depends.

26. What is space wave propagation? Give two examples of communication system which use space wave mode.

A TV tower is 80 m tall. Calculate the maximum distance upto which the signal transmitted from the tower can be received.

27. In a meter bridge, the null point is found at a distance of 40 cm from A. If a resistance of $12\,\Omega$ is connected in parallel with S, the null point occurs at 50.0 cm. from A. Determine the values of R and S.
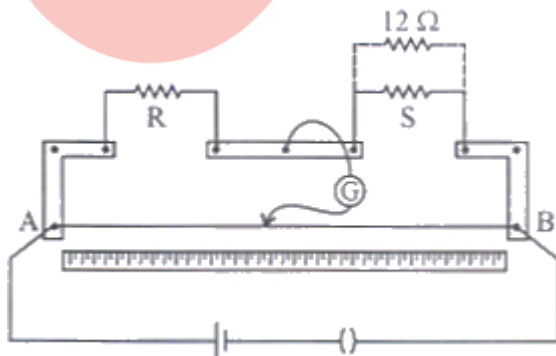
28. Describe briefly, with the help of a labelled diagram, the basic elements of an A.C. generator. State its underlying principle. Show diagrammatically how an alternating emf is generated by a loop of wire rotating in a magnetic field. Write the expression for the instaneous value of the emf induced in the rotating loop.

OR

A series LCR circuit is connected to an source having voltage $v = v_m \sin \omega t$. Derive the expression for the instantaneous current I and its phase relationship to the applied voltage.

Obtain the condition for resonance to occur. Define 'power factor'. State the conditions under which it is (i) maximum and (ii) minimum.

29. State Huygen's principle. Show, with the help of a suitable diagram, how this principle is used to obtain the diffraction pattern by a gingle slit.

Draw a plot of intensity distribution and explain clearly why the secondary maxima become weaker with increasing order (n) of the secondary maxima.

OR

Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point.

In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye piece has a focal length of 5 cm and the final image is formed at the near point, estimate the magnifying power of the microscope.

30. (a) Explain the formation of depletion layer and potential barrier in a p-n junction.

(b) In the figure given below, the input waveform is converted into the output waveform by a device 'X'. Name the device and draw its circuit diagram.

(c) Identify the logic gate represented by the circuit as shown and write its truth table.

OR

(a) With the help of the circuit diagram explain the working principle of a transistor amplifier as an oscillator.

(b) Distinguish between a conductor, a semiconductor and an insulator on the basis of energy band diagrams

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1. Stable position of the dipole: parallel to electric field

   Unstable position: perpendicular to the electric field

2. Gamma rays

3. Since flux is given as $\phi_B = L\dfrac{I}{N}$

   Larger is the slope of the graph between ϕ vs. I, more will be the value of self inductance L of the coil..

   In the given graphs,

   Slope of A > slope of B.

   Hence, A will represent coil of higher L

   B will represent coil of lower L.

4. Electric flux through the surface S will be as per Gauss law:

   $$\phi = \frac{\text{net charge}}{\varepsilon_o} = \frac{2q - q}{\varepsilon_o} = \frac{q}{\varepsilon_o}$$

5. Refractive index of the liquid will be same as that of the glass, i.e, 1.45

6. Radius of the nth orbit is given as

   $$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_o}{e^2}$$

   For the ground state, n=1

   For excited state, n=2

   So the ratio between radii of the first orbital & the ground state radii is 4.

7. Equivalent resistance across the diameter:

   $$\frac{1}{R_{eq}} = \frac{1}{4R} + \frac{1}{4R} = \frac{2}{4R} = \frac{1}{2R}$$

   So R_{eq} = 2R

8. Conditions for total internal reflection:

1. Light should travel from an optically denser medium to a rarer medium at the interface.

2. Angle of incidence in the denser medium should exceed the critical angle

9. A repeater, picks up the signal from the transmitter, amplifies and retransmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system.

10.(a) Two characteristics of materials used for making permanent magnets:

(i) High retentivity so that the magnet is strong and

(ii) High coercivity so that the magnetisation is not erased by stray magnetic fields, temperature fluctuations or minor mechanical damage.

(b) Core of electromagnets are made of ferromagnetic materials because they have high permeability and low retentivity. That is to ensure that heating losses are minimum as they will have narrow Hystersis curve.

OR

Magnetic field lines when a diamagnetic material is placed in external magnetic field:
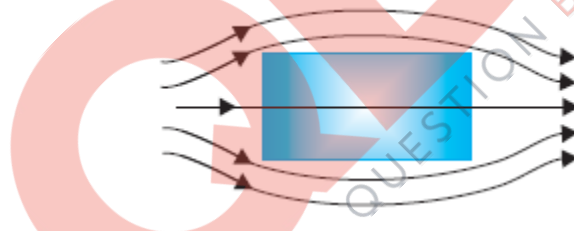
Magnetic field lines when a paramagnetic material is placed in external magnetic field:
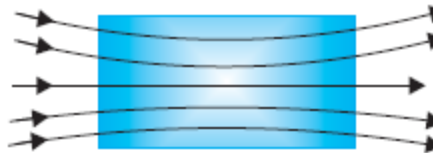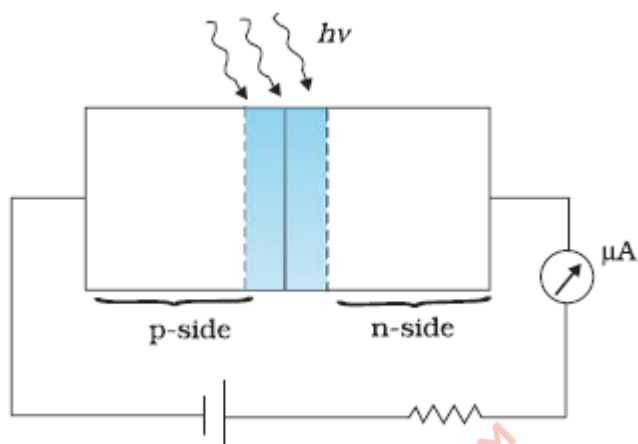

Property that is responsible for the above behaviour is magnetic dipole moment.

Diamagnetic material has zero magnetic moment

Paramagnetic material has non zero magnetic moment

11.

The magnitude of the photocurrent depends on the intensity of incident light as the photocurrent is proportional to incident light intensity.

