Measurements and Calculations

Measurements

Measurements

Measurement consists of two parts:

Number - Unit

2 pounds

Number

Unit

Measurement and Units

Metric system or SI (International System of Units)

meter, liter, gram …

English system (use in the United States)

miles, gallons, pounds …

Advantages of SI: we have base unit for each kind of measurement

other units are related to the base unit by power of 10.

Prefix (symbol)	Value
giga (G)	10^9
mega (M)	10^6
kilo (k)	10^3
deci (d)	10^{-1}
centi (c)	10^{-2}
milli (m)	10^{-3}
micro (μ)	10^{-6}
nano (n)	10^{-9}

base unit of length: meter (m)

1 kilometer (km) = 1000 meter (m)
1 centimeter (cm) = 0.01 meter (m)
1 nanometer (nm) = 1×10^{-9} meter (m)

base unit of mass: gram (g)

1 kilogram (kg) = 1000 gram (g)
1 milligram (mg) = 0.001 gram (g)

base unit of volume: liter (L)

1 milliliter (mL) = 0.001 liter (L)
1000 milliliter (mL) = 1 liter (L)

1 mL = 1 cc = $1 cm^3$

base unit of time: second (s)

60 seconds (s)= 1 minute (min)
60 minutes (min) = 1 hour (h)

Tools (equipment) of measurement

Length: Meterstick or Ruler

Volume: Graduated cylinder, Pipette

Mass: Balance

Temperature

english system $\longrightarrow$ Fahrenheit (°F)

metric system or SI $\longrightarrow$ Celsius or centigrade (°C)

