Phy.

Code No. **SS/40/1**

Roll No. | | | | | | | |

Candidates must write the Code on the title page of the answer-book

PHYSICS (Theory) & SOLUTION

Time allowed : $3\frac{1}{4}$ hours **Maximum Marks : 56**

General Instructions :

(i)

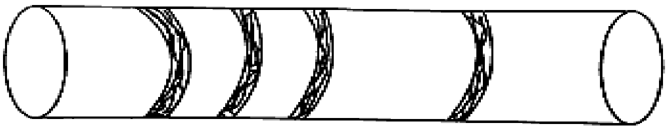
T Q. No. S.	*Marks per question*
1 – 13	*1*
14 – 24	*2*
25 – 27	*3*
28 – 30	*4*

(ii) ***There are internal choices in Q. No. 21 and 27 to 30.***

1. Calculate electric potential at a point 1 m distance from a point charge of 10^{-9} coulomb.

Ans. $V = \frac{kq}{r} = \frac{9\times10^{9}\times10^{-9}}{1} = 9\text{Volt}$

2. In a given diagram value of carbon resistor is $22\times10^{5}\Omega\pm5\%$. Write colour of first ring A.



Ans. Red

3. Write formula for force on a current carrying conductor in a magnetic field.
Ans. $F = BIL\sin\theta$

4. Define angle of dip. Write value of angle of dip at magnetic poles of earth.
Ans. (i) Angle of dip or magnetic inclination:
The angle made by the earth's total magnetic field with the horizontal direction in the magnetic meridian is called angle of dip (δ) at any place.
(ii) 90°

5. Write relation between root mean square (rms) value and peak value of alternating current.

Ans. $I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707\ I_0$, Where I_0 = peak value of alternating current.

6. In LCR alternating circuit, R = 10 Ω, X_L = 100 Ω and X_C = 100Ω. Write value of impedance of circuit.

Ans. $Z = \sqrt{R^2 + (X_L - X_C)^2}$, $X_L = X_C$, $Z = R = 10\Omega$

7. Write relation between power of lens and it's focal length.

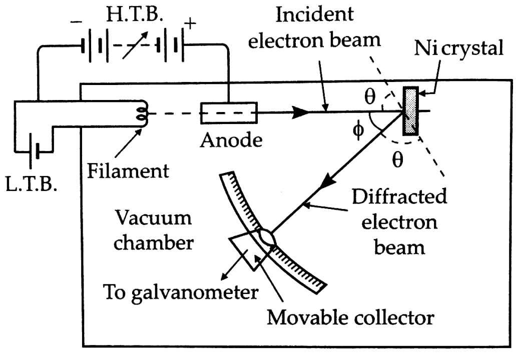
Ans. Power of lens = $\dfrac{1}{\text{Focal length(in m.)}}$

8. Define threshold frequency.

Ans. For a given photosensitive material, there exists a certain minimum cut-off frequency below which no photoelectrons are emitted, howsoever high in the intensity of incident radiation. This frequency is called threshold frequency.

9. Draw diagram of the experimental arrangement of Davisson and Germer experiment.

Ans. Here the electrons emitted by the hot filament of an electron gun are accelerated by applying a suitable potential difference V between the cathode and anode.

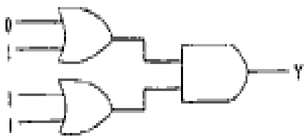


Experimental arra

10. Write name of series of hydrogen energy level n_2 = 2,3,4,5 ……….. to ground er

Ans. Lyman Series

11. Write value of output Y in diagram



Ans. Y = 1

12. Define modulation.

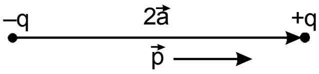
Ans. The original low frequency message signal cannot be transmitted to long distances. Hence, modulation of the low frequency signal is done. Modulation is the phenomenon of superimposing the low frequency message signal (called the modulating signal) on a high frequency wave (called the carrier wave).

13. In electromagnetic waves, write the value of (A) angle and (B) phase difference, between electric filed $\vec{E}$ and magnetic field $\vec{B}$.

Ans. angle = 90 and Phase difference = Zero.

14. Define:
(a) Electric dipole moment
(b) Equipotential surface

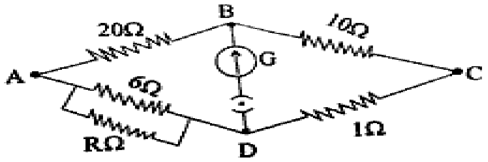
Ans. (a) Electric Dipole moment: It measures the strength of an electric dipole. The dipole moment of an electric dipole is a vector whose magnitude is the product of magnitude of both charge and the separation between the two opposite charges and the direction is along the dipole axis from the negative to the positive charge.



$\vec{p} = q(2\vec{a})$

(b) Equipotential surface: Any surface that has same electric potential at every point on it is called an equipotential surface.

15. Calculate the value of unknown resistance R in given circuit. If Wheatstone bridge is in balanced condition.



Ans. If $I_g = 0$ Then,

$$\frac{P}{Q} = \frac{R'}{S}$$

$$PS = R'Q$$

$$20 \times 1 = \frac{1}{\left(\frac{1}{6} + \frac{1}{R}\right)} \times 10$$

$$\Rightarrow R = 3\Omega$$

16. (a) Define Curie temperature.
(b) The pole strength of poles of a bar magnet of effective length 0.1 m is 40 A –m. Calculate its magnetic moment.

Ans. (a) The temperature at which a ferromagnetic substance becomes paramagnetic is called Curie temperature or Curie point T_C.

(b) $2l = 0.1m$

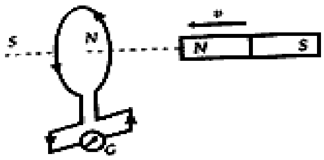
$m = 40A - m$

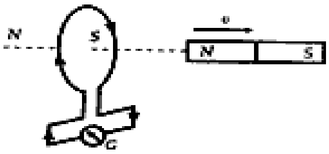
$M = m(2l)$

$M = 40 \times 0.1 = 4A. - m^2$

17. Write Lenz's law. Lenz's law obey's law of conservation of energy. Explain.

Ans. Lenz's law states that the direction of induced current in a circuit is such that it opposes the cause or the change which produces it.

