Mr. Wright's Math Extravaganza

Physical Sciences

(Chemistry, Physics, Physical Science)

Electromagnetic Radiation

Units 10 Waves and Sound, 11 Electromagnetic Rays, 12 Dual Nature of Light

Average Level for All Three Units

Level 2.0: 70% on test, Level 3.0: 80% on test, Level 4.0: level 3.0 and success on particle-wave lab

Score	I Can Statements
4.0	**12 Dual Nature of Light** ☐ I can decide whether the effects of different frequencies of electromagnetic radiation are best explained by the particle model or the wave model.
3.5	In addition to score 3.0 performance, partial success at score 4.0 content.
3.0	**11 Electromagnetic Rays** ☐ I can explain the effects of different frequencies of electromagnetic radiation on matter when absorbed. **12 Dual Nature of Light** ☐ I can explain differences between the particle model and the wave model for electromagnetic radiation.
2.5	No major errors or omissions regarding score 2.0 content, and partial success at score 3.0 content.
2.0	**10 Waves and Sound** ☐ I can explain that energy can be transferred from one point to another through a wave or a particle. ☐ I can define characteristics and properties of waves and wave interactions. ☐ I can explain how wave interactions would affect the amplitude of the wave. ☐ I can explain the relationship between the energy carried by a wave, its frequency, its wavelength, and its amplitude. ☐ I can explain the Doppler effect. **11 Electromagnetic Rays** ☐ I can describe the types of waves that compose the electromagnetic spectrum in order from low frequency to high frequency. ☐ I can explain the difference between electromagnetic waves traveling in a vacuum versus those traveling through various media. ☐ I can list characteristics of electromagnetic waves. ☐ I can explain why electromagnetic waves above visible light are considered dangerous to humans after too much exposure. ☐ I can explain how scientists use the emission and absorption spectra to identify the composition of substances. ☐ I can explain the behaviors of waves at a boundary. **12 Dual Nature of Light** ☐ I can relate photons to electromagnetic radiation in terms of waves and particles. ☐ I can explain how photons simultaneously act like particles and waves.

	☐ I can describe the behavior of waves passing through a slit(s). I can identify nodes and antinodes on a resonating wave.
1.5	Partial success at score 2.0 content, and major errors or omissions regarding score 3.0 content.
1.0	With help, partial success at score 2.0 content and score 3.0 content.
0.5	With help, partial success at score 2.0 content but not at score 3.0 content.
0.0	Even with help, no success.

Physics 10-01 Waves **_Name:_** ________________________

Waves

- A traveling ________________
- Carries ________________ from place to place

When a boat makes a wave,

- the water itself does not get up and move
- the water ________________ a little, then moves ________________
- energy is ________________ in the wave and is what you ________________

Transverse

- ________________ and ________________ disturbance
- Wave travels ________________ or ________________
- Disturbance is ________________ to direction of travel
- Examples:
  - ________________ waves, ________________ waves, ________________waves, ________________ instruments

Longitudinal Waves

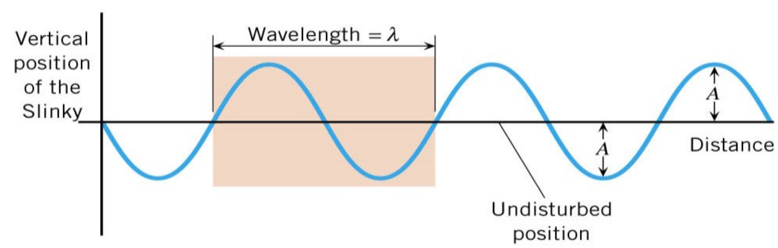
- Disturbance is ________________ and ________________
- Direction of travel is ________________ or ________________
- Disturbance and direction of travel are ________________
- Series of ________________ and ________________ regions
- Example:
  - ________________

Other

- Water waves are a ________________
- Water at the surface of a water wave travels in small ________________

Parts of a Wave at a Particular Time

- Periodic → pattern is regularly ______________
- Cycle → one unit of ________________
- Wavelength (λ) → ______________ of one cycle
- Amplitude (A) → ________________ from equilibrium to crest



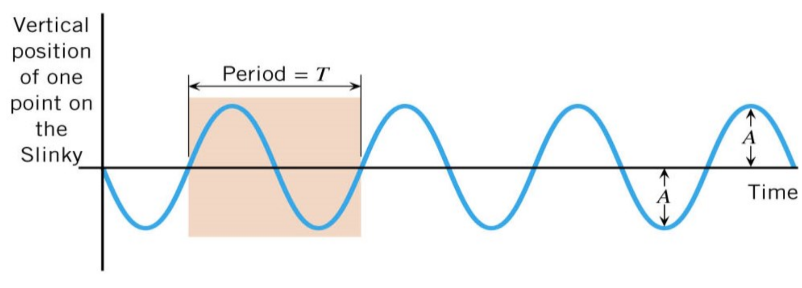
(a) At a particular time

Parts of a Wave at a Particular Location

- Period (T) → time it takes for one __________
- Unit: s
- Frequency (f) → number of ________________ per ________________
- Unit: 1/s = 1 hertz (Hz)

$$f = \frac{1}{T}$$

$$v = \frac{\lambda}{T} = f \cdot \lambda$$



(b) At a particular location

WAUS operates at a frequency of 90.7 MHz. These waves travel at 2.99×10^8 m/s. What is the wavelength and period of these radio waves?

Physics 10-01 Waves **Name:** ________________________

You are sitting on the beach and notice that a seagull floating on the water moves up and down 15 times in 1 minute. What is the frequency of the water waves?

