CBSE Class 12 Physics
Sample Paper 01 (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. Name the physical quantity, whose SI unit is volt metre^{-1}.
2. State the applications of Ultraviolet radiations.

OR

Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.

3. What is wavefront and Huygens' principle?
4. What is the direction of the force acting on a charged particle q, moving with a velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$?

OR

Why do the two parallel conductors carrying current exert force on each other?

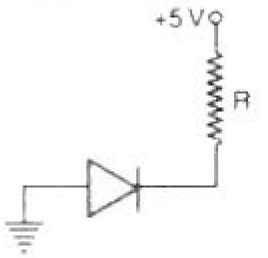
5. Why do lenses of large aperture suffer from spherical aberration?

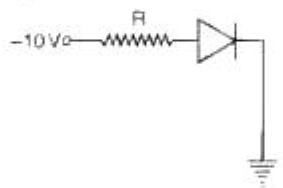
6. Find the maximum velocity of photoelectrons emitted by radiation of frequency 3×10^{15} Hz from a photoelectric surface having a work function 4.0 eV.
7. Express one atomic mass unit (1 a.m.u.) in kilogram.

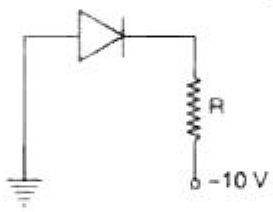
OR

Heavy water is often used as a modulator in thermal nuclear reactors. Give reason.

8. In the following circuits, which of the diodes is forward-biased and which is reverse-biased and why?

a. 

b. 

c. 

9. What is meant by the non-magnetic material?
10. What are photodiodes?
11. **Assertion (A):** A current flows in a conductor only when there is an electric field within the conductor.

    Reason (R): The drift velocity of electrons in the presence of electric field 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 (A):** Positive charge always moves from a higher potential point to a lower potential point.

    Reason (R): Electric potential is a vector quantity.

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

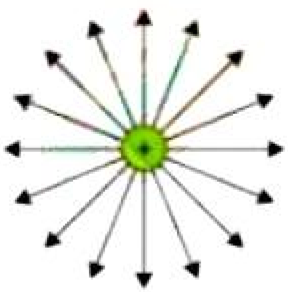
b. Both A and R are true but R is NOT the correct explanation of A
c. A is true but R is false
d. A is false and R is also false

13. **Assertion (A):** Young's double slit experiment can be performed using a source of white light.
Reason (R): The wavelength of red light is less than the wavelength of other colours in white light.
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

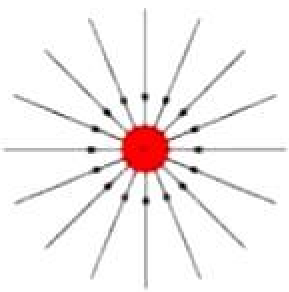
14. **Assertion (A):** In a hydrogen atom, there is only one electron, but its emission spectrum shows many lines.
Reason (R): In a given sample of hydrogen, there are many atoms, each containing one electron; hence many electrons in different atoms may be in different orbits, so many transitions from 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 any four out of the following questions:**
A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic field. Charges are scalar in nature and they add up like real numbers. Also, the total charge of an isolated system is always conserved. When the objects rub against each other charges acquired by them must be equal and opposite.



Electric field lines of a positive point charge

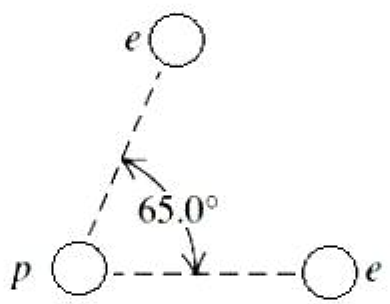


Electric field lines of a negative point charge

i. The cause of charging is:
   a. the actual transfer of protons
   b. the actual transfer of electrons
   c. the actual transfer of neutrons
   d. none of the above

ii. Pick the correct statement.
   a. The glass rod gives protons to silk when they are rubbed against each other.
   b. The glass rod gives electrons to silk when they are rubbed against each other.
   c. The glass rod gains protons from silk when they are rubbed against each other.
   d. The glass rod gains electrons when they are rubbed against each other.

iii. If two electrons are each $1.5 \times 10^{-10}\ m$ from a proton, as shown in Figure, magnitude of the net electric force they will exert on the proton is



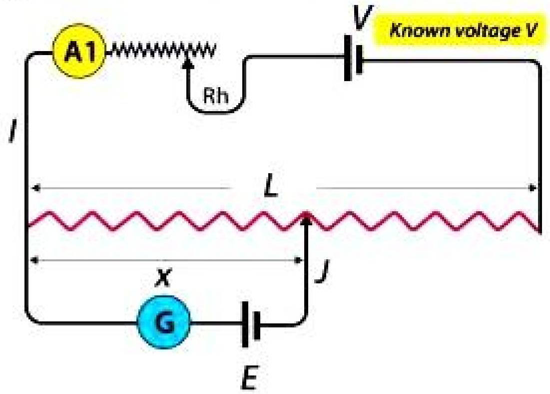
   a. $1.97 \times 10^{-8}\ N$
   b. $2.73 \times 10^{-8}\ N$
   c. $3.83 \times 10^{-8}\ N$
   d. $4.63 \times 10^{-8}\ N$

iv. A charge is a property associated with the matter due to which it produces and experiences :
   a. electric effects only
   b. magnetic effects only
   c. both electric and magnetic effects
   d. none of these

v. The cause of quantization of electric charges is:
   a. transfer of an integral number of neutrons
   b. transfer of an integral number of protons
   c. transfer of an integral number of electrons
   d. none of the above

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

The potentiometer consists of a long resistive wire(L) and a battery of known EMF, 'V' whose voltage is known as driver cell voltage. Assume a primary circuit arrangement by connecting the two ends of L to the battery terminals. One end of the primary circuit is connected to the cell whose EMF 'E' is to be measured and the other end is connected to galvanometer G. This circuit is assumed to be a secondary circuit.