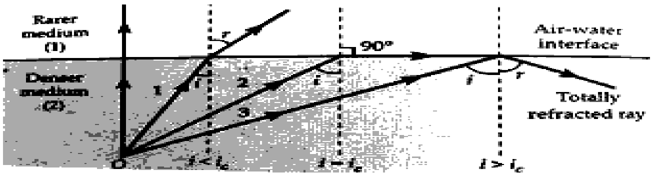




Whether a magnet is moved towards or away from a closed, coil, the induced current always opposes the motion of the magnet, as predicted by Lenz's law. For example, when the north pole of a magnet is brought closer to a coil its face towards the magnet develops north polarity and thus repels North Pole of the magnet. Work has to be done in moving the magnet closer to the coil against this force of repulsion. Similarly, when the north pole of the magnet is moved away from the coil its face towards the magnet develops south polarity and thus attracts the north pole of the magnet. Here work has to be done in moving the magnet away from the coil against this force of attraction. It is this work done against the force of repulsion or attraction that appears as electric energy in the form of induced current. Suppose that the Lenz's law is not valid. then the induced current flows through the coil in a direction opposite to one dictated by Lenz's law. The resulting force on the magnet makes it move faster and faster, i.e., the magnet gains speed and hence kinetic energy without expending an equivalent amount of energy. This sets up a perpetual motion machine, violating the law of conservation of energy. Thus Lenz's law is valid and is a consequence of the law of conservation of energy.

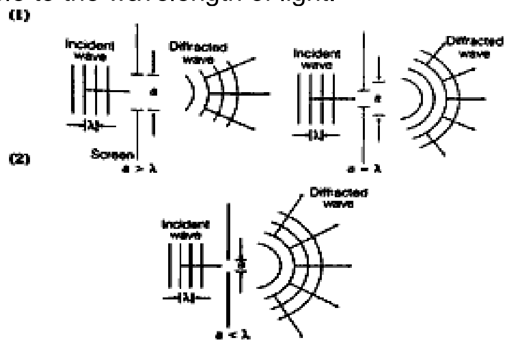
18. Write definitions
(a) Total internal reflection
(b) Diffraction of light.

Ans. (a) If light passes from an optically denser medium to a rarer medium, and then at the interface the light is partly reflected back into the denser medium and partly refracted to the rarer medium. This reflection is called internal reflection. Under certain conditions, the whole of the incident light can be made to be reflected back into the denser medium. This gives rise to an interesting phenomenon called total internal reflection.



Total internal reflection

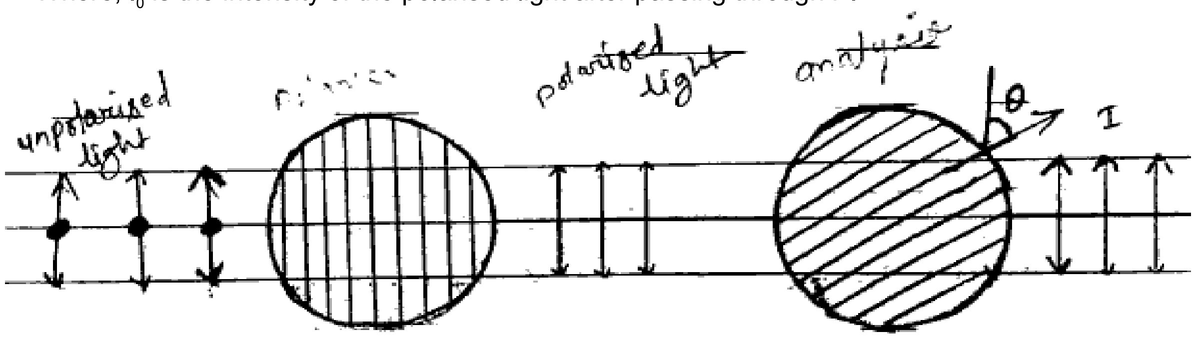
(b) DIFFRACTION OF LIGHT:
The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light. The light thus deviates from its linear path. The deviation becomes much more pronounced, when the dimensions of the aperture or the obstacle are comparable to the wavelength of light.



Diffraction of light.

19. (a)Write formula related to Malus law.
(b) When light is incident at 60° on a transparent sheet, the reflected light is completely polarised. Find the refractive index of the substance and refraction angle.

Ans. (a) According to this law, "when a beam of completely plane polarised light is incident on an analyser, the resultant intensity of light I transmitted from the analyser varies directly as the square of the cosine of the angle between the plane of transmission of analyser and polariser".
$I = I_0 \cos^2\theta$ [this rule is also called cosine squared rule]
Where, I_0 is the intensity of the polarised light after passing through P.



(b) $\mu = \tan i_p$

$\mu = \tan 60° = \sqrt{3} = 1.73$

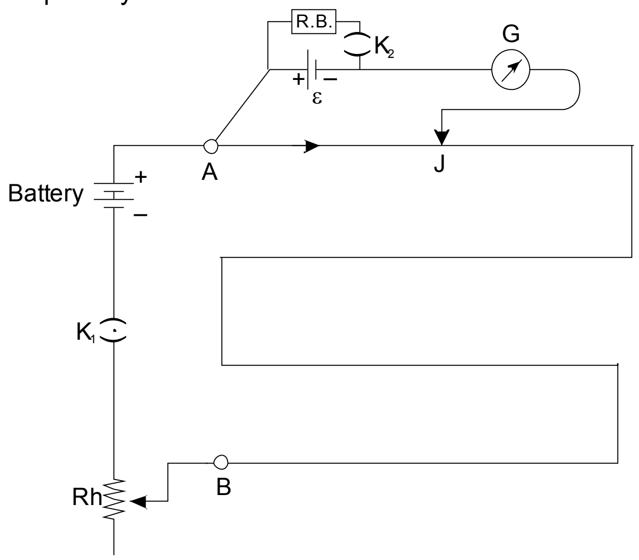
$i_p + r = 90°, r = 90° - i_p$, $r = 90° - 60° = 30°$ angle of refraction r = 30°

20. Calculate de Broglie wavelength of a wave associated with an electron, which is accelerated through a potential difference of 100 V.

Ans. $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.227\ \overset{0}{A}$.