$$°F = 1.8\ °C + 32$$

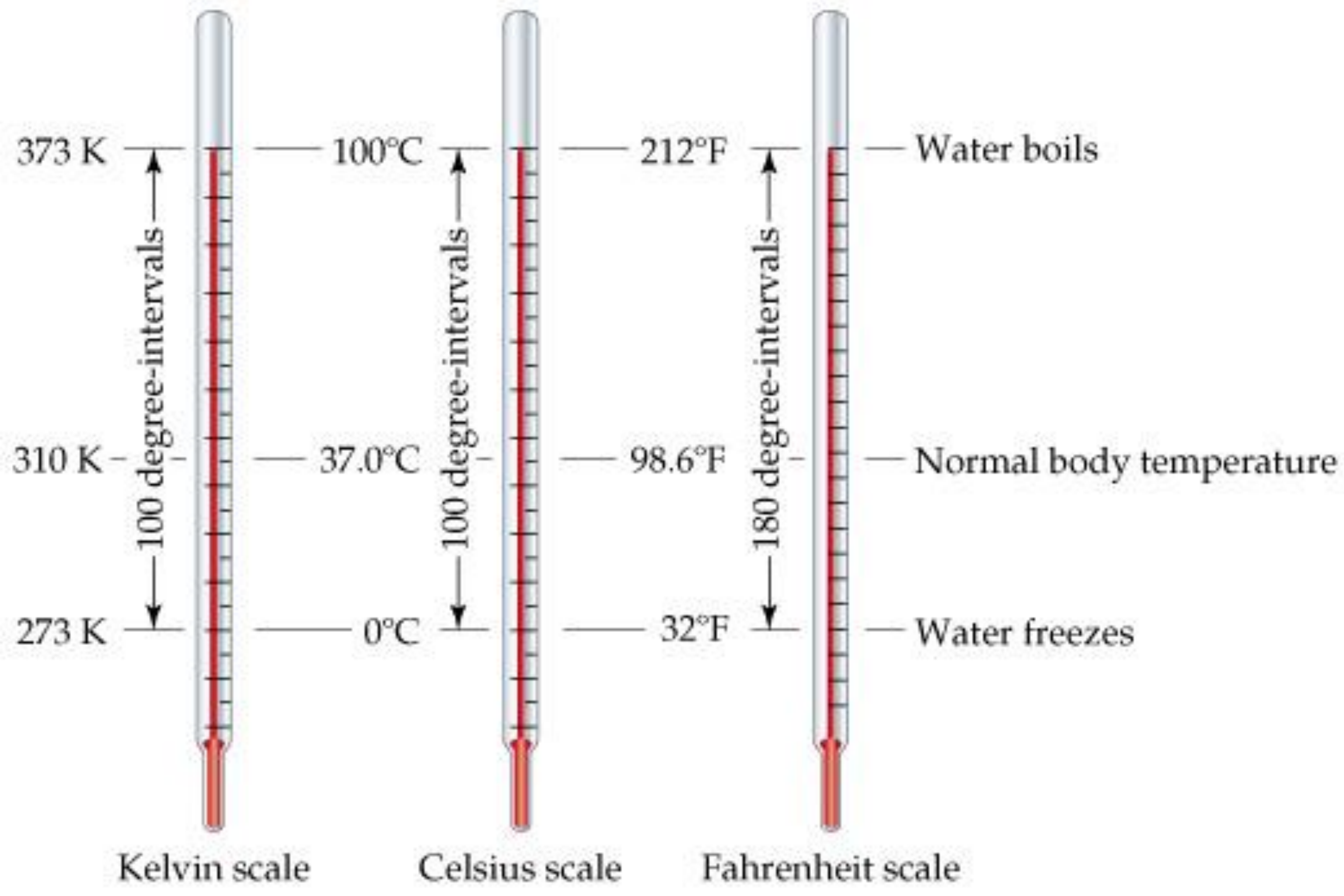
$$°C = \frac{°F - 32}{1.8}$$

Kelvin scale or absolute scale (K)

$$K = °C + 273$$

$$°C = K - 273$$

Temperature



Temperature

1. Size of degree is the same for Celsius and Kelvin scales.

2. Fahrenheit scale is smaller than others.

3. The zero points are different on all there scales.

Scientific (exponential) notation

based on power of 10

$10000 = 1\times10^{4}$

$0.0001 = 1\times10^{-4}$

$4500000 = 4.5\times10^{6}$

$0.000078 = 7.8\times10^{-5}$

$94800 = 9.48\times10^{4}$

$0.0121 = 1.21\times10^{-2}$

Positive power: greater than 1

Negative power: Less than 1

Scientific (exponential) notation

Power, Exponent

$$9.23 \times 10^{25}$$

Coefficient

Base

Scientific (exponential) notation

$$(3.62 \times 10^6)(7.43 \times 10^3) = 26.90 \times 10^9 = 2.69 \times 10^{10}$$

$$\frac{(3.62 \times 10^7)}{(1.35 \times 10^5)} = 2.68 \times 10^2$$

Moving the decimal point to right $\longrightarrow$ Decreasing the power one point

Moving the decimal point to left $\longrightarrow$ Increasing the power one point

Conversion of Units

Conversion Factor:

$$1 \text{ m} = 1000 \text{ mm}$$

Equivalence statement
(Equality)

$$\frac{1 \text{ m}}{1000 \text{ mm}} \quad \text{or} \quad \frac{1000 \text{ mm}}{1 \text{ m}}$$

Conversion factor

Ratios of two parts of equality

Conversion of Units

Factor-Label method (dimensional analysis):

$$36 \text{ m} = ? \text{ mm}$$

$$36 \text{ m} \times \text{conversion factor} = ? \text{ mm}$$

$$\frac{1 \text{ m}}{1000 \text{ mm}} \quad \text{or} \quad \frac{1000 \text{ mm}}{1 \text{ m}}$$

$$36 \cancel{\text{m}} \times \frac{1000 \text{ mm}}{1 \cancel{\text{m}}} = 36000 \text{ mm}$$

Conversion of Units

Factor-Label method

25kg = ? lb

$$25\cancel{kg} \times \frac{2.205\ lb}{1\ \cancel{kg}} = 55\ lb$$

78 mile = ? km

$$78\cancel{mi} \times \frac{1.609\ km}{1\ \cancel{mi}} = 130\ km$$

45 m/hr = ? in/min

$$45\ \frac{\cancel{m}}{\cancel{hr}} \times \frac{39.37\ in}{1\ \cancel{m}} \times \frac{1\ \cancel{hr}}{60 min} = 30.\ in/min$$

Density and Specific gravity

density: amount of mass present in a given volume.

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

d: density (g/mL or g/L) m: mass V: volume

The density of ice is less than the density of liquid water, so the ice floats on top of the water.

Salad oil is less dense than vinegar.

