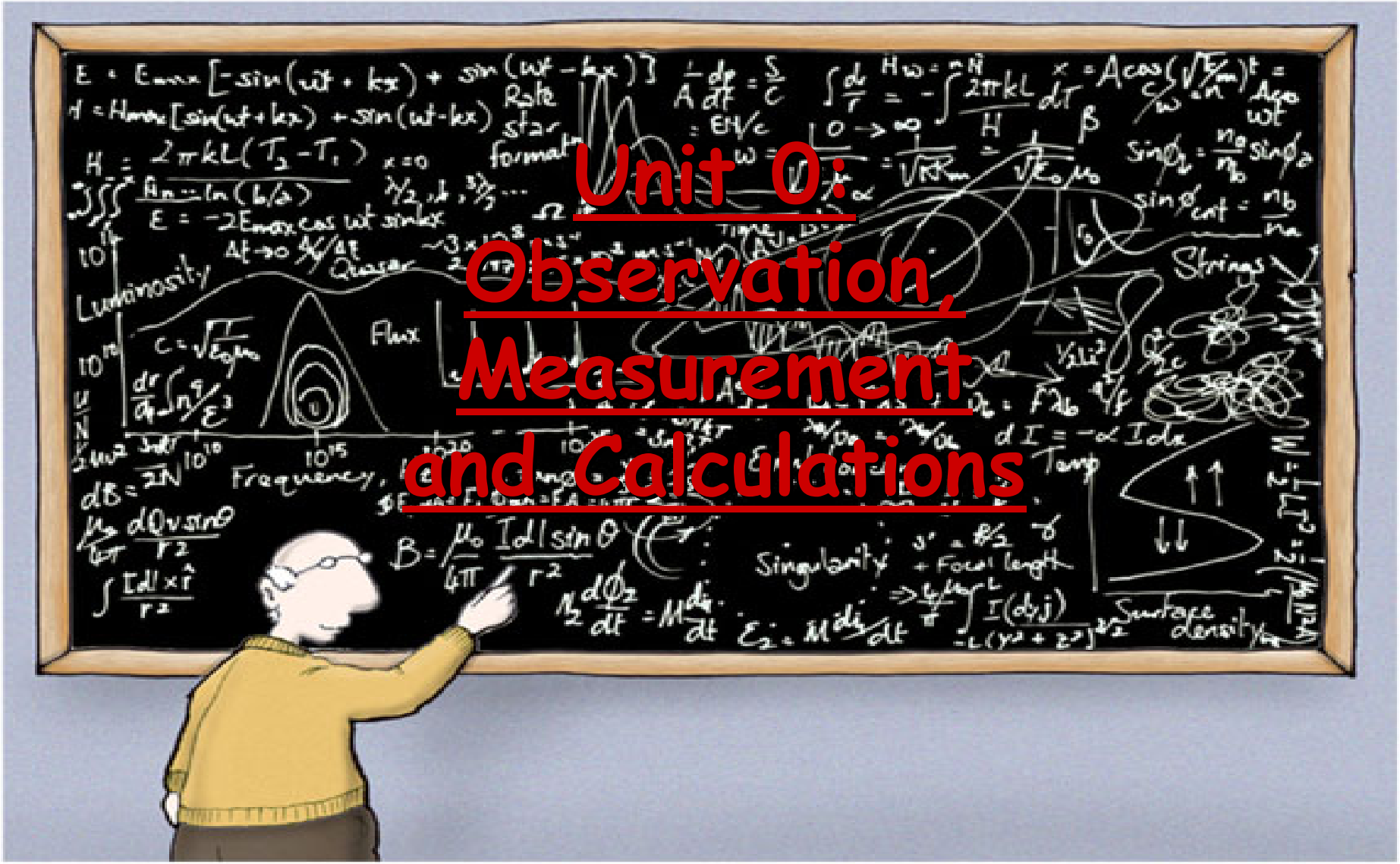
Unit 0: Observation, Measurement and Calculations



Cartoon courtesy of NearingZero.net

Steps in the Scientific Method

1. **Observations**
   - quantitative
   - qualitative
2. **Formulating hypotheses**
   - possible explanation for the observation
3. **Performing experiments**
   - gathering new information to decide whether the hypothesis is valid

Outcomes Over the Long-Term

Theory (Model)

- A set of tested hypotheses that give an overall explanation of some natural phenomenon.

Natural Law

- The same observation applies to many different systems
- Example - Law of Conservation of Mass

Law vs. Theory

- A **law** summarizes what happens
- A **theory** (model) is an attempt to explain why it happens.

