CBSE Class 12 Physics

Sample Paper 05 (2020-21)

Maximum Marks: 70

Time Allowed: 3 hours

General Instructions:

i. All questions are compulsory. There are 33 questions in all.

ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

Section A

1. Two point charges q and -2q are kept d distance apart. Find the location of point relative to charge q at which potential due to this system of charges is zero.
2. Name the EM waves used for studying the crystal structure of solids. What is its frequency range?

   OR

   What is the main difference between characteristic X- rays and γ-rays?
3. In Young's double-slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.
4. Is the resistance of an ammeter greater than or less than that of the galvanometer of

which it is formed?

OR

Why do two straight parallel metallic wires carrying current in the opposite directions repel each other?

5. A lens, when immersed in a transparent liquid, becomes invisible. Under what condition does it happen?
6. What is the difference between thermionic emission and photoelectric emission?
7. Write any two characteristic properties of nuclear force.

OR

What is meant by size of nucleus? Are all nuclei of the same size?

8. What are light emitting diodes (L.E.D.)?
9. A bar magnet is stationary in magnetic meridian. Another similar magnet is kept parallel to it, such that the centres lie on their perpendicular bisectors. If the second magnet is free to move, then what type of motion it will have: translatory, rotatory or both?
10. What is the most common use of photodiode?
11. **Assertion (A):** The drift velocity of electrons in a metallic wire will decrease if the temperature of the wire is increased.

    Reason (R): On increasing the temperature conductivity of metallic wire decreases.

    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false
12. **Assertion:** When a capacitor is filled completely with a metallic slab its capacity becomes very large.

    Reason: Dielectric constant for metal is zero.

    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false
13. **Assertion:** Diffraction is common in sound but not common in light waves.

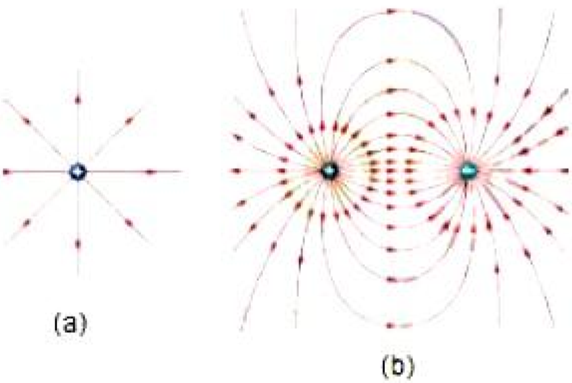
    Reason: The wavelength of light is more than the wavelength of sound.

a. Both A and R are true and R is the correct explanation of A
b. Both A and R are true but R is NOT the correct explanation of A
c. A is true but R is false
d. A is false and R is also false

14. **Assertion (A):** In a hydrogen atom, there is only one electron, but its emission spectrum shows many lines.
Reason (R): In a given sample of hydrogen, there are many atoms, each containing one electron; hence many electrons in different atoms may be in different orbits, so many transitions from higher to lower orbits are possible.
a. Both A and R are true and R is the correct explanation of A
b. Both A and R are true but R is NOT the correct explanation of A
c. A is true but R is false
d. A is false and R is also false

Section B

15. **Read the source given below and answer the following questions:**
Electric field lines as a path, straight or curved in an electric field such that tangent to it at any point gives the direction of electric field intensity at the point. Electric field lines are continuous curves they start from a positive charged body and end at the negatively charged body. (Refer image)



i. Electric field due to a single charge is:
a. asymmetric
b. cylindrically symmetric
c. spherically symmetric
d. none of the above

ii. The SI unit of electric field intensity is:
a. N

b. N/C

c. C/m^2

d. N/m^2

iii. Pick the wrong statement.

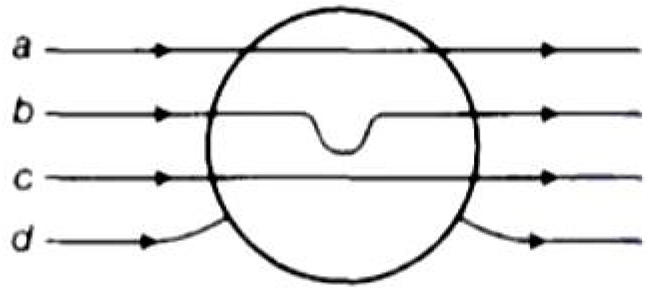
a. The electrostatic field does not form a closed loop.

b. Electric field lines are continuous curves.

c. Electric field lines can intersect each other.

d. Electric field lines are always normal to the surface of a conductor.

iv. A metallic sphere is placed in a uniform electric field as shown in the figure. Which path is followed by electric field lines?



a. path 'b'

b. path 'a'

c. path 'c'

d. path 'd'

v. Pick the true statements about electric field lines.

a. Electric field lines provide information about the direction of the electric field.

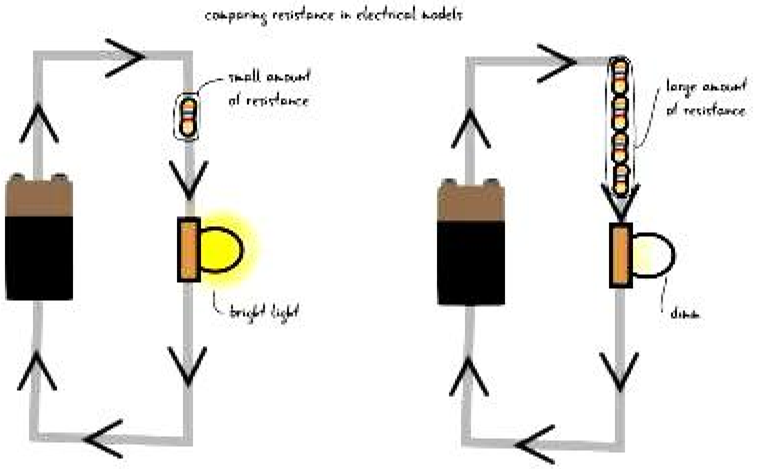
b. Electric field lines provide information about the type of charge.

