CQ 6. (a) Two waves interfere constructively if their path difference is either zero or some integral multiple of the wavelength; that is, if the path difference is $m\lambda$, where $m$ is an integer. (b) Two waves interfere destructively if their path difference is an odd multiple of one-half of a wavelength; that is, if the path difference equals $(m + \frac{1}{2})\lambda$.

24.3 The position of the $m^{th}$ bright fringe is given by $y_m = \frac{m\lambda L}{d}$.

Thus, $\Delta y = y_{m+1} - y_m = \frac{\lambda L}{d}$ is the spacing between consecutive bright fringes. With the given data this becomes:

$$\Delta y = \frac{(6.00 \times 10^{-7} \text{ m})(2.50 \text{ m})}{5.00 \times 10^{-5} \text{ m}} = 3.00 \times 10^{-2} \text{ m} = 3.00 \text{ cm}.$$  

24.5 For bright fringes, the condition is: $\delta = d\sin\theta = m\lambda$.

Thus, $d = \frac{m\lambda}{\sin\theta} = \frac{(1)(575 \times 10^{-9} \text{ m})}{\sin 16.5^\circ} = 2.02 \mu\text{m}$.  

24.8 Note, with the conditions given, the small angle approximation does not work well. The approach to be used is outlined below.

(a) At the $m = 2$ maximum: $\tan\theta = \frac{400 \text{ m}}{1000 \text{ m}} = 0.400$, and $\theta = 21.8^\circ$.

So, $\lambda = \frac{d\sin\theta}{m} = \frac{(300 \text{ m})\sin 21.8^\circ}{2} = 55.7 \text{ m}$.

(b) The next minimum encountered is the $m = 2$ minimum, and at that point: $d\sin\theta = (m + \frac{1}{2})\lambda$

, which becomes $d \sin\theta = \frac{5}{2} \lambda$, or

$\sin\theta = \frac{5\lambda}{2d} = \frac{5(55.7 \text{ m})}{2(300 \text{ m})} = 0.464$, and $\theta = 27.7^\circ$, so

$y = (1000 \text{ m})\tan 27.7^\circ = 524\text{ m}$. Therefore, the car must travel an additional 124 m.

24.13 The phase difference because of the difference in path lengths is $2nft$, where $n_f$ is the index of refraction of the film. The phase difference due to reflection at the upper surface is $\frac{\lambda}{2}$.

For constructive interference, $\delta = m\lambda$.

Thus, $2nft + \frac{\lambda}{2} = m\lambda$. For the minimum thickness, $m = 1$, and we have:

$$t = \frac{\frac{\lambda}{4n_f}}{500 \text{ nm}} = \frac{500 \text{ nm}}{4(1.36)} = 91.9 \text{ nm}.$$
24.20 Both reflections are of the same type, so there is no net phase difference due to reflections. Thus, for constructive interference:

\[ \delta = 2nfd = m\lambda. \]

For the minimum value of \(d\), \(m = 1\).

Thus, \(d = \frac{\lambda}{2nf} = \frac{580 \text{ nm}}{2(1.00)} = 290 \text{ nm.}\)

24.16 There is a phase shift at both the upper and lower film surfaces. Thus, for a bright fringe:

\[ \delta_{\text{total}} = 2nft + 0 = m\lambda, \quad \text{and} \]

\[ t = \frac{m\lambda}{2nf} = \frac{(1)(600 \text{ nm})}{2(1.29)} = 233 \text{ nm.}\)

24.17 There is a phase shift at the upper surface, but none at the lower so the total phase difference in the two reflected waves is \(\delta = 2nft + \frac{\lambda}{2}\).

For destructive interference, \(2nft + \frac{\lambda}{2} = (2m + 1)\frac{\lambda}{2}\), or \(\lambda = 2nf\frac{m}{m + 1}\).

When \(m = 1\), \(\lambda = \frac{2(1.55)(177.4 \text{ nm})}{1} = 550 \text{ nm} \) (located at the center of the visible spectrum).

24.27 (a) The dark bands occur where \(\sin \theta = \frac{m\lambda}{a}\). For the first dark band \((m = 1)\), \(\sin \theta = \frac{\lambda}{a}\). But \(\sin \theta \approx \frac{y}{1.5 \text{ m}}\). Thus, \(\frac{y}{1.5 \text{ m}} = \frac{\lambda}{a}\), and \(y = \frac{(1.5 \text{ m})(600 \times 10^{-9} \text{ m})}{4.0 \times 10^{-4} \text{ m}} = 2.25 \text{ mm}\).

(b) The width of the central maximum is the distance between the dark lines on each side of the central bright line. This is: \(2(2.25 \text{ mm}) = 4.50 \text{ mm}\).

24.32 The angles at which a dark fringe can occur are given by \(\sin \theta = \frac{m\lambda}{a}\), and the screen positions of these dark fringes are: \(y_m = Lt\tan \theta\). Making the small angle approximation \([\sin \theta \approx \tan \theta]\) gives, \(y_m = mL\left(\frac{\lambda}{a}\right)\) as the location of the \(m\)th order dark fringe. The distance from the first to the third dark fringes is then \(\Delta y = y_3 - y_1 = 2L\left(\frac{\lambda}{a}\right)\). With \(L = 50.0 \text{ cm}\), \(\lambda = 680 \text{ nm, and } \Delta y = 3.00 \text{ mm}, this gives:

\[3.00 \times 10^{-3} \text{ m} = 2(5.00 \times 10^{-1} \text{ m})\left(\frac{6.80 \times 10^{-7} \text{ m}}{a}\right), \quad \text{or} \quad a = 0.227 \text{ mm.}\]