Density and Specific gravity

Table 2.8 Densities of Various Common Substances at 20 °C

Substance	Physical State	Density (g/cm^3)
oxygen	gas	0.00133*
hydrogen	gas	0.000084*
ethanol	liquid	0.785
benzene	liquid	0.880
water	liquid	1.000
magnesium	solid	1.74
salt (sodium chloride)	solid	2.16
aluminum	solid	2.70
iron	solid	7.87
copper	solid	8.96
silver	solid	10.5
lead	solid	11.34
mercury	liquid	13.6
gold	solid	19.32

*At 1 atmosphere pressure

Gas = low density

Liquids: close to 1 g/cm^3, 1 g/mL

Metals: various heavy densities.

Density Examples

Example 1. A gas fills a volume of 1200. mL and has a mass of 1.60 g. What is the density of the gas?

$$d = \frac{m}{V} = \frac{1.60 \text{ g}}{1200. \text{ mL}} = 0.00133 \text{ g/mL}$$

Example 2. A cube of pure silver measures 2.0 cm on each side. The density of silver is 10.5 g/cm^3. What is the mass of the cube?

$$V = L \times H \times W = 2.0 \text{ cm x } 2.0 \text{ cm x } 2.0 \text{ cm} = 8.0 \text{ cm}^3$$

$$m = d \times V = 8.0 \text{ cm}^3 \text{ x } 10.5 \text{ g/cm}^3 = 84. \text{ g}$$

Density Examples

Example 3: The density of air is 1.25×10^{-3} g/cm^3. What is the mass of air in a room that is 5.00 meters long, 4.00 meters wide and 2.2 meters high?

$$V = L \times H \times W$$

$V = 5.0 \text{ m} \times 4.0 \text{ m} \times 2.2 \text{ m} = 44 \text{ m}^3$ Hmm, not so helpful.

$$V = 500.\text{ cm} \times 400.\text{ cm} \times 220 \text{ cm} = 44000000 \text{ cm}^3$$

$$d = \frac{m}{V} \qquad m = d \times V$$

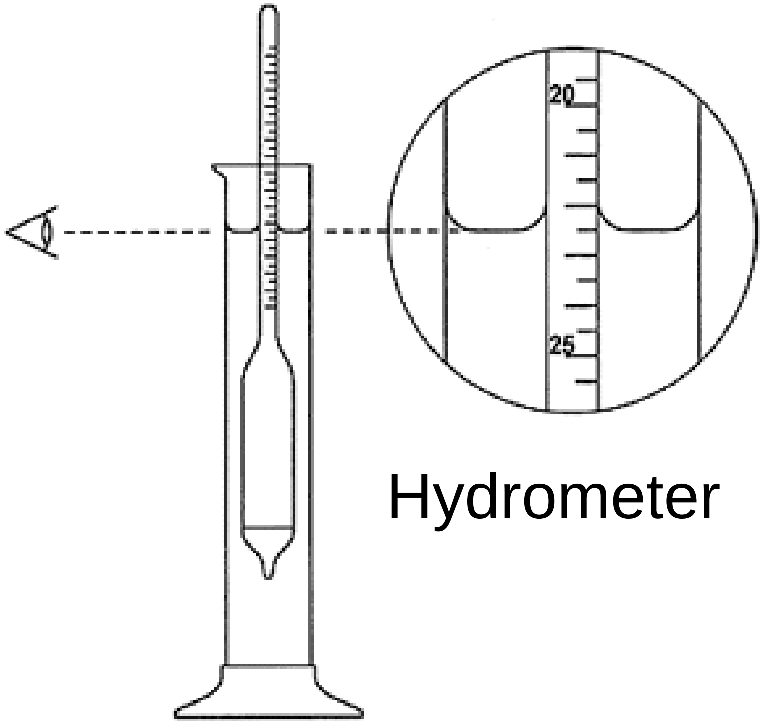
$$m = (4.4 \times 10^7 \text{ cm}^3) \times (1.25 \times 10^{-3} \text{ g/cm}^3) = 55000 \text{ g or } 55 \text{ kg}$$

Density and Specific gravity

Specific gravity:

$$SG = \frac{d_{substance}}{d_{water}}$$

No units (dimensionless)



Hydrometer

Significant Figures

Exact numbers: we do not use a measuring devise.