i. How can we increase the sensitivity of a potentiometer?
   a. Increasing the potential gradient
   b. Decreasing the potential gradient
   c. Decreasing the length of potentiometer wire
   d. Increasing resistance put in parallel

ii. If l_1 and l_2 are the balancing lengths of the potentiometer wire for the cells of EMFs ε_1 and ε_2, then
   a. $\varepsilon_1 + \varepsilon_2 = l_1 + l_2$
   b. $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$
   c. $\varepsilon_1 \varepsilon_2 = l_1 l_2$
   d. None of these

iii. Example of a potentiometer is
   a. Mobile
   b. Modem
   c. Joystick
   d. All of these

iv. The emf of a cell is always greater than its terminal voltage. Why?
   a. Because there is some potential drop across the cell due to its small internal resistance
   b. Because there is some potential drop across the cell due to its large internal

resistance

c. Because there is some potential drop across the cell due to its low current
d. Because there is some potential drop across the cell due to its high current

v. Why is a ten wire potentiometer more sensitive than a four-wire one?
a. Small potential gradient
b. Large potential gradient
c. Large length
d. None of these

Section C

17. The energy of the electron, in the ground state of hydrogen, is - 13.6 eV. Calculate the energy of the photon that would be emitted, if the electron were to make a transition corresponding to the emission of the first line of the (i) Lyman series (ii) Balmer series of the hydrogen spectrum.

18. An equiconvex lens of focal length f is cut into two identical plane convex lenses. How will the power of each part be related to the focal length of the original lens? A double convex lens of +5D is made of glass of refractive index 1.55 with both faces of equal radii of curvature. Find the value of its radius of curvature.

OR

A diverging lens of focal length F is cut into two identical parts, each forming a Plano concave lens. What is the focal length of each part?

19. Two pith-balls each of mass 5×10^{-4} kg are suspended from the same point by silk threads 0.2 m long. Equal charges are given to the balls, which separate, until the threads enclose an angle of 30^{o}. Calculate the charge on each pith-ball.

OR

An electric dipole is placed in a uniform electric field E with its dipole moment p parallel to the field. Find

i. the work done in turning the dipole till its dipole moment points in the direction opposite to E.
ii. the orientation of the dipole for which the torque acting on it becomes maximum.

20. Using the relevant Bohr's postulates, derive the expressions for the
i. speed of the electron in the nth orbit

ii. radius of the nth orbit of the electron in hydrogen atom.

21. The electric current in a wire in the direction from B to A is increasing. What is the direction of induced current in the metallic loop kept above the wire as shown in a given figure?

22. Define electron volt and atomic mass unit. Calculate the energy in joule equivalent to the mass of one proton.

23. Explain, why an air bubble inside a transparent liquid behaves like a diverging lens.

24. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its North tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place.

OR

An aeroplane is flying horizontally from west to east with a velocity of 900 km/hour. Calculate the potential difference developed between the ends of its wings having a span of 20 m. The horizontal component of the Earth's magnetic field is 5×10^{-4}T and the angle of dip is 30^{o}.

25. A giant telescope in an observatory has an objective of focal length 19 m and an eye-piece of focal length 1.0 cm. In normal adjustment, the telescope is used to view the moon. What is the diameter of the image of the moon formed by the objective? The diameter of the moon is 3.5×10^{6} m and the radius of the lunar orbit round the earth is 3.8×10^{8} m.

Section D

26. An inductor L of inductance X_L is connected in series with a bulb and an ac source. How would brightness of the bulb change when

  i. the number of turns in the inductor is reduced

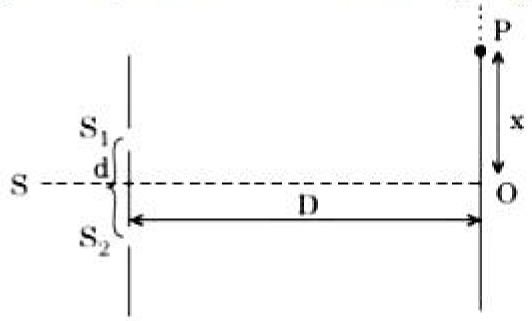
  ii. an iron rod is inserted in the inductor and

  iii. a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit.

  Justify your answer in each case.

27. i. Can the interference pattern be produced by two independent monochromatic sources of light? Explain.

ii. The intensity at the central maximum (O) in a Young's double slit experimental set-up shown in the figure is I_O. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P, would equal $\frac{I_o}{4}$.



iii. In Young's double slit experiment, the slits are separated by 0·5 mm and screen is placed 1·0 m away from the slit. It is found that the 5^{th} bright fringe is at a distance of 4·13 mm from the 2^{nd} dark fringe. Find the wavelength of light used.

OR

Explain the following giving reasons:

i. When monochromatic light is incident on a surface separating two media, then both reflected and refracted light have the same frequency as the incident frequency.

ii. When light travels from a rarer to a denser medium, then speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave?

iii. In the wave picture of light, the intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

28. Find the ratio of the potential differences that must be applied across the parallel and series combination of two capacitors C_1 and C_2 with their capacitances in the ratio 1 : 2, so that the energy stored in these two cases becomes the same.

