SCIENTIFIC MEASUREMENT

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COURSE CONTENT/OUTCOMES

1. Type of measurements and SI units
2. Units derived from based units
3. Measurement of mass, weight and temperature
4. Distinguish between accuracy and precision
5. Conversion of measurements to scientific notation
6. Importance of significant figures

Measurements

- Measurement – process of observing and recording objects or events
  - Gives the world meaning & gives reference to us
  - Allows us to solve problems, compare objects, record results etc.
- Measurements are made everyday
  - Buying products
  - Sports activities
  - Cooking
  - weather
- Scientific measurements can either be

  a) qualitative

  b) quantitative

Measurements

- **Qualitative** measurements are descriptive and non-numeric
  - e.g. heavy, hot, rough, bright
- **Quantitative** measurements involve numbers or values, and depend on:
  - The reliability of the measuring instrument
  - The care with which it is read by the user

Quantitative Measurement

- Measured with accuracy, clarity, without ambiguity and reported as a value.
- **Value** is a quantitative description that includes both a number and a unit e.g. 10 kg, 100 ^oC
- **Units** are quantities or dimensions generally accepted as standards for comparisons or exchange in measurements e.g. Kg, m

The International System of Units

- Measurements depend upon **units** that serve as reference or standards
- The standards of measurement used in science are those of the **Metric System**, devised in 18th century by the French
- Metric system was revised and named as the **International System of Units (SI)** , as of 1960

The International System of Units

- SI is simplistic and practical, based on multiples of 10
- Consists of **7 base units**, but only 5 commonly used in chemistry
  - Meter
  - Kilogram
  - Kelvin
  - Second
  - mole
  - *Ampere*
  - *Candela*

The Fundamental SI Units

Physical Quantity	Name	Abbreviation
Length	Meter	m
Mass	Kilogram	kg
Temperature	Kelvin	K
Time	Second	s
Amount of substance	Mole	mol
Not commonly used in chemistry:		
Luminous intensity	Candela	cd
Electric current	Ampere	A

Units Derived From SI Units

- Sometimes, non-SI units are used for measurement
  - E.g. Liter, celsius, calorie
- Some units of measurement are **derived** from the appropriate base units, such as:
  - Volume → m^3
  - Speed → Km/hour
  - Density → g/mL

Length

- In SI, the basic unit of **length** is the **meter (m)**
- Length is the distance between two objects
- Length is measured using a;
  - Metric ruler
  - Metric tape
  - Meter stick
- We use **Prefixes** for units larger or smaller than a meter

Conversion of SI Units

TABLE 1.5 Selected Prefixes Used in the Metric System

Prefix	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm) $= 1 \times 10^9$ m
Mega	M	10^6	1 megameter (Mm) $= 1 \times 10^6$ m
Kilo	k	10^3	1 kilometer (km) $= 1 \times 10^3$ m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm) $= 1 \times 10^{-6}$ m
Nano	n	10^{-9}	1 nanometer (nm) $= 1 \times 10^{-9}$ m
Pico	p	10^{-12}	1 picometer (pm) $= 1 \times 10^{-12}$ m
Femto	f	10^{-15}	1 femtometer (fm) $= 1 \times 10^{-15}$ m

[a]This is the Greek letter mu (pronounced "mew").

Mass and Weight

- **Mass** is a measure of the quantity or amount of matter present in an object
- The SI unit for mass is **kilogram (Kg)**
- Measured using a **balance scale**

- An object's mass always stays the same regardless of location i.e. **Constant**

Mass and Weight

- Weight is a **force** that measures the pull by **gravity** i.e. The force of gravity on an object
- Thus, calculated as:

  $w = mg$ where w = weight

  m = mass

  g = gravity

- The SI units of weight is **Newton (N)**, derived from $kg.m/s^2$
- Measured using a spring balance

