

Balloons 1

Balloons

Balloons 2

Introductory 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?

- A. Yes
- B. No

Balloons 3

Observations about Balloons

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

Balloons 4

5 Questions about Balloons

- How does air "inflate" a rubber balloon?
- Why doesn't the atmosphere collapse?
- Does air around a balloon exert a force on it?
- Why does a hot air balloon float in cold air?
- Why does a helium balloon float in air?

Balloons 5

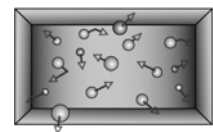
Question 1

- How does air "inflate" a rubber balloon?
 - How does air occupy space?
 - How does it push on the balloon's elastic skin?

Balloons 6

Air's Characteristics

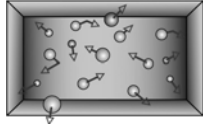
- Air is a gas
 - Consists of individual atoms and molecules
 - Particles kept separate by thermal energy
 - Particles bounce around in free fall



Balloons 7

Air and Pressure

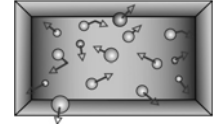
- Air has pressure
 - Air particles transfer momentum when they bounce
 - Each momentum transfer/bounce involves forces
 - Air particles exerts forces on container walls
 - Average force is proportional to surface area
 - Average force per unit of area is called “pressure”



Balloons 8

Air and Density

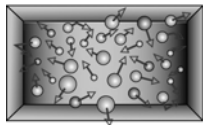
- Air has density
 - Air particles have mass
 - Each volume of air has a mass
 - Average mass per unit of volume is called “density”



Balloons 9

Air Pressure and Density

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



Balloons 10

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

Balloons 11

Question 2

- Why doesn’t the atmosphere collapse?
 - If air has weight, why doesn’t it fall to the ground?
 - Why is the air denser at lower altitudes?

Balloons 12

The Atmosphere

- Air near the ground supports the air overhead
 - The atmosphere is in stable equilibrium
 - Air pressure decreases with altitude
 - Each layer of air experiences an upward force
 - This upward force balances the layer’s weight
- Supporting itself structures the atmosphere
 - Air pressure is highest near the ground
 - Air density is highest near the ground

Question 3

- Does air around a balloon exert a force on it?

The Buoyant Force

- Because of the atmosphere's structure,
 - air pressure is
 - stronger near the bottom of a balloon,
 - weaker near the top of the balloon,
 - so air pushes up harder than it pushes down,
 - and this imbalance yields an upward buoyant force
- The atmosphere pushes upward on a balloon!

Archimedes' Principle

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

Question 4

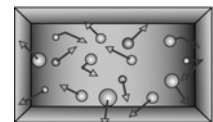
- Why does a hot air balloon float in cold air?
 - Why does a cold air balloon sink in cold air?
 - What is the difference between hot air and cold air?

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

Air and Temperature

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



An Aside About Temperature

- Like most things, air has a 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

Question 5

- Why does a helium balloon float in air?
 - How does helium differ from air?
 - Doesn't helium have mass and weight?

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

Introductory Question (revisited)

- A helium balloon has mass, yet it doesn't fall to the floor. Is there a real force pushing up on the helium balloon?
 - A. Yes
 - B. No

The Ideal Gas Law

- This law is a summary relationship for gases:
pressure = Boltzmann constant · particle
density · absolute temperature
 - Assumes, however, 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