OR

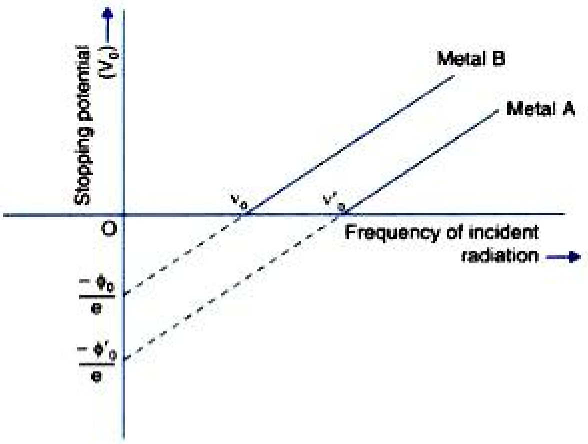
i. Plot a graph comparing the variation of potential V and electric field E due to a point charge Q as a function of distance R from the point charge.

ii. Find the ratio of the potential differences that must be applied across the parallel and the series combination of two capacitors, C_1 and C_2 with their capacitances in the ratio 1 : 2, so that the energy stored in the two cases becomes the same.

29. Sketch the graphs showing the variation of stopping potential with frequency of incident

radiations for two photosensitive materials A and B having threshold frequencies $\nu_0' > \nu_0$ respectively:

i. Which of the two metals, A or B has higher work function?
ii. What information do you get from the slope of the graphs?
iii. What does the value of intercept of graph 'A' on the potential axis represent?



30. A straight wire of length L is bent into a semi-circular loop. Use Biot-Savart's law to deduce an expression for the magnetic field at its centre due to the current I passing through it.

Section E

31. i. Why are Si and GaAs preferred materials for solar cells?
ii. Describe briefly with the help of a necessary circuit diagram, the working principle of a solar cell.

OR

i. In the following diagram, is the junction diode forward biased or reverse biased?

ii. Draw the circuit diagram of a full wave rectifier and state how it works?

32. An LC circuit contains a 20 mH inductor and a $50\mu F$ capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0.
a. What is the total energy stored initially? Is it conserved during LC oscillations?
b. What is the natural frequency of the circuit?
c. At what time is the energy stored
   i. completely electrical (i.e. stored in the capacitor)?

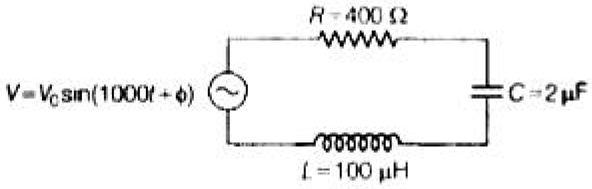
ii. completely magnetic (i.e. stored in the inductor)?

d. At what times is the total energy shared equally between the inductor and the capacitor?

e. If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

OR

i. Determine the value of phase difference between the current and the voltage in the given series L-C-R circuit.



ii. Calculate the value of additional capacitor which may be joined suitably to the capacitor C that would make the power factor of the circuit unity.

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

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

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. Electric field intensity
2. Ultraviolet radiations are used
   i. to preserve the food stuff,
   ii. to sterilizing the surgical instruments.

OR

Microwaves are used in RADAR. The frequency range is 10^{10} to 10^{12} Hz.

3. The locus of all the particles of the medium, which at any instant are vibrating in the same phase, is called the **wavefront**.
   Huygens' principle states that each point of the wavefront is the source of the secondary wavelets which spread out in all direction with the speed of a wave.
4. Since $\overrightarrow{\mathrm{F}} = q(\vec{v} \times \overrightarrow{\mathrm{B}})$, the force acts in the direction of $\vec{v} \times \overrightarrow{\mathrm{B}}$ i.e. perpendicular to both $\vec{v}$ and $\vec{B}$

OR

The current flows in a conductor due to the motion of electrons through it. When a current carrying conductor is placed inside a magnetic field, the electrons moving inside the conductor experience force due to the magnetic field in a direction perpendicular to the length of the conductor. As the electrons are confined to the conductor, the force on the electrons shows its effect as the force on the conductor.

5. In case of a lens of large aperture, the behaviour of the paraxial and the marginal rays are markedly different from each other. The two types of rays come to focus at different points on the principal axis of the lens. However, in case of a lens of small aperture, all the rays of light come to focus at one point.
6. $\frac{1}{2}mv^2{}_{\max} = h\nu - \phi_0$
   $= 6.63 \times 10^{-34} \times 3 \times 10^{15} - 4 \times 1.6 \times 10^{-19}$

or $v_{\max}^2 = \frac{2[19.89\times10^{-19}-6.4\times10^{-19}]}{9.1\times10^{-31}}$

$= \frac{26.98\times10^{-19}}{9.1\times10^{-31}} = 2.96 \times 10^{12}$

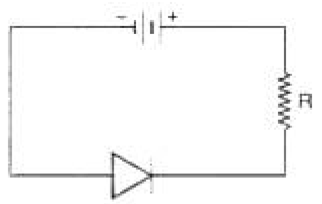
$v_{\max} = 1.72 \times 10^6 ms^{-1}$

7. 1 a.m.u = 1.66×10^{-27} kg

OR

Heavy water is used as a moderator because its mass is nearest to that of a neutron and it has negligible chances for neutron absorption.

8. The circuit shown in figure (a) can be redrawn as shown in figure.



As the p-section is connected to negative terminal of the battery, the diode has been reverse biased.

By redrawing the circuit diagrams, it can be shown that diode in circuit shown in figure (b) is **reverse biased** and in the circuit shown in figure (c), the diode is **forward biased**.

9. Non-magnetic materials are those materials, which are not affected by the magnetic field.
10. The junction diodes made from light (or photo) sensitive semiconductor are called photodiodes. It conducts when light is incident on the junction of the diode.
11. (c) A is true but R is false

Explanation: Current flows when there in P.D.

The presence of P.D implies the presence of an Electric field.

Drift velocity $\propto$ Electric field.

12. (c) A is true but R is false

Explanation: If two points P and Q in an electric field are separated by an infinitesimal distance Δ x and have a potential difference ΔV between them, E = $\frac{-\Delta V}{\Delta x}$. Here, negative sign implies that $\vec{E}$ has got a direction opposite to the potential gradient, i . e, in the direction of $\vec{E}$, the potential decreases, i. e, positive charge always moves from a higher potential point to a lower potential point.

