Problem 2: (30 pts.) You and your roommate have discovered a secret tunnel under Markle Hall and are attempting to determine how deep it is. Using an audio oscillator and a loudspeaker, you determine that the tunnel has resonances at 50, 70, and 90 Hz, and at no other frequencies in the range from 50 to 90 Hz. (At this point, a security guard comes along, so you don't have the opportunity to take measurements at higher or lower frequencies.) If the tunnel can be modeled as a tube open at one end and closed at the other, what is the depth of the tunnel? Assume that the speed of sound is 340 m/s.

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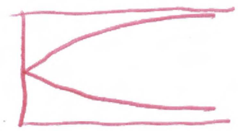
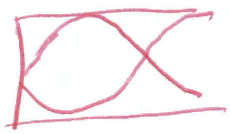
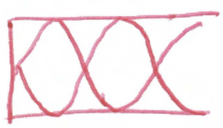


$L = \frac{1}{4}\lambda$ generally $L = \frac{\text{odd}}{4}\lambda$



$L = \frac{3}{4}\lambda$ $\lambda = \frac{4L}{\text{odd}}$



$L = \frac{5}{4}\lambda$

$$f = \frac{v}{\lambda} = \frac{v}{4L}\cdot(\text{odd})$$

Look at differences: $\Delta f = \frac{v}{4L}\cdot 2$

But measurements show $\Delta f = 20$ Hz :

$$\therefore\ 20 = \frac{340\,\text{m/s}}{4L}\cdot 2$$

$$\boxed{L = 8.5\,\text{m}}$$

Not necessary, but $f_1 = \frac{v}{4L}\cdot 1 = \frac{340}{4(8.5)} = 10\,\text{Hz}$.

The frequencies above are f_5, f_7, and f_9.