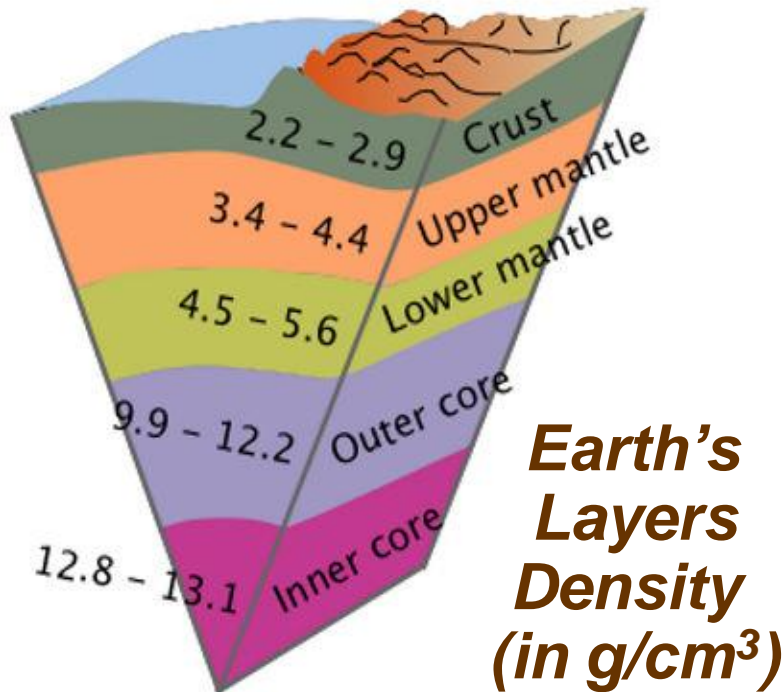
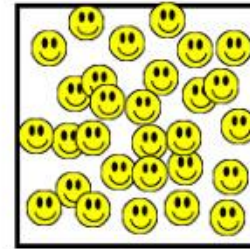
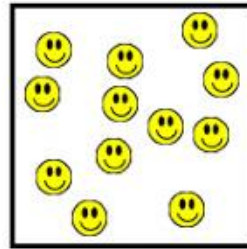


Density

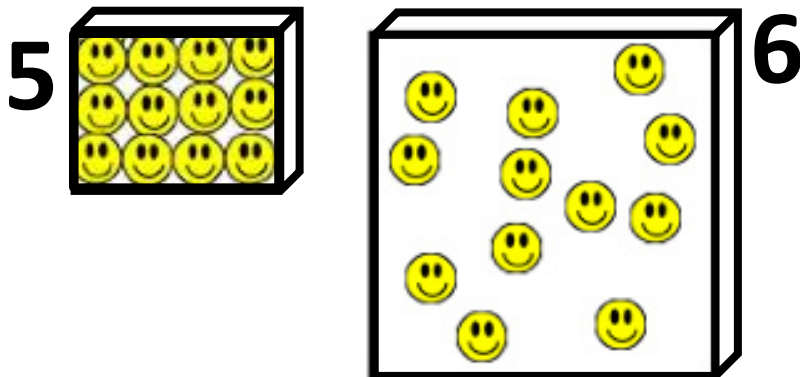
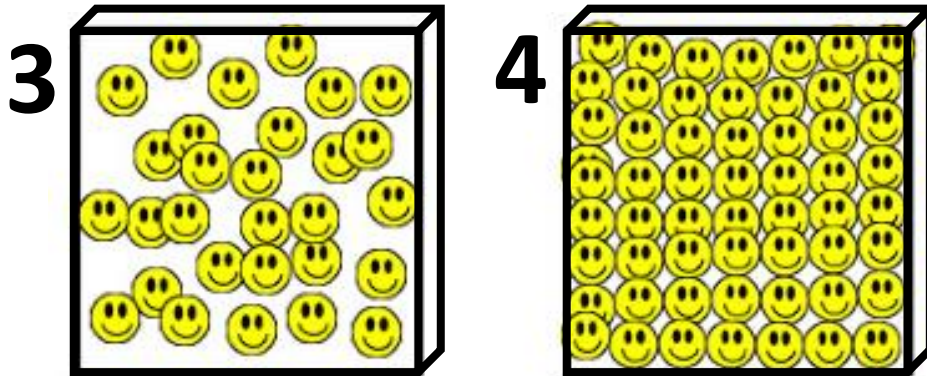
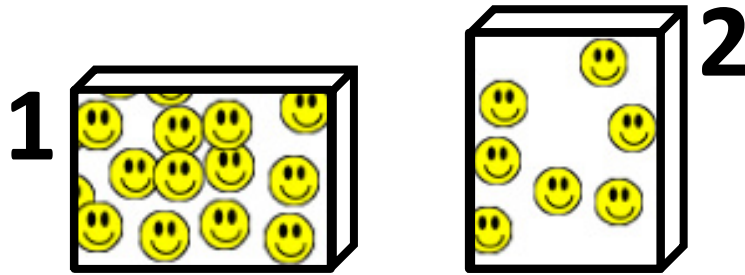
- **Density** is a measure of how much matter (particles!) is contained in a unit of volume:

- $\text{density} = \frac{\text{mass}}{\text{volume}}$
- SI unit is kg/m^3



- **The density of a material varies with temperature and pressure** (this variation is typically small for solids and liquids but much greater for gases).
- **In general, lowering the temperature results in density increase**
- **Increasing the pressure also results in density increase**

Which of the following objects...



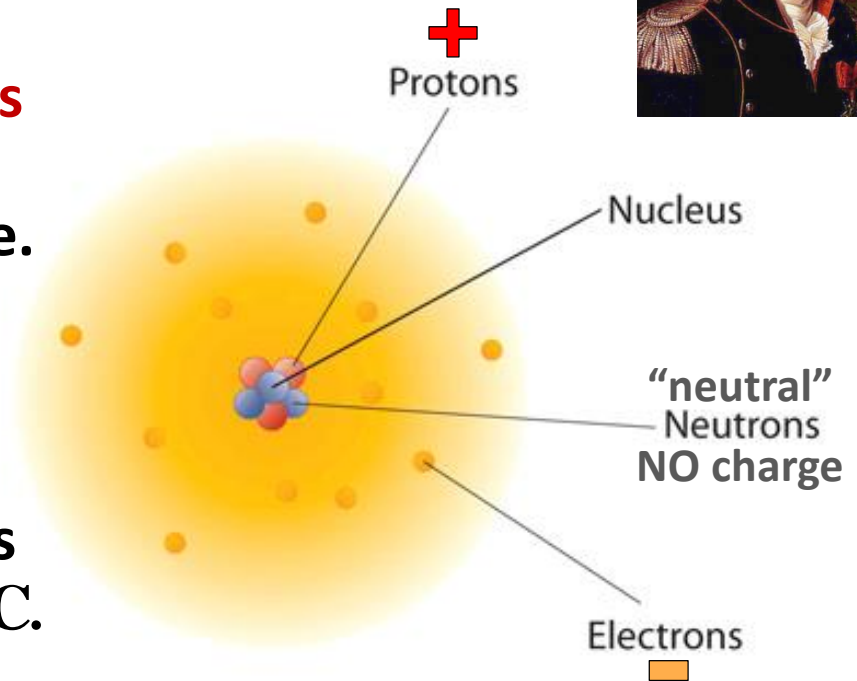
- ...have the **same** volume?
- ...have the **same** density?
- ...have **different** mass?
- ...have **different** volume?
- ...have the **same** mass?
- ...have **different** density?

(note: all “atoms” here are the same; all objects have the same thickness)

Charge, $+$ or $-$, is the basic property of matter that gives rise to all **electrical** and **magnetic** forces and interactions.

