Workshop Tutorials for Introductory Physics

Solutions to WI2: **Waves**

A. Review of Basic Ideas:

Waves

You are surrounded by **waves** all the time. Everything you see and everything you hear, is actually a wave. The rods and cones in your eyes are sensitive to **light**, which is a wave. The cilia in your cochlear respond to **sound** waves which are vibrations in the air.

Some waves, like sound, need a **medium** to propagate through, but electromagnetic waves, like light, don't. Which is why in **space** no-one can hear you scream, but they can see you scream.

Waves can be described by several quantities. The **period** is how long a single oscillation takes. The **wavelength** is how far it is between peaks, the **velocity** is how fast the peaks travel and the **amplitude** is how far from equilibrium the peaks are.

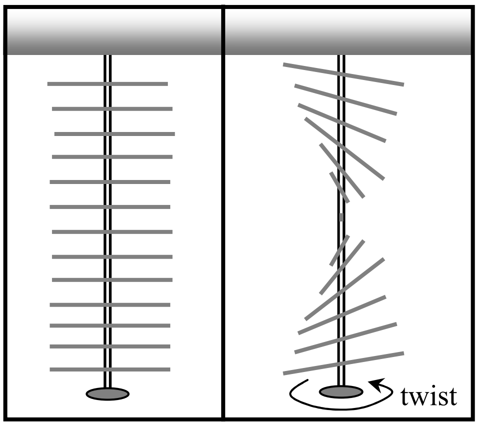
A wave is a disturbance in a material. The particles **oscillate**, but there is no net movement of matter. During a "Mexican wave" the disturbed particles are **people** and the disturbance travels around the venue. This is a **travelling** wave. Many waves you are familiar with, such as water waves, are travelling waves. Although there is no net movement of matter, waves do transmit **energy**.

Waves that stay in the same place are called **standing** waves. These are easy to observe on strings. If you pluck a taut string you will get a standing wave. This is the basis of many musical instruments. The standing wave on the string causes a **travelling** wave in the air, which causes a standing wave on your ear drum, which is transmitted to the cochlear, which your brain interprets as **music**.

B. Activity Questions:

1. Transverse waves

The torsional wave is a transverse wave because the direction of displacement of the particles (the rods) is perpendicular to the direction of travel of the wave. It is different to more familiar transverse waves, such as waves on a vibrating string, in that the displacement is due to twisting, and the amplitude would be described by an angle rather than a linear displacement.



2. Longitudinal Waves

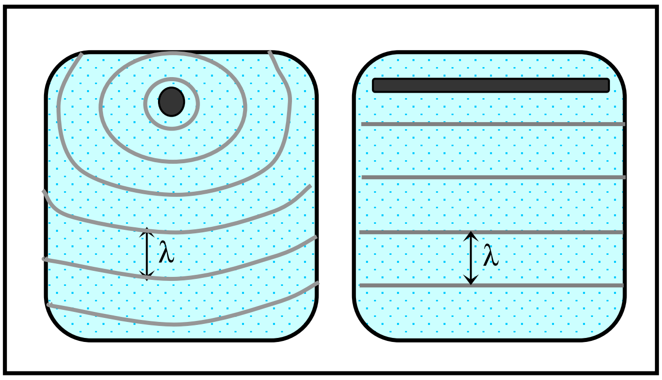
The amplitude of the wave does not affect the speed of the wave. The speed is determined by the medium it travels through, in particular it depends on the elastic and inertial properties of the medium, i.e. the tension and mass. You can change the wave speed on the slinky by stretching it more, and increasing the tension.

3. Waves in rubber tubes

The tube filled with water is much heavier, and hence the waves travel more slowly along it as velocity decreases with increasing mass per unit length.

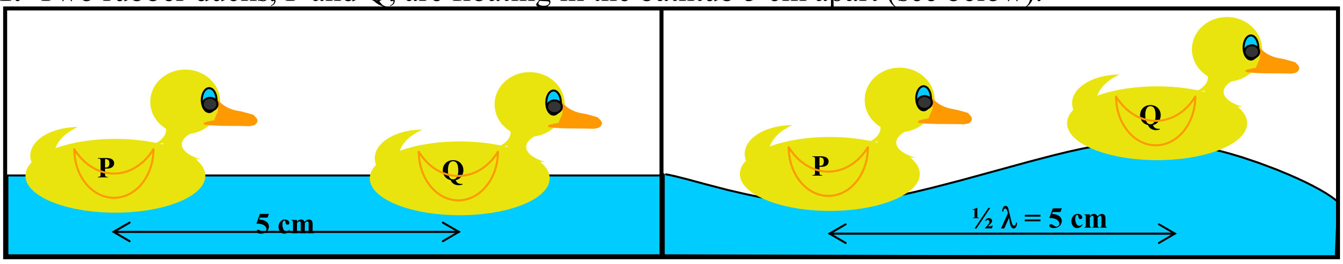
4. Ripple tank I – making waves

You should be able to produce circular wave fronts using the point oscillator, and plane waves using the long rod oscillator. Changing the frequency changes the wavelength, λ, of the waves produced, but does not affect the speed. The speed depends only on the medium, which is not changing.