Scientific Notation

In science, we deal with some very LARGE numbers:

1 mole = 602000000000000000000000

In science, we deal with some very SMALL numbers:

Mass of an electron = 0.00000000000000000000000000000091 kg

Imagine the difficulty of calculating the mass of 1 mole of electrons!

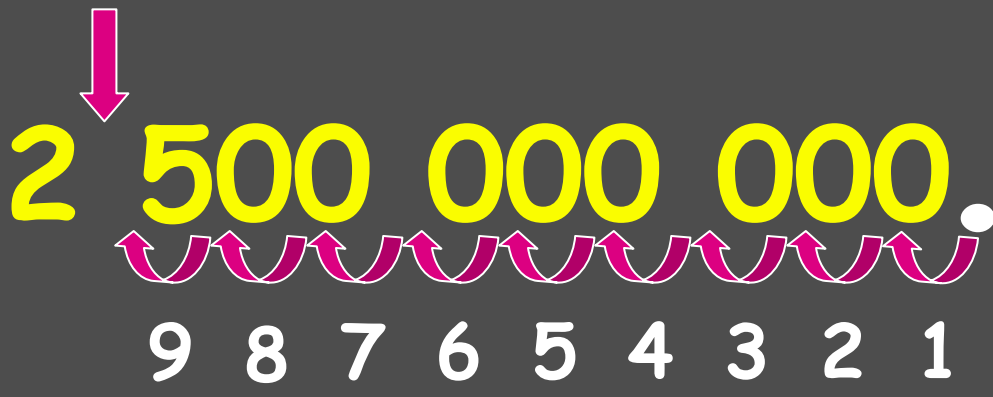
$$\begin{array}{r} 0.000000000000000000000000000091\ \text{kg} \\ \times\ 602000000000000000000000 \\ \hline ?????????????????????????????????????? \end{array}$$

Scientific Notation:

A method of representing very large or very small numbers in the form:

$$M \times 10^{n}$$

- **M** is a number between **1** and **10**
- **n** is an integer



Step #1: Insert an understood decimal point

Step #2: Decide where the decimal must end up so that one number is to its left

Step #3: Count how many places you bounce the decimal point

Step #4: Re-write in the form $M \times 10^n$

2.5×10^{9}

The exponent is the number of places we moved the decimal.

Step #2: Decide where the decimal must end up so that one number is to its left

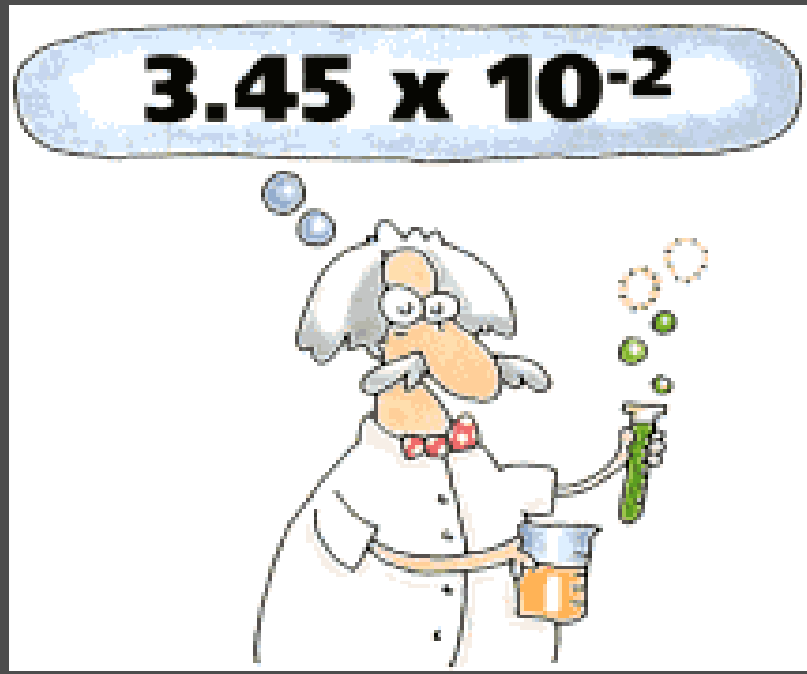
Step #3: Count how many places you bounce the decimal point

Step #4: Re-write in the form $M \times 10^n$

$$5.79 \times 10^{-5}$$

The exponent is negative because the number we started with was less than 1.

