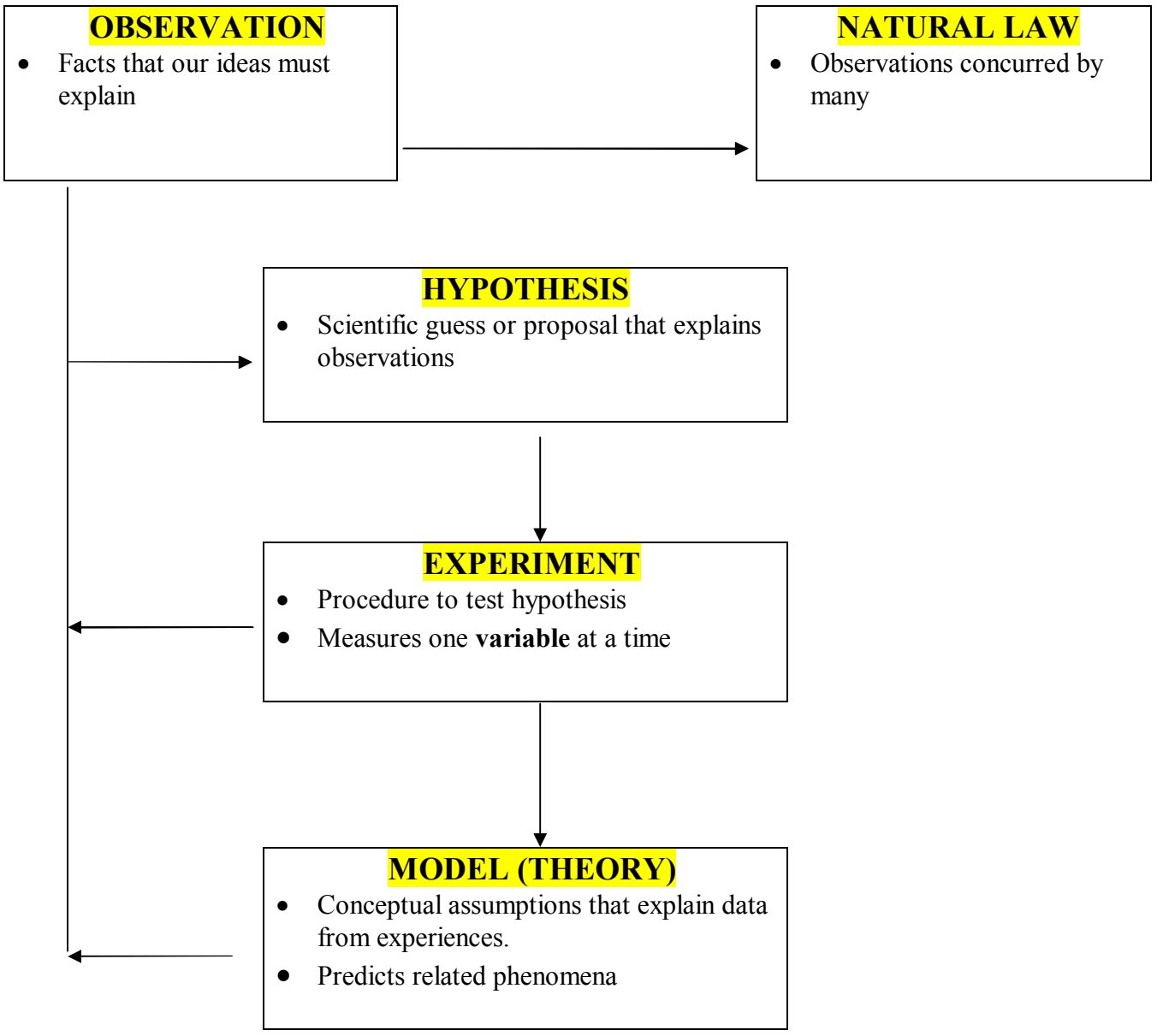
THE SCIENTIFIC METHOD

- The scientific method is a **process** of creative thinking and testing aimed at **objective** and **verifiable** discoveries.
- Knowledge gained through the scientific method is self-correcting and improves over time.
- Scientific method is composed of the following steps:



MEASUREMENTS / SI UNITS

- **Measurements** are made by scientists to determine size, length and other **properties** of matter.
- For measurements to be useful, a measurement **standard** must be used.
- A **standard** is an exact quantity that people agree to use for **comparison**.
- **SI** is the **standard** system of measurement used **worldwide** by scientists.