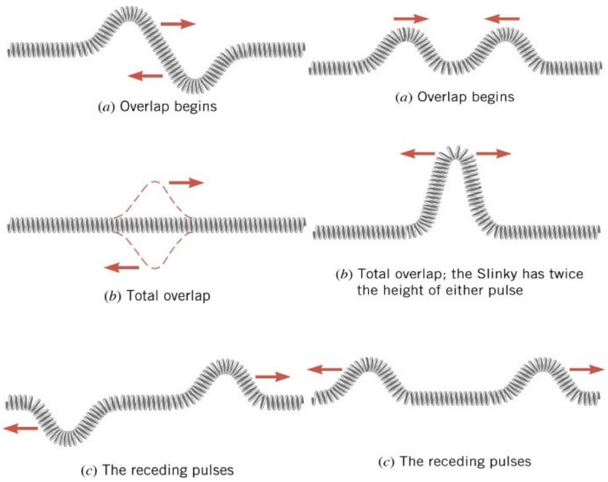
Practice Work

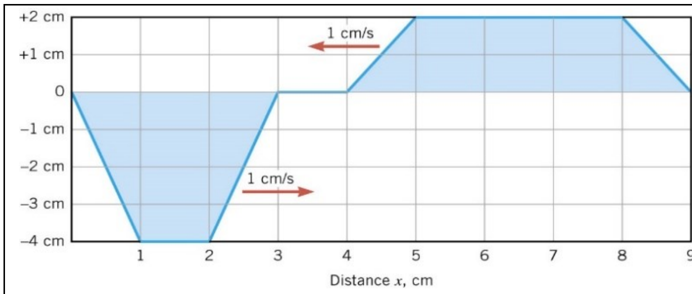
1. "Domino Toppling" is one entry in the *Guinness Book of World Records*. The event consists of lining up an incredible number of dominoes and then letting them topple, one after another. Is the disturbance that propagates along the line of dominoes transverse, longitudinal, or partly both? Explain.
2. Suppose that a longitudinal wave moves along a Slinky at a speed of 5 m/s. Does one coil of the Slinky move through a distance of 5 m in one second? Justify your answer.
3. Give one example of a transverse wave and another of a longitudinal wave, being careful to note the relative directions of the disturbance and wave propagation in each.
4. What is the difference between propagation speed and the frequency of a wave? Does one or both affect wavelength? If so, how?
5. What is the period of 60.0 Hz electrical power? (OpenStax 16.7) **16.7 ms**
6. If your heart rate is 150 beats per minute during strenuous exercise, what is the time per beat in units of seconds? (OpenStax 16.8) **0.400 s/beat**
7. Find the frequency of a tuning fork that takes 2.50×10^{-3} s to complete one oscillation. (OpenStax 16.9) **400 Hz**
8. A stroboscope is set to flash every 8.00×10^{-5} s. What is the frequency of the flashes? (OpenStax 16.10) **12500 Hz**
9. Storms in the South Pacific can create waves that travel all the way to the California coast, which are 12,000 km away. How long does it take them if they travel at 15.0 m/s? (OpenStax 16.47) **9.26 d**
10. Waves on a swimming pool propagate at 0.750 m/s. You splash the water at one end of the pool and observe the wave go to the opposite end, reflect, and return in 30.0 s. How far away is the other end of the pool? (OpenStax 16.48) **11.3 m**
11. Wind gusts create ripples on the ocean that have a wavelength of 5.00 cm and propagate at 2.00 m/s. What is their frequency? (OpenStax 16.49) **40.0 Hz**
12. How many times a minute does a boat bob up and down on ocean waves that have a wavelength of 40.0 m and a propagation speed of 5.00 m/s? (OpenStax 16.50) **7.50 times**
13. What is the wavelength of an earthquake that shakes you with a frequency of 10.0 Hz and gets to another city 84.0 km away in 12.0 s? (OpenStax 16.53) **700 m**
14. Radio waves transmitted through space at 3.00×10^8 m/s by the Voyager spacecraft have a wavelength of 0.120 m. What is their frequency? (OpenStax 16.54) $\mathbf{2.50 \times 10^9}$ **Hz**
15. A person lying on an air mattress in the ocean rises and falls through one complete cycle every five seconds. The crests of the wave causing the motion are 20.0 m apart. Determine (a) the frequency and (b) the speed of the wave. (Cutnell 16.6) **0.200 Hz, 4.00 m/s**

Physics 10-02 Superposition and Interference Name: ____________________

Superposition

- Often ____________ or more wave ____________ move through the same ____________ at once
- When two or more waves are present ________________ at the same place, the ____________ disturbance is the ____________ of the disturbances from ____________ waves



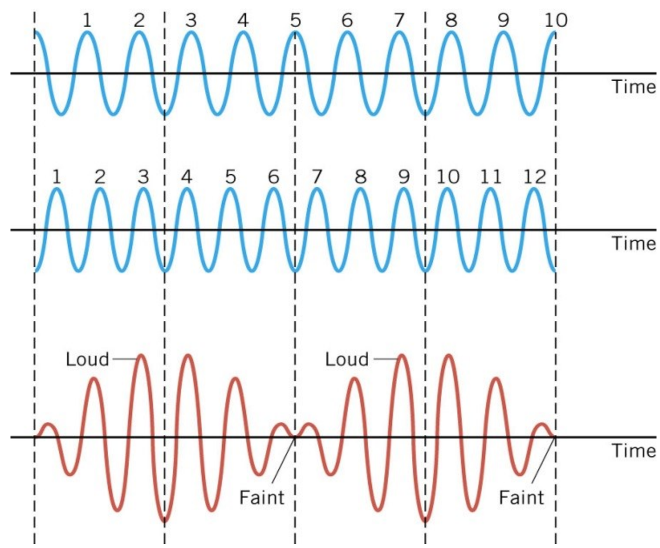


After 2 seconds, what is the height of the resultant pulse at x = 2, 4, and 6 cm?

Beats

- When two ____________ are the ____________
- Constructive and Destructive Interference give ____________ the amplitude or ____________ amplitude
- What if the two frequencies are just slightly ____________?
- Beat Frequency = ____________ of the two ____________ frequencies

$$Beats = |f_1 - f_2|$$



Two car horns have an average frequency of 420 Hz and a beat frequency of 40 Hz. What are the frequencies of both horns?

