Balloons

Question:

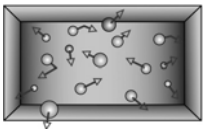
A helium balloon has mass, yet it doesn't fall to the floor. Is there a real force pushing up on the helium balloon?

Observations About Balloons

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

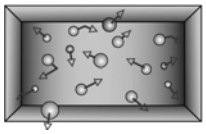
Air's Characteristics

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



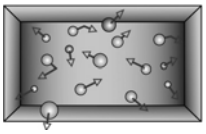
Air and Pressure

- Air has pressure
  - Air particles exerts 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"



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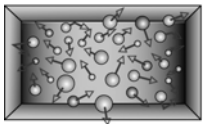
Air Pressure and Density

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



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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

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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

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Archimedes' Principle

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

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Room-Air Balloon in Air

- A rubber balloon filled with room air
  - weighs more than the room air it displaces
  - experiences a downward net force in room air
  - sinks in room air
- Its average density > density of room air

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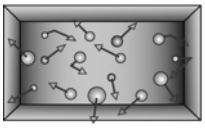
Air and Temperature

- 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 balloon filled with hot air
  - contains fewer air particles than if it were cold
  - weighs less than the room air it displaces
  - experiences an upward net force in room air
  - floats in room air
- Its average density < density of room air

Helium vs. Air

- Replacing air particles with helium atoms
  - leaves particle density unchanged
    - all particles contribute equally to pressure
  - reduces the gas's density
    - helium atoms are less massive than air particles
  - leaves the gas's pressure unchanged
    - helium atoms travel faster & hit more often

Helium Balloon in Air

- A rubber balloon filled with helium
  - 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 < density of room 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

- Assumes perfectly independent particles
- Real particles aren't perfectly 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 has lower particle density than cold air