21. Derive formula for obtaining internal resistance of a primary cell with help of potentiometer. Draw circuit diagram.

Ans. (i) Internal resistance of primary cell:



Internal resistance of primary cell

Close the key K_1. A constant current flows through the potentiometer wire. With key K_2 kept open, move the jockey along AB till it balances the emf ε of the cell. Let l_1 be the balancing length of the wire. If k is the potential gradient, then emf of the cell will be :

$\varepsilon = kl_1$

With the help of resistance box R.B., introduce a resistance R and close key K_2. Find the balance point for the terminal potential difference V of the cell. If l_2 is the balancing length, then

$V = kl_2$

Divide the above two equation

$\frac{\varepsilon}{V} = \frac{l_1}{l_2}$

Let r be the internal resistance of the cell. If current I flows through cell when it is shunted with resistance R, then from Ohm's law we get

$\varepsilon = I(R + r)$ and $V = IR$

$\therefore\ \frac{\varepsilon}{V} = \frac{R+r}{R} = \frac{l_1}{l_2}$; $1+\frac{r}{R} = \frac{l_1}{l_2}$ or $\boxed{\frac{r}{R} = \frac{l_1 - l_2}{l_2}}$

$\therefore$ internal resistance, $r = R\left[\frac{l_1 - l_2}{l_2}\right]$

OR

Explain the method to find unknown resistance with the help of Meter Bridge. Draw circuit diagram.

Ans. Metre bridge (or slide wire bridge) :

It is the simplest practical application of the Wheatstone bridge that is used to measure an unknown resistance.

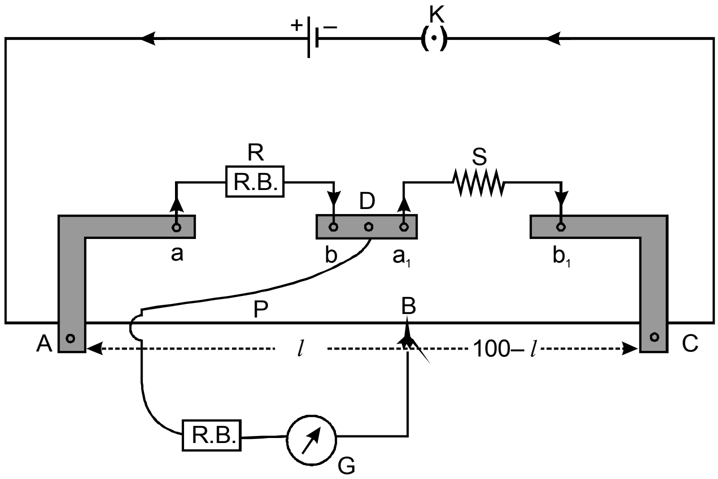
Principle: Its working is based on the principle of Wheatstone bridge.

When the bridge is balanced,

$$\boxed{\frac{P}{Q} = \frac{R}{S}}$$

Construction:

- It consists of usually one metre long manganin wire of uniform cross-section, stretched along a metre scale fixed over a wooden board and with its two ends soldered to two L-shaped thick copper strips and C.
- Between these two copper strips, another copper strip is fixed so as to provide two gaps ab and a_1b_1.
- A resistance box R.B. is connected in the gap ab and the unknown resistance S is connected in the gap a_1b_1.
- A source of emf ε is connected across AC. A movable jockey and a galvanometer are connected across BD, as shown in Figure.



Measurement of unknown resistance by a metre bridge

Working:

After selecting a suitable resistance R from the resistance box, the jockey is moved along the wire AC till there is no deflection in the galvanometer. This is the balanced condition of the Wheatstone bridge. If P and Q are resistances of the parts AB and BC of the wire, then for the balanced condition of the bridge, we have

$$\frac{P}{Q} = \frac{R}{S}$$

Let total length of wire AC = 100 cm and AB = l cm, then BC = $(100 - l)$ cm. Since the bridge wire is of uniform cross-section, therefore,

Resistance of wire $\propto$ length of wire or $\boxed{R \propto l}$

or $\frac{P}{Q} = \frac{\text{resistance of AB}}{\text{resistance of BC}}$

$$= \frac{\sigma l}{\sigma(100 - l)} = \frac{l}{100 - l}$$

where σ is the resistance per unit length of the wire

Hence

$$\boxed{\frac{R}{S} = \frac{l}{100 - l}}$$

or $S = \frac{R(100 - l)}{l}$

Knowing l and R, unknown resistance S can be determined.

22. Write Niels Bohr's any two postulates for hydrogen atom (hydrogen like ions).

Ans. (i) **Bohr's first postulate** was that an electron in an atom could revolve in certain stable orbits without the emission of radiant energy, contrary to the predictions of electromagnetic certain definite stable states in which it can exist and each possible state has definite total energy. These are called the stationary states of the atom.

(ii) **Bohr's second postulate** states that the electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $h/2\pi$, where b is the Planck's constant (= 6.63 × 10^{-34} J-s).

Thus, the angular momentum (L) of the orbiting electron is quantised,

i.e. $L = \frac{nh}{2\pi}$

As, angular momentum of electron = mvr

For any permitted (stationary) orbit

$$mvr = \frac{nh}{2\pi}$$

Where, n = any positive integer 1, 2, 3……

It is also called principal quantum number.

(iii) Bohr's third postulate states that an electron might make a transition from one of its specified non - radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states.

The frequency of the emitted photon is given by

Where, E_i and E_f are the energies of the initial and final states and . $E_i > E_f$

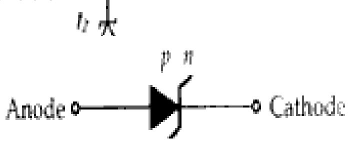
23. (a) Select acceptor type impurity among the following :

Arsenic (As), Antimony (Sb), gallium (Ga) and phosphorous (P).

(b) Draw symbol of Zener diode.

Ans. (a) Gallium (Ga)

(b)



Zener diode.

24. The magnitude of electric field $\vec{E}$ at a point in free space is 300 V/m. Find the magnitude of magnetic field $\vec{B}$ at this point. Velocity of light is 3 × 10^8 m/s.