c. Electric field lines provide information about the field strength.

d. All of the above

16. **Read the following source and answer any four out of the following questions:**

Resistance is a measure of the opposition to current flow in an electrical circuit. Resistance is measured in ohms. Also Resistivity, the electrical resistance of a conductor of unit cross-sectional area, and unit length. ... A characteristic property of each material, resistivity is useful in comparing various materials on the basis of their ability to conduct electric currents.



i. Resistivity is independent of:
   a. nature of material
   b. temperature
   c. dimensions of material
   d. none of the above
ii. As compare to short wires, long wires have _______ resistance.
   a. more
   b. less
   c. same
   d. zero
iii. As compare to thin wires, thick wires have _______ resistance.
   a. more
   b. less
   c. same
   d. zero
iv. The resistance of a wire depends upon:
   a. cross-sectional area
   b. length of wire
   c. wire's nature
   d. all of the above
v. A copper wire having the same size as steel wire have:
   a. more resistance
   b. less resistance
   c. same resistance
   d. none of the above

Section C

17. The wavelength of the first member of Lyman series is $1216\mathring{A}$. Calculate the wavelength of second member of Balmer series.

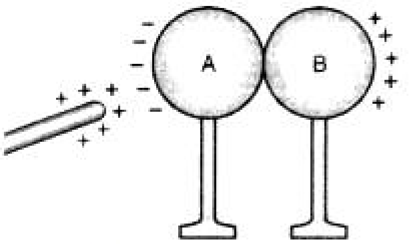
18. If the radii of curvature of the faces of a double convex lens are 9 cm and 15 cm, respectively and the refractive index of glass is 1.5, then determine the focal length and the power of the lens.

OR

A convex lens (refractive index μ_L) is immersed in a medium (refractive index μ_M). Will it behave as a convergent or divergent lens, if

i. $\mu_L > \mu_M$
ii. $\mu_L < \mu_M$

19. A glass rod rubbed with silk is brought close to two uncharged metallic spheres in contact with each other inducing charges on them as shown in figure



Describe what happens, when (i) the spheres are slightly separated, (ii) the glass rod is subsequently removed and finally (iii) the spheres are separated far apart.

OR

A simple pendulum consists of a small sphere of mass m suspended by a thread of length l. The sphere carries a positive charge q. The pendulum is placed in a uniform electric field of strength E directed vertically downwards. With what period will the pendulum oscillate if the electrostatic force acting on the sphere is less than the gravitational force? Assume that oscillations are small.

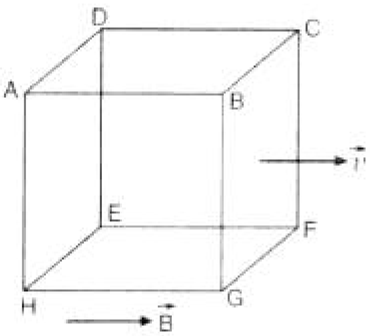
20. The energy of the electron, the hydrogen atom, is known to be expressible in the form $E_n = \frac{-13.6}{n^2} eV$ (n = 1, 2, 3, . . .)

Use this expression to show that the

i. Electron in the hydrogen atom can not have an energy of -2eV.
ii. Spacing between the lines (consecutive energy levels) within the given set of the

observed hydrogen atom spectrum decreases as n increases.

21. Twelve wires of equal lengths are connected in the form of a skeleton-cube which is moving with a velocity $\vec{v}$ in the direction of a magnetic field $\vec{B}$ [in a given figure]. Find the e.m.f. in each arm of the cube.



22. A nucleus with A = 235 splits into two new nuclei whose mass number are in the ratio of 2 : 1. Find the radii of the new nuclei.

23. Define refractive index of a transparent medium. A ray of light phases through a triangular prism. Plot a graph showing the variation of the angle of deviation with the angle of incidence.

24. The poles of a magnet cannot be separated. How does this statement derive support from the magnetic dipole behaviour of a current loop?

OR

A short bar magnet of magnetic moment m = $0.32 JT^{-1}$ is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its

i. stable, and
ii. unstable equilibrium?

What is the potential energy of the magnet in each case?

25. Light from a point source in air falls on a spherical glass surface (n = 1.5 and radius of curvature = 20 cm). The distance of the light source from the glass surface is 100 cm. At what position the image is formed?

Section D

26. A metallic rod of length l and resistance R is rotated with a frequency ν, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius l, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere.

i. Derive the expression for the induced emf and the current in the rod.
ii. Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.
iii. Hence obtain the expression for the power required to rotate the rod.

27. 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 λ/a. At the same angle of λ/a, we get a maximum for two narrow slits separated by a distance a. Explain.

OR

i. In what way is diffraction from each slit related to the interference pattern in a double slit experiment.
ii. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at single slit of aperture $2 \times 10^{-4} m$. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

28. A parallel plate capacitor, each with plate area A and separation d, is charged to a potential difference V. The battery used to charge it is then disconnected. A dielectric slab of thickness d and dielectric constant k is now placed between the plates. What changes, if any, will take place in
i. charge on the plates.
ii. electric field intensity between the plates,
iii. capacitance of the capacitor.

OR

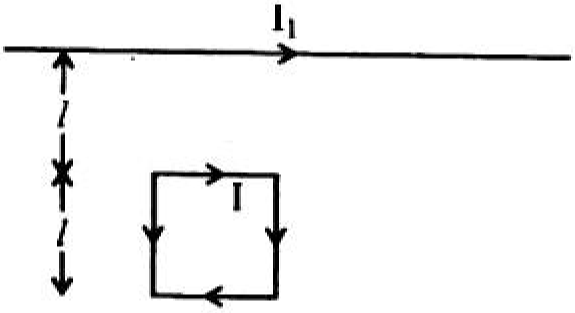
What is meant by a dielectric? Explain how it reduces the electric field between two oppositely charged plates, if the space between them be filled with it?