13. (d) A is false and R is also false

Explanation: A is false and R is also false

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. (b) the actual transfer of electrons
    ii. (b) The glass rod gives electrons to silk when they are rubbed against each other.
    iii. (a) $1.97 \times 10^{-8}\ N$
    iv. (c) both electric and magnetic effects
    v. (c) transfer of an integral number of electrons
16. i. (b) Decreasing the potential gradient
    ii. (b) $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$
    iii. (c) Joystick
    iv. (a) Because there is some potential drop across the cell due to its small internal resistance
    v. (a) Small potential gradient

Section C

17. Given: E_1 = - 13.6 eV

    Now,

    $E_n = -\frac{13.6}{n^2}\text{eV}$

    For n = 2,

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

    For n = 3,

    $E_3 = -\frac{13.6}{3^2}\text{eV}$ = - 1.5 eV

    i. For Lyman series, E = E_2 - E_1 = (- 3.4)- (- 13.6) = 10.2 eV
    ii. For Balmer series, E = E_3 - E_2 = (- 1.5)- (- 3.4) = 1.9 eV
18. The focal length of the original equiconvex lens is f. Let the focal length of each part after cutting be F.

    Here, $\frac{1}{f} = \frac{1}{F} + \frac{1}{F} \Rightarrow \frac{1}{f} = \frac{2}{F} \Rightarrow f = \frac{F}{2} \Rightarrow F = 2f$

    Power of each part will be given by

    $P = \frac{1}{F} \Rightarrow P = \frac{1}{2f}$

    From lens maker formula, we have

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

where R_1 and R_2 are radius of curvatures of the lens

$5 = (1.55 - 1)\left\{\frac{1}{R} - \left(\frac{1}{-R}\right)\right\}$ [as R_1 = R and R_2 = -R]

or $5 = 0.55 \times \frac{2}{R}$

$R = \frac{0.55 \times 2}{5}$ = 0.22 m = 22 cm

So, radius of curvature of each side is 22 cm.

OR

For single diverging lens,

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

Let R_1 = - R, R_2 = R

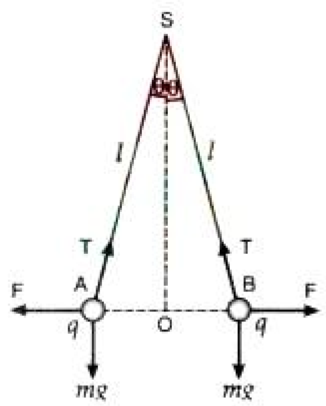
$\therefore \frac{1}{F} = (\mu - 1)\left(\frac{1}{-R} - \frac{1}{R}\right) = \frac{-2(\mu-1)}{R}$

For each half (which is plano concave) as shown in figure:

R_1 = -R and $R_2 = \infty$

$\therefore \frac{1}{F_1} = \frac{1}{F_2} = (\mu - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right) = \frac{-(\mu-1)}{R} = \frac{1}{2F}$

$\therefore F_1 = F_2 = 2F$

19. 

Here, AS = 0.2 m and $\theta = \frac{30^\circ}{2} = 15^\circ$

According to the triangle law of forces,

$\frac{F}{OA} = \frac{mg}{SO} = \frac{T}{AS}$

or F = mg $\times$ $\frac{OA}{SO}$

or $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q \times q}{(AB)^2}$ = $mg \times \frac{OA}{SO}$ = mg tanθ

Setting m = 5 $\times$ 10^{-4} kg, g = 9.8 ms^{-2} and

AB = 2 $\times$ OA = 2 $\times$ AS sinθ, we get

q = 3.958 $\times$ 10^{-8} C

OR

i. If a dipole is placed in an electric field, then in order to rotate it we have to do the work against electric field lines which can be found as:
   Work done in rotating the dipole, $W = \int_{\theta_1}^{\theta_2} \tau d\theta$
   If the dipole is turned from direction parallel to electric field to direction opposite to electric field, then angle θ will change from 0 to π.
ii. We know that, $\tau = pE \sin\theta$
   If $\theta = \pi/2$, then τ is maximum
   i.e. $\tau = pE \sin\frac{\pi}{2} \Rightarrow \tau = pE$ (maximum)
   Maximum torque will be experienced by the dipole when its dipole moment is perpendicular to electric field lines.

20. a. From Bohr's first postulate,
   $\frac{mv^2}{r} = \frac{kZe^2}{r^2}$
   where k = $\frac{1}{4\pi\varepsilon_o}$
   Thus, r = $\frac{kZe^2}{mv^2}$
   From Bohr's postulate of angular momentum,
   r = $\frac{nh}{2\pi mv}$
   $\therefore \frac{kZe^2}{mv^2} = \frac{nh}{2\pi mv}$ or v = $\frac{2\pi kZe^2}{nh}$
   This is the velocity of electron in Bohr's stationary orbit.

b. Now, mvr = $\frac{nh}{2\pi}$ or v = $\frac{nh}{2\pi mr}$
   Also, $\frac{mv^2}{r} = \frac{kZe^2}{r^2}$
   Putting the value of v, we get
   $\frac{m}{r} \frac{n^2h^2}{4\pi^2m^2r^2}$ = $\frac{kZe^2}{r^2}$ or $r = \frac{n^2h^2}{4\pi^2 mkZe^2}$
   This is the radii of Bohr's stationary orbit.

21. When the increasing current flows through the wire in the direction from point B to A, the increasing magnetic field is produced; which is directed perpendicular to the plane of the loop (or the plane of paper) and in inward direction. Due to this, induced e.m.f. is produced in the loop which opposes the magnetic field produced due to the current flowing through the wire i.e. induced current in the loop should flow in a direction so that it produces magnetic field perpendicular to the plane of the loop and in outward direction. Maxwell's cork screw rule tells that induced current in the loop will flow in anticlockwise direction.

