Preparation Notes for Chapter 16 (Wave motion; 2-3 classes)

Note: Chapter 16 is not very long but it can be confusing for many students. They are probably not used to working with functions of two variables (time and position in this case) and they may have problems visualizing what is going on. So I think it is important to have lots of discussion and graphical exercises at the start of this section.

Introduction to Waves

Reading is 16.1-16.2; no review problems

(1) Discussion (whole class): "What are some of the different types of waves that you have heard of?" sound, water, rope, light, radio waves, microwaves, X-rays; divide into mechanical waves and EM waves

(2) Discussion (small groups or whole class): "What are some of the things that we need in order to have mechanical waves?" a medium (no sound in a vacuum); a source of the disturbance; physical connection between adjacent portions of the medium

(3) Discussion (small groups): put up picture of ocean wave from start of Chapter 16, or another better picture of water waves; "What are some of the things we might want to know in order to describe these waves to someone?" height (amplitude), time between arrival of waves (period), bird's eye view of separation of waves (wavelength), how fast they are moving (wave velocity); point out that we are aiming to put this information together into a concise mathematical formula to describe the waves.

(4) Sketch a snapshot of a wave (sine wave) y vs x at some instant t. Ask volunteers to identify what variables from the previous discussion they can from this graph (amplitude and wavelength); can sketch a sine wave at some later time t+dt; point out wave velocity =dx/dt for a crest; sketch at time t+T later and identify T as time for next crest to reach a given point; point out that f=1/T is the number of crests that pass a point per second

(5) review difference between transverse and longitudinal waves; point out that water waves have both components (if you float in the surf zone you move forward and backward as well as up and down)

Travelling waves; interference; speed of wave on a string

Reading Ch 16.3-16.5; review problems P16.9, 16.53

(1) Graphical exercise: before class, sketch $y = 2/(x^2 + 1)$ on an overhead and label it t=0. "If the wave is moving to the right with a speed of 1 m/s, sketch what y(x) looks like at t=2 s"; students work together in groups; collect the sketch; "Can you write a new function that describes y(x) at time t=2 s?" $y = 2/((x - 2)^2 + 1)$; "How far has the wave traveled in t=2 s?; "In general, if the wave is moving to the right at speed v, how far does it travel in time t?" dx = vt; "So, can we write down a general expression that will tell us what y is at any x and at any time t?" $y = 2/((x - vt)^2 + 1)$

(2) Summarize: if we know y=f(x) at t=0 and the wave is moving to the right at speed v, then at any other time t, y(x,t) = f(x-vt) i.e. simply substitute (x-vt) everywhere you see x in the original equation; if the wave is moving to the left? y(x,t) = f(x+vt)

(3) Discussion (small groups): show Figure 16.8 on an overhead (superposition of two waves; constructive interference); "What are some of the things that are happening in this sequence of pictures?" (label that t increases downward and hide caption); waves pass through each other without being changed; combination of separate waves to produce a resultant wave is called intereference; constructive versus destructive interference.

(4) Graphical exercise: Problem 16.2 (on an overhead); students do in small groups; collect and discuss on the board

(5) Presentation by students on "Speed of waves on strings"

(6) Problem 16.53

(7) Presentation by students on "Speed of waves in deep and shallow water"

Reflection and Transmission; Sinusoidal Waves

Reading 16.6-16.8; review problems 16.33, 16.42

(Note: this section is rather boring; it's hard for me to find the discussion in it.)

(1) Reflection and transmission: would be good to do a demo if possible, otherwise use Figures 16.13-16.16; if end is fixed, reflected pulse is inverted; why?; if end can move freely the reflected pulse is not inverted; why? intermediate boundary get both reflection and transmission (why?); from light rope to heavy rope ($v_A > v_B$), reflected wave is inverted

(2) Sinusoidal Waves: simplest example of a periodic, continuous wave; sketch y=Asin(kx) on board and label t=0; "What are some of the factors that go into the formula for y(x)?" (question to whole class; small group discussion only if necessary) amplitude, wavelength, might also get period and speed; put together formula y=Asin(2πx/λ); now sketch y(x,t) for some arbitrary t; "Knowing y(t=0), how do we write the expression for y at any t?"; y=Asin((2π/λ)(x-vt)); "What are some of the things we know that could help us calculate the speed of the wave?" wavelength, period, frequency; $v = \lambda/T = \lambda f$; define angular wave number $k = 2\pi/\lambda$; $y = Asin(kx - \omega t)$ (and in general $+\phi$)

(3) Motion of pieces of the string: we have the general expression y(x,t) for a sinusoidal wave; suppose wave is being driven at one end (x=0); if wave is sinusoidal, then $y(x = 0) = Asin(-\omega t)$; this is SHM if $a_y = -\omega^2 y$; what are v_y and a_y?; derive using partial derivatives for x constant, i.e. $x = x_o$; evaluate a_y at $x = 0$; it IS SHM; so, if the end oscillates in SHM in the y direction, it will create a sinusoidal wave; point out that any position in the rope $x = x_o$ will also move in SHM

(4) Energy in sinusoidal wave: "What different kinds of energy are in a sinusoidal wave? Focus on one small piece of the string." kinetic energy of motion; gravitational potential energy; "spring-like" potential energy (from tension in string wanting to bring it back to rest); "What are the some of the things we would want to know to calculate the power (rate of energy transmission) by the wave?" kinetic energy, spring potential energy, time for energy to travel past a point, same amount of energy in each wavelength of the wave; book derives $U_\lambda = \frac{1}{4}\mu\omega^2 A^2 \lambda$; also $K_\lambda = \frac{1}{4}\mu\omega^2 A^2 \lambda$ (makes sense that are equal in a general way, since energy at a given point cycles back and forth between K and U and sometimes is all K and sometimes all U; $E_\lambda = K_\lambda + U_\lambda = \frac{1}{2}\mu\omega^2 A^2 \lambda$; $P = E/\Delta t$; time to use is the period = time for one whole wavelength of the wave to pass a single point; $P = \frac{1}{2}\mu\omega^2 A^2 \lambda / T = \frac{1}{2}\mu\omega^2 A^2 v$;

(5) Problem 16.42

(No concept map available yet for this chapter.)

Suggested Presentation Topics

1) Speed of waves on strings (I know, it's similar to the lab!)

2) Reflection and transmission

3) Speed of waves in deep/shallow water