24.3 (a) The distance between the central maximum and the first order bright fringe is 
\[ \Delta y = y_{\text{max}} - y_{\text{max,0}} = \frac{\lambda L}{d}, \text{ or (Note, it is safer to not use the}} \] 
approximation used here that \( \tan \theta = \sin \theta \) 
\[ \Delta y = \frac{\lambda L}{d} = \left( \frac{546.1 \times 10^{-3} \text{ m}}{0.250 \times 10^{-3} \text{ m}} \right)(1.20 \text{ m}) = 2.62 \times 10^{-3} \text{ m} = 2.62 \text{ mm} \]

(b) The distance between the first and second dark bands is 
\[ \Delta y = y_{\text{min,1}} - y_{\text{min,0}} = \frac{\lambda L}{d} = 2.62 \text{ mm} \text{ as in (a) above.} \]

24.7 Note that, with the conditions given, the small angle approximation does not work well. That is, \( \sin \theta, \tan \theta, \) and \( \theta \) are significantly different. The approach to be used is outlined below.

(a) At the \( m = 2 \) maximum, \( \delta = d \sin \theta = 2 \lambda \), 
\[ \text{or } \lambda = \frac{d}{2 \sin \theta} = \frac{d}{2} \left( \frac{y}{\sqrt{L^2 + y^2}} \right) \]
\[ \text{or } \lambda = \left( \frac{300 \text{ m}}{2} \right) \left[ \frac{400 \text{ m}}{\sqrt{(1000 \text{ m})^2 + (400 \text{ m})^2}} \right] = 55.7 \text{ m} \]

24.21 (a) For maximum transmission, we want destructive interference in the light reflected from the front and back surfaces of the film.

If the surrounding glass has refractive index greater than 1.378, light reflected from the front surface suffers no phase reversal, and light reflected from the back does undergo phase reversal. This effect by itself would produce destructive interference, so we want the distance down and back to be one whole wavelength in the film. Thus, we require that 
\[ 2t = \lambda / n_{\text{film}} \text{ or } t = \frac{\lambda}{2 n_{\text{film}}} = \frac{656.3 \text{ nm}}{2(1.378)} = 238 \text{ nm} \]

(b) The filter will expand. As \( t \) increases in \( 2n_{\text{film}} t = \lambda \), so does \( \lambda \text{ increase} \)
(c) Destructive interference for reflected light happens also for $\lambda$ in

$$2t = \frac{2\lambda}{n_{nh}}$$

or

$$\lambda = n_{mh}t = (1.378)(238 \text{ nm}) = 328 \text{ nm} \quad \text{(near ultraviolet)}$$

24.22 Light reflecting from the lower surface of the air layer experiences phase reversal, but light reflecting from the upper surface of the layer does not. The requirement for a dark fringe (destructive interference) is then

$$2t = m\lambda = m\left(\frac{\lambda}{n_{mh}}\right) = m\lambda, \quad \text{where } m = 0, 1, 2, \ldots$$

At the thickest part of the film ($t = 2.00 \mu m$), the order number is

$$m = \frac{2t}{\lambda} = \frac{2(2.00 \times 10^{-3} \text{ m})}{546.1 \times 10^{-7} \text{ m}} = 7.32$$

Since $m$ must be an integer, $m = 7$ is the order of the last dark fringe seen. Counting the $m = 0$ order along the edge of contact, a total of 8 dark fringes will be seen.

24.27 There is a phase reversal upon reflection at each surface of the film and hence zero net phase difference due to reflections. The requirement for constructive interference in the reflected light is then

$$2t = m\lambda = m\frac{\lambda}{n_{mh}}, \quad \text{where } m = 1, 2, 3, \ldots$$

With $t = 1.00 \times 10^{-3} \text{ cm} = 100 \text{ nm}$, and $n_{mh} = 1.38$, the wavelengths intensified in the reflected light are

$$\lambda = \frac{2n_{mh}t}{m} = \frac{2(1.38)(100 \text{ nm})}{m}, \quad \text{with } m = 1, 2, 3, \ldots$$

Thus, $\lambda = 276 \text{ nm}, 138 \text{ nm}, 92.0 \text{ nm}$...

and none of these wavelengths are in the visible spectrum.
24.36 (a) The longest wavelength in the visible spectrum is 700 nm, and the grating spacing is $d = \frac{1\text{ mm}}{600} = 1.67 \times 10^{-3} \text{ m} = 1.67 \times 10^{-6} \text{ m}$

Thus, $m_{\text{max}} = \frac{d \sin 90^\circ}{\lambda_{\text{max}}} = \frac{(1.67 \times 10^{-6} \text{ m}) \sin 90^\circ}{700 \times 10^{-9} \text{ m}} = 2.38$

so 2 complete orders will be observed.

