Stuff

- Friday 4 p.m. JSB Auditorium
  - Dr. Mario Capecchi, a Nobel laureate and distinguished professor of Genetics and Biology, HHMI investigator from the U of Utah

- Saturday 8:30 p.m. The Wall
  - Solo competition finals, $3?
  - Really excellent performer at 9:30
Other Decibel Scales

- Weighting
- dBm
- dBV
- dB SPL
- dBFV
You are driving north at 45 MPH, and you approach a car travelling south at 65 MPH. The other car honks, and you hear a frequency of 400 Hz. If the speed of sound is 767 MPH, what frequency does the driver of the other car hear?

A. 346 Hz
B. 463 Hz
C. 390 Hz
D. 347 Hz
E. None of the above
\[ f' = f \frac{v + v_0}{v + v_s} \]

Upper sign for approaching

\[ \begin{align*}
V_0 & \\
V_s & \\
\frac{f'}{f} & \\
\frac{f'}{f} & = \frac{V + V_0}{V - V_s} \\
& \text{Speed of sound} \\
& = 400 \text{Hz} \quad \frac{767 - 65}{767 + 45}
\end{align*} \]
Doppler Shift From a Moving Observer

\[ \lambda = \frac{\nu}{\xi} \quad T' = \frac{\lambda}{\nu \pm \nu_0} \]

\[ \xi' = \frac{1}{T'} = \frac{\nu \pm \nu_0}{\lambda} \]

\[ \xi' = \xi \frac{\nu \pm \nu_0}{\nu} \]
Doppler effect in sound

• An approaching source sounds higher in pitch than the source.
• A source that is moving away sounds lower in pitch than the source.

http://www.youtube.com/watch?v=a3RfULw7aAY&feature=related
Doppler Shift From a Moving Source

\[ f' = \frac{V}{\lambda} = \lambda \]

\[ \lambda = TV \]

\[ moving\ source \]

\[ \lambda = TV - TV_s = T (V - V_s) \]

\[ f' = \frac{V}{T(V - V_s)} = f \frac{V}{V - V_s} \]
\[ f' = \frac{v \pm v_o}{v \mp v_s} f \]

\[ v = \text{the velocity of the wave} \]

Approaching-use top sign --- Moving away-use bottom sign
Three stationary observers, $A$, $B$, and $C$ are listening to moving source of sound. The diagram shows the wavefronts of the source. Which of the following is true?

A. The wavefronts move faster at $A$ than at $B$ and $C$.
B. The wavefronts move faster at $C$ than at $A$ and $B$.
C. The frequency of the sound is highest at $A$.
D. The frequency of the sound is highest at $B$.
E. The frequency of the sound is highest at $C$.

(c) Dallin S. Durfee
A stationary observer hears a pitch from a source that moves *towards* him, the observed frequency will be ______________ the source frequency

A. Lower than  
B. The same as  
**C. Higher than**

\[
f' = \frac{v \pm v_o}{v \mp v_s} f
\]

\(v = \text{the velocity of the wave}\)

Approaching-use top sign --- Moving away-use bottom sign
An observer approaches a stationary frequency source, the observed frequency will be ______________ the source frequency

A. Lower than
B. The same as
C. Higher than

\[ f' = \frac{v \pm v_o}{v \mp v_s} f \]

\( v = \text{the velocity of the wave} \)

Approaching-use top sign --- Moving away-use bottom sign
Frequency is **Higher** when approaching each other.

Frequency is **Lower** when moving apart.

\[ f' = \frac{v \pm v_o}{v \mp v_s} f \]

\( v = \text{the velocity of the wave} \)

Approaching-use top sign --- Moving away-use bottom sign
Experience and preparation matters

Talk about Elder Eyring giving a graduation talk

Reading the defense
A stationary observer hears a pitch from a source that moves *towards* him at a half the speed of sound. Then the source stops and the observer moves at half the speed of sound *towards* the source. In the second case the frequency the observer hears is . . .

