Physics 9 — Friday, September 14, 2018

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- On Friday, 9/21, recent Penn ARCH/Music grad Davis Butner will speak about his developing career in arch. acoustics.
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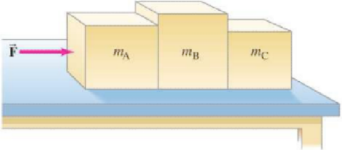
My favorite problem from HW1 is #7.

7*. Three blocks on a **frictionless** horizontal surface are in contact with each other, as shown below. A force $\vec{F} = 90.0$ N (pointing to the right) is applied to block A (mass m_A). The blocks' masses are $m_A = m_B = m_C = 10.0$ kg. (a) Draw three free-body diagrams: one for each block. (In this problem, just focus on the horizontal forces, since the two vertical forces on each block will sum to zero.) (b) Find the acceleration of the three-block system. (c) Find the net force (magnitude and direction) acting on each block. (d) What are the magnitudes and directions of the two horizontal forces acting on block A? (e) What are the magnitudes and directions of the two horizontal forces acting on block B? (f) What are the magnitude and direction of the one horizontal force acting on block C?



The blocks are rigid (inflexible) and are touching. When I push the left block toward the right, will the blocks all have the same acceleration? If so, how do I find that acceleration?

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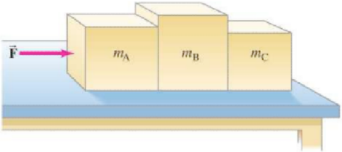

If you know the acceleration of each block, and you know the mass of each block, how do you find the net force acting on each block?

Some people also asked about the two-buckets problem.

Are sound waves transverse waves or are they longitudinal waves?

Longitudinal waves are harder to visualize than transverse waves.

http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html

Notice that the peaks of displacement are $\lambda/4$ (i.e. 90°) out of phase with the peaks of compression and rarefaction.

Notice that at a free end (like the open end of a flute or an organ pipe), displacement changes maximally (displacement *antinode*), while compression stays unchanged (compression *node*).

http://www.acs.psu.edu/drussell/Demos/StandingWaves/StandingWaves.html

Notice that at a fixed end (like the closed end of a tube), the displacement is zero (displacement *node*), while the compression varies maximally (compression *antinode*).

Displacement and compression in air $\leftrightarrow$ displacement and slope on a vibrating string. A sine or cosine function's displacement is maximum where its slope is zero, and vice versa.

If I take an organ pipe whose length is $L = 0.25\ \mathrm{m}$ (that's 25 cm) and let both ends be open to the atmosphere, what does the fundamental standing wave look like?

- Where are the displacement nodes and antinodes?
- Where are the pressure nodes and antinodes?
- What is the largest allowed wavelength?
- What is the fundamental (smallest allowed) frequency?

- What happens if instead I close off one end!

Sound: longitudinal waves propagating in a medium.

$$v_{\rm sound} = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\text{bulk modulus}}{\text{mass/volume}}} = 343\ \mathrm{m/s} \text{ in air at } 20^\circ\mathrm{C}.$$

(331 m/s in air at 0°C.)

Rule of thumb: stiffer $\rightarrow$ higher $f_{\rm resonant}$ & higher wave speed; more massive $\rightarrow$ lower $f_{\rm resonant}$ & lower wave speed.

(Cooler air is more dense than warmer air. You can remember that by thinking of a hot-air balloon.)

Question: Helium has a much lower density (lower mass/volume) than air, but a similar bulk modulus. If you exhale helium instead of air, do you expect your airway to resonate at a higher or lower frequency than usual? **Why?**

Sound waves in room-temperature air travel at a wave speed of 343 m/s. (Much more on sound in the next two weeks!)

Digression: About how long does it take for a pulse of sound (maybe a clap of thunder or the sound of a baseball bat hitting a ball) to travel 1 km?

What about a mile (1.61 km $\approx$ (5/3) km)?

What about one foot ((1/3.28) meter, or (1/5280) mile)?

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Sound waves in air travel 1 km in 3 s, 1 mile in 5 s,
1 foot in 1 millisecond.

Sound waves in room-temperature air travel at a wave speed of 343 m/s. At a frequency of about 34 Hz (near the lower end of the range of frequencies people can hear), what is the wavelength?

