Questions: Helmholtz resonance

1 Helmholtz resonance may occur when an enclosed volume of air is connected to the atmosphere by a short exit pipe when simple harmonic oscillations of air in the pipe are driven by pressure changes in the enclosed volume.

The frequency of the resonance is given by …

$$f = v/2\pi\,[A_x/VL]^{1/2}$$

… where v is the velocity of sound in air, V is the volume of air enclosed air, A_x is the cross sectional area and L is the effective length of the pipe.

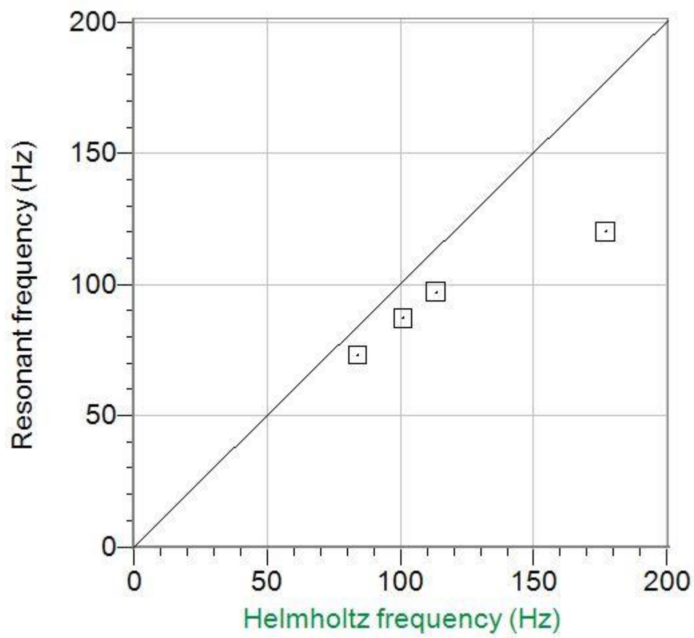
a Explain, in physical terms, why the effective length L in the frequency relationship is a little longer than the actual length of the exit pipe.

b Explain, in physical terms, why halving the volume of the enclosed air raises the resonant frequency.

c A Helmholtz resonator is completely filled with carbon dioxide. Will the resonant frequency change and if so by how much?

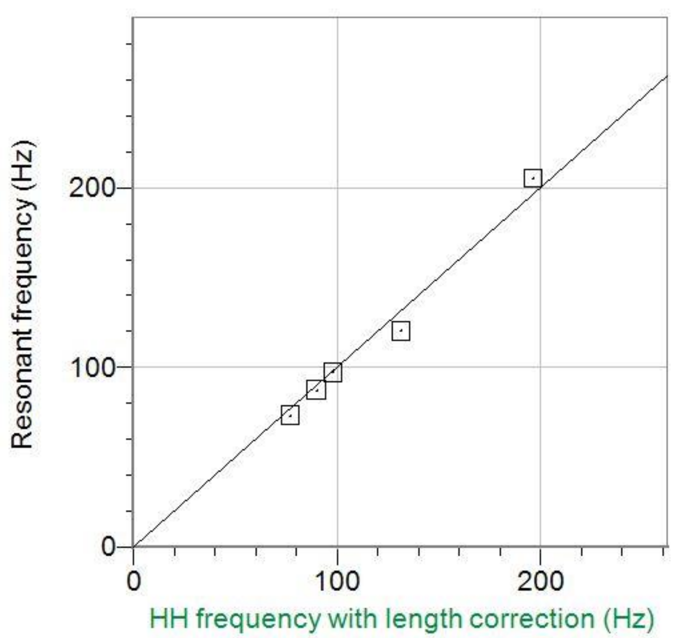
2 A empty coffee container is shown.

The round hole in the cap has a diameter of 1.45 cm. Short lengths of plastic pipe with an internal radius of 0.65 cm convert the container into a Helmholtz resonator. Measured resonant frequencies are plotted below against frequencies calculated with the Helmholtz relationship $f = v/2\pi\,[A_x/VL]^{1/2}$ for four pipe lengths.



a Are calculations less satisfactory for shorter or longer pipe lengths?

