Chapter 35

11. **THINK** The formation of Newton's rings is due to the interference between the rays reflected from the flat glass plate and the curved lens surface.

EXPRESS Consider the interference pattern formed by waves reflected from the upper and lower surfaces of the air wedge. The wave reflected from the lower surface undergoes a π rad phase change while the wave reflected from the upper surface does not. At a place where the thickness of the wedge is *d*, the condition for a maximum in intensity is $2d = \left(m + \frac{1}{2}\right)\lambda$, where λ is the wavelength in air and *m* is an integer. Therefore,

$$d = (2m + 1)\lambda/4.$$

ANALYZE As the geometry of Fig. 35-46 shows, $d = R - \sqrt{R^2 - r^2}$, where *R* is the radius of curvature of the lens and *r* is the radius of a Newton's ring. Thus, $(2m+1)\lambda/4 = R - \sqrt{R^2 - r^2}$. First, we rearrange the terms so the equation becomes

$$\sqrt{R^2 - r^2} = R - \frac{(2m+1)\lambda}{4}.$$

Next, we square both sides, rearrange to solve for r^2, then take the square root. We get

$$r = \sqrt{\frac{(2m+1)R\lambda}{2} - \frac{(2m+1)^2\lambda^2}{16}}.$$

If *R* is much larger than a wavelength, the first term dominates the second and

$$r = \sqrt{\frac{(2m+1)R\lambda}{2}}.$$

LEARN Similarly, the radii of the dark fringes are given by

$$r = \sqrt{mR\lambda}.$$

24. (a) We choose a horizontal x axis with its origin at the left edge of the plastic. Between $x = 0$ and $x = L_2$ the phase difference is that given by Eq. 35-11 (with L in that equation replaced with L_2). Between $x = L_2$ and $x = L_1$ the phase difference is given by an expression similar to Eq. 35-11 but with L replaced with $L_1 - L_2$ and n_2 replaced with 1 (since the top ray in Fig. 35-36 is now traveling through air, which has index of refraction approximately equal to 1). Thus, combining these phase differences with $\lambda = 0.600$ μm, we have

$$\frac{L_2}{\lambda}(n_2 - n_1) + \frac{L_1 - L_2}{\lambda}(1 - n_1) = \frac{3.50\ \mu\text{m}}{0.600\ \mu\text{m}}(1.55 - 1.40) + \frac{4.00\ \mu\text{m} - 3.50\ \mu\text{m}}{0.600\ \mu\text{m}}(1 - 1.40)$$
$$= 0.542.$$

(b) Since the answer in part (a) is closer to a half-integer than to an integer, the interference is more nearly destructive than constructive.

29. **THINK** A light ray reflected by a material changes phase by π rad (or 180°) if the refractive index of the material is greater than that of the medium in which the light is traveling.

EXPRESS Consider the interference of waves reflected from the top and bottom surfaces of the air film. The wave reflected from the upper surface does not change phase on reflection but the wave reflected from the bottom surface changes phase by π rad. At a place where the thickness of the air film is L, the condition for fully constructive interference is $2L = \left(m + \frac{1}{2}\right)\lambda$ where λ (= 420 nm) is the wavelength and m is an integer.

ANALYZE For L = 48 μm, we find the value of m to be

$$m = \frac{2L}{\lambda} - \frac{1}{2} = \frac{2(4.80\times10^{-5}\,\text{m})}{420\times10^{-9}\,\text{m}} - \frac{1}{2} = 228.$$

At the thin end of the air film, there is a bright fringe. It is associated with m = 0. There are, therefore, 229 bright fringes in all.

LEARN The number of bright fringes increases with L, but decreases with λ.

48. (a) We note that ray 1 travels an extra distance $4L$ more than ray 2. To get the least possible L that will result in destructive interference, we set this extra distance equal to half of a wavelength:

$$4L = \frac{\lambda}{2} \quad \Rightarrow \quad L = \frac{\lambda}{8} = \frac{620.0 \text{ nm}}{8} = 77.5 \text{ nm} .$$

(b) The next case occurs when that extra distance is set equal to $\frac{3}{2}\lambda$. The result is

$$L = \frac{3\lambda}{8} = \frac{3(620.0 \text{ nm})}{8} = 233 \text{ nm} .$$

55. (a) Since P_1 is equidistant from S_1 and S_2 we conclude the sources are not in phase with each other. Their phase difference is $\Delta\phi_{\text{source}} = 0.60\pi$ rad, which may be expressed in terms of "wavelengths" (thinking of the $\lambda \Leftrightarrow 2\pi$ correspondence in discussing a full cycle) as

$$\Delta\phi_{\text{source}} = (0.60\pi/2\pi)\lambda = 0.3\lambda$$

(with S_2 "leading" as the problem states). Now S_1 is closer to P_2 than S_2 is. Source S_1 is 80 nm ($\Leftrightarrow$ $(80/400)\lambda = 0.2\lambda$) from P_2 while source S_2 is 1360 nm ($\Leftrightarrow$ $(1360/400)\lambda = 3.4\lambda$) from P_2. Here we find a difference of $\Delta\phi_{\text{path}} = 3.2\lambda$ (with S_1 "leading" since it is closer). Thus, the net difference is

$$\Delta\phi_{\text{net}} = \Delta\phi_{\text{path}} - \Delta\phi_{\text{source}} = 2.90\lambda,$$

or 2.90 wavelengths.

(b) A whole number (like 3 wavelengths) would mean fully constructive, so our result is of the following nature: intermediate, but close to fully constructive.