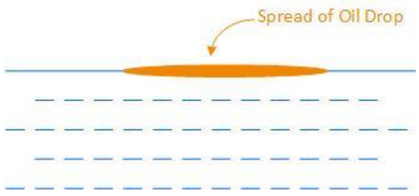
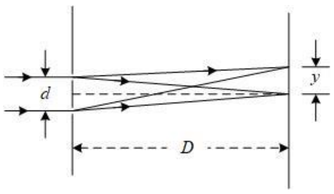
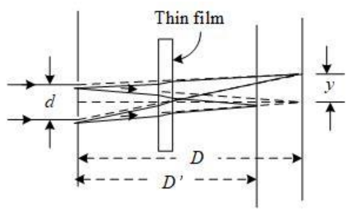
Wave and Motion : Light Waves – Typical Questions

(Illustrations Only)

I-01	Nature of light is decided by its behavior. Waves depict reflection, refraction, interference and diffraction which is true to light. But, corpuscular nature of light depicted in photoelectric and scattering phenomenon is observed with light depicts its particle nature. Thus light is both particle and wave phenomenon. **Hence answer is option (a).**
I-02	Since light can travel in vacuum and hence it does not require any material medium. Moreover, elasticity and inertia are properties of a material that can constitute medium, hence speed of light does not depend either of elasticity or inertia. **Thus answer is option (d).**
I-03	Primarily light can travels in vacuum and hence in the expression of $y = f(A, k, x, \omega, t)$ none of the parameters can be related to material properties. In light of this each option is being examined independently – (a) Displacement is of particle which is not essential for propagation of light, **hence option (a) is not correct** (b) Pressure is on a medium, which is not essential for propagation of light, **hence option (b) is not correct** (c) Density is property of a medium which is not essential for propagation of light, **hence option (a) is not correct** (d) Light is an electromagnetic wave where electric-field and magnetic-field undergo sinusoidal variation and hence electric field is one of the essential component of light. **Thus option (d) is correct.** **Thus answer is option (d).**
I-04	Transverse wave have effective variation perpendicular to the direction of propagation of the wave. Polarization phenomenon is about orientation of the variation in direction perpendicular to the direction of propagation of the wave. **This makes option (d) to be correct.** As regards reflection, refraction and diffraction phenomenon they are about effectiveness of wave on direction of propagation without consideration of the direction of the effective variation it can be longitudinal or transverse. Thus, phenomenon in respect of reflection, refraction and diffraction cannot be attributed to transverse nature of effective variation in light. **This makes option (a), (b) and (c) to be incorrect.** **Thus option (d) is the answer.**
I-05	Light is energy and energy contained in a wave packet is exprssed by $e = h\nu$ … (1). Here h is Planck's constant and ν is frequency expressed in Herts. As per the Principle of Conservation of Energy (PCE) of the refracted ray and incident ray is same as there is no loss of energy in the phenomenon. Further, $c = \lambda\nu$ …(2) Here, λ is wavelength. Accordingly each of the given option is vbeing examined – (a) If both wavelength and frequency increase, then energy of the wave should also change which contradics PCE which is not possible in refraction. **Thus option (a) is incorrect**. (b) During refraction when light travels from lighter to denser medium speed decreases. Given statement of frequency as constant conforms to (1) but contradicts (2) as per decrease of speed duruing refraction explained in this part, which is not possible.**Thus option (b) is also incorrect.** (c) As per (1) frequency is constant and is a part of statement is correct. Further since speed decreases and hence as per (2) wavelength would decrease is another part of the statement, is also correct. Thus both the parts of th statement are correct and **hence option (c) is correct.** (d) Second part of the statement contracdicts (1) and hence it is incorrect. Thus statement is correct if it

	is so in reach of ach of the part, which is not so. **Hence option (d) is incorrect**. **Thus correct answer is option (c).**
I-06	During refraction frequency of light does not change while, its speed changes that makes **option (c) to be incorrect.** Further, speed of light $c = \lambda\nu$ …(1), here, λ is wavelength, and ν is frequency. Hence with change of vlocity wavelength would change in direct proportion making option (a) to be incorrect. Energy equation of wave by $e = h\nu$ … (1) together with the Principle of Concervation of Energy (PCE) frequency would remain unchanged and thus **option (b) is correct**. Further, refrlection and refraction goes together, and if-and-only-if it is pure refraction then only amplitude would remain unchaged, which is always not true. Hence option (d) is incorrect. Hence it is only **option (b) which is correct, and is the answer**.
I-07	The problems statement is silent in respect of any other information that could lead to computation of wavelengths of AM radio wave and FM radio wave. Therefore it is not possible to calculate their respective wave lengths λ_a and λ_f and **hence option (d) is the correct answer**. .
I-08	Light produced by candle has different colors depends upon temperature of gases which vary over a range and hence it can't be called monochromatic **hence option (a) is incorrect**. Light produced by bulb is incandescence phenomenon which contains various frequencies depending upon temperature as per Boltzmann and Stefan's Law. Hence it can't be called monochromatic **hence option (b) is incorrect**. Light produced by mercury tube is by gaseous discharge phenomenon. This produces light of different frequencies based on relaxation energy by excited electrons of molecules of mercury vapour. These frequencies decide the colour of the light and hence this can't be called monochromatic. **Thus option (c) is incorrect,** Laser light by it is vary nature is monochromatic, **hence option (d) is correct.** **Thus answer is option (d).**
I-09	Equation of a line in space is $lx + my + nz = p$….(1)Here, direction ratios are $l = \cos\alpha$, $m = \cos\beta$, and $n = \cos\gamma$ …(2)where α, β and γ are angles made by the line with respect to X-axis, Y-axis and Z-axis such that $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$ …(3). These direction ratios are components of unit length along the respective directions; in the instant case unit length is wavelength λ. These direction ratios are so related that $l^2 + m^2 + p^2 = 1$….(4) and $p > 0$ The problem states that $x + y + z = c$…(5). On comparing (1) and (5) we have $l = k$, $m = k$, $n = k$ and $p = k$….(6). Combining (2), (4) and (6) we have $k^2 + k^2 + k^2 = 1 \Rightarrow k = \frac{1}{\sqrt{3}}$. And $\cos\alpha = \frac{1}{\sqrt{3}} \Rightarrow \alpha = \cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$. This values matches with part (d). **Hence answer is part (d).** **N.B.:** This question requires concept of Three-Dimensional coordinate geometry.
I-10	Wavefront as per Huygens' Theory is perpendicular to the direction of the wave. Light wave, as long as medium is unchanged, travels radially in a straight line i.e. wavefront on a plane is a tangential line and in space it is a tangential surface. Extending this analysis further, as distance of source increases radius of curvature of line or surface is $K = \frac{1}{D}$, here D is the distance of the point under consideration from the source. Thus as $D \to \infty \Rightarrow K \to 0$, it is the case for a straight line or a plane. Accordingly, the surface of wavefront at a point when source is at a large distance, also called a distant source, is a plane. **Hence, answer is option (a).**
I-11	As per Huygens' wave theory light propagates radially and a distance r from the source of intensity I , let intensity of light be I_r then total light coming out of the wavefront would be $I = I_r \times (4\pi r^2)$. It leads to $I_r = \frac{I}{4\pi r^2} \Rightarrow I_r \propto \frac{1}{r^2}$ as **provided in option (a). Thus it is true for a point source**. But, in case of line source or plane source or a cylindrical source, intensity at a point is integral effect of the intensity of each point of the source taken as point source and hence it comes out to be different than that state in the question. Accordingly**, option (b), (c) and (d) are incorrect.**

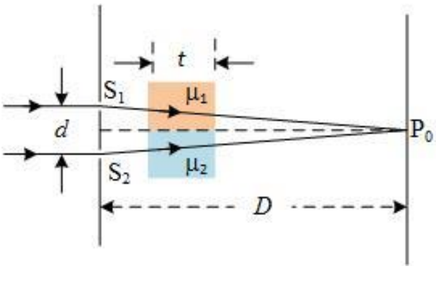
	Thus answer is option (a).
I-12	In case rays $y_1 = A_1 \sin \omega_1 \left(t - \frac{x}{v_1}\right)$ and $y_2 = A_2 \sin \left(\omega_2 \left(t - \frac{x}{v_2}\right) + \emptyset\right)$ from two sources interfere then resultant amplitude is $y = y_1 + y_2$. In case of coherent rays phase difference $\emptyset$ between them must be constant; this a consequence of angular velocities $\omega_1 = \omega_2$ and speed of propagation $v_1 = v_2$. Therefore for coherent rays phase difference must be constant and is provided in option (d). **Thus answer is option (d).**
I-13	When a drop of oil is spread on water surface it produces a disc as shown in the figure having different thickness. Thus rays of light that enter oil film undergo total reflection at the water surface and variation in thickness of the film causes different deviation to different wavelengths. Moreover, water together with oil surface experience stationary waves due to extraneous reasons. This enhances the deviation effect leading to change in optical path and thus interference as provided in option (d). **Hence answer is option (d).** 
I-14	Intensity of light from coherent sources is $I \propto A^2 \Rightarrow A \propto \sqrt{I}$ ... (1) here is amplitude of the wave. During interference at point of maximum intensity resultant amplitude is $A_{max} = A_1 + A_2$ and at point of minimum intensity $A_{mon} = A_1 - A_2$. Accordingly, using (1) $\frac{I_{max}}{I_{min}} = \frac{25}{1} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} \Rightarrow \frac{5}{1} = \frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}$. Applying componendo-dividendo $\frac{5+1}{5-1} = \frac{\sqrt{I_1}}{\sqrt{I_2}} \Rightarrow \frac{6}{4} = \frac{\sqrt{I_1}}{\sqrt{I_2}} \Rightarrow \frac{\sqrt{I_1}}{\sqrt{I_2}} = \frac{3}{2} \Rightarrow \frac{I_1}{I_2} = \frac{9}{4}$. This ratio matches with option (c). **Hence answer is option (c).**
I-15	Intensity of light from coherent sources is $I \propto A^2 \Rightarrow A \propto \sqrt{I}$ ... (1) here is amplitude of the wave. In Young's double slit experiment light from both the sources is coherent and hence intensity at central fringe is a result of constructive-interference of light amplitude A. Thus $A_0 = 2A \Rightarrow I_0 \propto (2A)^2 \Rightarrow I_0 \propto 4A^2$...(2) When one of the slit is closed light at central fringe is $A'_0 = A \Rightarrow I'_0 \propto A^2$ ... (3). Thus combining (2) and (3) $\frac{I'_0}{I_0} = \frac{A^2}{4A^2} \Rightarrow I'_0 = \frac{I_0}{4}$. This conclusion matches with **option (b), which is the answer.**
I-16	 Thin film is like a thin rectangular block on which incident rays from the slits would undergo equal displacement of emergent rays. Hence, there but for shift of fringes longitudinally affecting distance of screen marginally, while their width would remain same, as provided in option (c). **Thus answer is option (c).** 
I-17	When the experiment is performed in water, wavelength would decrease since speed of light in denser medium is lesser. Frequency of light however remain unchanged. Since $c = f\lambda$ and hence wavelength of light in water would be lesser. Thus with the decrease of wavelength fringe width also decreases, as provided in option (a), **hence answer is option (a).**
I-18	Though light can travel through ant transparent medium as provided in option (c), however, medium is not necessary since light is not a mechanical wave. Therefore, light can also travel through vacuum as provided in option (a). **Thus, answer is option (a) and (c).**
I-19	Taking each of the options u=independently, **Option (a):** Laws of collision of a moving particle with a stationary object of large mass is applicable to particles is similar to that of laws of reflection. Thus, though laws of reflection can be

