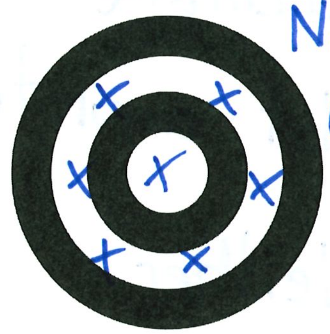
Precision and Accuracy

There is a major difference between counting and measuring. In counting unless you make a mistake you will be 100% correct. If you are measuring, there will always be a difference between the measured value and the true value.

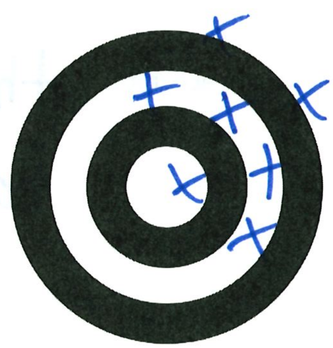
precision is a measure of how close measured values are to each other.
accurate is a measure of how close measured values are to the true value.

Precise but not accurate



Not precise but accurate

Precise and accurate



Neither precise nor accurate

Example: You measure an object that has mass of 5.61 grams on 4 different scales, 4 times each. Determine the average of the measurements and explain the precision and accuracy of each scale.

	Scale A	Scale B	Scale C	Scale D
Measurement 1	5.60 g	6.21 g	4.25 g	4.62 g
Measurement 2	5.62 g	6.23 g	8.23 g	6.05 g
Measurement 3	5.61 g	6.24 g	1.45 g	5.92 g
Measurement 4	5.63 g	6.24 g	2.45 g	5.23 g
AVERAGE	5.615	6.23	4.095	5.455

A: Accurate and precise

B: Not accurate but precise

C: Neither

D: Not precise but fairly accurate

If measurements are accurate: the average gets closer to the true value.

Practice:

1. An object has density of $1.65\ g/mL$. Its density is measured three times with the results of $1.36\ g/mL$, $1.25\ g/mL$ and $1.32\ g/mL$.
   a. Discuss the accuracy of the measurements.

   Not accurate

   b. Discuss the precision of the measurements.

   Fairly precise

2. An object has density of $9.25\ g/mL$. Its density is measured three times with the results of $9.26\ g/mL$, $9.24\ g/mL$ and $9.24\ g/mL$.
   a. Discuss the accuracy of the measurements.

   Very accurate

   b. Discuss the precision of the measurements.

   Very precise

3. A scale always adds exactly 0.32 grams to its measurements. When the real measurement is 1.00 grams the scale reads 1.32 grams. When the real measurement is 2.00 grams the scale reads 2.32 grams. Does the scale have a **precision problem** OR **an accuracy problem**?

   Accuracy Problem

4. A clock has stopped, its hands no longer move. Compare the accuracy and precision of this clock to a functioning clock.

   Less accurate

   More precise

Error

There are 3 broad categories of error in measurement.

Systemic Errors cause measurements to be always either too high or too low. Systemic errors affect the accuracy of your measurements. If systemic errors have occurred all measurements must be repeated or corrected.

Scale wasn't properly zeroed
Stop watch you start late each time
Reading volume measurements at an angle

Random Error cause the measurements to be too high sometimes and too low sometimes. Random errors affect the precision of your measurements are unavoidable and can be controlled by averaging several measurements.

Air pressure changes as doors open changes scale readings
Stop watch starts too early sometimes too late sometimes
Reading measurements, sometimes too high sometimes too low.

Blunders are major errors that are caused mistakes in measurement. Any measurement with a blunder should be removed from calculation.

Example: An experimenter is measuring the length of a ramp. They measure three times with a tape measure and record 5.62 metres, 5.61 metres, and 2.34 metres. What type of error is there and what should they do to fix it?

Blunder, throw out 2.34m measurement

Example: An experimenter measures the temperature of a solution in a test tube. They hold the test tube in their hand as they measure three times and get the following results. $12.23°C$, $12.24°C$ and $12.21°C$. What type of error is there and what should they do to fix it?

Systemic, redo experiment

Example: An experimenter measures the time it takes for a ball to fall and records the times as 5.62 seconds, 5.65 seconds, and 5.61 seconds. What type of error is there and what should they do to fix it?

Random, take average

Significant Figures

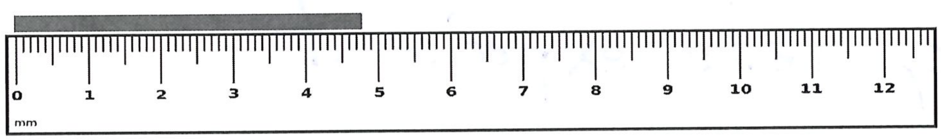
A number in science is not just a number, it also shows the __Uncertainty__ of the measurement.

The number of significant figures is equal to all the certain digits plus the first uncertain digit.