(Young human ears can hear roughly 20 Hz — 20 kHz.)

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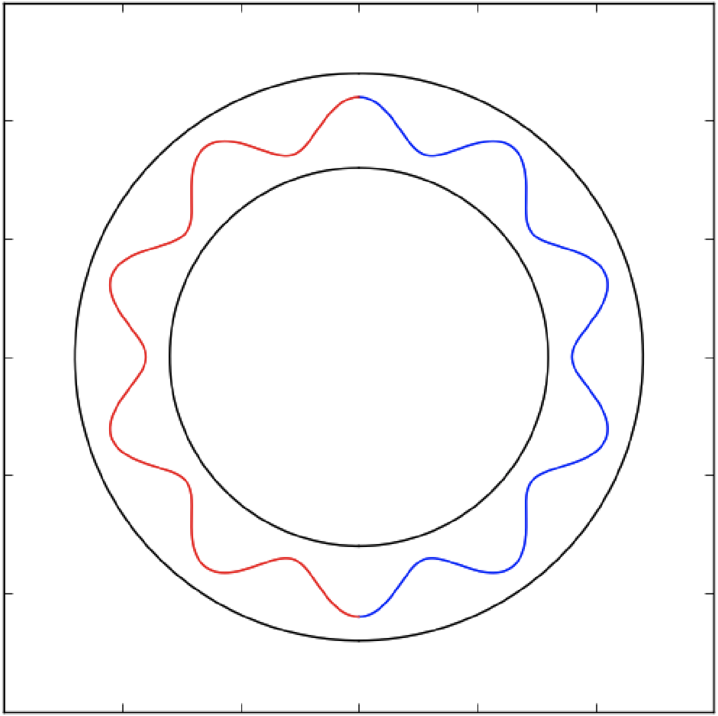
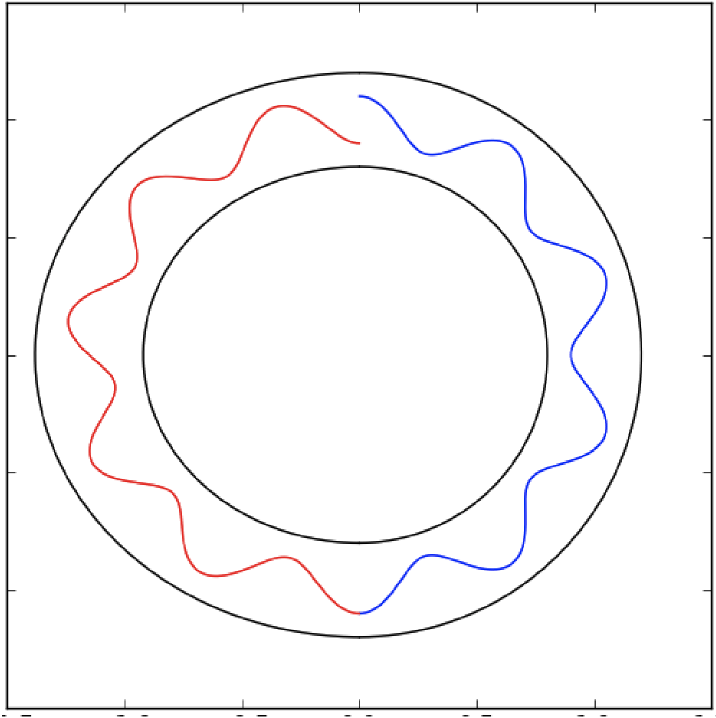
It turns out that the conventional telephone network only transmits sounds in the frequency range 300 Hz — 3400 Hz. What's the wavelength (for sound in air) at 343 Hz? At 3430 Hz?

- We saw earlier that when two waves overlap, the phases of the two waves can coincide, resulting in a larger amplitude ("constructive interference"), or the phases can be misaligned, resulting in a smaller (or even zero) amplitude ("destructive interference").
- You're adding two wave functions, each of which can be positive or negative, so the result can be larger in magnitude, smaller in magnitude, or zero.
- Imagine two sound waves meeting at a point: how can we vary their difference in path length to arrange for them to be "in phase" (constructive) or "180° out of phase" (destructive)?
- Important note: sound waves are **longitudinal** waves, but I've drawn transverse waves in the next two slides because it was easier for me to draw. Sorry!



