



PHYSICS

BOOKS - HC VERMA

LIGHT WAVES

Examples

1. (a) The refractive index of glass is 1.5. What is the speed of light in glass? (Speed of light in vacuum is $3.0 \times 10^8 \text{ms}^{-1}$)
(b) Is the speed of light in glass independent of the colour of light? If not, which of the two colours red and violet travels slower in a glass prism?

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2. In a Young's double slit experiment the separation between the slits is 0.10 mm, the wavelength of light used is 600 nm and the interference pattern is observed on a screen 1.0 m away. Find the separation between the successive bright fringes.

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3. The wavelength of light coming from a sodium source is 589 nm. What will be its wavelength in water? Refractive index of water 1.33.

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4. Find the minimum thickness of a film which will strongly reflect the light of wavelength 589 nm. The refractive index of the material of the film is 1.25.

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5. A parallel beam of monochromatic light of wavelength 450 nm passes through a long slit of width 0.2 mm. find the angular divergence in which most of the light is diffracted.



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6. A beam of light of wavelength 590 nm is focussed by a converging lens of diameter 10.0 cm at a distance of 20 cm from it. find the diameter of the disc image formed.



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Worked Out Examples

1. White light is a mixture of light of wavelengths between 400 nm and 700 nm. If this light goes through water ($\mu = 1.33$) what are the limits of the wavelength there ?



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2. The optical path of a monochromatic light is the same if it goes through 2.00 cm of glass or 2.25 cm of water. If the refractive index of water is 1.33, what is the refractive index of glass?

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3. White light is passed through a double slit and interference pattern is observed on a screen 2.5 m away. The separation between the slits is 0.5 mm. The first violet and red fringes are formed 2.0 mm and 3.5 mm away from the central white fringe. Calculate the wavelengths of the violet and the red light.

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4. A double slit experiment is performed with sodium (yellow) light of wavelength 589.3 nm and the interference pattern is observed on a

screen 100 cm away. The tenth bright fringe has its centre at a distance of 12 mm from the central maximum. Find the separation between the slits.

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5. The intensity of the light coming from one of the slits in a Young's double slit experiment is double the intensity from the other slit. Find the ratio of the maximum intensity to the minimum intensity in the interference fringe pattern observed.

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6. The width of one of the two slits in a Young's double slit experiment is double of the other slit. Assuming that the amplitude of the light coming from a slit is proportional to the slit width, find the ratio of the maximum to the minimum intensity in the interference pattern.

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7. Two coherent point sources S_1 and S_2 , vibrating in phase emit light of wavelength λ . The separation between the sources is 2λ . Consider a line passing through S_2 and perpendicular to the line S_1S_2 , What is the smallest distance from S_2 where a minimum of intensity occurs ?

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8. A beam of light consisting of two wavelengths, 6500 \AA and 5200 \AA is used to obtain interference fringes in a Young's double slit experiment ($1 \text{ \AA} = 10^{-10} \text{ m}$). The distance between the slits is 2.0 mm and the distance between the plane of the slits and the screen is 120 cm . (a) Find the distance of the third bright fringes on the screen from the central maximum for the wavelength 6500 \AA (b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide ?

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9. Monochromatic light of wavelength 600 nm is used in a Young's double slit experiment. One of the slits is covered by a transparent sheet of thickness 1.8×10^{-5} m made of a material of refractive index 1.6. How many fringes will shift due to the introduction of the sheet?

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10. While light is incident normally on a glass plate of thickness 0.50×10^{-6} m and index of refraction 1.50. Which wavelength in the visible region (400 nm - 700 nm) are strongly reflected by the plate?

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11. A parallel beam of green light of wavelength 546 nm passes through a slit of width 0.40 mm. The transmitted light is collected on a screen 40 cm away. Find the distance between the two first order minima.

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1. Is the Colour of 620 nm light and 780 nm light same? Is the colour of 620 nm light and 621 nm light same? How many colours are there in white light?

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2. The wavelength of light in a medium is $\lambda = \frac{\lambda_0}{\mu}$ where λ is the wavelength in vacuum. A beam of red light ($\lambda_0 = 720nm$) enters into water The wavelength in water is $\lambda = \frac{\lambda_0}{\mu} = 540nm$. To a person under water does this light appear green?

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3. Whether the diffraction effects from a slit will be more clearly visible or less clearly, if the slit-width is increased ?