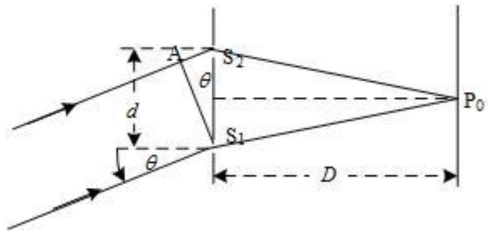
	explained with Huygens' Wave theory, it does not corroborate exclusive wave nature of light. Hence **option (a) is incorrect.** **Option (b):** Huygens' wave theory corroborates Snell's law which explains effect of change of speed of light with change of medium, in the instant case it is stated to be water. Thus it conclusively corroborates wave nature of light. **Thus option (b) is correct**. **Option (c):** Interference phenomenon occurs only in case of waves and thus it conclusively confirms wave nature of light. **Thus option (c) is correct** **Option (d):** Photoelectric phenomenon provides energy of wave packet $e = h\boldsymbol{\nu}$ here h is Planck's constant and is frequency of the wave. Yet quantum emission of electron on incidence of light on a surface supports particle nature of light, Thus conclusively it cannot be used to support wave nature of light. **Hence option (d) is incorrect**. **Thus answer is option (b) and (c).**
I-20	Taking each option independently – **Option (a):** Light being electromagnetic wave is electric and magnetic fields are not constant, **thus option (a) is incorrect.** **Option (b):** Since magnetic and electric fields are sinusoidal their average value over a cycle is Zero. **Thus option (b) is correct.** **Option (c):** Light has electric and magnetic fields are transverse in nature and hence variation of the two fields is perpendicular to direction of propagation of light. **Thus option (c) is correct.** **Option (d):** In light electric field and magnetic fields are mutually perpendicular to each other as explained by Maxwell's equation**. Thus option (d) is correct.** **Thus answer is options (b), (c) and (d).**
I-21	Examining each of the given option separately – **Option (a):** Secondary wavelets are used to construct new position of wavefront after a certain time based on speed of light in the medium. Thus is converse to the statement in the option. **Hence option (a) is incorrect.** **Option (b):** Huygens's principle explains propagation of light as a wave with particles of medium oscillating about their mean position. Hence, it has nothing to do with the particle nature of light, which makes **option (b) incorrect.** **Option (c):** As discussed in option (a), secondary wavelets are used to find new position of the wavefront. **Thus option (c) is correct**. **Option (d):** The effect of change of speed helps to construct new wavefront using secondary wavelets. **Thus option (d) is correct.** **Thus answer is option (c) and (d).**
I-22	Speed of light is constant and is independent of speed of the observer accordingly $v_a = v_b = v_c$, this makes **option (c) to be correct** and inequalities in **option (a) and (b) to be incorrect**. With the validity of option (c), it leads to $v_b = \frac{1}{2}(v_b + v_c)$ thus **making option(d) to correct**. **Thus answer is option (c) and (d).**
I-23	Speed of light is constant as long as medium is unchanged. In the instant case since space is filled with water speed of light would be $c' = \frac{c}{\mu}$, here is refractive index of the medium i.e. water. This speed is independent of velocity of the observer accordingly $v_a = v_b = v_c$, this makes **option (c) to be correct** and inequalities in **option (a) and (b) to be incorrect**. With the validity of option (c), it leads to $v_b = \frac{1}{2}(v_b + v_c)$ thus **making option(d) to correct**. **Thus answer is option (c) and (d).**
I-24	As per Huygens' wave theory wavefront is always perpendicular to the direction of equation. In the problem it is stated that wave is travelling along X-axis therefore the wavefront shall be perpendicular to X-axis. Accordingly, every point on the wavefront irrespective of its coordinates along Y-axis and Z-axis is defined by $x = c$. This is provided **in option (a) and is the answer**.

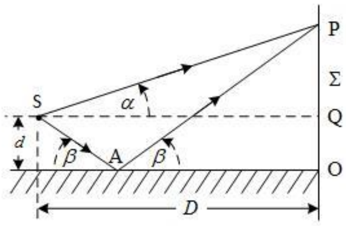
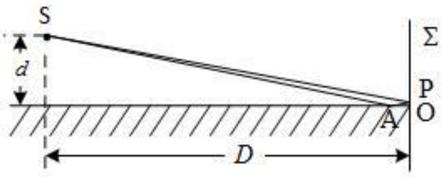
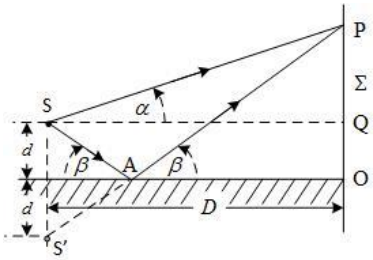
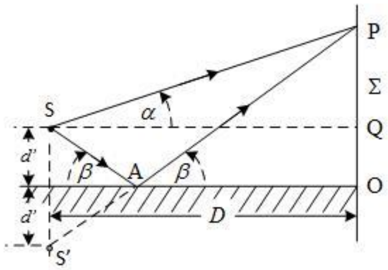
I-25	In Young's double slit experiment fringe width is defined by $\beta = \frac{\lambda D}{d}$…(1). Wavelength of red light is $\lambda_r = 620$ nm and that of violet light $\lambda_v = 380$ nm. With this information analyzing each option separately – **Option (a):** Intensity of light $I \propto A^2$, but in the problem there is no information on amplitude of the two clours. Hence, proposition in this part cannot be ascetrained. **Option (b):** It is seen from (1) that $\beta \propto \lambda$ since separation between the slits d and distance of screen from the slits D remain unchanged. Therefore, in violet colour, which has shorter wavelength, fringe width will reduce. In other words fringes will come closer **hence answer is option (b).** **Option (c):** Based on analysis no inference can be drawn on intensity. **Option (d):** Proposition in this part is alo an inference on intesity of central fringe, which cannt be ascertained as per discussions in part (a). **Hence answer is option (b).**
I-26	In Young's double slit experiment fringe width is defined by $\beta = \frac{\lambda D}{d}$…(1). Wavelength of red light in visible spectrum is $\lambda_r = 620$ nm, the largest and that of violet light $\lambda_v = 380$ nm, the shortest. With this information analyzing each option separately – **Part (a):** At the central fringe optical length of light of each colour is same and hence central fringe would be combined effect of constructive interference of the colours of the spectrum i.e. white. **Hence option (a) is the answer.** **Part (b):** White light is a combined effect of rays of its spectrum, therefore destructive interference at a point may occur for a particular wavelength i.e. colour, but not for all colours. Hence completely dark fringe will not occur. **Thus option (b) is correct.** **Part (c):** It is seen from (1) that fringes occur in increasing order of wavelength. Since red colour has highest wavelength and hence fringe of red colour about the central fringe would be farthest. **Thus option (c) is incorrect.** **Part (d):** Taking analysis in part (c), next fringe about the central fringe of colour having shortest wavelength which is violet. **Hence option (d) is correct**. **Thus answer is option (a), (b) and (d).**
I-27	Requirement for interference is that interacting waves are of same frequency but a constant phase difference. It is seen that among the given waves this condition is satisfied **waves (i) and (ii) as stated in option (a)**, and **waves (iii) and (iv) asstated in option (d).** **Thus answer is option (a) and (d).**
I-28	Speed of light in air for all wavelengths is $c = 3 \times 10^8$ m/s. And $c = \lambda\nu \Rightarrow \nu = \frac{c}{\lambda}$…(1) here λ is wavelength and ν is frequency. Wavelengths visible to human eye are in rage $\lambda_{max} = 700$ nm and $\lambda_{min} = 400$ nm. In light of reciprocal relationship at (1), $\nu_{max} = \frac{c}{\lambda_{min}} \Rightarrow \nu_{max} = \frac{3\times10^8}{400\times10^{-9}} = 7.5 \times 10^{14}$Hz and likewise we have $\nu_{min} = \frac{c}{\lambda_{max}} \Rightarrow \nu_{min} = \frac{3\times10^8}{700\times10^{-9}} = 4.3 \times 10^{14}$ Hz. **Thus range of frequencies desired are $\mathbf{4.3 \times 10^{14}}$ to $\mathbf{7.5 \times 10^{14}}$ is the answer.**
I-29	Speed of light in air for all wavelengths is $c = 3 \times 10^8$ m/s. And $c = \lambda\nu \Rightarrow \nu = \frac{c}{\lambda}$…(1) here λ is wavelength and ν is frequency. Wavelengths visible to human eye are in rage $\lambda_{max} = 700$ nm and $\lambda_{min} = 400$ nm. Thus solution of each part is as under – **Part (a):** Frequency of light in air is $\nu = \frac{c}{\lambda} = \frac{3\times10^8}{589\times10^{-9}} = \mathbf{5.09 \times 10^{14}}$ **Hz is the answer of part (a).** **Part (b):** Refractive index of a medium $\mu = \frac{c}{c_m} \Rightarrow c_m = \frac{c}{\mu}$, here c_m is speed of light in the medium under consideration. It is given that for water $\mu = 1.33$. Wavelength in water is $\lambda_m = \frac{c_m}{\nu} \Rightarrow \lambda_m = \frac{c}{\mu\nu}$. Since frequency of light wave does not change with change of medium and hence$\lambda_m = \frac{3\times10^8}{1.33\times5.09\times10^{14}}$. It reduces to **443 nm is the answer of part (b).** **Part (c):** Since frequency of light wave does not change with change of medium and hence it would remain