A change in the photocurrent will indicate a change in the light intensity, if a reverse bias is applied. Thus photodiode can be used as a photodetector to detect optical signals.
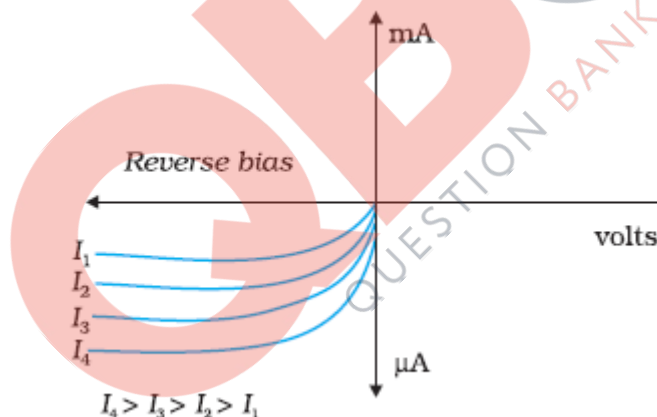
12. (a) By reducing the capacitance, the capacitive reactance ($X_c = \dfrac{1}{C\omega}$) will increase. So the bulb brightness will decrease.

(b) By reducing the frequency, the capacitive reactance will again increase. So the bulb brightness will again decrease.

13. Ascending order of the em waves (in terms of frequencies)

Radio waves < Microwaves< X rays < Gamma rays

Two uses of any one:

Radio waves: Radio & television communication systems; Cellular phones use radio waves to transmit voice communication

Microwaves: In microwave ovens; in radar systems of aircraft navigation

X rays: As diagnostic tool in medicine; for cancer treatment

Gamma rays: In medicine for cancer treatment; Solid state physics

14. Using the lens makers formula:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{12} = (n-1)\left(\frac{1}{10} + \frac{1}{15}\right)$$

Here for convex lens, R_1 = 10 cm, R_2 = -15 cm

Solving the above equation we get

Refractive index of the material of the lens, n = 1.5

15. According to de Broglie equation,

Wavelength associated with an electron through potential difference V is given as

$$\lambda = \frac{12.27}{\sqrt{V}}\,\overset{\circ}{A} = \frac{12.27}{\sqrt{100}}\,\overset{\circ}{A} = \frac{12.27}{10} = 1.227\,\overset{\circ}{A}$$

The wavelength corresponds to X-rays.

16. Given that X (A = 240) with BE/nucleon= 7.6 MeV/nucleon undergoes fission to release two daughter nuclei: Y (A=110) & Z (A = 130) with BE/nucleon of both being 8.5 MeV/nucleon.

For the fission to happen:

Total BE of X= 240 x 7.6 = 1824 MeV

Total BE of (Y+Z) = (110+130) x 8.5 = 2040 MeV

Energy released in the fission = 2040 – 1824 = 216 MeV

Energy released per fission = 216/240= 9.9 MeV

17. (a) As sunlight travels through the earth's atmosphere, it gets *scattered* by the atmospheric particles. Light of shorter wavelengths is scattered much more than light of longer wavelengths.

The amount of scattering is inversely proportional to the fourth power of the wavelength. This is known as Rayleigh scattering). Hence, the bluish colour predominates in a clear sky, since blue has a shorter wavelength than red and is scattered much more strongly.

(b) Violet colour undergoes maximum bending as it has the minimum wavelength & maximum refractive index with respect to the glass medium.

18.
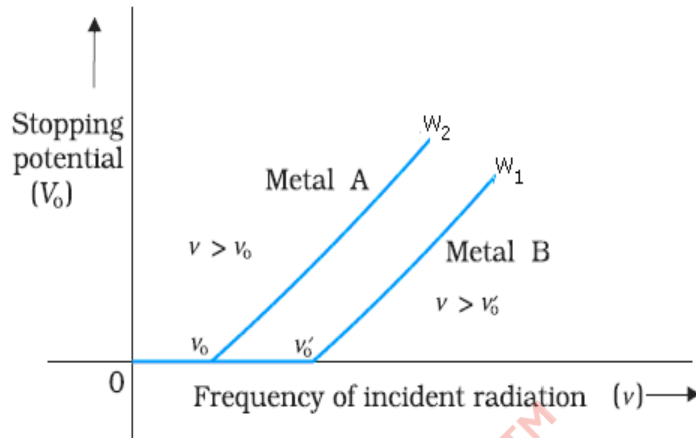
(i) Slope of the graph corresponds to h/e which is a constant & independent of the material

(ii) Intercept of this graph indicates threshold frequencies v_o & v_o' of the given materials. It depends on the nature of the material.

19. (i) Capacitance of the capacitor increases by a factor K, i.e., it becomes KC.

(ii) Net electric field will get reduced. As potential difference V =-Ed, as E is reduced, potential difference between the capacitor plates also reduces.

(iii) Energy of the capacitor:

As the charge Q is fixed on plates,

Energy stored in the capacitor

$$U = \frac{Q^2}{2C} \rightarrow \frac{1}{K} \text{ x (Energy without dielectric).}$$

So, $U \propto \frac{1}{K}$ it goes down.

20. Principle of working: The voltage drop along the wire is directly proportional to the length of the wire. The potentiometer works without drawing any current from the voltage source
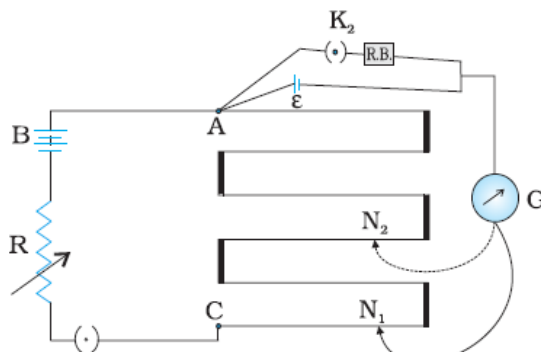
We can also use a potentiometer to measure internal resistance of a cell. For this the cell (emf E) whose internal resistance (r) is to be determined is connected across a resistance box through a key K_2, as shown in the figure.

With key K_2 open, balance is obtained at length L_1 (AN$_1$).

Then,

$E = \phi L_1$

When key K_2 is closed, the cell sends a current (I) through the resistance box (R). If V is the terminal potential difference of the cell and balance is obtained at length L_2 (AN$_2$), then

$V = \phi L_2$

So, we have $E/V = L_1/L_2$

But, E= $I(r + R)$ and $V = IR$. This gives

$E/V = (r+R)/R$

On comparing the above equations, we get,

$(R+r)/R = L1/L2$

$$r = R\left(\frac{L_1}{L_2} - 1\right)$$

Using the above equation, we can find the internal resistance of a given cell.

21. Magnetic moment due to current carrying loop:

m = I A = I x L x L, here A = area of the square loop = L x L

The net torque on the loop will be zero as $\vec{\tau} = \vec{m} \times \vec{B}$, here the angle between vector m and B is zero.
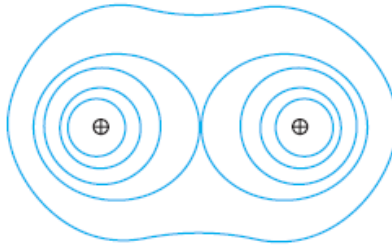
Force experienced by the nearer parallel side of the loop = $= \dfrac{\mu_o I I_1}{2\pi L}$ (attractive)

Force experienced by the farther parallel side of the loop = $= \dfrac{\mu_o I I_1}{2\pi.2L}$ (repulsive)

Net force on the loop towards the wire: $= \dfrac{\mu_o I I_1}{2\pi L} - \dfrac{\mu_o I I_1}{2\pi.2L} = \dfrac{\mu_o I I_1}{2\pi.2L}$

22.(a) An equipotential surface is a surface with a constant value of potential

at all points on the surface.