Standing Waves

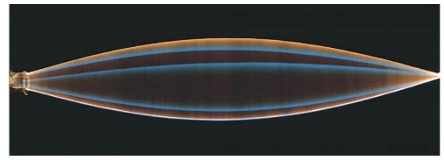
- Waves that don't appear to ____________
- Formed by the ____________________of two waves moving in ____________directions
- If the waves have the same ____________and ____________, then they alternate between constructive and destructive interference

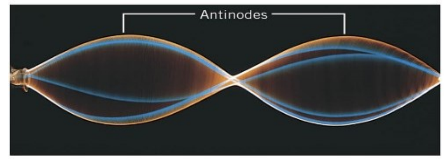
How Standing Waves are Created

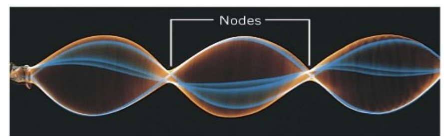
- The wave travels along the string until it hits the other end
- The wave ____________off the other end and travels in the opposite direction, but ____________down
- The returning wave hits the vibrating end and reflects again (this side the wave is ____________side up)
- If the timing is just right the reflecting wave and the new wave will ____________

Physics 10-02 Superposition and Interference *Name: ________________________*

- One end of a string is attached to a _____________point.
- The other end is _____________up and down.
- The ______________ is formed.
- Nodes – ______________
- Antinodes – ______________

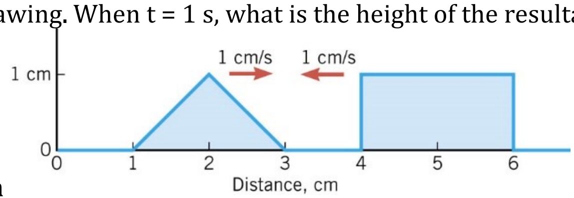






Practice Work

1. Speakers in stereo systems have two color-coded terminals to indicate how to hook up the wires. If the wires are reversed, the speaker moves in a direction opposite that of a properly connected speaker. Explain why it is important to have both speakers connected the same way.
2. Does the principle of linear superposition imply that two sound waves, passing through the same place at the same time, always create a louder sound than either wave alone? Explain.
3. A tuning fork has a frequency of 440 Hz. The string of a violin and this tuning fork, when sounded together, produce a beat frequency of 1 Hz. From these two pieces of information alone, is it possible to determine the exact frequency of the violin string? Explain.
4. A car has two horns, one emitting a frequency of 199 Hz and the other emitting a frequency of 203 Hz. What beat frequency do they produce? (OpenStax 16.57) **4 hz**
5. The middle-C hammer of a piano hits two strings, producing beats of 1.50 Hz. One of the strings is tuned to 260.00 Hz. What frequencies could the other string have? (OpenStax 16.58) **261.50 Hz, 258.50 Hz**
6. Two tuning forks having frequencies of 460 and 464 Hz are struck simultaneously. What average frequency will you hear, and what will the beat frequency be? (OpenStax 16.59) **462 Hz, 4 Hz**
7. Twin jet engines on an airplane are producing an average sound frequency of 4100 Hz with a beat frequency of 0.500 Hz. What are their individual frequencies? (OpenStax 16.60) **4099.750 Hz, 4100.250 Hz**
8. Three adjacent keys on a piano (F, F-sharp, and G) are struck simultaneously, producing frequencies of 349, 370, and 392 Hz. What beat frequencies are produced by this discordant combination? (OpenStax 16.62) **21 Hz, 22 Hz, 43 Hz**
9. Two pulses are traveling toward each other, each having a speed of 1 cm/s. At t = 0 s, their positions are shown in the drawing. When t = 1 s, what is the height of the resultant pulse at (a) x = 3 cm and at (b) x = 4 cm? (Cutnell 17.1) **2 cm, 1**

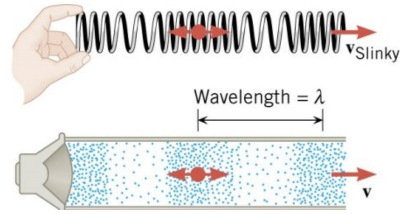


cm

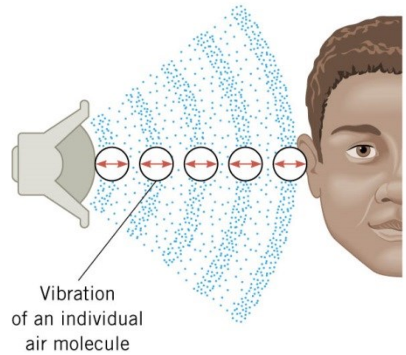
10. Two speakers, one directly behind the other, are each generating a 245-Hz sound wave. What is the smallest separation distance between the speakers that will produce destructive interference at a listener standing in front of them? The speed of sound is 343 m/s. (Cutnell 17.2) **0.700 m**
11. Two out-of-tune flutes play the same note. One produces a tone that has a frequency of 262 Hz, while the other produces 266 Hz. When a tuning fork is sounded together with the 262-Hz tone, a beat frequency of 1 Hz is produced. When the same tuning fork is sounded together with the 266-Hz tone, a beat frequency of 3 Hz is produced. What is the frequency of the tuning fork? (Cutnell 17.16) **263 Hz**
12. A 440-Hz tuning fork is sounded together with an out-of-tune guitar string, and a beat frequency of 3 Hz is heard. When the string is tightened, the frequency at which it vibrates increases, and the beat frequency is heard to decrease. What was the original frequency of the guitar string? (Cutnell 17.18) **437 Hz**
13. A tuning fork vibrates at a frequency of 524 Hz. An out-of-tune piano string vibrates at 529 Hz. How much time separates successive beats? (Cutnell 17.20) **0.2 s**

Physics 10-03 Sound **Name: ______________________**

How Sound Is Made



- Some ___________ object like a speaker moves and ___________ the air
- Air pressure rises called ___________
- Condensation moves ___________ at speed of ___________
- Object moves back creating ___________ air pressure called ___________
- Rarefaction moves ___________ at speed of ___________
- Particles move ___________ and ___________
- Distance between consecutive condensations or rarefactions is ___________



- String or speaker makes air ___________ vibrate
- That molecule pushes the ___________ one to vibrate and so on
- When it ___________ the ear, the ___________ are interpreted as ___________

Pitch

- 1 cycle = 1 ______________ + 1 ___________

$$Frequency = \frac{cycles}{second}$$

- Each frequency has own ___________
  - Sounds with 1 frequency called ___________
- Healthy ___________ people can hear frequencies of ___________ to ___________ Hz
- Brain can interpret frequency as ___________
  - High freq = ___________ pitch
  - ___________ because most people don't have ___________ pitch