22. **Electron volt:** It is defined as the energy gained by an electron when accelerated through a potential difference of 1 volt.

    Atomic mass unit: It is defined as one-twelfth the mass of one atom of carbon-12.

    The mass of a proton is 1.67×10^{-27} kg. Therefore, the energy equivalent of this mass is,

    $E = mc^2 = 1.67 \times 10^{-27} \times (3 \times 10^8)^2$

    $= 1.5 \times 10^{-10}$ J

23. An air bubble acts as a convex lens made of air and placed inside the liquid. Therefore, the air bubble acts as a lens, whose focal length is given by

    $\frac{1}{f_{\text{bubble}}} = \left({}^{l}\mu_a - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

    Here, $l_{\mu_a} < 1$ i.e. $l_{\mu_a} - 1$ is negative. Since the factor $\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ is positive, the value of f will be negative. Hence, the air bubble inside a transparent liquid behaves as a diverging lens.

24. Angle of dip, $\delta = 60^\circ = \frac{\pi}{3}$

    Horizontal component of the earth's magnetic field is, $B_H = 0.4\text{ G} = 0.4 \times 10^{-4}$ T

    Magnetic field of earth (B) =?

    Horizontal component of the earth's magnetic field,

    $B_H = Bcos\delta$

    $B = \frac{B_H}{\cos\delta}$

    $B = \frac{0.4 \times 10^{-4}\,T}{\cos 60^\circ}$

    $B = \frac{0.4 \times 10^{-4}\,T}{1/2}$

    $B = 0.8 \times 10^{-4}\,T \therefore B = 8 \times 10^{-5}\,T$

OR

Let the potential difference between the ends of the wings 'e' = B_V

Given Velocity, v = 900 km/hour = 250 m/s

Wing span length (l) = 20 m

Vertical component of Earth's magnetic field is given as

$B_V = B_H \tan\delta = 5 \times 10^{-4} \tan 30^o$

Potential difference, E = $B_V lv$

$= 5 \times 10^{-4} \tan 30^o \times 20 \times 250$

$= \frac{5 \times 20 \times 250 \times 10^{-4}}{\sqrt{3}}$

= 1.44 volt

So, 1.44 V potential difference is developed across the ends of the wings of aeroplane.

25. Since moon is situated very far, so its image is at the focal plane of objective lens.

So, angle subtended by diameter of moon is equal to angle subtended by the image,

$\beta = \alpha$

or $tan\beta = tan\alpha$

or $\frac{d}{f_o} = \frac{D}{r}$; where D is diameter of moon and r is the distance of moon from the earth.

$\therefore d = \frac{D \times f_o}{r} = \frac{3.5 \times 10^6 \times 19}{3.8 \times 10^8} = 17.5 \times 10^{-2} m = 17.5 cm$

Section D

26. i. When the number of turns of the inductor is reduced, its reactance X_L decreases. The current in the circuit increases and hence the brightness of the bulb decreases.

ii. When an iron rod is inserted, it increases the inductive reactance, which in turn decreases the current and hence the brightness of the bulb.

iii. When $X_L = X_C$, the circuit i.e., the impedance becomes minimum and maximum current flows. This makes the bulb glow more.

27. i. No. Sustained interference pattern cannot be obtained. Light waves emitted from a source undergoes abrupt phase changes in times of the order of 10^{-10}s. So light from two independent sources will not have fixed phase relationship and will be incoherent.

ii. $x = \frac{\beta}{3}$, path difference = $\frac{\lambda}{3}$

phase difference = $\frac{2\pi}{3}$

$I = I_0 \cos^2 \frac{\phi}{2}$

$I = I_o \cos^2 (\frac{2\pi}{3 \times 2}) = I_o \cos^2 (\frac{\pi}{3})$

$I = I_o (\frac{1}{4}) = \frac{I_o}{4}$

iii. Distance of 5^{th} bright fringe from 2^{nd} dark fringe

$x = \frac{5\lambda D}{d} - \frac{3\lambda D}{2d} = \frac{7}{2}\frac{\lambda D}{d}$

$\lambda = \frac{2xd}{7D} = \frac{2 \times 4.13 \times 10^{-3} \times 0.5 \times 10^{-3}}{7 \times 1}$

$\lambda = 0.59 \times 10^{-6}$ m = 5900 $\overset{o}{A}$

OR

i. Frequency is the characteristic of the sources while wavelength is the characteristic of the medium. When monochromatic light travels from one medium to another, its speed changes, so its wavelength changes but frequency remains same. Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

ii. Speed decreases due to decrease in wavelength of wave but energy carried by the light wave depends on the amplitude of the wave.

iii. In the photon picture of light, intensity of a light is determined by the number of photons incident per unit area.

For a given frequency, intensity of light in the photon picture is determined by

$I = \frac{\text{Energy of photons}}{\text{area} \times \text{time}} = \frac{n \times hv}{A \times t}$

28. Total energy stored in series or parallel combination of capacitors is equal to the stored energy in the equivalent capacitor.