Equipotential surfaces for two identical positive charges.

(b) First, we calculate the work done in bringing the charge $q1$ from infinity to $\mathbf{r_1}$.

Work done in this step is $q1\ V\ (\mathbf{r_1})$.

Next, we consider the work done in bringing q_2 to $\mathbf{r_2}$. In this step, work is done not only against the external field $\mathbf{E}$ but also against the field due to $q1$.

Work done on q_2 against the external field $= q_2\ V\ (\mathbf{r_2})$

Work done on q_2 against the field due to $q_1 = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$

Where r_{12} is the distance between q_1 and q_2. By the superposition principle for fields, we add up the work done on q_2 against the two fields ($\mathbf{E}$ and that due to q_1):
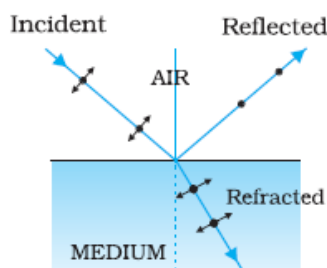
Work done in bringing q_2 to $\mathbf{r_2} = q_2 V\ r_2\ + \dfrac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$

Thus, Potential energy of the system

     = the total work done in assembling the configuration

$$= q_1 V(\mathbf{r_1}) + q_2 V(\mathbf{r_2}) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

23. For an unpolarised wave the displacement will be randomly changing with time though it will always be perpendicular to the direction of propagation.

When unpolarised light is incident on the boundary between two transparent media, the reflected light is polarised with its electric vector perpendicular to the plane of incidence when the refracted and reflected rays make a right angle with each other.

Thus when reflected wave is perpendicular to the refracted wave, the reflected wave is a totally polarised wave. The angle of incidence in this case is called Brewster's angle and is denoted by iB. We can see that iB is related to the refractive index of the denser medium.

Since we have iB + r = $\pi/2$, we get from Snell's law

$$\mu = \frac{\sin i_B}{\sin r} = \frac{\sin i_B}{\sin \ \pi/2 - i_B} = \frac{\sin i_B}{\cos i_B} = \tan i_B$$

24. (i) The total decay rate of a sample of one or more radionuclides is called the activity of that sample. The SI unit for activity is becquerel, named after the discoverer of radioactivity, Henry Becquerel.

(ii)
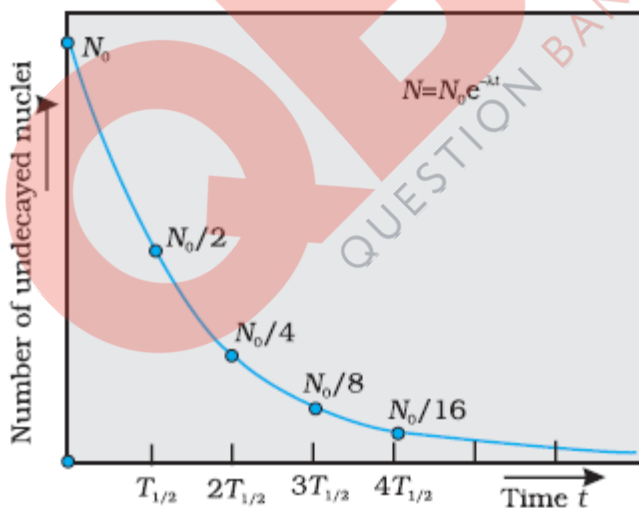
Variation of Activity of a given radioactive sample with time.

(iii) In a β - decay an electron is emitted by the nucleus.

Therefore for D_1 we can write

Mass number of D_1 = Mass number of D_2 = 176

Atomic number of D_1 = Atomic number of D_{2+1} = 71+1 = 72

In a α decay the mass number and the atomic number of the daughter nucleus decreases by four and two, respectively.
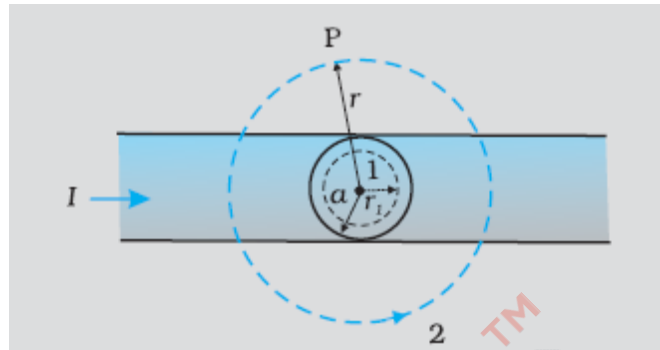
Thus for D we can write

Mass number of D = Mass number of D_1 + 4 = 176 + 4 = 180

Atomic number of D = Atomic number of D_1 + 2 = 72 + 2 = 74

25.

(i) Consider the case $r < a$. The Amperian loop is a circle labelled 1.

For this loop, taking the radius of the circle to be r,

L = 2 пr

Now the current enclosed Ie is not I, but is less than this value.

Since the current distribution is uniform, the current enclosed is,

$$I_e = I\left(\frac{\pi r^2}{\pi a^2}\right) = \frac{Ir^2}{a^2}$$

Using Ampere's law, _

$$B(2\pi r) = \mu_0 \frac{Ir^2}{a^2}$$

$$B = \left(\frac{\mu_0 I}{2\pi a^2}\right)r$$

$B \propto r \qquad (r < a)$

(ii) Consider the case $r > a$. The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop,

