Exam III: Chapters 20 and 21

1. Compare an oscillation and a wave.
   A) A wave combines an oscillation and propagation: An oscillation in time propagated through space.
   B) An oscillation is a periodic motion with respect to a fixed point. A wave is not periodic, just linear.
   C) An oscillation depends on wave motion; you cannot have an oscillation without a wave.
   D) Huh? Why? They are exactly the same thing: A periodic motion with respect to a fixed reference.

2. As a wave propagates, the molecules of the medium
   A) vibrate, but do not propagate forward with the wave.
   B) remain rigid, neither vibrating nor propagating as the wave passes.
   C) are pulled forward along with the traveling wave, but do not vibrate.
   D) actually travel in the opposite direction, as the wave "pushes off" the molecules.
   E) roll forward, like water boiling in a pan: wave propagation is a convective process.

3. Mechanical waves
   A) must be transverse, and require a medium through which to propagate.
   B) must be transverse, and propagate only through a vacuum.
   C) must be longitudinal, and require a medium through which to propagate.
   D) must be longitudinal, and propagate only through a vacuum.
   E) may be either longitudinal or transverse, but require a medium through which to propagate.

4. A longitudinal wave
   A) only exists in theory; there are no longitudinal waves actually found naturally.
   B) occurs when the direction of oscillation is perpendicular to the direction of travel.
   C) occurs when the direction of oscillation is parallel to the direction of travel.
   D) is identical to a transverse wave. If the medium is solid, the wave is called longitudinal. In a fluid medium, it's called a transverse wave.

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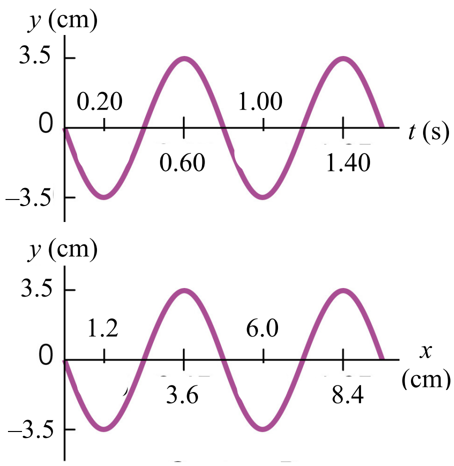
   D) is identical to a longitudinal wave. If the medium is solid, the wave is called transverse. In a fluid medium, it's called a longitudinal wave.

6. The compressions of a longitudinal wave are analogous to the
   A) wavelength of a transverse wave.
   B) amplitude of a transverse wave.
   C) troughs of a transverse wave.
   D) crests of a transverse wave.

7. Compare the density of the medium in regions of compression and rarefaction.
   A) Why? Because longitudinal waves only travel through solids, the density remains constant in all regions.
   B) A rarefaction is a region where the density is unchanged. Compressions may have higher or lower density, just not the same density as a rarefaction.
   C) Compressions are denser regions than rarefactions, but both are denser than node regions.
   D) A compression is a region of reduced density, a rarefaction has greater density.
   E) A compression has greater density than a node. A rarefaction is a region of lower density than a node.



On the left are two graphs describing the oscillation and propagation of a wave.

8. What is the **amplitude** of this oscillation?
   Answer numerically with two sig figs. $A = 3.5\text{cm}$

9. What is the **period** of the wave?
   Answer numerically with three sig figs. $T = 0.80\text{s}$

10. What is the **frequency** of the wave?
    Answer numerically with three sig figs. $f = (1/0.8\text{s}) = 1.25\text{Hz}$

11. What is the **wavelength** of this wave?
    Answer numerically with two sig figs. $\lambda = 4.8\text{cm}$

12. What is the **wave speed** of this wave?
    Answer numerically with two sig figs. $v = \lambda f = 6 \text{ cm/s}$
    $v = (4.8\text{cm})(1.25\text{Hz})$

13. **Position** (y) as a function of **time** (t) and **displacement** (x) will be described by the equation:
A) $y = +(3.5\text{cm})\cos[2\pi(1.25t - 0.139x)]$
B) $y = +(3.5\text{cm})\sin[2\pi(1.25t - 0.139x)]$
C) $y = -(3.5\text{cm})\cos[2\pi(1.25t - 0.139x)]$
D) $y = -(3.5\text{cm})\sin[2\pi(1.25t - 0.139x)]$
E) $y = +(3.5\text{cm})\cos[2\pi(0.8t + 7.2x)]$
F) $y = +(3.5\text{cm})\sin[2\pi(0.8t + 7.2x)]$

A steel guitar string has length l = 75cm long, and diameter d = 0.12cm. Its mass is measured to be m = 6.8g. The fundamental frequency of vibration is f = 288Hz.

