Significant Figures & Rounding

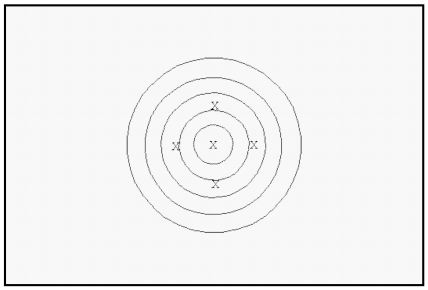
There is no such thing as a perfect measurement

All measurements have errors

Calculators display meaningless digits

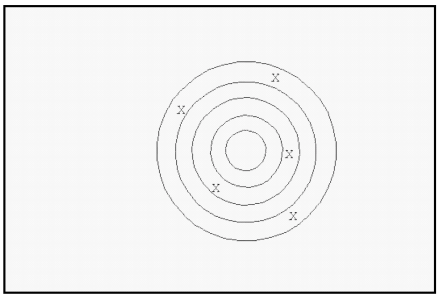
Can you really measure 0.00000001 ml?

Accurate Measurements



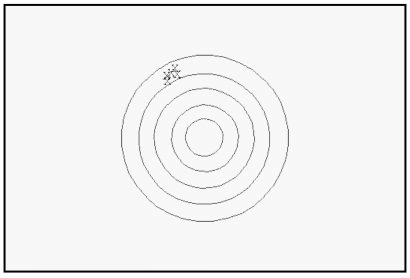
Measurements "average" to approximate value

Random Measurements



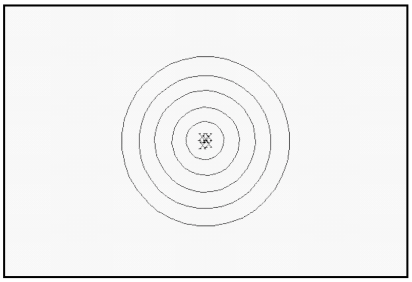
Represents experimental measurements

Precise Measurements



Measurements reliable, but not "on target"

Accurate & Precise Measurements



Measurements reliable and "on target"

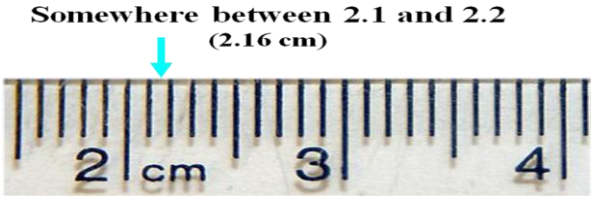
Significant Figures:

Indicate the degree of certainty (*precision*) in a measured quantity
or
in a calculated result

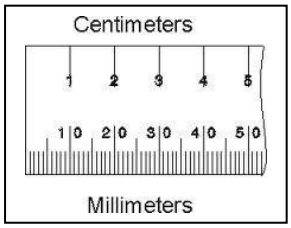
All the digits that are known
plus
the first uncertain digit (*doubtful digit*) in a measurement

Uncertain (Doubtful) Digits

Significant numbers apply only to measurements.

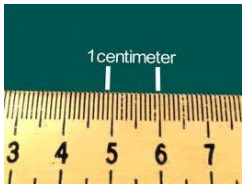


Reported Digits Convey Measurement Quality



2.8 cm Implies ruler has 0 marks between 2 & 3; 8 is doubtful
2.84 cm Implies ruler has 10 marks between 2 & 3; 4 is doubtful

Lab Measurements



Distance (cm) measurements: 2 decimal digits

Mass: all displayed digits

Volume (mL) measurements: 1 or 2 decimal digits

(depends on cylinder markings)

Never Round Data

Always record digits displayed on digital devices
Always record one more digit beyond the scale of non-digital measuring device

If multiple measurements are used in calculations:
errors in measurements are multiplied (propagated)
magnitude of error may exceed ability to measure
large error invalidates the experiment

Round Only after last calculation is completed

Certain & Doubtful Digits

	Certain	**Doubtful**
15.25 cm	**15.2**	**5**
894.22 g	**894.2**	**2**
1.7 L	**1**	**7**
36.94 mL	**36.9**	**4**
3.1 mg	**3**	**1**

Exact Numbers

Numbers that are determined by counting or by definition
("per" expressions are exact)
contain no uncertainty
have infinite or unlimited significant figures.

