

Balloons

Question:

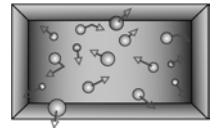
- A helium balloon has mass, yet it doesn't fall to the floor. Is there a real force pushing up on the helium balloon?

Observations About Balloons

- Balloons are held taut by the gases inside
- Some balloons float while others don't
- Hot-air balloons don't have to be sealed
- Helium balloons "leak" even when sealed

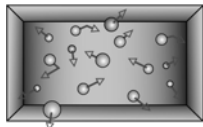
Air's Characteristics

- Air is a gas
 - Consists of individual atoms and molecules
 - Particles kept separate by thermal energy
 - Particles bounce around in free fall



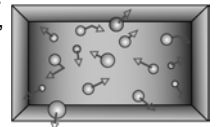
Air and Pressure

- Air has pressure
 - Air particles exert forces on container walls
 - Average force is proportional to surface area
 - Average force per unit of area is called "pressure"



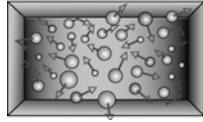
Air and Density

- Air has density
 - Air particles have mass
 - Each volume of air has a mass
 - Average mass per unit of volume is called "density"



Air Pressure and Density

- Air pressure is proportional to density
 - Denser particles hit surface more often
 - Denser air → more pressure



Pressure Imbalances

- Balanced pressure exerts no overall force
 - Forces on balloon's sides cancel
- Unbalanced pressure exerts overall force
 - Forces on balloon's sides don't cancel
 - Forces push balloon toward lower pressure
- Air pressure also pushes on the air itself
 - Air itself is pushed toward lower pressure

The Atmosphere

- Air near the ground supports air overhead
 - Air pressure is highest near the ground
 - Air density is highest near the ground
- Key observations:
 - Air pressure decreases with altitude
 - A balloon feels more force at bottom than top
 - Imbalance yields an upward buoyant force

Archimedes' Principle

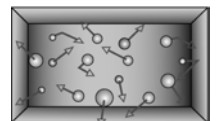
- A balloon immersed in a fluid experience an upward buoyant force equal to the weight of the fluid it displaces

Cold-Air Balloon in Air

- A rubber, cold-air-filled balloon
 - weighs more than the cold air it displaces
 - experiences a downward net force in cold air
 - sinks in cold air
- Its average density is greater than that of cold air

Air and Temperature

- Air pressure is proportional to temperature
 - Faster particles hit surface more and harder
 - Hotter air → more pressure



An Aside About Temperature

- Air has temperature
 - Air particles have thermal kinetic energy
 - Average thermal kinetic energy is proportional to absolute temperature
- SI absolute temperature: kelvins or K
 - 0 K is absolute zero — no thermal energy left
 - Step size: 1 K step same as 1 °C step

Hot-Air Balloon in Air

- A rubber, hot-air-filled balloon
 - contains fewer air particles than if it were cold
 - weighs less than the cold air it displaces
 - experiences an upward net force in cold air
 - floats in cold air
- Its average density is less than that of cold air

Helium vs. Air

- Replacing air particles with helium atoms
 - reduces the gas's density
 - helium atoms have less mass than air particles
 - leaves the gas's pressure unchanged
 - less massive helium atoms travel faster & hit more

Helium Balloon in Air

- A rubber, helium-filled balloon
 - has same particle density as air
 - weighs less than the air it displaces
 - experiences an upward net force in air
 - floats in air
- Its average density is less than that of air

Question:

- A helium balloon has mass, yet it doesn't fall to the floor. Is there a real force pushing up on the helium balloon?

Ideal Gas Law

- Pressure = Boltzmann constant · Particle density · Absolute temperature
- Only applies perfectly to independent particles
 - Real particles are not completely independent

Summary About Balloons

- Balloons float when their average densities are less than that of air
- Helium balloons float because helium atoms are lighter than air particles
- Hot-air balloons float because hot air is less dense than cold air