14. What is the linear mass density μ of this string?
Answer numerically with three sig figs. Make sure to watch your units! Careful!!! μ = 0.009kg/m

$$\mu = \frac{m}{l} = \frac{0.0068\text{kg}}{0.75\text{m}} = 0.009\text{kg/m}$$

15. If the tension in the string is T = 1680N, how fast will a wave propagate along the string?
Answer numerically with three sig figs. Make sure to watch your units! Careful!!! v = 431m/s

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{1680\text{N}}{0.009\text{kg/m}}} = 431\,\text{m/s}$$

16. You replace the string with a thinner one having the same length, but a smaller linear mass density. When this new string is plucked, how fast will the wave propagate?
A) As long as the string is still 75cm long, the wave speed will be unaffected.
B) As long as the diameter is still 0.12cm, the wave speed will be unaffected.
C) As long as the tension remains 1680N, the wave speed will be unaffected.
D) Because the mass density decreases, the wave speed increases with constant tension.
E) If the tension remains constant, the wave speed decreases with decreasing linear mass density.

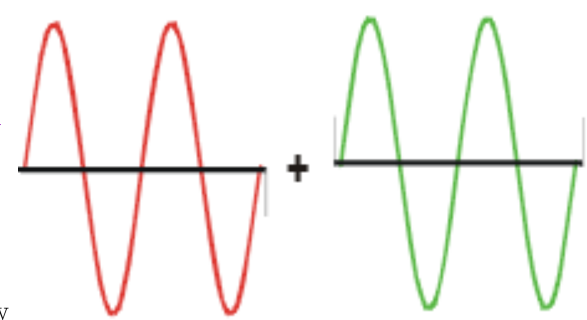
17. A single raindrop falls onto the smooth surface of the pool. As the resulting water wave propagates,
A) the amplitude of the wave crests remains constant.
B) the amplitude of the crests increases linearly with increasing distance.
C) the amplitude of the crests decreases with increasing distance from the source.
D) the amplitude of the crests remains constant, but the wave troughs grow increasingly deeper.

18. The intensity of a sound is exactly I_1 = 8 W/m² at a distance r_1 = 4m. At r_2 = 1m, the intensity will be
A) I_2 = 0.5 W/m²
B) I_2 = 1 W/m²
C) I_2 = 2 W/m²
D) I_2 = 16 W/m²
E) I_2 = 32 W/m²
F) I_2 = 64 W/m²
G) I_2 = 128 W/m²
H) I_2 = 256 W/m²

19. Calculate the intensity of a P = 750W stereo speaker at a distance r = 2m.
Answer numerically with three sig figs. I = 14.9W/m²

$$I = \frac{P}{4\pi r^2} = \frac{(750\text{W})}{4\pi(2\text{m})^2} = 14.9\text{W/m}^2$$

20. The superposition principle is based on the idea that
A) a wave propagates by superimposing a propagation over an oscillation. The result is that the wave medium moves right along with the energy.
B) two waves can occupy the same space at the same time: they superimpose to result in a new wave having the combined amplitude: $A = A_1 + A_2$.
C) two particles can occupy the same space at the same time: they superimpose to result in a new particle having the combined mass: $m = m_1 + m_2$.
D) two waves cannot occupy the same space at the same time. Neither can two particles. Which must mean that there really isn't any superposition of matter or energy. What a crazy universe we live in!



21. The to waves shown above will interfere
A) photogenically.
B) perspectively.
C) destructively.
D) constructively.

22. Why do you sound so awesome when you sing in the shower? No, I wasn't spying. Really, I just heard a rumor.
A) Only opera singers sound awesome in the shower. And Eddie Vedder. He sounds amazing anywhere.
B) The warm water on your face changes the frequency of your voice to a lower, more soothing pitch.
C) The hard, smooth tile reflects well, and the high humidity increases the wave speed. As a result, you hear your voice bouncing back at you with no appreciable delay, the echo interfering constructively with the original sound wave.
D) The small, enclosed space means that the background noise (like the water running and the exhaust fan) gets canceled out (this is a perfect example of destructive interference). This leaves only your pure, clear voice. Has anyone ever told you you sound just like Eddie Vedder? That's the rumor, anyway.

