21.68. Model: The changing sound intensity is due to the interference of two overlapped sound waves.

Visualize: Please refer to Figure P21.68.

Solve: Minimum intensity implies destructive interference. Destructive interference occurs where the path length difference for the two waves is \( \Delta r = (m + \frac{1}{2})\lambda \). We have assumed \( \Delta \phi_0 = 0 \) rad for two speakers playing “exactly the same” tone. The wavelength of the sound is \( \lambda = \frac{v_{\text{sound}}}{f} = \frac{343 \text{ m/s}}{686 \text{ Hz}} = 0.500 \text{ m} \). Consider a point that is a distance \( x \) in front of the top speaker. Let \( r_1 \) be the distance from the top speaker to the point and \( r_2 \) the distance from the bottom speaker to the point. We have

\[
r_1 = x \quad r_2 = \sqrt{x^2 + (3 \text{ m})^2}
\]

Destructive interference occurs at distances \( x \) such that

\[
\Delta r = \sqrt{x^2 + 9 \text{ m}^2} - x = (m + \frac{1}{2})\lambda
\]

To solve for \( x \), isolate the square root on one side of the equation and then square:

\[
x^2 + 9 = [x + (m + \frac{1}{2})\lambda]^2 = x^2 + 2(m + \frac{1}{2})\lambda x + (m + \frac{1}{2})^2 \lambda^2 \Rightarrow x = \frac{9 - (m + \frac{1}{2})^2 \lambda^2}{2(m + \frac{1}{2})\lambda}
\]

Evaluating \( x \) for different values of \( m \):

<table>
<thead>
<tr>
<th>( m )</th>
<th>( x ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>17.88</td>
</tr>
<tr>
<td>1</td>
<td>5.62</td>
</tr>
<tr>
<td>2</td>
<td>2.98</td>
</tr>
<tr>
<td>3</td>
<td>1.79</td>
</tr>
</tbody>
</table>

Because you start at \( x = 2.5 \text{ m} \) and walk away from the speakers, you will only hear minima for values \( x > 2.5 \text{ m} \).

Thus, minima will occur at distances of 2.98 m, 5.62 m, and 17.88 m.