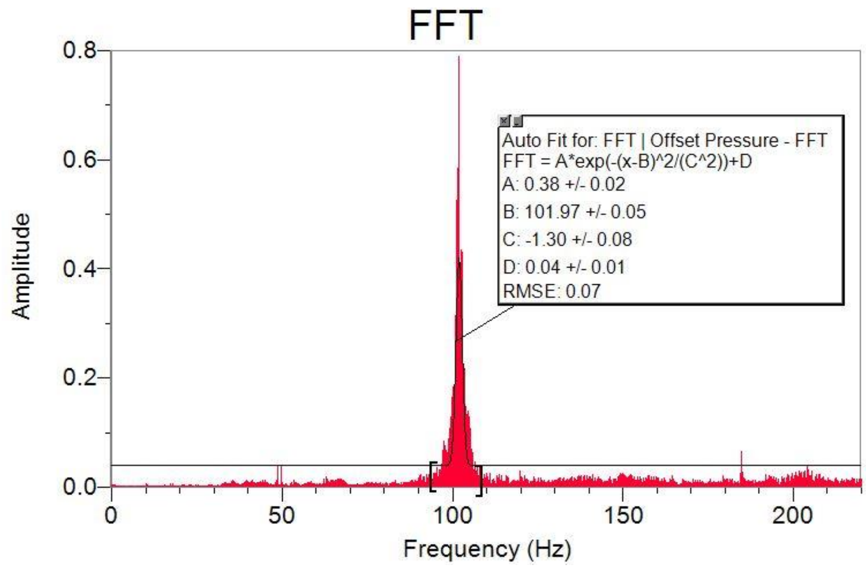
b Increasing the effective length of the pipe by 1.3 cm, recalculating and plotting the revised data gives the graph below.



c Which additional point on the graph represents the resonance when the pipe length is zero?

d The sound box on a guitar is said to behave as Helmholtz resonator with an effective pipe length. In what way does the data above support this view?

3 The FFT plot below shows Helmholtz resonance in a container with a short exit pipe.



a The resonance frequency has been found by fitting a Gaussian function to the FFT plot. How could the frequency be found from a data plot in the time domain?

b The condition for Helmholtz resonance (the simple harmonic oscillation of air in the exit pipe of a closed container) is that the wavelength of the sound be much longer than the dimensions of the container. Explain why.

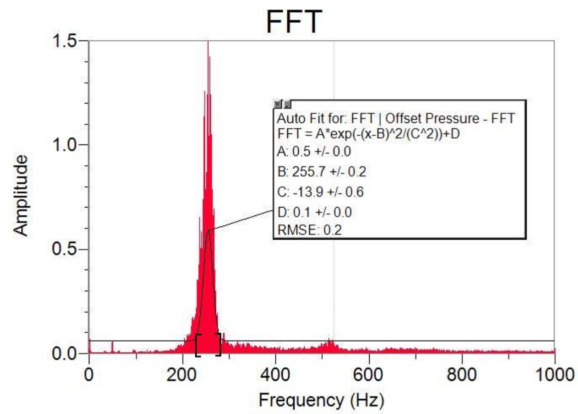
The bottle shown is to be emptied and used to demonstrate Helmholtz resonance.

c A student calculates the cross sectional area of the neck by measuring the diameter of the opening. Are they correct, or do you have a more appropriate suggestion?

The student measures the length of the neck and the volume of the bottle.

d He finds that a calculation using the relationship $f = v/2\pi\,[A_x/VL]^{1/2}$ does not give the measured resonant frequency to better than 20%. How and why should he modify one or more of the constants used in the calculation?

4 The coffee container shown has a round 2.40 cm diameter hole in the top and a volume of 780 mL Blowing gently across the hole sets up resonance at 255 Hz.



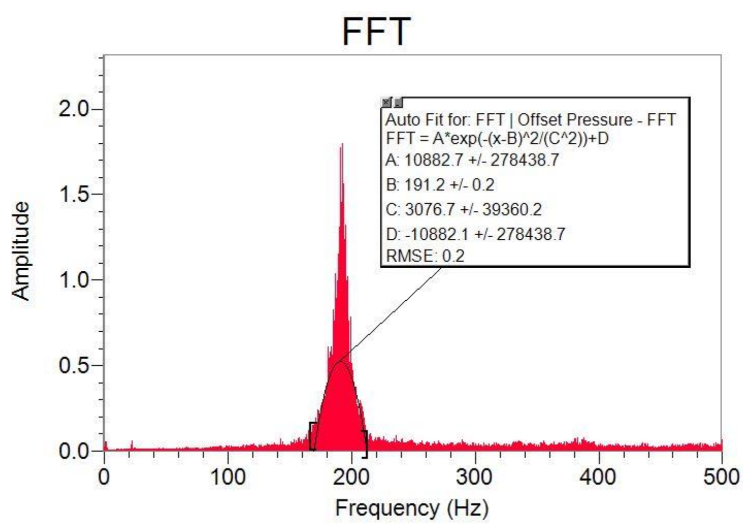
The Helmholtz resonance relationship is $f = v/2\pi\ [A_x/VL]^{1/2}$.

a Define the symbols in the relationship.

b The container, like the sound box of a guitar, has a single opening but no exit pipe. Show that the effective exit pipe length is 2.6 cm in this case.

c Justify the use of effective length in physical terms when a container has an opening but no exit pipe.

A short 1.6 cm pipe that is 2.30 cm in internal diameter is now added to the container. Blowing gently across the open end sets up resonance at 192 Hz.



d Show by calculation that the same length correction applies.

e Helmholtz resonance is said to be single frequency resonance. Is this strictly true, or just a good approximation?