23. Why does the speed of sound increase with air temperature?
   A) The speed of sound in air does not depend on temperature at all.
   B) The speed of sound actually decreases with increasing temperature.
   C) Increased molecular motion increases the rate at which the molecules collide, which aids in the transmission of the sound energy.
   D) Increased temperature means that the air molecules are moving less; this permits the sound energy to be transmitted unimpeded.

24. On a hot, humid day you would expect the speed of sound
   A) to be higher than on a cold, dry day.
   B) to be the same as the speed on a dry day of the same temperature.
   C) to be lower on days with high humidity, regardless of temperature.
   D) to be constant, because it is. Temperature and humidity have no effect on the propagation of sound waves.

25. The 512Hz tuning fork is struck inside the lab (22°C). The wave speed is less than outdoors, where the temperature is 33°C. Striking the fork outside will result in a sound wave having the same
   A) wavelength, but decreased frequency.
   B) wavelength, but increased frequency.
   C) frequency, but increased wavelength.
   D) frequency, but decreased wavelength.
   E) wavelength and frequency both. Changing the temperature does not change the sound wave.

26. Calculate the speed of sound outdoors, where $T = 30°C$.
   Answer numerically with one decimal place. v = 349.0m/s

$$v = [331 + 0.6T]\,\text{m/s} = 331 + 0.6(30) = 349\,\text{m/s}$$

27. Compare the speed of sound through brass to the speed of sound through air.
   A) Brass is a very fast medium compared to air. Sound travels approximately ten times faster through brass than air.
   B) Brass is faster, but no way is it a factor of ten. It's more like a factor of three faster than air.
   C) Air is about the fastest medium through which sound propagates (only vacuum is faster). Sound travels roughly ten times faster through air than through brass.
   D) The speed of sound is constant for all media: $v = [331 + 0.6T]$m/s. The composition of the medium is simply not relevant. If the air and brass have the same temperature, they have the same speed.
   E) The speed of sound is not constant for all media, but by coincidence brass and air have almost identical speeds.

28. Carbon is added to iron to form steel. The addition does not change the density by an appreciable amount, but it does increase the elasticity substantially. How is the speed of sound affected?
   A) It is not affected. Neither iron nor steel is capable of sound transmission.
   B) Increasing the elasticity will decrease the speed of sound through the steel.
   C) Increasing the elasticity will increase the speed of sound through the medium.

29. A sound wave has a frequency $f = 288$Hz and an intensity $I = 10^{-9}$W/m^2.
   A) This is a trick question, like that "If a tree falls in the forest…" question in the exam archive. The intensity of this sound would shatter glass. Even though you did not hear it, it would probably rupture your eardrums.
   B) The sound in inaudible because the intensity is too low. The frequency is in the range of human sensitivity, but there is simply not enough energy to hear anything.
   C) This sound is not audible because the frequency is below the limit of human sensitivity. An elephant could probably hear this just fine, though.
   D) This sound is probably just barely audible to you. The frequency is about as high as human ears can hear,and the intensity is almost at the threshold of pain. You could hear it, but it would be like a dog whistle.
   E) This sound should be perfectly audible to human ears. It would not be very loud, though.

30. You perceive that sound B is twice as loud as sound A. What is the difference in the intensity of these?
   A) B has half the intensity of A.
   B) B must have ¼ the intensity of A.
   C) Twice the loudness implies twice the intensity.
   D) Twice the loudness means the intensity is four times greater.
   E) A doubling of the loudness means an order of magnitude, or factor of 10, increase in intensity.

31. Doubling the intensity of a sound results in an intensity level increase of
   A) 1 dB B) 2 dB C) 3 dB D) 5 dB E) 10 dB

32. Calculate the intensity level in decibels of a $P = 750$W stereo speaker at a distance $r = 2$m. Answer numerically with three sig figs. β = 132dB

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{14.9}{10^{-12}}\right) = 132\text{dB}$$

33. You're driving home from Best Buy, where you bought a cool new sound meter. Suddenly, the tornado siren sounds just as you are driving past the loudspeaker mounted on the power pole. Coincidence? I don't think so.
    A) The siren will probably be wailing at 120dB or even higher.
    B) The tornado siren cannot exceed 90dB.
    C) The siren comes in at about 60dB.
    D) The siren registers no more than 15dB on your most excellent digital device.