Temperature

- Temperature is a measure of the intensity of heat i.e. how hot or cold an object is
- Temperature is measured using a thermometer
- 3 different scales are used to measure temperature
  - Celsius (^oC)
  - Fahrenheit (^oF)
  - Kelvin (K)
- In SI system, temperature is based on the Kelvin (K) scale

$$\mathbf{K = {}^oC + 273.15}$$

Temperature

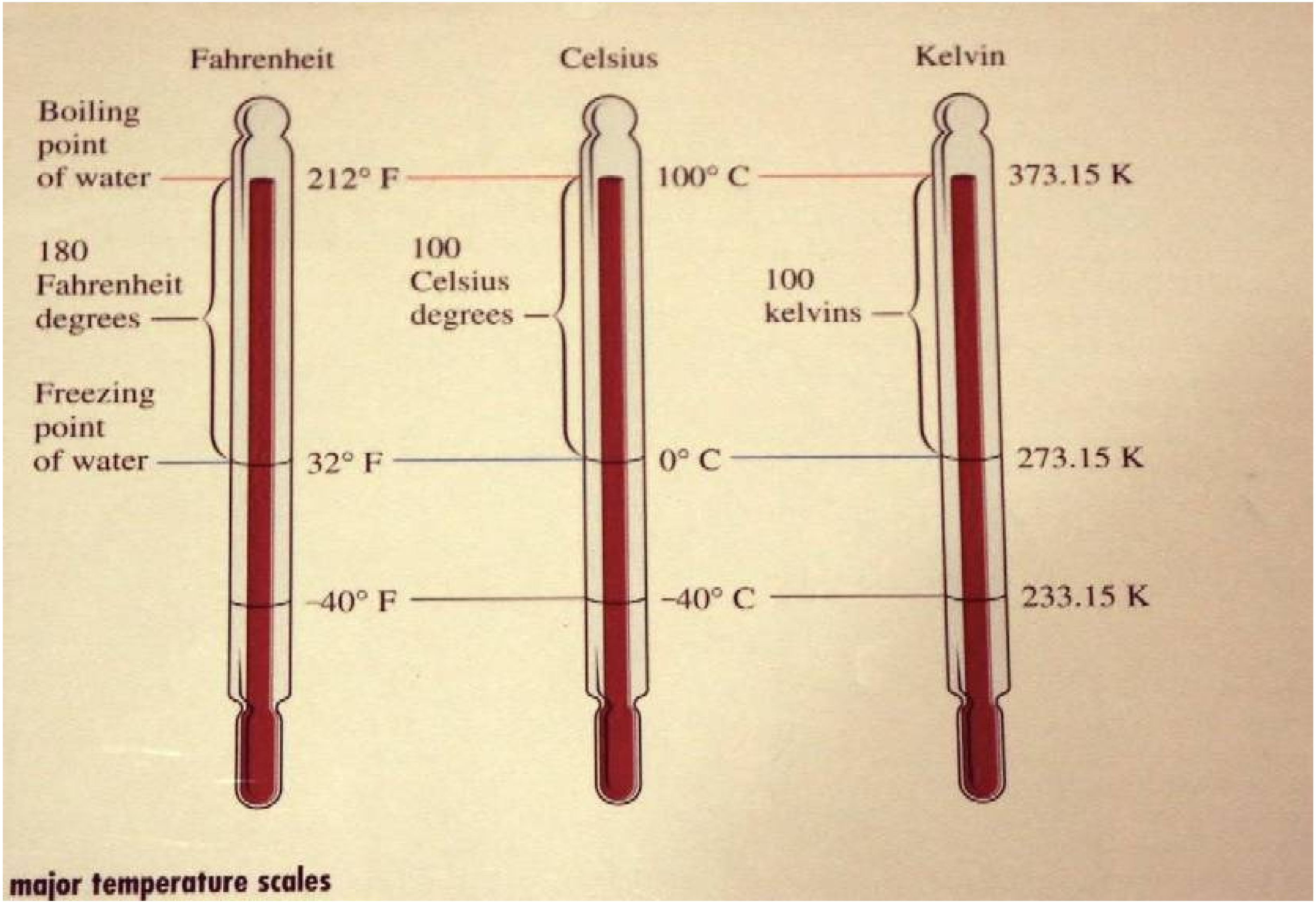
- On Celsius thermometer, freezing point of water is 0 ^{o}C and boiling point is 100 ^{o}C
- On Fahrenheit scale, freezing point of water is 32 ^{o}F and boiling point is 212 ^{o}F

$$^{o}F = 1.8\,(^{o}C) + 32$$

- the lowest possible temperature is referred to as absolute zero

0 K, -273.15 ^{o}C and -459.67 ^{o}F

Temperature Scales



Measurement Error and Uncertainty

- Quantitative measurements involve numbers or values and depend on:
  - The care with which it is read by the user
  - The reliability of the measuring instrument
- It is necessary to make good, reliable measurements
- Measurements have a degree of error and uncertainty

