Physics 161

Lecture 19 Summary

Sound waves

November 7, 2017

Lecture 19: learning objectives

You will be able to define the characteristics of sound waves and the speed of sound.

You will be able to define sound intensity level, and the threshold of hearing and of pain. You will be able to discuss wave fronts and rays and apply them to spherical and plane waves.

You will be able to describe standing waves and calculate harmonics of strings under tension.

Types of sound waves

There are three groups of sound wave.

Audible: (to humans)
Longitudinal waves that lie within the range of sensitivity of the human ear, approximately 20 to 20 000 Hz.

Infrasonic: (audible to elephants and whales)
Longitudinal waves with frequencies below the range of sensitivity of the human ear (below ~ 20 Hz).

Ultrasonic: (audible to bats)
Longitudinal waves with frequencies above the range of sensitivity of the human ear (above ~ 20 000 Hz).

Speed of sound

Bulk modulus:
The ratio of the change in pressure to the resulting fractional change in the volume.

The bulk modulus, B, tells you how compressible (i.e. how responsive to changes in pressure) a material is.

Speed of sound:
The square root of the ratio of the bulk modulus to the density.

$$v = \sqrt{\frac{B}{\rho}}$$

Power and intensity

Power: P
The rate of energy flow (energy per unit time).

$$P = \frac{\Delta E}{\Delta t}$$

Power is measured in Watts (W) where 1 W = 1 J/s.

Intensity: I
The intensity of a wave is the rate of energy flow through a surface per unit are.

$$I = \frac{1}{A}\frac{\Delta E}{\Delta t} \qquad I = \frac{P}{A}$$

Intensity is measured in units of W/ m^2.

Sound relative intensity

Relative intensity (intensity level):
The intensity of a sound wave, relative to the intensity at the threshold of hearing.

$$\beta = 10 \log \left(\frac{I}{I_0} \right)$$

$I_0 = 1.0 \times 10^{-12}$ W/m^2

Standing waves

$$f_n = \frac{n}{2L}\sqrt{\frac{F_T}{\mu}}$$

Natural frequencies for string of length L fixed at both ends (n = 1,2,3,...)

Open pipe

$$f_n = n\frac{v}{2L}$$

n = 1,2,3,...

Closed pipe

$$f_n = n\frac{v}{4L}$$

n = 1,3,5,...