Ans. $C = \frac{\vec{E}}{\vec{B}}$

$$\vec{B} = \frac{\vec{E}}{C}$$

$$\vec{B} = \frac{300}{3} \times 10^{-8}$$

$$\vec{B} = 10^{-6}\,T$$

25. Write Rutherford – Soddy law of radioactive decay and derive related equation.

Draw exponential decay curve of a radioactive substance.

Write ratio of half life and mean life of a radioactive substance.

Ans. (a) Soddy-Fajan's displacement laws (or Radioactive displacement laws) :

1. When a radioactive nucleus emits an α-particle, its atomic number decreases by 2 and mass number decreases by 4.

2. When a radioactive nucleus emits a β-particle, its atomic number increases by 1 but mass number remains the same.

3. The emission of a γ-particle does not change the mass number or the atomic number of the radioactive nucleus.

Radioactive decay law :

The number of nuclei disintegrating per second of a radioactive sample at any instant is directly proportional to the number of undecayed nuclei present in the sample at that instant.

Let

N_0 = the number of radioactive nuclei present initially at time t = 0 in a sample of radioactive substance.

N = the number of radioactive nuclei present in the sample at any instant t, and

dN = The number of radioactive nuclei which disintegrate in the small time interval dt.

According to radioactive law, the rate of decay at any instant is proportional to the number of undecayed nuclei, i.e.,

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

or $\boxed{-\frac{dN}{dt} = \lambda N}$ Mathematical form of radioactive decay law.

where λ is a proportionality constant called the decay or disintegration constant.

Here the negative sign shows that the number of undecayed nuclei, (N) decreases with time.

The above equation can be written as

Integrating, $\int \frac{dN}{N} = -\lambda \int dt$

or $\log_e N = -\lambda t + C$

where C is a constant of integration.

At t = 0, N = N_0 therefore from equation (2), we get $\log_e N_0 = C$

Then the equation (2) becomes

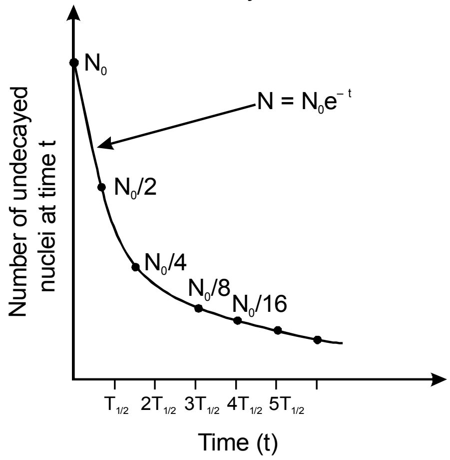
$$\log_e N_0 = -\lambda t + \log_e N_0$$

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

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

or $\boxed{N = N_0 e^{-\lambda t}}$ Another Mathematical form of radioactive decay law.

(b) Graph showing variation of number of undecayed nuclei with time :



Decay curve for a radioactive element

(C) Relation between half life and mean life :

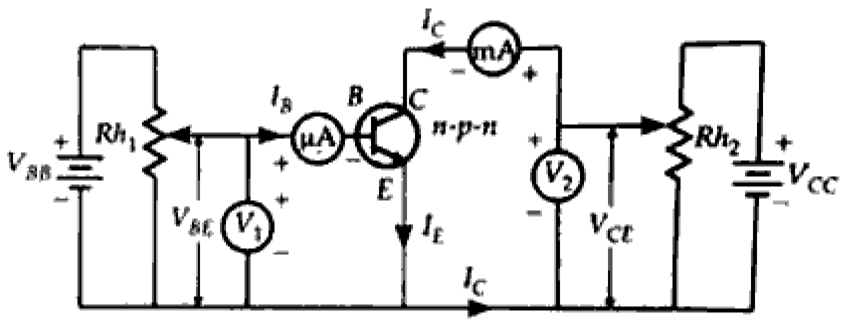
We know that $\tau = \frac{1}{\lambda}$ .... (1)

$T_{1/2} = \frac{0.693}{\lambda} \Rightarrow \frac{1}{\lambda} = \frac{T_{1/2}}{0.693}$ .... (2)

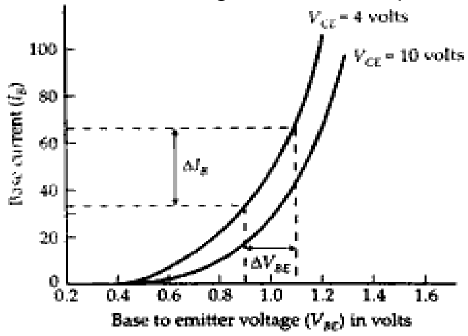
Put (2) in (1) $\boxed{\tau = \frac{T_{1/2}}{0.693} = 1.44\, T_{1/2}}$

26. Describe the experimental set up for obtaining output characteristic curve of a PNP transistor in common emitter configuration with suitable circuit diagram. Also draw the curve obtained.
Select possible value of common base current amplification factor α of a transistor among the following. 0.9,9,19,49 and 99.

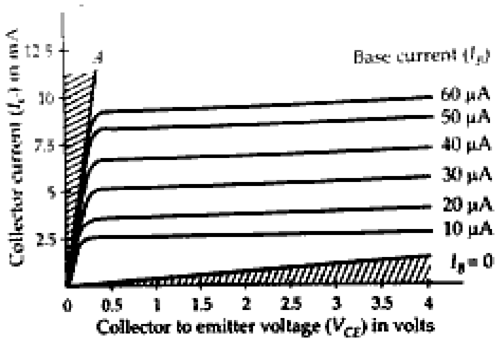
Ans. **Common emitter characteristics:** The common emitter characteristics are the graphs drawn between appropriate voltages and currents for a transistor when its emitter is taken as the common terminal and grounded (zero potential), base is the input terminal and collector is the output terminal.
The emitter-base junction is forward biased by means of battery V_{BB} through rheostat Rh_1. The emitter-collector circuit is reverse biased by means of battery V_{CC} through rheostat Rh_2. The base-emitter voltage V_{BE} and the collector-emitter-voltage V_{CE} are measured by high resistance voltmeters. The base current I_B. is measured by a microammeter and the collector current I_C by a miliammeter.



Input Characteristic : A graph showing the variation of base current I_B with base-emitter voltage V_{BE} at constant collector-emitter voltage V_{CE} is called the input characteristic of the transistor. Two such curves for two different collector-emitter voltages have been plotted in fig.