Error in Measurement

- Error in a measurement is related to both the accepted/true value and experimental value
- Accepted Value – the correct value based on reliable references/standards e.g. density of H_2O at 25 ^oC = 1.0 g/mL
- Experimental Value – the value measured by an individual in the lab
- Error – difference between the accepted/true value and experimental value

Error = Accepted value – experimental value

- can be positive or negative

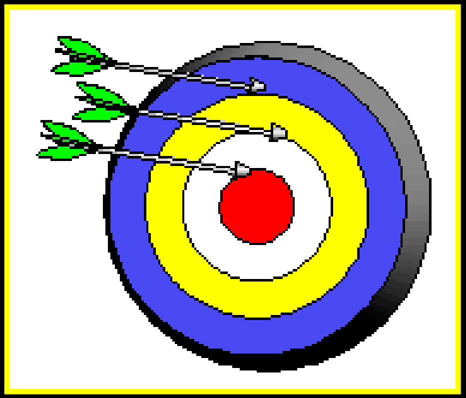
Uncertainty in Measurement

- Measurements are performed with instruments, and no instrument can read to an infinite number of decimal places
- Thus, all measurements are uncertain to an extent
- Uncertainty – degree of inexactness in an instrument
  - Describes the range within which the value lies
- Always best to use instruments that offer the most exact measurement i.e. Lowest uncertainty

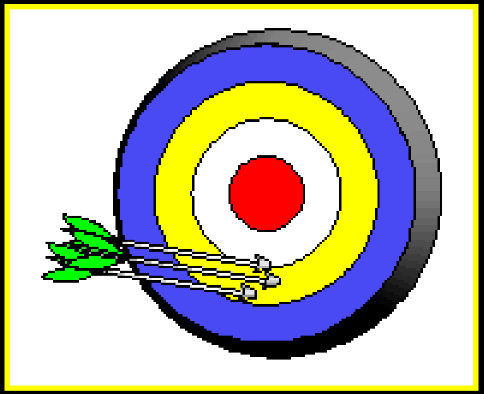
Accuracy and Precision

- The uncertainty of a measurement is related to both the accuracy and precision of the measurement
- Accuracy – how close a measurement is to the true value
- Precision – how close the measurements are to each other (reproducibility) i.e. not related to the true value