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4. If we put a cardboard (*say* $20\text{cm} \times 20\text{cm}$) between a light source and our eyes, we can't see the light. But when we put the same cardboard between a sound source and our ear, we hear the sound almost clearly, Explain.

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5. TV signals broadcast by Delhi studio cannot be directly received at Patna which is about 1000 km away. But the same signal goes some 36000 km away to a satellite, gets reflected and is then received at Patna. Explain.

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6. Can we perform Young's double slit experiment with sound waves? To get a reasonable fringe pattern what should be the order of separation

between the slits? How can the bright fringes and the dark fringes be detected in this case?

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7. Is it necessary to have two waves of equal intensity to study interference pattern? Will there be an effect on clarity if the waves have unequal intensity?

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8. Can we conclude from the interference phenomenon whether light is a transverse wave or a longitudinal wave?

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9. Why don't we have interference when two candles are placed close to each other and the intensity is seen at a distant screen? What happens if

the candles are replaced by laser sources?

- A. wave phenomenon
- B. particle phenomenon
- C. both particle and wave phenomenon
- D. none of these

Answer:



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10. If the separation between the slits in a Young's double slit experiment is increased. What happens to the fringe width? If the separation is increased too much will the fringe pattern remain detectable?



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11. Suppose white light falls on a double slit but one slit is covered by a violet filter (allowing $\lambda = 400nm$). Describe the nature of the fringe pattern observed.



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Objective 1

1. Light is

- A. wave phenomenon
- B. particle phenomenon
- C. both particle and wave phenomenon
- D. none of these

Answer: C



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2. The speed of light depends

- A. on elasticity of the medium only
- B. on inertia of the medium only
- C. on elasticity as well as inertia
- D. neither on elasticity nor on inertia

Answer: D



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3. The equation of a light wave is written as $y = A \sin(kx - \omega t)$. Here y represents

- A. displacement of either particles
- B. pressure in the medium
- C. density of the medium
- D. electric field

Answer: D



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4. Which of the following properties show that light is a transverse wave?

- A. Reflection
- B. interference
- C. Diffraction
- D. Polarization

Answer: D



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5. When light is refracted into a denser medium

- A. its wavelength and frequency both increases

- B. its wavelength increases but frequency remains unchanged
- C. its wavelength decreases but frequency remains unchanged
- D. its wavelength and frequency both decrease.

Answer: C



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6. When light is refracted which of the following does not change?

- A. Wavelength
- B. Frequency
- C. Velocity
- D. Amplitude

Answer: B



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7. The amplitude modulated (AM) radio wave bends appreciably round the corners of a $1m \times 1m$ board but the frequency modulated (FM) wave only negligible bends. If the average wavelengths of AM and FM waves are λ_a and λ_f .

A. $\lambda_a > \lambda_f$

B. $\lambda_a = \lambda_f$

C. $\lambda_a < \lambda_f$

D. We don't have sufficient information to decide about the relation of λ_a and λ_f .

Answer: A



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8. Which of the following sources gives best monochromatic light?

A. A candle

B. A bulb

C. A mercury tube

D. A laser

Answer: D



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9. The wavefronts of a light wave travelling in vacuum are given by $x + y + z = c$. The angle made by the direction of propagation of light with the X-axis is

A. 0°

B. 45°

C. 90°

D. $\cos^{-1}(1/\sqrt{3})$.

Answer: D



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10. The wavefronts of light coming from a distant source of unknown shape are nearly

- A. Plane
- B. elliptical
- C. cylindrical
- D. spherical.

Answer: A



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11. The inverse square law of intensity (i.e., the intensity $\propto \frac{1}{r^2}$) is valid for a

- A. point source

B. line source

C. plane source

D. cylindrical source.

Answer: A



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12. Two sources are called coherent if they produce waves

A. of equal wavelength

B. of equal velocity

C. having same shape of wavefront

D. having a constant phase difference.

Answer: D



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13. When a drop of oil is spread on a water surface, it displays beautiful colours in daylight because of

- A. dispersion of light
- B. reflection of light
- C. polarization of light
- D. interference of light.

Answer: D



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14. Two coherent sources of different intensities send waves which interfere. The ratio of the maximum intensity to the minimum intensity is

25. the intensities are in the ratio :-

- A. 25 : 1
- B. 5 : 1

C. 9:4

D. 625:1

Answer: C



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15. The slits in a Young's double slit experiment have equal width and the source is placed symmetrically with respect to the slits. The intensity at the central fringe is I_0 . If one of the slits is closed, the intensity at this point will

A. I_0

B. $I_0/4$

C. $I_0/2$

D. $4I_0$

Answer: B



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16. A thin transparent sheet is placed in front of a Young's double slit. The fringe width will

- A. increases
- B. decrease
- C. remain same
- D. become nonuniform.

