

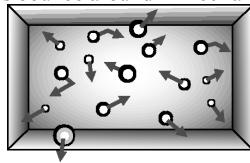
Balloons

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?

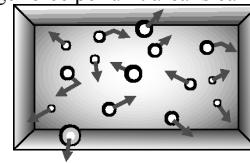
Air's Characteristics

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



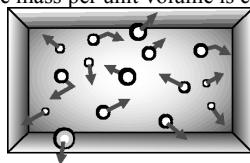
Air and Pressure

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



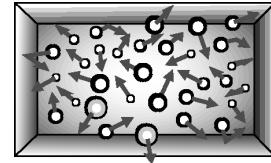
Air and Density

- Air has density
 - Air particles have mass
 - Each volume of air has a certain amount of mass
 - Average mass per unit 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 opposite sides of balloon cancel
- Unbalanced pressure exerts an overall force
 - Forces on opposite sides of balloon don't cancel
 - Forces push balloon toward lower pressure

The Atmosphere

- Air pressure pushes on the air itself
- 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 at top
 - Force imbalance yields an upward *buoyant* force

Archimedes' Principle

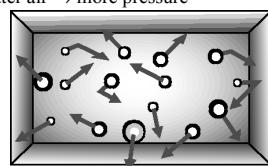
A balloon immersed in a fluid experience an upward buoyant force equal to the weight of the fluid it displaces

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
 - has an average density greater than that of cold air

Air and Temperature

- Air pressure is proportional to:
 - Temperature
 - Faster particles hit surface more often 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 scale: kelvins or K
 - 0 K is absolute zero—no thermal energy left
 - 1 K is equivalent to 1 degree Celsius

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
 - has an average density 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
 - has an average density 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 \propto Boltzmann constant \cdot Particle density \cdot Absolute temperature
- Only applies perfectly to independent particles
 - Real particles are not completely independent