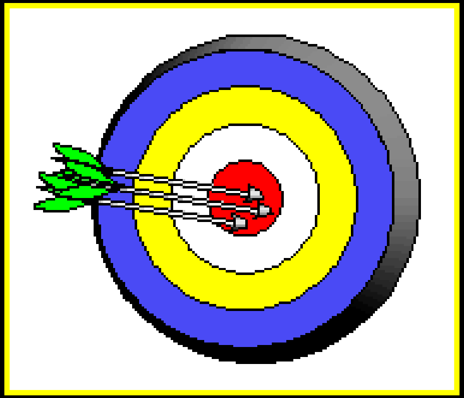
Precision and Accuracy



Neither accurate nor precise



Precise, but not accurate



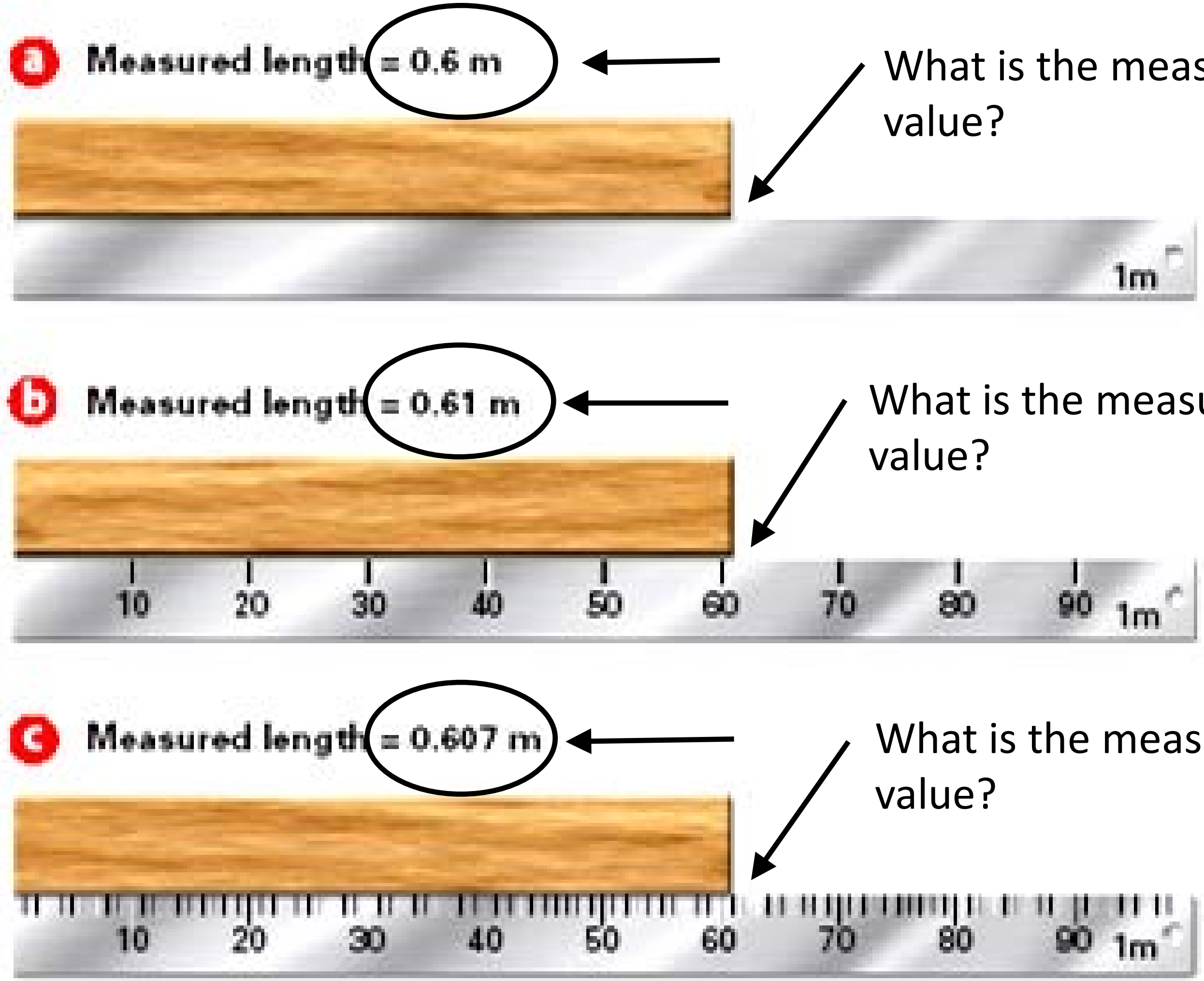
Precise AND accurate

Significant Figures

- Degree of reliability in a measurement is related to the # of significant figures
- Significant figure - # of figures in a value that are known with a degree of accuracy and precision
- These figures take into consideration the embedded uncertainty
- Important to record measurements to the correct # of significant figures

Significant Figures

Which measurement is the best?



What is the measured value?

What is the measured value?

What is the measured value?

Rules for Counting Significant Figures

Non-zeros always count as significant figures:

3456 has

4 significant figures

Rules for Counting Significant Figures

<u>Zeros</u>

Leading zeroes do not count as significant figures:

0.0486 has

3 significant figures

Rules for Counting Significant Figures

<u>Zeros</u>

Captive zeroes always count as significant figures:

16.07 has

4 significant figures

Rules for Counting Significant Figures

Zeros

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

9.300 has

4 significant figures

Sig Fig Practice #1

How many significant figures in the following?

