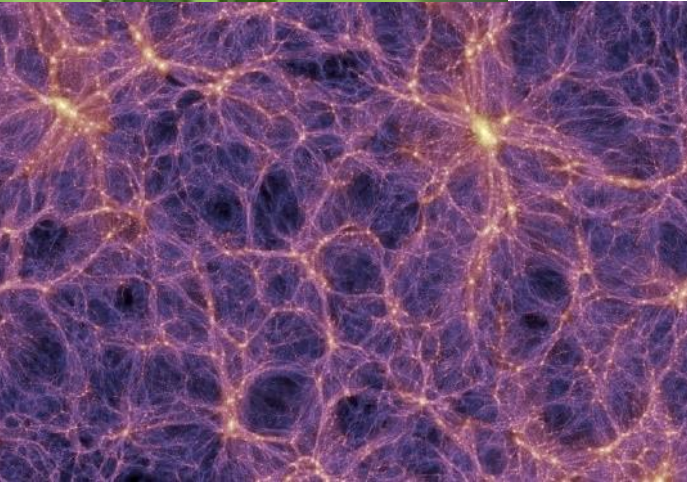




OH DEAR, WHAT CAN THE
MATTER
BE?



What is Matter?

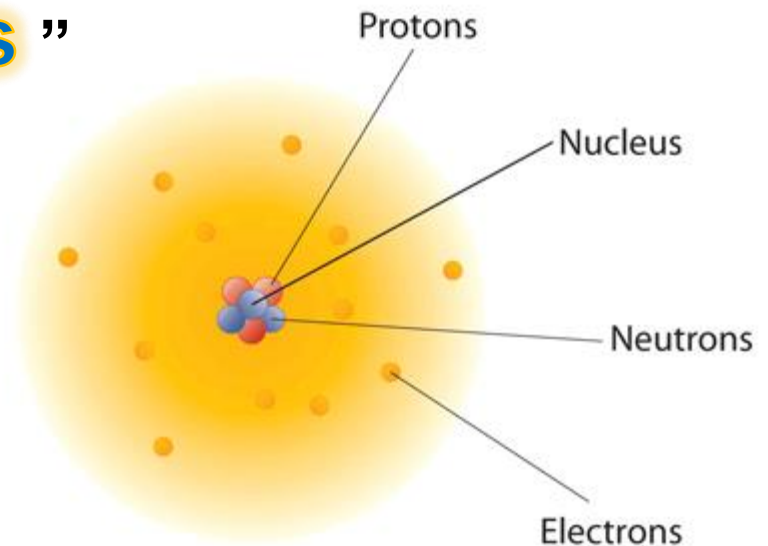
1. Common “classical” definition (known as *mechanical, abstract mathematical*), **René Descartes, Isaac Newton** - 17th century:

“**Matter is anything that has mass and takes up space**”

2. Late 19th century definition (based on physical and chemical structure):

“**Matter is made up of atoms**”

This *atomic, or ordinary,* matter is in turn made up of interacting *subatomic particles* — usually a nucleus of *protons* and *neutrons*, and a cloud of orbiting *electrons*.



Voyage into the World of Atoms



THERE ARE
MORE ATOMS IN
A SINGLE
GRAIN OF SAND
THAN GRAINS
OF SAND ON
EARTH.

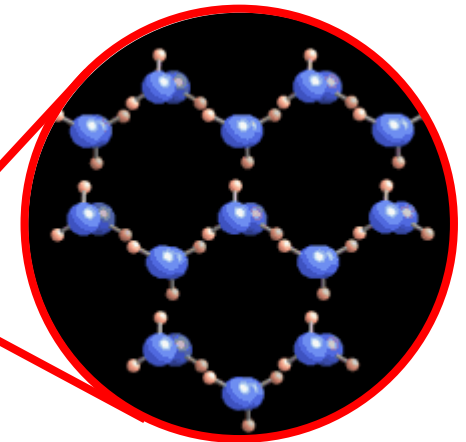
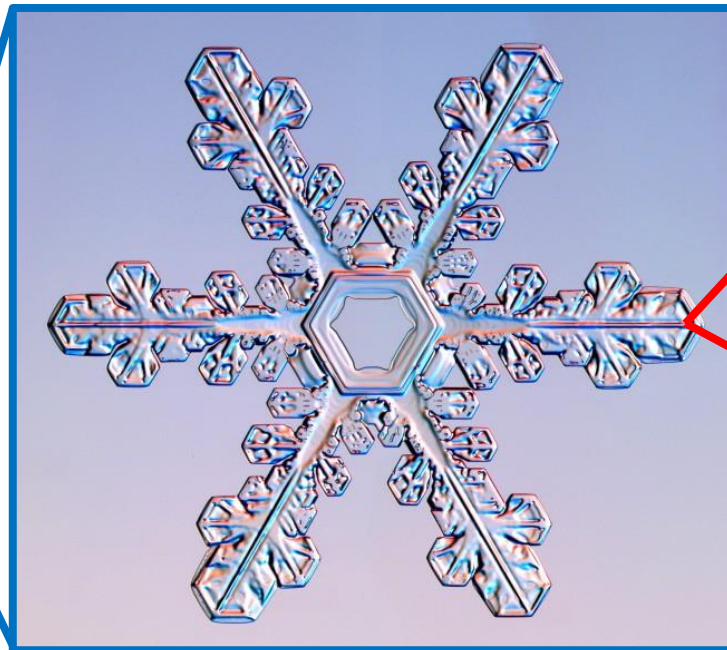
Atoms are very small!