L = 2 п r

I_e = Current enclosed by the loop = I

The result is the familiar expression for a long straight wire

$$B(2\pi r) = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$
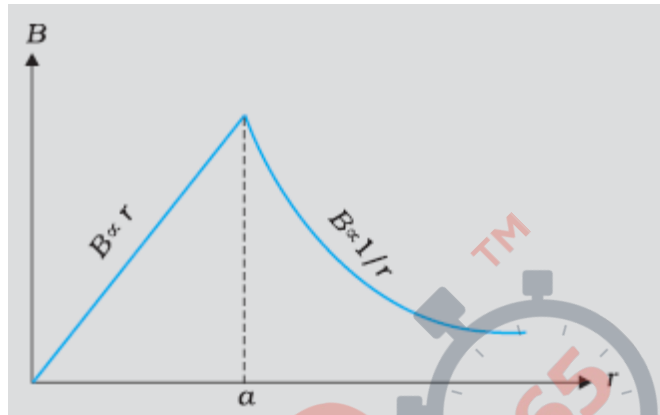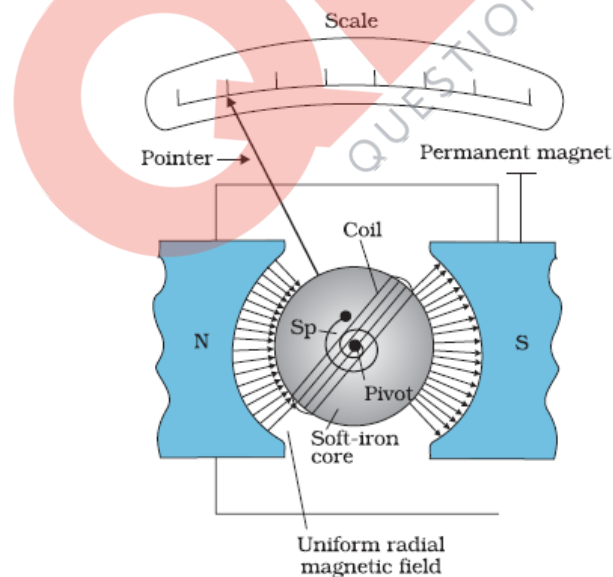
$$B \propto \frac{1}{r} \qquad (r > a)$$

Figure shows a plot of the magnitude of **B** with distance *r* from the centre of the wire. The direction of the field is tangential to the respective circular loop (1 or 2) and given by the right-hand rule described earlier in this section

Or

The Principle: When a current flows through the conductor coil, a torque acts on it due to the external radial magnetic field. Counter torque due to suspension balances it after appropriate deflection which indicates the presence of the current in the circuit.

Two reasons why galvanometer cannot be used for measuring current:

(i) Galvanometer is a very sensitive device, it gives a full-scale deflection for a current of the order of μA.

(ii) For measuring currents, the galvanometer has to be connected in series, and as it has a large resistance, this will change the value of the current in the circuit.

Current sensitivity of the galvanometer is given as:

$$\frac{\phi}{I} = \frac{NAB}{k}$$

It depends on:

    i .Number of turns in the coil

        ii. Area of the coil

26. A space wave travels in a straight line from transmitting antenna to the receiving antenna. Space waves are used for line-of-sight (LOS) communication as well as satellite communication. At frequencies >40 MHz, communication is essentially limited to line-of-sight paths. At these frequencies, the antennas are relatively smaller and can be placed at heights of many wavelengths above the ground. Because of line-of-sight nature of propagation, direct waves get blocked at some point by the   curvature of the earth. If the signal is to be received beyond the horizon then the receiving antenna must be high enough to intercept the line-of-sight waves.

Line of sight communication by space waves.
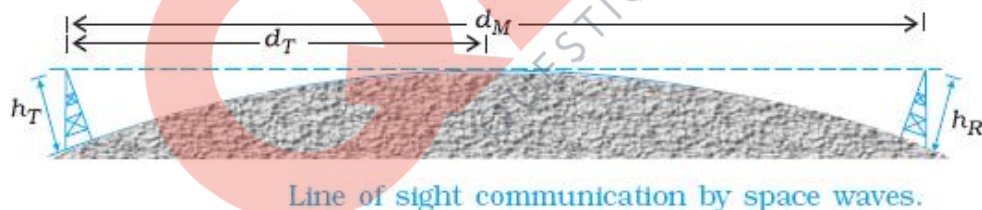
Two examples of communications systems which use space wave mode are – Television broadcast, microwave links and satellite communication.

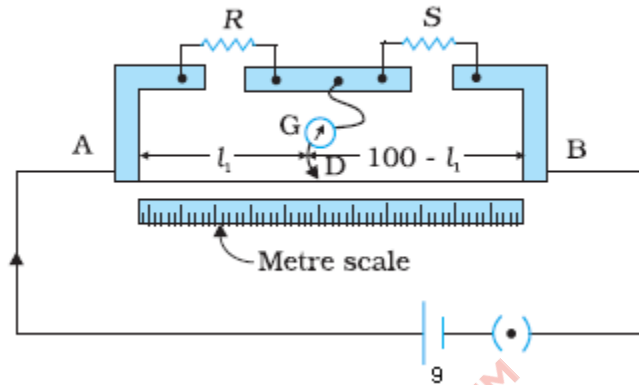Given h_T = 80 m

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

Taking h_T = h_R = 80 m. , we get

d_M = 2 $\sqrt{2Rh_T}$ = $2x\sqrt{2x6400x1000x80}$ = 64000 m. = 64 km.

Therefore the maximum distance upto which the signal transmitted from the tower can be received is 64 km.

27. When 12 Ω resistance is not connected in parallel to S than we can write,

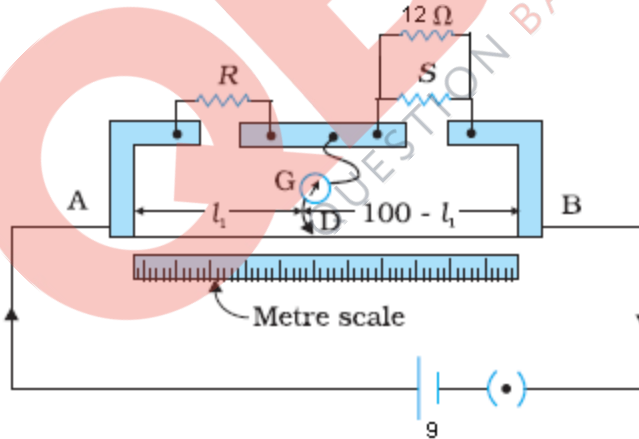$$R = S \frac{l_1}{100 - l_1}$$

Where l_1 = 40 cm.

Therefore, R = S (40/60) = (2/3)S..................(i)

When 12 Ω is connected in parallel to S, then

The effective resistance can be written as

$1/S_1$ = 1/S + 1/12 = (12+S)/12S

i.e. S_1 = 12S/ (12+S)

Now we can write,

$$R = S_1 \frac{l}{100 - l}$$

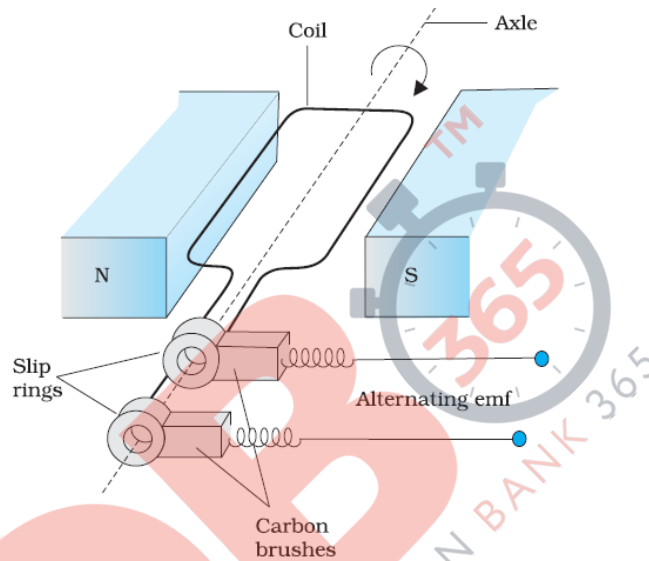Where l' = 50 cm.

i.e. R = 12S/ (12+S) (50/50) = 12S/ (12+S) ………….. (ii)

Now using (i) & (ii) we get,

(2/3)S = 12S/ (12+S)

S = 6 Ω

Therefore from (i), R = (2/3) (6) = 4Ω.

