Chapter 12
Wave Motion Chapter Review

EQUATIONS:

- $y = A\,sin(\,kx \pm \omega t\,)$ [Waves move. That means that their displacement *y* above or below the medium's equilibrium position at a given time *t* will vary with position *x*, AND that displacement at a given position *x* will vary with time *t*. In other words, there are two variables that have to be taken into account when trying to determine the displacement of a wave--the position of interest and the time of interest. The function above allows you to determine the displacement (i.e., the *y* coordinate) of a wave as it exists at a given position *x* at a given time *t*. Note: Understanding the constants ω and *k* can be tricky. Think about them this way. At a given *x*, as time goes on, the displacement *y* changes. The angular frequency term ω governs how fast that change occurs (ω's units are *radians/second*--a big angular frequency means THE DISPLACEMENT CHANGES QUICKLY IN TIME). Likewise, at a given *t*, as you move positionally from point to point, the displacement *y* changes. The wave number *k* governs how fast that change occurs, relative to position (*k's* units are *radians/meter*---a big wave number means THE DISPLACEMENT CHANGES QUICKLY FROM POINT TO POINT IN SPACE).]

- $T = \frac{1}{\nu}$ [The time *T* it takes for one full wavelength to pass a point is equal to the inverse of the frequency ν of the wave.]

- λ [The wavelength λ of a wave is defined as the distance between one peak to the next, OR one trough to the next.]

- $v_{wave} = \lambda \nu$ [The wave velocity *v* equals the product of the wavelength λ in *meters per cycle* and the wave frequency ν in *cycles per second*. Note that with physical waves (i.e., waves on a string, not light waves), the frequency of the wave is the same as the frequency of the vibratory motion that produced the wave.]

- $\nu_{observed/heard} = \frac{(\nu_{original\ from\ source})(v_{sound\ in\ air})}{v_{sound\ in\ air} - v_{of\ source}}$ [Called the Doppler effect, this relationship gives you the frequency $\nu_{observed/heard}$ you actually *hear* when a sound source of frequency $\nu_{original\ source}$ approaches you at velocity $v_{of\ source}$. Note that $v_{sound\ in\ air}$ is the velocity of sound in air. Note also that if we were talking about light being Doppler shifted from a star that is, say, receding from earth, the expression would read

  $\nu_{observed} = \frac{(\nu_{original\ from\ source})(c)}{c - v_{of\ source}}$, where *c* is the speed of light in a vacuum, $v_{of\ source}$ is the speed of the star, relative to the earth, $\nu_{observed}$ is the frequency taken in by the telescope making the observation, and $\nu_{original\ from\ source}$ is the frequency actually being given off by the star.]

- $\nu_{beat} = \nu_{higher} - \nu_{lower}$ [This is the relationship between the frequency of the beats (variations in intensity) created when two signals whose very close frequencies superimpose on each other.]

<u>COMMENTS, HINTS, and THINGS to be aware of</u>:

- A **wave** is a **disturbance** that moves through a medium. If you don't have a medium, you can't have a wave (example: sound in space . . . doesn't happen).

- A **transverse wave** is created when a force directed *perpendicular to* the direction of the wave motion is applied to a medium. A pebble breaking the surface of a still pond produces a transverse wave.

- A **longitudinal wave** is created when a force directed *parallel to* the direction of the wave motion is applied to a medium. Sound coming from a speaker is an example of a longitudinal wave.

- **Resonance** occurs when the frequency of a force being applied to an oscillating system matches one of the natural frequencies of the system. When it occurs, the amplitude of the oscillation increases dramatically.

- To **determine** one of the many possibly **natural frequencies** of an oscillating system (i.e., to find a frequency that produces a standing wave when resonance happens):
  --Look to see what the endpoint constraints must be for your system (for ease below, assume that one end point is called *endpoint A* and the other is called *endpoint B*). These will either be nodes (fixed ends), antinodes (free ends), or a combination thereof.
  --Draw a sine wave.
  --On the sine wave, start at a node or an antinode--whichever corresponds to the constraint at *endpoint A*.
  --Proceed down the sine wave until you hit either a node or an antinode, whichever corresponds to the constraint at *endpoint B*.
  --On the wave form you have created, look to see if any internal constraints in the system are being satisfied. That is, if there should be a node halfway between the endpoints, does the wave form you are working with *have* a node halfway between the endpoints?
    --Note that there is no artificial way to ensure that an internal point will act like an antinode, so all internal constraints MUST BE nodes.
    --To check to see if an internal constraint is being satisfied, especially in complicated situations, note that if the product of the *number of quarter wavelengths* in the wave form and the *fractional distance* from a chosen endpoint is A WHOLE NUMBER, you *might* have a satisfied constraint. That is, if the endpoint from which the fractional distance is measured is a node, all that is required is that the product be ANY whole number. If the constraint from which the fractional distance is measured is an antinode, the product has to be an ODD whole number to comply.
  --If all of the internal constraints are met, you have an acceptable wave form. If not, continue down the wave form until *endpoint B's* constraint is again met, and repeat the process outlined above.

--Assume that the length of the system is L.
--Once the wave form has been identified, ask the question, "How many wavelengths are there in L?" (I usually count these in quarter wavelengths.) Writing that relationship down will allow you to determine the wavelength that fits the situation in terms of a physical parameter associated with the system, or L.
--Knowing λ in terms of L, you can now use $v = \lambda\nu$ to determine the required natural frequency (you will usually be given the wave velocity v).
--Note that if a force varying at that frequency impinges on the system, the standing wave produced will look just like the wave sketch, assuming you are dealing with a *transverse wave.*

- The **Doppler Shift** is particularly useful in determining the velocity of an object moving relative to you. Examples: Measuring the speed of a star via spectroscopic analysis, relative to the earth, or measuring the speed of a car via Doppler radar, relative to a cop.

- **Beats** are used by a guitarist to tune a guitar. One string is held down (fretted) and plucked to produce a tone. A second string, one that should produce the same tone (frequency) as the first if the two are really in tune, is then plucked. The superposition of the two frequencies will produce variations in sound intensity (beats) if they are just a little bit out of tune.