3.7: Impedance

Tutorial 3.7: Impedance: Collisions with boundaries

Generally the term **impedance** refers to how easily oscillating energy is transferred from one location to another. There are many kinds of impedance; mechanical, electrical, acoustic and wave impedances all have definitions specific to their use in different fields. Here we will briefly investigate the mechanical energy transferred from one medium to another.

In many cases a wave colliding with a boundary will partially reflect and be partially transmitted. The kind of wave reflected and the amount of energy transmitted depend on the properties of the material on either side of the boundary. This animation again simulates a string as a row of individual masses connected by invisible springs. In this case the mass of the string is different on the left as compared with the right.

Impedance

Questions:

Exercise 3.7.1

Run the simulation and describe what happens when a pulse goes from a light string to a heavy string.

Exercise 3.7.2

Click the 'Heavy to Light' button, run the simulation and describe what happens when a pulse goes from a heavy string to a light string.

Exercise 3.7.3

In which case is the reflected pulse inverted? Based on what you learned about reflections from soft and hard boundaries in the previous simulation, explain this result.

Exercise 3.7.4

In which case is the reflected pulse larger than the transmitted pulse?

Exercise 3.7.5

In which case is the reflected pulse faster? Based on what you learned about how physical properties determine the speed of a wave, explain this result.

In this simulation the change in mass of the string affects the amount of reflected and transmitted energy and the speeds of the waves. If the string had the same mass on both sides there would be no reflection. A similar thing happens when two electrical devices are hooked together and one device is sending energy to the second one (for example signals going from a stereo system to a set of speakers). In this case the impedance is determined by the components (resistors, capacitors, inductors, etc. in the circuits) and is frequency dependent. If the electrical impedance of the two devices is different, some energy is reflected rather than being transmitted to the second device.

Exercise 3.7.6

You are buying a stero system and a set of speakers. The stereo has an output imedance of $10\ \mathrm{ohms}$. What impedance speakers do you need to buy to get the loudest sound?

One way to try to **match impedances** is to gradually change the medium between two different values. This is the purpose of the bell on brass and woodwind instruments. An instrument such as a trumpet would not produce as much sound if it ended abruptly with no flared bell on the end. This is because there is an impedance missmatch for waves inside the instrument (where the pressure is constrained by the sides of the instrument) and the pressure outside.

Exercise 3.7.7

Why are flutes softer than trombones?

The bell on an instrument also affects the frequencies produced. If there was no impedance missmatch at all there would be no reflected wave going back into the instrument from the bell region. This reflected wave is needed to set up a standing wave (much like the standing wave in on a string) in the instrument so that a given pitch is produded.

Exercise 3.7.8

At the mouthpiece of a trumpet the wave reflects from a "hard" surface. At the other end (the bell) the wave reflects at a boundary that is going from stiffer (inside the horn) to softer; a "soft" boundary. Based on this and simulation 3.2, which end has a dispacement node and which end has an anti-node?

Note

The closed end at the mouthpiece doesn't allow the movement of air but that means there is a large fluctuation of pressure. So an air displacement node occurs at the same location as a pressure anti-node and vice versa.