**28.** The diagram of AC generator:

Basic parts of the AC generator:

i. Rectangular coil mounted on a rotor shaft. The coil also called armature is mechanically rotated in the uniform magnetic field by some external means.

ii. The axis of rotation of the coil is perpendicular to the direction of the magnetic field. The rotation of the coil causes the magnetic flux through it to change, so an emf is induced in the coil.

iii. The ends of the coil are connected to an external circuit by means of slip rings and brushes.

iv. N and S are two permanent magnets which provide a constant magnetic field region in which the coil rotates.

Principle of working:

A wire loop of area A is free to rotate about an axis which is perpendicular to a uniform magnetic field B. If the normal to the loop makes an angle θ with $\vec{B}$, then, flux through the loop $\Phi = BA\cos\theta$.

If this loop rotates with a constant angular velocity $\omega = \dfrac{d\theta}{dt}$
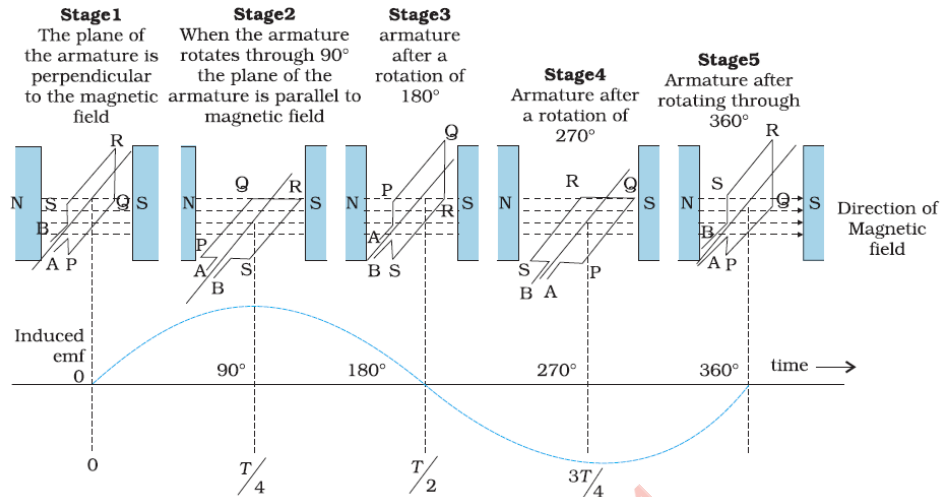
The flux through it changes at the rate,

$$\frac{d\Phi}{dt} = -BA\sin\theta\frac{d\theta}{dt} = -BA\,\omega\sin(\omega t + C_o)$$

Where C_o is a constant

$\therefore$ emf is induced between ends A and B given by:

$$V = \frac{-d\Phi}{dt} = BA\,\omega\sin(\omega t + C_o)$$

$V = V_m\sin(\omega t + C_o)$, here $V_m = BA\,\omega$ Peak value of emf generated.

Since the emf induced in the coil is varying as a function of sine, it is alternating in value & direction
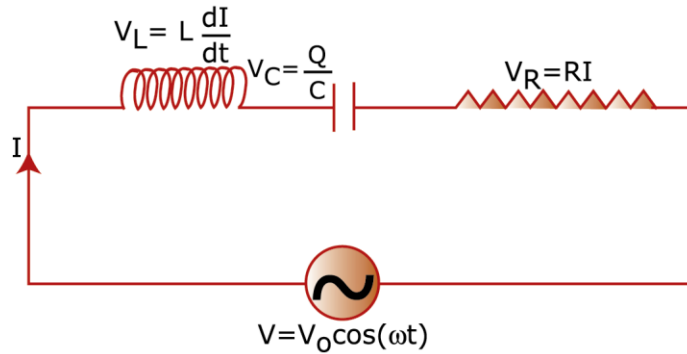
OR

If I is the instantaneous current through LCR circuit, the instantaneous voltage across the resistor is $V_R = RI$, across the inductor is $V_L = L\dfrac{dI}{dt}$ and across the capacitor is $V_C = \dfrac{Q}{C}\left(I = \dfrac{dQ}{dt}\right)$.

From conservation of energy, when all of them are connected in series, the total work required is just the sum of these.

So, $V = V_R + V_L + V_C$

The current will have the same frequency as *V*, but in general will *not* be in phase with *V*.

The current can be written as

$$I = I_0 \cos(\omega t + \phi)$$

with the peak value I_0 and the relative phase ϕ fixed by equation.

Hence the voltage equations across each of the components will be

$$V_R = RI = (V_R)_0 \cos(\omega t + \phi)$$
$$V_L = L\frac{dI}{dt} = (V_L)_0 \cos(\omega t + \phi + \pi/2)$$
$$V_C = \frac{Q}{C} = (V_C)_0 \cos(\omega t + \phi - \pi/2)$$

Where $(V_R)_0 = RI_0$, $(V_L)_0 = X_L I_0$ and $(V_C)_0 = X_C I_0$ with $X_L = L\omega$, $X_C = \dfrac{1}{C\omega}$.

In the phasor diagram, the external source of EMF is $V = V_0$ (peak value), which is the *x* component of the phasor $\mathbf{V}$, this vector will be along the *X* axis.
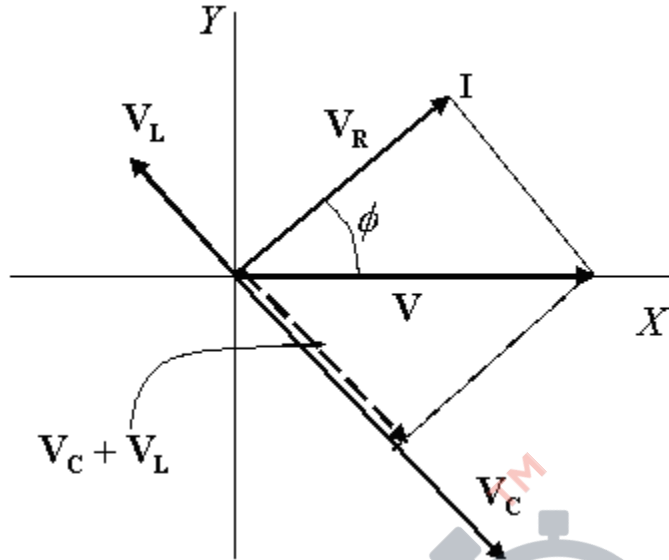
The current phasor $\mathbf{I}$ will be at an angle ϕ relative to this.

