PHYSICS

BOOKS - NEW JYOTHI PHYSICS (TAMIL ENGLISH)

WAVE OPTICS

Solved Problems

1. Wavelength of light in air is 6000Å. Calculate its wavelength in water(n =4/3) and glass(n=

3/2).

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2. A light of wavelength 5800Å incident on a glass slab and undergoes refraction. Calculate the speed, wavelength and frequency of the refracted light (Refractive index of glass is $3/2$)

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3. A star emiting light of wavelength 4500Å is moving towards the eart with a speed of 3600 km/sec. Determine the wavelength shift and apparent wavelength due to Doppler effect. The speed of light is $3 \times 10^8 m/s$

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4. What speed should be galaxy move with respect to us to the sodium line at 589.0 nm is observed at 589.6nm?

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

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

c. In the wave picture of light, intensity of light

is determined by the square of the amplitude of the wave. What determine the intensity of light in the photon picture of light?

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6. In an interference pattern, the ratio of maximum intensity to minimum intensity is 25:1. Find the ratio of the amplitudes and intensities of the two interfering waves.

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7. Two wavelengths λ_1 and λ_2 are used in Young's double slit expt. $\lambda_1 = 430nm$. What is the value of λ_2 if 4th bright band of one coincides with 6th bright band of the other?

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8. Two slits are made 1 min apart and the screen is placed 1 m away from the slits. What is the firnge separation when blue green light of wavelength 500 nm is used?

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9. What is the effect on the interference fringes in a Young' double slit experiment due to each of the following operations.

a. the screen is moved away from the plane of the slits.

b. the (monolchromatic) source is replaced by another (monochromatic) source of shorter wavelength.

c. the separation between the two slits is increased.

d. the source slit is moved closer to the double

slit plane:

e. the width of the source slit is increased.

f. The monochromatic source is replaced by a source of white light?

(in each operation, take all parameters, other than the one specified, to remain unchanged).

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10. Plane wave of $\lambda = 600$ nm incident normally on a slit of width 0.18 mm. Calculate

the total angular wideth of the central maximum.

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11. In a single slit diffraction the distance between the first minima on either side of the central maximum is 5mm. The screen is place data distance of 75 cm from the slit and the wavelength of light used is 546nm. Calculate the slit width.

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12. Assume that light of wavelength $6000A$ is coming from a star. What is the limit of resolution of a telescope whose objective has a diameter of 100 inch?

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13. For what distance is ray optics a good approximation when the aperture is 3mm wide and the wavelength is 500 nm?

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14. Discuss the intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids.

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15. The angle of polarisation on a certain crystal is $55^{\circ} C$. The reflected light is completely polarised. Find the refractive index of the crystal andangle of refraction.

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16. Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other? (Given n=1.5)

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17. Two polarising sheets are arranged with their axes parallel so that the intensity of

transmitted polarized light is maximum. Through what angle must the sheet be rotated so that the intensity of transmitted light drops to $\frac{1}{3}$ of the maximum intensity?

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Solution To Exercises From Ncert Text

1. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of

refracted light? Refractive index of water is 1.33.

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2. What is the shape of the wavefront in each of the following cases?

a. Light diverging from a point source.

b. Light emerging out of a convex lens when a point source is placed at its focus.

c. The portion of the wavefront of light from a distanct star intercepted by the Earth.

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3. a. The refractive index is glass is 1.5. What is the speed of light in glasss? (Speed of light invacuum is $3.0 \times 10^8 ms^{-1}$)

b. Is the speed of light inglass independent of he colour of light? If not, which of the two colours red and violet travels slower in a glass prism?

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4. In a Young's double slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

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5. In Young's double slit experiment using monochromatic light of wavelength λ, the

intensity of light at a point on the screen where path difference is λ is K units. What is the intensity of light at a point where path difference is $\frac{\lambda}{3}$?

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6. A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtained interference friges ina Young's double slit experiment.

a. Find the distance of the third bright fringe

on the screen from the central maximum for wavelength 650 nm.

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7. Ina double slit experiment the angular width of a fringe is found to be 0.2° on a screen placed 1m away.The wavelength of light is 600 nm. What will be the angular width of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water of be $\frac{4}{3}$

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8. What is the Breswster angle for air to glass transition? (Refractive indexof glass=1.5)

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9. Light of wavelength 5000Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

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10. Estimate the distance for which ray optics is good approximation foran aperture of 4mm and wavelength 400 nm.

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11. The $6563\text{Å} H\alpha$ line emitted by hydrogen in a star is found to be red shifted by 15Å.

Estimate the speed with which the star is receding from the Earth.

