An organ pipe is open at one end, and closed at the other. It is adjusted so that the first overtone (the first resonant frequency higher than the fundamental) occurs when the tube is 2.25 m long. Take the velocity of sound to be 330 m/s.

(a) Find the wavelength of the first overtone.
(b) Find the frequency of the first overtone.
(c) Find the frequency of the fundamental.
(d) If the velocity of sound is increased by 1.00%, find the new frequency of the first overtone.

Report numerical answer to three significant figures.

The modes of an organ pipe which is closed at one end and open at the other are shown on page 326 of your text. For this problem, you need to know the wavelength of the fundamental and of the first overtone. The quantity \( l \) is given as 2.25 m, and \( v = 330 \text{ m/s} \).

![Wavelength Diagrams]

Remember that a full wavelength looks like

\[
\begin{align*}
\lambda & \Rightarrow \frac{3}{4} \lambda,
\end{align*}
\]
(a) Wavelength of first overtone:

\[ l = \frac{3}{4} \lambda \Rightarrow \lambda = \frac{4}{3} l = \frac{4}{3} (2.25 \text{ m}) = 3.00 \text{ m} \]

(b) Frequency of first overtone:

\[ \nu = \lambda \nu \Rightarrow \nu = \frac{\nu}{\lambda} = \frac{330 \text{ m/s}}{3.00 \text{ m}} = 110 \text{ Hz} \]

(c) Frequency of fundamental:

First find the wavelength of the fundamental,

\[ l = \frac{\lambda}{4} \Rightarrow \lambda = 4l = 4 (2.25 \text{ m}) = 9.00 \text{ m} \Rightarrow \nu = \frac{\nu}{\lambda} = \frac{330 \text{ m/s}}{9.00 \text{ m}} \]

\[ = 36.7 \text{ Hz} \]

(d) The new velocity of sound in air is

\[ (1.01) (330 \text{ m/s}) = 333 \text{ m/s} \Rightarrow \nu = \frac{\nu}{\lambda} = \frac{333 \text{ m/s}}{3.00 \text{ m}} = 111 \text{ Hz} \]

Remember that the pipe length is fixed. Specifying fundamental, a overtone, etc., tells you how many wavelengths fit in pipe. The open end is always an antinode; the closed end is always a node.