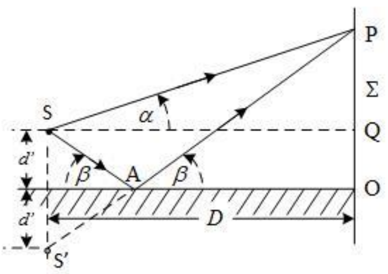
	same as in part (a) i.e. $\mathbf{5.09 \times 10^{14}}$ **Hz is the answer of part (c).** **Part (d): Speed of light in water as discussed in part (b) is** $c_m = \frac{c}{\mu}$ and with the given data it is $c_m = \frac{3\times10^8}{1.33} = 2.255 \times 10^8$ m/s, say 2.255×10^8 m/s. is the answer of part (d). **Thus partwise answers are (a)** $\mathbf{5.09 \times 10^{14}}$ **Hz (b) 443 nm (c)** $\mathbf{5.09 \times 10^{14}}$ **Hz (d)** $\mathbf{2.25 \times 10^8}$ **m/s.** **N.B.:** Rounding in part (d) is based on principles of SDs**.**
I-30	Refractive index of a medium $\mu = \frac{c}{c_m} \Rightarrow c_m = \frac{c}{\mu}$. We know that in air speed of light is $c = 3 \times 10^8$ m/s. We are given for wavelength-1, $\lambda_1 = 400$ nm, $\mu_1 = 1.472$ and for wavelength-2, $\lambda_2 = 760$ nm, refractive index is $\mu_2 = 1.452$. Accordingly using the given data- - **Speed of light in quartz crystal for** $\boldsymbol{\lambda_1 = 400}$**nm** is $c_{m1} = \frac{c}{\mu_1} = \frac{3\times10^8}{1.472} = 2.038$ or **2.04 m/s** - **Speed of light in quartz crystal for** $\boldsymbol{\lambda_1 = 760}$**nm** is $c_{m1} = \frac{c}{\mu_1} = \frac{3\times10^8}{1.452} = 2.066$ or **2.07 m/s** **Thus answer is** $\mathbf{2.04 \times 10^8}$ **m/s** $\mathbf{2.07 \times 10^8}$ **m/s.**
I-31	Refractive index of a medium $\mu = \frac{c}{c_m}$. We know that in air speed of light is $c = 3 \times 10^8$ m/s. Given that speed of yellow light in certain liquid is $c_m = 2.4 \times 10^8$ m/s. Accordingly, using the available data we have $\boldsymbol{\mu} = \frac{3\times10^8}{2.4\times10^8} = \mathbf{1.25}$ **is the answer.**
I-32	The narration of system in the problem corresponds to Young's double slit experiment where Seperation between slits is $d = 0.01$m, distance between slits and screen is $D = 1.0$ m and wavelength of the light source is $\lambda = 5.0 \times 10^{-7}$ m. In this experiment fringe width is $\beta = \frac{\lambda D}{d}$ ...(1) Taking each part separately – **Part (a):** Seperation between maxima is the fringe width and thus using available data as per (1) we have $\boldsymbol{\beta} = \frac{5.0\times10^{-7}\times1.0}{0.01} = 5.0 \times 10^{-5}$ m, or **0.05 mm is the answer. This is not distinguishable with bare human eye.** **Part (b):** For obtaining $\beta = 1.0$mm, the separation between slits from (1) comes to $d = \frac{\lambda D}{\beta}$. Accordingly, $\boldsymbol{d} = \frac{5.0\times10^{-7}\times1.0}{0.001} = \mathbf{0.50}$ **mm**. **Thus answers are (a) 0.05 mm (b) 0.50 mm.**
I-33	In Young's double slit experiment cited here given that separation between dark fringes is $\gamma = 0.001$ m. while in the apparatus separation between slits is $d = 0.001$m, distance between slits and screen is $D = 2.5$ and it is required to calculate wavelength λ. In this experiment fringe width is $\beta = \frac{\lambda D}{d}$ ...(1) and since fringes are equally spaced $\gamma = \beta \Rightarrow \lambda = \frac{\gamma d}{D}$. Using the given data $\boldsymbol{\lambda} = \frac{0.001\times0.001}{2.5} = 4 \times 10^{-7}$ m or **400 nm is the answer.**
I-34	In Young's double slit experiment cited here given that separation between slits is $d = 1\text{mm} = 10^{-3}$m, distance between slits and screen is $D = 1.0$ m and wavelength of light used is $\lambda = 5.0 \times 10^{-7}$m. In the experiment fringe width is $w = \frac{\lambda D}{d}$ ...(1) and distance between first minimum from the center of the central maxima is $w' = \frac{w}{2} = \frac{\lambda D}{2d}$. Moreover, all bright fringes are equally spaced. Accordingly solving each part separately – **Part (a):** Distance of first minima from the central of the central maxima is $w' = \frac{(5.0\times10^{-7})\times1.0}{2\times10^{-3}} = 2.5 \times 10^{-6}$ m or 0.**25 mm is the answer of part (a)**. **Part (b):** Fringe width $w = 2w' = 2 \times 0.25 = 0.5$ mm. Therefore number of fringes, which are equally spaces, in One centimeter is $\boldsymbol{n} = \frac{10}{0.5} =$ **20 fringes is answer of part (b).**

	Thus answers are (a) 0.25 mm (b) 20.
I-35	In Young's double slit experiment cited here given that separation between slits is $d = 0.800\text{ mm} = 8 \times 10^{-4}\text{m}$, distance between slits and screen is $D = 2.0$ m and wavelength of yellow light used is $\lambda = 589 \times 10^{-9}\text{nm}$. Since fringe width is $w = \frac{\lambda D}{d}$s …(1), hence using the available data $\boldsymbol{w} = \frac{(589\times10^{-9})\times2.0}{8\times10^{-4}} = \mathbf{1.47}$ **mm, is the answer.**
I-36	In Young's double slit experiment fringe width $w = \frac{\lambda D}{d}$ where, $d = 2 \times 10^{-3}$ separation between slits is given, distance between slits and screen is D, and wavelength of blue-green light is $\lambda = 589 \times 10^{-9}\text{nm}$. Angular separation between consecutive bright fringes is $\theta = \frac{w}{D} \Rightarrow \theta = \frac{\lambda D}{d} \times \frac{1}{D} \Rightarrow \theta = \frac{\lambda}{d}$. Thus using the available data $\theta = \frac{500\times10^{-9}}{2\times10^{-3}} = 2.50 \times 10^{-4}$ rad or $\boldsymbol{\theta} = (2.50 \times 10^{-4}) \times \frac{180}{\pi} = \mathbf{0.014}$ **degree, is the answer.**
I-37	In Young's double slit experiment fringe width $w = \frac{\lambda D}{d}$ where, $d = 2.5 \times 10^{-4}$ separation between slits is given, distance between slits and screen is $D = 1.50\text{m}$, and two wavelength used are $\lambda_1 = 480 \times 10^{-9}\text{nm}$ and $\lambda_2 = 600 \times 10^{-9}\text{nm}$. Accordingly linear separation of first maxima i.e. fringe width corresponding to the two wavelengths is – - For $\lambda_1$we have $w_1 = \frac{\lambda_1 D}{d}$, using available data $w_1 = \frac{(480\times10^{-9})\times1.5}{2.5\times10^{-4}} = 288 \times 10^{-5}$ m or 2.88 mm - For $\lambda_2$we have $w_2 = \frac{\lambda_2 D}{d}$, using available data $w_2 = \frac{(600\times10^{-9})\times1.5}{2.5\times10^{-4}} = 360 \times 10^{-5}$ m or 3.60 mm Therefore separation between first maxima of the two wavelengths would be $\Delta\boldsymbol{w} = \lvert w_1 - w_2\rvert = \lvert 3.60 - 2.88\rvert = \mathbf{0.72}$ **mm is the answer.**
I-38	In Young's double slit experiment fringe width $w = \frac{\lambda D}{d}$ …(1) where, d separation between slits is given, distance between slits and screen is D, and two wavelength used are $\lambda_1 = 400 \times 10^{-9}\text{nm}$ and $\lambda_2 = 700 \times 10^{-9}\text{nm}$. In the experimental system d and D are constants and hence $w = \frac{D}{d}\lambda$ …(2). Thus from central fringe minimum distance at which violet fringe will coincide with red fringe shall be $W = mw_1 = nw_2$…(3). Accordingly, $m\left(\frac{D}{d}\right)\lambda_1 = n\left(\frac{D}{d}\right)\lambda_2 \Rightarrow m \times 400 = n \times 700 \Rightarrow \frac{m}{n} = \frac{7}{4}$. Thus minimum order of violet fringes to coincide with a red fringe is **7, is the answer.**
I-39	*Optical path length (OPL)* is the product of the geometric length of the path (l) followed by light through a given system, and refractive index of the medium (μ) through which it propagates and is expressed as s and is expressed as $\wedge = l\mu$. In the instant case $l \rightarrow t$ accordingly $\wedge = t\mu$ such that $\lvert t - \wedge\rvert = \frac{\lambda}{2}$. Since $\mu > 1$, it leads to $t(\mu - 1) = \frac{\lambda}{2} \Rightarrow \boldsymbol{t} = \frac{\boldsymbol{\lambda}}{\mathbf{2}(\boldsymbol{\mu}-\mathbf{1})}$ **is the answer**.
I-40	*Optical path length (OPL)* is the product of the geometric length of the path (l) followed by light through a given system, and refractive index of the medium (μ) through which it propagates and is expressed as s and is expressed as $\wedge = l\mu$. In the instant case $l \rightarrow t$ accordingly $\wedge = t\mu$. Taking each part separately – **Part (a):** Change in path length due to the plate is $\Delta t = \lvert t - \wedge\rvert$. Since, $\mu > 1$ it leads to $\Delta t = \boldsymbol{t}(\boldsymbol{\mu} - \mathbf{1})$ **is the answer of part (a).** **Part (b):** Since central fringe patter is required to be zero with the plate placed in front of one of the slits, it is possible if $\Delta t = \frac{\lambda}{2} \Rightarrow \frac{\lambda}{2} = t(\mu - 1) \Rightarrow \boldsymbol{t} = \frac{\boldsymbol{\lambda}}{\mathbf{2}(\boldsymbol{\mu}-\mathbf{1})}$ **is the answer of part (b).** **Thus answers are (a)** $(\boldsymbol{\mu} - \mathbf{1})\boldsymbol{t}$ **(b)** $\frac{\boldsymbol{\lambda}}{\mathbf{2}(\boldsymbol{\mu}-\mathbf{1})}$

I-41	*Optical path length (OPL)* is the product of the geometric length of the path (l) followed by light through a given system, and refractive index of the medium (μ) through which it propagates and is expressed as s and is expressed as $\wedge = l\mu$. In the instant case $l \to t$ accordingly $\wedge = t\mu$. Thus, change in path length due to the plate is $\Delta t = \|t - \wedge\|$. Since, $\mu > 1$ it leads to $\Delta t = t(\mu - 1)$. Change in path-length by every λ causes crossing of one fringe. Therefore, on removal of paper number of fringes that would cross through the center is $n = \frac{\Delta t}{\lambda} \Rightarrow n = \frac{t(\mu-1)}{\lambda}$. Using the available data $\boldsymbol{n} = \frac{0.02\times10^{-3}\times(1.45-1)}{620\times10^{-9}} = 1.45 \times 10^1$ or **14.5 is the answer.**
I-42	Given that a mica sheet of thickness $t = 1.964 \times 10^{-6}$ m having refractive index $\mu = 1.6$ is introduced on the path of one ray of Young's double slit experiment. This causes change in path length along the central line to be $\Delta x = (\mu - 1)t$. Consequently, shift in the number of fringes is $n = \frac{\Delta x}{\lambda} \Rightarrow n = \frac{(\mu-1)t}{\lambda}$. Since, fringe width in the experiment $w = \frac{\lambda D}{d}$, thus corresponding change in the fringe width is $\Delta y = nw$. It leads to $\Delta y = \frac{(\mu-1)t}{\lambda} \times \frac{\lambda D}{d} \Rightarrow \Delta y = \frac{(\mu-1)tD}{e}$…(1) It is stated the fringe width $w' = \Delta y$ …(2)with $D' = 2D$ in the experiment. Accordingly, $w' = \frac{D'\lambda}{d}$, it leads to $w' = \frac{2D\lambda}{d}$ …(3) Combining (1) and (3) in (2) we have $\frac{(\mu-1)tD}{e} = \frac{2D\lambda}{d} \Rightarrow \lambda = \frac{(\mu-1)t}{2}$…(4) Using the given data in (4) we have $\lambda = \frac{(1.6-1)\times(1.964\times10^{-6})}{2} \Rightarrow \boldsymbol{\lambda = 589.2 \times 10^{-9}}$**m or 590 nm is the answer.** **N.B.: Since least SDs are in μ accordingly answer reported is 590 which has Two SDs using unit as nm, normally used for wavelengths in optical spectrum.**
I-43	It is given that in double slit interference experiment with light of wavelength $\lambda = 590$ nm and separation between the slits is $d = 0.12$ cm. Two separate mica strips of equal thickness $t = 0.5\,mm = 5 \times 10^{-4}$m but of different refractive indices $\mu_1 = 1.58$ and $\mu_2 = 1.55$ are introduced. Thus change in wavelength of one ray is $\Delta x_1 = (\mu_1 - 1)t$ and $\Delta x_2 = (\mu_2 - 1)t$. Solving each part separately, **Part (a):** With separation between slits and the screen $D = 1$m, fringe width without mica strips is $w = \frac{\lambda D}{d}$ or $\boldsymbol{w} = \frac{(590\times10^{-9})\times1}{1.2\times10^{-3}} = 492$ µm or **0.49 mm, is the answer of part (a).** **Part (b):** On introduction of given mica strips in the path of the two rays net path difference would be $\Delta x = \Delta x_1 - \Delta x_2 \Rightarrow \Delta x = (\mu_1 - 1)t - (\mu_2 - 1)t \Rightarrow \Delta x = (\mu_1 - \mu_2)t$. Accordingly, number of fringes shifted are $n = \frac{\Delta x}{\lambda} \Rightarrow n = \frac{(\mu_1-\mu_2)t}{\lambda}$. Using the given data $n = \frac{(1.58-1.55)\times(5\times10^{-4})}{590\times10^{-9}} = 25.4$. Thus discriminant $\delta = 0.4$ would cause shift of first maxima by $\boldsymbol{\Delta y} = \delta \times w = 0.4 \times 0.49 = 0.196$ mm or **0.020 cm, this on the one side of the central-line.** Since fringes are equidistant and hence on the other side of the central-line would be $\boldsymbol{\Delta y'} = (1 - \delta) \times w = (1 - 0.4) \times 0.4 = 0.294$ mm or **0.029 cm on the other side. Thus distance of first maxima from the central-line on one side is at a distance 0.020 cm and on the other side 0.028 cm.** **Thus answers are (a) $\boldsymbol{4.9 \times 10^{-4}}$ (b) 0.020 cm on side and 0,028 cm on the other side**
I-44	Arrangement in the system is show in the figure. Change in path length caused by slab of refractive index μ_1 is $\Delta x_1 = (\mu_1 - 1)t$ and in another slab it is $\Delta x_2 = (\mu_2 - 1)t$. Thus net difference in path length is $\Delta x = \Delta x_1 - \Delta x_1 \Rightarrow \Delta x = (\mu_1 - 1)t - (\mu_2 - 1)t$ It leads to $\Delta x = \|\mu_1 - \mu_2\|t$ …(1) For minima to occur at P_0 necessary requirement is that the two rays should be out of phase i.e. $\Delta x = \frac{\lambda}{2}$ …(2). Combining (1) and (2) we have $\|\mu_1 - \mu_2\|t = \frac{\lambda}{2} \Rightarrow \boldsymbol{t} = \frac{\boldsymbol{\lambda}}{2\|\boldsymbol{\mu_1 - \mu_2}\|}$ **is the answer.** 

