17.18  
- Intensity minimum => extra path length must produce a relative phase shift of \( \pi, 3\pi, 5\pi \) etc.
- Smallest relative phase shift difference between the paths, so the phase shift must be \( \pi \), and therefore the path length difference must be \( \frac{\pi}{2} \).

\[ \Delta L = \pi r - 2r = \frac{\pi}{2} \]

Since \( r = 40 \text{ cm} \) we have that

\[ r (\pi - 2) = 20 \text{ cm} \]

\[ r = 17.5 \text{ cm} \]
17-21  \[ e \; d \; d \; d \; d \; d \; d \; d \; \cdots \; p \]

d) If \( d = \frac{\pi}{4} \) then \( \theta_1 + \theta_2 \) are \( \pi \) out of phase and \( \theta_3 + \theta_4 \) are also \( \pi \) out of phase so the amplitudes at \( P \) is zero.

b) \( d = \frac{\pi}{2} \) also gives zero amplitude since now \( \theta_1, \theta_2, \theta_3, \theta_4 \) are all \( \pi \) out of phase we are

c) If \( d = \pi \) all 4 sources are in phase and the amplitude at \( P \) will be \( 4.5 \)
5 dB per vertical division in the scale for the plot. Since the two curves are always 5 dB apart (i.e., the ratio of their intensities does not depend on position) the two sources must be at the same location.

\[ 10 \log \left( \frac{I_1}{I_2} \right) = 5 \text{ dB} \]

\[ \Rightarrow \log \left( \frac{I_1}{I_2} \right) = 0.5 \text{ dB} \]

\[ I_1 = I_2 \cdot 10^{0.5} = \sqrt{10} \cdot I_2 \]

\[ \frac{I_1}{I_2} = 3.2 \]

b) As noted above, the difference between the two curves is constant.
According to the generalized Doppler effect formula (17.47), the reflector allows detecting a frequency given by:

\[ f' = f \cdot \frac{v_{W} + v_{A}}{v_{W} - v_{A}} = 1200 \text{ Hz} \cdot \frac{32.9 \text{ m/s} + 65.8 \text{ m/s}}{32.9 \text{ m/s} - 29.9 \text{ m/s}} \]

\[ f' = 1.58 \times 10^3 \text{ Hz} \]

\[ \lambda = \frac{329 \text{ m/s}}{1580 \text{ Hz}} = 0.208 \text{ m} \]

To be a detector mounted at the observer, it appears that there is a source at the reflector of the above frequency, and this detector would see:

\[ f'' = f' \cdot \frac{329 \text{ m/s} + 29.9 \text{ m/s}}{329 \text{ m/s} - 65.8 \text{ m/s}} = 13636.1580 \text{ Hz} \]

\[ f'' = 2150 \text{ Hz} \]

\[ \lambda = \frac{329 \text{ m/s}}{2150 \text{ Hz}} = 0.153 \text{ m} \]
\[ \Delta d = \alpha_{AE} \Delta T \]

\[ \frac{\Delta d}{\Delta t} = v_{source} = d \alpha_{AE} \cdot \frac{dT}{dt} \]

where \( \Delta t \) is a time interval and \( \Delta T \) is a temperature change.

\[ \alpha_{AE} = 23 \times 10^{-6} / ^\circ C \] (from table 18-2)

\[ 100 \times 10^{-6} \text{ m/s} = 2.00 \times 10^{-2} \text{ m/s} \cdot 23 \times 10^{-6} / ^\circ C \cdot \frac{dT}{dt} \]

\[ \Rightarrow \frac{dT}{dt} = \frac{50 \times 10^{-6} \text{ m/s}}{23 \times 10^{-6} / ^\circ C} = 0.217 ^\circ C / s \]

\[ \frac{dT}{dt} = 0.217 \text{ K/s} \]

Remember \( 1 ^\circ C = 1 K \) when talking about temperature difference.
As heat is exchanged between the ball and the hoop:

The hoop expands and the ball shrinks:

\[
D = D_0(1 + \alpha_C \Delta T_0) \quad \text{and} \quad d = d_0(1 - \alpha_{AE} \Delta T_{AE})
\]

\[
= D_0(1 + \alpha_C (T_f - T_0)) \quad \text{and} \quad d = d_0(1 - \alpha_{AE}(T_i - T_f))
\]

Where \(T_0 = 0.00^\circ C\) = initial \(T\) of the Cu + Ti to the initial temperature of the Al. At \(T_f\) we are told \(D = d\) (the ball just passes through the hoop)

\[
D_0 (1 + \alpha_C T_f) = d_0 (1 - \alpha_{AE} T_i + T_f \Delta N)
\]

\[
T_f (\alpha_C D_0 - \alpha_{AE} d_0) = d_0 - d_0 \alpha_{AE} T_i - D_0
\]

\[
T_f = \frac{2545000((1.23 \times 10^6 - 100^2) - 254000)}{(17 \times 10^6)(254000 - 1.23 \times 10^6(2.54, \%)) + T_0}
\]

\[
= 50.38^\circ C
\]

b) The heat capacity of the sphere is \(C_{AE} \cdot M_{AE}\)

And of the ring is \(C_{Cu} \cdot M_{Cu} \cdot \alpha_{AE} \cdot M_{AE}\). Any heat lost by the sphere must go into the ring hence

\[
M_{AE} \cdot C_{AE} (100 - T_f) = M_{Cu} \cdot C_{Cu} (T_f - 0^\circ C)
\]

\[
M_{AE} = \frac{20 g \times 0.089 \text{cal/g} \cdot \text{K}}{0.125 \text{cal/g} \cdot \text{K}} \frac{50.38^\circ C}{(100 - 50.38)^\circ C}
\]

\[
M_{AE} = 8.72 \text{ gram}
\]

Note: The sphere is not solid since a solid sphere of radius 1.27 cm would have a volume of

\[
\frac{4}{3} \pi r^3 = 8.58 \text{ cm}^3
\]

And a solid Al sphere of the same mass would have a mass of 23.2 gram!