Voyage into the World of Atoms:

https://www.youtube.com/watch?v=7WhRJV_bAiE

Snowflake ~1-3 mm

Ice crystal unit
cell 5 nm



Single atom
 $\sim 1\text{\AA} = 10^{-10}\text{ m}$

A typical **snowflake** is made of about 10^{18} - 10^{19} atoms.

Everyday Properties of Matter

We can observe the following about ordinary matter:

- How it **looks** (Shiny, Dull, Color, etc.)
- How it **feels** (Hard, Soft, Rough, Smooth, etc.)
- How it **smells or tastes** (Sweet, Sharp, Terrible, etc.)
- How it **sounds** (Loud, Soft, Echo, No Sound, etc.)
- What it **does** (Stretch, Break, Magnetize, Ignite etc.)

P
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- Anything **else**?

- How it **moves**

- How it **changes**

Study of Matter

- **Physics** – *physical science* that studies forms of matter, its change and motion through space-time, and related concepts such as energy and force.
- **Chemistry** – *physical science* that studies material substances, their composition and change of composition (chemical reactions), as well as matter behavior related to chemical reactions.

Physical science
– branch of natural science that studies non-living systems.

Natural science – major branch of science, that tries to explain and predict nature's phenomena, based on empirical evidence.

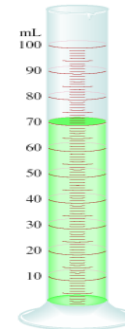
Science – systematic effort of acquiring knowledge—through observation and experimentation coupled with logic and reasoning.

Physical Properties of Matter

We can describe physical properties of matter in terms of physical quantities and laws.

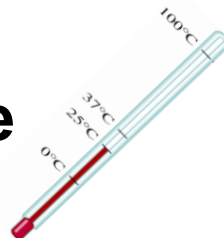
- An extensive property **depends upon how much matter is being considered:**

