Exercise 1. Radio Wavelength

Suppose you tune your radio to 650 kHz (AM Radio). What is the wavelength of these waves? Hint: $v = \lambda f$.

(a) 650 [m]
(b) 46.2 [m] ***
(c) 2.99 [m]
(d) 0.00217 [m]

Exercise 2. Voice

Suppose that the average wavelength of someone's voice during a conversation is 1.72 [m]. If the speed of sound is 343 [m/s], what is the average frequency of their voice?

(a) 240 [Hz]
(b) 220 [Hz]
(c) 200 [Hz] ***
(d) 180 [Hz]
(e) 160 [Hz]
(f) 140 [Hz]

Exercise 3. Tuning an Instrument

Middle C has a frequency of 440 [Hz], if the speed of sound is 343 [m/s], then using $L = n\lambda/2$, what length of string gives Middle C as its fundamental frequency? ($n = 1$)

(a) 0 [m]
(b) 0.20 [m]
(c) 0.39 [m] ***
(d) 0.78 [m]

Exercise 4. Eardrum

Approximate your eardrum as a 1 [cm] long string that weighs 8.5 [mg]. Assuming that sound propagates at 343 [m/s], what force does sound exert on your eardrum? Hint: for a string, $v = \sqrt{F/\mu}$. Convert to SI.

(a) 100 [N] ***
(b) 10 [N]
(c) 1 [N]
(d) 0.1 [N]

Exercise 5. Sound in Steel

The speed of sound in a typical steel is 6000 [m/s]. Find the wavelength of a wave propagating with angular frequency 600 [rad/s]. Hint: $\omega = vk$, and $k = 2\pi/\lambda$.

(a) 6000 [m]
(b) 600 [m]
(c) 62.8 [m] ***
(d) 6.28 [m]

Exercise 6. Changing Power

Keeping force constant and angular frequency constant, by what factor does doubling the wave vector k change the power?

(a) 2 ***
(b) 1
(c) 0.5
(d) 0

Exercise 7. Snake

For a snake to move forward, are the oscillations transverse or longitudinal?

(a) transverse ***
(b) longitudinal

Exercise 8. Power I

Suppose that power is given by $P(x,t) = F_y(x,t)v_y(x,t) = F\ \partial_x y(x,t)\partial_t y(x,t)$. Find power as a function of position and time for a rope stretched with a force of 50 [N], and a wave given by $y(x,t) = A\sin(kx - \omega t)$, for an amplitude of 0.1 [m], a wavevector of 2 [m^{-1}], and an angular frequency of 4.71 [rad/s].

(a) $0.942\cos^2(2x - 4.71t)$ ***

(b) $0.942\cos^2(4.71x - 2t)$

(c) $22.2\cos^2(2x - 4.71t)$

(d) $4\cos^2(4.71x - 2t)$

Exercise 9. Power II

Suppose that power is given by $P(x,t) = F_y(x,t)v_y(x,t) = F\ \partial_x y(x,t)\partial_t y(x,t)$. Find the maximum power at $x = 0$ and the time at which it occurs for a rope stretched with a force of 50 [N], and a wave given by $y(x,t) = A\sin(kx - \omega t)$, for an amplitude of 0.1 [m], a wavevector of 2 [m^{-1}], and an angular frequency of 4.71 [rad/s].

(a) 0.942 [W] ***

(b) 4 [W]

(c) 4.71 [W]

(d) 22.2 [W]

Exercise 10. Power III

Suppose that power is given by $P(x,t) = F_y(x,t)v_y(x,t) = F\ \partial_x y(x,t)\partial_t y(x,t)$. Find the average power at $x = 0$ for a rope stretched with a force of 50 [N], and a wave given by $y(x,t) = A\sin(kx - \omega t)$, for an amplitude of 0.1 [m], a wavevector of 2 [m^{-1}], and an angular frequency of 4.71 [rad/s].

(a) 0 [W]

(b) 0.74 [W] ***

(c) 0.94 [W]

(d) 4.71 [W]

Exercise 11. Surfing

Approximating waves as sinusoidal waves, find the maximum velocity of a surfer stationary at position x on wave that obeys $y(x,t) = 2\cos(5x - 0.075t)$. Assume that units are SI.

(a) ± 0.03 [m/s]

(b) ± 0.075 [m/s]

(c) ± 0.15 [m/s] ***

(d) ± 5 [m/s]

Exercise 12. 15.27A

By measurement you determine that sound waves are spreading out equally in all directions from a speaker and that the intensity is 0.026 [W/m^2] at a distance of 4.3 m from the source. What is the intensity at a distance of 3.1 [m] from the source?

(a) 0.026 [W/m^2]

(b) 0.031 [W/m^2]

(c) 0.036 [W/m^2]

(d) 0.050 [W/m^2] ***

Exercise 13. 15.27B

How much sound energy does the source emit in one hour if its power output remains constant? How much does this cost if electricity costs \$0.11/kWh?

