RESONANCE TUBE

IDEA TO REMEMBER!

Harmonics are standing waves!

OBJECTIVE:

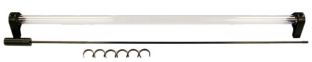
Illustrate standing wave resonance in an open ended cylindrical tube, describe how resonance can occur, and measure frequency and wavelength to find sound speed.

MATERIALS:

PASCO 550 Interface

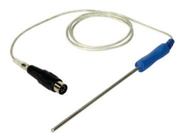
Banana jack cables

PASCO Mini speaker



Resonance tube set

Meter stick



Temperature Sensor

CONCEPT:

All objects vibrate at a **natural frequency**. When an object is acted upon by a periodic force with a frequency precisely at the natural frequency, the object vibrates with a *greater amplitude*. This phenomenon is called **resonance**.

The air will resonate depending on the tube's length, form, and whether it has closed or open ends. Sound waves flow through a tube of air and are reflected back at the other end when a periodic sound source is placed at one end of the tube. This can create **standing waves** within the tube, like our string experiment from Standing Wave! If there is an **anti-node** at the open end then the tube will resonate, see Figure (1).

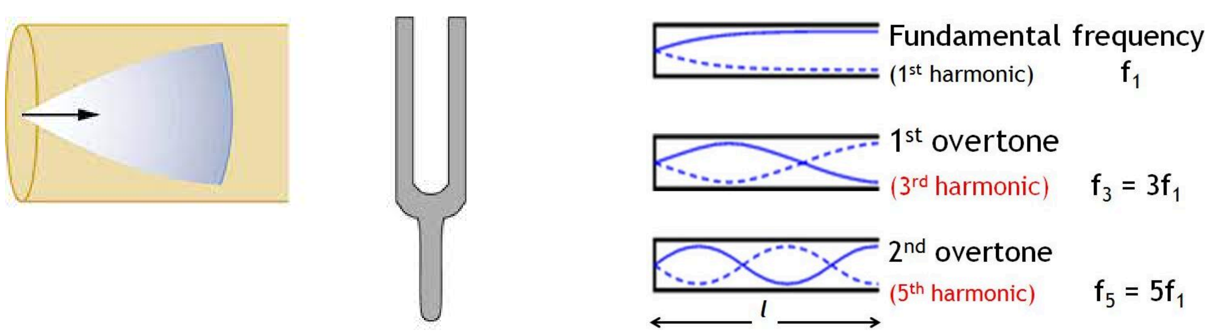


Figure 1: Standing wave patterns for the first three resonances in an open ended tube.

In other words, the amplitude increases dramatically if the exact time of this reflected wave and a new wave from the source coincide at the opening of the tube.

> **FUN FACT!** "The lowest resonant frequency is called the **fundamental**, while all higher resonant frequencies are called **overtones**. The resonant frequencies that are [integer] multiples of the fundamental are collectively called **harmonics**," (OpenStax) which are also called **modes**.

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Before continuing, recall the Standing Wave lab demonstration where the fundamental frequency creates a half wavelength λ in the distance L between the two nodes. Each harmonic n wavelength λ is proportional to twice the length:

$$\lambda_n = \frac{2L}{n} \tag{1}$$

Also remember that wave speed v can be shown as the product of wavelength and frequency:

$$v = \frac{\lambda}{T} = f\lambda = \sqrt{\frac{F_T}{\mu}} \tag{2}$$

Thus, the harmonic frequencies for the Standing Wave string demonstration can be derived as follows:

$$f_n = n\frac{v}{2L} = nf_1 \tag{3}$$

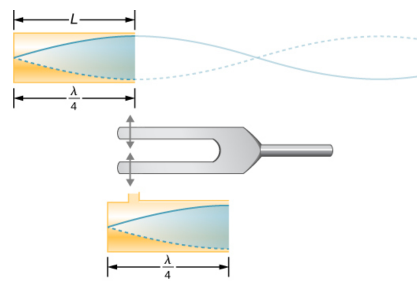

Figure 2 (OpenStax)

However, looking at Figure (2), you can visualize that we are looking for **resonance between a node and an anti-node**, which is one-fourth of a wavelength! You can see that all of the **odd harmonics *n* will land on an anti-node**, therefore, our equation for the anti-node resonant frequencies is:

$$f_n = n\frac{v}{4L} = nf_1 \qquad n = 1, 3, 5, \ldots \tag{4}$$

The speed of sound in air travels 331.3 m/s @ 0°C and increases with the square root of absolute temperature:

$$v = (331.3 + 0.606T_C)\frac{m}{s} \tag{5}$$

Where T_C is the room temperature in Celsius and v has the units of m/s.

Real World Applications

- Soldiers un-sync their steps while marching across a bridge to avoid generating resonant frequencies.
- Microwave ovens are designed to resonate their waves to heat up food faster.
- Engineers of all fields, including manufacturing, construction, automotive, and ***music***, keep natural frequency in mind to use or avoid it in their designs!

1) The secret of synchronization!
2) Oscilloscope ***MUSIC!***

PRECAUTIONS:

Not much for worry! Have fun and learn!

PROCEDURE:

1. ☐ Fill out the top information **and** complete the memory exercise—Question M1 and M2—on the worksheet.

2. ☐ REQUIRED: Read the *Concept* section.

3. ☐ Assemble the setup as shown in Figure (3).

