1. **SSM** ***REASONING AND SOLUTION*** The angular position θ of the bright fringes of a double slit are given by Equation 27.1 as $\sin\theta = m\lambda / d$, with the order of the fringe specified by $m = 0, 1, 2, 3, \ldots.$ Solving for λ, we have

$$\lambda = \frac{d \sin\theta}{m} = \frac{(3.8\times10^{-5}\ \text{m})\sin 2.0°}{2} = 6.6\times10^{-7}\ \text{m} = \boxed{660\ \text{nm}}$$

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2. ***REASONING*** The angles θ that determine the locations of the dark and bright fringes in a Young's double-slit experiment are related to the integers m that identify the fringes, the wavelength λ of the light, and the separation d between the slits. Since values are given for m, λ, and d, the angles can be calculated.

SOLUTION The expressions that specify θ in terms of m, λ, and d are as follows:

Bright fringes $\sin\theta = m\dfrac{\lambda}{d}$ $m = 0, 1, 2, 3, \ldots$ (27.1)

Dark fringes $\sin\theta = \left(m+\tfrac{1}{2}\right)\dfrac{\lambda}{d}$ $m = 0, 1, 2, 3, \ldots$ (27.2)

Applying these expressions gives the answers that we seek.

a. $$\sin\theta = \left(m+\tfrac{1}{2}\right)\frac{\lambda}{d} \quad \text{or} \quad \theta = \sin^{-1}\left[\left(0+\tfrac{1}{2}\right)\frac{520\times10^{-9}\ \text{m}}{1.4\times10^{-6}\ \text{m}}\right] = \boxed{11^\circ}$$

b. $$\sin\theta = m\frac{\lambda}{d} \quad \text{or} \quad \theta = \sin^{-1}\left[(1)\frac{520\times10^{-9}\ \text{m}}{1.4\times10^{-6}\ \text{m}}\right] = \boxed{22^\circ}$$

c. $$\sin\theta = \left(m+\tfrac{1}{2}\right)\frac{\lambda}{d} \quad \text{or} \quad \theta = \sin^{-1}\left[\left(1+\tfrac{1}{2}\right)\frac{520\times10^{-9}\ \text{m}}{1.4\times10^{-6}\ \text{m}}\right] = \boxed{34^\circ}$$

d. $$\sin\theta = m\frac{\lambda}{d} \quad \text{or} \quad \theta = \sin^{-1}\left[(2)\frac{520\times10^{-9}\ \text{m}}{1.4\times10^{-6}\ \text{m}}\right] = \boxed{48^\circ}$$

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5. **SSM** ***REASONING*** The slit separation d is given by Equation 27.1 with $m = 1$; namely $d = \lambda / \sin\theta$. As shown in Example 1 in the text, the angle θ is given by $\theta = \tan^{-1}(y / L)$.

SOLUTION The angle θ is

$$\theta = \tan^{-1}\left(\frac{0.037\ \text{m}}{4.5\ \text{m}}\right) = 0.47°$$

Therefore, the slit separation d is

$$d = \frac{\lambda}{\sin\theta} = \frac{490 \times 10^{-9}\ \text{m}}{\sin 0.47°} = \boxed{6.0 \times 10^{-5}\ \text{m}}$$

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10. ***REASONING AND SOLUTION*** This problem is analogous to Example 3 in the text, where the condition for destructive interference is obtained as $2t = m\lambda_{\text{film}}$. For the minimum non-zero thickness, $m = 1$. In addition, the wavelength in the film is given by Equation 27.3: $\lambda_{\text{film}} = \lambda_{\text{vacuum}}/n$. Therefore, green light is removed when the minimum non-zero thickness is

$$t = \frac{m}{2}\lambda_{\text{film}} = \frac{1}{2}\left(\frac{\lambda_{\text{vacuum}}}{n}\right) = \frac{1}{2}\left(\frac{551\text{ nm}}{1.33}\right) = \boxed{207\text{ nm}}$$