34. What is the Doppler effect?
    A) A change in the actual frequency of a wave because the source of the wave begins to vibrate at a different frequency. Any motion of either the source or the observer is not relevant.
    B) A change in the actual frequency of a wave because the medium changes, resulting in a speed change. When the speed of the wave changes, the frequency changes because the wavelength remains constant.
    C) A change in the perceived frequency of a wave because the source of the wave either approaches toward or recedes away from the receiver. There is no effect if the source remains stationary and the observer is in motion.
    D) A change in the perceived frequency of a wave because the source of the wave either approaches toward or recedes away from the receiver. Or, if the source is stationary, the same effect occurs for an observer in motion.
    E) The inexorable sequence of events set in motion when, through no fault of your own, your tornado-propelled domicile is thrust into an alternate reality and lands on a fabulous pair of shoes rather inconveniently still attached to the feet of a witch with a vindictive (and quite literally green) sister who just happens to have a terrifying army of flying monkeys. *Flying. Monkeys.*

35. As you are standing stationary on the sidewalk, a black '76 Firebird zooms past (doing like, 45, in a school zone) with windows open, blasting *Crazy On You* from the in–dash 8–track (did I mention that you have traveled back in time and it actually is 1976?).
    A) The actual frequency of the song changes as it changes its vibration. If the car moves forward, the frequency increases (regardless of what you are doing).
    B) The actual frequency does not change, and neither does your perception of it. The song remains the same.
    C) The actual frequency does not change, but your perception of it does. It seems to decrease in frequency as the car approaches you.
    D) The actual frequency does not change, but your perception of it does. It seems to increase in frequency as the car approaches you.
    E) You have no idea what happened to the frequency, because you were so astonished when Tony slammed on the brakes and offered you a ride. Must've been those fabulous freaky shoes that caught his eye. That, and not every girl has a monkey on a leash flying rings around her head.

36. You are driving down the street with Tony (you're still trapped in 1976–good luck finding a radio station that isn't playing something off *Frampton Comes Alive!*, and good luck finding a Radio Shack that has replacement parts for your time machine, unless you need a CB radio to fix your time machine). He's letting you drive the Firebird, so you are proceeding at a sensible 80 mph ($v_o = 36\text{m/s}$), moving away from the factory, when the whistle blows to mark the shift change. Tony always carries that portable guitar tuner you brought him from the future, which reads a frequency $f_o = 440$ Hz. Calculate the true frequency f_s of the whistle. Answer numerically. $f_s = 492\text{Hz}$

$$f_o = \left[\frac{v+v_o}{v-v_s}\right] f_s \implies f_s = \left[\frac{v-v_s}{v+v_o}\right] f_o$$

$$f_s = \left[\frac{343-0}{343+(-36)}\right](440\text{Hz}) = 492\text{Hz}$$

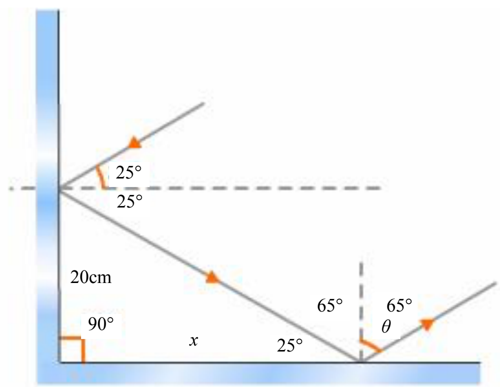
37. Light (e·m) waves are
    A) transverse and require a medium of propagation.
    B) transverse and do not require a medium of propagation.
    C) longitudinal and require a medium of propagation.
    D) longitudinal and do not require a medium of propagation.

38. A propagating light wave follows a
    A) curved, sinusoidal path.
    B) straight-line path.
    C) helical (spiral like a spring) path.
    D) none of these; the path cannot be seen.

39. Light traveling through the air strikes a boundary: Now what?
    A) If the material is opaque, all the light will be transmitted.
    B) If the material is transparent, all the light will be transmitted.
    C) Typically some combination of reflection, transmission, and absorption.
    D) Now nothing. Nothing happens when light strikes a boundary, because light has no mass.

