Resonance

Physics

Module 11

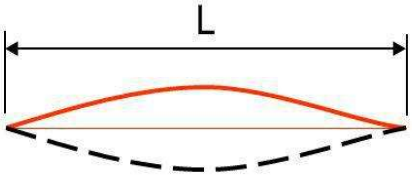
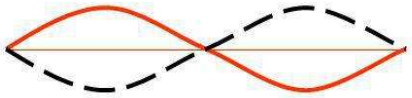
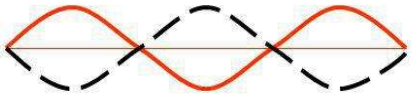
Resonance occurs when the frequency of an object's oscillations matches the object's natural frequency of vibration. It may cause violent swaying motions and even catastrophic failure in improperly constructed structures including bridges, buildings and airplanes—a phenomenon known as resonance disaster. The classic example of failure by resonance is the Tacoma Narrow Bridge collapse that occurred in 1940. Watch a video of the collapse at https://www.youtube.com/watch?v=nFzu6CNtqec High winds caused the bridge to oscillate at its natural frequency and the bridge shook itself apart.

Musical instruments also demonstrate resonance. An acoustically resonant object usually has more than one resonance frequency, especially at harmonics of the strongest resonance. The instrument will easily vibrate at those frequencies, and vibrate less strongly at other frequencies.

Harmonics on a String

Strings or parts of strings may resonate at their fundamental or overtone frequencies when other strings are sounded. For example, an A string at 440 Hz will cause an E string at 330 Hz to resonate, because they share an overtone of 1320 Hz (3rd overtone of A and 4th overtone of E).

Strings can have odd or even harmonics. Use the table below to calculate wavelengths and frequencies.

n = 1; 1st harmonic (fundamental)		$\lambda_1 = 2\,L$	$f_1 = \frac{v}{2L}$
n = 2; 2nd harmonic (1st overtone)		$\lambda_2 = L$	$f_2 = \frac{v}{L} = 2f_1$
n = 3; 3rd harmonic (2nd overtone)		$\lambda_3 = {}^2/_3\,L$	$f_3 = \frac{3v}{2L} = 3f_1$

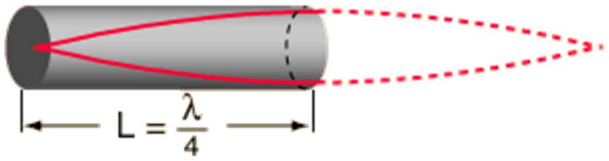
Harmonics in an Open-End Pipe

The shape of a standing wave in a pipe depends on whether the pipe has two open ends or an open end and a closed end. On a pipe with two open ends, the formulas for the wavelengths and frequencies of harmonics are the same formulas used for harmonics on a string.

n		
1	$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$
2	$\lambda_2 = L$	$f_2 = \frac{v}{L} = 2f_1$
3	$\lambda_3 = {}^2/_3 L$	$f_3 = \frac{3v}{2L} = 3f_1$

Harmonics in a Closed-End Pipe

On a pipe with one closed end, only odd harmonics are formed.



	$\lambda_1 = 4L$	$f_1 = \frac{v}{4L}$
n = 3	$\lambda_2 = {}^4/_3 L$	$f_2 = \frac{3v}{4L} = 3f_1$
n = 5	$\lambda_3 = {}^4/_5 L$	$f_3 = \frac{5v}{4L} = 5f_1$