So, since $\mathbf{V_R} = R\mathbf{I}$, it will be parallel to this current phasor I, at angle ϕ relative to $\mathbf{V}$.

$\mathbf{V_L}$ will make an angle $+\dfrac{\pi}{2}$ and $\mathbf{V_C}$ will make angle $-\dfrac{\pi}{2}$ relative to $\mathbf{V_R}$.

This also implies that $\mathbf{V_L}$ and $\mathbf{V_C}$ will lie in *opposite* directions, as the following figure shows.

The vector $\mathbf{V_R}$ is perpendicular to the vector $\mathbf{V_C} + \mathbf{V_L}$, and *also*, of course,

$$\mathbf{V} = \mathbf{V_R} + (\mathbf{V_L} + \mathbf{V_C})$$

Taking the dot product

$\mathbf{V} \bullet \mathbf{V}$ gives

$$V_0^2 = (V_R)_0^{\ 2} + (\mathbf{V_C} + \mathbf{V_L}) \bullet (\mathbf{V_C} + \mathbf{V_L})$$
$$= (V_R)_0^{\ 2} + [(V_L)_0 - (V_C)_0]^2$$
$$= [R^2 + (X_C - X_L)^2]I_0^{\ 2}$$

From this, we get

$$I_0 = \frac{V_0}{Z}; \quad Z = \sqrt{R^2 + (X_C - X_L)^2}$$

The factor Z is the analog of resistance in a purely resistive circuit, and is called *Impedance*.

The phase angle ϕ is found as

$$\tan\phi = \frac{X_C - X_L}{R}$$

Condition for resonance:

The amplitude or peak value of the current through the circuit will be

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\dfrac{1}{C\omega} - L\omega\right)^2}}$$

The expression clearly shows that I_0 is maximum if the term inside the bracket in the denominator is zero, since then the denominator is *minimum* and the impedance is completely resistive.

This means that the current is maximum at frequency ω_0, such that $\dfrac{1}{C\omega_0} - L\omega_0 = 0$

$$\Rightarrow \omega_0 = \dfrac{1}{\sqrt{LC}}$$

The maximum current is $(I_0)_{\max} = \dfrac{V_0}{R}$, as if the reactive elements are not there at all!

This phenomenon, in which the peak value of current shoots up at this particular frequency is called 'resonance'.

The condition for resonance is hence:

$$\dfrac{1}{C\omega_0} = L\omega_0$$

Power factor:

Average power dissipated per cycle, is given by

$$\overline{P} = \dfrac{V_0^2}{2R}\cos\phi$$

The factor $\cos\phi$ is called the 'Power Factor', since the power crucially depends on it. This factor depends on the applied frequency, apart from circuit parameters like *L,C* and *R*.

At resonance, $X_L = X_C$, so that $\tan\phi = 0$. This implies that $\phi = 0$, or that the power factor attains its maximum value, equal to unity.

For the (ii) capacitive and (iii) inductive circuits, the current and voltage differ in phase by $\pm\dfrac{\pi}{2}$, so either way, it is minimum, ie., zero.

29. According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.
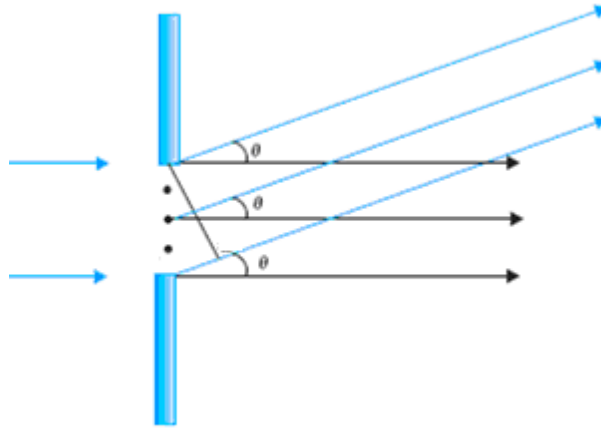
The geometry of path differences for diffraction by a single slit.
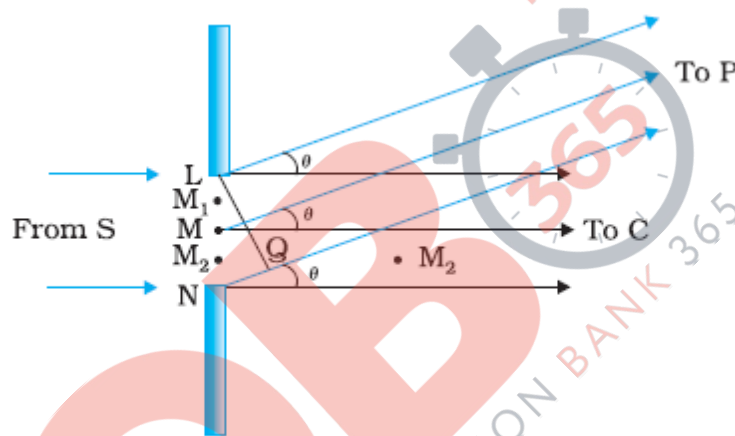
When a monochromatic light passes through a single slit, there are alternate dark and bright regions, the intensity becoming weaker away from the centre on the screen.

We can apply Huygen's principle to explain this.

The diffracted light goes on to meet a screen.

The basic idea is to divide the slit into much smaller parts, and add their contributions at P with the proper phase differences.

The midpoint of the slit is M. The path difference NP – LP between the two edges of the slit can be calculated, where P is some point on the screen.

If θ is the angle with the normal MC, then if two points M_1 and M_2 in the slit plane are separated by y, the path difference

$M_2P - M_1P = y\ \theta$

At the central point C on the screen, the angle θ is zero. All path differences are zero and hence all the parts of the slit contribute in phase.

This gives maximum intensity at C.

Experimental observation indicates that the intensity has a central maximum at $\theta = 0$ and other secondary maxima at $\theta = (n+1/2)\lambda/a$, and has minima (zero intensity) at $\theta = n\lambda/a$,

$n = \pm 1, \pm 2, \pm 3, \ldots$

Consider first the angle θ where the path difference $a\theta$ is λ. Then,

$\theta = \lambda/a \ldots\ldots\ldots(i)$

Now, divide the slit into two equal halves LM and MN each of size $a/2$. For every point M_1 in LM, there is a point M_2 in MN such that $M_1M_2 = a/2$. The path difference between M_1 and M_2 at P = $M_2P - M_1P = \theta a/2 = \lambda/2$ for the angle chosen. This means that the contributions from M_1 and M_2 are 180° out of phase and cancel in the direction $\theta = \lambda/a$. Contributions from the two halves of the slit LM and MN, therefore, cancel each other.

