1. (a) We use Eq. 36-3 to calculate the separation between the first ($m_1 = 1$) and fifth ($m_2 = 5$) minima:

$$\Delta y = D\Delta \sin\theta = D\Delta\left(\frac{m\lambda}{a}\right) = \frac{D\lambda}{a}\Delta m = \frac{D\lambda}{a}(m_2 - m_1) .$$

Solving for the slit width, we obtain

$$a = \frac{D\lambda(m_2 - m_1)}{\Delta y} = \frac{(400\,\text{mm})(550\times 10^{-6}\,\text{mm})(5-1)}{0.35\,\text{mm}} = 2.5\,\text{mm} .$$

(b) For $m = 1$,

$$\sin\theta = \frac{m\lambda}{a} = \frac{(1)(550\times 10^{-6}\,\text{mm})}{2.5\,\text{mm}} = 2.2\times 10^{-4} .$$

The angle is $\theta = \sin^{-1}(2.2 \times 10^{-4}) = 2.2 \times 10^{-4}$ rad.

7. The condition for a minimum of a single-slit diffraction pattern is

$$a \sin\theta = m\lambda$$

where a is the slit width, λ is the wavelength, and m is an integer. The angle θ is measured from the forward direction, so for the situation described in the problem, it is 0.60° for $m = 1$. Thus,

$$a = \frac{m\lambda}{\sin\theta} = \frac{633\times10^{-9}\text{ m}}{\sin 0.60°} = 6.04\times10^{-5}\text{ m}.$$

13. (a) $\theta = \sin^{-1}(0.011\text{ m}/3.5\text{ m}) = 0.18°$.

(b) We use Eq. 36-6:

$$\alpha = \left(\frac{\pi a}{\lambda}\right)\sin\theta = \frac{\pi(0.025\,\text{mm})\sin 0.18°}{538\times10^{-6}\text{ mm}} = 0.46\,\text{rad}\ .$$

(c) Making sure our calculator is in radian mode, Eq. 36-5 yields

$$\frac{I(\theta)}{I_m} = \left(\frac{\sin\alpha}{\alpha}\right)^2 = 0.93\ .$$

25. Using the notation of Sample Problem — "Pointillistic paintings use the diffraction of your eye," the minimum separation is

$$D = L\theta_{\mathrm{R}} = L\left(1.22\frac{\lambda}{d}\right) = \left(3.82\times10^{8}\,\mathrm{m}\right)\frac{(1.22)\left(550\times10^{-9}\,\mathrm{m}\right)}{5.1\mathrm{m}} = 50\,\mathrm{m}\,.$$

35. Bright interference fringes occur at angles θ given by $d \sin \theta = m\lambda$, where m is an integer. For the slits of this problem, we have $d = 11a/2$, so

$$a \sin \theta = 2m\lambda/11 .$$

The first minimum of the diffraction pattern occurs at the angle θ_1 given by $a \sin \theta_1 = \lambda$, and the second occurs at the angle θ_2 given by $a \sin \theta_2 = 2\lambda$, where a is the slit width. We should count the values of m for which $\theta_1 < \theta < \theta_2$, or, equivalently, the values of m for which $\sin\theta_1 < \sin\theta < \sin\theta_2$. This means $1 < (2m/11) < 2$. The values are $m = 6, 7, 8, 9$, and 10. There are five bright fringes in all.

46. The angular location of the *m*th order diffraction maximum is given by $m\lambda = d \sin\theta$. To be able to observe the fifth-order maximum, we must let $\sin\theta|_{m=5} = 5\lambda/d < 1$, or

$$\lambda < \frac{d}{5} = \frac{1.00\,\text{nm}/315}{5} = 635\,\text{nm}.$$

Therefore, the longest wavelength that can be used is $\lambda = 635$ nm.

55. **THINK** If a grating just resolves two wavelengths whose average is λ_{avg} and whose separation is $\Delta\lambda$, then its resolving power is defined by $R = \lambda_{avg}/\Delta\lambda$.

EXPRESS As shown in Eq. 36-32, the resolving power can also be written as Nm, where N is the number of rulings in the grating and m is the order of the lines.

ANALYZE Thus $\lambda_{avg}/\Delta\lambda = Nm$ and

$$N = \frac{\lambda_{avg}}{m\Delta\lambda} = \frac{656.3\,\text{nm}}{(1)(0.18\,\text{nm})} = 3.65\times10^{3}\ \text{rulings.}$$

LEARN A large N (more rulings) means greater resolving power.

64. We use Eq. 36-34. For smallest value of θ, we let $m = 1$. Thus,

$$\theta_{\min} = \sin^{-1}\left(\frac{m\lambda}{2d}\right) = \sin^{-1}\left[\frac{(1)(30\,\text{pm})}{2(0.30\times10^{3}\,\text{pm})}\right] = 2.9°.$$

where d is the spacing of the crystal planes and λ is the wavelength. The angle θ is measured from the surfaces of the planes. For a second-order reflection $m = 2$, so

$$d = \frac{m\lambda}{2\sin\theta} = \frac{2\left(0.12\times10^{-9}\,\mathrm{m}\right)}{2\sin 28^\circ} = 2.56\times10^{-10}\,\mathrm{m} \approx 0.26\,\mathrm{nm}.$$

69. Bragg's law gives the condition for diffraction maximum:

$$2d\sin\theta = m\lambda$$

where d is the spacing of the crystal planes and λ is the wavelength. The angle θ is measured from the surfaces of the planes. For a second-order reflection $m = 2$, so

$$d = \frac{m\lambda}{2\sin\theta} = \frac{2\left(0.12\times10^{-9}\,\text{m}\right)}{2\sin 28^\circ} = 2.56\times10^{-10}\,\text{m} \approx 0.26\,\text{nm}.$$