- mass
- volume
- electrical charge



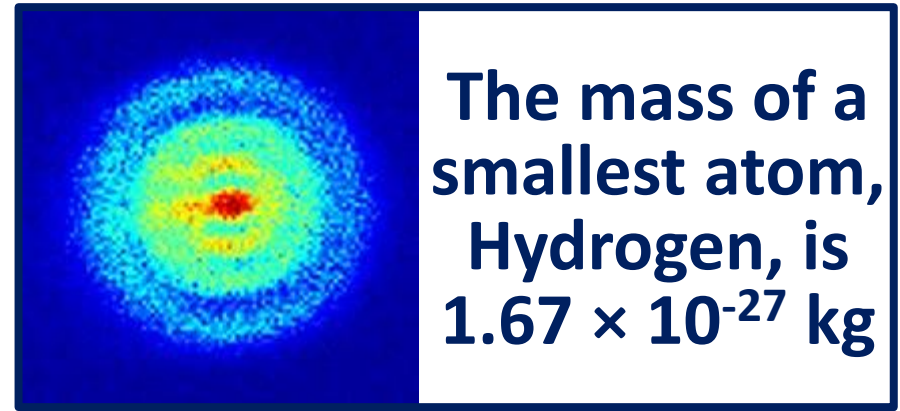
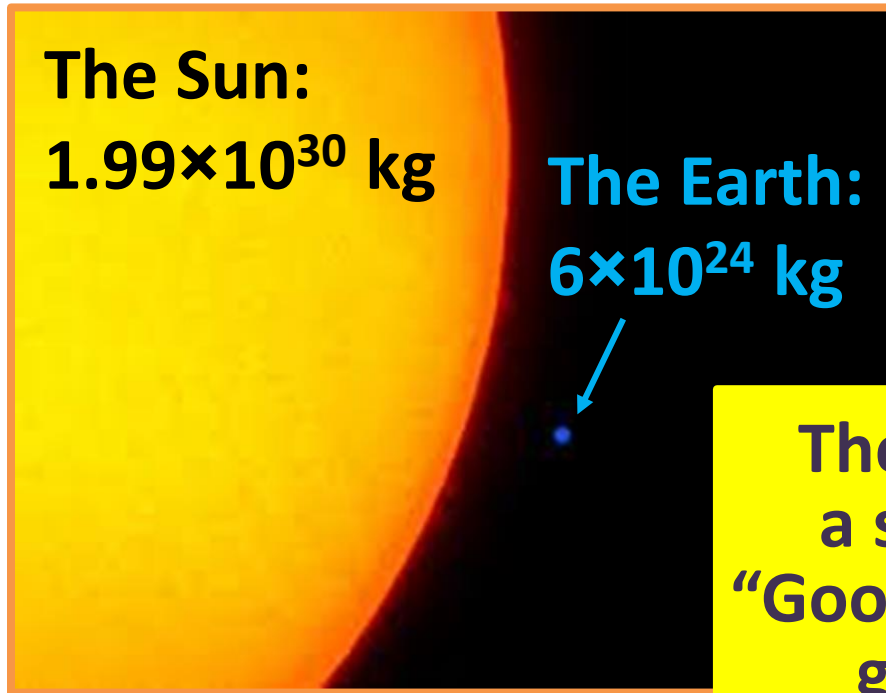
- An intensive property **does not depend upon how much matter is being considered:**

- density
- temperature
- color
- elasticity
- metallicity
- solubility etc...



Mass

- **Mass** is the **amount of material** in an object (**doesn't change**).
- Don't confuse with **weight**, a measure of how strongly gravity is pulling on an object (**decreases** as elevation increases).

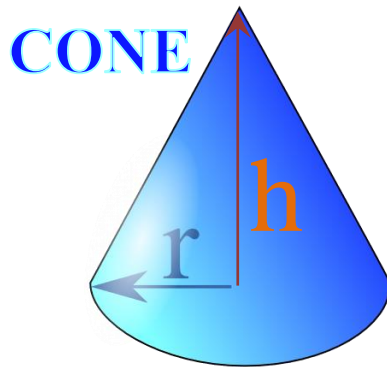
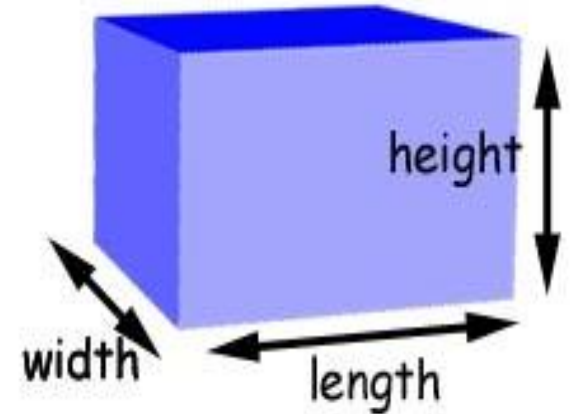


- SI unit of mass is **kg**

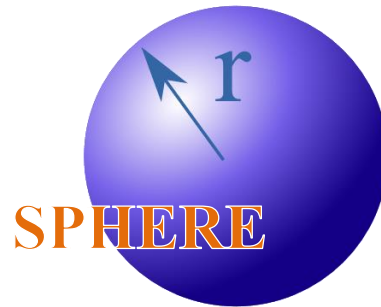


Volume

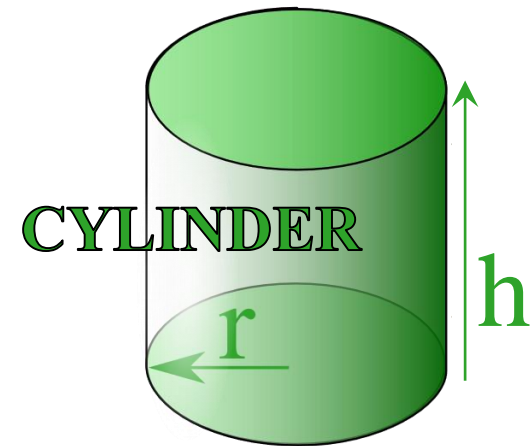
- **Volume** is the amount of three-dimensional space that a substance or shape occupies or contains.
- SI unit of volume is m^3 (*cubic meters*)
- $V_{\text{rectangular prism}} = \text{length} \times \text{width} \times \text{height}$