40. The principle of least time states that
   A) the shortest distance between two points is a straight line.
   B) the shortest path between two points is always the fastest path.
   C) it always takes less time for light to travel a path than anything else.
   D) a beam of light will always travel along the shortest path from one point to another.
   E) a beam of light will always follow the fastest path from one point to another.

41. The law of reflection states that
   A) incoming light is reflected back along its original path.
   B) the angle of incidence is equal to the angle of reflection.
   C) the angles of incidence and reflection always add up to 90°.
   D) for curved mirrors, the angle of reflection is twice the angle of incidence.
   E) angle of incidence only equals angle of reflection for flat, perfectly smooth, plane mirrors.



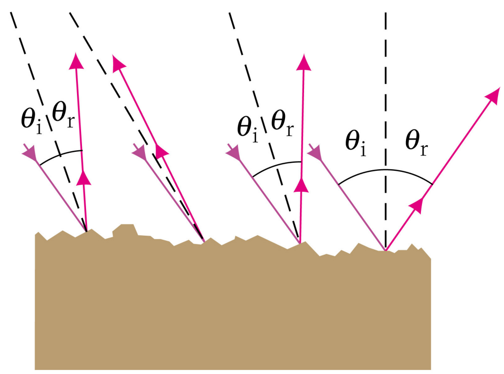
42. Calculate the angle θ at which the light ray emerges. Answer numerically. $\theta = 65°$

43. Calculate the distance x from the wall where the light ray strikes the horizontal mirror. Answer numerically. $x = 42.9\text{cm}$

$$\tan(25°) = \frac{20\text{cm}}{x} \implies x = \frac{20\text{cm}}{\tan 25°} = 42.9\text{cm}$$

44. When measuring the angles of incidence and reflection, why measure with respect to the normal to the surface?
   A) No reason. It's an historical convention, much like using positive test charges to determine the direction of current.
   B) Convenience. Modern protractors are designed to measure angles with respect to the vertical, or y-axis.
   C) Necessity. Light may be incident on surfaces which are curved, rough, or uneven. Constructing a normal to the surface creates a uniform method to apply to any shape or texture of surface.
   D) Obstinance. When Fermat developed his Principle of Least Time, he chose the convention for measurement. He selected the normal for no other reason than to annoy Isaac Newton.

45. The parallel rays shown strike the surface and reflect as shown.
   A) Specular reflection.
   B) Spectacular reflection.
   C) Vehicular reflection.
   D) Diffuse reflection.
   E) Refuse reflection.
   F) Confuse reflection.



46. Specular reflection occurs when
   A) parallel rays of incoming light are reflected from a smooth surface. The reflected rays are also parallel.
   B) parallel rays of light are reflected from a rough or uneven surface. The reflected rays are not parallel.
   C) randomly oriented rays of incoming light reflect off a smooth surface. The reflected rays are all normal to the surface.
   D) randomly oriented rays of incoming light reflect off a rough surface. The reflected rays are all normal to the surface.
   E) randomly oriented rays of light are passed through a parallel ray lens, to create a narrow beam of light. This narrow beam strikes a smooth surface and is reflected normal to the surface.

47. When light passes from one medium to another,
   A) it continues to travel at $c = 3\times10^8$ m/s regardless of the type of medium.
   B) it always slows down, and it always refracts regardless of the angle of incidence.
   C) it always speeds up, and it never refracts regardless of the angle of incidence.
   D) it bends only when it strikes the boundary between the media at a 90° angle to the surface.
   E) it may slow down or speed up, depending on the medium. The amount of refraction depends on the angle at which the light strikes the boundary.

48. True or false: The index of refraction of air is effectively the same as vacuum: $n = 1$.

49. The index of refraction of diamond is $n_1 = 2.42$. The index of refraction of acetone is $n_2 = 1.36$.
   A) The speed of light through diamond is faster than through acetone: $v_1 > v_2$.
   B) The speed of light through diamond is slower than through acetone: $v_1 < v_2$.
   C) The speed of light through diamond is equal to the speed through acetone: $v_1 = v_2$.

