Chapter 2

Waves and Wavelike Motion

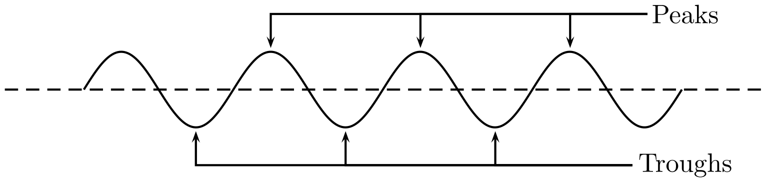
Waves occur frequently in nature. The most obvious examples are waves in water, on a dam, in the ocean, or in a bucket. We are most interested in the properties that waves have. All waves have the same properties so if we study waves in water then we can transfer our knowledge to predict how other examples of waves will behave.

2.1 What are waves?

Waves are disturbances which propagate (move) through a medium [1]. Waves can be viewed as a transfer energy rather than the movement of a particle. Particles form the medium through which waves propagate but they are not the wave. This will become clearer later.

Lets consider one case of waves: water waves. Waves in water consist of moving peaks and troughs. A peak is a place where the water rises higher than when the water is still and a trough is a place where the water sinks lower than when the water is still. A single peak or trough we call a *pulse*. A wave consists of a *train* of *pulses*.

So waves have peaks and troughs. This could be our first property for waves. The following diagram shows the peaks and troughs on a wave.



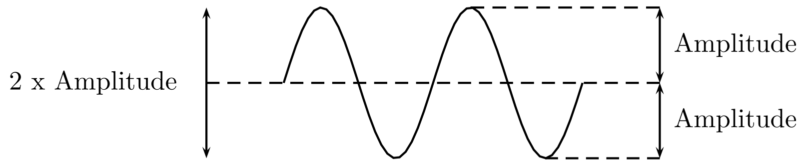
In physics we try to be as quantitative as possible. If we look very carefully we notice that the height of the peaks above the level of the still water is the same as the depth of the troughs below the level of the still water. The size of the peaks and troughs is the same.

2.1.1 Characteristics of Waves : Amplitude

The characteristic height of a peak and depth of a trough is called the *amplitude* of the wave. The vertical distance between the bottom of the trough and the top of the peak is twice the amplitude. We use symbols agreed upon by convention to label the characteristic quantities of

[1]Light is a special case, it exhibits wave-like properties but does not require a medium through which to propagate.

the waves. Normally the letter A is used for the amplitude of a wave. The units of amplitude are metres (m).



Worked Example 1

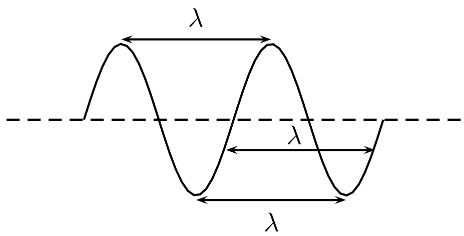
Question: (NOTE TO SELF: Make this a more exciting question) If the peak of a wave measures 2m above the still water mark in the harbour what is the amplitude of the wave?
Answer: The definition of the amplitude is the height that the water rises to above when it is still. This is exactly what we were told, so the answer is that the amplitude is 2m.

2.1.2 Characteristics of Waves : Wavelength

Look a little closer at the peaks and the troughs. The distance between two *adjacent* (next to each other) peaks is the same no matter which two adjacent peaks you choose. So there is a fixed distance between the peaks.

Looking closer you'll notice that the distance between two adjacent troughs is the same no matter which two troughs you look at. But, *more importantly*, its is the same as the distance between the peaks. This distance which is a characteristic of the wave is called the *wavelength*.

Waves have a characteristic wavelength. The symbol for the wavelength is λ. The units are metres (m).



The wavelength is the distance between any two adjacent points which are in *phase*. Two points in phase are separate by an integer (0,1,2,3,...) number of complete wave cycles. They don't have to be peaks or trough but they must be separated by a complete number of waves.

2.1.3 Characteristics of Waves : Period

Now imagine you are sitting next to a pond and you watch the waves going past you. First one peak, then a trough and then another peak. If you measure the time between two adjacent peaks you'll find that it is the same. Now if you measure the time between two adjacent troughs you'll find that its always the same, no matter which two adjacent troughs you pick. The time you have been measuring is the time for one wavelength to pass by. We call this time the period and it is a characteristic of the wave.