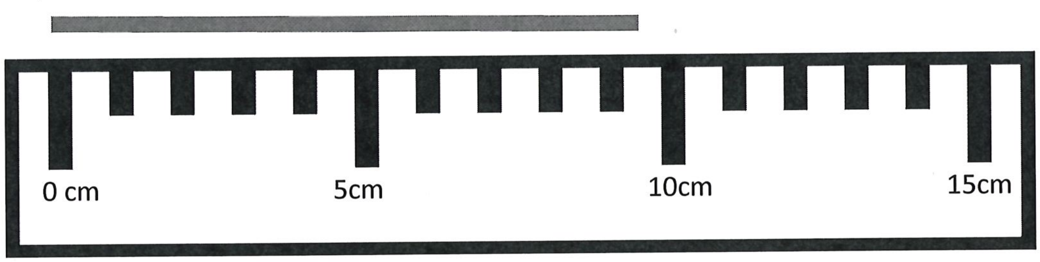
Example: The measurement of the volume of liquid in this beaker was recorded as "37 mL" Which of those digits is certain, which is uncertain?

↑ 3 ↑ 7

Example: Determine the length of the following lines:



4.78 mm



9.5 cm

Example: A digital scale reads "5.4 grams", another reads "5.40" grams, what is the difference?

5.4 g ± 0.1 g 5.40 ± 0.01 g

5.3 g – 5.5 g 5.39 g – 5.41 g

Rules of Sig Figs:

Leading zeros are not significant

Example: How many significant digits are there in the following measurements?

25 g 2

0.025 kg 2

0.000304 cm 3

3005 mL 4

Trailing zeros are significant only if the number is written with a decimal

Example: How many significant digits are there in the following measurements?

250 g 2

250.0 g 4

0.006 mL 1

0.0060 mL 2

0.00603 mL 3

0.00560 g 3

2.340×10^3 4

KEY IDEA: If you need the zero to write the number mathematically that zero is not significant

To show a measurement that IS exactly a "round" number use scientific notation

Example: Radhanath Sikdar measures the height of a mountain to be exactly 29 000 feet tall how should he record this measurement to show it is not rounded.

2.9000×10^4 ft

Round the following to 2 significant figures:

16.23 16

19.523 20 but need 2 sig figs 2.0×10^1

0.003523 0.0035

1006 1.0×10^3

0.000102 0.00010

Significant figures are only used for measured quantities, for counted quantities we assume the measurement is perfect.

Example: Which of the following was likely obtained by measurement, which was likely obtained by counting?

23 graduated cylinders each with 23 mL of solution in them.

↑ counted ↑ measured

Operations with sig figs

What is wrong with saying a desk is 110 cm long, so if we add 5.75 cm to it then it will be 115.75 cm long?

110cm ±10cm 5.75cm (120cm)

100 – 120cm 5.74cm – 5.76cm

Result is between 105.74 — 125.76

But 115.75 claims 115.74 – 115.76

SIG FIG RULE FOR CALCULATIONS IN THIS CLASS:

# of sig figs in answer = least # of sig figs in problem.

$5.6 + 7.23 =$ 12.83 ≈ 13

(2) (3)

$\frac{0.025}{29.3} =$ 0.000853242 ≈ 0.00085 or 8.5×10^{-4}

(2) (3)

$600 + 30 =$ 630 ≈ 600

(1) (1)

$(5.6)^3 =$ 175.616 ≈ 180

(2)

$6.2 \times 10^5 + 2.7 \times 10^6 =$ 3320000 ≈ 3300000 or 3.3×10^6

(2) (2)

If a number is a counted value or is part of a formula, we do not apply the rules of significant figures to it.

1. The formula for the circumference of a circle is $C = 2\pi r$. What is the circumference of a circle with ~~diameter~~ radius of 5.623 cm?

   4

   $C = 2 \times \pi \times 5.623\text{cm}$

   $= 33.33035098...\text{ cm}$

   $\approx 35.33\text{ cm}$

2. The formula for the volume of a cone is $V = \frac{\pi r^2 h}{3}$ where r is the radius and h is the height. What is the volume of a cone with height of 620 cm and radius of 44.25 cm?

   $V = \frac{\pi (44.25\text{cm})^2 (620\text{cm})}{3}$

   $= 1271296.518 \approx 1.3 \times 10^6\text{ cm}^3$

3. The formula for the surface area of a cylinder is $SA = 2\pi rh + 2\pi r^2$ where r is the radius and h is the height. What is the surface area of a cylinder with radius of 2.34 cm and height of 52 cm?

   $2\pi(2.34\text{cm})(52\text{cm}) + 2\pi(2.34\text{cm})^2$

   $= 798.9421976$

   ≈ 800 but need 2 sig figs $8.0 \times 10^2\text{ cm}^2$

4. There are 30 beakers each of which has mass of 46.0 grams. What is the total mass?

   counted measured

   $46.0\text{ grams} \times 30 = 1380\text{ grams}$