In parallel combination, total energy stored in both the capacitors

$= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_1^2$..... (i) (since C = $C_1 + C_2$ in parallel combination of two capacitors of capacitances C_1 and C_2)

In series combination, energy stored in the the equivalent capacitor = $\frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}V_2^2$ ...(ii) (applying the formula of equivalent capacitance for series combination of the above two capacitors)

According to the question, energy in both the cases is same so,

$\left(\frac{1}{2}C_1 + \frac{1}{2}C_2\right)V_1^2 = \frac{C_1C_2}{2(C_1+C_2)}V_2^2$

$\Rightarrow \quad \frac{V_1^2}{V_2^2} = \frac{C_1C_2\times2}{2(C_1+C_2)(C_1+C_2)} \Rightarrow \frac{V_1}{V_2} = \frac{\sqrt{C_1C_2}}{C_1+C_2}$

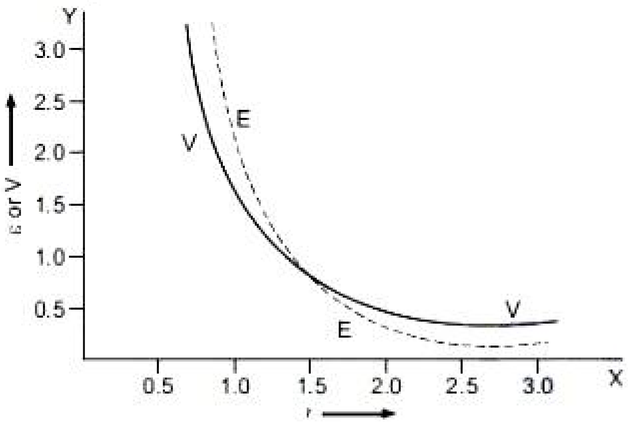
But, $\frac{C_1}{C_2} = \frac{1}{2} \Rightarrow C_2 = 2C_1$

So, $\frac{V_1}{V_2} = \frac{\sqrt{C_1\times2C_1}}{C_1+2C_1} = \frac{\sqrt{2}C_1}{3C_1} = \frac{\sqrt{2}}{3}$

OR

i. The graph comparing the variation of potential V and electric field is shown below:

Here $\varepsilon \propto \frac{1}{r^2}$ and $V \propto \frac{1}{r}$



ii. Let C_1 = C and C_2 = 2C

Equivalent capacitance in parallel combination, C_P = 2C + C = 3C

and in series combination, $C_s = \frac{2C\times C}{2C+c} = \frac{2C^2}{3C} = \frac{2C}{3}$

Let V_P and V_s are potential difference across the equivalent capacitance in parallel and series combination respectively, to have same potential energy.

i.e. $U_P = U_s$

$\therefore \frac{1}{2}C_pV_p^2 = \frac{1}{2}C_sV_s^2 \Rightarrow \frac{V_p}{V_s} = \sqrt{\frac{C_s}{C_p}}$

$\Rightarrow \frac{V_P}{V_S} = \sqrt{\frac{(2C/3)}{(3C)}} = \sqrt{\frac{2}{9}}$

$\therefore V_p : V_s = \sqrt{2} : 3$

This is the required ratio of the potential differences across the parallel and series combination of the capacitors.

29. i. Since work function, $\phi = h\nu$

$\therefore \phi_0{}' = h\nu_0{}'$

Metal 'A' has higher work function as $\nu_0{}' > \nu_0$

ii. We know that,

$K_{max} = h\nu - \phi_o = eV_o$

Dividing the whole equation by e, we get,

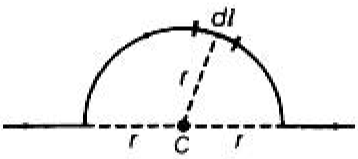
$\frac{h\nu}{e} - \frac{\phi_o}{e} = V_o$

From the above equation, the slope of the graph is $\frac{h}{e}$ (on comparing with the straight line equation). Thus, we see that the slope is independent of the nature of the photoelectric material.

iii. Intercept of graph A on the potential axis = $-\frac{\phi_0'}{e}$

In this way, the work function can be determined.

30. A straight wire of length L carrying a current I is bent into semi-circular loop of arc radius r. Consider the figure.



Considering a small element dl on circular current loop. The magnitude dB of magnetic field due to small current element dl is given by Biot-Savart's law:

$dB = \frac{\mu_0}{4\pi}\frac{I|dl \times r|}{r^3}$

Now, dB due to the straight segments is zero as dl and r are parallel.

The magnetic field at the centre C of the loop for segments of semi-circular arc is calculated below.

Length of wire = Circumference of semi-equal circular wire

$\Rightarrow \quad L = \pi r \Rightarrow r = \frac{L}{\pi}$ .... (i)

The magnetic field dB,

$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl \sin 90^\circ}{r^2}$ $[\because \text{ Idl } \perp \mathbf{r}, \ldots \theta = 90^\circ]$

$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{r^2}$

$\therefore$ Net magnetic field at C due to semi-circular loop

$B = \int_{\text{semicircle}} \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \Rightarrow B = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int_{\text{semicircle}} dl$

$B = \frac{\mu_0}{4\pi} \cdot \frac{I}{r^2} L$

Using (i), $r = L/\pi$

$B = \frac{\mu_0}{4\pi} \cdot \frac{IL}{(L/\pi)^2} = \frac{\mu_0}{4\pi} \times \frac{IL}{L^2} \times \pi^2 \Rightarrow B = \frac{\mu_0 I\pi}{4L}$

This is the required expression of the magnetic field. From right hand rule, direction of B is normal to the plane of the paper going into it.

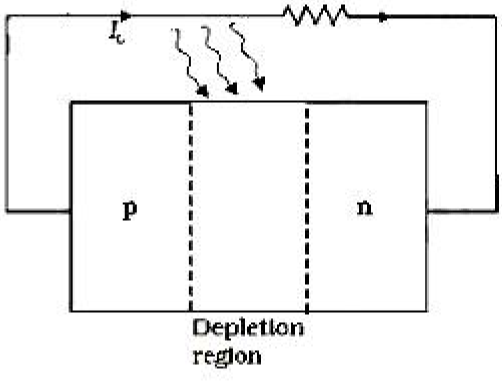
Section E

31. i. The energy for the maximum intensity of the solar radiation is nearly 1 5 eV. In order to have photo excitation, the energy of radiation ($h\nu$) must be greater than energy band gap (E_g), i.e. $h\nu > E_g$ Therefore , the semiconductor with energy band gap about 1.5 eV or lower and with higher absorption coefficient, is likely to give better solar conversion efficiency.

