Interference of Sound Waves

- Constructive interference occurs when the path difference between two waves' motion is zero or some integer multiple of wavelengths
  - path difference: $\Delta d = n\lambda$
- Destructive interference occurs when the path difference between two waves' motion is an odd half wavelength
  - path difference: $\Delta d = (n + \frac{1}{2})\lambda$

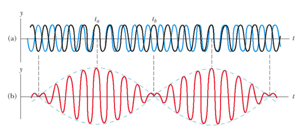
Sound Wave Interference Example

Two speakers on opposite ends of a basketball court (28m wide) emit sound waves in phase with a frequency of 171.5 Hz.

1. If someone stood exactly halfway between the two speakers, would they hear constructive or destructive interference?
2. If the person wanted to hear destructive interference, how much closer should they move towards one speaker (either side)?

Beats

- *Beats* are variations in loudness due to interference
- Two waves have slightly different frequencies and the time between constructive and destructive interference alternates
- The **beat frequency** equals the difference in frequency between the two sources:

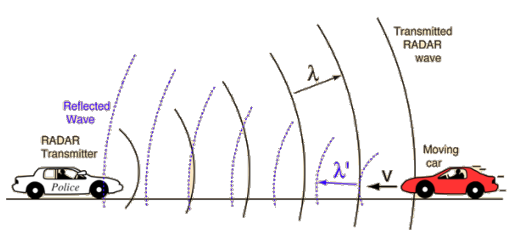


$$f_b = |f_1 - f_2|$$

Beats Example

The second-chair saxophone player is trying to get in tune, listening to the first-chair player. The first-chair player is playing a note at 440 Hz, while the second-chair player is a little off at 442 Hz. What is the beat frequency?

Doppler Effect and Beats: Speeding!



Density

Definition of Density, ρ

$\rho = M/V$

SI unit: $\mathrm{kg/m^3}$

- The densities of most liquids and solids vary only slightly with changes in temperature and pressure
- Densities of gases vary greatly with changes in temperature and pressure

Pressure

- Pressure is force per unit area

Definition of Pressure, *P*

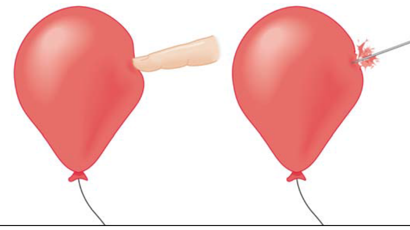
$P = F/A$

SI unit: N/m^2

- $1\ N/m^2$ = 1 Pascal (Pa)
- Other common pressure units:
  - Pounds per Square inch (PSI) - tires, etc.
  - mm Hg - blood pressure
  - inches Hg - weather barometer

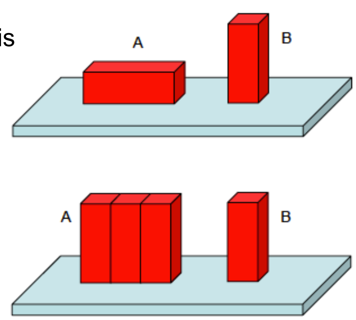
Pressure changes with Contact Area

The same force applied over a smaller area results in greater pressure – think of poking a balloon with your finger and then with a needle.



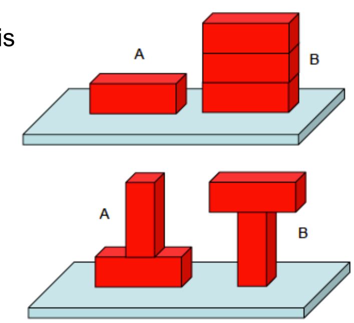
Conceptual Check

In which case is the pressure greatest?



Conceptual Check

In which case is the pressure greatest?

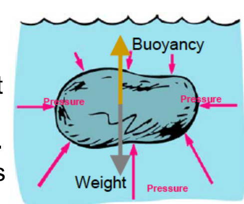


Pressure in Liquids

- Consider forces on a small amount of liquid in terms of pressure
- $P_f = \rho g d + P_0$
- Similarly to PE_g, we mostly only care about pressure differences.
- Atmospheric pressure (at sea level) = 101.3 kPa

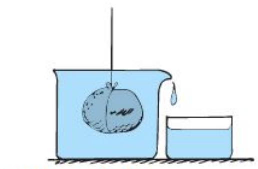
Buoyancy

- Pressure depends on depth.
- Consider a large rock: The bottom of the rock is at a lower depth, so it feels more pressure than the top of the rock.
- This net upward force is called buoyancy.



Displacement of Liquid

- Objects displace a volume of liquid equal to their volume
- This is useful for determining irregular or odd volumes



Helpful to know:

- Properties of water:
  - 1 kg of liquid water takes up 1 L of volume
  - 1 kg of water weighs 10 N.
  - Water has a mass density of 1 g/cm^3, or 1000 kg/m^3
- What would it take for the buoyant force to be greater than the weight of the object displacing some volume of water?

Archimedes' Principle

The buoyant force on an immersed object is equal to the weight of the fluid it displaces.

$$F_B = m_f g = \rho_f V_f g$$

- Note: Buoyant force does NOT depend on depth!

Will it float?

Any object immersed in a liquid will feel a buoyant force, but that doesn't mean it will float.

1. An object more dense than the fluid in which it is immersed will sink.
2. An object less dense than the fluid in which it is immersed will float.
3. Same density? Neutral buoyancy.

Archimedes' Principle (Again)

- Applies for air as well as water!
- An object surrounded by air is buoyed up by a force equal to the weight of the air displaced.
- 1 m^3 of air has a mass of about 1.2 kg, whereas 1 m^3 of water has a mass of 1000 kg!
- Buoyant force due to air is usually very small

Which object feels the largest buoyant force due to the atmosphere?

A. An elephant
B. A helium-filled party balloon
C. A skydiver at terminal velocity

Which object feels a buoyant force due to the atmosphere that is closest in magnitude to its weight?

A. An elephant
B. A helium-filled party balloon
C. A skydiver at terminal velocity