I-45	Let I_1 is the intensity of the incident light and I_2 is the intensity of light transmitted through paper of refractive index $\mu = 1.45$. It is given that ratio of incident energy to energy transmitted through paper is $\frac{E_t}{E_i} = \frac{4}{9}$. Since, $\frac{E_t}{E_i} = \frac{I_2}{I_1} = \frac{4}{9}$…(1). Further, amplitude (A) of the wave is $I \propto A^2$…(2). Therefore, $\frac{I_2}{I_1} = \frac{A_2^2}{A_1^2}$ …(3). Combining (1) and (3) we get $\frac{A_2^2}{A_1^2} = \frac{4}{9} \Rightarrow \frac{A_2}{A_1} = \frac{2}{3}$. In constructive interference wave through slit covered with paper is in-phase with wave coming from uncovered slit in the Young's double slit experiment. Therefore, amplitude of wave is $A_{max} = 3x + 2x = 5x$. But in destructive interference the two waves are anti-phase to each other. Accordingly, $A_{min} = 3x - 2x = x$. Therefore, ratio of amplitudes is $\frac{A_{max}}{A_{min}} = \frac{5x}{x} = \frac{5}{1}$…(4) Using, (2) in (4), $\frac{I_{max}}{I_{min}} = \frac{{A_{max}}^2}{{A_{min}}^2} = \frac{5^2}{1^2} \Rightarrow \frac{\boldsymbol{I_{max}}}{\boldsymbol{I_{min}}} = \frac{25}{1} = \mathbf{25}$ **is the answer of part (a).** When identical paper of thickness $t = 0.02$ mm is pasted on the other slit also change in its path length is $\Delta x = (\mu - 1)t$ and accordingly number of fringes that would cross through are $n = \frac{\Delta x}{\lambda} \Rightarrow n = \frac{(\mu-1)t}{\lambda}$. Using the available data $\boldsymbol{n} = \frac{(1.45-1)\times(2\times10^{-5})}{600\times\times10^{-9}}$=**15, is the answer of part (b).** **Thus answers are (a) 25 (b) 15.**
I-46	Fringe pattern is the fringe width $w = \frac{\lambda_w D}{d}$,,,(1), where $D = 0.48$ m is distance between slits and the screen and $d = 2.8 \times 10^{-4}$m and λ_w is the wavelength of light in water. We know that refractive index of water $\mu_w = \frac{4}{3}$. We know that $\mu = \frac{C}{v}$…(2). Further, during refraction frequency of light remains unchanged and $c = f\lambda \Rightarrow c \propto \lambda \Rightarrow \frac{C}{v} = \frac{\lambda}{\lambda_w}$…(3). Combining (2) and (3) we have $\mu_w = \frac{\lambda}{\lambda_w} \Rightarrow \frac{4}{3} = \frac{\lambda}{\lambda_w} \Rightarrow \lambda_w = \frac{3}{4}\lambda$…(4). Combining (1) and (4) we have $w = \frac{\left(\frac{3}{4}\lambda\right)D}{d} \Rightarrow w = \frac{3\lambda D}{4d}$. Using the given data $\boldsymbol{w} = \frac{3\times(700\times10^{-9})\times0.48}{4\times(2.8\times10^{-4})} = \mathbf{0.90}$ **mm is the answer.**
I-47	As per Huygens' Wave Theory, wavefront is perpendicular to the direction of propagation of the wave. Accordingly, when a ray of beam at an angle θ with the normal to the plane of slits reaches slit S1 another ray heading to slit S2 reaches A. Thus at the slits path difference $\Delta x = AS_2 = d \sin\theta$…(1)  After passing through the slits the rays travel along S_2P_0 and S_1P_0 and the path difference is maintained to produce a dark fringe. This is possible only when $\Delta x = \frac{\lambda}{2}$…(2). Combining (1) and (2) we have $d \sin\theta = \frac{\lambda}{2} \Rightarrow \sin\theta = \frac{\lambda}{2d} \Rightarrow \boldsymbol{\theta} = \mathbf{sin}^{-1}\left(\frac{\boldsymbol{\lambda}}{\mathbf{2}\boldsymbol{d}}\right)$**, proved**.

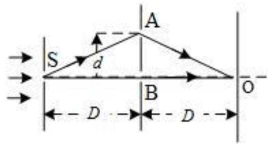
I-48	Point of interference P caused by two incident waves, one after reflection at A and other direct from the source is shown in the figure. Reflection phenomenon causes a change of phase by an angle π. This consideration is important in solving the problem. Each part is taken below separately.  **Part (a):** Determination of intensity on the screen at a point just above O would require consideration of reflection of wave incident on a point A very close to O, as shown in the figure. It is seen that as SA → SP the path length of the composite ray SA and AP tends to be SP. But, due to reflection a phase difference π has crept in. Thus interference of the direct ray $r_1 = a \sin \omega \left(t - \frac{x}{v}\right)$ and the reflected ray $r_2 = a \sin \omega \left(t - \frac{x}{v} + \pi\right) \Rightarrow r_2 = -a \sin \omega \left(t - \frac{x}{v}\right)$. Accordingly, on superimposition if the two rays we get $r = r_1 + r_2 = a \sin \omega \left(t - \frac{x}{v}\right) - a \sin \omega \left(t - \frac{x}{v}\right) \Rightarrow \boldsymbol{r = 0}$ **is the answer of part (a)**,   **Part (b):** Determination of the occurrence of first bright fringe on the screen requires a path difference $\Delta x = \lambda$. This can be simulated by extending reflected ray coming from a image S' in the mirror of the source S. Thus, it is equivalent to a Young's double slit experiment where separation between the two sources is $d' = 2d$. Further, the requirement of phase difference is $\phi = 2\pi$. Since reflection has caused a phase difference $\phi_r = \pi$. Another phase difference of ϕ_p caused during propagation of rays optical path should meet the requirement $\phi = 2\pi = \phi_p + \phi_r \Rightarrow \phi_p = 2\pi - \phi_r \Rightarrow \phi_p = 2\pi - \pi = \pi$. In the experiment $D \gg 2d$ and hence $\frac{\Delta x}{2d} = \frac{y}{D} \Rightarrow y = \frac{\Delta x \times D}{2d}$…(1) Further, as $\phi_p = \pi$ the corresponding path difference $\Delta x = \frac{\lambda}{2}$…(2). Combining (1) and (2) we have $y = \frac{\lambda}{2} \times \frac{D}{2d} \Rightarrow \boldsymbol{y = \frac{\lambda D}{4d}}$ **is the answer of part (b).** **Thus answers are (a) Zero (b) $\boldsymbol{\frac{D\lambda}{4d}}$.** **N.B.:** This problem is an excellent blending of phenomenon of reflection phenomenon, interference and its application in Young's double slit experiment
I-49	The given experimental setup is shown in the figure with $d' = 10^{-3}$ m is the distance of slit S in front of the mirror and distance of screen from the source is $D = 10^{-3}$. Reflection from the mirror creates a virtual slit S' vertically below the source S and behind the mirror at a distance d'. This is equivalent to Young's double slit experiment. Accordingly, separation between slits is $d = 2d'$. Wavelength of light is given to be $\lambda = 700 \times 10^{-9}$m.  Thus fringe width in the experiment is $w = \frac{\lambda D}{d}$. Using the available data $w = \frac{(700 \times 10^{-9}) \times 1.0}{2 \times 10^{-3}} \Rightarrow w = 350 \times 10^{-6}$ m or $\boldsymbol{w = 0.35}$ **mm, is the answer**.