(Counting numbers)

Number of students in class, 1m = 100cm

Inexact numbers: we use a measuring devise.

(measuring numbers)

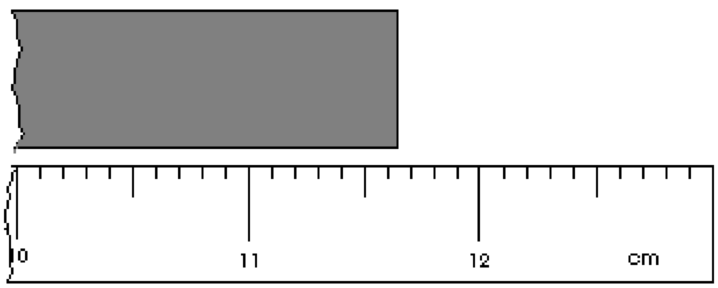
Temperature of room, mass of table

Significant Figures

We always have errors in measurement: Personal and instrumental errors.

⇓

All measurements need an estimate.



between 11.6 and 11.7 ⟶ 11.62 or 11.63 or 11.67 or …

Significant Figures

Certain numbers: 11.6

Uncertain number: 11.66

(estimated digit - only the last digit)

Significant Figures: all numbers recorded in a measurement.

(certain and uncertain)

When we report, we show uncertainty with ± 11.66 ± 0.01

Significant Figures rules

1. Nonzero digits count as significant figures. 297.32 ⟶ 5 S.F.

2. Zeros:

a) Zeros at the beginning of numbers do not count as S.F. (Leading zeros).

0.0031 ⟶ 2 S.F.

b) Zeros between two nonzero digits count as S.F. (Captive zeros).

600067 ⟶ 6 S.F.

c) Zeros at the end of numbers (Trailing zeros):

If there is a decimal point, count as S.F. 2.800 ⟶ 4 S.F.

If there is not a decimal point, do not count as S.F.

2800 ⟶ 2 S.F.

Rounding off

1. If the digit to be removed:

a) is less than 5, the preceding digit stays the same.

5.343 $\longrightarrow$ 5.34 (2 decimal places)

5.343 $\longrightarrow$ 5.3 (1 d.p.)

b) is equal to or greater than 5, the preceding digit is increased by 1.

6.456 $\longrightarrow$ 6.46 (2 decimal places)

6.456 $\longrightarrow$ 6.5 (1 d.p.)

2. We round off at the end of calculation.

Significant Figures in calculation

1. **Multiplication or division:**

Number of significant figures in result = Smallest number of significant figures.

$$\underset{4\text{ S.F.}}{4.000} \times \underset{2\text{ S.F.}}{560} \times \underset{4\text{ S.F.}}{7001} \times \underset{1\text{ S.F.}}{0.003} = \cancel{47046.72} = \underset{1\text{ S.F.}}{50000}$$

$$\begin{array}{l} 4\text{ S.F.} \longleftarrow \\ 2\text{ S.F.} \longleftarrow \end{array} \frac{8.600}{44000} = \cancel{0.000195454} = \underset{2\text{ S.F.}}{0.00020}$$

Significant Figures in calculation

2. **Addition or subtraction:**

Number of decimal places in result = Smallest number of decimal places.

57.93 + 0.05 - 0.230 + 4600 = 4657.75 = 4658

2 d.p. 2 d.p. 3 d.p. 0 d.p. 0 d.p.

710.0 - 0.0063 – 4098.1 + 4.63 = -3383.4763 = -3383.5

1 d.p. 4 d.p. 1 d.p. 2 d.p. 1 d.p.

Significant Figures in calculation

- Significant Figures in Mixed operations

$$(1.7 \times 10^6 \div 2.63 \times 10^5) + 7.33 = ???$$

Step 1: Divide the numbers in the parenthesis. How many sig figs?

$(\underline{6.4}63878327\ldots) + 7.33$

Step 2: Add the numbers. How many decimal places to keep?

$$\begin{array}{r|l} \underline{6.4} & 63878327\ldots \\ +\ 7.3 & 3 \\ \hline 13.7 & 938 \end{array}$$

Step 3: Round answer to the appropriate decimal place.

13.8 or 1.38×10^1