Loudness

- The condensations have more ___________ than the rarefactions
- Amplitude = ___________ pressure
- Typical conversation, Amp = ___________ Pa
- Atmospheric air pressure = ___________ Pa
- ___________ is ear's interpretation of ___________ amplitude

Speed of Sound

- For ___________ waves

$$v_w = f\lambda$$

- Sound travels slowest in ___________, faster in ___________, and fastest in ___________
- Air at 20 °C → 343 m/s

Table 17.1 Speed of Sound in Various Media

Medium	v_w(m/s)
Gases at 0°C	
Air	331
Carbon dioxide	259
Oxygen	316
Helium	965
Hydrogen	1290
Liquids at 20°C	
Ethanol	1160
Mercury	1450
Water, fresh	1480
Sea water	1540
Human tissue	1540
Solids (longitudinal or bulk)	
Vulcanized rubber	54
Polyethylene	920
Marble	3810
Glass, Pyrex	5640
Lead	1960
Aluminum	5120
Steel	5960

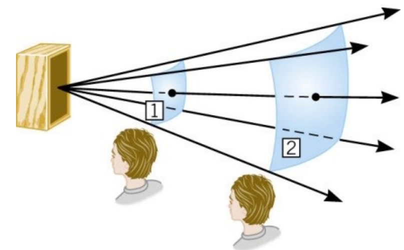
How far away is a ship if it takes 3.4 s to receive a return signal in seawater?

Physics 10-03 Sound	***Name: ______________________***
Practice Work	

1. When sound passes from one medium to another where its propagation speed is different, does its frequency or wavelength change? Explain your answer briefly.
2. A loudspeaker produces a sound wave. Does the wavelength of the sound increase, decrease, or remain the same, when the wave travels from air into water? Justify your answer.
3. When poked by a spear, an operatic soprano lets out a 1200-Hz shriek. What is its wavelength if the speed of sound is 345 m/s? (OpenStax 17.1) **0.288 m**
4. What frequency sound has a 0.10-m wavelength when the speed of sound is 340 m/s? (OpenStax 17.2) **3400 Hz**
5. Calculate the speed of sound on a day when a 1500 Hz frequency has a wavelength of 0.221 m. (OpenStax 17.3) **332 m/s**
6. (a) What is the speed of sound in a medium where a 100-kHz frequency produces a 5.96-cm wavelength? (b) Which substance in the table is this likely to be? (OpenStax 17.4) $\mathbf{5.96 \times 10^3}$ **m/s, steel**
7. Dolphins make sounds in air and water. What is the ratio of the wavelength of a sound in air to its wavelength in seawater? Assume air temperature is 20.0 °C. (OpenStax 17.7) **0.223**
8. A sonar echo returns to a submarine 1.20 s after being emitted. What is the distance to the object creating the echo? (Assume that the submarine is in the ocean, not in fresh water.) (OpenStax 17.8) **924 m**
9. (a) If a submarine's sonar can measure echo times with a precision of 0.0100 s, what is the smallest difference in distances it can detect? (Assume that the submarine is in the ocean, not in fresh water.) (b) Discuss the limits this time resolution imposes on the ability of the sonar system to detect the size and shape of the object creating the echo. (OpenStax 17.9) **7.70 m**
10. For research purposes a sonic buoy is tethered to the ocean floor and emits an infrasonic pulse of sound. The period of this sound is 71 ms. Determine the wavelength of the sound. (Cutnell 16.30) **110 m**
11. The distance between a loudspeaker and the left ear of a listener is 2.70 m. (a) Calculate the time required for sound to travel this distance if the air temperature is 20 °C. (b) Assuming that the sound frequency is 523 Hz, how many wavelengths of sound are contained in this distance? (Cutnell 16.31) $\mathbf{7.87 \times 10^{-3}}$ **s, 4.12**

Physics 10-04 Intensity	Name: ______________________

Sound Intensity



- Sound waves carry ____________ that can do ____________
- Amount of ____________ transported per ____________ = ____________
- As sound moves away from a ____________, it spreads out over a ____________ and larger ____________
- As the areas get ____________, intensity at any 1 point is ____________

$$I = \frac{P}{A}$$

  - Units: W/m^2
- If sound is transmitted ____________ in all directions, the areas are the surfaces of ____________.

$$A_{sphere} = 4\pi r^2$$

- Intensity is proportional to ____________

$$I = \frac{(\Delta p)^2}{2\rho v_w}$$

- Where Δp = pressure amplitude, ρ = density of the medium, v_w = speed of the wave

You and a friend are watching fireworks that are launching from the observatory. You are standing right in front of Berman Hall (150 m) and your friend is across campus at AA (700 m). The sound intensity at AA is 0.2 W/m^2. What is the sound intensity at your location, and how much power is the firework emitting?

Sound Level and Decibels

- Unit of measure to ____________ two sound ____________.
- Based on how human ear perceives ____________.
- If you ____________ the intensity, I, the sound is ____________ twice as loud.
- Use a ______________ scale
- Intensity Level

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

  - where β = intensity level β, I and I_0 are intensities of two sounds
- I_0 is usually ____________ W/m^2
  - Unit: dB (decibel)
- An intensity level of ____________ only means that $I = I_0$ since log (1) = 0
- Intensity can be ____________
- Loudness is simply how ear ____________
- Doubling ____________ does not double ____________

Table 17.2 Sound Intensity Levels and Intensities

Sound intensity level β (dB)	Intensity I(W/m^2)	Example/effect
0	1×10^{-12}	Threshold of hearing at 1000 Hz
10	1×10^{-11}	Rustle of leaves
20	1×10^{-10}	Whisper at 1 m distance
30	1×10^{-9}	Quiet home
40	1×10^{-8}	Average home
50	1×10^{-7}	Average office, soft music
60	1×10^{-6}	Normal conversation
70	1×10^{-5}	Noisy office, busy traffic
80	1×10^{-4}	Loud radio, classroom lecture
90	1×10^{-3}	Inside a heavy truck; damage from prolonged exposure[1]
100	1×10^{-2}	Noisy factory, siren at 30 m; damage from 8 h per day exposure
110	1×10^{-1}	Damage from 30 min per day exposure
120	1	Loud rock concert, pneumatic chipper at 2 m; threshold of pain
140	1×10^{2}	Jet airplane at 30 m; severe pain, damage in seconds
160	1×10^{4}	Bursting of eardrums

Physics 10-04 Intensity **Name: ________________________**

You double the intensity of sound coming from a stereo. What is the change in loudness?