    3.1. Place the Mini Speaker very close (within a few millimeters) to the end of the tube.

    3.2. Use two banana wires to connect the tiny speaker to the PASCO 550 Interface output channel (On the right ±8V @400mA).

    3.3. Get the room temperature from the blackboard or TA and record on the worksheet.

4. ☐ Pick **5 random frequencies** between 400Hz and 1500Hz and record your choices in the first column of Table 1 on the worksheet.

5. ☐ Before moving on, answer Question 2–3 on the worksheet.

6. ☐ Open the PASCO Capstone application, select *Hardware Setup*, then click on the output channel (the furthest right yellow circle) to pick *Output Frequency Sensor*.

7. ☐ Click on *Signal Generator* and select a *Frequency* between 400Hz and 1500Hz. Click *On* and adjust *Amplitude* to 1V. **You must click *Off* and then *On* each time you adjust the frequency**. See Figure (4).

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CONCEPT & PROCEDURE VIDEOS:

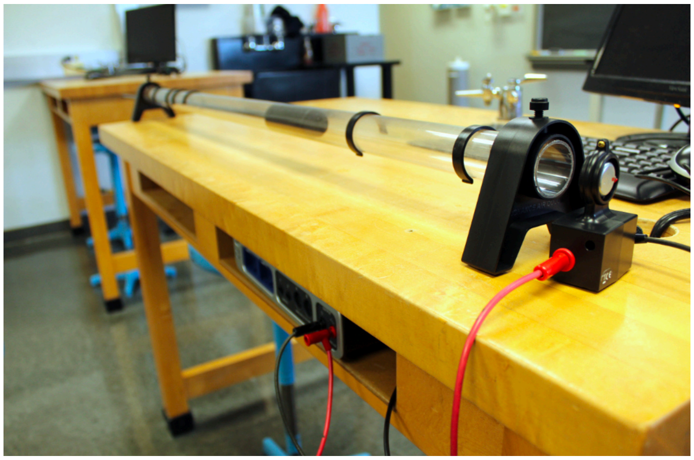

Figure 3

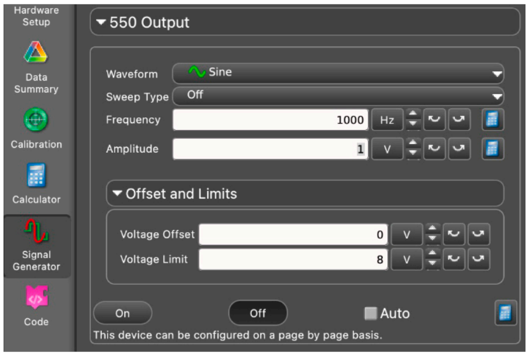

Figure 4

8. ☐ With the tip of the piston at the opposite end from the speaker, slowly move the piston inward until you hear the sound get louder.

9. ☐ When you hear the sound get louder, stop moving the piston and mark the position of the end of the piston with a plastic clip on the outer tube. The clips are shown on the tube in Figure (3)—positions are unimportant as shown in the figure.

10. ☐ Once again, move the piston slightly inward until the sound is louder again and mark it with another plastic clip.

11. ☐ Repeat steps 9–11 to complete Table 1 on the worksheet.

12. ☐ Answer Questions 4–5 on the worksheet.

13. ☐ Follow the **Let's THINK!** instructions below.

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Let's THINK!

- **Ask questions**: What are you learning here?... Why is this Physics concept important and how can it be used?... What do you not understand?... (For more information on this Physics topic, scan the QR codes in the *Real World Applications* and at the start of the *Procedure* section.)
- **Discuss** the concept and demonstration with your partner to help each other understand better. Discussion makes learning active instead of passive!
- For **FULL PARTICIPATION [15 points]** you must call on the TA when you have finished your group discussion to answer some comprehensive questions. If you do not fully understand and the TA asks you to discuss more, you must call on them one more time to be dismissed with full marks.
- **CONCLUSION [10 points]**: In the Conclusion section at the end of the worksheet, write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those as well.

Updated Date	Personnel	Notes
2022.08	Chase Boone, Udeshika Perera, Ahmad Sohani, Brooks Olree	2022 Summer Improvement: Created new format.

Name: ________________________________ *PH2233* Section #:__________

Name: ________________________________ TA Name:____________________

RESONANCE TUBE
WORKSHEET [70 points]

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Memory exercise [each 2 extra credit points]:

M1) Interference causes waves to ___________________

M2) Springs can model what type of motion? ________________

1) Room temperature: __________°C [1.5 points]

Table 1: [12.5 points, 0.5 point per cell]

Signal Generator Frequency f (Hz)	Position 1 x_1 (m)	Position 2 x_2 (m)	Wavelength $\lambda = 2(x_2 - x_1)$ (m)	Speed of Sound $v = f\lambda$ (m/s)

2) Calculate the fundamental (n = 1) distance *L* (node to anti-node) in cm for your 5 random frequencies. Show your work! [10 points]

3) Can any of your calculated lengths L resonate for the **fundamental** harmonic in the tube? What happened to L as the frequencies changed? Using the maximum length of the tube, calculate the lowest possible frequency we could use with our demonstration setup. [16 points]

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4) What is the average speed of sound in the experiment, according to Table 1? How does that compare with the theoretical speed of sound in Equation (5)? [10 points]

5) Explain why the full wavelength is equal to twice the distance between two nodes, and explain why the sound resonates at the lengths that you found (in other words, explain what anti-nodes are). [10 points]

Conclusion

Write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those here as well. [10 points]

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