PERFORMING CALCULATIONS IN SCIENTIFIC NOTATION



ADDITION AND SUBTRACTION

Review:

Scientific notation expresses a number in the form:

$$M \times 10^n$$

$1 \leq M < 10$

n is an integer

$$\begin{array}{r} 4 \times 10^6 \\ +\ 3 \times 10^6 \\ \hline 7 \times 10^6 \end{array}$$

IF the exponents are the same, we simply add or subtract the numbers in front and bring the exponent down unchanged.

$$\begin{array}{r} 4 \times 10^6 \\ -\ 3 \times 10^6 \\ \hline 1 \times 10^6 \end{array}$$

The same holds true for subtraction in scientific notation.

$$\begin{array}{r} 4 \times 10^{6} \\ +\ 3 \times 10^{5} \\ \hline \end{array}$$

If the exponents are NOT the same, we must move a decimal to <u>make</u> them the same.

4.00×10^6

$+ 3.00 \times 10^5$

4.00×10^6

$+ .30 \times 10^6$

4.30×10^6

Move the decimal on the smaller number!

A Problem for you…

$$2.37 \times 10^{-6}$$
$$+ \; 3.48 \times 10^{-4}$$

Solution…

$$002.37 \times 10^{-6}$$

$$+\ 3.48 \times 10^{-4}$$

Solution…

$$
\begin{array}{rl}
 & 0.0237 \times 10^{-4} \\
+ & 3.48 \times 10^{-4} \\
\hline
 & 3.5037 \times 10^{-4}
\end{array}
$$

Nature of Measurement

Measurement - quantitative observation consisting of 2 parts

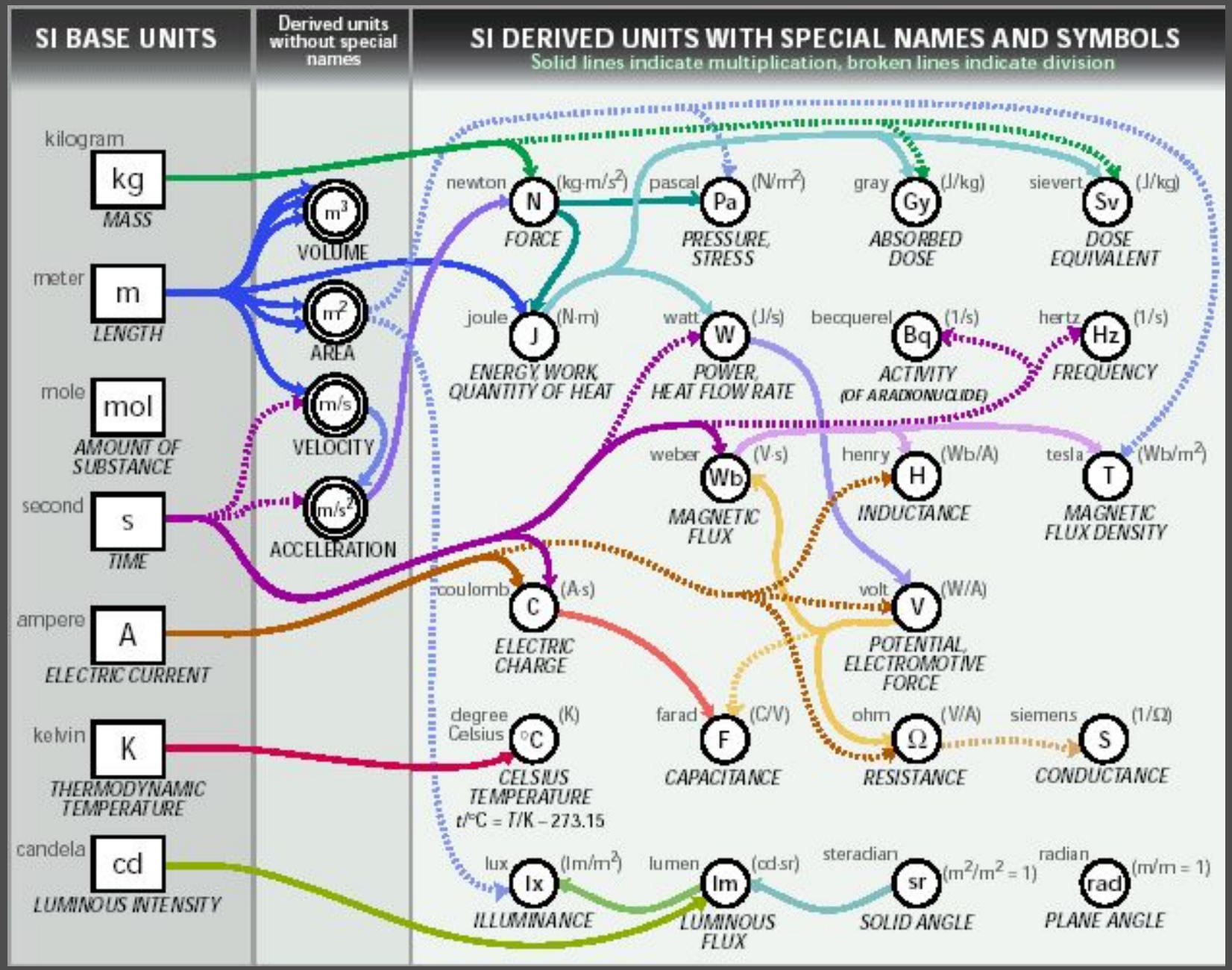
Part 1 - number
Part 2 - scale (unit)

