Standing wave in an open pipe

Apparatus

Sound sensor set to dBA range

Length of pipe about 1 m long and at least 10cm diameter..

Variable oscillator / signal generator and speaker.

Metre rule, expandable tape or long stick marked with 1 cm divisions.

Rubber bands / sticky tape to fix sensor to the stick

Tape or retort stand(s) to fix the apparatus in place

Data recording setup.

Graph and table display

Recording setup

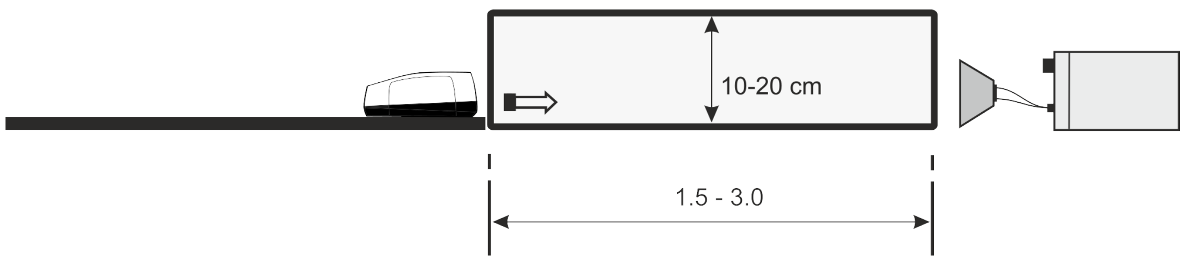
Snapshot with prompt for value on each samle active

Click start. Click stop

A note can be produced from a pipe that is open at both ends e.g. organ pipes. A pipe can be made to resonate (produce a vibration of large amplitude from a relatively small source vibration.) at different frequencies that are determined by the length of the pipe.

The resonance frequency is the fundamental frequency of the pipe and is referred to as its first harmonic.

Tuning a pipe to produce a note can be achieved by trial and error, by adding or subtracting material from the pipe. Understanding of resonance will allow a pipe to be designed and then fine-tuned by removal of a very small amount of material to produce a given note.



Method

1. Place the pipe on a bench with the small speaker close to one end. You may need to tape the tube to the table or put objects either side of it to prevent rolling.
2. Attach the speaker to a signal generator and set the signal generator to produce a sine wave. Turn on the signal generator and test to see if a sound is being produced at the speaker. If possible position the speaker so that it is central to the tubes opening.
3. Place the ruler / tape along the table with the 0 cm mark at the opening of the tube. Secure in place with some tape or similar.
4. Connect the Sound sensor to a metre ruler marked in centimetres. Push the Sound sensor into the tube as far as it will go (do not let the sensor touch the speaker or come out of the other end of the tube). Make a mark on the ruler to indicate the edge of the tube on the fixed rule. This will indicate the 0 cm position of the sensor to the speaker. Connect the Sound sensor to the data logger.
5. Set the signal generator frequency to about 4 times the fundamental frequency for your pipe (See calculation at end of the method). This should give 4 nodes (points of low sound level) inside the pipe.
6. Turn on the signal generator and select Start.

7. With the mark on the moving ruler at next to the end of the tube, click on the centre of the graph area to record the first reading. A small box will open up asking for a value. For this first snapshot you should enter 0.
8. Pull the Sound sensor out of the tube by 1 cm.
9. Take a snapshot reading of the sound pressure, when the value box opens enter 1.0. Make sure you enter the decimals correctly.
10. Repeat at regular intervals (every 1 cm) as the sensor is pulled out of the pipe. You may wish to reduce the interval to parts of a cm as the nodes are reached.
11. When you have recorded all the information you need, select Stop and use "Save as" to save the data file.