- Experiment shows that if the intensity level increases by ____________, the sound will seem ____________ as loud.

See Table 17.2

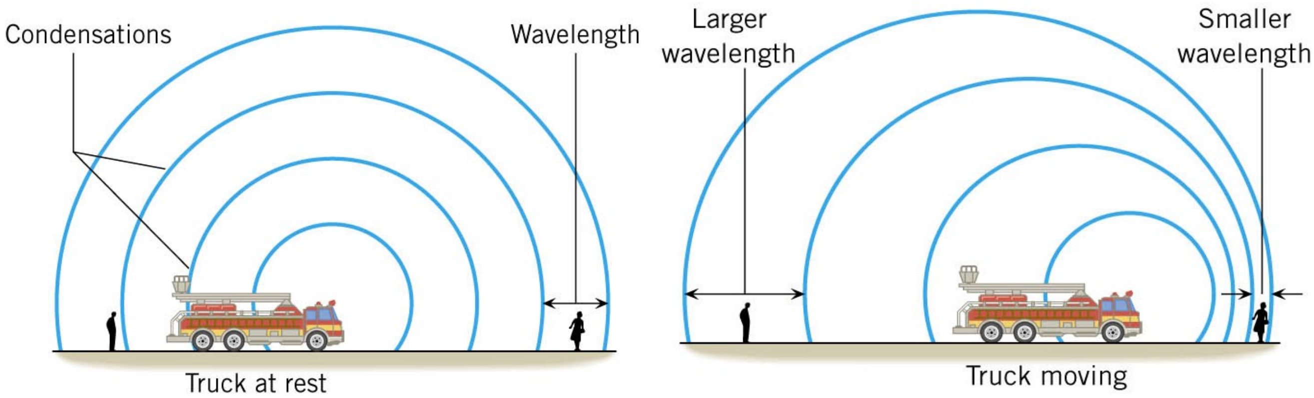
What is the intensity of a 20 dB sound?

Practice Work

1. A source is emitting sound uniformly in all directions. There are no reflections anywhere. A *flat* surface faces the source. Is the sound intensity the same at all points on the surface? Give our reasoning.
2. If two people talk simultaneously and each creates an intensity level of 65 dB at a certain point, does the total intensity level at this point equal 130 dB? Account for your answer.
3. A typical adult ear has a surface area of 2.1×10^{-3} m². The sound intensity during a normal conversation is about 3.2×10^{-6} W/m² at the listener's ear. Assume that the sound strikes the surface of the ear perpendicularly. How much power is intercepted by the ear? (Cutnell 16.48) $\mathbf{6.7 \times 10^{-9}}$ **W**
4. What is the intensity in watts per meter squared of 85.0-dB sound? (OpenStax 17.12) $\mathbf{3.16 \times 10^{-4}}$ **W/m²**
5. The warning tag on a lawn mower states that it produces noise at a level of 91.0 dB. What is this in watts per meter squared? (OpenStax 17.13) $\mathbf{1.26 \times 10^{-3}}$ **W/m²**
6. A sound wave traveling in 20 °C air (density is 1.29 kg/m³) has a pressure amplitude of 0.5 Pa. What is the intensity of the wave? (OpenStax 17.14) $\mathbf{2.83 \times 10^{-4}}$ **W/m²**
7. What intensity level does the sound in the preceding problem correspond to? (OpenStax 17.15) **85 dB**
8. What sound intensity level in dB is produced by earphones that create an intensity of 4.00×10^{-2} W/m²? (OpenStax 17.16) **106 dB**
9. (a) What is the intensity of a sound that has a level 7.00 dB lower than a 4.00×10^{-9} W/m² sound? (b) What is the intensity of a sound that is 3.00 dB higher than a 4.00×10^{-9} W/m² sound? (OpenStax 17.19) $\mathbf{7.98 \times 10^{-10}}$ **W/m²,** $\mathbf{7.98 \times 10^{-9}}$ **W/m²**
10. People with good hearing can perceive sounds as low in level as –8.00 dB at a frequency of 3000 Hz. What is the intensity of this sound in watts per meter squared? (OpenStax 17.21) $\mathbf{1.58 \times 10^{-13}}$ **W/m²**
11. If a large housefly 3.0 m away from you makes a noise of 40.0 dB, what is the noise level of 1000 flies at that distance, assuming interference has a negligible effect? (OpenStax 17.22) **70.0 dB**
12. An 8-hour exposure to a sound intensity level of 90.0 dB may cause hearing damage. What energy in joules falls on a 0.800-cm-diameter eardrum so exposed? (OpenStax 17.26) $\mathbf{1.45 \times 10^{-3}}$ **J**
13. The bellow of a territorial bull hippopotamus has been measured at 115 dB above the threshold of hearing. What is the sound intensity? (Cutnell 16.59) **0.316 W/m²**
14. Humans can detect a difference in sound intensity levels as small as 1.0 dB. What is the ratio of the sound intensities? (Cutnell 16.61) **1.3**

Physics 10-05 Doppler Effect	**Name: ________________________**
Doppler Effect	

- As a source of a sound moves by a listener
- ________________ pitch as they were ________________, ________________ pitch as they were ________________.



$$f_o = f_s\left(\frac{v_w \pm v_o}{v_w \mp v_s}\right)$$

- v_w, v_s, and v_o are ________________
- Use the top signs when that object is moving ________________ the other ________________

You are driving down the road at 20 m/s when you approach a car going the other direction at 15 m/s with their radio playing loudly. If you hear a certain note at 600 Hz, what is the original frequency? (Assume speed of sound is 343 m/s)

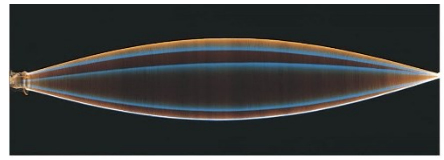
A duck is flying overhead while you stand still. As it moves away, you hear its quack at 190 Hz. Because you are a brilliant naturalist, you know that this type of duck quacks at 200 Hz. How fast is the duck flying?

