Doppler Shift

$$f' = f\frac{v \pm v_o}{v \pm v_s}$$

+ observer moving towards, - observer moving away,

- source moving towards, + source moving away.

- A car is approaching an observer at 30 m/s and sounds its horn at 500 Hz. What frequency does the observer hear?

548 Hz

- If the observer is driving at 30 m/s towards a stationary car which is sounding its horn, what frequency will the moving car hear?

544 Hz

Sonic Boom

- Have you personally heard a sonic boom?

A. Yes

B. I think so

D. No

Sonic Boom

Describe to your neighbor(s)

1. What it sounded like
2. What you think causes a sonic boom

Sonic Boom

Mach Number:

Speed / Speed of Sound

Mach 1: v = 343 m/s

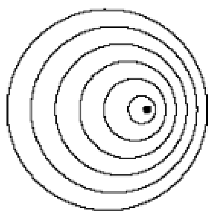
Mach 2: v = 686 m/s

What would Mach 0.5 be?

~170 m/s

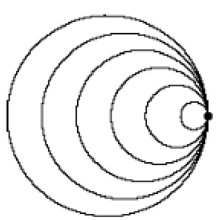
Sonic Boom

Source moving with $v_{source} < v_{sound}$ (Mach 0.7)

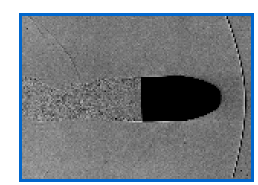


In the movie at left the same sound source is radiating sound waves at a constant frequency in the same medium. However, now the sound source is moving to the right with a speed $v_s = 0.7\ v$ (Mach 0.7). The wavefronts are produced with the same frequency as before. However, since the source is moving, the center of each new wavefront is now slightly displaced to the right. As a result, the wavefronts begin to bunch up on the right side (in front of) and spread further apart on the left side (behind) of the source. An observer in front of the source will hear a higher frequency $f' > f_0$, and an observer behind the source will hear a lower frequency $f' < f_0$.

Source moving with $v_{source} = v_{sound}$ (Mach 1 - breaking the sound barrier)



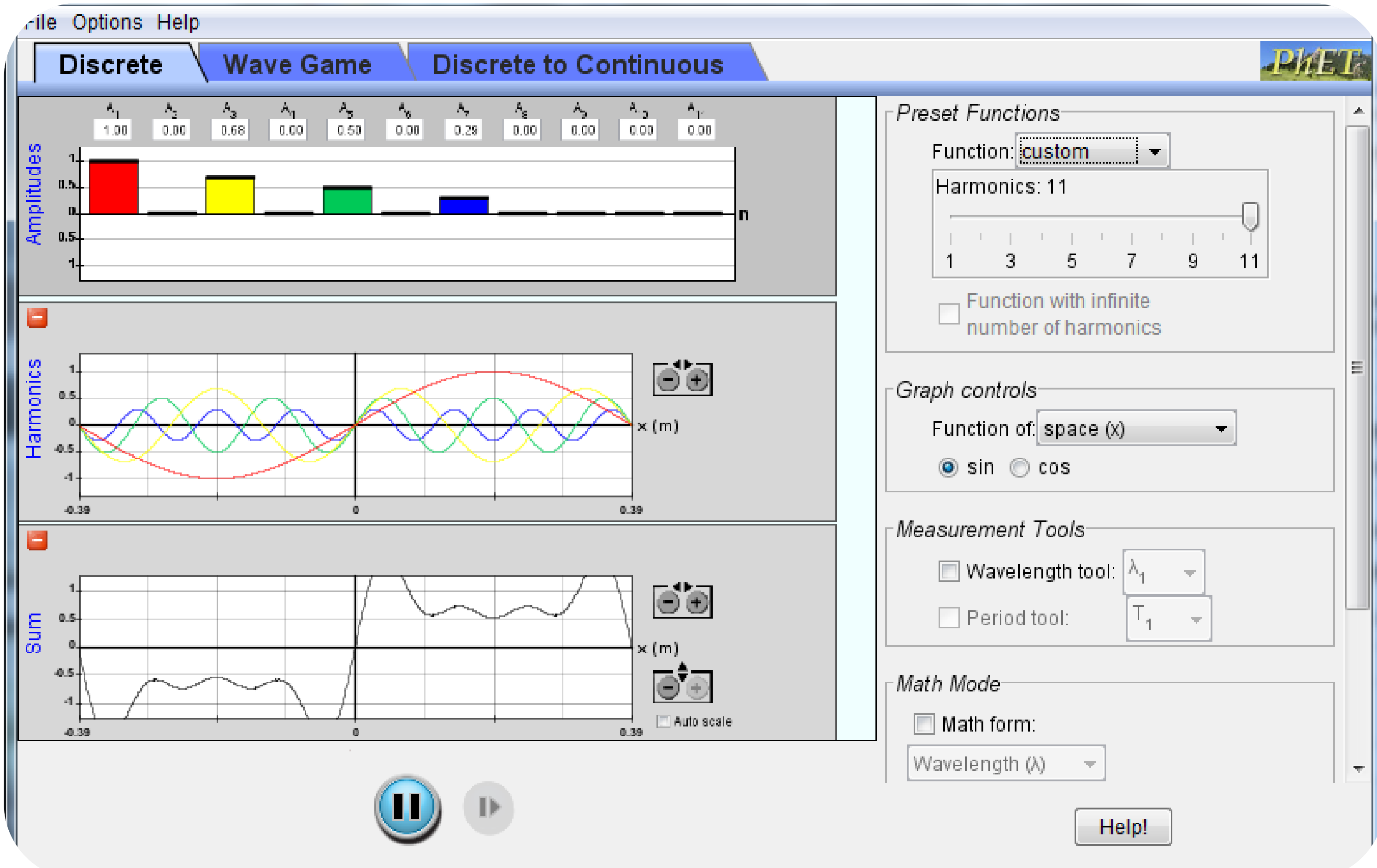
Now the source is moving at the speed of sound in the medium ($v_s = v$, or Mach 1). The speed of sound in air at sea level is about 340 m/s or about 750 mph. The wavefronts in front of the source are now all bunched up at the same point. As a result, an observer in front of the source will detect nothing until the source arrives. The pressure front will be quite intense (a shock wave), due to all the wavefronts adding together, and will not be percieved as a pitch but as a "thump" of sound as the pressure wall passes by. The figure at right shows a bullet travelling at Mach 1.01. You can see the shock wave front just ahead of the bullet.