SI BASE UNITS:

	Quantity Measured	Units	Symbol
⇒	Length	Meter	m
⇒	Mass	Kilogram	kg
⇒	Time	Seconds	s
⇒	Temperature	Kelvin	K
	Electric current	Ampere	A
	Amount of substance	Mole	mol
	Intensity of light	Candela	cd

DERIVED UNITS:

- In addition to the **fundamental** units above, several useful **derived** units are commonly used in SI system.

	Quantity Measured	Units	Symbol
⇒	Volume	Liter	L
⇒	Density	grams/cc	g/cm^3

VOLUME & DENSITY

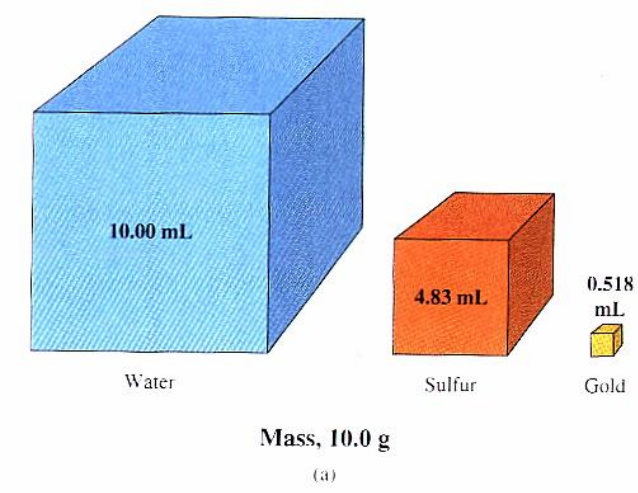
- **Volume** is the amount of **space** an object occupies. Common units are **cm^3** or **liter** (L) and **milliliter** (mL).

1 L = 1000 mL **1 mL=1 cm^3**

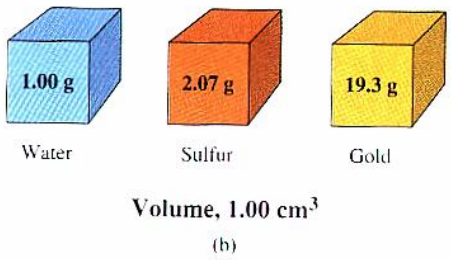
- **Density** is **mass per unit volume** of a material. Common units are **g/cm^3** or **g/mL**.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad d = \frac{m}{v}$$

- **Density** is **directly related to mass** of an object, and **indirectly related to the volume** of an object.



Comparison of the *volume* of equal masses of 3 materials with different *densities*

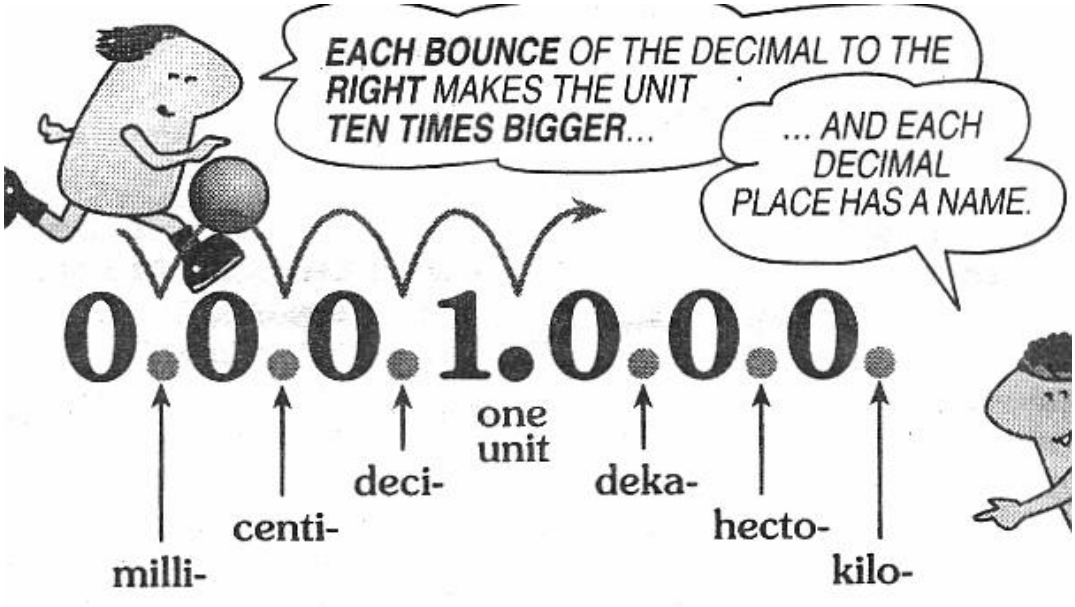


Comparison of the *masses* of equal volumes of 3 materials with different *densities*

CONVERSION OF UNITS

- The **SI** system of units is easy to use because it is based on **multiples of ten**.

