

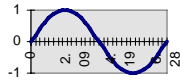
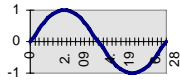
The Lost Lectures

Waves and Sound

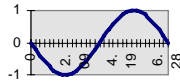
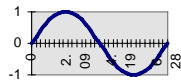
• Waves can be single pulses or continuous. A continuous sine wave has a *wavelength*, λ , a *frequency*, f , and a *wave speed*, v . They are all related by $v = f \lambda$.

• In a vibrating string, the string vibrates perpendicular to the wave. This is a *transverse wave*. In a gas, the sound wave exists as an overpressure and underpressure about the base air pressure. The gas molecules compress and expand – this is a *longitudinal wave*. A Slinky™ can do both longitudinal and transverse waves.

• If you have more than one wave, or if one wave is split into pieces and recombined, then the waves can add together. The two extreme cases are *Constructive Interference*, where the waves are in phase and they add up together, and *Destructive Interference*, where the two waves are exactly 180° out of phase and they cancel each other out.



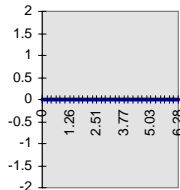
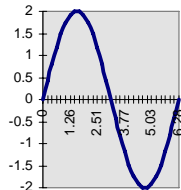
Wave 1



Wave 2

Constructive Interference

Destructive Interference

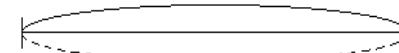


Wave 1 + 2

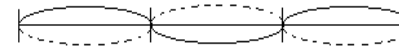
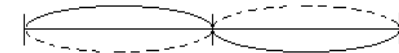
• *Standing waves* are the result of confining a wave to a particular geometry, such that the reflection at the ends create a *resonance* – where we can more directly detect the wave. The wavelength λ (or some multiple of $\lambda/2$) fits into the dimensions of the object, the length L of a string, for example. A vibrating string actually looks like the pictures...

• For standing waves in general, places where the vibrations are maximized are called *anti-nodes*. Places where the vibrations appear to disappear are called *nodes*. Resonance and interference are very important properties in Physics. But do not confuse the amplitude of the vibrating wave with the motion of the wave.

• For standing waves on a string fixed at both ends, one has to have nodes at both ends. That means that the longest wavelength wave that will fit the string has $\lambda/2 = L$ or $\lambda = 2L$. This longest wave is called the *fundamental*. (The dashed lines represents the reflected wave also just fitting the geometry.)



• The next resonance occurs when we fit in another node. For a string fixed at both ends, the *first overtone* occurs when $\lambda = L$. And the *second overtone* has yet another node, for $3/2 \lambda = L$ or $\lambda = 2/3 L$.



• For a tube open at one end and closed at the other, the resonance conditions change: you need a node at the closed end and an anti-node at the open end. (This is the same as for a vibrating string fixed at one end and free at another – this is how cowboys do their tricks with a lariat.) The

fundamental is then $\lambda/4 = L$ and the first overtone is $3/4 \lambda = L$. (If you had a tube open at both ends, you would need anti-nodes at both ends, but the equations would be the same as for a string fixed at both ends.)



• If you play two notes that are very close in frequency (or wavelength), you will get an interference pattern that sometimes is in phase and sometimes out of phase. A sort of *Waa-Waa-Waa...* change of volume as the two waves alternately constructively and destructively interfere with each other. The frequency of this volume pattern is called the *beat frequency*, and it is equal to Δf , the difference between the two frequencies.

• If you try to move through a media faster than the prevailing waves can, you will get a shock wave. In air this is called a *sonic boom*. In water you get a *wake*. The shock waves spread out at an angle θ behind you, with θ determined by your speed. There are usually two shock waves, one from the front and one from the back – hence if you hear a sonic boom, you hear a double-boom. Should you go faster than the local speed of light in air or water, you will see a blue glow called *Cerenkov radiation*, but it is also the same sort of shock wave.