29. An electron gun with its collector at a potential of 100 V fires out electrons in a spherical bulb containing hydrogen gas at low pressure (-10^{-2}mm of Hg). A magnetic field of $2.83 \times 10^{-4} T$ curves the path of the electrons in a circular orbit of radius 12.0 cm (The path can be viewed because the gas ions in the path focus the beam by attracting electrons, and emitting light by electron capture this method is known as the 'fine beam tube' method.) Determine e/m from the data.

30. Write the expression for the magnetic moment (m) due to a planar 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.



Section E

31. a. Distinguish between metals, insulators and semiconductors on the basis of their energy bands.

 b. Why are photodiodes used preferably in reverse bias condition? A photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 6000 nm? Justify.

OR

 i. Describe the working principle of a solar cell. Mention three basic processes involved in the generation of emf.

 ii. Why are Si and GaAs preferred materials for solar cells?

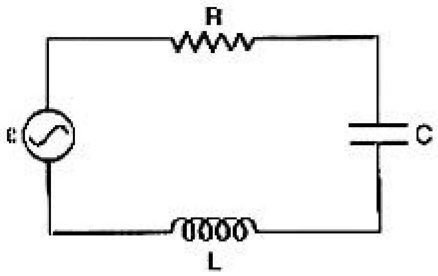
32. i. Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device.

 ii. The primary coil of an ideal step-up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate

  a. number of turns in secondary
  b. current in primary
  c. voltage across secondary
  d. current in secondary
  e. power in secondary

OR

A series of LCR circuit is connected to a variable frequency 230 V source, L = 5.0 H,
$C = 80\mu F, R = 40\Omega$



i. Determine the source frequency which drives the circuit in resonance.
ii. Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.
iii. Determine the rms potential drops across the three elements of the circuit. Show that the potential drop across the LC combination is zero at the resonating frequency.

33. A plane wavefront propagating in a medium of refractive index μ_1 is incident on a plane surface making an angle of incidence i and enters into another medium of refractive index μ_2 ($\mu_2 > \mu_1$). Use Huygens' construction of secondary wavelets to trace the propagation of the refracted wavefront. Hence, verify Snell's law of refraction.

OR

In Young's double slit experiment, deduce the condition for (a) constructive and (b) destructive interference at a point on the screen. Draw a graph showing a variation of intensity in the interference pattern against position x on the screen.

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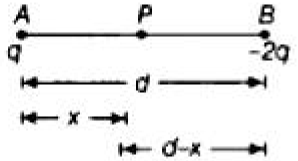
Solution

Section A

1. Here, q_A = q and q_B = -2q. Say at a distance x from the charge q_A, potential will be zero.



Since the potential due to system of charges is zero, therefore

$V_{PA} + V_{PB} = 0 \Rightarrow \frac{kq}{x} = \frac{2kq}{(d-x)}$

$\therefore d - x = 2x \Rightarrow 3x = d \Rightarrow x = d/3$

2. X-rays are used for studying crystal structure of solids. Their frequency range is 10^{16} Hz to $3 \times 10^{21} Hz$.

OR

X-rays are emitted, when orbital electron jumps from some outer shell to the inner shell in case of an atom of a heavy element (Z = high), while γ-rays are emitted by radioactive nuclei.

3. Given, d = 0.28 mm = 0.28×10^{-3} m, D = 1.4 m, y = 1.2 cm = 1.2×10^{-2} m, n = 4, λ = ?

For constructive interference, distance between two fringes, y = $\frac{nD\lambda}{d}$

Thus, wavelength λ = $\frac{yd}{nD}$ = $\frac{1.2\times10^{-2}\times0.28\times10^{-3}}{4\times1.4}$ = 6×10^{-7} m

or λ = 600 nm

4. The resistance of an ammeter is always less than that of the galvanometer, of which it is formed.

OR

The current through one metallic wire produces magnetic field and the other parallel current carrying metallic wire experiences force due to this magnetic field. The application of Biot Savart's law tells that when currents flow through the two conductors in opposite directions, the two wires repel the other.

5. When the refractive index of the liquid is equal to the refractive index of lens, a lens becomes invisible.
6. During thermionic emission, electrons are emitted from metal surface by providing heat energy, whereas, during photoelectric emission, electrons are emitted from metal surface by providing light energy.
7. Nuclear force is the responsible force behind the stability of the nucleus. Its characteristics are-
   i. These are short range forces.
   ii. These are the strongest forces of attractive nature upto a certain distance i.e upto 10^{-12} m.

OR

The extremely small central core of the atom, in which whole of its positive charge and practically the entire mass is confined, is called nucleus.
All nuclei are not of the same size. The size (radius) of the nucleus is directly proportional to $A^{1/3}$, where A is its mass number.

8. The junction diodes, which emit light in infra-red or visible region on being forward-biased, are called light emitting diodes.
9. There will be only translatory motion. It can be shown by finding the net force on the two poles of the second magnet due to the poles of the first by drawing a vector diagram.
10. The photodiode can be used as light detector.
11. (b) Both A and R are true but R is NOT the correct explanation of A
    Explanation: Both the assertion and reason are true but the reason is not the correct explanation of assertion. On the increasing temperature of wire the kinetic energy of free electrons increases and so they collide more rapidly with each other and hence, their drift velocity decreases. Also when the temperature increases, resistance increases, and resistance is inversely proportional to the conductivity of the material.
12. (d) A is false and R is also false
    Explanation: A is false and R is also false
13. (c) A is true but R is false
    Explanation: For diffraction of a wave, the size of an obstacle or aperture should be comparable to the size of As wavelength of the wave. As the wavelength of light is of the

order of 10^{-6} m and obstacle or aperture of the size are rare, therefore, diffraction is not common in light waves. On the contrary, the wavelength of sound is of the order of 1 m and obstacle/aperture of this size are readily available, therefore, diffraction is common in sound.