Answer: C

17. If young's double slit experiment is performed in water

- A. the fringe width will decrease
- B. the fringe width will increase

C. the fringe width will remain unchanged

D. there will be no fringe.

Answer: A



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Objective 2

1. A light wave can travel

A. in vacuum

B. in vacuum only

C. in a material medium

D. in a material medium only.

Answer: A::C



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2. Which of the following properties of light conclusively support wave theory of light?

- A. Light obeys laws of reflection
- B. speed of light in water is smaller than the speed in vacuum.
- C. Light shows interference
- D. Light shows photoelectric effect.

Answer: B::C



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3. When light propagates in vacuum there is an electric field and a magnetic field. These fields

- A. are constant in time
- B. have zero average value

C. are perpendicular to the direction of propagation of light

D. are mutually perpendicular.

Answer: B::C::D



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4. Huygen's principle of secondary wavelets may be used to

A. find the velocity of light in vacuum

B. explain the particle behaviour of light

C. find the new position of wavefront

D. explain Snell's law

Answer: C::D



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5. Three observers A, B and C measure the speed of light coming from a source to be v_A , v_B and v_C . The observer A moves towards the source and C moves away from the source at the same speed. The observer B stays stationary. The surrounding space is vacuum everywhere.

A. $v_A > v_B > v_C$

B. $v_A < v_B < v_C$

C. $v_A = v_B = v_C$

D. $v_B = \frac{1}{2}(v_A + v_C)$.

Answer: C::D



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6. Light waves travel in vacuum along the X-axis. Which of the following may represent the wavefronts?

A. $x = c$

B. $y = c$

C. $z = c$

D. $x + y + z = c$.

Answer: A



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7. If the source of light used in a young's double slit experiment is changed from red to violet

A. the fringes will become brighter

B. consecutive fringes will come closer

C. the intensity of minima will increase

D. the central bright fringe will become a dark fringe

Answer: B



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8. A Young's double slit experiment is performed with white light.

- A. The central fringe will be white
- B. There will not be a completely dark fringe.
- C. The fringe next to the central will be red
- D. The fringe next to the central will be violet

Answer: A::B::D



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9. Four light waves are represented by

i. $y = a_1 \sin \omega t$

ii. $y = a_2 \sin(\omega t + \varepsilon)$

iii. $y = a_1 \sin 2\omega t$

iv. $y = a_2 \sin 2(\omega t + \varepsilon)$ Inteferece fringes may be observed due to superposition of

A. (i) and (ii)

B. (i) and (iii)

C. (ii) and (iv)

D. (iii) and (iv).

Answer: A:D



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Exercises

1. Find the range of frequency of light that is visible to an average human being ($400nm < \lambda < 700nm$)



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2. The wavelength of sodium light in air is 589 nm. (a) Find its frequency in air. (b) Find its wavelength in water (refractive index = 1.33). (c) find its

frequency in water : (d) Find its speed in water.

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3. The index of refraction of fused quartz is 1.472 for light of wavelength 400 nm and is 1.452 for light of wavelength 760 nm. Find the speeds of light of these wavelengths in fused quartz.

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4. The speed of the yellow light in a certain liquid is $2.4 \times 10^8 \text{ m s}^{-1}$. Find the refractive index of the liquid.

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5. Two narrow slits emitting light in phase are separated by a distance of 1.0 cm. The wavelength of the light is 5.0×10^{-7} m. The interference pattern is observed on a screen placed at a distance of 1.0 m. (a) Find the

separation between the consecutive maxima. Can you expect to distinguish between these maxima ? (b) Find the separation between the sources which will give a separation of 1.0 mm between the consecutive maxima.

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6. The separation between the consecutive dark fringes in a Young's double slit experiment is 10^{-3} m. he is placed at a distance of 2.5 m from the slits screen s and separation between the slits is 1.0 mm. Calculate the wavelength of light used for the experiment.

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7. In a double slit interference experiment, the separation between the slits is 1.0 mm, the wavelength of light used is 5.0×10^{-7} m and the distance of the screen from the slits is 1.0 m. (a) Find the distance of the centre of the first minimum from the centre of the central maximum. (b)

How many bright fringes are formed in one centimeter width on the screen ?

