Physics 152

Lecture 03

Friday, January 19, 2007

• Wave motion - history and snapshot graphs
• Period, frequency, amplitude, functions

http://www.voltnet.com/ladder/

Announcements

• Help sessions TBA
• GM returns Monday, Jan. 22
• MasteringPhysics due on both Wed. and Fri. next week (see website)
• E&M diagnostic exam due today at 11:55 pm (see homepage for details)

Ch. 14: Oscillations

Pendulum

The motion of a bob at the end of the pendulum can be thought of as acting under a restoring force, just like the mass on a spring. But this time, the agent responsible for the restoring force is gravity.

Using geometry, we find the restoring force is

\[ F_s = mg \sin \theta \]

As long as the amplitude of the oscillations remains relatively small, we can use the small angle approximation for \( \sin \theta \) and get

\[ F = -mg \theta \]

\[ F = -\frac{mg}{L} x \]

which now has the form \( F = -kx \)
Now using our results from the motion of the mass-spring system to describe the motion of the pendulum with the substitution

\[ k \rightarrow \frac{mg}{L} \]

and we find the period of our pendulum to be

\[ T = 2\pi \sqrt{\frac{L}{g}} \]

Good for SMALL amplitude oscillations!

Ch. 20: Traveling Waves

We’ve looked at systems in which an object moves with a periodic, repeating position function and characterized that behavior with trigonometric functions. We will now look at systems, also characterized by trig functions, in which the waves propagate.

• Notice that while pieces of the slinky moved up and down or left and right (depending on your perspective) as the wave passed by, those pieces ended up right back in (nearly) the same places they started out!

• Therefore, we note that waves do NOT ultimately transport matter. They only temporarily displace the matter in which they move.

So what do waves carry?

- Energy
- Momentum

TRAVELING WAVES:

Transverse Waves

Longitudinal Waves

What are waves?

Demo Time!

Wave Motion

Make a plot the position of a small piece of the slinky as a function of time as a series of waves pass through it.

Worksheet Problem #2

What kind of plot do you get?

Sinusoidal again! Just like the motion of the mass-spring system and the pendulum system!
Now, draw a picture of the shape of the slinky at ONE INSTANT in time. That is make an x-y plot of the shape of the slinky at a specific instant—as if your eye were taking a photograph of the slinky.

Next, let the movie advance 1 frame in your head. Sketch the shape of the slinky at this next instant in time.

What kind of plots do you have? Still sinusoidal, right?

It’s relatively easy for me to measure the wavelength of a wave...if I have a camera. And I can record the frequency of the wave as well, just by counting the number of crests that pass each second.

So, how fast is the wave moving?

The wavelength gives me the distance between crests. And the frequency tells me how many pass per second, so multiply the two gives me distance over time, which has the right form.

In fact, if you know the wavelength of a wave and you know its frequency, you can find the magnitude of its velocity (or phase speed). These three quantities are related by the expression:

\[ \nu = f \lambda \]

where
\( \nu \) is the velocity (phase speed) of the wave
\( f \) is the frequency of the wave and
\( \lambda \) is the wavelength of the wave.

We’d like to be able to write down a function that describes the vertical position of each piece of our slinky as a function of time. Therefore, our function needs to depend upon both position and time.

We had an easy time describing the position of our mass on a spring system, since that was really only a function of time.

\[ y = A\cos(\omega t + \phi) \]

Let’s say that at time \( t = 0 \), our wave appears to be described (in our photograph, say) by

\[ y = A\sin(k_w x) \quad \text{where} \quad k_w = \frac{2\pi}{\lambda} \]

\( k_w \) is called the “wave number” or spatial frequency

And let’s say our wave moves in the positive x-direction with a phase speed \( v_w \). Then each point in our wave will have moved through a distance \( d = v_w t \) in time \( t \).
So, the magnitude of the displacement that was observed at \( x = x_0 \) at time \( t = 0 \) will now be located at \( x = x_0 + v_w t_1 \) at time \( t = t_1 \).

Yet, the shape of the function must remain identical to what it was at time \( t = 0 \). In order to recover that original function, we would need to subtract \( v_w t_1 \) from the argument of the position function.

\[
y = A \sin(k_w (x - v_w t_1))
\]

There's nothing special about time \( t = t_1 \). So we can generalize our function to

\[
y = A \sin(k_w (x - v_w t_1))
\]

More commonly, we write this function as

\[
y = A \sin(k_w x - \omega t)
\]

where \( \omega = k_w v_w \).

A wave function for a traveling wave on a taut string is given (in mks units) by

\[
y(x,t) = 0.350 \sin(10(\pi - 3x) + \pi/4)
\]

(a) What is the speed and direction of the wave?
(b) What is the wavelength?
(c) What is the frequency?
(d) What is the maximum transverse speed?