Jet pilots flying at Mach 1 report that there is a noticeable "wall" or "barrier" which must be penetrated before achieving supersonic speeds. This "wall" is due to the intense pressure front, and flying within this pressure front produces a very turbulent and bouncy ride. Chuck Yeager was the first person to break the sound barrier when he flew faster than the speed of sound in the X-1 rocket-powered aircraft on October 14, 1947. Check out the movie The Right Stuff for more about this significant milestone, and the beginnings of the US space project. The figure at right shows a n F-18 at the exact

Sonic Boom

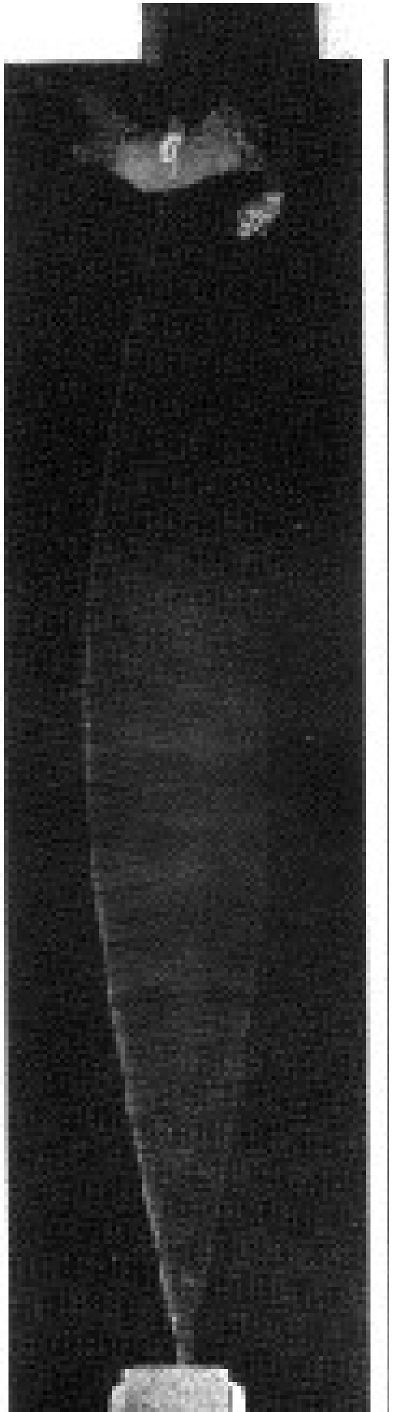
Harmonics and perception



Standing Waves

Superposition Creates Standing Waves

Two sinusoidal waves traveling in opposite directions add to create a standing wave.

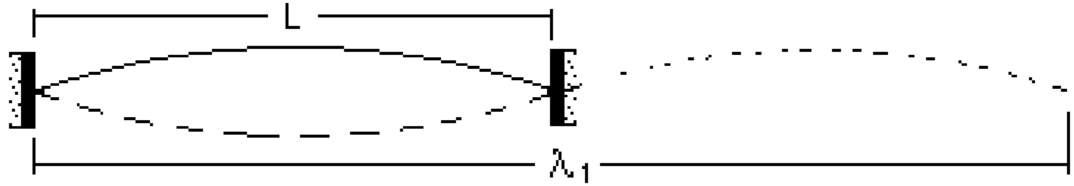


The Fundamental – the longest wavelength that will fit on a string.
Also known as the 1st harmonic

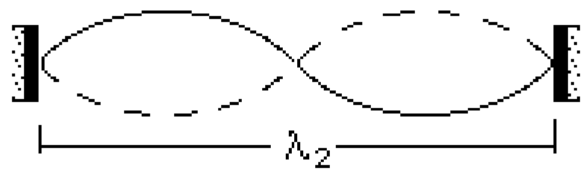
2nd Harmonic

$f = v/\lambda$

1st harmonic $\lambda_1 = 2L$

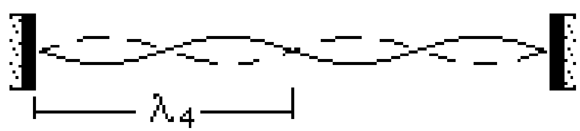


2nd harmonic $\lambda_2 = L$



3rd harmonic $\lambda_3 = 2/3L$

4th harmonic $\lambda_4 = 1/2L$



Nth harmonic $\lambda_n = 2L/n$ so $f = nv/(2L)$

Tacoma Narrows Bridge