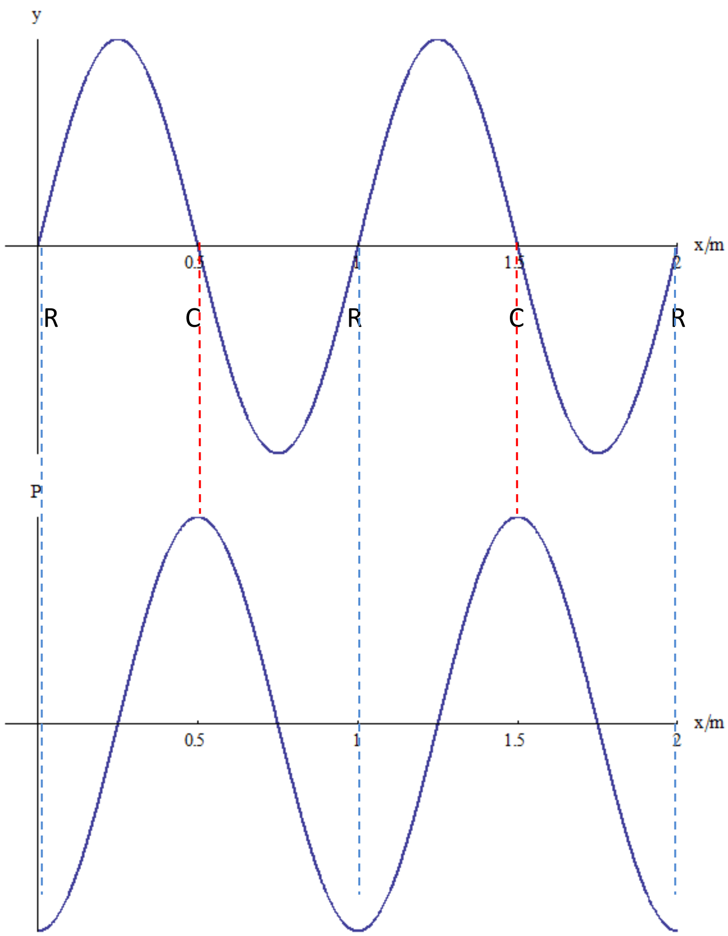
# Teacher notes
# Topic C

## Reflection of a longitudinal wave from an open end.

A common query from students is how does a longitudinal wave in a pipe that is open, get reflected from the open end.

It is relatively easy to explain reflection from a closed end: molecules incident on the closed end exert a force on the closed end (waves carry momentum!) and by Newton's third law the closed end exerts an opposite force to the molecules creating the reflected wave. But what about the open end?

In this course we represent waves by graphs of displacement versus distance or time. However, this is not the only way. We can also represent the wave in terms of the pressure in the pipe as a function of distance or time. As the wave travels inside the pipe, the pressure in the pipe oscillates to values above and below atmospheric pressure, the pressure of air outside the pipe. Here we plot the difference in pressure in the pipe minus atmospheric. Suppose the displacement versus distance graph is the following and notice the formation of compressions (C) and rarefactions (R). The pressure graph is then the second graph (the zero of pressure corresponds to atmospheric pressure).



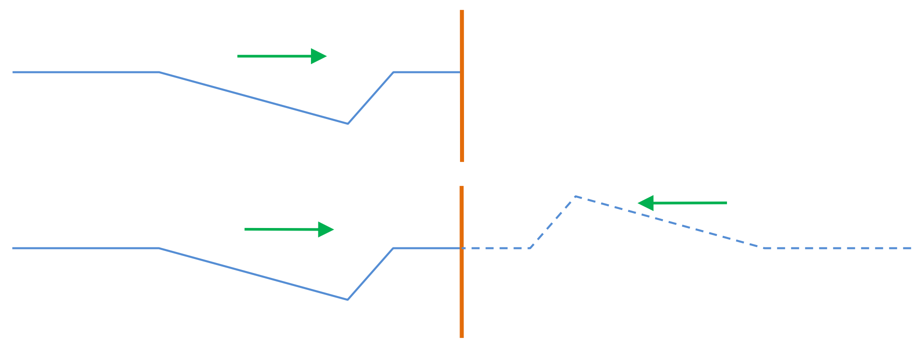

Displacement graph

Pressure graph

Notice that displacement peaks and troughs correspond to atmospheric pressure. Now, at an open end we have a displacement antinode and hence zero in the pressure difference. How can the pressure difference be zero at all times at the open end? The answer is by having a *reflected* pressure wave which differs from the incident pressure wave by a phase of $\pi$ so that we always get a pressure node there when the incident and reflected waves superpose. (The reflected displacement wave does not suffer a phase change which is why we get a displacement antinode there.)

This is a formal/mathematical way of explaining the reflection. But what actually *causes* the reflected wave? Well, if the pressure wave arriving at the open end has a pressure below atmospheric, air from the outside will push air *into* the pipe causing the reflected wave. If the pressure arriving at the open end is above atmospheric the outside air will be pushed away from the pipe and so by Newton's third law the air in the pipe will again be pushed back into the pipe again causing the reflected wave.

The argument above is a general argument that can be used for reflection in general. How do we explain the inversion of a pulse upon reflection from a fixed end? Newton's third law again does the job but here is another way. Shown is a pulse approaching a fixed end. We know the point of the string attached to the fixed end must remain motionless (a node). How can we achieve that? We can do so by considering an imaginary pulse to the right of the fixed end that travels to the left. We then ask, what should the shape of this pulse be for the end point to stay fixed? The answer is shown in the second diagram. The real pulse disappears behind the fixed end and the imaginary dotted pulse enters the real world to the left of the fixed end as the reflected wave. The superposition of the two pulses ensures that the end point stays fixed.



This is an abstract but very powerful and elegant way of thinking about reflection.