$$\left(\frac{1}{3}\right)\pi r^2 h$$



$$\left(\frac{4}{3}\right)\pi r^3$$



$$\pi r^2 h$$

Where r = radius, h = height, and $\pi = 3.14$

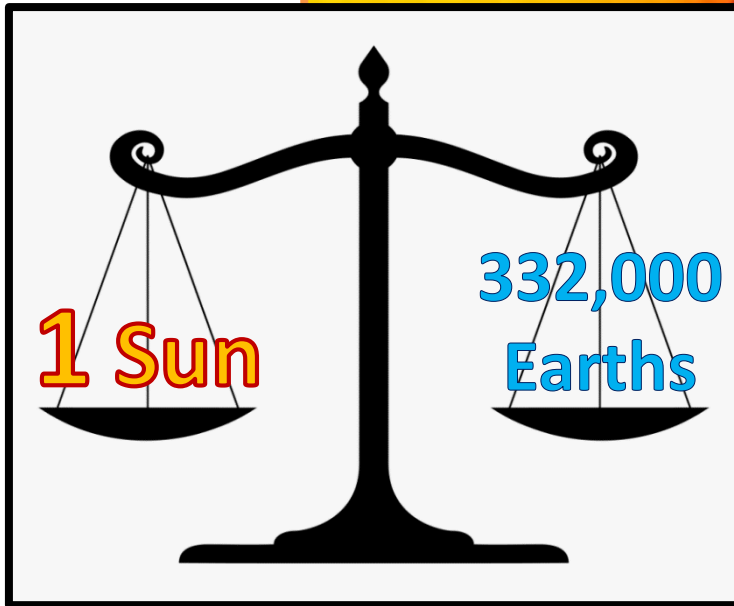
Sun and Earth comparison

The Sun

volume: 1.4×10^{27}
cubic meters
mass: 1.99×10^{30}
kilograms

The Earth

volume: 1.1×10^{21}
cubic meters
mass: 6×10^{24}
kilograms



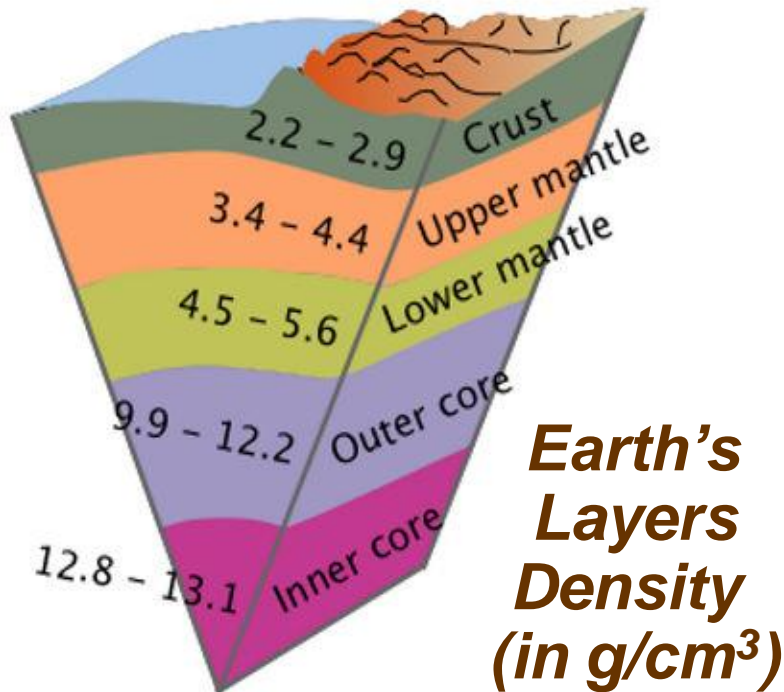
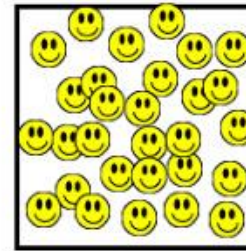
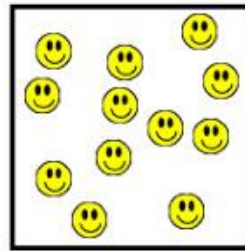
???

1,300,000
Earths
can fit inside
1 Sun

Density

- **Density** is a measure of how much matter (atoms!) 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**