(a) \$0.664

(b) \$0.0664

(c) \$0.00664

(d) \$0.000664 ***

Exercise 14. 15.42A

A piano tuner stretches a piano wire with a tension of 800 [N]. The wire is 0.400 [m] long and has a mass of 3.00 [g]. What is the frequency of its fundamental mode of vibration?

(a) 409 [Hz] ***
(b) 440 [Hz]
(c) 818 [Hz]
(d) 880 [Hz]

Exercise 15. 15.42B

What is the number of the highest harmonic that could be heard by a person who is capable of hearing frequencies up to 10000 [Hz]?

(a) 1
(b) 2
(c) 6
(d) 24 ***

Exercise 16. 15.42C

Suppose that the wire is steel, and the speed of sound is 6000 [m/s]. If a piano hammer strikes at a 45 degree angle to the wire, both longitudinal and transverse waves will be produced. How fast do the transverse waves propagate? Hint: $v = \sqrt{F/\mu}$

(a) 300 [m/s]
(b) 327 [m/s] ***
(c) 343 [m/s]
(d) 359 [m/s]

Exercise 17. 15.59

The lower end of a uniform bar of mass 45.0 [kg] is attached to a wall by a frictionless hinge. The bar is held by a horizontal wire attached at its upper end so that the bar makes an angle of 30 degrees with the wall. The wire has length 0.330 [m] and mass 0.0920 [kg]. What is the frequency of the fundamental standing wave for transverse waves on the wire? Hint: equate the torques at each end of the wire to find the force. $\boldsymbol{\tau} = \boldsymbol{r} \times \boldsymbol{F}$.

(a) 16.2 [Hz]
(b) 32.4 [Hz] ***
(c) 64.8 [Hz]
(d) 129.6 [Hz]

Exercise 18. Wind

Suppose that there is wind at your back blowing at 13 [m/s] and you yell. At what time will a person 33 [m] from you hear your yell? Assume the speed of sound is 343 [m/s].

(a) 0.1041 [s]
(b) 0.1000 [s]
(c) 0.0962 [s]
(d) 0.0927 [s] ***

Exercise 19. Left and Right

Which wave travels left and which travels right as time increases? Hint: think about where $kx \pm \omega t = 0$.

$$\psi_1 = A\cos(kx + \omega t); \qquad \psi_2 = A\cos(kx - \omega t)$$

(a) ψ_1 is left, ψ_2 is right ***
(b) ψ_2 is left, ψ_1 is right

Exercise 20. Superposition of Waves

Where is a maximum of $y(x) = \cos(x) + \sin(x)$?

(a) 0
(b) $\pi/4$ ***
(c) $\pi/2$
(d) $3\pi/4$
(e) π
(f) 2π

Exercise 21. Phase Shift

Show that $\sin(x + \pi/2) = \cos(x)$. Hint: Euler's identity states $\exp(i\theta) = \cos(\theta) + i\sin(\theta)$, which means $\exp(i\pi/2) = i$, and $\exp(i\pi) = \exp(-i\pi) = -1$. Factoring helps.

Exercise 22. Even and Odd

Give an example of an even function. Give an example of an odd function.

Exercise 23. Wave Equation I

Show that:

$$y(x,t) = A\cos(kx - \omega t)$$

Obeys the wave equation:

$$\partial_{xx} y(x,t) = \frac{1}{v^2}\partial_{tt} y(x,t)$$

Exercise 24. Wave Equation II

Find the velocity for the wave $y(x,t) = 0.33\cos(50x - 1.5t)$. Assume that units are SI.

Exercise 25. Arguments

i. Argue that takes energy to keep generating a wave.

ii. Argue that a wave propagates but the medium stays at rest.

iii. Give an example where a wave propagates in a medium that is not at rest.

Exercise 26. Interference I

Draw a picture of waves that interfere constructively. Draw a picture of waves that interfere destructively. If applicable, label the nodes and antinodes.

Exercise 27. Interference II

Waves do not necessarily interfere exclusively constructively or destructively. For example $y(x) = \cos(x) + \cos(2x)$ has regions of both constructive and destructive interference. State the conditions for constructive and destructive interference.

Exercise 28. Types of Waves

When I was young I knew that light had a frequency of 5×10^{14} [Hz], so I thought if someone could sing at that frequency, you could see the sound of their voice. Explain why this is strictly incorrect. What would happen if someone sang like this?

Exercise 29. Longitudinal Light

Einstein's relativity says that nothing can move faster than c, the speed of light's propagation. Argue that light propagating in $\hat{\boldsymbol{z}}$ has only $\hat{\boldsymbol{x}}$ and $\hat{\boldsymbol{y}}$ polarization. Equivalently, argue that there can be no longitudinal electromagnetic waves.

Exercise 30. De Broglie Postulate

In quantum mechanics, the De Broglie Postulate relates the momentum of a particle to the wave-vector of a corresponding "matter wave", according to $p = \hbar k$. If $\hbar = 1.055 \times 10^{-34}$ [J s], show that $\hbar k$ has units of momentum. Note: quantum mechanics is the wave description of matter, so if $\hbar = 0$ there would be no need for quantum mechanics.