Exercise 1. Loudness

For a sound wave given by $y(x,t) = y_0 + A\cos(kx - \omega t)$, what factor determines loudness?

(a) y_0
(b) A ***
(c) k
(d) ω

Exercise 2. Pitch

For a sound wave given by $y(x,t) = y_0 + A\cos(kx - \omega t)$, what factor determines pitch?

(a) y_0
(b) A
(c) k
(d) ω ***

Exercise 3. Speed of Sound I

Show that $\sqrt{B/\rho}$ has units of [m/s]. Hint: $[B] = [\text{Pa}]$, and $[\rho] = [\text{kg/m}^3]$.

Exercise 4. Speed of Sound II

Assuming that the velocity of a wave in an elastic medium is $v = \sqrt{F/\mu}$, one may show that $v = \sqrt{B/\rho}$. Assuming $B = 1.42 \times 10^5$ [Pa], and $\rho = 1.23$ [kg/m^3], calculate the speed of sound.

(a) 343.0 [m/s]
(b) 339.8 [m/s] ***
(c) 294.3 [m/s]
(d) 0.00294 [m/s]

Exercise 5. Speed of Sound III

Air pressure goes down at higher altitude. Assuming that B is constant, is the speed of sound at 5000 [ft] higher or lower than at sea level? Hint: $n = PV/RT$.

(a) slower at high altitude ***
(b) faster at high altitude

Exercise 6. Speed of Sound IV

Air pressure goes up at higher temperatures. Assuming that B is constant, is the speed of sound at 35 [°C] higher or lower than at 0 [°C]? Hint: $n = PV/RT$.

(a) slower at high temperature
(b) faster at high temperature ***

Exercise 7. Speed of Sound V

What is the speed of sound in liquid helium if $B = 5 \times 10^7$ [Pa], and $\rho = 0.125$ [g/cm^3].

(a) 20000 [m/s]
(b) 9480 [m/s]
(c) 632 [m/s] ***
(d) 343 [m/s]

Exercise 8. Speed of Sound VI

Rank the following from slowest speed of sound to highest: solid water (ice), liquid water, gaseous water (steam).

(a) SLG
(b) SGL
(c) LSG
(d) LGS
(e) GSL
(f) GLS ***

Exercise 9. Pressure I

Find the pressure as a function of time for a room at 1 [atm] = 10^5 [Pa], with sound waves given by $y(x,t) = A\cos(kx - \omega t)$, for $A = 0.1$ [m], $\omega = 2155$ [s^{-1}], and $k = 0.5$ [m^{-1}]. Assume that the bulk modulus of air is $B = 10^3$ Pa. Hint: $p_{\text{wave}}(x,t) = -B\partial_x y(x,t)$.

(a) $10^5 + 0.1\cos(0.5x - 2155t)$ [Pa]

(b) $10^5 - 0.05\sin(0.5x - 2155t)$ [Pa]

(c) $10^5 - 100\cos(0.5x - 2155t)$ [Pa]

(d) $10^5 + 50\sin(0.5x - 2155t)$ [Pa] ***

Exercise 10. Pressure II

Find the difference between the lowest and highest pressure for a room at 1 [atm] = 10^5 [Pa], with sound waves given by $y(x,t) = A\cos(kx - \omega t)$, for $A = 0.1$ [m], $\omega = 2155$ [s^{-1}], and $k = 0.5$ [m^{-1}]. Assume that the bulk modulus of air is $B = 10^3$ Pa. Hint: $p_{\text{wave}}(x,t) = -B\partial_x y(x,t)$.

(a) 1.0 [Pa]

(b) 10 [Pa]

(c) 100 [Pa] ***

(d) 1000 [Pa]

Exercise 11. Intensity I

Find the intensity as a function of time for a wave given by $y(x,t) = A\cos(kx - \omega t)$. Hint: $I = p(x,t)v_y(x,t)$, where $p(x,t) = -B\partial_x y(x,t)$ and $v_y(x,t) = \partial_t y(x,t)$.

Exercise 12. Intensity II

Find the average intensity in [W/m^2] of a wave given by $y(x,t) = A\cos(kx - \omega t)$, with $A = 0.2$ [mm], $k = 8.33$ [1/m], and $\omega = 60$ [rad/s]. Assume that the bulk modulus of air is 10^5 [Pa]. Hint: $\int_0^{n\pi} d\theta\ \sin^2(\theta)/n\pi = 1/2$.