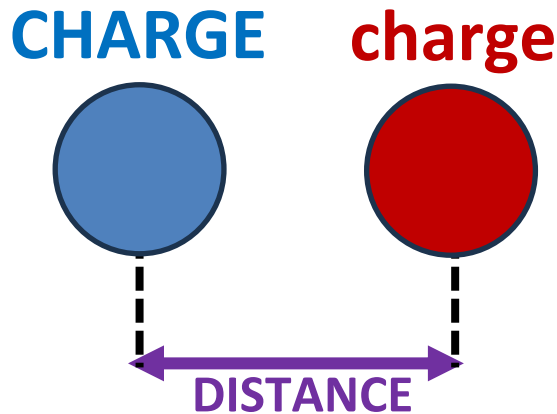


- In atoms, **electrons** carry the **negative (-)** charge, and **protons** carry the **positive (+)** charge; neutrons have **NO (zero)** charge.
- SI unit of charge is **Coulomb**.
- The charge of a single electron, known as *elementary charge*, is equal to **negative 1.602×10^{-19} C**.
- The charge of a single proton is the same but *positive*.
- Matter is usually *charge-neutral*, meaning the positive and negative charges balance out.



Electromagnetism

is an interaction that occurs between particles that have electric charge

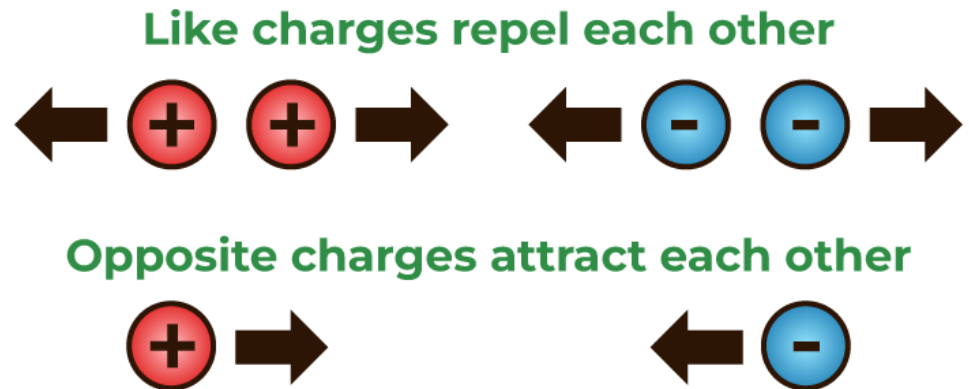


$$\text{ELECTRIC FORCE} = k \cdot \frac{\text{CHARGE} \cdot \text{charge}}{(\text{DISTANCE})^2}$$

$8.99 \cdot 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

“electrostatic force constant”

A “strong” force at the atomic level... responsible for binding atoms into molecules and molecules into liquids and solids!



States of Matter

- Matter can exist in several different *forms*, or *states of aggregation*.

- Matter commonly exists in four fundamental states:

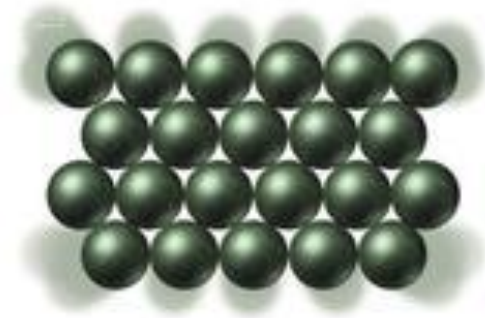
- Solid
- Liquid
- Gas
- Plasma



- The different states of matter are based upon distance between particles (atoms and/or molecules), particle arrangement, and energy of particles.

SOLIDS

- Particles of solids are **tightly packed**.
- The forces (*electromagnetic!*) between particles are strong: the particles cannot move freely but can only vibrate about a fixed position.
- Solids have a stable, **definite shape** and a **definite volume**.
- Solids can only change their shape *by force*, as when broken or cut.