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12. Explain how Corpuscular theory predicts the speed of light in a medium, say, water, to be greater than the speed of light in vacuum. Is the prediction confirmed by experimental determination of the speed of light in water? If not, which alternative picture of light is consistent with experiment?

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13. You have learnt in the text how Huygens' principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a plane mirror produces a virtual image whose distance from the mirror is equal to the object distance from the mirror.

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14. Let us list some of the factors, which could possibly infuence the speed of wave propagation.

(i) Nature of the source (ii) Direction of propagation

(iii) Motion of the source and /or observer (iv) Wavelength

v. Intensity of the wave.

On which of these factors, if any, does

a. the speed of light in vacuum.

b. the speed of light in a medium (say, glass or water), depend?

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15. For sound waves, the Doppler formula for frequency shift differs slightly between the two situations: (i) source at rest, observer moving and (ii) source moving, observer at rest. The exact Doppler formulas for the case of light waves in vacuum are, however strictly identical for these situations. Explain why this should be so. Would you expect the formulas to be strictly identical for the two situations in case of light travelling in a medium?

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16. In double slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distance screen is 0.1°. What is the spacing between the two slits?

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17. Answer the following questions:

a. In a single slit diffraction experiment, the

width of the slit is made double the original width. How does this affect the size and intensity of the cenral diffraction band?

b. In what way is diffraction from each slit related to the interference pattern in a double slit experiment?

c. When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why.

d. Two students are separated by a 7m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles,

howare the students unable to see each other even though they can converse easily.

e.Ray optics is based on the assumption that the light travels in a straight lin. Diffraction effects (observed when light propagates through small apertures/slits a or around small obstacles) disprove this assumption. Yet the ray options assumptioni is so commonly used in understanding location and several other properties of images in optical instruments. What is the justification?

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18. Two towers on top of two hills are 40 km apart. The line joining them passes 50 m above a hil halfway between the towers. What is the longest wavelength of radio waves, which can be sent between the towers without appreciable diffraction effects?

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19. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting

diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.

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20. Suggest a possible explanation.

As you have learnt in the text, the principle of linear super position of wave displacement is basic to understanding intensity distributions

in diffraction and interference patterns. What is the justidication of this principle?

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21. In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of $\frac{n\lambda}{a}$. Justify this by suitably dividing the slit to bring out the cancellation.

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Practice Problems For Self Assessment

1. Two polaroids are placed 90° to each other and the transmitted intensity is zero. What happens when one more polaroid is placed between these two bisecting the angle between them?

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2. Two towers on the top of the two hills are 40 mm apart. The line joining them passses

50m above a hill half way between the towers. What is the longest wavelength of radio waves, which can be sent between the towers without appreciable diffraction effect?

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3. Two coherent sources of intensity ratio 81:64 interfere. Deduce the ratio of intensities beween the maxima and minimain the interference pattern.

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4. In Young's double slit experiment, the band width on a screen is double when the screen is moved through 1m. If te distance between the slits is 0.4mm and the wavelength of light used is 600nm , find the band width.

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5. In Young's double slit experiment, the distance of the screen from the two slits in 1m. When a light of wavelength 600nm is allowed

to fall on the slits width of the fringes obtained on the screen is 2mm. Calculate the width of the fringe if the wavelength of the incident light is 400nm. Calculate band width in each case if the arrangement is immersed in water of refractive index 1.33.

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6. In Young's double slit experiment, the separatation of the slit is 2mm. The screen is at a distance 1m from the slit. How many

bands can be seen in a space of 1cm? Given wavelength of light =400nm.

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7. Two coherent souces of intensity ratio α intefere. Show that $\frac{I_{\max} - I_{\text{mini}}}{I_{\max} + I_{\text{mini}}} = \frac{2\sqrt{\alpha}}{1+\alpha}$

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8. A central fringe of the interference pattern produced by a light of wavelength 6000Å is

shifted to the position of 5th bright firnge when a glass plate of refractive index 1.5 is introduced in the path of the ray. Calculate the thickness of the glass plate.

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9. A parallel beam of light of wavelength 435 nm falls on a slit of width 0.4 mm. Find the distance between two dark bands on either side so the central maximum of the pattern

produced on a screen placed at a distance of 2m from the slit.

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10. A slit of width a is illuminated by white light. For what value of a does the first minimum for red light of wavelength 650 nm fall at angle of diffraction $\theta = 15^\circ$?

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11. A slit 4 cm wide is irradiated with microwaves of wavelength 2 cm. Find the angular spread of central maxima assuming incidence normal to the plane of the slit.