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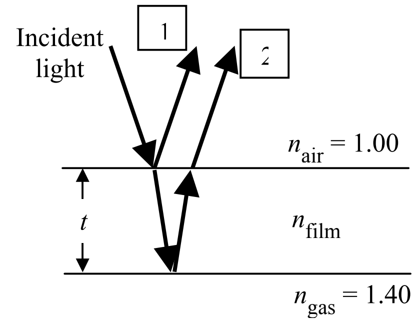
12. ***REASONING*** The wavelength in the film is $\lambda_{\text{film}} = \lambda_{\text{vacuum}} / n_{\text{film}}$ (Equation 27.3), so that the refractive index of the film is



$$n_{\text{film}} = \frac{\lambda_{\text{vacuum}}}{\lambda_{\text{film}}} \qquad (1)$$

The wavelength in a vacuum is given, and we can determine the wavelength in the film by considering the constructive interference that occurs. The drawing shows the thin film and two rays of light shining on it. At nearly perpendicular incidence, ray 2 travels a distance of $2t$ farther than ray 1, where t is the thickness of the film. In addition, ray 2 experiences a phase shift of $\frac{1}{2}\lambda_{\text{film}}$ upon reflection at the bottom film surface, while ray 1 experiences the same phase shift at the upper film surface. This is because, in both cases, the light is traveling through a region where the refractive index is lower toward a region where it is higher. Therefore, there is no net phase change for the two reflected rays, and only the extra travel distance determines the type of interference that occurs. For constructive interference the extra travel distance must be an integer number of wavelengths in the film:

$$\underbrace{2t}_{\substack{\text{Extra distance}\\\text{traveled by}\\\text{ray 2}}} + \underbrace{0}_{\substack{\text{Zero net phase}\\\text{change due to}\\\text{reflection}}} = \underbrace{\lambda_{\text{film}},\ 2\lambda_{\text{film}},\ 3\lambda_{\text{film}},\ldots}_{\substack{\text{Condition for}\\\text{constructive interference}}}$$

This result is equivalent to

$$2t = m\lambda_{\text{film}} \qquad m = 1,\ 2,\ 3,\ \ldots$$

The wavelength in the film, then, is

$$\lambda_{\text{film}} = \frac{2t}{m} \qquad m = 1,\ 2,\ 3,\ \ldots \qquad (2)$$

SOLUTION Substituting Equation (2) into Equation (1) gives

$$n_{\text{film}} = \frac{\lambda_{\text{vacuum}}}{\lambda_{\text{film}}} = \frac{\lambda_{\text{vacuum}}}{\dfrac{2t}{m}}$$

Since the given value for t is the minimum thickness for which constructive interference can occur, we know that $m = 1$. Thus, we find that

$$n_{\text{film}} = \frac{m\lambda_{\text{vacuum}}}{2t} = \frac{(1)(625\ \text{nm})}{2(242\ \text{nm})} = \boxed{1.29}$$

19. SSM ***REASONING*** This problem can be solved by using Equation 27.4 for the value of the angle θ when $m = 1$ (first dark fringe).

SOLUTION

a. When the slit width is $W = 1.8 \times 10^{-4}$ m and $\lambda = 675 \text{ nm} = 675 \times 10^{-9}$ m, we find, according to Equation 27.4,

$$\theta = \sin^{-1}\left(m\frac{\lambda}{W}\right) = \sin^{-1}\left[(1)\frac{675 \times 10^{-9}\text{ m}}{1.8 \times 10^{-4}\text{ m}}\right] = \boxed{0.21°}$$

b. Similarly, when the slit width is $W = 1.8 \times 10^{-6}$ m and $\lambda = 675 \times 10^{-9}$ m, we find

$$\theta = \sin^{-1}\left[(1)\frac{675 \times 10^{-9}\text{ m}}{1.8 \times 10^{-6}\text{ m}}\right] = \boxed{22°}$$