(b) From $\lambda = d \sin \theta$, the angular separation of the red and violet edges in the first order will be

\[
\Delta \theta = \sin^{-1}\left(\frac{\lambda_{\text{red}}}{d}\right) - \sin^{-1}\left(\frac{\lambda_{\text{violet}}}{d}\right) = \sin^{-1}\left(\frac{700 \times 10^{-9} \text{ m}}{1.67 \times 10^{-6} \text{ m}}\right) - \sin^{-1}\left(\frac{400 \times 10^{-9} \text{ m}}{1.67 \times 10^{-6} \text{ m}}\right)
\]

or $\Delta \theta = 10.9^\circ$

24.40 With 2000 lines per centimeter, the grating spacing is

\[d = \frac{1}{2000} \text{ cm} = 5.00 \times 10^{-4} \text{ cm} = 5.00 \times 10^{-6} \text{ m}\]

Then, from $d \sin \theta = m \lambda$, the location of the first order for the red light is

\[\theta = \sin^{-1}\left(\frac{m \lambda}{d}\right) = \sin^{-1}\left(\frac{(1)(640 \times 10^{-9} \text{ m})}{5.00 \times 10^{-6} \text{ m}}\right) = 7.35^\circ\]
24.42 The grating spacing is \[ d = \frac{1 \text{ cm}}{1200} = 8.33 \times 10^{-4} \text{ cm} = 8.33 \times 10^{-6} \text{ m} \]

Using \( \sin \theta = \frac{m \lambda}{d} \) and the small angle approximation, the distance from the central maximum to the maximum of order \( m \) for wavelength \( \lambda \) is \( y_m = L \tan \theta \approx L \sin \theta = (\lambda L/d) m \). Therefore, the spacing between successive maxima is \( \Delta y = y_{m+1} - y_m = \lambda L/d \).

The longer wavelength in the light is found to be

\[ \lambda_{long} = \frac{(\Delta y) d}{L} = \frac{(8.44 \times 10^{-1} \text{ m})(8.33 \times 10^{-6} \text{ m})}{0.150 \text{ m}} = 469 \text{ nm} \]

Since the third order maximum of the shorter wavelength falls halfway between the central maximum and the first order maximum of the longer wavelength, we have

\[ \frac{3 \lambda_{short} L}{d} = \left( \frac{0+1}{2} \right) \frac{\lambda_{long} L}{d} \text{ or } \lambda_{short} = \left( \frac{1}{6} \right) (469 \text{ nm}) = 78.1 \text{ nm} \]

24.58 The wavelength is \( \lambda = \frac{v_{sound}}{f} = \frac{340 \text{ m/s}}{2000 \text{ Hz}} = 0.170 \text{ m} \)

Maxima occur where \( d \sin \theta = m \lambda \), or \( \theta = \sin^{-1} \left[ \frac{m(\lambda/d)}{L} \right] \) for \( m = 0, 1, 2, \ldots \)

Since \( d = 0.350 \text{ m} \), \( \lambda/d = 0.486 \) which gives \( \theta = \sin^{-1}(0.486m) \)

For \( m = 0, 1, \) and \( 2 \), this yields \([\text{maxima at}0^\circ, 29.1^\circ, \text{and } 76.3^\circ] \)

No solutions exist for \( m \geq 3 \) since that would imply \( \sin \theta > 1 \)

Minima occur where \( d \sin \theta = (m + 1/2) \lambda \) or \( \theta = \sin^{-1} \left[ \frac{(m + 1/2) \lambda}{2d} \right] \) for \( m = 0, 1, 2, \ldots \)

With \( \lambda/d = 0.486 \), this becomes \( \theta = \sin^{-1} \left[ (2m + 1)(0.243) \right] \)

For \( m = 0 \) and \( 1 \), we find \([\text{minima at}14.1^\circ \text{and } 46.2^\circ] \)

No solutions exist for \( m \geq 2 \) since that would imply \( \sin \theta > 1 \)