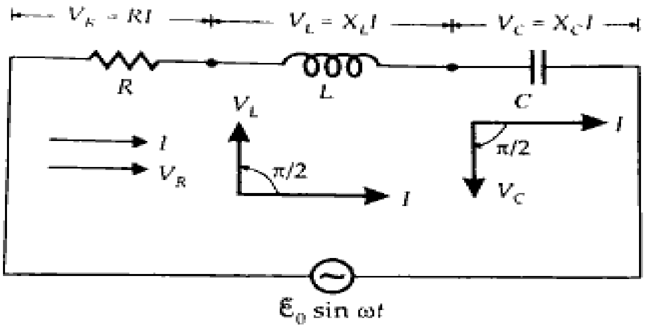
Output characteristic A: graph showing the variation of collector current I_C with collector-emitter voltage V_{CE} at constant base-current I_B the output characteristic of the transistor. Fig. shows such curves for different values of I_B.



The possible value of common base current amplification factor α of a transistor is 0.9

27. Draw vector diagram (phasor diagram) for a series RLC circuit which is connected with an alternating voltage source and determine the expression for impedance of the circuit.

Ans. **Series LCR - circuit : -** Suppose a resistance R, an inductance L and capacitance C are connected in series to a source of alternating emf given by



A series LCR - circuit.

1. Voltage $\vec{V}_R = R\vec{I}$ across the resistance R will be in phase with current $\vec{I}$. So phasors $\vec{V}_R$ and $\vec{I}$ are is same direction. The amplitude of $\vec{V}_R$ is

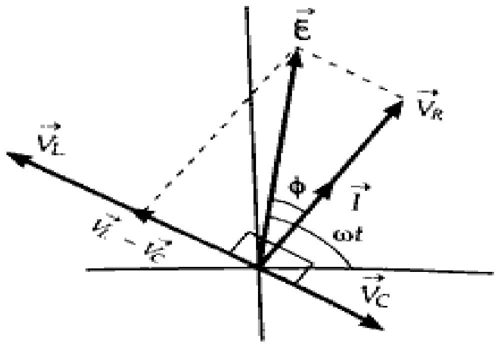
$$V_0^R = I_0 R$$

2. Voltage $\vec{V}_L = X_L\vec{I}$ across the inductance L is ahead of current I in phase by $\pi/$ rad. So phasor $\vec{V}_L$ lies $\pi/$ rad anticlockwise w.r.t. the phasor $\vec{I}$. Its amplitude is

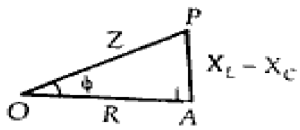
$$V_0^L = I_0 X_L$$

3. Voltage $\vec{V}_C = X_C\vec{I}$ across the capacitance C lags behind the current $\vec{I}$ in phase by $\pi/$ rad. So phasor $\vec{V}_C$ lies $\pi/$ clockwise w.r.t. the phasor $\vec{I}$. Its amplitude is

$V_0^C = I_0 X_C$



Phasor diagram
for a series LCR - circuit
when $V_L > V_C$



Impedance
triangle when $X_L > X_C$

As $\vec{V}_L$ and $\vec{V}_C$ are in opposite directions, their resultant is $\left(\vec{V}_L - \vec{V}_C\right)$. By parallelogram law, the resultant of $\vec{V}_R$ and $\left(\vec{V}_L - \vec{V}_C\right)$ must be equal to the applied emf $\vec{\varepsilon}$, given by the diagonal of the parallelogram.

$$\varepsilon_0^2 = \left(V_0^R\right)^2 + \left(V_0^L - V_0^C\right)^2 = (I_0R)^2 + (I_0X_L - I_0X_C)^2 = I_0^2\left[R^2 + (X_L - X_C)^2\right]$$

$$I_0 = \frac{\varepsilon_0}{\sqrt{R^2 + (X_L - X_C)^2}}$$

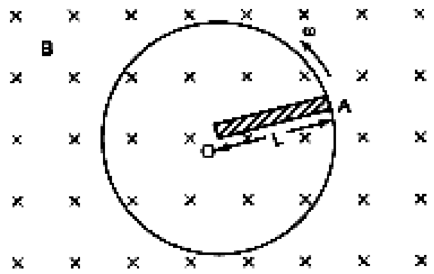
Clearly, $\sqrt{R^2 + (X_L - X_C)^2}$ is the effective resistance of the series LCR - circuit which opposes or impedes the flow of current through it and is called its impedance. It is denoted by Z and its SI unit is ohm (Ω). Thus

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

OR

Derive an expression for induced emf in a rod rotating in a uniform magnetic field. Draw necessary diagram.

Ans.



O will be at a higher potential than A.

Suppose the rod completes one revolution in time T.
Area swept in one rotation $= \pi L^2$
Change in flux in one rotation = $B.\pi L^2$
Induced emf =Rate of change of magnetic flux