Equation (i) gives the angle at which the intensity falls to zero. Similarly we can show that the intensity is zero for $\theta = n\lambda/a$, with n being any integer (except zero!).

Angular size of the central maximum increases when the slit width a decreases.

Consider an angle $\theta = 3\lambda/2a$ which is midway between two of the dark fringes.

Divide the slit into three equal parts. If we take the first two thirds of the slit, the path difference between the two ends would be

$$\frac{2}{3}a \times \theta = \frac{2a}{3} \times \frac{3\lambda}{2a} = \lambda$$

The first two-thirds of the slit can therefore be divided into two halves which have a $\lambda/2$ path difference. The contributions of these two halves cancel in the same manner as described earlier. Only the remaining one-third of the slit contributes to the intensity at a point between the two minima. This will be much weaker than the central maximum.
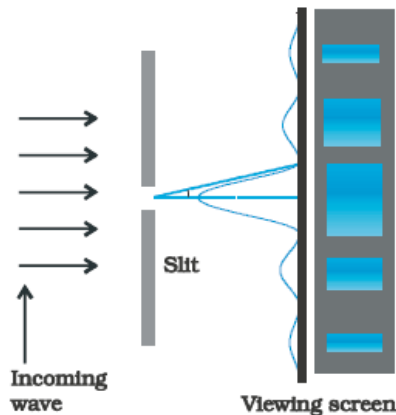
Intensity distribution and photograph of fringes due to diffraction at single slit.

Similarly we can show that there are maxima at $(n + 1/2)\, \theta/a$ with n = 2, 3, etc.

These become weaker with increasing n, since only one-fifth, one-seventh, etc., of the slit contributes in these cases.

OR

A simple microscope has a limited maximum magnification (≤ 9) for

realistic focal lengths. For much larger magnifications, one uses two lenses, one compounding the effect of the other. This is known as a *compound microscope*.

A schematic diagram of a compound microscope is shown below
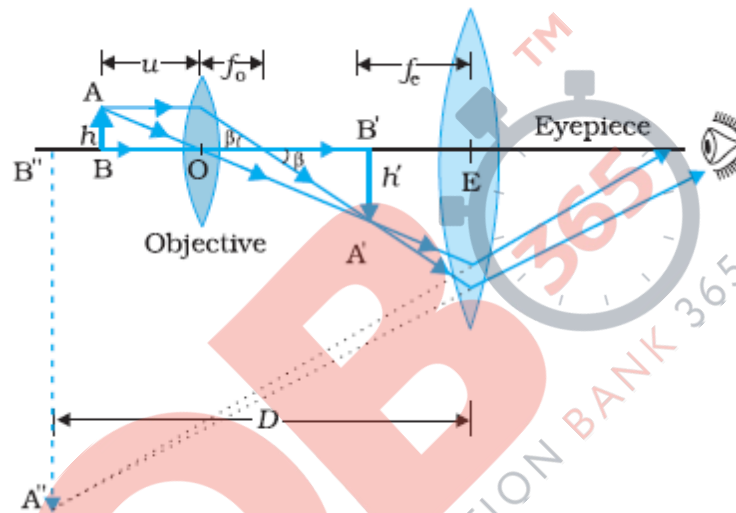
The result for a compound microscope to obtain the (angular) magnification m_e due to it when the final image is formed at the near point, is $m_{e} = 1 + D/f_e$

Where,

D = Image Distance

f_e = focal length of eyepiece

Given,

f_o = 1.25 cm.

u = 1.5 cm.

f_e = 5 cm.

We know,

$1/v - 1/u = 1/f$

Therefore, $1/v = 1/f + 1/u = 1/1.25 + 1/1.5$

i.e. v= 1. 46

We can write,

L = f_o + fe + (v - f_o) = 1.25 + 5 + (1.46 − 1.25) = 6.46

As the final image is formed at a near point we can take

D = 25 cm.

Therefore,

m_e = 1 + D/ fe

$\quad$ = 1 + 25/5 = 1 + 5 = 6

m_o = L/ f_o = 6.46/1.25 = 5.17

Thus magnification of the microscope is given by,

m = m_o m_e = 5.17 $\times$ 6 = 31.04

30. (a) When a p-n junction is formed, there are more electrons on the n-side and more holes on the p-side. Because of this concentration gradient, electrons from n-side will diffuse towards the p-side and holes from the p-side will diffuse to the n-side. On crossing the p-n boundary, these electrons and holes may collide with each other and recombine. Hence, the donor or acceptor atoms get depleted of their associated electrons or holes and will be left with a charged ion core in the layer near the junction boundary. Hence, a layer called the **depletion layer** is formed at the junction.

An important consequence of formation of this depletion layer is the appearance of a junction potential. This is in a direction opposing any further diffusion of majority carriers from either side. This potential acts as a barrier and is hence, known as a 'barrier potential', V_B. The potential barrier and the depletion layer width is directly proportional to the doping concentration on both sides.

(b) The device is Full wave rectifier.

Diagram of the full wave rectifier is:
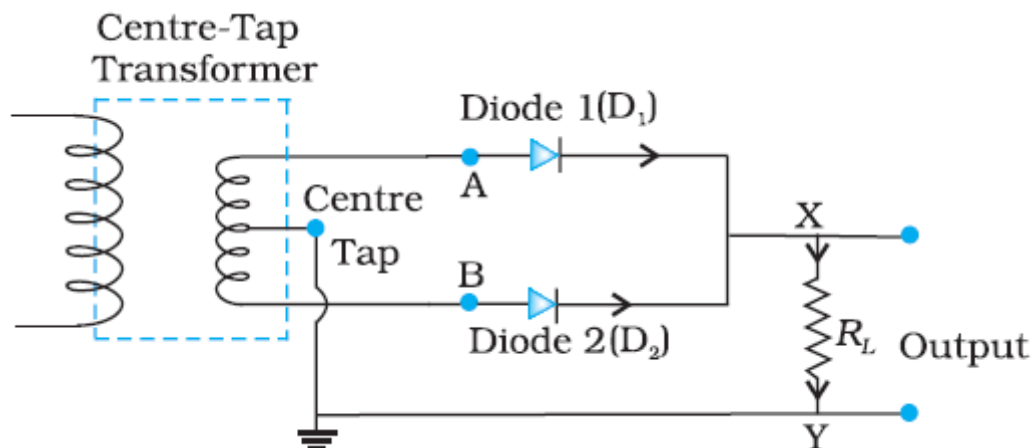
(c) The given logic gate is that of an AND gate.