The energy band gap for Si is about 1.1 eV, while for GaAs, it is about 1.43 eV. The gas GaAs is better inspite of its higher band gap than Si because it absorbs relatively more energy from the incident solar radiations being of relatively higher absorption coefficient

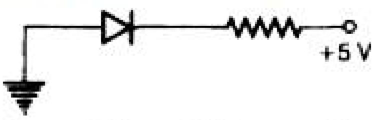
ii. A solar cell is based on the photovoltaic effect i.e. to convert light directly into electrical energy.

When light of frequency, ν such that $h\nu > E_g$ (band gap) is incident on junction, then electron-hole pair liberated in the depletion region drifts under the influence of potential barrier. The gathering of these charge carriers make p-type as positive electrode and n-type as negative electrode and hence, generating photo-voltage across solar cell. When an external load is connected as shown in the Fig. a photocurrent I_L flows through the load.



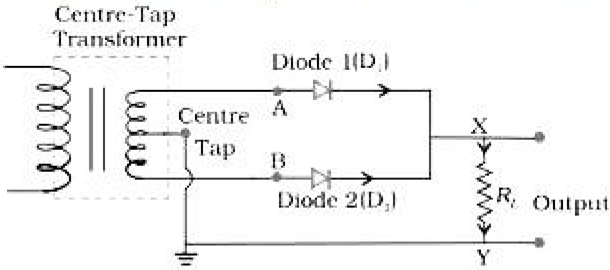
OR

i. In this case, the p-side is at 0V, whereas the n-side is at +5V. As, $V_p < V_n$, hence the diode is reverse biased.



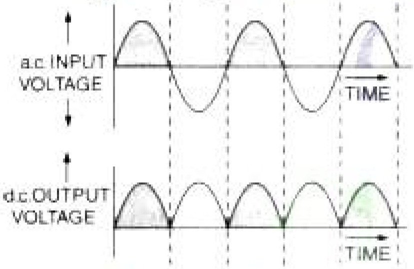
ii. A rectifier which rectifies both halves of each a.c. input cycle is called a full wave rectifier.

The circuit arrangement is shown in the figure.



Suppose the input voltage to A with respect to the centre tap at any instant is positive. It is clear that, at that instant, voltage at B being out of phase will be negative. So, diode D_1 gets forward biased and conducts (while D_2 being reverse biased is not conducting). Hence, during this positive half cycle we get an output current (and a output voltage across the load resistor R_L). In the course of the ac cycle when the voltage at A becomes negative with respect to centre tap, the voltage at B would be positive. In this part of the cycle diode D_1 would not conduct but diode D_2 would, giving an output current and output voltage (across R_L) during the negative half cycle of the input ac. Thus, we get output voltage during both the positive as well as the negative half of the cycle.

The input-output waveforms are shown in the figure.



32. a. Total initial energy,

$$E = \frac{Q_0^2}{2C} = \frac{10^{-2}\times 10^{-2}}{2\times 50\times 10^{-6}} = 1\ \text{J}$$

This energy shall remain conserved in the absence of resistance.

b. Angular frequency, $\omega = \frac{1}{\sqrt{LC}}$

$$= \frac{1}{(20\times 10^{-3}\times 50\times 10^{-6})^{1/2}}$$

$= 10^3$ rads^{-1}

$$Thus, f = \frac{10^3}{2\pi} = 159 Hz$$

c. $Q = Q_0 \cos \omega t$

Or $Q = Q_0 \cos \frac{2\pi}{T} t$, where $T = \frac{1}{f} = \frac{1}{159} s$ = 6.3 ms

Energy stored is completely electrical at t = 0, T/2, 3T/2 . . .

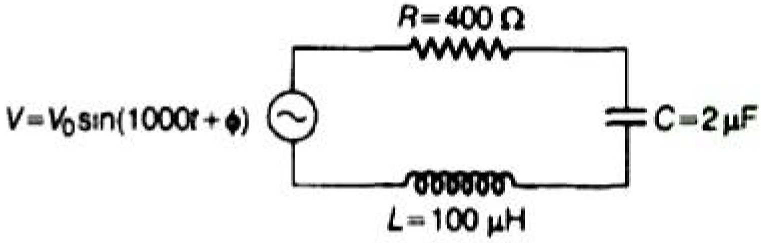
Electrical energy is zero i.e. energy stored is completely magnetic at
$t=\frac{T}{4},\frac{3T}{4},\frac{5T}{4},\ldots$

d. At $t=\frac{T}{8},\frac{3T}{8},\frac{5T}{8},\ldots$, the total energy is shared equally between the inductor and the capacitor. As,$\because Q=Q_0\cos\frac{\omega T}{8}=Q_0\cos\frac{\pi}{4}=\frac{Q_0}{\sqrt{2}}$

$\therefore$ Electrical energy $=\frac{Q^2}{2C}=\frac{1}{2}\frac{Q_0^2}{2C}$, which is half of the total energy.

e. R damps out the LC oscillations eventually. The whole of the initial energy 1.0 J is eventually dissipated as heat.

OR

i. 