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12. Determine the angular separation between central maximum and first order maximum of the diffraction pattern due to a single slit of

width 0.25 mm when light of wavelength 589nm falls normally on it.

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13. When a beam of white light illuminates a narrow list,what is the width of the slit so that the second minimum for light of wavelength 600 nm falls at $\theta = 12^{\circ}$.

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14. Two nicols prisms are so orientated that the maximum amount of light is transmitted. Two what fraction of itsmaximum value is the intensity of transmitted light reduced when the analyser is rotated through 30°?

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Evaluation Questions And Answers

1. What is the path difference between the two waves,when the crest of one wave falls on the crest of the other?

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2. What is the path difference between the two waves the crest of the wave falls on the trough of the other?

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3. What is constructive interference?

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4. In Young's double slit experiment, 62 fringes are seen in visible region for sodium light of wavelength 5893 Å. If violet light of wavelength 4359 Å is used in place of sodium light, then what is the number of fringes seen?

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5. In Young's Double slit Experiment, if one of the slits is closed, what happens?

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6. When both the slits are opened, we can see interference pattern. Why?

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7. If two sources are used, what is the resultant amplitude of electric field and

intensity of light for constructive interference?

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8. For destructive intergerence, what is the value of resultant amplitude and intensity of light?

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9. If one of the slits in the interference experiment is closed, what will be your

observation?

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10. Compare the intensities of maxima and minima in terms of amplitude ratio

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11. Give an example of interference of light in our daily life situation.

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12. a. When a low flying aircraft passes over head, we sometimes notice a slight shaking of the picture on our TV screen. Identify the reason behind it.

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13. The diffraction pattern becomes invisible when the slit is very wide. Give reason.

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14. Diffraction phenomenon is common in sound but not common in light. Why is it so?

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15. a. When we look through a muslin cloth,we can see coloured spectrum. How will you explain this?

b. Observe the shadow of your book when it is held a few centrimeters above as table with a lamp serveral centimeter above the book. Why

is the shadow the book fuzzy at the edges?

c.If you observe a distant street light between two fringers pinched together, you can visualise alternate bright and dark fringes. What is this due to? Explain.

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16. Why longitudinal waves can't be polarized?

OR Light waves can be polarized while sound waves can't. Why?

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17. Will ultrasonic waves how any polarization? Give reason for your answer.

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18. How would the angular separation of interference bands in Young's double slit experment change when the distance of separation between the slits and the screen is doubled?

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Continuous Evaluation Assignment

1. Mention the various theories put forward by the scientist to explain nature of light.

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2. What is interference of light?

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3. Study the interference fringes with white light.

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4. Mention some uses of inteference of light.

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5. Demonstrate diffraction round and straight edge in a ripple tank.

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6. Explain applications of polaroids.

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7. Compare Doppler effect in light and sound.

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8. Mention some applications and uses of Doppler effect in light.

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Previous Year Questions

1. a. describe Young's experiment in interference with necessary theory.

b. Explain the refraction at a spherical surface using a schematic diagram.

c. Mention the shape of wave front for the portion of wave front of light form a distant star intercepted by the earth.

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2. We obtained alternate dark and bright regions If we look at the shadow byan obstacle close to geometrical shadow.

a. Mention the phenomenon behind it.

b.Differentiate the interference pattern with a

coherently illuminated single slit diffraction pattern.

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3. A. Interference of light from two sources can be observed if

a. the sources are independent

b. the soures are of different frequencies and random phases.

c. the sources are of different frequency.

d. the sources are coherent.

B. Draw Young's arrangement to produce interference pattern.

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Competitive Exam Corner

1. Young's experiment is performed with light of wavelength 6000Å where in 16 frignes occupy a certain region on the screen. If 24 fringes occupy the same region with another light of wavelength λ then λ is

A. 6000Å

B. 4500Å

C. 5000Å

D. 4000Å

Answer: D

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2. In a Young's double slit experiment, the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ- wavelength of the light) is 1. If I_0

denotes the maximum intensity, then $\frac{I}{I_0}$ is equal to

A. $\frac{1}{2}$

B. $\frac{\sqrt{3}}{2}$

C. $\frac{1}{\sqrt{2}}$

D. $\frac{3}{4}$

Answer: D

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3. A narrow slit of width 2 mm is illuminated by monochromatic light of wavelength 500 mm. The distance between the first minima on either side on a screen at a distance of 1 m is

A. 5mm

B. 0.5mm

C. 1mm

D. 10mm

Answer: B

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4. In Young's double slit experiment if d, D and λ represent the distance between the slits, the distance of the screen from the slits and wavelenfth of light used respectively, then the band width is width is inversely proportional to

A. λ

B. d

C. D

D. λ^2

Answer: B

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5. In Young's double slit experimental set up, it the wavelength alone is doubled the band width β becomes,

A. $\frac{\beta}{2}$

B. 2β

C. 3β

D. β

Answer: B

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6. Which one of the following statements is correct?