1.0070 m → 5 sig figs

17.10 kg → 4 sig figs

100,890 L → 5 sig figs

3.29 x 10^3 s → 3 sig figs

0.0054 cm → 2 sig figs

3 200 000 mL → 2 sig figs

5 dogs → unlimited

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 x 2.0 =
  - 12.76 → 13 (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 ft x 3.23 ft	5872.786 ft^2	5870 ft^2
1.030 g x 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 → 18.7** (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 m + 3.37 m	1821.57 m	1821.6 m
2.030 mL - 1.870 mL	0.16 mL	0.160 mL

*Note the zero that has been added.

Rounding off

- Rules for rounding off numbers include:

1. When the number dropped is < 5, the preceding number remains unchanged

   e.g. 2.222 becomes 2.22

2. When the number dropped is > 5, one (1) is added to the preceding number

   e.g. 2.227 becomes 2.23

3. When the number dropped is = 5;

   - if the preceding number is even, then it remains unchanged

     e.g. 2.2225 becomes 2.222

   - If the preceding number is odd, then one (1) is added to it

     e.g. 2.2235 becomes 2.224

Scientific Notation

- Several methods used to record values which have been measured
- Measurements can be extremely large e.g. distance between two stars or extremely small e.g. microscopic size of a cell.
- Scientific notation – use of exponents to represent large and small numbers, as a product of powers of 10

$$\mathbf{a \times 10^{b}}$$

where a = coefficient, any real #

b = exponent, an integer

  – Positive exponents for values > 1
  – Negative exponents for values < 1

Scientific notation must always be written with the same components as the following model:

$$1.5876 \times 10^{6}$$

- A number in the ones' place. → 1
- decimal → .
- As many numbers as necessary after the decimal → 5876
- $x10^{?}$ → $\times 10$
- (Any positive or negative exponent.) → 6

8 790 000 000 = 8.79×10^9

Step 1: put in a decimal after the 0

879000000.

Step 2: Count how many spaces there are from the decimal to the end of the number.

8 7 9 0 0 0 0 0 0 0

9 8 7 6 5 4 3 2 1

Step 3: Your exponent is going to be 9 since you counted 9 spaces from the decimal. Write your number in scientific notation.

8.79×10^9

You must include all nonzero numbers, but do not include the 0's in scientific notation.

Your exponent is 9 since you counted 9 spaces to the right.

$5 \times 10^8 = 5.0\,0\,0\,0\,0\,0\,0\,0 = 500\ 000\ 000$

1 2 3 4 5 6 7 8

Step 1: Add a decimal after the 5.

5.

Step 2: Move the decimal point 8 spaces to the right since the power of 10 is 8.

5.

1 2 3 4 5 6 7 8

Step 3: Add 8 zeros since you have 8 extra spaces.

5.0 0 0 0 0 0 0 0

1 2 3 4 5 6 7 8

Step 4: 5×10^8 is equal to 500 000 000

$$1.4958 \times 10^6 = 1.495800 = 1{,}495{,}800$$

1 2 3 4 5 6

1. Step 1: Move the decimal point 6 spaces to the right since the power of 10 is 6.

1.4958

1 2 3 4 5 6

2. Step 2: Add 2 zeros since you have 2 extra spaces.

1.495800

1 2 3 4 5 6

3. 1.4958×10^6 is equal to 1,495,800.

Scientific Notation

65000000.

7 6 5 4 3 2 1

$$6.5 \times 10^{7}$$

Scientific Notation

0.0000987

-1 -2 -3 -4 -5

↓

$$9.87 \times 10^{-5}$$

Numeral	Is it written in scientific notation?	Why
19.5625×10^3	No	19.5625×10^3 ↖ There are two places before the decimal – there should only be one.
837×10^2	No	837×10^2 ↑ There is no decimal.
5.8938×5^2	No	5.8938×5^2 ↑ Must be multiplied by 10
2.894×10^{-3}	YES	2.894×10^{-3} ↑ Numeral written correctly with decimal ↖ Multiplied by 10 to a power.

THE END

Scientific Method