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8. In a Young's double slit experiment, two narrow vertical slits placed 0.800 mm apart are illuminated by the same source of yellow light of wavelength 589 nm. How far are the adjacent bright bands in the interference pattern observed on a screen 2.00 m away ?

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9. Find the angular separation between the consecutive bright fringes in a Young's double slit experiment with blue-green light of wavelength 500 nm. The separation between the slits is 2.0×10^{-3} m.

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10. A source emitting light of wavelengths 480 nm and 600 nm is used in a double slit interference experiment. The separation between the slits is 0.25 mm and the interference is observed on a screen placed at 150 cm from the slits. Find the linear separation between the first maximum (next to the central maximum) corresponding to the two wavelengths.

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11. White light is used in a Young's double slit experiment. Find the minimum order of the violet fringe ($\lambda = 400nm$) which overlaps with a red fringe ($\lambda = 700nm$).

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12. Find the thickness of a plate which will produce a change in optical path equal to half the wavelength λ of the light passing through it normally. The refractive index of the plate is μ .

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13. A plate of thickness t made of a material of refractive index μ is placed in front of one of the slits in a double slit experiment. (a) Find the changes in the optical path due to introduction of the plate. (b) What should be the minimum thickness t which will make the intensity at the centre of the fringe pattern zero? Wavelength of the light used is λ . Neglect any absorption of light in the plate.

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14. A transparent paper (refractive index = 1.45) of thickness 0.02 mm is pasted on one of the slits of a Young's double slit experiment which uses monochromatic light of wavelength 620 nm. How many fringes will cross through the centre if the paper is removed?

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15. In a Young's double slit experiment using monochromatic light, the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 1.964 micron (1 micron = $10^{-6}m$) is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the screen and the slits is doubled. It is found that the distance between the successive maxima now is the same as the observed fringe-shift upon the introduction of the mica sheet. Calculate the wavelength of the monochromatic light used in the experiment.



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16. A mica strip and a polystyrene strip are fitted on the two slits of a double slit apparatus. The thickness of the strips is 0.50 mm and the separation between the slits is 0.12 cm. The refractive index of mica and polystyrene are 1.58 and 1.55 respectively for the light of wavelength 590 nm which is used in the experiment. The interference is observed on a

screen a distance one meter away. (a) What would be the fringe-width ?
(b) At what distance from the centre will the first maximum be located ?

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17. Two transparent slabs having equal thickness but different refractive indices μ_1 and μ_2 , are pasted side by side to form a composite slab. This slab is placed just after the double slit in a Young's experiment so that the light from one slit goes through one material and the light from the other slit goes through the other material. What should be the minimum thickness of the slab so that there is a minimum at the point P_0 which is equidistant from the slits ?

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18. A thin paper of thickness 0.02 mm having a refractive index 1.45 is pasted across one of the slits in a YDSE. The paper transmits $4/9$ of the light energy falling on it.

a. Find the ratio of maximum intensity to the minimum intensity in

interference pattern.

b. How many fringes will cross through the center if an identical paper piece is pasted on the other slit also? The wavelength of the light used is 600 nm.



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19. A Young's double slit apparatus has slits separated by 0.28 mm and a screen 48 cm away from the slits. The whole apparatus is immersed in water and the slits are illuminated by the red light ($\lambda = 700$ nm in vacuum). Find the fringe-width of the pattern formed on the screen.



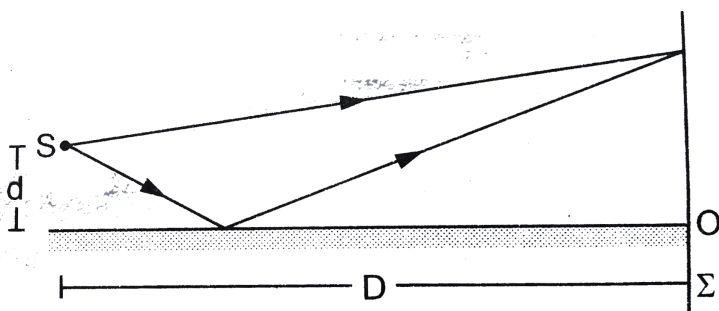
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20. A parallel beam of monochromatic light is used in a Young's double slit experiment. The slits are separated by a distance d and the screen is placed parallel to the plane of the slits. Show that if the incident beam

makes an angle $\theta = \sin^{-1}\left(\frac{\lambda}{2d}\right)$ with the normal to the plane of the slits, there will be a dark fringe at the centre Po of the pattern.

