Physics 1408/1420

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Hello Fellow Physicists

I am Aman Patel, the Master Tutor for Physics this semester. I have created this resource document to help you review some of the topics you have been introduced to this semester to better prepare for your Final in physics.

Keywords: Sound, Standing Waves in Strings and Tubes, Doppler Effect

Important Notes

Important Conventions

Sound:

Sound is a longitudinal wave that travels through a medium. It always requires a medium for propagation. Due to this characteristic, sound travels through different substances at different velocities. The closer the molecules of the substance are, the faster the propagation of sound. Hence, sound travels faster in solids then air. Due to this quality, the speed of sound air also varies due to the temperature of air. The velocity can be calculated using the following

$$v \approx (331 + 0.60T)$$

As sound is a wave, the characteristics of the wave can affect the sound. Loudness is related to the intensity of the wave. The pitch of a sound is determined by the frequency of the wave. The intensity is the energy transported by a wave. This relationship is used to quantify the sound level(β) using decibels. It is measured in reference to a chosen intensity level. For humans it is 10^{-12} W/m^2

$$\beta \text{ (in dB)} = 10 \log \frac{I}{I_0}$$

Example:

At a busy street corner, the sound level is 75 dB. What is the intensity of sound there?

Solution

$\beta = 10 \log (I / I_0)$

$75/10 = \log (I / 10^{-12})$

$10^{7.5} = I / 10^{-12}$

$I = 3.2 \times 10^{-5}$ W/m^2

Strings:

Stringed instruments like guitars, violins and pianos all depend on the production of standing waves. As we saw last week, standing waves depend on the fundamental frequency of the strings. The order of the standing wave determines the frequency of the sound produced. Using this and its relation to the wave speed, length of the string and tension in the string, musical instruments are designed to produce the various notes they do. The frequency of the standing waves and its wave speed is calculated using the following equations.

$$f_n = nf_1 = n\frac{v}{2\ell}, \qquad n = 1, 2, 3, \cdots \qquad\qquad v = \sqrt{F_T/\mu}.$$

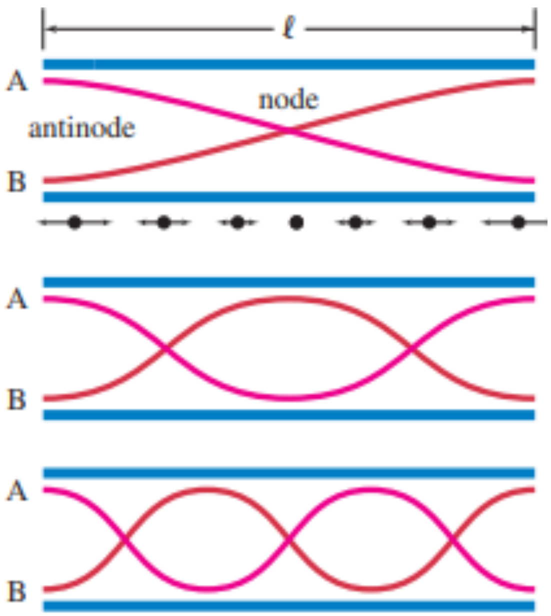
The F_T is the tension of the string. The μ is the mass per unit length for the string.

μ = mass/length.

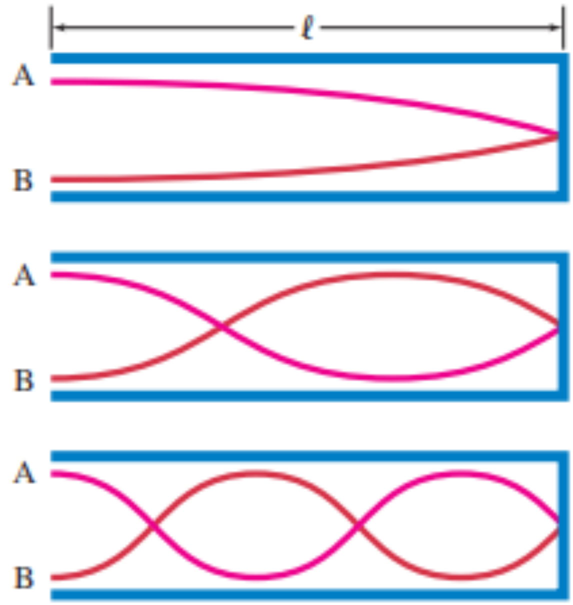
Wind:

In wind instruments, sound still travels as waves. The behavior of the waves is affected by the morphology of the tube that it travels in. either both ends can be open or one of the ends can be closed. Due to this, the formation of standing waves in wind instruments changes its behavior.

Both Open Ends



One Closed End



Both Open Ends:

Length (l) = (n/2) λ_n

f_n = (n/2) (v/l) = nf_1

n = 1, 2, 3, …

One Closed End:

Length (l) = (n/4) λ_n

f_n = (n/4) (v/l) = nf_1

n = 1, 3, 5, …

The conditions for standing waves are indicated below the diagram. It is important to keep these characteristics for the wave straight and to remember that in on closed end tube, the order for the wave is odd for each sequential harmonic.

Example

What will be the fundamental frequency for a 26 cm long organ pipe at 20°C if both ends are open and if one end is closed?

Solution

Open: f_1 = v/2l

= 343 / 2(0.26)

= 660 Hz

Closed: f_1 = v/4l

= 343 / 4(0.26)

= 330 Hz

Doppler Effect:

When the source of sound is no longer stationary, the pitch of the sound changes for an observer based on the direction of motion of the source relative to the observer. This effect is known as the Doppler Effect and it occurs with light and sound. When the source is moving toward the observer, the frequency of the wave is higher for the observer. When the source is moving away from the observer, the frequency of the wave decreases for the observer. When it is sound, the pitch increases when the source moves toward the observer and the pitch decreases when moving away from the observer. To calculate the new frequency for the observer, we use the following equations.

$$f' = \frac{f}{\left(1 - \frac{v_{source}}{v_{snd}}\right)}. \qquad \left[\begin{array}{l}\text{source moving toward} \\ \text{stationary observer}\end{array}\right]$$

$$f' = \frac{f}{\left(1 + \frac{v_{source}}{v_{snd}}\right)}. \qquad \left[\begin{array}{l}\text{source moving away from} \\ \text{stationary observer}\end{array}\right]$$

Example

The Siren of a police car at rest emits at a predominant frequency of 1600 Hz. What frequency will you hear if you are at rest and the police car moves at 25 m/s.

(a) Toward you
(b) Away from you

Solution

(a) $$f' = \frac{f}{\left(1 - \frac{v_{source}}{v_{snd}}\right)} = \frac{1600\text{ Hz}}{\left(1 - \frac{25.0\text{ m/s}}{343\text{ m/s}}\right)} = 1726\text{ Hz}$$

(b) $$f' = \frac{f}{\left(1 + \frac{v_{source}}{v_{snd}}\right)} = \frac{1600\text{ Hz}}{\left(1 + \frac{25.0\text{ m/s}}{343\text{ m/s}}\right)} = 1491\text{ Hz}$$

This chapter requires lots of practice with using these equations. I recommend you use the practice questions in the textbook to reinforce using each of them

All Images are from Physics: Principles with Applications (7^{th} Edition) by Douglas C. Giancoli