Physics 10-05 Doppler Effect	***Name: ________________________***
Practice Work	

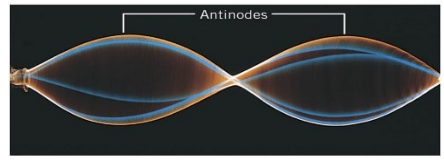
1. Is the Doppler shift real or just a sensory illusion?
2. When you hear a sonic boom, you often cannot see the plane that made it. Why is that?
3. Two cars, one behind the other, are traveling in the same direction at the same speed. Does either driver hear the other's horn at a frequency that is different from that heard when both cars are at rest? Justify your answer.
4. When a car is at rest, its horn emits a frequency of 600 Hz. A person standing in the middle of the street hears the horn with a frequency of 580 Hz. Should the person jump out of the way? Account for your answer.
5. (a) What frequency is received by a person watching an oncoming ambulance moving at 110 km/h and emitting a steady 800-Hz sound from its siren? The speed of sound on this day is 345 m/s. (b) What frequency does she receive after the ambulance has passed? (OpenStax 17.30) **878 Hz, 735 Hz**
6. (a) At an air show a jet flies directly toward the stands at a speed of 1200 km/h, emitting a frequency of 3500 Hz, on a day when the speed of sound is 342 m/s. What frequency is received by the observers? (b) What frequency do they receive as the plane flies directly away from them? (OpenStax 17.31) $\mathbf{1.38 \times 10^5}$ **Hz,** $\mathbf{1.77 \times 10^3}$ **Hz**
7. What frequency is received by a mouse just before being dispatched by a hawk flying at it at 25.0 m/s and emitting a screech of frequency 3500 Hz? Take the speed of sound to be 331 m/s. (OpenStax 17.32) $\mathbf{3.79 \times 10^3}$ **Hz**
8. A spectator at a parade receives an 888-Hz tone from an oncoming trumpeter who is playing an 880-Hz note. At what speed is the musician approaching if the speed of sound is 338 m/s? (OpenStax 17.33) **3.05 m/s**
9. A commuter train blows its 200-Hz horn as it approaches a crossing. The speed of sound is 335 m/s. (a) An observer waiting at the crossing receives a frequency of 208 Hz. What is the speed of the train? (b) What frequency does the observer receive as the train moves away? (OpenStax 17.34) **12.9 m/s, 193 Hz**
10. Can you perceive the shift in frequency produced when you pull a tuning fork toward you at 10.0 m/s on a day when the speed of sound is 344 m/s? To answer this question, calculate the factor by which the frequency shifts and see if it is greater than 0.300%. (OpenStax 17.35) **1.030**
11. The security alarm on a parked car goes off and produces a frequency of 960 Hz. The speed of sound is 343 m/s. As you drive toward this parked car, pass it, and drive away, you observe the frequency to change by 95 Hz. At what speed are you driving? (Cutnell 16.71) **17 m/s**
12. Suppose you are stopped at a traffic light, and an ambulance approaches you from behind with a speed of 18 m/s. the siren on the ambulance produces sound with a frequency of 955 Hz. The speed of sound in air is 343 m/s. What is the wavelength of the sound reaching your ears? (Cutnell 16.72) **0.340 m**
13. A speeder looks in his rearview mirror. He notices that a police car has pulled behind him and is matching his speed of 38 m/s. The siren on the police car has a frequency of 860 Hz when the police car and the listener are stationary. The speed of sound is 343 m/s. What frequency does the speeder hear when the siren is turned on in the moving police car? (Cutnell 16.73) **860 Hz**
14. A bird is flying directly toward a stationary bird-watcher and emits a frequency of 1250 Hz. The bird-watcher, however, hears a frequency of 1290 Hz. What is the speed of the bird, expressed as a percentage of the speed of sound? (Cutnell 16.74) **3.1%**

Physics 10-06 Resonance *Name:* ________________________

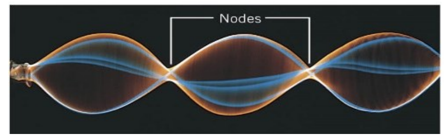
String Attached at Both Ends



- The ________________ wave is formed.
- Nodes – ________________
- Antinodes – ________________



- The wave ________________ along the string until it hits the other ______________
- The wave ________________ off the other end and travels in the ________________ direction, but ________________
- The returning wave hits the ________________ end and ________________ again (this side the wave is ________________________)
- Unless the timing is just right the reflecting wave and the new wave will not ________________



- When they do coincide, the waves add due to ________________ interference
- When they don't coincide; ________________ interference

Harmonics

- When you vibrate the string faster, you can get standing waves with ________________ nodes and antinodes
- Standing waves are named by number of ________________
- 1 antinode → 1st harmonic (fundamental frequency)
- 2 antinodes → 2nd harmonic (1st overtone)
- 3 antinodes → 3rd harmonic (2nd overtone)

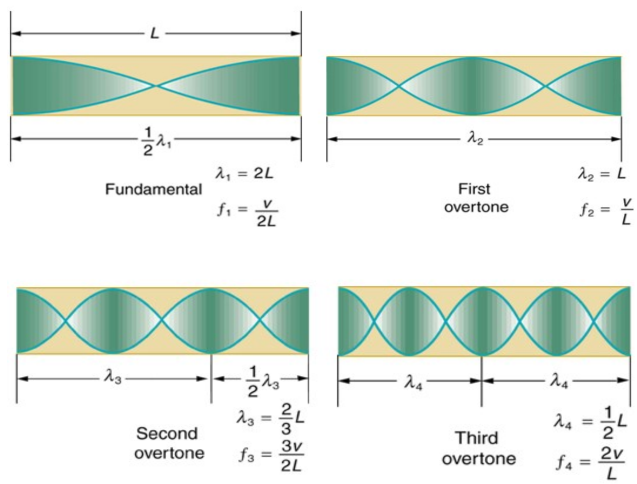
- f_1 = fundamental frequency (1st harmonic)
- $f_2 = 2f_1$ (2nd harmonic)
- $f_3 = 3f_1$ (3rd harmonic)

- To find the fundamental frequencies and harmonics of a string fixed at ________________ ends

$$f_n = n\left(\frac{v_w}{2L}\right)$$

- Where f_n = frequency of the n^{th} harmonic, n = integer (harmonic #), v_w = speed of wave, L = length of string

Tube open at both ends



- Wind instruments rely on standing __________________ sound waves in ________________
- The waves ________________ off the open ends of tubes
- One difference at the ends are ________________ instead of nodes

Formula for Tube Open at Both Ends

$$f_n = n\left(\frac{v_w}{2L}\right)$$

What is the lowest frequency playable by a flute that is 0.60 m long if that air is 20 °C.

