Lect 2: Density & Buoyancy

1. **What is density?**
2. **How do you measure density?**

UNIT FIVE :
THE CONVECTION OF HEAT

What is density?

Steel 7.8 g   Aluminum 2.7 g

- Think about the many kinds of matter you come into contact with every day.
  - Wood, cement, aluminum, plastic, foam, liquids, steel, etc.
- In solids, we have huge differences.
- A block of steel and a block of aluminum may be the same size, but one has a lot more mass than the other.

What is density?

Steel 7.8 g   Aluminum 2.7 g

- Density describes how much **mass (stuff)** is in a given **volume** of a material.
- Steel has a high density; 7.8 grams of mass per cubic centimeter   or: grams/ cm^3
- Aluminum has a lower density; 2.7 grams/ cm^3.
- Liquids & gases are matter & have density too.

Measuring Density

$$Density\ (g/mL\ or\ g/cm^3) \rightarrow D = \frac{m}{V} \quad \begin{array}{l} Mass\ (kg\ or\ g) \\ Volume\ (mL\ or\ cm^3) \end{array}$$

- The more matter you place into a defined volume, the denser it becomes.
- For example, New York City is DENSELY populated because there are a lot of people in a small area.
- 20 people in an elevator is DENSER than 2 people in an elevator.

Which one is MORE dense?
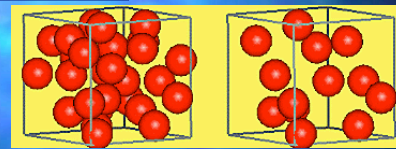
- **If each box has the same volume, and each ball has the same mass, which box would weigh more? Why?**

Which weighs more?
100 pounds of lead or 100 pounds of feathers?

Feathers   Lead

Lead and Feathers

- **Although 100 pounds of feathers may take up much more room than 100 pounds of lead, they both still weigh 100 pounds.**
- **The steel is heavier for its size, due to the fact that it is denser!!!.**
- **Thus, a material such as feathers takes up much more room (volume) than a denser material such as steel, for the same mass or weight.**


Density of Common Materials

Steel density

Steel cube
Volume: 1.0 cm³
Mass: 78 g
Density: 7.8 g/cm³

Nail
Volume: 1.6 cm³
Mass: 12.5 g
Density: 7.8 g/cm³

- Density is a property of materials - independent of shape or quantity.
- For example, a steel nail and a steel cube have different amounts of matter and therefore different masses.
- They also have different volumes.
- However, if you calculate density by dividing mass by volume, the result is the same for both the nail and the cube.

Density of Common Materials

- Solids that are **strong**, such as steel, typically have **high** density.
  - High density means there are many atoms per cubic centimeter.
- **Soft** materials typically have **lower** density.
  - Solids with low density, such as cork or foam, are often used as cushioning material.
  - Low density means there are relatively large spaces between atoms.

Densities of Common Substances	
Substance	Density (g/cm³)
Mercury	13.60
Lead	11.34
Aluminum	2.70
Bone	1.85
Milk (whole)	1.03
Seawater	1.03
Water	1.00
Ice	0.92
Gasoline	0.73
Cork	0.24

Why does density vary?

Diamond (density = 3,500 kg/m³)

Paraffin (density = 870 kg/m³)
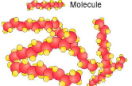Carbon atom   Hydrogen atom
Molecule

- The density of a material depends on two things:
  - the **individual mass** of each atom or molecule
  - on **how tightly** the atoms are packed
- A diamond is made of carbon atoms and has a density of 3,500 kg/m3.
- The carbon atoms in diamonds are closely packed.

Why does density vary?

Diamond (density = 3,500 kg/m³)

Paraffin (density = 870 kg/m³)
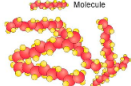Carbon atom   Hydrogen atom
Molecule

- Paraffin wax is mostly carbon, but the density of paraffin is only 870 kg/m3.
- The density of paraffin is low because the carbon atoms are mixed with hydrogen atoms in long molecules that take up a lot of space.

Calculating Density Problems

■ **Here are 3 density problems you are going to do with the video: Follow the video as we do them**

1. A student determines the density of manganese to be 5.54 g/cm^3. If a sample had a mass of 3.43g what was the volume?
2. A cube 5.7cm on a side has a mass of 630 g. Find the Density!
3. The density of a gas is 0.0043 g/cm^3. Find the mass of 280 cm^3 of this gas.

Density Calculations

Calculating Density

$$D = \frac{m}{V}$$

Density (g/mL or g/cm³) → $D = \dfrac{m}{V}$ ← *Mass* (kg or g) / *Volume* (mL or cm³)

■ There are several different ways to find the density of an objects.
■ It depends on the shape of the object.