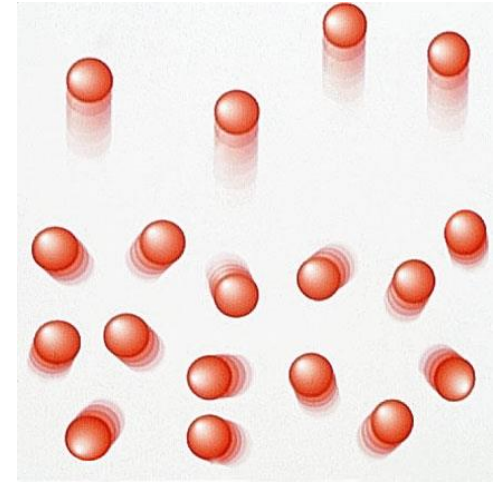


LIQUIDS

- Particles of liquids are **tightly packed** but are **far enough apart** to slide over one another (*mobile structure*).
- The **shape** of a liquid is **not definite** but is determined by its container.
- Liquids are known to be *nearly incompressible*. At constant temperature and pressure, liquids have a **definite volume**.
- The volume of liquid is usually greater than the volume of the corresponding solid (the best-known *exception* being *water*).



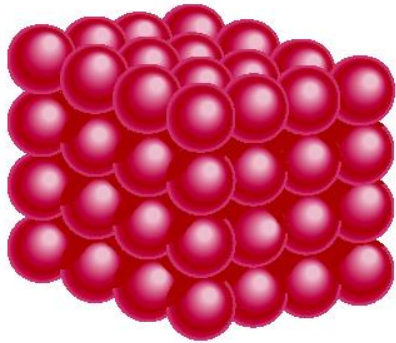
GAS



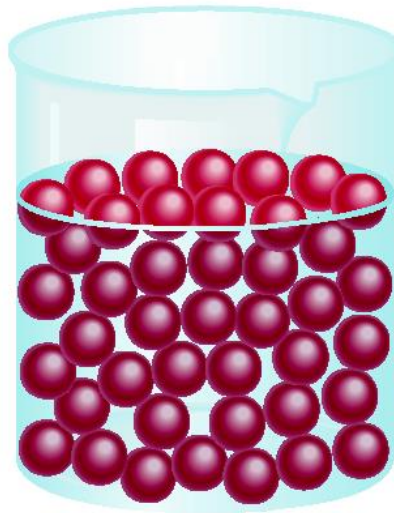
- Particles of a gas are very far apart and move freely.
- A gas has an **indefinite shape** and an **indefinite volume**: it will expand to *fill the entire container* in which it is confined.
 - A gas is *compressible*.



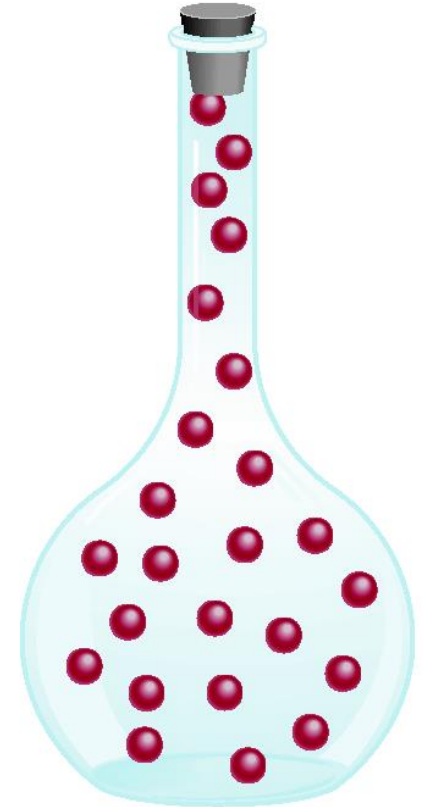
A Comparison: The Three States of Matter



Solid



Liquid



Gas

Example: ICE → WATER → WATER VAPOR