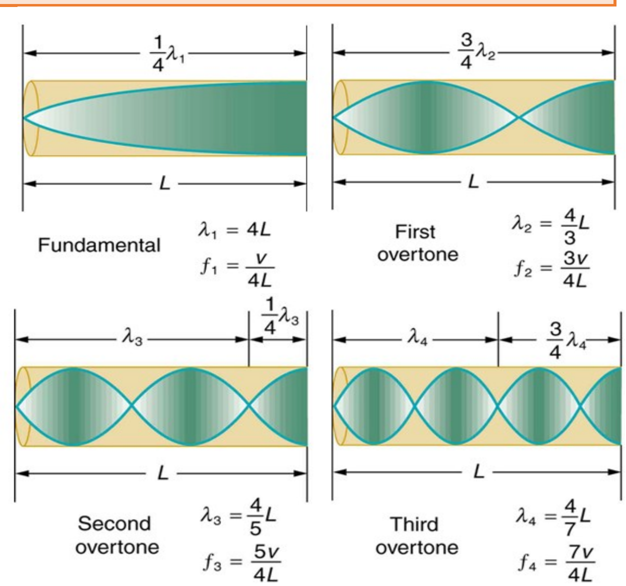
Physics 10-06 Resonance *Name:* ________________________

Tube open at one end

- Node at the _______________ end
- Antinode at the _______________ end
- Lengths are *odd integer* multiples of ¼ λ

$$f_n = n\left(\frac{v_w}{4L}\right)$$

- Only _______________ harmonics

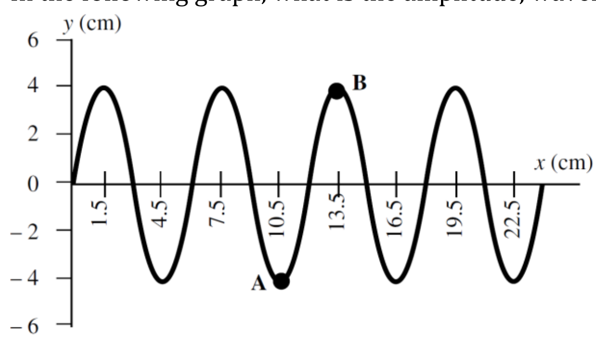


Practice Work

1. A rope is hanging vertically straight down. The top end is being vibrated back and forth. Standing waves can develop on the rope analogous to those on a horizontal rope. There is a node at the top end. Is there a node or an antinode at the bottom end? Try it.
2. How does an unamplified guitar produce sounds so much more intense than those of a plucked string held taut by a simple stick?
3. What is the difference between an overtone and a harmonic? Are all harmonics overtones? Are all overtones harmonics?
4. (a) What is the fundamental frequency of a 0.672-m-long tube, open at both ends, on a day when the speed of sound is 344 m/s? (b) What is the frequency of its second harmonic? (OpenStax 17.42) **256 Hz, 512 Hz**
5. If a wind instrument, such as a tuba, has a fundamental frequency of 32.0 Hz, what are its first three overtones? It is closed at one end. (The overtones of a real tuba are more complex than this example, because it is a tapered tube.) (OpenStax 17.43) **96.0 Hz, 160 Hz, 224 Hz**
6. What are the first three overtones of a bassoon that has a fundamental frequency of 90.0 Hz? It is open at both ends. (The overtones of a real bassoon are more complex than this example, because its double reed makes it act more like a tube closed at one end.) (OpenStax 17.44) **180 Hz, 270 H, 360 Hz**
7. How long must a flute be in order to have a fundamental frequency of 262 Hz (this frequency corresponds to middle C on the evenly tempered chromatic scale) on a day when air temperature is 20.0 °C? It is open at both ends. (OpenStax 17.45) **65.4 cm**
8. What length should an oboe have to produce a fundamental frequency of 110 Hz on a day when the speed of sound is 343 m/s? It is open at both ends. (OpenStax 17.46) **1.56 m**
9. What is the length of a tube that has a fundamental frequency of 176 Hz and a first overtone of 352 Hz if the speed of sound is 343 m/s? (OpenStax 17.47) **0.974 m**
10. (a) Find the length of an organ pipe closed at one end that produces a fundamental frequency of 256 Hz when air temperature is 18.0 °C. (Speed of sound is 342 m/s.) (b) What is its fundamental frequency at 25.0 °C? (Speed of sound is 346 m/s.) (OpenStax 17.48) **0.334 m, 259 Hz**
11. The G string on a guitar has a fundamental frequency of 196 Hz and a length of 0.62 m. This string is pressed against the proper fret to produce the note C, whose fundamental frequency is 262 Hz. What is the distance *L* between the fret and the end of the string at the bridge of the guitar? (Cutnell 17.25) **0.46 m**
12. Sound enters the ear, travels through the auditory canal, and reaches the eardrum. The auditory canal is approximately a tube open at only one end. The other end is closed by the eardrum. A typical length for the auditory canal in an adult is about 2.9 cm. The speed of sound is 343 m/s. What is the fundamental frequency of the canal? (Interestingly, the fundamental frequency is in the frequency range where human hearing is most sensitive.)(Cutnell 17.36) **3000 Hz**

Physics Unit 10: Waves and Sound Review

1. Know meanings of reflect, interference, beats, constructive, destructive, frequency, superposition, wavelength, standing wave, fundamental frequency, harmonics (i.e. 1st harmonic, 2nd harmonic), overtones (i.e. 1st overtone, 2nd overtone), resonate.
2. Be able to classify waves by type (longitudinal, transverse, or both).
3. Know the value of the threshold of hearing.
4. Know how frequency and pitch are related.
5. Know how decibels and loudness are related.
6. Know what affects the speed of a wave ($v = f\lambda$ and how each variable is determined)
7. Know some drawings to represent standing waves in open and closed tubes.
8. How are standing waves produced?
9. How are beats produced?
10. What happens when two wave pulses traveling opposite directions meet?
11. Do waves: move energy? Move matter from place to place? Have a traveling disturbance?
12. What is the λ for a wave with a speed of 10 m/s and a period of 40 s?
13. A wave has a frequency of 30 Hz and a speed of 60 m/s. What is the wavelength of the wave?
14. In the following graph, what is the amplitude, wavelength and frequency of wave A is its speed is 5 cm/s?