I-50	Let intensity of light wave along SP and SA is I_1, but the intensity of light wave after reflection is given to be $I_2 = 0.64I_1 \Rightarrow \frac{I_2}{I_1} = \frac{0.64}{1.0}$. It leads $\frac{I_2}{I_1} = \frac{16}{25}$. Since intensity of light $I \propto A^2 \Rightarrow \frac{I_2}{I_1} = \left(\frac{A_2}{A_1}\right)^2 \Rightarrow \frac{A_2}{A_1} = \sqrt{\frac{16}{25}} \Rightarrow \frac{A_2}{A_1} = \frac{4}{5}$.  At the point of constructive interference net amplitude of wave would be $A_c = A_1 + A_2$ and at point of destructive interference $A_d = A_1 - A_2$. Using (1), it leads to constructive amplitude $A_c = 5x + 4x = 9x$ and in case of destructive interference amplitude of wave is$A_d = 5x - 4x = x$. Accordingly, $\frac{I_{max}}{I_{min}} = \left(\frac{I_c}{I_d}\right)^2$, it leads to $\frac{I_{max}}{I_{min}} = \left(\frac{9x}{x}\right)^2 \Rightarrow \frac{I_{max}}{I_{min}} = \frac{81}{1} \Rightarrow$ $\boldsymbol{I_{max}: I_{min} :: 81: 1}$ **is the answer.**
I-51	In the ray diagram distance between slits and mirror (D_1) is traversed twice. Hence, equivalent distance between slits, separated by a distance d, and the screen is $D = 2D_1 + D_2$…(1). This setup accordingly becomes equivalent to Young's double slit experiment. Accordingly, fringe width is $w = \frac{\lambda D}{d}$ …(2). Combining (1) and (2) we have $\boldsymbol{w = \frac{\lambda(2D_1 + D_2)}{d}}$ **is the answer**.
I-52	The given experimental setup is identical to Young's double slit experiment where separation between the slits is $d = 5 \times 10^{-4}$m, and distance between slits and screen is $d = 0.5$ m. On the screen there is a hole at a distance $y = 10^{-3}$m. Instead of monochromatic light white light such that 400 nm $\leq \lambda \leq 700$nm, here λ is wavelength of light. Fringe width in the experiment is $w = \frac{\lambda D}{d}$ and bright spots on screen at distance y_n from the central line shall correspond to wavelength such that $y = \frac{n\lambda D}{d}$ and for $y = \frac{(2n+1)\lambda D}{2d}$ corresponding wavelength that shall be absent, here $n \in N$. With this analysis each part is attempted separately. **Part (a):** Wavelengths that shall be absent within the given spectrum are $\lambda = \frac{2yd}{(2n+1)D}$. Using the available data we have $\lambda = \frac{2\times10^{-3}\times(5\times10^{-4})}{0.5(2n+1)} = \frac{2\times10^{-6}}{(2n+1)}$ m or $\lambda = \frac{2000}{(2n+1)}$ nm. Since $n \in N$ hence wavelengths within the given spectrum would be – $\lambda\|_{n=1} = \frac{2000}{(2\times1+1)} = \frac{2000}{3} =$ **667 nm, within the spectrum, will be absent** $\lambda\|_{n=2} = \frac{2000}{(2\times2+1)} = \frac{2000}{5} =$ **400 nm, within the spectrum, will be absent** $\lambda\|_{n=3} = \frac{2000}{(2\times3+1)} = \frac{2000}{7} = 286$ nm, out of spectrum and thus for n>2 wavelengths do not exit **Part (b):** Wavelengths that shall be absent within the given spectrum are $\lambda = \frac{yd}{nD}$. Using the available data we have $\lambda = \frac{10^{-3}\times(5\times10^{-4})}{0.5n} = \frac{10^{-6}}{n}$ m or $\lambda = \frac{1000}{n}$ nm. Since $n \in N$ hence wavelengths within the given spectrum would be – $\lambda\|_{n=1} = \frac{1000}{1} = 1000$ nm, out of spectrum and thus this wavelength do not exit $\lambda\|_{n=2} = \frac{1000}{2} =$ **500 nm, within the spectrum, will cause bright spot** $\lambda\|_{n=3} = \frac{1000}{3} = 333$ nm, out of spectrum and thus this wavelength do not exit so will be for all values of n>2 **Thus answers are (a) 400 nm, 667 nm (b) 500 nm.**

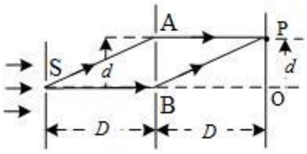
I-53

Each of the part is being analyzed here under-

Part (a): Interference of the two rays emanating from source S, which through slits A and B cause dark fringe at O has path length $x_1 = SA + AO = 2\times\sqrt{d^2+D^2}$ and $x_2 = SB + BO = 2\times D$. Path difference of the two waves is $\Delta x = x_1 - x_2 = 2\times\sqrt{d^2+D^2} - 2D \Rightarrow \Delta x = 2\left(\sqrt{d^2+D^2} - D\right)$. It is stated that dark fringe occurs at O for which necessary condition is $\Delta x = (2n+1)\frac{\lambda}{2} \Rightarrow 2\left(\sqrt{d^2+D^2} - D\right) = (2n+1)\frac{\lambda}{2} \Rightarrow \sqrt{d^2+D^2} = D + (2n+1)\frac{\lambda}{4}$, here $n \in W$. Squaring the final form $d^2 + D^2 = D^2 + (2n+1)^2\frac{\lambda^2}{16} + (2n+1)\frac{\lambda D}{2} \Rightarrow d^2 = (2n+1)\frac{\lambda D}{2}$, this simplified form is neglecting $(2n+1)^2\frac{\lambda^2}{16}$ since $\lambda \ll$. Accordingly, $d = \sqrt{(2n+1)\frac{\lambda D}{2}}$, and with all other parameters to be constant for $d_{min} \Rightarrow n = 0 \Rightarrow$ $\boldsymbol{d = \sqrt{\frac{\lambda D}{2}}}$**, is the answer of part (a).**



Part (b): For next bright fringe to occur on the screen say at point P, as shown in the diagram, path length SA+AP=AB+BP, this is possible when SABP is a parallelogram where geometrically **PO =** $\boldsymbol{d}$ **, is the answer of part (b).**

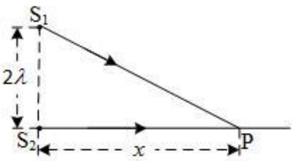


Part (c): Fringe width (w) is distance between two consecutive bright fringes or double of the distance between adjacent bright and dark fringe. It leads to $\boldsymbol{w = 2d}$ **is the answer of part (c).**

(a) **Thus answers are (a)** $\boldsymbol{\sqrt{\frac{\lambda D}{2}}}$ **(b) d (c) 2d.**

I-54

Let distance of point P from source S_1 be x' and of the point from source S_2 be x. Difference in path length is $\Delta x = x' - x$. Wavelength of light waves from two sources is λ while distance between the two sources is $d = 2\lambda$. Geometrically, $x' = \sqrt{x^2 + (2\lambda)^2}$ therefore, $\Delta x = \sqrt{x^2+(2\lambda)^2} - x$…(1). For minimum intensity at P it requires that $\Delta x = (2n+1)\frac{\lambda}{2}$ …(2), here $n \in W$.

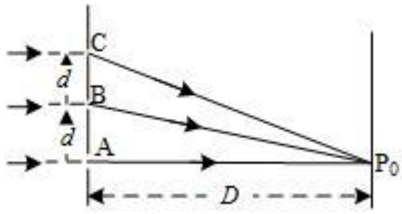


Equating (1) and (2) we have $\sqrt{x^2+(2\lambda)^2} - x = (2n+1)\frac{\lambda}{2} \Rightarrow x^2 + (2\lambda)^2 = \left(x + (2n+1)\frac{\lambda}{2}\right)^2$. It leads to $x^2 + (2\lambda)^2 = x^2 + (2n+1)^2\frac{\lambda^2}{4} + 2\times x\times(2n+1)\frac{\lambda}{2} \Rightarrow (2n+1)x\lambda = \left(4 - \frac{(2n+1)^2}{4}\right)\lambda^2$. It further resolves to $x = \frac{(16-(2n+1)^2)}{4(2n+1)}\lambda$. For smallest x possible search starts with n=0,1,2… and is as under.

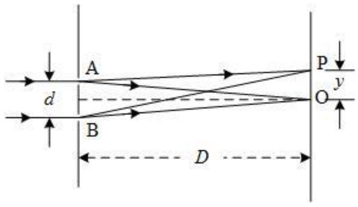
- n=0, $x = \frac{(16-1)}{4}\lambda = \frac{15}{4}\lambda$, possible
- n=1, $x = \frac{(16-9)}{4\times3}\lambda = \frac{7}{12}\lambda$, possible
- n=2, $x = \frac{(16-25)}{4\times5}\lambda = -\frac{9}{20}\lambda$, not possible and is true for all $n \geq 2$.

Among the possible values of x minimum value $\boldsymbol{\frac{7}{12}\lambda}$ **is the answer.**

N.B.: Though, in light λ<< as compared to other length under consideration and hence in solution terms containing λ^2 are generally ignored. But, in the instant case terms with λ^2 have been retained since, in final form only terms contain only λ and we have a reachable solution.

I-55	The experimental setup is shown in the figure. Each part is illustrated separately-  **Part (a):** This part is purely geometrical. As per Pythagoras theorem we have $BP_0 = \sqrt{D^2 + d^2}$, and given that $\Delta x_1 = BP_0 - AP_0 = \frac{\lambda}{3}$, therefore, $\frac{\lambda}{3} = \sqrt{D^2 + d^2} - D \Rightarrow \sqrt{D^2 + d^2} = D + \frac{\lambda}{3}$. On squaring we get $D^2 + d^2 = D^2 + \frac{\lambda^2}{9} + \frac{2\lambda D}{3}$…(1) In light $\lambda <<$ as compared to other length under consideration and hence in the solution of quadratic form terms containing λ^2 are ignored in (1). Thus, it resolves into $d^2 = \frac{2\lambda D}{3} \Rightarrow \boldsymbol{d} = \sqrt{\frac{2\lambda D}{3}}$ **is proved**. **Part (b):** In order to calculate change in path length wave through slit A is take as reference and similar to that in part (a) $\Delta x_2 = CP_0 - AP_0 = \sqrt{D^2 + (2d)^2} - D \Rightarrow \Delta x_2 = \sqrt{D^2 + 4 \times \frac{2\lambda D}{3}} - D$. It resolves to$\Delta x_2 = D\left[\left(1 + \frac{8\lambda}{3D}\right)^{\frac{1}{2}} - 1\right] \Rightarrow \Delta x_2 = D\left[\left(1 + \frac{1}{2} \times \frac{8\lambda}{3D} \ldots \text{higher order binomial terms}\right) - 1\right]$. It reduces to $\Delta x_2 = D\frac{4\lambda}{3D} \Rightarrow \Delta x_2 = \frac{4\lambda}{3}$. Resultant amplitude of the interference requires transformation of path difference into phase difference. We know $\Delta\emptyset = 2\pi\frac{\Delta x}{\lambda}$ accordingly with the given $\Delta x_1 = \frac{\lambda}{3}$ for wave along BP_0 we have $\Delta\emptyset_1 = 2\pi\frac{\Delta x_1}{\lambda} \Rightarrow \Delta\emptyset_1 = 2\pi\frac{\frac{\lambda}{3}}{\lambda} \Rightarrow \Delta\emptyset_1 = \frac{2\pi}{3}$. Likewise for wave along CP_0, $\Delta\emptyset_2 = 2\pi\frac{\Delta x_2}{\lambda}$, it leads to $\Delta\emptyset_2 = 2\pi\frac{\frac{4\lambda}{3}}{\lambda} \Rightarrow \Delta\emptyset_2 = \frac{8\pi}{3} = 2n\pi + \frac{2\pi}{3}$, here $n \in W$ and instant case $n = 1$. Trigonometrically, $2n\pi + \frac{2\pi}{3} \equiv \frac{2\pi}{3}$ and therefore $\Delta\emptyset_2 = \frac{2\pi}{3}$, thus waves along CP_0 and BP_0 are in phase with difference $\frac{2\pi}{3}$ w.r.t. to wave AP_0. Interference is a superimposition phenomenon and waves can be represented as vectors, therefore, resultant amplitude is $a_r = \sqrt{a^2 + (2a)^2 + 2 \times a \times 2a \times \cos\frac{2\pi}{3}} \Rightarrow a_r = \sqrt{5a^2 + 4a^2\left(-\frac{1}{2}\right)}$. It resolves to $a_r = \sqrt{3a^2} \Rightarrow a_r = \sqrt{3}\,a$. We know that intensity of light $I = a^2$ here a is the intensity of individual wave, therefore, intensity of the resultant wave is $I_r = \left(\sqrt{3}a\right)^2 \Rightarrow I_r = 3a^2 \Rightarrow \boldsymbol{I_r = 3I}$**, hence proved.** **N.B.:** In the problem intensity at P_0 is required to be three times that with any single ray. Accordingly, resultant amplitude due to interference has to be used to arrive at the required result.
I-56	In Young's double slit experiment $\Delta x = \frac{yd}{D}$, given that $d = 2.9 \times 10^{-3}$m, $D = 2.0$m, $y = 5 \times 10^{-3}$m. Therefore, $\Delta x = \frac{(5\times10^{-3})\times(2.0\times10^{-3})}{2.0} = 5 \times 10^{-6}$m. Further, it is given that wave length $\lambda = 600 \times 10^{-9}$m. Since $\lambda \to 2\pi \Rightarrow \Delta x \to \Delta\emptyset$, where $\Delta\emptyset = \frac{2\pi}{\lambda} \times \Delta x \Rightarrow \Delta\emptyset = \frac{2\pi}{600\times10^{-9}} \times 5 \times 10^{-6} = \frac{100\pi}{6} \Rightarrow \Delta\emptyset = \frac{50\pi}{3}$, or we can say that $\Delta\emptyset = 8 \times 2\pi + \frac{2\pi}{3} \equiv \frac{2\pi}{3}$. In double slit experiment rays from both slits are from same source and hence they shall have same amplitude. Moreover the two waves are like vectors therefore, resultant amplitude at the point of interference is $a_r = \sqrt{a^2 + a^2 + 2 \times a \times a \times \cos\left(\frac{2\pi}{3}\right)} \Rightarrow a_r = \sqrt{2a^2 + 2a^2\left(-\frac{1}{2}\right)}$. It resolves to $a_r = \sqrt{a^2} \Rightarrow a_r = a$. Further, intensity of light $I \propto a^2$ and at the central fringe constructive interference occurs ant therefore it will have resultant amplitude of wave $a_c = 2a$. Given that $I_c = 0.20$ W/m^2, therefore with the available data, $\frac{I_r}{I_c} = \frac{a^2}{(2a)^2} \Rightarrow I_r = \frac{0.20}{4} = \mathbf{0.05}$ **W/m^2 is the answer.**
I-57	Amplitudes of waves from both the slits of the experiment that cause interferences are say a. At central line on the screen waves from both the slits are in phase and hence resultant amplitude is $2a$. We know that