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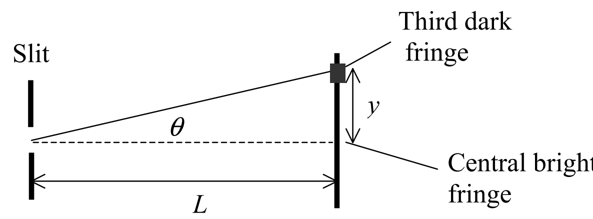
21. ***REASONING*** The drawing shows a top view of the slit and screen, as well as the position of the central bright fringe and the third dark fringe. The distance y can be obtained from the tangent function as $y = L \tan \theta$. Since L is given, we need to find the angle θ before y can be determined. According to Equation 27.4, the angle θ is related to the wavelength λ of the light and the width W of the slit by $\sin\theta = m\lambda / W$, where $m = 3$ since we are interested in the angle for the third dark fringe.



SOLUTION We will first compute the angle between the central bright fringe and the third dark fringe using Equation 27.4 (with $m = 3$):

$$\theta = \sin^{-1}\left(\frac{m\lambda}{W}\right) = \sin^{-1}\left[\frac{3\left(668\times10^{-9}\text{ m}\right)}{6.73\times10^{-6}\text{ m}}\right] = 17.3°$$

The vertical distance is

$$y = L\tan\theta = (1.85\text{ m})\tan 17.3° = \boxed{0.576\text{ m}}$$

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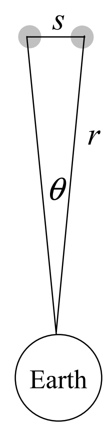
29. ***REASONING AND SOLUTION*** The minimum angular separation of the cars must be
$\theta_{min} = 1.22\ \lambda/D$, and the separation of the cars is $y = L\theta_{min} = 1.22\ L\lambda/D$.

a. For red light, $\lambda = 665$ nm, and

$$y = (1.22)(8690\ \text{m})(665 \times 10^{-9}\ \text{m})/(2.00 \times 10^{-3}\ \text{m}) = \boxed{3.53\ \text{m}}$$

b. For violet light, $\lambda = 405$ nm, and

$$y = (1.22)(8690\ \text{m})(405 \times 10^{-9}\ \text{m})/(2.00 \times 10^{-3}\ \text{m}) = \boxed{2.15\ \text{m}}$$



40. ***REASONING*** The angle that specifies the third-order maximum of a diffraction grating is $\sin\theta = m\lambda/d$ (Equation 27.7), where $m = 3$, λ is the wavelength of the light, and d is the separation between the slits of the grating. The separation is equal to the width of the grating (1.50 cm) divided by the number of lines (2400).

SOLUTION Solving Equation 27.7 for the wavelength, we obtain

$$\lambda = \frac{d\sin\theta}{m} = \frac{\left(\dfrac{1.50\times10^{-2}\text{ m}}{2400}\right)\sin 18.0^\circ}{3} = 6.44\times10^{-7}\text{ m} = \boxed{644\text{ nm}}$$

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41. **SSM** ***REASONING AND SOLUTION*** According to Equation 27.7, the angles that correspond to the first-order (m = 1) maximum for the two wavelengths in question are:

a. for $\lambda = 660\text{ nm} = 660\times10^{-9}\text{ m}$,

$$\theta = \sin^{-1}\left(m\frac{\lambda}{d}\right) = \sin^{-1}\left[(1)\left(\frac{660\times10^{-9}\text{ m}}{1.1\times10^{-6}\text{ m}}\right)\right] = \boxed{37^\circ}$$

b. for $\lambda = 410\text{ nm} = 410\times10^{-9}\text{ m}$,

$$\theta = \sin^{-1}\left(m\frac{\lambda}{d}\right) = \sin^{-1}\left[(1)\left(\frac{410\times10^{-9}\text{ m}}{1.1\times10^{-6}\text{ m}}\right)\right] = \boxed{22^\circ}$$