- Common **prefixes** are used with the base units to indicate the multiple of ten that the unit represents.



SI PREFIXES

Prefixes	*Symbol*	*Multiplying factor*
mega-	M	1,000,000
kilo-	k	1000
centi-	c	0.01
milli-	m	0.001
micro-	μ	0.000,001

CONVERSION OF UNITS

- Any unit can be converted into another by use of the appropriate **conversion factor**, as shown below:

$$\text{beginning unit} \times \frac{\text{final unit}}{\text{beginning unit}} = \text{final unit}$$

↑

conversion factor

Examples:

1. The length of a football field is 100 yards. What is the length of the field in meters? (1m = 1.094 yd)

$$100\ \text{yd} \times \frac{1\ \text{m}}{1.094\ \text{yd}} = 91.4\ \text{m}$$

2. The thickness of a book is 2.5 cm. What is this measurement in mm?

$$2.5\ \text{cm} \times \frac{\qquad}{\qquad} = \qquad\ \text{mm}$$

3. How many centimeters are in 2.0 ft? (1 in=2.54 cm)

ft → in → cm

$$2.0\ \cancel{ft} \times \left(\frac{12\ \cancel{in}}{1\ \cancel{ft}}\right) \times \left(\frac{2.54\ cm}{1\ \cancel{in}}\right) = 61\ cm$$

4. How many seconds are in one day?

day → hr → min → sec

5. If the density of gold is 19.3 g/cm^3, how many grams does a 5.00 cm^3 nugget weigh?

5.00 cm^3 x ——— = g

6. What volume of mercury has a mass of 60.0 g if its density is 13.6 g/ml?

60.0 g x ——— = ml

SCIENTIFIC NOTATION

- Scientific Notation is a convenient way to express **very large** or **very small** quantities.

General form:

$$A \times 10^{n} \qquad 1 \leq A < 10 \qquad n = \text{integer}$$

Using Scientific Notations:

- Changing between conventional and scientific notation:

75,000,000 changes to 7.5×10^{7} (7 to the left)
0.00642 changes to 6.42×10^{-3} (3 to the right)

Examples:

1. Write 6419 in scientific notation:

2. Write 0.000654 in scientific notation:

Calculations with Scientific Notations:

- Addition and subtraction (NOT COVERED)

- Multiplication and division :
  1. Change numbers to exponential form.
  2. Multiply or divide coefficients.
  3. **Add** exponents if **multiplying**, or **subtract** exponents if **dividing**.
  4. If needed, reconstruct answer in **standard** exponential notation.

Examples:

1. Multiply 30,000 x 600,000

$$(3\times10^{4})(6\times10^{5}) = 18\times10^{9} = 1.8\times10^{10}$$

2. Divide 30,000 by 0.006

$$\frac{3\times10^{4}}{6\times10^{-3}} = \frac{3}{6}\times10^{|4-(-3)|} = 0.5\times10^{7} = 5\times10^{6}$$

Follow-up Problems:

1. $(5.5 \times 10^{3})(3.1 \times 10^{5}) =$

2. $(9.7 \times 10^{14})(4.3 \times 10^{-20}) =$

3. $\dfrac{\mathbf{2.6x10^{6}}}{\mathbf{5.8x10^{2}}} =$

4. $\dfrac{\mathbf{1.7x10^{-5}}}{\mathbf{8.2x10^{-8}}} =$

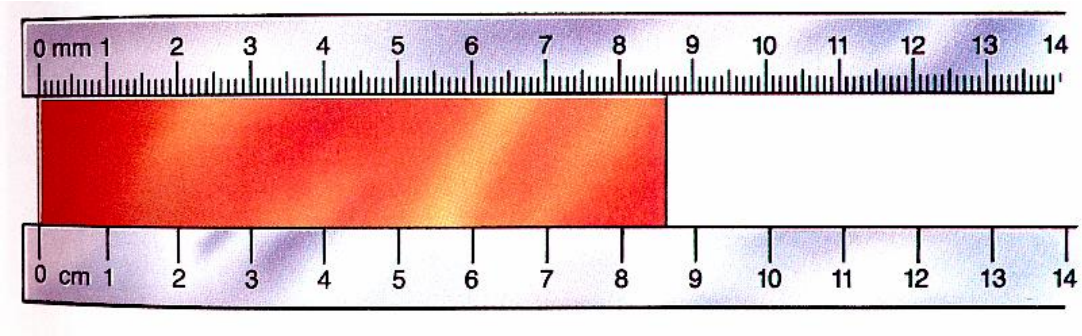
5. $(3.7 \times 10^{-6}) \times (4.0 \times 10^{8}) =$