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21. A narrow slit S transmitting light of wavelength λ is placed a distance d above a large plane mirror as shown in figure. The light coming directly from the slit and that coming after the reflection interference at a screen Σ placed at a distance LD from the slit. a. What will be the intensity at a point just above the mirror. i.e., just above O? b. At what distance from O does the first maximum occur?



?

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22. A long narrow horizontal slit is placed 1 mm above a horizontal plane mirror. The interference between the light coming directly from the slit and that after reflection is seen on a screen 1.0 m away from the slit, Find the fringe-width if the light used has a wavelength of 700 nm.

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23. Consider the situation of the previous problem, if the mirror reflects only 64% of the light energy falling on it, what will be the ratio of the maximum to the minimum intensity in the interference pattern observed on the screen ?

A. 4:1

B. 9:1

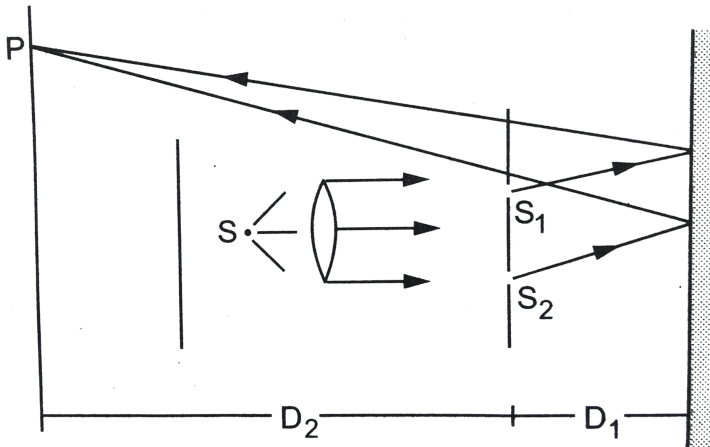
C. 16:1

D. 81:1

Answer: A

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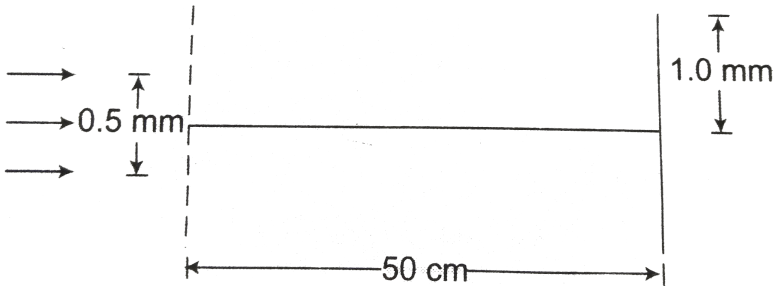
24. A double slit $S_1 - S_2$ is illuminated by a coherent light of wavelength λ . The slits are separated by a distance d . A plane mirror is placed in front of the double slit at a distance D_1 , from it and a screen Σ is placed behind the double slit at a distance D_2 , from it. The screen Σ receives only the light reflected by the mirror. Find the fringe-width of the interference pattern on the screen.



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25. White coherent light ($400\text{nm} - 700\text{nm}$) is sent through the slits of a YDSE. $D = 0.5\text{mm}$, $D=50\text{ cm}$. There is a hole in the screen at a point 1.0mm away (along the width of the fringes) from the central line.

- (a) Which wavelength will be absent in the light coming from the hole?
 (b) Which wavelength(s) will have a strong intensity?



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26. Consider the arrangement shown in figure. The distance D is large compared to the separated d between the slits. a. Find the minimum value of d so that there is a dark fringe at O . b. Suppose d has this value. Find the distance x at which the next bright fringe is formed. c. Find the fringe width.

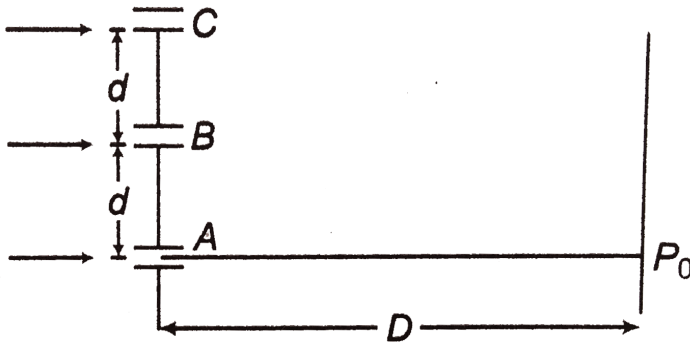


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27. Two coherent point sources S_1 and S_2 emit light of wavelength λ . The separation between sources is 2λ . Consider a line passing through S_2 and perpendicular to the line S_1S_2 . What is the smallest distance on this line from S_2 where a minimum of intensity occurs?

