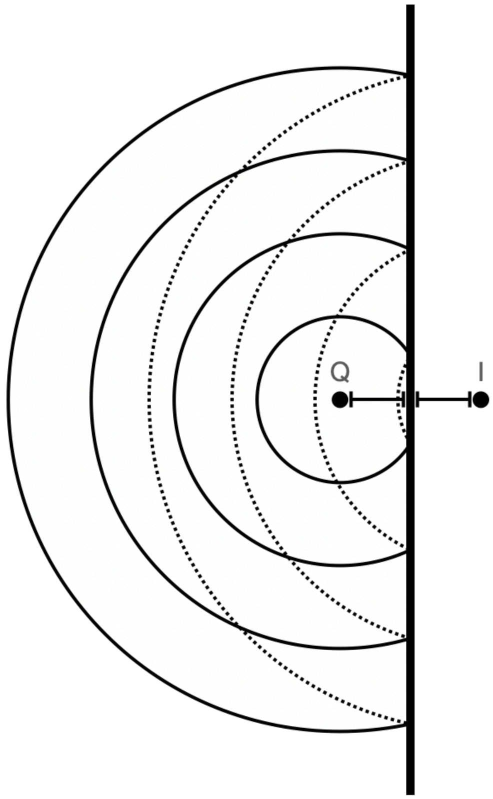
Lesson 4. Wave Properties

Reflection

When a wave front impacts a point where the properties of the medium carrying it suddenly change (such as a wall), the wave will **reflect**. The waves will bounce off the wall at the inverse angle of their travel. The reflected sound waves will appear to originate from an **image** source, located as far behind the the wall as the **incident** source was in front of it.



Because the image source will seem to the observer to have produced its sound waves at precisely the same time as the incident source, the reflected waves will be delayed in time, causing an **echo**.

Refraction

All waves also *refract* in a medium where the properties change slowly, causing the wave to change directions, but this is not especially important for music.

Diffraction

If a wave front encounters a small obstacle, there will be some reflection, but also **diffraction** as the waves move around the obstacle and fill in the space behind it. This is why you can hear sounds around corners or if something is blocking your view of the source.

Interference

When sounds from two sources travel through the same medium, each wave front travels as it would if the other were not there. However, the displacement of any point in the medium cannot have two values simultaneously, so if both waves are acting on a point at the same time, the displacement will be the sum of the displacement of each wave. If the sum is positive (the crests and troughs align), this is called **constructive interference** and will result in a larger amplitude. If the sum is negative (the crests of one wave align with the troughs of the other wave), it will result in **destructive interference** and cause a smaller amplitude.

The “**beats**” when a note is out of tune are the result of alternating constructive and destructive interference, since the frequencies are close but not identical. The frequency of the beats will be equal to the difference in frequency between the two waves.

Energy, Power, and Intensity

To produce a wave continuously, the source must continue to provide power, which is measured in *watts*. Not all the power applied to an instrument (through a bow, blowing, etc.) will go to sound production, but the amount that does is measured in **acoustic watts**. The percentage of applied power converted to acoustic watts is called the instrument's *efficiency*. Most instruments have an efficiency of less than 1%, but this is more than enough for the ear to detect.

The intensity (I) of a sound is measured in *watts per square meter*. This shows the amount of acoustic watts (P) passing through an area 1m x 1m at a given distance (R) from the sound source, then extrapolated to the amount of energy that would pass through a sphere surrounding the source with uniform intensity.

$$I = \frac{P}{4\pi R^2}$$

Absorption

A perfectly rigid wall would be unable to absorb any energy from a sound wave striking it, and would create a reflection of equal amplitude as the incident source. However, walls are not perfectly rigid, and some energy is absorbed.

The intensity (I) of the incident sound will always be greater than the intensity (I_R) of the reflected sound. The difference between the two is the absorption I_A. Different materials will have a different *absorption coefficient (a)*, the ratio of absorbed sound to incident sound.

$$a = \frac{I_A}{I}$$