14. (a) Both A and R are true and R is the correct explanation of A

    Explanation: Both A and R are true and R is the correct explanation of A

Section B

15. i. (c) Spherically symmetric
    ii. (b) N/C
    iii. (c) Electric field lines can intersect with each other.
    iv. (d) path 'd'
    v. (d) all of the above
16. i. (c) dimensions of material
    ii. (a) more
    iii. (b) less
    iv. (d) all of the above
    v. (a) more resistance

Section C

17. We know that $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

    For first member of Lyman series, $n_1 = 1$ and $n_2 = 2$.

    $\therefore \frac{1}{\lambda_1} = R\left(\frac{1}{1^2} - \frac{1}{4}\right)$
    or $\frac{1}{\lambda_1} = \frac{3R}{4}$
    or $\lambda_1 = \frac{4}{3R}$ ...(i)

    For second member of Balmer series, $n_1 = 2$, $n_2 = 4$

    $\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16}$
    or $\lambda_2 = \frac{16}{3R}$ .... (ii)

    Dividing equation (ii) by (i), we get

    $\frac{\lambda_2}{\lambda_1} = \frac{16}{3R} \times \frac{3R}{4} = 4$

    or $\lambda_2 = 4\lambda_1 = 4 \times 1216\mathring{A} = 4864\mathring{A}$
18. Here it is given that radii of curvature, $R_1 = 9$ cm and $R_2 = -15$ cm

Also, refractive index, μ = 1.5, f = ?, P = ?

By using lens Maker's formula, we can write

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

$\Rightarrow \frac{1}{f}=(1.5-1)\left[\frac{1}{9}-\left(\frac{-1}{15}\right)\right]$

$\Rightarrow \frac{1}{f}=(0.5)\left(\frac{1}{9}+\frac{1}{15}\right)=(0.5)\left(\frac{5+3}{45}\right)$

$\Rightarrow \frac{1}{f}=0.5\times\frac{8}{45}\Rightarrow f=\frac{45}{4}=11.25\text{cm}$

Power, $P=\frac{1}{f}=\frac{1}{11.25\times10^{-2}}=\frac{10000}{1125}$ = 8.88 D

OR

i. When $\mu_L>\mu_M$: The convex lens will still behave as a convex lens. It is because, ${}^M\mu_L=\frac{\mu_L}{\mu_M}$ is greater than 1 and the lens maker's formula gives a positive value for the focal length of the lens.

ii. When $\mu_L<\mu_M$: The convex lens will behave as a concave lens. It is because, ${}^M\mu_L$ is less than 1 and hence focal length of the lens has a negative value.

19. i. On separating the two spheres, the right face of the sphere A will acquire positive induced charge and the left face of B will acquire negative induced charge.

ii. If the glass rod is removed, the charges on the two spheres will disappear.

iii. In this case also, charges on the spheres will disappear.

OR

Upward force on bob = qE

Weight of bob acting downward = mg

Net downward force on bob = mg - qE

$\therefore$ Acceleartion, $a=\frac{mg-qE}{m}=\left(g-\frac{qE}{m}\right)$

The time period of the oscillations is, $T=2\pi\sqrt{\frac{l}{a}}=2\pi\sqrt{\frac{l}{(g-qE/m)}}$

20. As, $E_n=-\frac{13.6}{n^2}eV$

Putting n = 1, 2, 3, . . ., ∞ we get

$E_1=\frac{-13.6}{1^2}=-13.6eV$

$E_2=\frac{-13.6}{2^2}=-\frac{13.6}{4}=-3.4eV$

$E_3=\frac{-13.6}{3^2}=-\frac{13.6}{9}=-1.51eV$

$E_4 = \frac{-13.6}{4^2} = \frac{-13.6}{16} = -0.85 eV\, E_\infty = \frac{-13.6}{\infty^2} = 0 eV$

i. Hence, it can be observed that the electron in the hydrogen atom can not have an energy of -2eV.
ii. As n increases, energies of the excited states come closer and closer together. Therefore, as n increases, E_n becomes less negative until at $n = \infty$, E = 0.

21. Force on a charged particle moving inside magnetic field is given by

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

Since $\vec{v}$ and $\vec{B}$ are parallel, the force on electrons in any arm of the skeleton cube will be zero. As such, there cannot be drift of electrons in any arm from its one end to the other. Hence, no induced e.m.f. will be produced in any arm of the skeleton cube.

22. We know that the radius R of a nucleus of mass number A is given by the relation.

$R = R_0 A1/3$, where R_0 = 1.4 fm. Let r_1 and r_2 denote the radii of new nuclei formed and A_1 and A_2 denote their mass number. Then we have

$A_1 = \frac{1}{3}(235)$

and $A_2 = \frac{2}{3}(235)$

Using, $R = R_0(A)^{1/3}$ we have

$R_1 = R_0(A_1)^{1/3}$

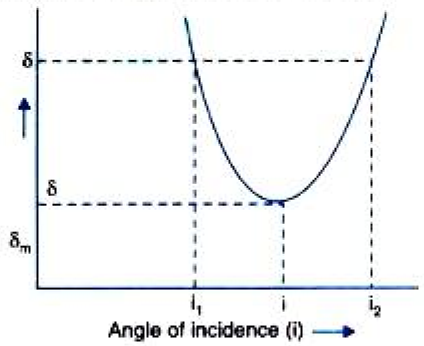
$= (1.4 fm)\left(\frac{235}{3}\right)^{1/3}$ = 5.99 fm

and $R_2 = R_0(A_2)^{1/3}$

$= (1.4 fm)\left(\frac{235 \times 2}{3}\right)^{1/3}$ = 7.55 fm

23. Ratio of the speed of light in air (vacuum) to the speed of light in the medium is called the refractive index of the medium I.e., n = c/v.