Its truth table is

A	B	X	Y
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

OR

(a) Principle:

In an oscillator, one gets sinusoidal output signal without any sinusoidal input signal. That is, essentially the output is self-sustained. To get self-sustained oscillations, one requires an amplifier, which returns a portion of the output power back to the input, in phase with the starting power (positive feedback).
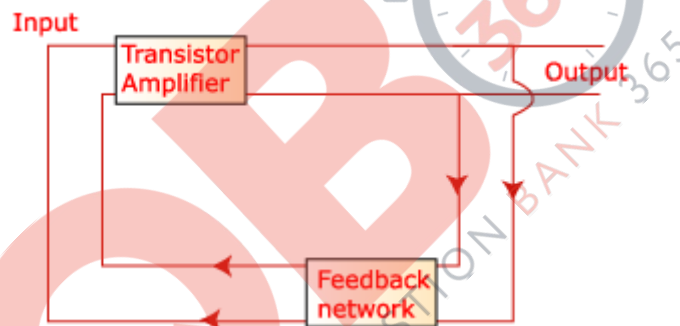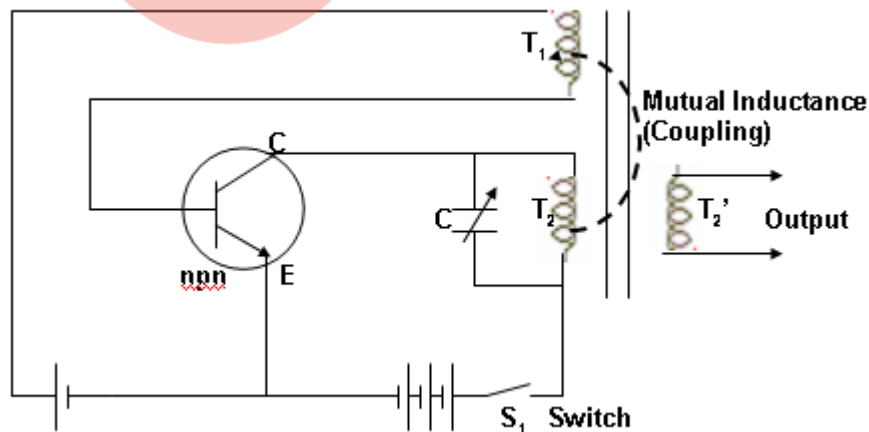

Fig: Feedback mechanism in the oscillator circuit

Fig. A simple LC Oscillator

Working:

Coils T_1 and T_2 are wound on the same core and are hence inductively coupled through mutual inductance. Now, suppose switch S_1 is put on the first time. This

makes collector current through the transistor flow. This flows through coil T_2, which through inductive coupling to coil T_1, makes emitter current flow. This is the feedback effect.

As current through T_2 reaches saturation, there is no EMF induced in T_2, and feedback stops, making the emitter current fall. This also makes the collector current fall, inducing an EMF in T_1, making the emitter current decay further till it makes the transistor reach 'cut-off'. Then, both I_C and I_E cease to flow. So, the transistor has come back to its starting position.

The process now repeats itself repeatedly, with a frequency

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where L is the inductance of T_2.

(b) In case of a metal, the band gap is zero, which makes a large number of electrons available for conduction.
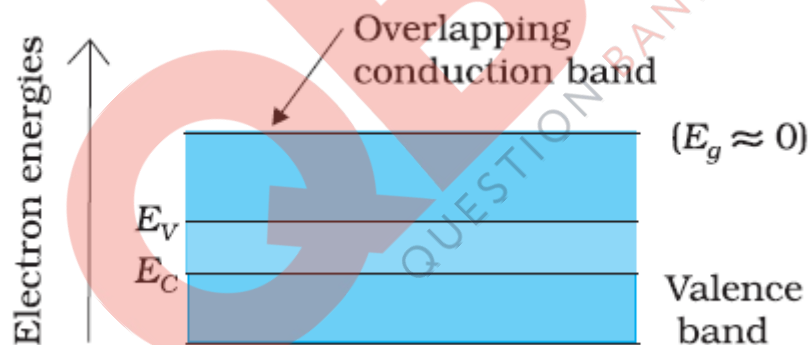

Fig: Energy band diagram of metals

In semi-conductors, a finite, but small energy gap exists, which makes it possible for some electrons to be thermally excited to the conduction band.
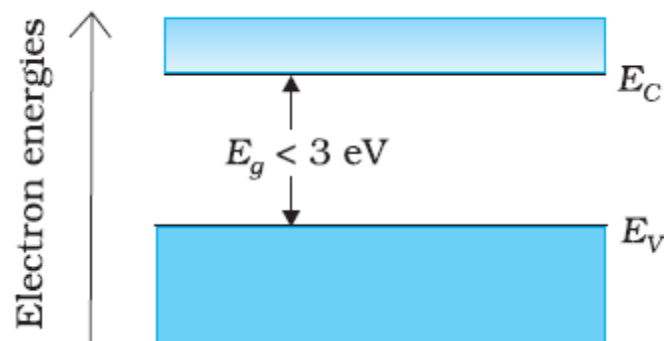
Fig: Energy band diagram of semiconductors

In case of insulators, this gap is large, $E_g > 3eV$. There are no electrons in the conduction band, and so no conduction is possible. The band gap is so large, that no external stimulation can excite electrons from the valence band to the conduction band.
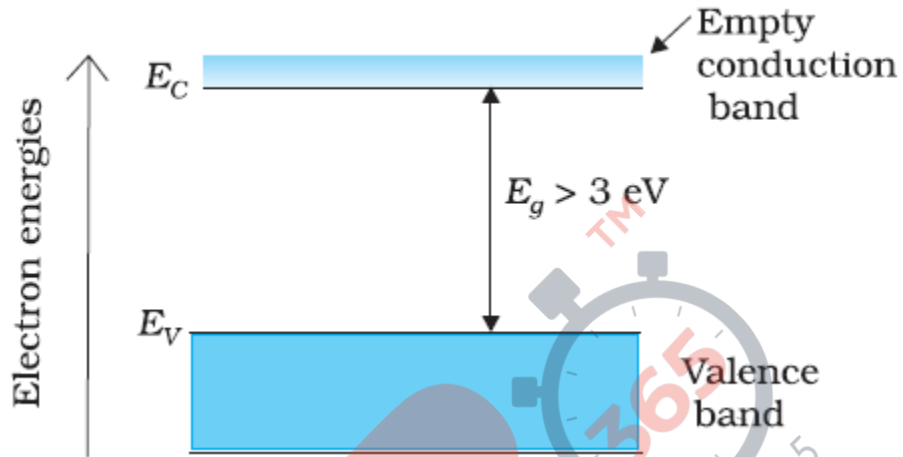

Fig: Energy band diagram of insulators