Examples:

25
18 apples
2.54 cm = 1 in
100 cm = 1 m
6 students
491 cars
12 in = 1 ft
1000 g = 1 kg

Significant figures (doubtful digits) do not apply to exact umbers

Quantity	Exact or Measured	Estimated Digit
6.27 meters	Measured	7
15 students	Exact	
1.94 liters	Measured	4
8,295 kg	Measured	5
2.54 cm ≡ 1 inch	Exact	
0.348 cm	Measured	8
16	Exact	
45.0 mL	Measured	0
1000 mg ≡ 1 g	Exact	

Significant Figures

Begin with the first nonzero digit and end with the doubtful digit.
The location of the decimal point has nothing to do with significant figures**.**

Nonzero digits
78.391 km (5 figures) 422.8 gal (4 figures)
Leading zeros - never
0.000391 m (3 figures) 0.00255 g (3 figures)
Captive zeros
7,503 lbs (4 figures) 100,038 cm (6 figures)
Trailing decimal point zeros
14,000 kg (2 figures) 15.60 mL (4 figures) 160. mm (3 figures)
Exact numbers -unlimited
100 cm º 1 m 60 s º 1 min 200 cars

How many significant figures in:

18.043 m	5
1,000 km	1
1,000. mg	4
0.000667 L	3
90.800 tons	5
35	-
35 mL	2
0.0500700 g	6
9.360×10^4 s	4
8,628,000 cm	4
439.00 mL	5
1 mL = 1 cm	-

Zero

can be the doubtful digit can be used to show the decimal

use scientific notation to indicate significant figures:

ex: distance between the earth and the sun is 150,000,000 km

1.5×10^8 km	2 significant
1.50×10^8 km	3 significant
1.500×10^8 km	4 significant

Indicate if the underlined zero is significant:

0.050800 kg	**n**	0.008070 km	**n**
0.050800 kg	**n**	0.008070 km	**n**
0.050800 kg	**y**	0.008070 km	**n**
0.050800 kg	**y**	0.008070 km	**y**
0.050800 kg	**y**	0.008070 km	**y**

Re-write the quantity 40,000 mg

to show 1 sig. fig. 4×10^4 mg
to show 2 sig. fig. 4.0×10^4 mg
to show 3 sig. fig. 4.00×10^4 mg
to show 4 sig. fig. 4.000×10^4 mg

Re-write the quantity 9,340,000,000,000 ps

to show 3 sig. fig. 9.34×10^{12} ps
to show 4 sig. fig. 9.340×10^{12} ps
to show 5 sig. fig. 9.3400×10^{12} ps
to show 6 sig. fig. 9.34000×10^{12} ps

Rounding

Calculators may contain digits that are not significant

If the first digit to be dropped is less than 5, leave the digit before it unchanged.
If the first digit to be dropped is 5 or more, increase the digit before it by 1.

Round at end of calculations

5.324657894
3 significant = 5.32
4 significant = 5.325
5 significant = 5.3247

Problems

Round 5.43 g 0.0448 m to 2 sig. figs.
5.4 g 0.045 m

Round each of the following to 3 significant figures:

16.8477 L	16.8 L
5.6732 g	5.67 g
0.14986 L	0.150 L
861.85 kg	862 kg
4.203×10^4 km	4.20×10^4 km
5.09810×10^{-3} mm	5.10×10^{-3} mm
0.00318756 m	0.00319 m
0.09025011 cm^3	0.0903 cm^3

Calculations - Multiplication & Division

Round answer to the smallest number of sig. fig. in any factor

$4.62 \text{ m} \times 3.1 \text{ m} = 14.322 \text{ m}^2$ (14 m^2)

$\frac{248.37}{18.3 \text{ mL}} = 13.572131 \text{ g/mL}$ (13.6 g/mL)

Calculations - Addition & Subtraction

Round off the answer to the first column that has a doubtful digit.

