16-1  See the sketch below, using Eq. (7-14),

\[ I = I_1 + I_2 + \sqrt{I_1 I_2} \cos \delta = I_1 + I_2 + 2\sqrt{I_1 I_2}[2\cos^2(\delta/2) - 1] \]

with \( \delta = 2\pi \Delta / \lambda \). From the sketch,

\[ (s + \Delta)^2 = s^2 + 2s\Delta + \Delta^2 \approx s^2 + 2s\Delta = r^2 + s^2 \Rightarrow \Delta \approx \frac{r^2}{2s} \]

and \( \delta = \pi r^2 / \lambda s \). Thus, we have,

Figure 1: Problem 16-1
\[ I = I_1 + I_2 + 2\sqrt{I_1 I_2}[2\cos^2\left(\frac{\pi r^2}{2\lambda s}\right) - 1] = A + B\cos^2(\alpha r^2) \]

where \( A = I_1 + I_2 - 2\sqrt{I_1 I_2}, \) \( B = 4\sqrt{I_1 I_2}, \) \( \alpha = \pi/(2s\lambda) \)

16-4
\[ d = \frac{\lambda n}{2\sin \theta} = \frac{0.633 \mu m}{2\sin 10^\circ} = 1.82 \mu m \]

16-5
\[ v = \frac{\Delta}{t} = \frac{\lambda/10}{10^{-9} s} = \frac{633 \times 10^{-10} m}{10^{-9} s} = 63.3 \text{ m/s} \]

16-9 There is ambiguity in the problem, if the emulsion is illuminated from the side, (See the sketch.)

a) In air, the incident angle with respect to the normal to the emulsion is \( \varphi_0 = 30^\circ \). The angle with respect to the normal in the film is then

\[ \sin \varphi_F = (1/n) \sin \varphi_0 = (1/1.6) \sin(30^\circ) \Rightarrow \varphi_F = 18.21^\circ \]

so that the Bragg angle in the film is \( \theta = 90^\circ - \varphi_F = 71.79^\circ \).

b) The Bragg condition for \( m = 1 \) gives
\[ d = \frac{\lambda}{2n \sin \theta} = \frac{633 \text{ nm}}{2 \times 1.6 \times \sin 71.79^\circ} = 208 \text{ nm} \]

c) Using the Bragg condition, the correct Bragg angle is
\[ \sin \theta = \frac{\lambda_0}{2nd} = \frac{450 \text{ nm}}{2 \times 1.6 \times 208 \text{ nm}} = 0.6761 \Rightarrow \theta = 42.54^\circ \]
The current angle with respect to the normal within the film is then \( \varphi_F = 90^\circ - 42.54^\circ \). The angle of incident from air with respect to the normal is given by Snell’s law,

\[
\sin \varphi_0 = 1.6 \sin \varphi_F = 1.6 \sin 47.46^\circ = 1.18
\]

No solution is possible for this wavelength and this film.

If, instead, the emulsion is illuminated “head-on”, as depicted in Figure 16-7.

a) \( \theta = \sin^{-1}(\sin 60^\circ / 1.6) = 32.76^\circ \)

b) The Bragg condition for \( m = 1 \) gives

\[
d = \frac{\lambda}{2n \sin \theta} = \frac{633 \text{ nm}}{2 \times 1.6 \times \sin 32.76^\circ} = 366 \text{ nm}
\]

c) Using the Bragg condition, the angle w.r.t. the silver planes is

\[
\sin \theta = \frac{\lambda_0}{2d} = \frac{450 \text{ nm}}{2 \times 366 \text{ nm}} = 0.6761 \Rightarrow \theta = 37.93^\circ
\]

16-11

a) \( m = \frac{\lambda_R}{\lambda_u \nu} = \frac{633}{337} = 1.88 \times \)

b) \( m = \frac{\lambda_R}{\lambda_{\text{x-ray}}} = \frac{633}{0.10} = 6330 \times \)