Examples:

20 grams
6.63×10^{-34} Joule seconds

The Fundamental SI Units
(le Système International, SI)

Physical Quantity	Name	Abbreviation
Mass	kilogram	kg
Length	meter	m
Time	second	s
Temperature	Kelvin	K
Electric Current	Ampere	A
Amount of Substance	mole	mol
Luminous Intensity	candela	cd


SI BASE UNITS
Derived units without special names
SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS
Solid lines indicate multiplication, broken lines indicate division
kilogram
kg
MASS
meter
m
LENGTH
mole
mol
AMOUNT OF SUBSTANCE
second
s
TIME
ampere
A
ELECTRIC CURRENT
kelvin
K
THERMODYNAMIC TEMPERATURE
candela
cd
LUMINOUS INTENSITY
m3
VOLUME
m2
AREA
m/s
VELOCITY
m/s2
ACCELERATION
newton
N
(kg·m/s2)
FORCE
pascal
Pa
(N/m2)
PRESSURE, STRESS
gray
Gy
(J/kg)
ABSORBED DOSE
sievert
Sv
(J/kg)
DOSE EQUIVALENT
joule
J
(N·m)
ENERGY, WORK, QUANTITY OF HEAT
watt
W
(J/s)
POWER, HEAT FLOW RATE
becquerel
Bq
(1/s)
ACTIVITY (OF A RADIONUCLIDE)
hertz
Hz
(1/s)
FREQUENCY
weber
Wb
(V·s)
MAGNETIC FLUX
henry
H
(Wb/A)
INDUCTANCE
tesla
T
(Wb/m2)
MAGNETIC FLUX DENSITY
coulomb
C
(A·s)
ELECTRIC CHARGE
volt
V
(W/A)
POTENTIAL, ELECTROMOTIVE FORCE
degree Celsius
°C
(K)
CELSIUS TEMPERATURE
t/°C = T/K – 273.15
farad
F
(C/V)
CAPACITANCE
ohm
Ω
(V/A)
RESISTANCE
siemens
S
(1/Ω)
CONDUCTANCE
lux
lx
(lm/m2)
ILLUMINANCE
lumen
lm
(cd·sr)
LUMINOUS FLUX
steradian
sr
(m2/m2 = 1)
SOLID ANGLE
radian
rad
(m/m = 1)
PLANE ANGLE

SI Prefixes Common to Chemistry

Prefix	Unit Abbr.	Exponent
Kilo	k	10^{3}
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}

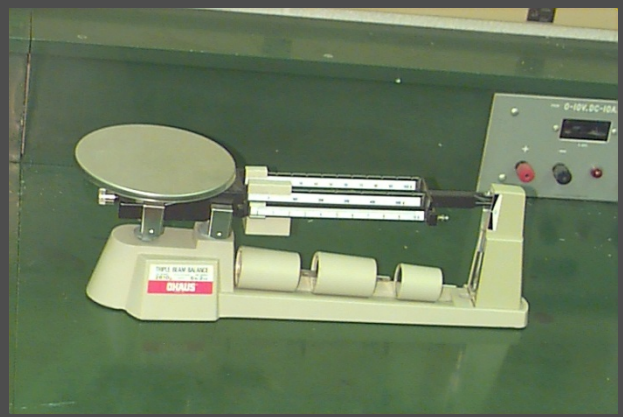
Uncertainty in Measurement

A digit that must be **estimated** is called **uncertain**. A **measurement** always has some degree of uncertainty.

Why Is there Uncertainty?

- Measurements are performed with instruments
- No instrument can read to an infinite number of decimal places

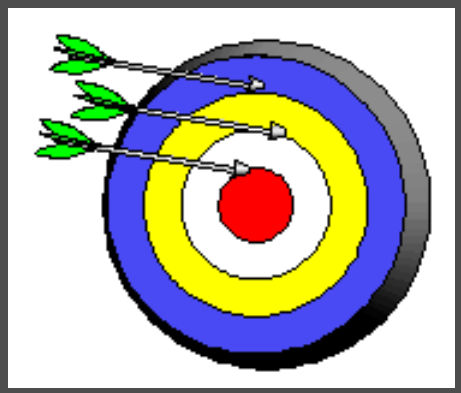
Which of these balances has the greatest uncertainty in measurement?