Graph: The graph of angle of deviation (δ) versus angle of incidence (i) for a triangular prism is given as follows:



24. A current loop behaves as a magnetic dipole. Its one face behaves as n-pole, while the other as s-pole. As the two faces of the current loop cannot be separated from each other, it follows that the magnetic poles developed on the two faces also cannot be separated from each other.

OR

Magnetic Moment of the bar magnet, M = $0.32 JT^{-1}$

External magnetic field, B = 0.15 T

i. For the system to be in stable equilibrium the angle θ, between the bar magnet and the magnetic field is taken as 0°.

   Potential energy of the system = $-MB\cos\theta$

   $= -0.32 \times 0.15 \cos 0^\circ$

   $= -4.8 \times 10^{-2} J$

ii. For unstable equilibrium, the bar magnet is oriented at 180°to the magnetic field.

   $\theta = 180^\circ$

   Potential energy = $-MB\cos\theta$

   $= -0.32 \times 0.15 \cos 180^\circ$

   $= 4.8 \times 10^{-2} J$

25. Here it is given that the object distance, u = -100 cm, R = + 20 cm, n_1 = 1 and n_2 = 1.5

Image distance, v = ?

We know that

$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

$\Rightarrow \frac{1.5}{v} + \frac{1}{100} = \frac{1.5-1}{20}$

$\Rightarrow \frac{1.5}{v} = \frac{0.5}{20} - \frac{1}{100}$

$= \frac{2.5-1}{100} = \frac{1.5}{100} \Rightarrow v = +100\text{cm}$

Thus, the image is formed at a distance of 100 cm from the glass surface in the direction of incident light.

Section D

26. i. In the one revolution, change of area,

   $dA = \pi l^2$

   $\therefore$ Change of magnetic flux in one revolution of the rod,

   $d\phi_B = \vec{B} \cdot d\vec{A} = BdA\cos 0^\circ = B\pi l^2$

   (Given, magnetic field intensity, $\vec{B}$ is parallel to change in area, $d\vec{A}$)

If period of revolution is T,

a. Induced emf (e) = $\frac{d\pi}{dt} = \frac{B\pi l^2}{T} = B\pi l^2\nu$ ($\because \nu = \frac{1}{T}$)

b. Induced current in the rod,

$I = \frac{e}{R} = \frac{\pi\nu Bl^2}{R}$

(Given R = resistance of the rod)

ii. Magnitude of force acting on the rod,

$|\vec{F}| = |I(\vec{l} \times \vec{B})| = BIlsin90^0 = \frac{\pi\nu B^2 l^3}{R}$

The external force required to rotate the rod opposes the Lorentz force acting on the rod, i.e external force acts in the direction opposite to the Lorentz force.

iii. Power required to rotate the rod,

$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

27. The angle will be $\frac{\lambda}{a}$.

Here, the statement considers interference as a general term to represent both diffraction (and interference phenomenon in single slit) and interference by two slits. In terms of physical point of view diffraction is also an interference of secondary wavelets from a single slit.

From the theory of diffraction we know that minima condition is given by

nλ = asinθ

for the minima n = 1

$\Rightarrow \lambda$ = a sinθ

As because is small we have sin $\theta \approx \theta$

$\Rightarrow \lambda$ = aθ

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

Thus in single slit the first minima occurs at angle.

But when we consider interference of two slits separated by a distance a and distance of screen from the slit = D, the position of the first maxima is given by

$y = \frac{\lambda D}{a}$

Again, y being small compared to D.

y = Dθ

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

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

This means in the case of two slits we have a miximum at $\frac{\lambda}{a}$ angle.

OR

i. Relation between diffraction from each slit to the interference pattern in a double slit experiment:

(a) If slit width in interference pattern is reduced to the size of wavelength of light used the diffraction will also take place along with interference.

(b) The diffraction pattern is itself due to the interference of wavelength belonging to same.

ii. Given that, wavelength of the light beam,

$\lambda_1 = 590\text{nm} = 5.9 \times 10^{-7}\text{m}$

Wavelength of another light beam, $\lambda_2 = 596\text{nm} = 5.96 \times 10^{-7}\text{m}$

Distance of the slit from the screen, D = 1.5 m

Aperture of the slit = d $= 2 \times 10^{-4}\text{m}$

For the first secondary maxima,

$x_1 = \frac{3\lambda_1 D}{2d}$ and for the second wavelength, $x_2 = \frac{3\lambda_2 D}{2d}$

∴ Spacing between the positions of first secondary maxima of two sodium lines

$x_2 - x_1 = \frac{3D}{2d}(\lambda_2 - \lambda_1)$

Substituting the value of all elements

$= \frac{3\times1.5}{2\times2\times10^{-4}}(5.96 - 5.9) \times 10^{-7}$

$= 6.75 \times 10^{-5}\text{m}$

28. The capacitance of the capacitor before a dielectric slab is placed in between is given by $C_0 = \frac{\varepsilon_0 A}{d}$

Potential difference = V

Initial charge on capacitor $q_0 = C_0V$

i. When, the battery is disconnected, charge on the capacitor remains unchanged.

i.e, $q = q_o = \frac{\varepsilon_0 A}{d}$

ii. Initial electric field between the plates, $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q/A}{\varepsilon_0} = \frac{q}{A\varepsilon_0}$

When, dielectric is introduced in between the plates, the permittivity of medium becomes $K\varepsilon_0$

Now, electric field in between the plates $E = \frac{q}{AK\varepsilon_0} = \frac{E_0}{K}$