A. a. Monochromatic light is never coherent

B. b. Monochromatic light is always coherent

C. c. Two independent monochromatic sources are coherent

D. d. Coherent light is always monochromatic.

Answer: D

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7. In Young's double slit experiment with slit separation d, a monochromatic light of wavelength λ is used. The angular separation of the fringes is

A. a. $\frac{d}{\lambda}$

B. b. $\frac{\lambda}{d}$

C. c. $\frac{2\lambda}{d}$

D. d. $\frac{\lambda}{2d}$

Answer: B

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8. Unpolarized light is incident on a plane sheet of water surface. The angle of incidence for which the reflected and refracted rays are perpendicular to each other is (μ of water $= \frac{4}{3}$)

A. a. $\sin^{-1}\left(\frac{4}{3}\right)$

B. b. $\tan^{-1}\left(\frac{3}{4}\right)$

C. c. $\tan^{-1}\left(\frac{4}{3}\right)$

D. d. $\sin^{-1}\left(\frac{1}{3}\right)$

Answer: C

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9. If the intensity ratio of two coherent sources used in Young's double slit experiemnt is 49:1 then the ratio between the maximum and minimum intensities in the interference pattern is

A. a. $1:9$

B. b. $9:16$

C. c. $25:16$

D. d. $16:9$

Answer: D

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10. According to Rayleigh scattering law, the amount of scattering is

A. a. directly proportional to wavelength of light

B. b. directly proportional to square of wavelength of light

C. c. independent of wavelength of light

D. d. inversely proportional to fourth power of wavelength of light

Answer: D

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11. When we close one slit in the Young's double slit experiment, then

A. a. the bandwidth is increased

B. b. the bandwidth is decreased

C. c. the bandwidth remains unchanged

D. d. the diffraction pattern is observed

Answer: D

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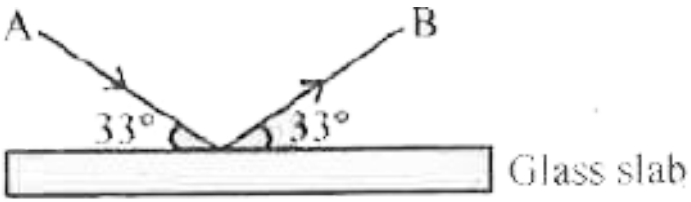
12. A beam of light is incident on a glass slab $(\mu = 1.54)$ in a direction as shown in the figure. The reflected light is analysed by a polaroid prims. On rotating the polaroid $(\tan 57^\circ = 1.54)$



A. a. the intensity remains unchanged

B. b. the intensity is reduced to zero and remains at zero

C. c. the intensity gradually reduces to zero and then again increases

D. d. the intensity increases continuously

Answer: C

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13. The polarising angle for a medium is found to be 60°.The critical angle of the medium is

A. a. $\sin^{-1}\left(\frac{1}{2}\right)$

B. b. $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$

C. c. $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

D. d. $\sin^{-1}\left(\frac{1}{4}\right)$

Answer: C

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14. In Youngs double slit experiment, to increase the fringe width

A. a. the wave length of the source is increased

B. b. the source is moved towards the slit

C. c. the source is moved away from the slit

D. d. the slit separation is increased

Answer: A

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15. Light of the wavelength 5000Å is incident normally on a slit of width $2.5 \times 10^{-4} cm$. The angular position of second minimum from the central maximum is

A. a. $\sin^{-1}\left(\frac{1}{5}\right)$

B. b. $\sin^{-1}\left(\frac{2}{5}\right)$

C. c. $\left(\frac{\pi}{3}\right)$

D. d. $\left(\frac{\pi}{6}\right)$

Answer: B

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16. Two plane wave fronts of light, one incident on a thin convex lens and another on there fraction face of a thin prism. After refraction at them, the emerging wave fronts respectively become

A. a. plane wavefront and plane wavefront

B. b. plane wavefront and spherical wavefront

C. c. spherical wavefront and Plane wavefront

D. d. spherical wavefront and spherical wavefront

Answer: C

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17. If a ray of light is incident at a glass surface at the Brewster's angle of 60°, then the angle of deviation inside glass is

A. a. 90°

B. b. 60°

C. c. 45°

D. d. 30°

Answer: D

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