15. A submarine sends out a sonar ping. The return echo is heard 20 s later. If the speed of sound is 1522 m/s, how far away is the reflecting surface?
16. A guitar string produces 10 beats/s when sounded with a 440 Hz tuning fork and 5 beats/s when sounded with a 445 Hz tuning fork. What is the vibrational frequency of the string?
17. The intensity of a spherical wave 5 m from the source is 200 W/m^2. What is the intensity at a point 10 m away from the source?
18. The decibel level of rock concert is 120 dB relative to the threshold of hearing. Determine the sound intensity produced by the concert.
19. A car moving at constant speed passes a boy playing a concert A (440 Hz) on an instrument. After the car has passed the driver hears the note as a concert E (330 Hz). How fast was the car going (speed of sound = 343 m/s)?
20. A car moving at 50 m/s approaches a train whistling. The train is moving towards the car at a speed of 10 m/s. The whistle is set at 200 Hz. What is the frequency heard by the driver of the car?
21. A 2-m long string vibrates in 4 segments. The wave speed is 40 m/s. What is the frequency of vibration?
22. A 2-m long string vibrates in 4 segments. The wave speed is 40 m/s. What is the lowest possible frequency for standing waves on this string?
23. Determine the shortest length of pipe, open at both ends, which will resonate at 440 Hz. The speed of sound is 343 m/s.

Physics Unit 10: Waves and Sound Review

Answers

3. $\mathbf{1 \times 10^{-12}\ W/m^2}$

11. a. **Yes** b. **No** c. **Yes**

12. $v = 10\frac{m}{s}, 40\ s$

$$v = \frac{\lambda}{T}$$

$$10\frac{m}{s} = \frac{\lambda}{40\ s}$$

$$\lambda = 10\frac{m}{s}(40\ s) = \mathbf{400\ m}$$

13. $f = 30\ Hz, v = 60\frac{m}{s}$

$$v = f\lambda$$

$$60\frac{m}{s} = 30\ Hz\ \lambda$$

$$\lambda = \mathbf{2\ m}$$

14. $\mathbf{A = 4\ cm, \lambda = 6\ cm, f = 0.83\ Hz}$

$$v = f\lambda = f \cdot 6\ cm = 5\frac{cm}{s}$$

15. $t = 20\ s(t = 10\ s$ for one way$), v = 1522\frac{m}{s}$

$$x = vt$$

$$x = 1522\frac{m}{s}(10\ s) = \mathbf{15220\ m}$$

16. $|f_g - 440\ Hz| = 10\ Hz$

$f_g = \mathbf{450\ Hz}$ or $430\ Hz$

$|f_g - 445\ Hz| = 5\ Hz$

$f_g = \mathbf{450\ Hz}$ or $440\ Hz$

17. $5\ m, I = 200\frac{W}{m^2}$

$10\ m, I = ?$

$$I = \frac{P}{A}, A = 4\pi r^2$$

$$200\frac{W}{m^2} = \frac{P}{4\pi(5\ m)^2} \rightarrow P = 62832\ W$$

$$I = \frac{62832\ W}{4\pi(10\ m)^2} = \mathbf{50\ W/m^2}$$

18. $\beta = 120\ dB, I_0 = 10^{-12}\frac{W}{m^2}$

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

$$120\ dB = (10dB)\ log\left(\frac{I}{10^{-12}\frac{W}{m^2}}\right)$$

$$12 = log\left(\frac{I}{10^{-12}\frac{W}{m^2}}\right)$$

$$10^{12} = \frac{I}{10^{-12}\frac{W}{m^2}}$$

$$\mathbf{I = 1.0\ W/m^2}$$

19. $f_s = 440\ Hz, f_0 = 330\ Hz, v = 343\frac{m}{s}$

$$f_0 = f_s\left(\frac{v_w \pm v_o}{v_w \mp v_s}\right)$$

$$330\ Hz = 440\ Hz\left(\frac{343\frac{m}{s} - v_o}{343\frac{m}{s} + 0}\right)$$

$$0.75 = \frac{343\frac{m}{s} - v_o}{343\frac{m}{s}}$$

$$257.25\frac{m}{s} = 343\frac{m}{s} - v_o$$

$$\mathbf{v_0 = 85.8\frac{m}{s}}$$

20. $v_0 = 50\frac{m}{s}, v_s = 10\frac{m}{s}, f_s = 200\ Hz$

$$f_0 = f_s\left(\frac{v_w \pm v_o}{v_w \mp v_s}\right)$$

$$f_0 = 200\ Hz\left(\frac{343\frac{m}{s} + 50\frac{m}{s}}{343\frac{m}{s} - 10\frac{m}{s}}\right) = \mathbf{236\ Hz}$$

21. $L = 2\ m, n = 4, v = 40\frac{m}{s}, f = ?$

$$f_n = n\left(\frac{v}{2L}\right)$$

$$f_4 = 4\left(\frac{40\frac{m}{s}}{2(2\ m)}\right) = \mathbf{40\ Hz}$$

22. $L = 2\ m, n = 1, v = 40\frac{m}{s}$

$$f_n = n\left(\frac{v}{2L}\right)$$

$$f_1 = 1\left(\frac{40\frac{m}{s}}{2(2\ m)}\right) = \mathbf{10\ Hz}$$

23. $f_1 = 440\ Hz, n = 1, v = 343\frac{m}{s}$

$$f = n\left(\frac{v}{2L}\right)$$

$$440\ Hz = 1\left(\frac{343\frac{m}{s}}{2L}\right)$$

$$440\ Hz = \frac{171.5\frac{m}{s}}{L}$$

$$L = \frac{171.5\frac{m}{s}}{440\ Hz} = \mathbf{0.390\ m}$$