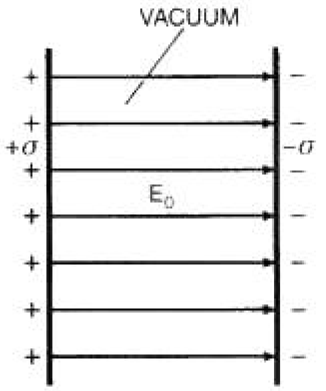
Thus, electric field is reduced by a factor of $\frac{1}{K}$

iii. The capacitance increases due to the decreases in potential difference and for any dielectric, K > 1

$\therefore C = kC_O$

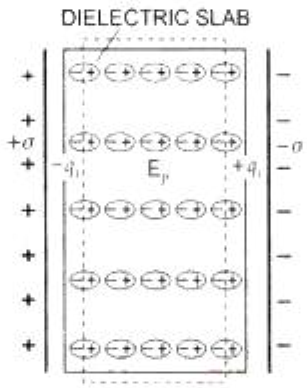
OR

Dielectric: It may not conduct electricity through it but on applying electric field, induced charges are produced on its faces. Such an insulator is called dielectric.



Consider a parallel plate capacitor having vacuum between the plates. Suppose that the capacitor is charged with a battery so that electric field of strength E_0 is set up between the plates as shown in Fig. If σ and $-\sigma$ are surface charge densities of the two plates of the capacitor, then the electric field between two plates is given by

$$\mathbf{E_0} = \frac{\sigma}{\varepsilon_0}$$



Suppose that a dielectric slab of non-polar atoms is introduced between the two plates of the capacitor as shown in Fig. As soon as the dielectric slab is introduced, each molecule of the dielectric gets polarised i.e. centres of gravity of positive and negative charges get displaced from each other. On the left face, a net negative charge - q and on the right face, a positive charge + q_i appears. There is no net charge in the interior of the dielectric marked by the dotted boundary. The charges - q_i and + q_i on the two surfaces of the dielectric slab are called induced charges. The induced charges set up an electric field Ep inside the dielectric. It is called electric field due to polarisation. The direction of electric field due to polarisation is from positive to the negative induced charges developed on the two faces of the dielectric slab i.e. along a direction opposite to the direction of applied electric field E_0. Therefore, the resultant electric field in the dielectric is given by

$E = E_0 - E_p$

In other words, on placing a dielectric slab inside an electric field, the strength of the electric field gets reduced and likewise E is called the reduced value of the electric field.

29. Here, V = 100 V

Magnetic field, $B = 2.83 \times 10^{-4} T$

r = 12.0 cm $= 12.0 \times 10^{-2} m$

When electrons are accelerated through V volt, the gain in K.E. of the electron is given by

$\frac{1}{2} m v^2 = eV$

$\Rightarrow v^2 = \frac{2eV}{m}$ ....(i)

Since the electron moves in circular orbit under magnetic field, therefore, force on the electron due to magnetic field provides the centripetal force to the electron.

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

or $eB = \frac{mv}{r}$

or, $v^2 = \frac{e^2 B^2 r^2}{m^2}$ ...(ii)

From equations (i) and (ii), we get

$\frac{2eV}{m} = \frac{e^2 B^2 r^2}{m^2}$

$\Rightarrow \frac{e}{m} = \frac{2V}{r^2 B^2}$

or $\frac{e}{m} = \frac{2 \times 100}{(12 \times 10^{-2})^2 \times (2.83 \times 10^{-4})^2}$

$= 1.73 \times 10^{11}$ Ckg^{-1}

30. The magnetic moment due to the planar square current-carrying loop of side l is,

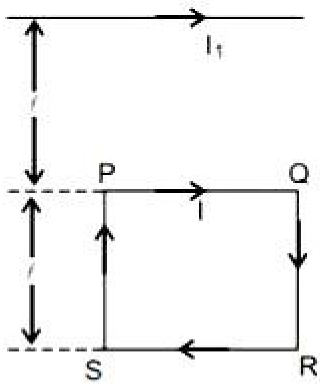
$m = I\ A = I\ l^2$

where A = area of the loop (square)

$\therefore \quad \mathbf{A} = l^2 \hat{\mathbf{n}}$

Here, $\hat{n}$ is a unit vector normal to the direction of area vector

The forces acting on the arms QR and SP of the given loop are equal and opposite and collinear. Hence, they are balanced by one another and the net force on these sides is zero.



Force on arm PQ, $F_1 = B_1\ I\ l = \frac{\mu_o\ I_1}{2\pi l} I\ l = \frac{\mu_o\ I\ I_1}{2\pi}$

Since the direction of the current in the arm PQ and the wire is the same, so F_1 is of the attractive nature.

Force on arm RS,

$F_2 = B_2 Il = \frac{\mu_0 I_1 Il}{2\pi(2l)} = \frac{\mu_0 I_1 I}{4\pi}$

Since, the direction of the current in the arm RS and the wire is opposite, so F2 is repulsive in nature.

The net force on loop PQRS,

$\Rightarrow \quad F_{\text{net}} = F_1 - F_2 = \frac{\mu_0 I_1 I}{2\pi} - \frac{\mu_0 I_1 I}{4\pi}$

or $F_{\text{net}} = \frac{\mu_0 I_1 I}{4\pi}$

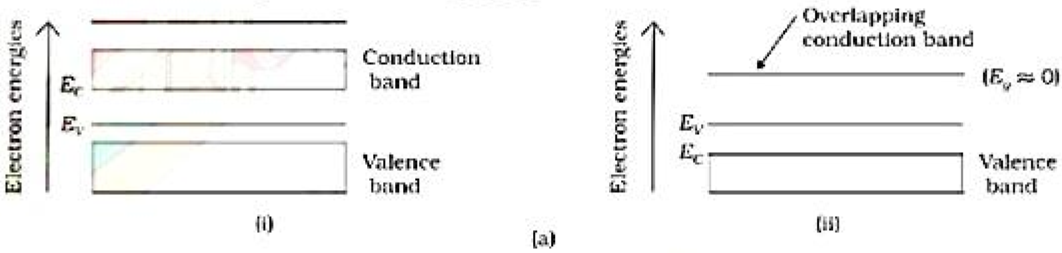
Torque is given by, $\tau = m \times\ B$

Net Torque is zero as angle between m and B is zero. Also as F_1 and F_2 are collinear, hence they do not produce torque on the loop PQRS.