$$= \frac{\text{Change in flux}}{\text{Time}}$$

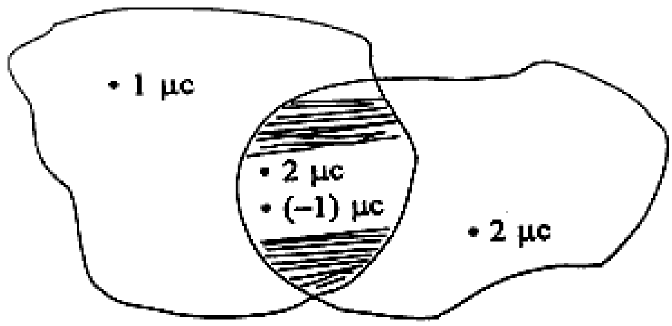
$$= \frac{B.\pi L^2}{T}$$

$$= \frac{B.\pi L^2}{\frac{2\pi}{\omega}}$$

$$= \frac{1}{2} BL^2\omega$$

$$\therefore \quad |e| = \frac{1}{2} BL^2\ \omega.$$

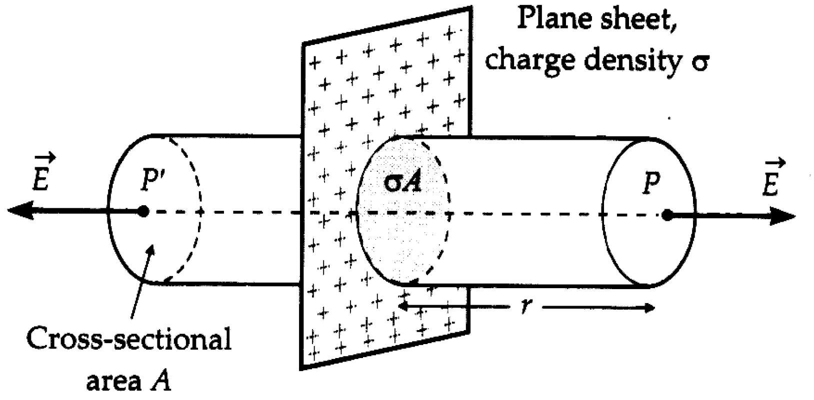
28. (a) Write the statement of Gauss's law for electrostatics. Derive an expression for electric field due to an uniformly charged infinite non – conducting sheet at a point near to it. Draw suitable diagram.
(b) Calculate net electric flux from shaded region in given diagram.



Ans. **(a) Gauss theorem** states that the total flux through a closed surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the closed surface.
Mathematically, it can be expressed as

$$\phi_E = \oint \vec{E}.d\vec{s} = \frac{q}{\varepsilon_0}$$

Consider a thin, infinite plane sheet of charge with uniform surface charge density σ. We wish to calculate its electric field at a point P at distance r from it.



By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P and P′ equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2r with its axis perpendicular to the sheet.

As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is

$\phi_E = EA + EA = 2\,EA$ (A = cross sectional area of plane-end faces)

Charge enclosed by the Gaussian surface,

$$q = \sigma A$$

According to Gauss's theorem,

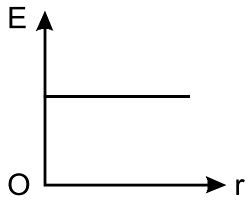
$$\phi_E = \frac{q}{\varepsilon_0}$$

$$\therefore \quad 2\,EA = \frac{\sigma A}{\varepsilon_0} \text{ or } E = \frac{\sigma}{2\varepsilon_0}$$

Clearly, E is independent of r, the distance from the plane sheet.

(i) If the sheet is positively charged ($\sigma > 0$), the field is directed away from it.

(ii) If the sheet is negatively charged ($\sigma > 0$), the field is directed towards it.



Variation of electric field (E) due to a uniformly charged infinite plane sheet with distance (r)

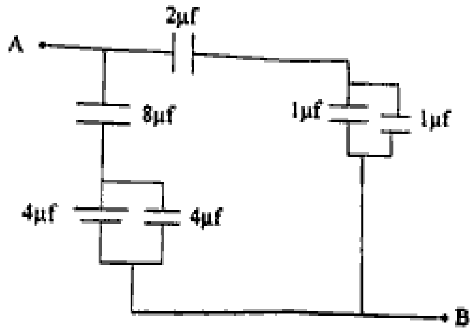
(b) $\phi_\varepsilon = \dfrac{(q_{in})_{net}}{\varepsilon_0}$

$$\phi_\varepsilon = \frac{+2\mu C - 1\mu C}{\varepsilon_0} = \frac{+1\mu C}{\varepsilon_0} = \frac{1\times 10^{-6}}{8.854\times 10^{-12}} = 0.1129\times 10^{6}\,\text{Vm}$$

OR

(a) Define capacitor. Draw a circuit diagram and obtain a relation for equivalent capacitance for the series combination of three capacitors.

(b) Find the equivalent capacitance between points A and B in given figure.

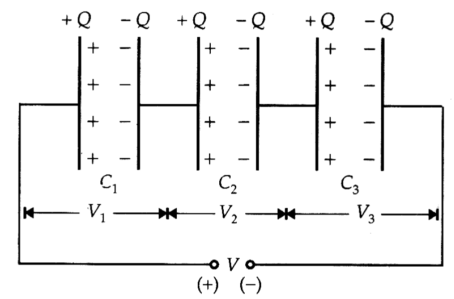


Ans. (a) A capacitor is an arrangement of two conductor separated by an insulating medium (or dielectric medium) that is used to store electric charge and electric energy.

The capacitance of an insulated charged conductor is considerably increased when we place an earthed connected conductor near it. Such a system of two conductors is called a capacitor.

Series combination of capacitor –

When the negative plate of one capacitor is connected to the positive plate of the second and the negative of the second to the positive of third and so on, the capacitors are said to the connected in series.



In series:

(i) Charge across each capacitor remains same

(ii) Potential difference across each capacitor is different

The potential differences across the various capacitors are

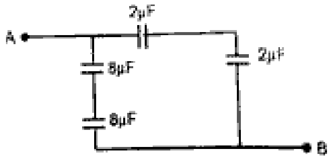
$$V_1 = \frac{Q}{C_1},\ V_2 = \frac{Q}{C_2},\ V_3 = \frac{Q}{C_3}$$

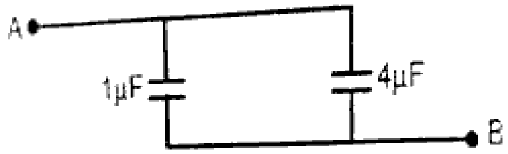
For the series circuit, the sum of these potential differences must be equal to the applied potential difference

$$\therefore \quad V = V_1 + V_2 + V_3 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \text{ or } \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad \text{.................. (1)}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(b) Capacitor 4μF and 4μF are parallel to each other, so there equivalent capacitance is 4μF + 4μF = 8μF. Also capacitors of 1μF and 1μF are parallel to each other so that the equivalent capacity 1 + 1 = 2μF. This is as shown below.





Now capacitors 2mF are in series, so that their equivalent capacitance = $\frac{2\times2}{2+2}=\frac{4}{4}=1\mu F$. Similarly capacitors of 8μF are in series, so that their equivalent capacitance $=\frac{8\times8}{8+8}=\frac{64}{16}=4\mu F$.

Now capacitors of capacitance 1μF and 4μF are parallel to each other, so equivalent capacitance = 4 + 1 = 5μF

Thus the equivalent capacitance between A and B in the given circuit = 5μF.