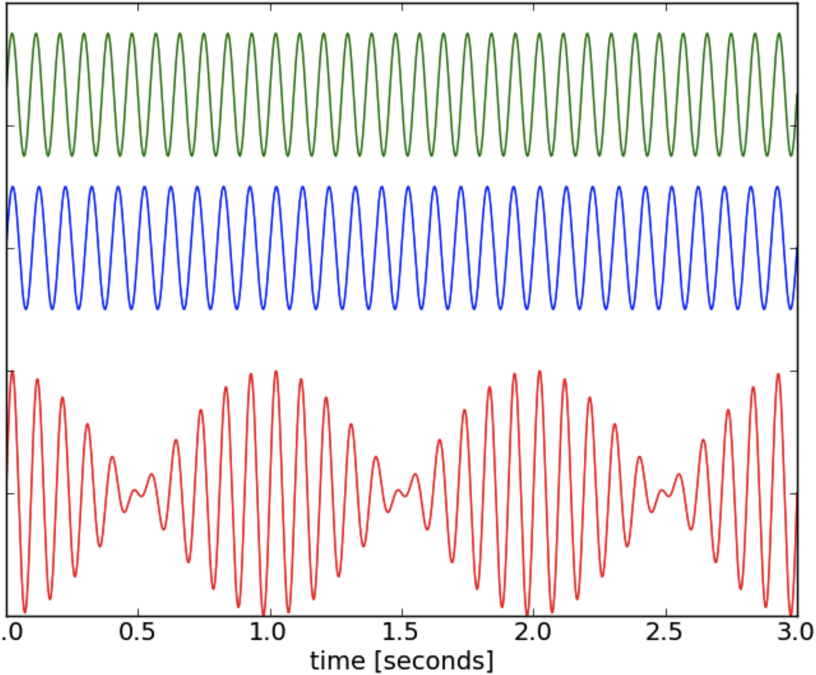


- We've seen that when two waves overlap, the phases of the two waves can coincide, resulting in a larger amplitude ("constructive interference"), or the phases can be misaligned, resulting in a smaller (or even zero) amplitude ("destructive interference").
- You're adding two wave functions, each of which can be positive or negative, so the result can be larger in magnitude, smaller in magnitude, or zero.
- Imagine two sound waves, at only slightly different frequencies, produced at the same place and time. How often will they be "in phase" (constructive interference) or "180° out of phase" (destructive interference)?

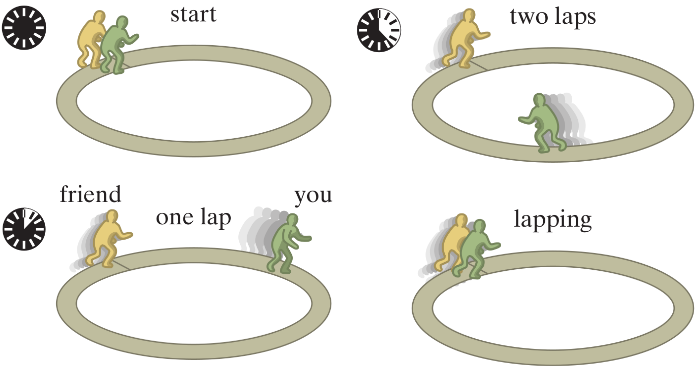
When you add together two tones of comparable amplitude and slightly different frequency, instead of hearing two separate tones, your ear hears the average of the two frequencies, *modulated* by the difference of the two frequencies. **"Beats."**

$$\sin(\alpha) + \sin(\beta) = 2\cos\left(\frac{\alpha - \beta}{2}\right)\sin\left(\frac{\alpha + \beta}{2}\right)$$

11 Hz sine, 10 Hz sine, and sum of the two sines



Analogy from Mazur ch17 (read next week): you run around a track faster than your friend does. How often do you overtake your friend?



Beat frequency is the difference between the two frequencies:

$$f_{\text{beat}} = |f_1 - f_2|$$

Tuning forks, speaker, guitar, etc.

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