3.2: Collisions with Boundaries

Tutorial 3.2: Collisions with boundaries

In the previous simulation we did not take the wave nature of reflected waves into account; the waves were assumed to be exactly the same after reflection. However the phase of the wave may be different after reflection, depending on the surface from which they reflect. The example below is for strings but a similar effect occurs when light or sound reflect off of different types of surfaces or boundaries.

Waves reflect from a boundary in two basic ways depending on whether the boundary is "hard" or "soft". In the case of waves on a string a "hard" boundary is where the string is firmly attached and a "soft" boundary is when the end of the string can slide up and down. The string in this animation is simulated as a row of individual masses connected by invisible springs.

In the case of strings a boundary where the end is free is called a **free boundary condition**. If the end is fixed it is called a **rigid** or **fixed boundary condition**. A third possible boundary is **circular boundary conditions** which is the case if the right end of the string loops around to smoothly connect to the left end. For circular boundary conditions a pulse moving the the right would re-appear at the left after it leaves the right hand side of the simulation. Fixed and free boundaries can also occur for sound waves in a tube and determine the resonant frequencies for the tube.

Reflection from Boundaries

Questions:

Exercise 3.2.1

Run the simulation to see how a Gaussian pulse reflects off the two different boundaries. How is a pulse reflected from a fixed boundary different from one reflected from a free boundary?

Exercise 3.2.2

Now check the sine wave check box to see what happens when a sine wave hits the two types of boundaries. What is the end result in these cases? (Hint: Go back to simulation 2.1 and add two identical waves moving in opposite directions.)

Exercise 3.2.3

Although the reflecting sine waves in both cases interacts with the incoming wave to form a standing waves there is a slight difference between the two. Which case has a node at the boundary and which has an anti-node at the boundary? (Nodes and anti-nodes were defined in simulation 2.1.)

A wave reflected from a stiff or fixed boundary is said to have a **phase shift** of 180° (or π radians). This means a pulse will invert itself on reflection and the first anti-node of a standing wave will occur 180° from the boundary. If the boundary is soft the first anti-node occurs at the boundary. As we will see shortly, other kinds of waves also experience a phase shift on reflection from some kinds of boundaries. For example when light in air reflects from a material that is more optically dense (such as a glass) there is a phase change of 180° but when light in glass reflects from a glass/air boundary there is no phase change since the light is going from a more optically dense material (glass) to a less optically dense material (air).