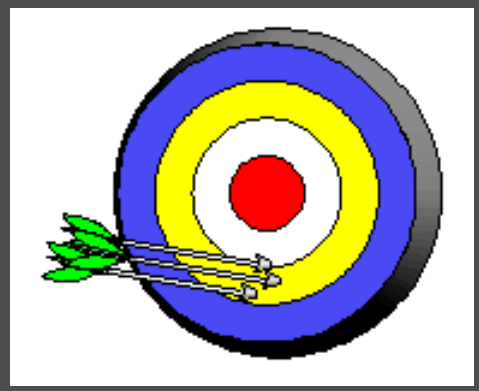
Precision and Accuracy

Accuracy refers to the agreement of a particular value with the true value.

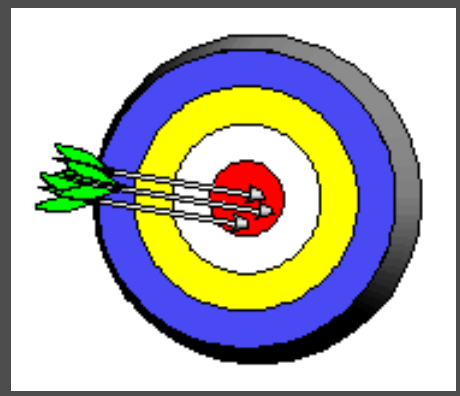
Precision refers to the degree of agreement among several measurements made in the same manner.



Neither accurate nor precise



Precise but not accurate



Precise AND accurate

Types of Error

Random Error (Indeterminate Error) - measurement has an equal probability of being high or low.

Systematic Error (Determinate Error) - Occurs in the **same direction** each time (high or low), often resulting from poor technique or incorrect calibration.

Rules for Counting Significant Figures - Details

Nonzero integers always count as significant figures.

3456 has

4 sig figs.

Rules for Counting Significant Figures - Details

Zeros

- **Leading zeros** do not count as significant figures.

0.0486 has

3 sig figs.

Rules for Counting Significant Figures - Details

Zeros

- **Captive zeros** always count as significant figures.

16.07 has

4 sig figs.

Rules for Counting Significant Figures - Details

Zeros

Trailing zeros are significant only if the number contains a decimal point.

9.300 has

4 sig figs.

Rules for Counting Significant Figures - Details

Exact numbers have an infinite number of significant figures.

1 inch = 2.54 cm, exactly

Sig Fig Practice #1

How many significant figures in each of the following?

1.0070 m → 5 sig figs

17.10 kg → 4 sig figs

100,890 L → 5 sig figs

3.29×10^3 s → 3 sig figs

0.0054 cm → 2 sig figs

3,200,000 → 2 sig figs

Rules for Significant Figures in Mathematical Operations

Multiplication and Division: # sig figs in the result equals the number in the least precise measurement used in the calculation.

$$6.38 \times 2.0 =$$

$$12.76 \rightarrow 13 \text{ (2 sig figs)}$$

Sig Fig Practice #2

Calculation	Calculator says:	Answer
3.24 m x 7.0 m	22.68 m^2	23 m^2
100.0 g ÷ 23.7 cm^3	4.219409283 g/cm^3	4.22 g/cm^3
0.02 cm x 2.371 cm	0.04742 cm^2	0.05 cm^2
710 m ÷ 3.0 s	236.6666667 m/s	240 m/s
1818.2 lb x 3.23 ft	5872.786 lb·ft	5870 lb·ft
1.030 g ÷ 2.87 mL	2.9561 g/mL	2.96 g/mL

Rules for Significant Figures in Mathematical Operations

Addition and Subtraction: The number of decimal places in the result equals the number of decimal places in the least precise measurement.

$$6.8 + 11.934 =$$

$$18.734 \rightarrow 18.7 \text{ (3 sig figs)}$$

Sig Fig Practice #3

Calculation	Calculator says:	Answer
3.24 m + 7.0 m	10.24 m	10.2 m
100.0 g - 23.73 g	76.27 g	76.3 g
0.02 cm + 2.371 cm	2.391 cm	2.39 cm
713.1 L - 3.872 L	709.228 L	709.2 L
1818.2 lb + 3.37 lb	1821.57 lb	1821.6 lb
2.030 mL - 1.870 mL	0.16 mL	0.160 mL