29. (a) Write Ampere's law.

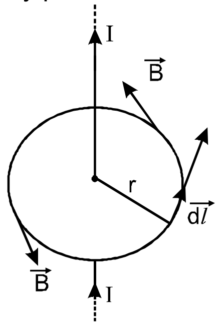
(b) Draw a diagram and derive and expression for magnetic field due to an infinitely long straight current carrying conductor at any point

Ans. **(a) Ampere's circuital law:**

Ampere's circuital law states that the line integral of the magnetic field $\vec{B}$ around any closed circuit is equal to μ_0 (permeability constant) times the total current I threading or passing through this closed circuit. Mathematically.

$$\oint \vec{B} d\vec{l} = \mu_0 I$$

(b) Consider a circular loop of radius r around an infinitely long straight wire carrying current I. As the field lines are circular, the field $\vec{B}$ at any point of the circular loop is directed along the tangent to the



circle at that point. By symmetry, the magnitude of field $\vec{B}$ is same at every point of the circular loop. Therefore,

$$\oint \vec{B}.dl = \oint \vec{B} dl \cos 0 = \vec{B}\oint dl = B.2\pi r$$

From Ampere's circuital law,

$$B.2\pi r = \mu_0 I$$

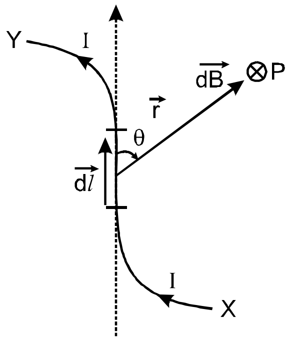
$$\therefore \quad \boxed{B = \frac{\mu_0 I}{2\pi r}}$$

OR

(a) Write Biot – Savart law.

(b) Write the working of cyclotron in brief. Draw a schematic sketch of the cyclotron showing path of accelerated charged particles (ions) in both dees. Derive expression for cyclotron frequency.

Ans. **(a)** According to **Biot-Savart law,** the magnitude of the field $\overrightarrow{dB}$ is :



1. Directly proportional to the current I through the conductor,
$dB \propto I$

2. Directly proportional to the length dl of the current element,
$dB \propto dl$

3. Directly proportional to $\sin\theta$,
$dB \propto \sin\theta$

4. Inversely proportional to the square of the distance r of the point P from the current element,
$dB \propto \frac{1}{r^2}$

Combining all these four factors, we get

$$dB \propto \frac{I\,dl\,\sin\theta}{r^2}$$

or $$dB = \frac{\mu_0}{4\pi}.\frac{I\,dl\,\sin\theta}{r^2}$$

Here $\frac{\mu_0}{4\pi} = 10^{-7}\,TmA^{-1}$ (or $Wb\text{-}m^{-1}\,A^{-1}$)

Here μ_0 is a constant called permeability of free space.

(b) **Cyclotron :**

it is a device used to accelerate charged particles like protons, deuterons, α-particles, etc. to very high energies.

Principle :

A charged particle can be accelerated to high speeds (energies) by passing it through electric field many number of times and at the same time magnetic field makes the charged particle to move in a circular path.

Construction :

A cyclotron consists of the following main parts :

1. It consists of two small, hollow, metallic half-cylinders D_1 and D_2, called dees (as they are in the shape of D).

2. They are mounted inside a vacuum chamber between the poles of a powerful electromagnet.

3. The dees are connected to the source of high frequency alternating voltage source of few hundred kilovolts.

4. The beam of charged particles to be accelerated is injected into the dees near their centre, in a plane perpendicular to the magnetic field.

5. The charged particles are pulled out of the dees by a deflecting plate (which is negatively charged) through a window W.

6. The whole device is in high vacuum (pressure -10^{-6} mm of Hg) so that the air molecules may not Collide with the charged particles.

Theory :

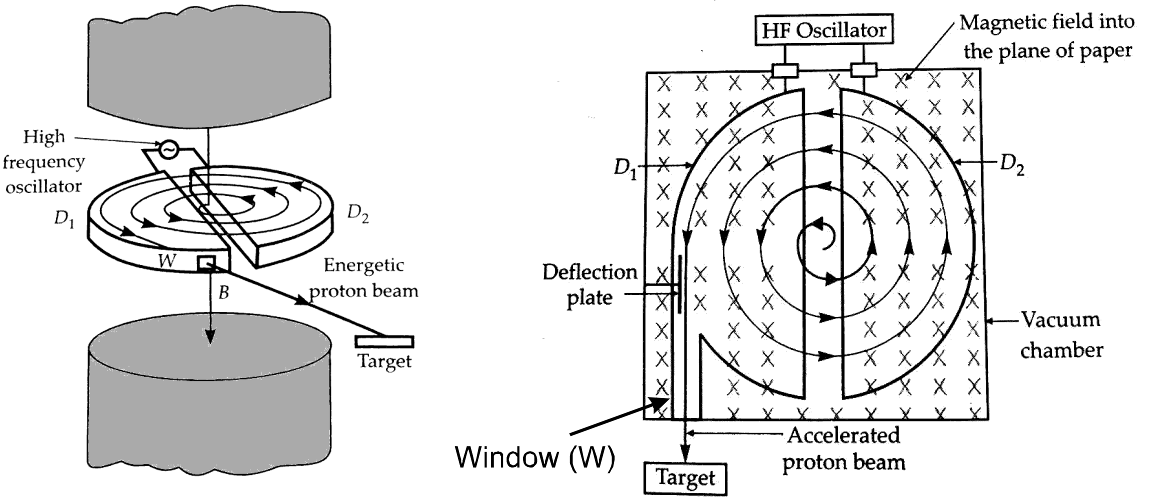
Let a particle of charge q and mass m enters a region of magnetic field $\vec{B}$ with a velocity $\vec{v}$, normal to the field $\vec{B}$. The particle follows a circular path, the necessary centripetal force is provided by the magnetic field. Therefore,

Magnetic force on charge q = Centripetal force on charge q

or qv B sin 90° = $\frac{mv^2}{r}$ or $\boxed{r = \frac{mv}{qB}}$

Period of revolution of the charged particle is given by

$$\boxed{T = \frac{2\pi r}{v} = \frac{2\pi}{v}, \frac{mv}{qB} = \frac{2\pi m}{qB}}$$



(a) (b)

Hence frequency of revolution of the particle will be

$$\boxed{f_c = \frac{1}{T} = \frac{qB}{2\pi m}}$$

Clearly, this frequency is independent of both the velocity of the particle and the radius of the orbit and is called cyclotron frequency or magnetic resonance frequency. This is the key fact which is used in the operation of a cyclotron.

