SPH3U UNIVERSITY PHYSICS

WAVES & SOUND

- Speed of Sound (P.393-397)

Speed of Sound

Sounds seems to move very quickly. However, during a thunderstorm, you see the lightning before you hear the thunder it causes. A similar phenomenon occurs at a high school track meet where the timer of a 100 m sprint stands at the finish line and watches for a puff of smoke from the starter's pistol. Shortly after the smoke is seen, the sound of the gun is heard. Light travels extremely fast (3.0×10^8 m/s in air); sound travels much more slowly.

Speed of Sound

Accurate measurements of the speed of sound in air have been made at various temperatures and air pressures. At normal atmospheric pressure and 0°C, the speed of sound in air is ~ 331 m/s. If the air pressure remains constant, the speed of sound increases as the temperature increases. For every rise in temperature of 1°C, the speed of sound in air increases by ~ 0.60 m/s. The speed of sound in air at normal atmospheric pressure can be calculated using the equation:

$$v = 331 \text{ m/s} + (0.60 \text{ m/s/°C})\, T$$

NOTE!

Different sources list the speed of sound formula slightly differently.

Speed of Sound

SPEED OF SOUND (in air)

- increases as the air temperature increases

$$v = 331 + (0.60)T$$

where v is the speed of the sound wave in air (m/s)
T is the air temperature (°C)

Speed of Sound – DYK?

The speed of sound in air was first accurately measured in 1738 by members of the French Academy. Cannons were set up on two hills approximately 29 km apart. By measuring the time interval between the flash of a cannon and the "boom," the speed of sound was calculated. Two cannons were fired alternately to minimize errors due to the wind and to delayed reactions in the observers. From their observations, they deduced that sound travels at about 336 m/s at 0°C.

Speed of Sound

PRACTICE

1. Calculate the speed of sound in air when the temperature is 15°C.

v = 340 m/s

Speed of Sound

PRACTICE

2. If the speed of sound is measured to be 318 m/s, what is the current air temperature?

   T = -21.7 °C

Speed of Sound

PRACTICE

3. A 200 m dash along a straight track was timed at 21.1 s by a timer located at the finish line who used the flash from the starter's pistol to start the stopwatch. If the air temperature was 30°C, what would the time have been if the timer had started the watch upon hearing the sound of the gun?

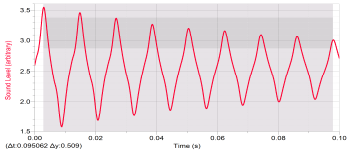
   t = 20.5 s

Activity: Speed of Sound

INSTRUCTIONS

A. Open the program "LoggerPro"
B. Retrieve the "Speed of Sound" movie clip located in Sample Movies/Speed of Sound. (The video shows the removal of the cap on the end of the PVC pipe and the graph shows the recorded sound.)
C. Use the information from the video to estimate the speed of sound – recall $v = \lambda/T$. Express your answer to 1 decimal place.

Activity: Speed of Sound



- first peak to the last peak (8 waves) — $\Delta t_8 = 0.09506$ s
- 1 wave ($\Delta t_8 \div 8$) — $\Delta t_1 = 0.01188$ s
- period for 1 complete wave ($T = \Delta t_1$) — T = 0.01188 s
- length of air column — L = 1.0 m
- closed air column ($\lambda = 4L$) — λ= 4.0 m
- speed of sound ($v = \lambda/T$) — v = 336.6 m/s

Activity: Speed of Sound

QUESTIONS

1. Assuming the temperature was 16°C, what is the accepted value for the speed of sound? Express your answer to 1 decimal place.

   v= 340.6 m/s

Activity: Speed of Sound

QUESTIONS

2. Use your answer to Q.1 to calculate the % error of your experimental value. Express your answer to 2 significant digits.

   error = 1.2 %

Speed of Sound in Other Media

Sound can be transmitted through any medium – gas, liquid, or solid. Children at play may discover that sound travels very easily along a metal fence. Swimmers notice that they can hear a distant motorboat better with their ears under the water than in the air. In both examples, sound is travelling in a medium other than air.

State	Medium	Speed of Sound (m/s)
solid	glass (Pyrex)	5170
	steel	5000
	wood (maple)	4110
liquid	water (fresh)	1496
	water (salt)	1470
	alcohol	1241
gas	helium	970
	air (20° C)	344
	air (-20° C)	319

Speed of Sound in Other Media

As you learned earlier, waves travel more rapidly in certain solids (rigid intermolecular forces) and in hotter gases than in cooler gases. Thus, the speed of sound depends not only on the temperature of the medium but also on the characteristic properties of the material.

State	Medium	Speed of Sound (m/s)
solid	glass (Pyrex)	5170
	steel	5000
	wood (maple)	4110
liquid	water (fresh)	1496
	water (salt)	1470
	alcohol	1241
gas	helium	970
	air (20° C)	344
	air (-20° C)	319

Speed of Sound in Other Media

SPEED OF SOUND (cont …)

- also depends on the medium's properties, **not** just its temperature

State	Medium	Speed of Sound (m/s)
solid	glass (Pyrex)	5170
	steel	5000
	wood (maple)	4110
liquid	water (fresh)	1496
	water (salt)	1470
	alcohol	1241
gas	helium	970
	air (20° C)	344
	air (-20° C)	319

Speed of Sound in Other Media

PRACTICE

4. A vibrating 400 Hz tuning fork is placed in fresh water. The speed of sound in fresh water at 25°C is 1493 m/s. What is the (i) frequency in hertz and the (ii) wavelength in metres:
   (a) within the water at 25°C?

   (a) f = 400 Hz λ = 3.73 m

Speed of Sound in Other Media

PRACTICE

4. A vibrating 400 Hz tuning fork is placed in fresh water. The speed of sound in fresh water at 25°C is 1493 m/s. What is the (i) frequency in hertz and the (ii) wavelength in metres:
   (b) when the sound waves move into the air at 25°C?

   (b) f = 400 Hz λ = 0.865 m

✔ Check Your Learning

TEXTBOOK

P.393 Q.1-3 (Practice)

ACTIVITY: Measuring The Speed Of Sound (Inv.8.5.1/P.404)

① Follow procedure steps 1-8.
② Look for the mode (i.e. the value that is most common or the average of the values that are most common) and use this for your time value. Express this value to 3 decimal places.
③ Calculate the speed of sound (to 3 significant digits) using:
   (a) experimental value v = d/t
   (b) accepted value v = 332 m/s + (0.60) T
④ Calculate the % error.
⑤ Answer the following: Q.(i),(j)/P.405