Section E

31. a. **Metals:** The energy band structure in solids have two possibilities:

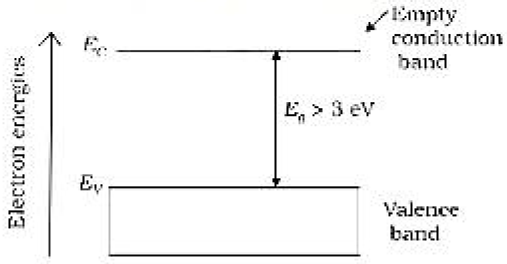
(i) The valence band may be completely filled and the conduction band partially filled with an extremely small energy gap between them [Fig. a(i)].



(ii) The valence band is completely filled and the conduction band is empty but the two overlap each other [Fig. a(ii)].

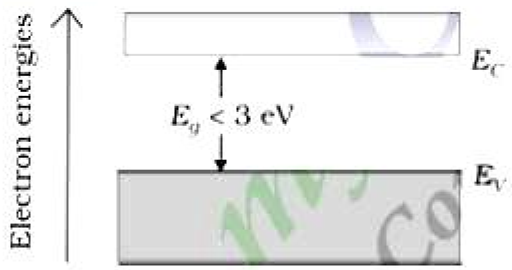
In both situations, it can be assumed that there is a single energy band, which is partially filled. Therefore, on applying even a small electric field, the metals conduct electricity.

Insulators: In this case, as shown in Fig. (b), a large bandgap E_g exists (E_g > 3 eV). There are no electrons in the conduction band, and therefore no electrical conduction is possible. Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.



(b)

Semiconductors: This situation is shown in Fig. (c). Here a finite but small band gap (E_g < 3 eV) exists. Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band. These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of semiconductors is not as high as that of the insulators.



(c)

b. The fractional change due to the photo effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

Now,

$\lambda = 6000nm = 6 \times 10^{-6}m$

Since, $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{6\times10^{-6}} = 3.3 \times 10^{-20}J$

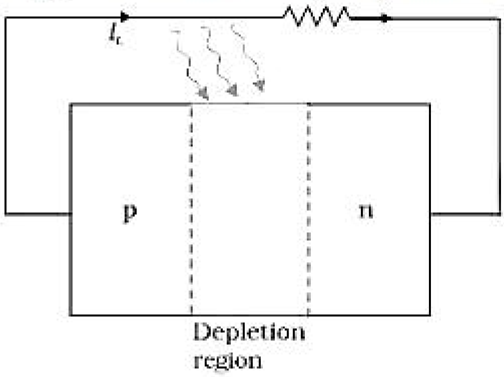
or, $E = \frac{3.3\times10^{-20}}{1.6\times10^{-19}} = 0.206eV$

As the energy of the photon is less than E_g = 2.8eV of the semiconductor, so a wavelength of 6000 nm cannot be detected.

OR

i. A solar cell is a semiconductor device that converts photons of solar light into electricity.

A typical illuminated p-n junction solar cell is shown in the figure.



When light falls on the n-type layer, which is on top of the solar cell, it gets absorbed. The absorbed energy knocks out electrons, which flow across the p-n junction to create a current. The current flows through the p-layer. Load resistance is connected across the metal contacts of n-type and p-type layers to store the electricity. After flowing through the load resistance, the current flows back into the n-layer. Thus, a current I_L is generated without any mechanical input energy. Obviously, the output of a solar cell is d.c.

The generation of emf by a solar cell, when light falls on, it is due to the following three basic processes: generation, separation and collection-

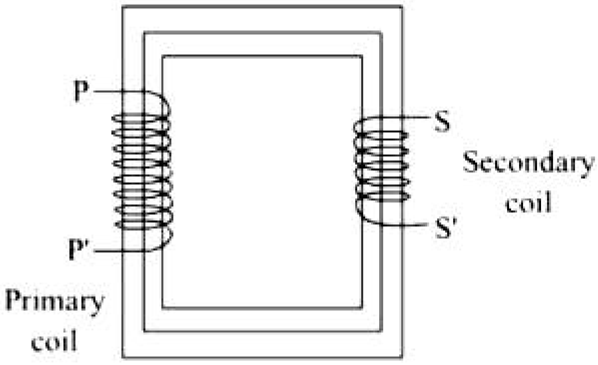
a) generation of e-h pairs due to light (with $h\nu > E_g$) close to the junction;

b) separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side;

c) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photovoltage. When an external load is connected as shown in Fig., a photocurrent I_L flows through the load.

ii. In solar cell, the energy of the sun rays should always be more than the amount of energy required for photoexcitation. The maximum solar irradiance intensity(energy) is equal to 1.5eV. So in order to get better solar efficiency, we should use a material that needs excitation energy less than 1.5eV. Now Si has band gap E_g = 1.1eV and GaAs has E_g = 1.53eV. Here E_g of GaAs is more than 1.5eV but we still use it a solar cell material because it has a higher absorption coefficient.

32. i. A transformer is a device that changes a low alternating voltage into a high alternating voltage or vice versa. The transformer works on the principle of mutual induction. A changing alternate current in the primary coil produces a changing magnetic field, which induces a changing alternating current in the secondary coil.