intensity $I \propto a^2$, accordingly $\frac{I'}{I} = \frac{a'^2}{(2a)^2} \Rightarrow \frac{I'}{I} = \frac{a'^2}{4a^2}$ …(1), here a' is the amplitude of the resultant wave at any other point P and $2a$ is amplitude at O on the central line on the screen. It is required in the problem to determine distance from central line where $I' = kI$ for two different values of k. Change of amplitude of resultant wave on the screen causes fringe pattern with different intensities. This resultant amplitude is a result of phase difference at a point due to difference in distance of the point called path-length from the slits, sources of light in the experiment. We know that difference in path length, in the experiment, is $y = \frac{\Delta x D}{d}$ …(2) and correspondence of wavelength to phase difference is $\lambda \rightarrow 2\pi$. Accordingly, we have $\frac{\theta}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \Delta x = \frac{\lambda\theta}{2\pi}$…(3). Further, resultant amplitude of the two waves of same amplitude in the experiment is $a'^2 = 2a^2 + 2a^2\cos\theta \Rightarrow a'^2 = 2a^2(1+\cos\theta)$. Using trigonometric identity it leads to $a'^2 = 2a^2\left(1 + 2\cos^2\frac{\theta}{2} - 1\right) \Rightarrow a'^2 = 4a^2\cos^2\frac{\theta}{2} \Rightarrow a' = 2a\cos\frac{\theta}{2}$…(4). Taking each of the given cases separately –

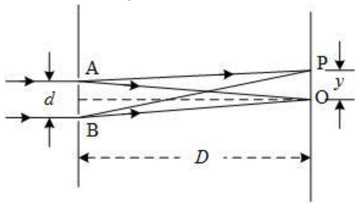


Case a: It is required to determine distance from central line where $I' = \frac{I}{2}$ therefore from (1) $\frac{\frac{I}{2}}{I} = \frac{a'^2}{(2a)^2}$, it leads to $\frac{a'^2}{4a^2} = \frac{1}{2} \Rightarrow a' = \sqrt{2}a$. Combining this with (4) we have $\sqrt{2}a = 2a\cos\frac{\theta}{2} \Rightarrow \cos\frac{\theta}{2} = \frac{1}{\sqrt{2}}$, or $\frac{\theta}{2} = \cos^{-1}\frac{1}{\sqrt{2}} \Rightarrow \frac{\theta}{2} = \frac{\pi}{4} \Rightarrow \theta = \frac{\pi}{2}$. Using (3) we have $\Delta x = \frac{\lambda\frac{\pi}{2}}{2\pi} \Rightarrow \Delta x = \frac{\lambda}{4}$. Substituting this in (2) it leads to $y = \frac{\left(\frac{\lambda}{4}\right)D}{d} \Rightarrow y = \boldsymbol{\frac{\lambda D}{4d}}$ **is the answer in case (a).**

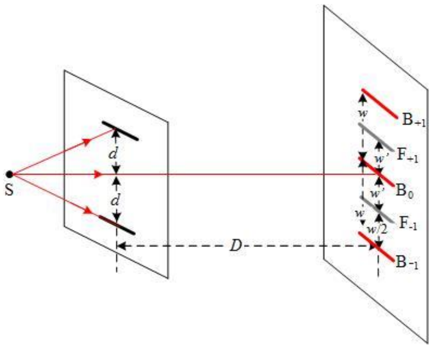
Case b: It is similar to the case (a) except that $I' = \frac{I}{4}$, accordingly $\frac{a'^2}{4a^2} = \frac{1}{4} \Rightarrow a' = a \Rightarrow a = 2a\cos\frac{\theta}{2}$, or $\cos\frac{\theta}{2} = \frac{1}{2} \Rightarrow \frac{\theta}{2} = \cos^{-1}\frac{1}{2} \Rightarrow \frac{\theta}{2} = \frac{\pi}{3} \Rightarrow \theta = \frac{2\pi}{3} \Rightarrow \Delta x = \frac{\lambda\frac{2\pi}{3}}{2\pi} \Rightarrow \Delta x = \frac{\lambda}{3} \Rightarrow y = \frac{\left(\frac{\lambda}{3}\right)D}{d} \Rightarrow y = \boldsymbol{\frac{\lambda D}{3d}}$ **is the answer on case (b)**

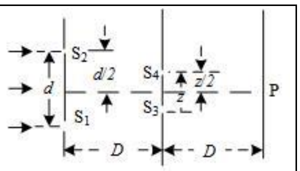
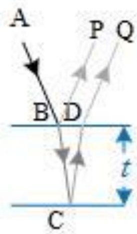
Thus answers are (a) $\boldsymbol{\frac{D\lambda}{4d}}$ **(b)** $\boldsymbol{\frac{D\lambda}{3d}}$

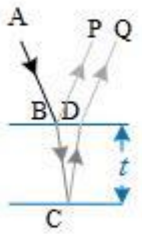
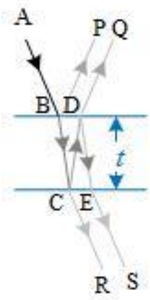
I-58 Amplitudes of waves from both the slits of the experiment that cause interferences are say a. At central line on the screen waves from both the slits are in phase and hence resultant amplitude is $2a$. We know that intensity $I \propto a^2$, accordingly $\frac{I'}{I} = \frac{a'^2}{(2a)^2} \Rightarrow \frac{I'}{I} = \frac{a'^2}{4a^2}$ …(1), here a' is the amplitude of the resultant wave at any other point P and $2a$ is amplitude at O on the central line on the screen. It is required in the problem to determine distance from central line where $I' = kI$ for two different values of k. Change of amplitude of resultant wave on the screen causes fringe pattern with different intensities. This resultant amplitude is a result of phase difference at a point due to difference in distance of the point called path-length from the slits, sources of light in the experiment. We know that difference in path length, in the experiment, is $y = \frac{\Delta x D}{d}$ …(2) and correspondence of wavelength to phase difference is $\lambda \rightarrow 2\pi$. Accordingly, we have $\frac{\theta}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \Delta x = \frac{\lambda\theta}{2\pi}$…(3). Further, resultant amplitude of the two waves of same amplitude in the experiment is $a'^2 = 2a^2 + 2a^2\cos\theta \Rightarrow a'^2 = 2a^2(1+\cos\theta)$. Using trigonometric identity it leads to $a'^2 = 2a^2\left(1 + 2\cos^2\frac{\theta}{2} - 1\right) \Rightarrow a'^2 = 4a^2\cos^2\frac{\theta}{2} \Rightarrow a' = 2a\cos\frac{\theta}{2}$…(4).

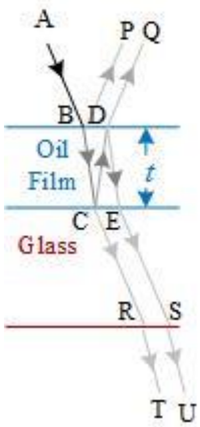
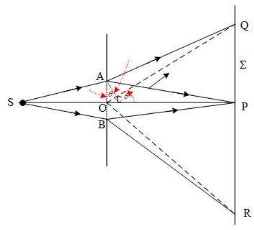


It is required to determine distance from central line where $I' = \frac{I}{2}$ therefore from (1) $\frac{\frac{I}{2}}{I} = \frac{a'^2}{(2a)^2}$, it leads to $\frac{a'^2}{4a^2} = \frac{1}{2} \Rightarrow a' = \sqrt{2}a$. Combining this with (4) we have $\sqrt{2}a = 2a\cos\frac{\theta}{2} \Rightarrow \cos\frac{\theta}{2} = \frac{1}{\sqrt{2}}$, or $\frac{\theta}{2} = \cos^{-1}\frac{1}{\sqrt{2}} \Rightarrow \frac{\theta}{2} = \frac{\pi}{4} \Rightarrow \theta = \frac{\pi}{2}$. Using (3) we have $\Delta x = \frac{\lambda\frac{\pi}{2}}{2\pi} \Rightarrow \Delta x = \frac{\lambda}{4}$. Substituting this in (2) it leads to $y = \frac{\left(\frac{\lambda}{4}\right)D}{d} \Rightarrow y =$