To calculate the fundamental frequency of the pipe being used

The fundamental frequency (f_o) of the pipe =

λ_o = 2 x length of pipe

Velocity of sound = 342 ms^{-1}

For example the fundamental frequency (f_o) of a 3 m open pipe:

λ_o = 2 x length of pipe = 6 m

f_o = <u>342 / 6</u> = ~57Hz

Multiple nodes

To find the frequency for multiple nodes,

f = nv/2L

Where

n = the number of nodes (1, 2, 3, 4, etc).

V = speed of sound (342 ms^{-1})

L = length of the tube in meters

Prediction of wavelength

λ = speed of sound / frequency

Find the frequency of the signal generator.

Speed of sound is taken as 345 ms^{-1} (you will need to correct for temperature)

Correcting speed of sound with temperature

If you measure the temperature in the room before the experiment starts you can make the correction for temperature.

The value of the velocity of sound increases with temperature.

At 0˚C v = 331.3 ms^{-1}

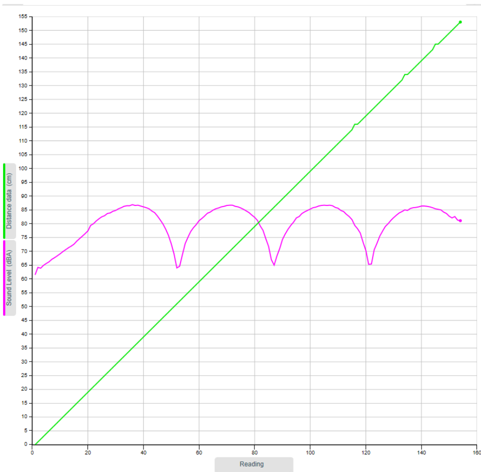
The velocity of sound increases at 0.607 $ms^{-1}C^{-1}$. (Ref: Kaye and Laby)

For example at 24˚C

v = 331.3 + 24 x 0.607 = 331.3 +14.6 = 345.9 ms^{-1}.

An example set of data. This was for a 500 Hz signal and a 1.3m tube. The first reading was taken outside the tube and subsequent readings as the sensor was inserted into the tube.

A table view is used to help keep track of the data.



Reading (-)	Distance data (cm)	Sound Level (dBA)
1	0.00	61.5
2	1.00	64.2
3	2.00	63.9
4	3.00	64.9
5	4.00	65.6
6	5.00	66.2
7	6.00	67.1
8	7.00	67.7
9	8.00	68.4
10	9.00	69.1
11	10.00	69.9
12	11.00	70.6
13	12.00	71.3
14	13.00	71.9
15	14.00	72.6
16	15.00	73.7
17	16.00	74.6
18	17.00	75.5
19	18.00	76.4
20	19.00	77.4
21	20.00	79.4
22	21.00	80.0
23	22.00	81.0
24	23.00	81.8
25	24.00	82.5
26	25.00	82.9
27	26.00	83.7
28	27.00	83.9
29	28.00	84.5
30	29.00	84.8
31	30.00	85.4
32	31.00	85.8

Results and analysis.

You should be able to use the difference or values tool to find the distance between one and two nodes for the calculations.

If required change the x axis to distance and the y axis to intensity - dBA, rescale to get the best graph.

Use theory to calculate the wavelength and node distances.

Compare theoretical (calculated results) against practical results.

Workout the % error for the practical.

Results table

Length of tube (m)			
Diameter of tube (m)			
Distance between the first two nodes			
Distance between the first three nodes			
Frequency of signal			

Questions.

1. What happens to the number of nodes in the pipe if the frequency is doubled?
2. Use frequency/velocity of sound = d/2 to give the theoretical distance between nodes. How does the calculated value match the experimentally derived values?
3. What would be an application of this information?

Extension.

The apparatus can be used to make a small project / study of standing waves resonance.

1. Use the same frequency and apparatus but close one end of the pipe.
2. Sue the same frequency but use a different diameter or length of pipe, try open and closed.
3. Try a pipe of the same dimensions but a different material, for example card vs. plastic.
4. What happens if you change the frequency?