Energy losses in the transformer:

a. Flux leakage due to poor structure of the core and air gaps in the core.

b. Loss of energy due to heat produced by the resistance of the windings.

c. Eddy currents due to alternating magnetic flux in the iron core, which leads to loss of energy due to heat.

d. Hysterisis, frequent and periodic magnetisation and demagnetisation of the core, leading to loss of energy due to heat.

ii. a. Now,

$N = \frac{N_s}{N_p}$

$\Rightarrow \frac{N_S}{100} = 100$

$\Rightarrow N_S = 10000$ turns

b. Current in primary is given by,

$I_P V_P = P$

$\Rightarrow I_P = \frac{1100}{220} = 5A$

c. Voltage across secondary is given by,

$\frac{V_s}{V_p} = \frac{N_s}{N_p} = N$

$\Rightarrow V_S = 100 \times 220 = 22000$ V

d. Current in secondary is given by

$V_S I_S = P$

$\Rightarrow I_S = \frac{P}{V_s} = \frac{1100}{22000} = 0.05$ A

e. In an ideal transformer,

Power in secondary = Power in primary = 1100 W

OR

Here, L = 5.0 H, $R = 40\Omega$

$C = 80\mu F = 80 \times 10^{-6} F$

E_v = 230 volt $E_0 = \sqrt{2}E_v = \sqrt{2} \times 230V$

i. Resonance angular frequency,

$\omega_r = \frac{1}{\sqrt{LC}}$

$= \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}} = \frac{1}{2 \times 10^{-7}}$ = 50 rad/sec

ii. Impedance, $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

At resonance, $\omega L = \frac{1}{\omega C}$

$Z = \sqrt{R^2} = R = 40\Omega$

Amplitude of current at resonating frequency,

$I_0 = \frac{E_0}{Z} = \frac{\sqrt{2} \times 230}{40}$ = 8.13 A

$I_v = \frac{I_0}{\sqrt{2}} = \frac{8.13}{\sqrt{2}} = 5.75$ A

iii. Potential drop across L,

$V_L = I_v \omega_r L = 5.75 \times 50 \times 5.0$ = 1437.5 V

Potential drop across R,

$V_R = I_v \times R = 5.75 \times 40$ = 230 V

Potential drop across C,

$V_C = I_v\left(\frac{1}{\omega_r C}\right)$

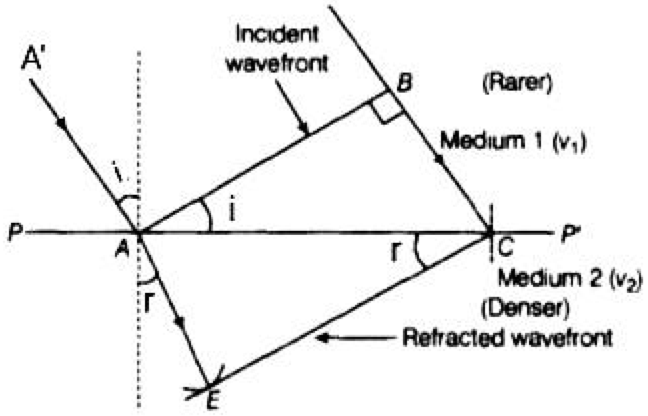
$= 5.75 \times \frac{1}{50 \times 80 \times 10^{-6}}$

$= \frac{5.75}{4} \times 10^3$ = 1437.5 V

Potential drop across LC circuit,

$V_{LC} = V_L - V_C = 0$

33. Let PP' represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront AB propagating in the direction A'A incident on the interface at an angle of incidence i. Let t be the time taken by the wavefront to travel the distance BC in medium 1 and AE in medium 2 respectively.

$\therefore$ BC = speed of light in medium 1 × time = v_1 t [$\because$ distance = speed $\times$ time]

In order to determine the shape of the refracted wavefront, we draw an arc of radius v_2 t from the point A in the second medium (the speed of the wave in second medium is v_2 and applying the formula, distance = speed × time). Let CE represents a tangent plane drawn from the point C.

Then AE = speed of light in medium 2 × time = v_2 t

$\therefore$ CE would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$$\frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \cdot \frac{AC}{v_2 t}; \quad \therefore \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

If c represents the speed of light in vacuum, then

$\mu_1 = \frac{c}{v_1}$ and $\mu_2 = \frac{c}{v_2}$ [since refractive index of a medium = speed of light in vacuum or air ÷ speed of light at that medium]

$$\Rightarrow \quad v_1 = \frac{c}{\mu_1} \text{ and } v_2 = \frac{c}{\mu_2}$$

where, μ_1 and μ_2 are the refractive indices of medium 1 and medium 2 respectively.

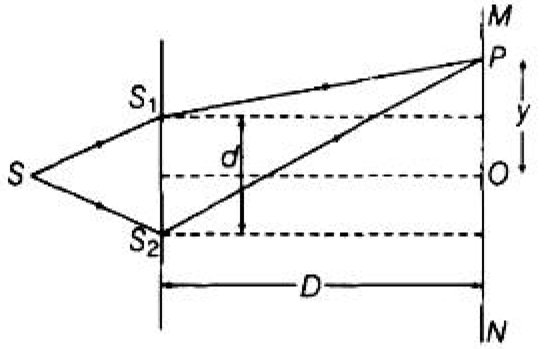
$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c/\mu_1}{c/\mu_2}$$

$$\Rightarrow \quad \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$$

This proves the snell's law of refraction.

OR

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



Consider a point P at a distance y from 0, the centre of the screen.

The path difference between two waves arriving at point Pis 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 $S_2P + S_1P \approx 2D \therefore \quad S_2P - S_1P \approx \frac{dy}{D}$

a. For constructive interference (Bright fringes)

   Path difference $= \frac{dy}{D} = n\lambda$, where,

   n = 0, 1, 2, 3,......

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

b. For destructive interference (Dark fringes)

   Path difference $= \frac{dy}{D} = (2n-1)\frac{\lambda}{2}$

The distribution of intensity in Young's double slit experiment is as shown below