Working :

• Suppose a positive ion, say a proton, enters the gap between the two dees and finds dee D_1 to be negative. It gets accelerated towards dee D_1.

• As it enters the dee D_1, it does not experience any electric field due to shielding effect of the metallic dee. The perpendicular magnetic field throws it into a cricular path with constant speed.

• At the instant the proton comes out of dee D_1, it finds dee D_1 positive and dee D_2 negative. It now gets accelerated towards dee D_2.

• It moves faster through D_2 describing a larger semicircle than before.

• Thus if the frequency of the applied voltage is kept exactly the same as the frequency of revolution of the proton, then every time the proton reaches the gap between the two dees, the electric field is reversed and proton receives a push and finally it acquires very high energy.

• This condition in which frequency of applied voltage is equal to the frequency of revolution of charged particle is called the **cyclotron's resonance condition.**

• The accelerated proton is ejected through a window by a deflecting voltage and hits the target.

Maximum K.E. of the accelerated ions : The ions will attain maximum velocity near the periphery of the dees. If v_0 is the maximum velocity acquired by the ions and r_0 is the radius of the dees, then

$\frac{mv_0^2}{r_0} = qv_0B$ or $\boxed{v_0 = \frac{qBr_0}{m}}$

The maximum kinetic energy of the ions will be

$$K_0 = \frac{1}{2}mv_0^2 = \frac{1}{2}m\left(\frac{qBr_0}{m}\right)^2$$

or $\boxed{K_0 = \frac{q^2B^2r_0^2}{2m}}$

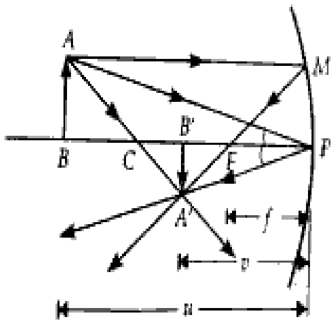
Frequency of revolution of the particle will be

$$\boxed{f_c = \frac{1}{T} = \frac{qB}{2\pi m}}$$

30. (a) Deduce an expression for mirror equation. Draw necessary ray diagram.

(b) Find focal length of a spherical mirror of radius of curvature 10 cm.

Ans. (a) Derivation of mirror formula for a concave mirror when it forms a real image. Consider an object AB placed on the principal axis beyond the centre of curvature C of a concave mirror of small aperture, as



Object distance, BP = – u

image distance, $B'P = -v$

Focal length, $FP = -f$

Radius of curvature, $CP = -R = -2f$

Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP - B'P}{BP - CP} = \frac{-R + v}{-u + R} \qquad \text{.................(1)}$$

As $\angle A'PB' = \angle ABP$, therefore,

$\Delta A'B'P \cong \Delta ABP$

Consequently,

$$\frac{A'B'}{AB} = \frac{B'P}{BP} = \frac{-v}{-u} = \frac{v}{u} \qquad \text{.................(2)}$$

From equation (i) and (2), we get

$$\frac{-R + u}{-u + R} = \frac{v}{u}$$

or – uR + uv = uv + vR

or vR + uR = 2uv

Dividing both sides by uvR, we get

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{R}$$

But R = 2f

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

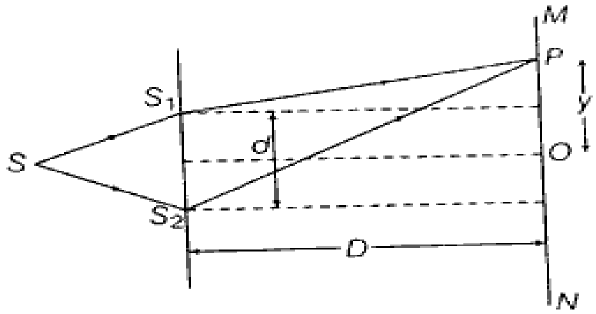
(b) R = 2f, f = $\frac{R}{2} = \frac{10}{2}$ = 5 cm

OR

(a) Draw a ray diagram to produce interference fringe pattern in Young's double slit experiment. Derive an expression for fring width of bright fringes.

(b) In Young's double slit experiment, fringe width is 2 mm. Find distance of second dark fringe from central fringe.

Ans. (a) Suppose S_1 and S_2 are two fine slits, as small distance d apart. They are illuminated by a strong source S of monochromatic light of wavelength. MN is a screen at a distance D from the slits.



Young's double slit arrangement to produce interference pattern

Consider a point P at a distance y from I, the centre of screen.

The path difference between two waves arriving at point P is equal to $S_2P - S_1P$.

Now,

$$(S_2P)^2 - (S_1P)^2 = \left[D^2 + \left(y + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right] = 2yd$$

Thus, $$S_2P - S_1P = \frac{2yd}{S_2P + S_1P}$$

But $$S_2P + S_1P \approx 2D$$

$$S_2P - S_1P \approx \frac{dy}{D}$$

For constructive interference (Bright fringes)

Path difference $= \frac{dy}{D} = n\lambda$ where, n = 0,1,2,3..........

$\therefore$ $$y = \frac{nD\lambda}{d} \quad [\because = 0,1,2,3, ...]$$

Hence, for n = 0, $y_0 = 0$ at O central bright fringe

for n = 1, $y_1 = \frac{D\lambda}{d}$ for 1st bright fringe

for n = 2, $y_2 = \frac{2D\lambda}{d}$ for 2nd bright fringe

for n = n, $y_n = \frac{nD\lambda}{d}$ for nth bright fringe

The separation between two consecutive bright fringes is $\beta = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{D\lambda}{d}$

(b) Distance between secondary Dark Fringe from central fringe $y_2 = \frac{3D\lambda}{2d} \Rightarrow y_2 = \frac{3\beta}{2} \Rightarrow \frac{3}{2} \times 2$ = 3 mm