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28. figure shows three equidistant slits illuminated by a monochromatic parallel beam of light. Let $BP_0 - AP_0 = \frac{\lambda}{3}$ and $D \gg \lambda$.



(a) Show that $d = \sqrt{(2\lambda D)/3}$

(b) Show that the intensity at P_0 is three times the intensity due to any of the three slits individually.



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29. In a Young's double slit experiment, the separation between the slits = 2.0 mm, the wavelength of the light = 600 nm and the distance of the screen from the slits = 2.0 m. If the intensity at the centre of the central maximum is 0.20 W m^{-2} , what will be the intensity at a point 0.5 cm away from this centre along the width of the fringes ?



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30. In a Young's double slit interference experiment the fringe pattern is observed on a screen placed at a distance D from the slits. The slits are separated by a distance d and are illuminated by monochromatic light of wavelength λ . Find the distance from the central point where the intensity falls to (a) half the maximum, (b) one fourth of the maximum.



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31. In a Young's double slit experiment $\lambda = 500nm$, $d = 1.0mm$ and $D = 1.0m$. Find the minimum distance from the central maximum for which the intensity is half of the maximum intensity.



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32. The line-width of a bright fringe is sometimes defined as the separation between the points on the two sides of the central line where the intensity falls to half the maximum. Find the line-width of a bright fringe in a Young's double slit experiment in terms of λ , d and D where the symbols have their usual meanings



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33. Consider the situation shown in figure. The two slits S_1 and S_2 placed symmetrically around the central line are illuminated by a monochromatic light of wavelength λ . The separation between the slits is d . The light transmitted by the slits falls on a screen Σ_1 placed at a distance D from the slits. The slit S_3 is at the placed central line and the slit S_4 , is at a distance z from S_3 . Another screen Σ_2 is placed a further distance D away from Σ_1 . Find the ratio of the maximum to minimum intensity observed on Σ_2 if z is equal to a. $z = \frac{\lambda D}{2d}$ b. $\frac{\lambda D}{d}$ c. $\frac{\lambda D}{4d}$



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34. Consider the arrangement shown in figure. By some mechanism, the separation between the slits S_3 and S_4 can be changed. The intensity is measured at the point P which is at the common perpendicular bisector of S_1S_2 and S_3S_4 . When $z = \frac{\lambda D}{2d}$

the intensity measured at P is I . Find the intensity when z is equal to $a \cdot \frac{D\lambda}{d}$,



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35. A soap film of thickness 0.0011 mm appears dark when seen by the reflected light of wavelength 580 nm.. What is the index of refraction of the soap solution, if it is known to be between 1-2 and 1.5 ?

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36. A parallel beam of light of wavelength 560 nm falls on a thin film of oil (refractive index = 1.4). What should be the minimum thickness of the film so that it strongly reflects the light ?

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37. A parallel beam of white light is incident normally on a water film 1.0×10^{-4} cm thick. Find the wavelength in the visible range (400 nm-700 nm) which are strongly transmitted by the film Refractive index of water = 1.33.

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38. A glass surface is coated by an oil film of uniform thickness 1.00×10^{-4} cm. The index of refraction of the oil is 1.25 and that of the glass is 1.50. Find the wavelengths of light in the visible region ($400\text{nm} - 750\text{nm}$) which are completely transmitted by the oil film under normal incidence.

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39. Plane microwaves are incident on a long slit having a width of 5.0 cm. Calculate the wavelength of the microwaves if the first diffraction minimum is formed at $\theta = 30^\circ$.

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40. Light of wavelength 560 nm goes through a pinhole of diameter 0.20 mm and falls on a wall at a distance of 2.00 m. What will be the radius of

the central bright spot formed on the wall ?



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41. A convex lens of diameter 8.0 cm is used to focus a parallel beam of light of wavelength 620 nm. If the light be focused at a distance of 20 cm from the lens, what would be the radius of the central bright spot formed ?



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