	2.22	cm		
	3.9	cm	15.85	g
+	8.9382	cm	- 9.4052	g
	15.0582	cm	6.4448	g
	(15.1	cm)	(6.44	g)

Calculate to the correct number of significant figures

$$\frac{2.2745\ g}{3.40\ cm \times 8.1\ cm \times 7.090\ cm} = 1.16487\ g/cm^3 \quad (1.2\ g/cm3)$$

$$95.34\ cm^3 \times \frac{21.3\ g}{cm^3} = 2030.74\ g \quad (2030\ g)$$

$$58.953\ g \times \frac{1\ mL}{0.877\ g} = 67.2212\ mL \quad (67.2\ mL)$$

$$\frac{36.0059\ g}{13.3\ cm^3} = 2.70721\ g/cm^3 \quad (2.71\ g/cm3)$$

	95.202	g		
	12.33	g	42.75	g
+	40.9556	g	- 40.8356	g
	148.4876	g (148.49)	1.9144	g (1.91 g)

Calculation with many Conversions

A sprinter does the 100.0 m dash in 10.1 seconds. What is this speed in mph?

Start with Given and Wanted:

$$\frac{100.0\ m}{10.1\ sec} = ?\ mi / hr$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{100.0\ m}{10.1\ sec} \times \frac{100\ cm}{1\ m} \times \frac{1\ inch}{2.54\ cm} \times \frac{1\ foot}{12\ in} \times \frac{1\ mile}{5{,}280\ ft} \times \frac{60\ sec}{1\ min} \times \frac{60\ min}{1\ hr} = ?\ mi / hr$$

Units the same on both sides of equal sign; do the math:

$$\frac{100.0\ m}{10.1\ sec} \times \frac{100\ cm}{1\ m} \times \frac{1\ inch}{2.54\ cm} \times \frac{1\ foot}{12\ in} \times \frac{1\ mile}{5{,}280\ ft} \times \frac{60\ sec}{1\ min} \times \frac{60\ min}{1\ hr} = 22.1479\ mi/ hr$$

Round to 3 significant figures (dictated by 10.1 sec)

$$= 22.1\ mi/ hr$$

Insurance statistics state that a person loses 8.00 minutes of average life for each cigarette smoked. Over the next 25 years, how much life is lost on average for a person smoking 0.5 pack (10 cigarettes) a day for 25 years?
Express this loss in both minutes and years.

Start with Given and wanted:

$$\frac{10 \text{ cigarettes}}{\text{day}} = ?\text{min}$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{10 \text{ cigarettes}}{\text{day}} \times \frac{365.25 \text{ days}}{\text{year}} \times \frac{8.00 \text{ min}}{\text{cigarette}} \times 25 \text{ years} = ? \text{ min}$$

Units the same on both sides of equal sign; do the math; round to 3 sig figs:

$$\frac{10 \text{ cigarettes}}{\text{day}} \times \frac{365.25 \text{ days}}{\text{year}} \times \frac{8.00 \text{ min}}{\text{cigarette}} \times 25 \text{ years} = 7.31 \times 10^5 \text{ min}$$

Continue (without isolating) converting to years

$$7.31 \times 10^5 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ year}}{365.25 \text{ days}} = 1.39 \text{ years}$$

Assignment

Continue Taking Unit 3 Practice Test
Blackboard only records highest score
Take until multiple 100's have been scored (questions are variable)
(Gives sense of test exam format and content)

The Practice Quiz is very similar to the Unit Exam
Success on Unit exam is directly related to practice exam experiences

Continue memorizing:
Conversion factors
Polyatomic Ions
Elemental Symbols

Units 4 & 5 have an enormous amount of memorization
… best to continue memorizing now!

Pay particular attention to significant figures and rounding on the Unit Exam!