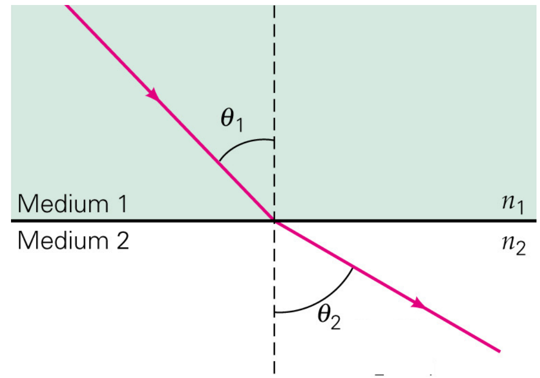
50. Which medium will bend the light more?
   A) The medium with the higher index.
   B) The medium wit the lower index.

51. The index of refraction for lucite is $n = 1.495$. What is the speed of light through this medium?

$$v = \frac{c}{n} = \frac{3\times10^8\,\text{m/s}}{1.495} = 2.0\times10^8\,\text{m/s}$$

A) $v = 2.0\times10^8$m/s B) $v = 2.3\times10^8$m/s C) $v = 3\times10^8$m/s D) $v = 4.5\times10^8$m/s

A beam of light is shown on the right striking a boundary between two media. Neither medium is vacuum or air, and Medium 1 is not the same as Medium 2. Answer Questions 50 through 52 using this ray diagram.



52. At what angle of incidence will the incident ray experience no refraction as it crosses the boundary into Medium 2?
   A) When $\theta_1 = 90°$, $\theta_2 = 0°$.
   B) When $\theta_1 = 45°$, $\theta_2 = 45°$.
   C) When θ_1 = zero, θ_2 also = 0°.
   D) There is no possible incident angle for zero refraction, since the two media are not the same.

53. Which medium must have the greater index of refraction?
   A) $n_1 > n_2$ B) $n_1 < n_2$ C) $n_1 = n_2$

54. When the light passes from Medium 1 to Medium 2, the speed changes.
   A) The frequency remains constant, so the wavelength will change.
   B) The wavelength remains constant, so the frequency will change.
   C) Either wavelength or frequency will change, but you cannot predict which.
   D) Neither the wavelength nor the frequency will change. Wave speed is unrelated to both.

55. Increasing the angle of incidence will have what effect on the refracted ray?
   A) None. The angle of refraction is a constant that depends on the index f refraction.
   B) Increasing θ_1 will increase θ_2.
   C) Increasing θ_1 will decrease θ_2.

Formula Sheet

Right Triangle Trigonometry:

$$\sin\theta = \frac{opposite}{hypotenuse}$$

$$\cos\theta = \frac{adjacent}{hypotenuse}$$

$$\tan\theta = \frac{opposite}{adjacent}$$

Pythagorean Theorem

$$(opposite)^2 + (adjacent)^2 = (hypotenuse)^2$$

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

Wave Speed: $$v = \frac{\lambda}{T} = \lambda f$$

Stretched String: $$f_n = n\frac{v}{2L} = \frac{n}{2L}\sqrt{\frac{F_T}{\mu}}$$

Wave Speed on Stretched String: $$v = \sqrt{\frac{F_T}{\mu}}$$

Mass per Unit Length: $$\mu = \frac{m}{L}$$

Speed of Sound in Air: $$v = \left[331 + 0.6T\right]\tfrac{\mathrm{m}}{\mathrm{s}}$$

Power: $$P = \frac{W}{t}$$

Intensity of a Point Source: $$I = \frac{P}{4\pi r^2}$$

Threshold of Hearing: $$I_o = 10^{-12}\,\tfrac{\mathrm{W}}{\mathrm{m}^2}$$

Threshold of Pain: $$I_p = 1\,\tfrac{\mathrm{W}}{\mathrm{m}^2}$$

Intensity Level: $$\beta = 10\log\left(\frac{I}{I_o}\right)$$

Doppler Effect: $$f_o = \left[\frac{v + v_o}{v - v_s}\right] f_s$$

$v > 0$: Always use (+)
$v_o > 0$: Observer moves toward source (+)
$v_o < 0$: Observer moves away from source (–)
$v_s > 0$: Source moves toward observer (+)
$v_s < 0$: Source moves away from observer (–)

Law of Reflection: $$\theta_i = \theta_r$$

Index of Refraction: $$n = \frac{c}{v}$$

Snell's Law: $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Wavelength Change With Medium Change: $$\lambda' = \frac{\lambda}{n}$$

Critical Angle for Total Internal Reflection: $$\sin\theta_c = \frac{n_2}{n_1}$$