C. Qualitative Questions:

1. Two rubber ducks, P and Q, are floating in the bathtub 5 cm apart (see below).



As the waves pass by the ducks you notice that when P is at its highest position, Q is at its lowest.

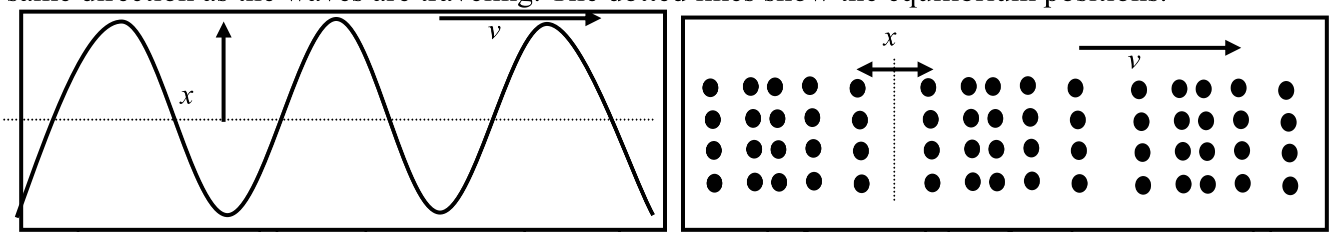
a. We know that the distance from peak to trough, which is ½ a wavelength is 5 cm, therefore the wavelength of the waves must be 10 cm.

b. You can't make the waves travel by dropping in bigger objects. Bigger objects will give you bigger waves, but the wave speed depends on the properties of the medium, which is water.

c. Dropping in objects more frequently will increase the frequency, and decrease the wavelength, but will not affect the wave speed, as explained in part **b.**

2. An animal moving along on the ground produces both a transverse travelling wave and a longitudinal travelling wave.

a. In a transverse wave (below, left) the displacement of the medium is perpendicular to the direction the waves are traveling in. In longitudinal waves (below, right), the displacement of the medium is in the same direction as the waves are traveling. The dotted lines show the equilibrium positions.



b. The wave speed is not the same as the maximum speed of any particle, often the wave speed is much greater. The wave speed depends on the properties of the medium, the particle speed depends on the wave frequency and amplitude.

c. The same is true for longitudinal waves.

d. Wave speed is proportional to the elastic property over the inertial property. The inertial property (mass, density), has to be the same for both longitudinal and transverse waves in the ground – they're both traveling through the same medium. However the elastic property (tension), is greater for longitudinal waves – the particles can move up and down more easily than side to side, which requires compression. (Ground has a lower sheer modulus than compression.)

D. Quantitative Question:

Rebecca and Brent are trying to teach Barry to jump over a rope. Brent suddenly jiggles the rope at his end sending a wave traveling along it towards Rebecca. The wave can be described the equation $y(x,t) = 0.02\text{ m} \sin(63\text{ m}^{-1}\, x - 2510\text{ rad.s}^{-1}\, t)$.

This is of the form $y(x,t) = A \sin(kx - \omega t)$

a. The amplitude of this wave is $A = 0.02$ m.

b. The wavelength of this wave is $\lambda = 2\pi/k = 2\pi / 63\text{ m}^{-1} = 0.1\text{ m} = 10\text{ cm}$.

c. The frequency of this wave is $f = \omega / 2\pi = 2510\text{ rad.s}^{-1} / 2\pi = 400\text{ Hz}$.

d. The velocity of the wave is $v = f \times \lambda = 0.1\text{ m} \times 400\text{ s}^{-1} = 40\text{ m.s}^{-1}$.

e. The reflected wave is identical to the transmitted wave but traveling in the opposite direction, hence it can be described by the equation $y(x,t) = A \sin(kx + \omega t) = 0.02\text{ m} \sin(63\text{ m}^{-1}\, x + 2510\text{ rad.s}^{-1}\, t)$.