	$\frac{\lambda D}{4d}$. Using the given data $y=\frac{(500\times10^{-9})\times1.0}{4\times(1.0\times10^{-3})} \Rightarrow y=\mathbf{1.25\times10^{-4}}$ **mm is the answer.**
I-59	The setup of Young's double slit experiment with central bright fringe B_0 and adjacent bright fringes above it is B_{+1} and the one below it is B_{-1}. Let a is the amplitude of each wave forming bright fringe at central line the resultant amplitude B_0 is $a_0=2a$. Further intensity of light at any point is $I\propto a^2$ …(1). Therefore $I_0\propto(2a)^2$. Lines F_{+1} and F_{-1} are on two sides of B_0 where intensity of light is given to be $I_F=\frac{I_0}{2}\Rightarrow I_F\propto a_f^2$. Thus, $\frac{I_F}{I_0}=\frac{I_f^2}{4a^2}=\frac{1}{2}\Rightarrow a_f^2=2a^2$, or $a_f=\sqrt{2}a$.  Waves are vector and thus $a_f=\sqrt{2}a=\sqrt{2a^2+2a^2\cos\emptyset}$, Thus, it resolves into $1=1+\cos\emptyset\Rightarrow\cos\emptyset=0\Rightarrow\emptyset=\frac{\pi}{2}$, Since, $\lambda\to2\pi$ and hence $\frac{\Delta x}{\lambda}=\frac{\frac{\pi}{2}}{2\pi}\Rightarrow\Delta x=\frac{\lambda}{4}$. Further, in the experiment $y=\frac{\Delta xD}{d}$ and therefore $w'=\frac{\frac{\lambda}{4}D}{d}\Rightarrow w'=\frac{\lambda D}{4d}$. In the problem line-width of a bright fringe is defined as $u=2w'\Rightarrow u=2\left(\frac{\lambda D}{4d}\right)\Rightarrow u=\frac{\boldsymbol{\lambda D}}{\mathbf{2d}}$ **is the answer.**
I-60	The experimental set up is extension of Young's double slit experiment in which screen Σ_1 is made an intermediate screen with slits S_3 and S_4 on it and screen Σ_2 is the ultimate screen on which fringe patterns are observed. The slit S_3 is on the central line of slits S_1 and S_2 therefore constructive interference would occur at it leading to a bright fringe having amplitude of wave $a_{s3}=2a$. At any point above it say at a distance z path difference is $\Delta x=\frac{zd}{D}$. There are three possible values of Δx for which ratio of maximum and minimum intensities is asked which is $\frac{I_{max}}{I_{min}}=\frac{(a_{s3}+a_{s4})^2}{(a_{s3}-a_{s4})^2}$. Accordingly, the ratio for each of the value of z is being analyzed – **Case (a):** Given that $z=\frac{\lambda D}{2d}$, it leads to $\Delta x_{S4}=\frac{\frac{\lambda D}{2d}d}{D}\Rightarrow\Delta x_{S4}=\frac{\lambda}{2}$, this is a case of destructive interference of two coherent in-phase waves at and therefore $a_{s4}=a-a=0$. Therefore, $\frac{\boldsymbol{I_{max}}}{\boldsymbol{I_{min}}}=\frac{(2a+0)^2}{(2a-0)^2}=$ **1 is the answer in case (a).** **Case (b):** Given that $z=\frac{\lambda D}{d}$, it leads to $\Delta x=\frac{\frac{\lambda D}{d}d}{D}\Rightarrow\Delta x=\lambda$, this is a case of constructive interference of two coherent in-phase waves and therefore $a_{s4}=a+a=2a$. Therefore, the required ratio is $\frac{\boldsymbol{I_{max}}}{\boldsymbol{I_{min}}}=\frac{(2a+2a)^2}{(2a-2a)^2}=\frac{\mathbf{16a^2}}{\mathbf{0}}=\infty$ **is the answer in case (b).** **Case (c):** Given that $z=\frac{\lambda D}{4d}$ it leads to $\Delta x=\frac{\frac{\lambda D}{4}d}{D}\Rightarrow\Delta x=\frac{\lambda}{4}$. Since $\lambda\to2\pi\Rightarrow\frac{\theta_c}{2\pi}=\frac{\frac{\lambda}{4}}{\lambda}\Rightarrow\theta_c=\frac{\pi}{2}$. This leads to $a_{s4}=\sqrt{2a^2+2a^2\cos\theta_c}\Rightarrow a_{s4}=\sqrt{2a^2+2a^2\cos\frac{\pi}{2}}\Rightarrow a_{s4}=\sqrt{2}a$. Acc0rdingly, we have $a_{\Sigma2-\max}=2a+\sqrt{2}a=(2+\sqrt{2})a$ and $a_{\Sigma2-\max}=2a-\sqrt{2}a=(2-\sqrt{2})a$ case of constructive interference of two coherent in-phase waves and therefore $a_{s4}=a+a=2a$. Therefore, the required ratio is $\frac{\boldsymbol{I_{max}}}{\boldsymbol{I_{min}}}=\frac{(2+\sqrt{2})^2a^2}{(2-\sqrt{2})^2a^2}=\frac{(2+\sqrt{2})^2}{(2-\sqrt{2})^2}=33.94\approx\mathbf{34}$ **is the answer in case (c).** **Thus answers are (a) 1 (b) ∞ (c) 34** **N.B.:** In the question only ratio of maximum and minimum intensities are asked and not the location. This makes solution straight and simple.

I-61	Path difference at any point above central line is $\Delta x = \frac{yd}{D}$. Accordingly, $\Delta x_3 = \frac{\left(\frac{z}{2}\right)d}{D} \Rightarrow \Delta x_3 = \frac{zd}{2D}$; likewise, $\Delta x_4 = \frac{\left(\frac{z}{2}\right)d}{D} \Rightarrow \Delta x_4 = \frac{zd}{2D}$. With the given symmetry $\Delta x_3 = \Delta x_4 = \Delta x = \frac{zd}{2D}$.  Further, it is Given that when $z = \frac{\lambda D}{2d} \Rightarrow \Delta x = \frac{\left(\frac{3\lambda D}{2d}\right)d}{2D} \Rightarrow \Delta x = \frac{\lambda}{4}$. Also, $\lambda \to 2\pi \Rightarrow \frac{\theta}{2\pi} = \frac{\frac{\lambda}{4}}{\lambda} \Rightarrow \theta = \frac{\pi}{2}$ it leads to $a_{s3-4} = \sqrt{2a^2 + 2a^2 \cos\frac{3\pi}{2}} \Rightarrow a_{s3-4} = \sqrt{2a^2} \Rightarrow a_{s4} = \sqrt{2}a \Rightarrow I = I_p = (2a_{s3-4})^2$. It leads to $\boldsymbol{I} = \left(2\sqrt{2}a\right)^2 = \boldsymbol{8a^2}$**…(1)** In the problem three possible values of z are given and accordingly intensity at the P would be – **Case (a):** Given that $z = \frac{\lambda D}{d} \Rightarrow \Delta x = \frac{\left(\frac{\lambda D}{d}\right)d}{2D} \Rightarrow \Delta x = \frac{\lambda}{2}$. Thus amplitude at both the slits S3 and S4 is zero, it implies that no light will reach at P and hence intensity of the light at P is Zero. **Case (b):** Given that $z = \frac{3\lambda D}{2d} \Rightarrow \Delta x = \frac{\left(\frac{3\lambda D}{2d}\right)d}{2D} \Rightarrow \Delta x = \frac{3\lambda}{4}$. Since $\lambda \to 2\pi \Rightarrow \frac{\theta}{2\pi} = \frac{\frac{3\lambda}{4}}{\lambda} \Rightarrow \theta = \frac{3\pi}{2}$. Thus amplitude at the S3 and S4 is $a_{s3-4} = \sqrt{2a^2 + 2a^2 \cos\frac{3\pi}{2}} \Rightarrow a_{s3-4} = \sqrt{2a^2} \Rightarrow a_{s4} = \sqrt{2}a$. therefore intensity at P is $I_p = (2a_{s3-4})^2 \Rightarrow I_p = \left(2\sqrt{2}a\right)^2 = 8a^2$..(2). Combining (1) and (2), intensity at P is $\boldsymbol{I_p = I}$**, is the answer.** **Case (c):** Given that $z = \frac{2\lambda D}{d} \Rightarrow \Delta x = \frac{\left(\frac{2\lambda D}{d}\right)d}{2D} \Rightarrow \Delta x = \lambda$. Thus intensity at both the slits S3 and S4 is $a_{s3-4} = 2a$, and it implies that amplitude of two coherent and in-phase at P is $a_p = 2a_{s3-4} = 4a$. Accordingly, $I_p = a_p^2 \Rightarrow I_p = (4a)^2 \Rightarrow I_p = 16a^2 \Rightarrow \boldsymbol{I_p = 2I}$**, is the answer.** **Thus answer is (a) Zero (b) *I* (c) 2*I***
I-62	Phenomenon of reflection of light wave through film of a bubble is shown in the figure. Incident wave AB on transparent surface is subjected to partial refraction at outer surface of the bubble (as ray BC) and on the same surface partial reflection (as ray BP). The refracted ray BC again undergoes total reflection (as ray CD) at inner surface of the bubble at C as ray along CD. This reflected ray CD undergoes refraction at outer surface of the bubble along DQ.  Reflection of wave at B causes a phase shift $\pi \to \frac{\lambda}{2}$, since incident wave AB encounters denser medium at B, this cause crest reflected as crest and trough reflected as trough. But, ray BC in the film encounters rarer medium at C and hence crest reflected as trough and trough reflected as crest; hence there is continuity of wave without phase shift. Thus net optical path difference in reflected rays is caused by ray BC and CD which is equivalent to $\Delta x = \mu \times 2t + \frac{\lambda}{2}$…(1) Given that soap film appears dark and it requires $\Delta x = (2n+1)\frac{\lambda}{2}\Big\|_{n\in N}$…(2). Combining (1) and (2) we have $\mu \times 2\mu t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2} \Rightarrow \mu \times 2\mu t$…(3) Given that thickness of the film is $t = 0.0011$mm or 1.1×10^{-6}m. Using the available data $n = \frac{2\mu t}{\lambda} = \frac{2\times\mu\times1.1\times10^{-6}}{580\times10^{-9}} = 3.793\mu$. With the $1.2 < \mu < 1.5$ and factor of μ is 3.793 the possible integral value $n = 5$. Thus, $3.793\mu = 5 \Rightarrow \mu = \frac{5}{3.793} \Rightarrow \boldsymbol{\mu = 1.32}$ **is the answer.** **N.B.:** In this case incident ray is are nearly perpendicular to the surface and hence BC = CD = t. However, angle of the incident ray is only for diagrammatic discrimination and convenience.

