1.3: Transverse Waves

Tutorial 1.3: Transverse Waves

Transverse waves are the kind of wave you usually think of when you think of a wave. The motion of the material constituting the wave is up and down so that as the wave moves forward the material moves perpendicular (or **transverse**) to the direction the wave moves. Examples of transverse waves include waves on a string and electromagnetic waves. Water waves can be approximately transverse in some cases.

The following simulation shows a graph of the motion of one location, the red circle, on a string which has a transverse wave on it. The vertical location of points on the string (represented by the circles) as a function of horizontal location along the x-axis and time is again described mathematically by $y(x,t) = A\sin(kx - \omega t + \varphi)$. Notice that, while the wave moves forward along the string, the red circle does not (in fact none of the circles move forward).

Transverse Wave

Questions:

Exercise 1.3.1

Play the animation (lower left button). From the graph, what are the amplitude and period of the motion of the red dot?

Exercise 1.3.2

Clicking on the lower panel gives the mouse location (in the yellow box) which in this case are the x and y location of points on the wave. Use these numbers to determine the wavelength of the wave (this is easiest to do with the animation paused or finished).

Exercise 1.3.3

From the period and wavelength that you just measured, calculate the forward speed of the wave (as you did in the previous simulation).

A *second* velocity associated with a wave is how fast the material of the wave moves up and down at a single location (the vertical speed of the circles in the simulation). This velocity, the **transverse velocity**, is <u>not</u> a constant but is a function of location and time (different places on the wave move upward or downward at different speeds at different times). Since velocity is the rate of change of position, this second speed (in the *y* direction) is given by the derivative of the amplitude with respect to time:

$$v(x,t) = \partial y(x,t)/\partial t = -A\omega\cos(kx - \omega t + \varphi)$$

Notice that the maximum speed of a section of the wave at location x and time t will be given by $v_{\max} = A\omega$. We use a partial derivative here because $y(x,t)$ is a function of two variables.

Exercise 1.3.4

Click on the 'Velocity' button and then 'play'. The upper graph now gives the speed of the red circle in the y-direction as a function of time. What is the maximum speed (approximately) of the red circle according to the graph? How does this compare with the speed of the wave which you found in $1.3.3$; are they the same or different?

Exercise 1.3.5

Where is the red dot (relative to the rest position before the wave passes) when the maximum transverse velocity occurs? Where is it when the transverse velocity is approximately zero?

Exercise 1.3.6

Using $v_{\max}$ from the graph, the amplitude from $1.3.1$ and $v_{\max} = A\omega$, what is the angular frequency? How does this compare with the value calculated from the period?

Since points on the wave change their transverse velocity over time there must also be a vertical or **transverse acceleration**. Since acceleration is the time rate of change of velocity we have $a(x,t) = \partial v(x,t)/\partial t = -A\omega^2 \sin(kx - \omega t + \varphi)$ where the **maximum acceleration** is $a_{\max} = A\omega^2$.

Exercise 1.3.7

Calculate the maximum acceleration of the red circle. What are the units of this acceleration if amplitude is in meters and angular frequency is in radians per second?

Exercise 1.3.8

Based on the equation for acceleration, where will the red circle be when the acceleration is a maximum? Where will it be when the acceleration is approximately zero?

Exercise 1.3.9

Carefully state the relationship between positon, velocity and acceleration. When the position is zero (equilibrium position of the red dot) what are the velocity and acceleration? When the position is a maximum, what are the velocity and acceleration?

Exercise 1.3.10

State in your own words the difference between wave speed and transverse speed of a wave.