(a) 1 [W/m^2] ***

(b) 10 [W/m^2]

(c) 100 [W/m^2]

(d) 1000 [W/m^2]

Exercise 13. Intensity III

How many decibels is this? Hint: $\beta = 10\log_{10}(I/I_0)$ [dB], where $I_0 = 10^{-12}$ [W/m^2].

(a) 0 dB

(b) 30 dB

(c) 60 dB

(d) 120 dB ***

Exercise 14. Nodes of Standing Waves

Draw standing waves in each of the following tubes, noting that closed ends are nodes, and open ends are antinodes. Draw pressure on the y-axis and position on the x axis.

Closed tube

Half-open tube

Open tube

Label the pressure and displacement nodes and antinodes, noting that "a pressure node is always a displacement antinode, and a pressure antinode is always a displacement node."

Exercise 15. Open Pipe

Consider an open pipe, of diameter $d = 2$ [cm], length $L = 0.3$ [m]. Assuming that the speed of sound is 344 [m/s], find the frequency of the second harmonic. Hint: $f_n = nv/2L$, for $n \in \mathbb{N}$. How does mode number relate to harmonic?

Exercise 16. Stopped Pipe

Consider an pipe, stopped at one end, of diameter $d = 2$ [cm], length $L = 0.3$ [m]. Assuming that the speed of sound is 344 [m/s], find the frequency of the second harmonic. Hint: $f_n = nv/4L$, for $n \in \{\mathbb{N} : n \text{ odd}\}$.

Exercise 17. Interference I

Suppose you stand at the midpoint between two speakers that are separated by 5 [m]. If the speed of sound is 343 [m/s], and the speakers play a tone at 1372 [Hz], do you hear anything? Hint: $\lambda = v/f$.

Exercise 18. Interference II

Now, suppose that you take a one meter step forward. Do you hear anything now?

Exercise 19. Beats

Can humans detect the changing loudness of beats frequency of two musicians, one who plays C = 261.63 Hz and one who plays A = 440.00 Hz? Hint: assume that at above 20 [Hz], humans hear beats as a new frequency, while below 20 [Hz], beats like an oscillation of loudness.

(a) No, the beats frequency is 701.63 [Hz]

(b) No, the beats frequency is 178.37 [Hz] ***

(c) Yes, the beats frequency is 1.6818 [Hz]

(d) Yes, the beats frequency is 0.5946 [Hz]

Exercise 20. Doppler I

Consider a runner crossing the finish line of a race at 6 [m/s], and yelling in excitement at 300 [Hz]. At what frequency does a stationary observer in front of the runner hear the yell?

(a) 294.8 [Hz] ***

(b) 297.4 [Hz]

(c) 300.0 [Hz]

(d) 305.3 [Hz]

Exercise 21. Doppler II

Now, the observer responds and shouts at a frequency of 250 [Hz]. At what frequency does the runner hear the shout?

(a) 245.7 [Hz]

(b) 250.0 [Hz]

(c) 252.2 [Hz] ***

(d) 254.4 [Hz]

Exercise 22. Speed of Sound in an Ideal Gas I

Show that $v = \sqrt{\gamma RT/M}$ has units of [m/s], where γ is the heat capacity $[\gamma] = [\text{J/K}]$, R is the Boltzmann (gas) constant $[R] = [\text{J/mol K}]$, temperature has units $[T] = [\text{K}]$, and M is the molar mass and has units of $[M] = [\text{kg/mol}]$. Note: molar mass is often given in [g/mol].

Exercise 23. Speed of Sound in an Ideal Gas II

Assuming that oxygen gas, O_2, and nitrogen gas, N_2, have the same heat capacity and are at the same temperature, in which medium does sound travel faster? Hint: $M_{\text{oxygen}} = 0.016$ [kg/mol], and $M_{\text{nitrogen}} = 0.014$ [kg/mol].

(a) sound is faster in oxygen

(b) sound is faster in nitrogen ***

Exercise 24. Transverse Wave

Draw a transverse wave given by $y(x,t) = A\cos(kx - \omega t)$. Label your axes, x and y.

Exercise 25. Longitudinal Wave

Draw a longitudinal wave given by $y(x,t) = A\cos(kx - \omega t)$. Label your axis, x. What is y here?