I-63	 Phenomenon of reflection of light wave through a thin oil film is shown in figure. Incident wave AB on transparent surface is subjected to partial refraction at top surface of the film (as ray BC) and on the same surface partial reflection (as ray BP). The refracted ray BC again undergoes total reflection (as ray CD) at bottom surface of the film at C as ray along CD. This reflected ray CD undergoes refraction at outer surface of the oil film along DQ. Reflection of wave at B causes a phase shift $\pi \to \frac{\lambda}{2}$, since incident wave AB encounters denser medium at B, this cause crest reflected as crest and trough reflected as trough. But, ray BC in the film encounters rarer medium at C and hence crest reflected as trough and trough reflected as crest; hence there is continuity of wave without phase shift. Thus net optical path difference in reflected rays is caused by ray BC and CD which is equivalent to $\Delta x = \mu \times 2t + \frac{\lambda}{2}$…(1) Given that soap film appears dark and this in case of reflection is opposite to the transmission and requires $\Delta x = (2n+1)\frac{\lambda}{2}\Big\|_{n\in \mathrm{N}}$…(2). Combining (1) and (2) we have $\mu \times 2\mu t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2} \Rightarrow \mu \times 2\mu t$…(3) Constructive interference would exhibit strongly reflected light for which minimum thickness of the oil film of refractive index $\mu = 1.4$ should be such that the reflected light is in phase with the incident light. Thus an additional phase shift during to-and-fro traversal of light through the oil film of minimum thickness t is such that $2t\mu = \frac{\lambda}{2} \Rightarrow t = \frac{\lambda}{4\mu}$. Using the given data $t = \frac{560\times10^{-9}}{4\times1.6} \Rightarrow \boldsymbol{t = 100}$ **nm is the answer.** **N.B.:** In this case incident ray is are nearly perpendicular to the surface and hence $\mathrm{BC} = \mathrm{CD} = t$. However, angle of the incident ray is only for diagrammatic discrimination and convenience.
I-64	 Phenomenon of reflection of light wave through water film is shown on the figure. Incident wave AB on transparent surface is subjected to partial refraction at top surface of the film (as ray BC) and on the same surface partial reflection (as ray BP). The refracted ray BC again undergoes total reflection (as ray CD) at bottom surface of the film at C as ray along CD. This reflected ray CD undergoes partial refraction at outer surface of the water film along DQ and remaining part of the wave is reflected at D and wave travels along DE. This reflected wave at E undergoes refraction along ES. When a wave encounters denser medium, this causes crest reflected as crest and trough reflected as trough. Thus reflection of wave at denser medium causes phase shift $\pi \to \frac{\lambda}{2}$. But when a wave in denser medium encounter a lighter medium crest reflected as trough and trough reflected as crest. And hence there is no change of phase. Thus ray ES is a reflection of wave at B and E, , i.e. double reflection. While, the ray CR is not at all subjected to reflection. But, path BC of the ray BCR is common to BCDES. Thus net optical path difference in refracted rays is caused by ray CR and ES is equivalent to $\Delta x = \mu \times 2t$…(1). Given that through the water film there is bright transmission which is possible when $\Delta x = n\lambda\|_{n\in \mathrm{N}}$ …(2). Combining (1) and (2) we have $2\mu t = n\lambda$. It leads $2\mu t = m\lambda\|_{n\in \mathrm{N}}$. It leads to $\lambda = \frac{2\mu t}{m}$…(3). Using the given data $\lambda = \frac{2\times1.33\times1\times10^{-6}}{n} \Rightarrow \lambda = \frac{2.66\times10^{-6}}{n}$. Further it is given that $0.6\times10^{-6} < \lambda < 0.7\times10^{-6}$. It leads to $0.4\times10^{-6} < \frac{2.66\times10^{-6}}{n} < 0.7\times10^{-6} \Rightarrow 0.4 < \frac{2.66}{n} < 0.7 \Rightarrow 0.4\times n < 2.66 < 0.7\times n$. Thus, we have $n < \frac{2.66}{0.4}$ or $n < \frac{2.66}{0.4} \Rightarrow n < 6.65$ and $2.66 < 0.7\times n \Rightarrow \frac{2.66}{0.7} < n \Rightarrow 3.8 < n$. Since, $n \in N$ accordingly we have set M such that $n = \{k: 3.8 < k < 6.65; k \in N\} \Rightarrow n = \{4,5,6\}$. Accordingly, $\lambda = \left\{\frac{2.66\times10^{-6}}{4}, \frac{2.66\times10^{-6}}{5}, \frac{2.66\times10^{-6}}{6}\right\}$. It leads to $\lambda = \{443\times10^{-9}, 532\times10^{-9}, 666\times10^{-9}\}$meter, or $\boldsymbol{\lambda = \{443, 532, 666\}}$**nm is the answer.** **N.B.:** In this case incident ray is are nearly perpendicular to the surface and hence $\mathrm{BC} = \mathrm{CD} = \mathrm{DE} = t$. However, angle of the incident ray is only for diagrammatic discrimination and convenience.

I-65	Given that thickness of a thin oil film is $t = 1.00 \times 10^{-4}$ cm or 10^{-6}, its refractive index $\mu = 1.25$. It is required to determine wavelengths in the range 0.400×10^{-6} m $< \lambda < 0.750 \times 10^{-6}$ m which would be completely transmitted. This is the case of complete transmission of a ray through a compose medium out of which one is a thin oil thin film on glass a medium denser than that of the oil, and is shown in the conceptual figure.  When a wave encounters denser medium, this causes crest reflected as crest and trough reflected as trough. Thus reflection of wave at denser medium causes phase shift $\pi \rightarrow \frac{\lambda}{2}$. But when a wave in denser medium encounter a lighter medium crest reflected as trough and trough reflected as crest. In the instant case traversal of ray along BC is common but physical distance CR and ED are equal, while reflection at E at boundary with lighter medium does not cause any phase difference. Thus optical path difference between transmitted rays RT and SU is caused (a) reflection from glass surface at C and traversal of ray in the film along CD and DE. Thus net path difference in refracted rays is caused by ray CR and ES is equivalent to $\Delta x = \mu \times 2t + \frac{\lambda}{2}$…(1). Given that through the water film there is bright transmission which is possible when $\Delta x = n\lambda\|_{n\in N}$ …(2). Combining (1) and (2) we have $2\mu t + \frac{\lambda}{2} = n\lambda$. It leads $2\mu t = (2n-1)\frac{\lambda}{2}\Big\|_{n\in N}$. It leads to $\lambda = \frac{4\mu t}{2n-1}$…(3). Using the given data $\lambda = \frac{4\times 1.25\times 1\times 10^{-6}}{2n-1} \Rightarrow \lambda = \frac{5.00\times 10^{-6}}{2n-1}$. Considering the range of wavelength stated in the problem we have $0.400 \times 10^{-6} < \frac{5.00\times 10^{-6}}{2n-1} < 0.750 \times 10^{-6} \Rightarrow 0.400 < \frac{5.00}{2n-1} < 0.750$. It, further, resolves into $0.400 \times (2n-1) < 5.00 < 0.750 \times (2n-1)$. Resolving each limit separately, for lower limit we have $2n - 1 < \frac{5.00}{0.400} \Rightarrow n < \frac{5.40}{0.8} \Rightarrow n < 6.75$ and on the upper limit $5.00 < 0.75 \times (2n-1) \Rightarrow \frac{5.00}{0.75} < 2n - 1$. It solves into $\frac{5.75}{0.75} < 2n \Rightarrow 3.83 < n$. Since, $n \in N$ accordingly we have set such that $n = \{k: 3.63 < k < 6.75; n \in N\} \Rightarrow n = \{4,5,6\} \Rightarrow 2n - 1 = \{7,9,11\}$. Accordingly, $\lambda = \left\{\frac{5.00\times 10^{-6}}{7}, \frac{5.00\times 10^{-6}}{9}, \frac{5.00\times 10^{-6}}{11}\right\}$. It leads to $\lambda = \{455 \times 10^{-9}, 556 \times 10^{-9}, 714 \times 10^{-9}\}$meter, or $\boldsymbol{\lambda} = \{\mathbf{455}, \mathbf{556}, \mathbf{714}\}$**nm is the answer.** **N.B.:** In this case incident ray is are nearly perpendicular to the surface and hence all the path lengths in oil film and glass is taken to be t. However, angle of the incident ray is only for diagrammatic discrimination and convenience.
I-66	Diffraction phenomenon through single slit of width $b = AB$ is shown in the figure. Point P is bright fringe where interfering rays AP and BP are of equal length. But, rays interfering at Q are AQ and OQ have a path difference $OC = \frac{b}{2}\sin\theta$ such that $\Delta x = \frac{b}{2}\sin\theta$…(1). It is required to determine wavelength when at Q at an angle $\theta = 30^0$ first diffraction minimum is formed . This requires that $\Delta x = \frac{\lambda}{2}$…(2).  Combining (1) and (2) we have $\frac{\lambda}{2} = \frac{b}{2}\sin\theta \Rightarrow \lambda = b\sin\theta$…(3). Given that $b = 5.0$ cm $= 5.0 \times 10^{-2}$m hence with the given data $\lambda = (5.0 \times 10^{-2})\sin 30^0 \Rightarrow \lambda = (5.0 \times 10^{-2}) \times \frac{1}{2}$ or $\boldsymbol{\lambda} = 2.5 \times 10^{-2}$m or **2.5 cm is the answer.** **N.B.:** Diffraction phenomenon, is though governed by principles of interference, in this case interference of the ray from edge with the that from central line is considered and not the rays from the two edges of the narrow slit. And this make is different from normal interference.
I-67	This is the case of Fraunhfer diffraction by a circular aperture not small as width of slit in single slit diffraction. In this case interference take place between rays form the diametrical points on the edge of the circular aperture. Mathematically, radius of the central bright spot is approximated to $R = 1.22\frac{\lambda D}{d}$. Using the available data $R = 1.22 \times \frac{(560\times 10^{-9})\times 2.00}{2.0\times 10^{-4}} = 0.683$ cm and hence diameter of the central bright fringe is $D = 2R \Rightarrow \boldsymbol{D} = 2 \times 0.683 = \mathbf{1.37}$ **cm is the answer.**

I-68	This is the case of Fraunhfer diffraction by a circular aperture diffraction. In this case interference take place between rays form the diametrical points on the edge of the circular aperture. In this diameter of the convex lens serves diameter of the circular aperture accordingly $d = 8.0 \times 10^{-2}$m. The diffraction pattern is focused at a distance $D = 0.20$ m. Mathematically, radius of the central bright spot is approximated to $R = 1.22\frac{\lambda D}{d}$. Thus, $R = 1.22 \times \frac{(620\times10^{-9})\times0.20}{8.0\times10^{-2}} = 1891 \times 10^{-9}$ cm and hence diameter of the central bright fringe is $D = 2R \Rightarrow \boldsymbol{D} = 2 \times 1.9 = \mathbf{3.8}$ **μm or $\mathbf{3.8 \times 10^{-6}}$ m is the answer.** **N.B.:** Illustration of formula $R = 1.22\frac{\lambda D}{d}$ is requires advanced mathematics involving Bessel's function and hence skipped here.
I-69	Fringe pattern in the experiment has ratio intensities $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$ and this ratio is given to be $\frac{I_{max}}{I_{min}} = \frac{9}{1}$. Combining these two ratios $\frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{9}{1} \Rightarrow \frac{a_1+a_2}{a_1-a_2} = \frac{3}{1}$. Applying componendo-dividendo we have $\frac{\boldsymbol{a_1}}{\boldsymbol{a_2}} = \frac{2}{1} = \mathbf{2}$, **thus option (d) is the answer**. Likewise, their intensities $\frac{\boldsymbol{I_1}}{\boldsymbol{I_2}} = \left(\frac{a_1}{a_2}\right)^2 \Rightarrow \frac{I_1}{I_2} = \left(\frac{2}{1}\right)^2 \Rightarrow \frac{I_1}{I_2} = \frac{4}{1} = \mathbf{4}$, **thus option (b) is the answer.** **Thus answers are option (b) and (d).**
I-70	White light contains a spectrum of wavelengths. In Young's double slit experiment fringe width $w = \frac{n\lambda d}{b}$ or $n\lambda = \frac{wb}{d}$, here w is separation between bright fringes. Since. dark fringes are equally spaced between adjacent bright fringes and separation between a dark fringe with adjacent bright fringe is $w' = \frac{w}{2}$. It leads to $w' = \frac{(2n+1)\lambda d}{2b} \Rightarrow (2n+1)\lambda = \frac{2bw\prime}{d}$…(1), here $n \in W$, In the problem it is stated that the point which is being observed for missing fringes is in front of one of the slit. It implies that $w' = \frac{b}{2}$…(2). Combining (1) and (2) we have $(2n+1)\lambda = \frac{2b\left(\frac{b}{2}\right)}{d} \Rightarrow \lambda = \frac{b^2}{(2n+1)d}$ **.** Since $n \in W$. Hence testing with a few values of n we have values of missing wavelengths as under – • $n = 0 \Rightarrow \boldsymbol{\lambda} = \frac{\boldsymbol{b^2}}{\boldsymbol{d}}$ **is the answer in option (a).** • $n = 1 \Rightarrow \lambda = \frac{b^2}{(2\times1+1)d} \Rightarrow \boldsymbol{\lambda} = \frac{\boldsymbol{b^2}}{\boldsymbol{3d}}$ **is the answer in option (c).** • $n = 2 \Rightarrow \lambda = \frac{b^2}{(2\times2+1)d} \Rightarrow \lambda = \frac{b^2}{5d}$ is not the answer in any of the given options. • This shall be true for all $n \geq 2$ **Hence answers are options (a) and (c).**

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