A. Lower than before
B. The same
C. Higher than before
You stand on a platform at a train station and listen to a train approaching the station at a constant velocity. While the train approaches, but is still far away, what do you hear?

A. The intensity and the frequency of the sound both increasing.
B. The intensity and the frequency of the sound both decreasing.
C. The intensity increasing and the frequency decreasing.
D. The intensity decreasing and the frequency increasing.
E. The intensity increasing and the frequency remaining the same.
Light is also Doppler shifted

- Atomic spectra of galaxies moving away is shifted to lower frequencies.
- Some are shifted more than others—they must be moving away faster.
- The farther away, the faster they are moving.
- The universe is expanding
\[ f_{\text{red}} = 4.8 \times 10^{14} \text{ Hz} \]
\[ f_{\text{green}} = 5.5 \times 10^{14} \text{ Hz} \]

for an observer traveling toward the light

\[ f_{\text{green}} = f_{\text{red}} \sqrt{\frac{c + v}{c - v}} \]

\[ v = 4.1 \times 10^7 \text{ m/s} \approx 10^8 \text{ mph} \approx 0.14c \]
Practical use . . .

Bats emit ~60kHz bursts of sound and listen for Doppler shifted reflections off victims.

With “Doppler radar” meteorologists can see how storms move and police can measure your speed.

Astronomers use Doppler shifts to determine how stars and galaxies are moving.
Sonic Booms

- http://www.youtube.com/watch?v=6o0zmafxTmE
The following figure shows the wavefronts generated by an airplane flying past an observer $A$ at a speed greater than that of sound. After the airplane has passed, the observer reports hearing

A. 1. a sonic boom only when the airplane breaks the sound barrier, then nothing.
B. 2. a succession of sonic booms.
C. 3. a sonic boom, then silence.
D. 4. first nothing, then a sonic boom, then the sound of engines.
E. 5. no sonic boom because the airplane flew faster than sound all along.

(c) Dallin S. Durfee
Concorde pilot Peter Benn, from an interview with BBC about being able to hear the sonic boom while he was piloting

"You don't actually hear anything on board. All we see is the pressure wave moving down the aeroplane - it gives an indication on the instruments. And that's what we see of Mach 1. But we don't hear the sonic boom or anything like that. That's rather like the wake of ship - it's behind us."
On a particularly windy day the wind is blowing at half the speed of sound. If I am standing still and a cow is flying towards me at the same velocity as the wind, by what factor will I hear her mooing shifted in frequency?

A : $f' = \frac{1}{2} f$

B : $f' = \frac{2}{3} f$

C : $f' = \frac{3}{2} f$

D : $f' = 2 f$

E : None of the above.

We must use the velocities in the reference frame of the wave medium (the air), not the ground!
The Bell Tower plays a G (392 Hz) as I drive past at 20 m/s (about 40 mph). What do I hear?

\[
f' = \frac{v \pm v_o}{v \mp v_s} f
\]

\[
v = 343 \text{ m/s (velocity of sound in air)}
\]

\[
v_o = 20 \text{ m/s}
\]

\[
v_s = 0 \text{ m/s}
\]

Approaching

Moving away

(c) Dallin S. Durfee
The Bell Tower plays a G (392 Hz) as I drive past at 20 m/s (about 40 mph). What do I hear?

\[
f' = \frac{v \pm v_o}{v \mp v_s} f
\]

Approaching

\[
f' = \frac{v + v_o}{v} f = \left( \frac{343 \text{ m/s} + 20 \text{ m/s}}{343 \text{ m/s}} \right) 392 \text{ Hz} = 415 \text{ Hz}
\]

Moving away

\[
f' = \frac{v - v_o}{v} f = \left( \frac{343 \text{ m/s} - 20 \text{ m/s}}{343 \text{ m/s}} \right) 392 \text{ Hz} = 369 \text{ Hz}
\]

415 Hz is a G sharp, 369 Hz is a G flat