$V=V_0\sin(1000t+\phi)\Rightarrow\omega=1000\text{Hz}$
$R=400\Omega, C=2\mu F, L=100\text{mH}$
Capacitive reactance, $X_c=\frac{1}{\omega C}$
$\Rightarrow\quad X_C=\frac{1}{1000\times2\times10^{-6}}$
$\Rightarrow\quad X_c=\frac{10^3}{2}\Rightarrow X_c=500\Omega$
Inductive reactance, $X_L=\omega L$
$\Rightarrow\quad X_L=1000\times100\times10^{-3}\Rightarrow X_L=100\Omega$
So, $X_c>X_L$
$\Rightarrow\tan\phi$ is negative.
Hence, the voltage lags behind the current by a phase angle ϕ .
Phase difference, tanϕ = $=\frac{X_L-X_C}{R}$
$\tan\phi=\frac{100-500}{400}\Rightarrow\tan\phi=\frac{-400}{400},\tan\phi=-1$
$\Rightarrow\quad\tan\phi=-\tan\left(\frac{\pi}{4}\right)\Rightarrow\phi=-\frac{\pi}{4}$
This is the required value of the phase difference between the current and the voltage in the given series L-C-R circuit.

ii. Suppose, new capacitance of the circuit is C'. Thus, to have power factor unity
$\cos\phi'=1=\frac{R}{\sqrt{R^2+\left(X_L-X_C'\right)^2}}$
$\Rightarrow\quad R^2=R^2+\left(X_L-X_C'\right)^2$

$\Rightarrow \quad X_L = X'_C = \frac{1}{\omega C'}$ or $\quad \omega L = \frac{1}{\omega C'}$

$\Rightarrow \omega^2 = \frac{1}{LC'}$ or $(1000)^2 = \frac{1}{LC'}$ $(\because \omega = 1000)$

$\Rightarrow \quad C' = \frac{1}{L\times 10^6} = \frac{1}{100\times 10^{-3}\times 10^6}$

$= \frac{10}{10^6} = \frac{1}{10^5} = 10^{-5}$

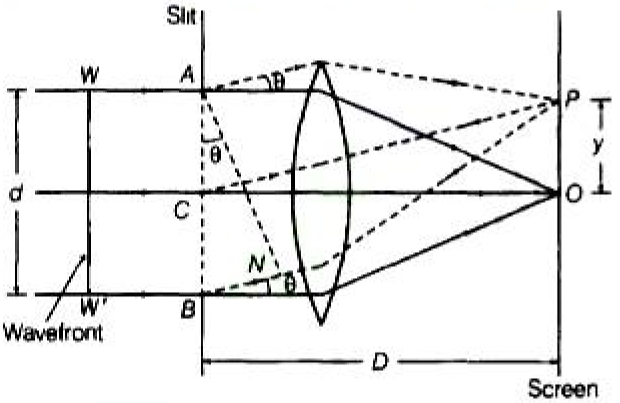
$\Rightarrow \quad C' = 10^{-5}\text{F} = 10 \times 10^{-6}\text{F} = 10\mu\text{F}$

As, C' > C, hence, we have to add an additional capacitor of capacitance =

$10\mu F - 2\mu F = 8\mu F$ in parallel with previous capacitor.

33. i. A single narrow slit is illuminated by a monochromatic source of light. The diffraction pattern is obtained on the screen placed in front of the slits. There is a central bright region called as central maximum. All the waves reaching this region are in phase hence the intensity is maximum. On both side of central maximum, there are alternate dark and bright regions, the intensity becoming weaker away from the center. The intensity at any point P on the screen depends on the path difference between the waves arising from different parts of the wave-front at the slit.

Diffraction of light at a single slit A parallel beam of light with a plane wavefront WW' is made to fall on a single slit AB. As width of the slit AB = dis of the order of wavelength of light, therefore, diffraction occurs on passing through the slit.



The wavelets from the single wavefront reach the centre O on the screen in same phase and hence, interfere constructively to give central maximum (bright fringe). The diffraction pattern obtained on the screen consists of a central bright band having alternate dark and weak bright band of decreasing intensity on both sides.

Consider a point P on the screen at which wavelets travelling in a direction making an angle θ with CO are brought to focus by the lens. The wavelets from points A and B will have a path difference equal to BN.

From the right angled ΔANB, we have BN = AB sinθ or BN = d sinθ.

To establish the condition for secondary minima, the slit is divided into 2,4,6... equal parts such that corresponding wavelets from parts such that corresponding wavelets from successive regions interfere with path difference $\lambda/2$

or for nth secondary minlmum.the slit can be divided into 2n equal parts. Hence, for nth secondary minimum, path difference= $= d\sin\theta_n = n\lambda$.

or $\sin\theta_n = \frac{n\lambda}{d}(n = 1, 2, 3, \ldots)$

To establish the condition for secondary maxima, the slit is divided into 3,5,7... equal parts such that corresponding wavelets from alternate regions interfere with path difference of A./2 or for nth secondary maximum, the slit can be divided into (2n+ 1)equal parts.

Hence, for nth secondary maximum

$d\sin\theta_n = (2n+1)\frac{\lambda}{2}$ (n = 1, 2, 3,...)

ii. For $\lambda_1 = 590\text{mm}$

Location of 1 maxima $y_1 = (2n+1)\frac{D\lambda_1}{2d}$

If $n = 1 \Rightarrow y_1 = \frac{3D\lambda_1}{2d}$

For $\lambda_2 = 596\text{nm}$

Location of III maxima

$y_2 = (2n+1)\frac{D\lambda_2}{2d}$, if n = 1

$\Rightarrow y_2 = \frac{3D\lambda_2}{2d}$

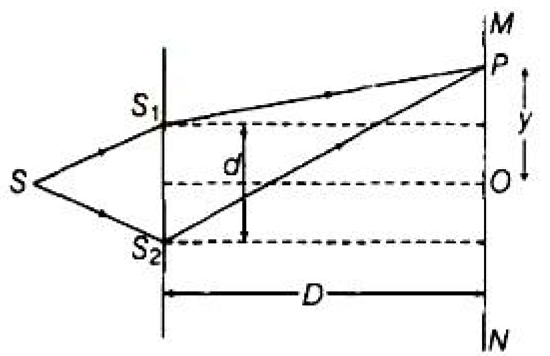
$\therefore$ Path difference $= y_2 - y_1 = \frac{3D}{2d}(\lambda_2 - \lambda_1)$

$= \frac{3\times1.5}{2\times2\times10^{-6}}(596 - 590)\times10^{-9}$

$= 6.75\times10^{-3}\text{m}$

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,......

   $\therefore \quad y = \frac{nD\lambda}{d}$ [∵ 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