Waves have a characteristic time interval which we call the *period* of the wave and denote with the symbol T. It is the time it takes for any two adjacent points which are in phase to pass a fixed point. The units are seconds (s).

2.1.4 Characteristics of Waves : Frequency

There is another way of characterising the time interval of a wave. We timed how long it takes for one wavelength to pass a fixed point to get the period. We could also turn this around and say how many waves go by in 1 second.

We can easily determine this number, which we call the *frequency* and denote f. To determine the frequency, how many waves go by in 1s, we work out what fraction of a waves goes by in 1 second by dividing 1 second by the time it takes T. If a wave takes $\frac{1}{2}$ a second to go by then in 1 second two waves must go by. $\frac{1}{\frac{1}{2}} = 2$. The unit of frequency is the Hz or s^{-1}.

Waves have a characteristic frequency.

$$f = \frac{1}{T}$$

f	: frequency (Hz or s^{-1})
T	: period (s)

2.1.5 Characteristics of Waves : Speed

Now if you are watching a wave go by you will notice that they move at a constant velocity. The speed is the distance you travel divided by the time you take to travel that distance. This is excellent because we know that the waves travel a distance λ in a time T. This means that we can determine the speed.

$$v = \frac{\lambda}{T}$$

v	: speed ($m.s^{-1}$)
λ	: wavelength (m)
T	: period (s)

There are a number of relationships involving the various characteristic quantities of waves. A simple example of how this would be useful is how to determine the velocity when you have the frequency and the wavelength. We can take the above equation and substitute the relationship between frequency and period to produce an equation for speed of the form

$$v = f\lambda$$

v	: speed ($m.s^{-1}$)
λ	: wavelength (m)
f	: frequency (Hz or s^{-1})

Is this correct? Remember a simple first check is to check the units! On the right hand side we have velocity which has units ms^{-1}. On the left hand side we have frequency which is measured in s^{-1} multiplied by wavelength which is measure in m. On the left hand side we have ms^{-1} which is exactly what we want.

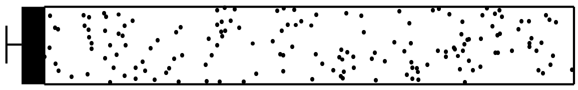
2.2 Two Types of Waves

We agreed that a wave was a moving set of peaks and troughs and we used water as an example. Moving peaks and troughs, with all the characteristics we described, in any medium constitute a wave. It is possible to have waves where the peaks and troughs are perpendicular to the direction of motion, like in the case of water waves. These waves are called *transverse waves*.

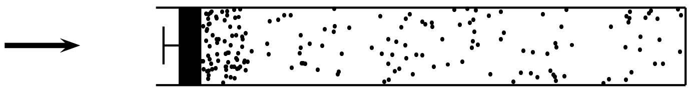
There is another type of wave. Called a *longitudinal wave* and it has the peaks and troughs in the same direction as the wave is moving. The question is how do we construct such a wave?

An example of a longitudinal wave is a pressure wave moving through a gas. The peaks in this wave are places where the pressure reaches a peak and the troughs are places where the pressure is a minimum.

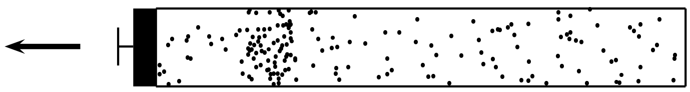
In the picture below we show the random placement of the gas molecules in a tube. The piston at the end moves into the tube with a repetitive motion. Before the first piston stroke the pressure is the same throughout the tube.



When the piston moves in it compresses the gas molecules together at the end of the tube. If the piston stopped moving the gas molecules would all bang into each other and the pressure would increase in the tube but if it moves out again fast enough then pressure waves can be set up.



When the piston moves out again before the molecules have time to bang around then the increase in pressure moves down the tube like a pulse (single peak). The piston moves out so fast that a pressure trough is created behind the peak.



As this repeats we get waves of increased and decreased pressure moving down the tubes. We can describe these pulses of increased pressure (peaks in the pressure) and decreased pressure (troughs of pressure) by a sine or cosine graph.