Cubes & Rectangular Prisms

· **Find mass**
  · Use a **balance**
  · Units: **grams** or kg
· **Find volume**
  · Use a ruler
  · Measure all 3 **sides**: length, width, height
  · Units: **cm^3**, m^3, km^3
  · Use this equation:
    Volume = length × width × height
    V = l × w × h
· **Density = mass / volume**
  · Units: **g/cm^3**

Cylinders

1. **Find mass**
2. **Find volume**
   ■ Use a ruler
   ■ Measure the height & **diameter**
   ■ Divide the diameter in half to find the **radius**
   ■ Units: cm^3, m^3, km^3
   ■ Use this equation:
     Volume of a cylinder = 3.14 × radius^2 × height
     V = π r^2 h
3. **Density = mass / volume**
   ■ Units: g/cm^3

Irregular Objects

1. **Find mass**
2. **Find volume**
   ■ **Displacement** method
     ■ Fill a graduated cylinder with water.
     ■ Drop the object in without splashing water.
     ■ Calculate the change in volume!
   ■ Units: **mL**, L
3. **Density = mass / volume**
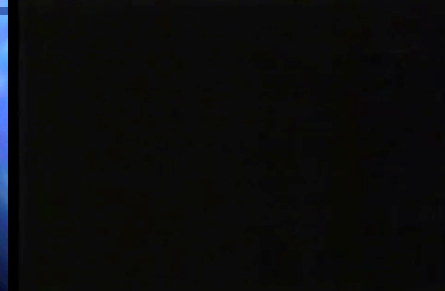   ■ Units: **g/mL**
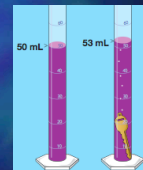
50 mL   53 mL

Buoyancy & Density

1. What is buoyancy?
2. What is the relationship between density & buoyancy?

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10. Eureka!!! Buoyancy!
Take Notes on your lecture notes.

Will it float or sink?

- The largest ship in the world is the *Jahre Viking*, an oil-carrying tanker.
- This super-sized ship is 1,504 feet long and 264 feet wide, longer than 5 football fields laid end-to-end.
- If the Empire State building was laid on its side, the *Jahre Viking* would be longer by 253 feet!
- Crew members use bicycles to get from place to place on the ship.
- The *Jahre Viking* is largely constructed of steel, so how can a big, heavy ship like this actually float?

Will it float or sink?

- Let's look at something we're more familiar with….Soda!
- Write down 2 *similarities* between these two cans.
- Write down 2 *differences*.
- Predict what happens when I place a can of regular coke and a can of diet coke into regular tap water.
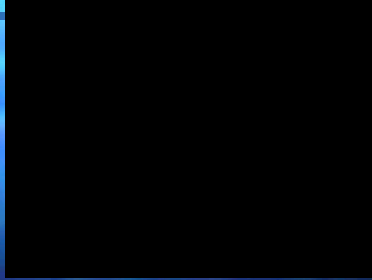

Will it float or sink?

What is your best guess??
Diet soda will:
Regular soda will:

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11. Sink or float?

Floating Diet Coke Demo

But, WHY does is sink or float

Will it float or sink?

- What did you see?
  - The diet coke floats & the regular sinks.
- Why does the diet float??
  - Regular soda contains 39 grams of sugar.
  - Diet coke contains 100 mg of Nutra-sweet.
  - More "stuff" (matter) is crammed into the same amount of space, or VOLUME, and that increases the MASS.
  - The relationship of Mass to Volume is Density.
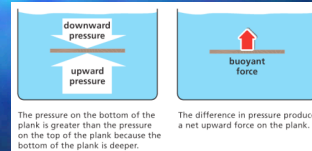
Buoyant Force

- Why do ice cubes float in water?
- Even though gravity forces an ice cube down, water exerts an upward force on the ice.
- This upward force is called **buoyancy**.
- All objects submersed a fluid, whether it be a liquid or **gas**, experience this buoyant force.

Gravity
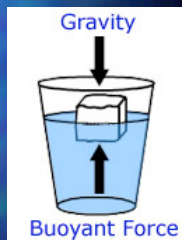
Buoyant Force

Buoyant Force

- **The buoyant force exists because of _pressure_ differences in fluids.**
- **In any fluid, the greater the depth, the greater the pressure.**
- **In this picture, a thin plank of wood has been pushed underwater.**

downward pressure

upward pressure

The pressure on the bottom of the plank is greater than the pressure on the top of the plank because the bottom of the plank is deeper.

buoyant force

The difference in pressure produces a net upward force on the plank.

Floating & Sinking

- An object will float in a fluid if the buoyant force is _equal_ or _greater_ than the object's weight.
- A cork floats because the weight is less than the buoyant force.
- An object _sinks_ if the object's weight is greater than the buoyant force.
- A marble sinks because its weight is more than the buoyant force.

weight | buoyant force

no net force

weight | buoyant force

net force

The Egg Experiment

BrainPop: Buoyancy

BUOYANCY

BrainPop Answers

- 1. A
- 2. C
- 3. A
- 4. B
- 5. B

6. C
7. A
8. B
9. C
10. B

Formulas to Remember!

- Density: D= m/v   (mass / volume)

You can also rearrange the formulas as:
- Mass: m= D x V
- Volume: V = m/D

Density Problems
Pg8 in your LB

- 1. Find the density of a substance with a mass of 5kg and a volume of 43 m^3
- 2. Suppose you have a lead ball with a mass of 454g. What is its volume? (density of lead is: 11.35 g/cm^3)
- 3. What is the mass of a 15mL sample of mercury? (density of mercury is: 13.55 g/cm^3)
- 4. A block of pine wood has a mass of 120g and a volume of 300 cm^3. What is the density of wood?

Answers

- 1. D= M/V
  D = 5 kg / 43 m^3 Which equals: 0.12 kg/ m^3

- 2. Volume: V = M/D
   = 454 g / 11.35 g/cm^3 = 40 cm^3

- 3. Mass: M = D x V
     M =13.55 g/mL x 15 mL   = 203 g

- 4. D= M/V
   = 120g / 300 cm^3 = 0.4 g/cm^3