SIGNIFICANT FIGURES

Two kinds of numbers are used in science:

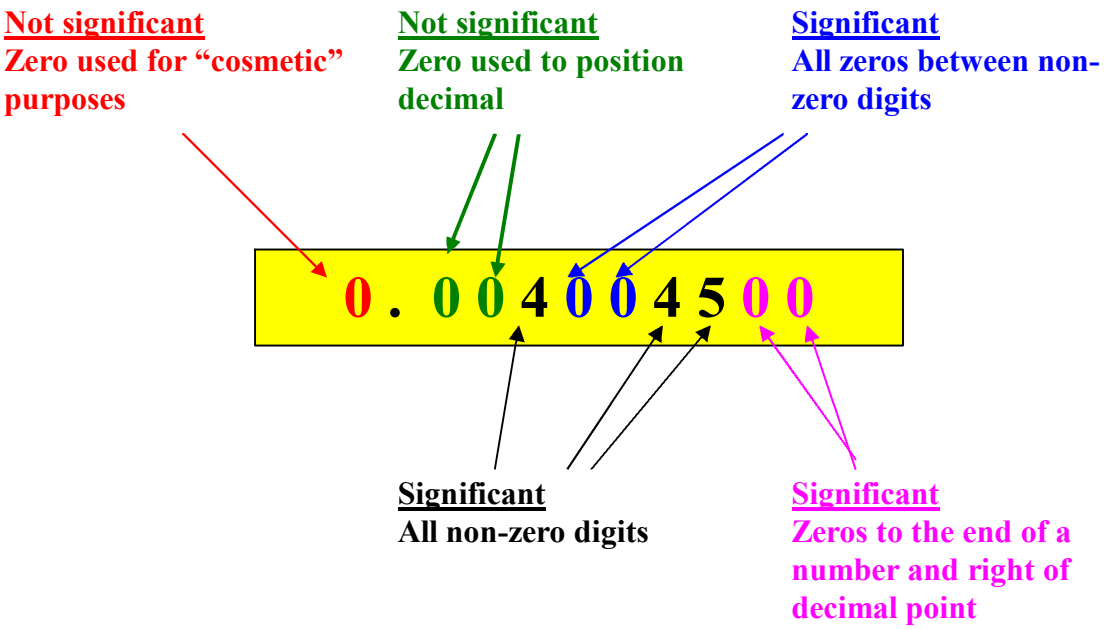
- **Counted or Defined**: exact numbers; **no uncertainty**
- **Measured**: are subject to error; have **uncertainty**

Uncertainty in Measurements:



- Every measurement has **uncertainty** because of instrument limitations and human error.
- The **last** digit is the **estimated** one.
- **Significant numbers** are the **certain** and **uncertain** digits.

Significant Figure Rules



Examples:

Determine the number of significant figures in each of the following measurements:

461 cm	93.500 g
1025 g	0.006 m
0.705 mL	5500 km

Rounding Off Rules

	rounded to 3 sig. figs
1. If the rounded digit is **<5**, the digit is simply dropped.	51.2**34** → 51.2
2. If the rounded digit is **≥5**, the digit is increased.	51.3**8**, 51.3**59**, 51.3**503** → 51.4

SIGNIFICANT FIGURES IN CALCULATIONS

1. For **multiplication and division,** the **answer** must contain the **same number of significant figures** as there are in the measurement with the **fewest significant figures**.

9.2 x 6.8 x 0.3744 = **23**.4225 (calculator answer)

= **23** (rounded answer)

2. For **addition and subtraction**, the **answer** must have the **same number of decimal places** as there are in the measurement with the **fewest decimal places**.

83.**5**
+ 23.28
106.**7**8 (calculator answer)

106.**8** (rounded answer)

20.0**2**
+ 20.002
+ 20.0002
60.0222 (calculator answer)

60.0**2** (rounded answer)

Examples:

1) 5.008 + 16.2 + 13.48 =

2) $\dfrac{\mathbf{3.15 \times 1.53}}{\mathbf{0.78}} =$