Introduction

Standard Unit: Metric is the preferred unit of measure in science. Metric is often referred to as “S.I” for Systèm Internatianale. Historically, S.I. has been referred to as MKS system for meters, kilograms and seconds.

Example	Non Standard	Standard
speed	km/s, mph	m/s
volume	L, gal.	m^3
Forces	lbs.	$kg \cdot m/s^2$

Scientific Notation: Often, physicists work with measurements that are either extremely large or extremely small. Scientific notation makes calculations much more manageable.

Example:

$$37010000m \rightarrow 3.701 \times 10^{7} m$$

when shifting the decimal to the left, the exponent is **positive**

$$0.000003152s \rightarrow 3.152 \times 10^{-6} s$$

when shifting the decimal to the right, the exponent is **negative**

Significant Figures: In general all non-zero digits are considered to be significant; however, there are some situations where this does not necessarily apply

Example:

32000m	2 sig. figs. unless other wise stated. (ie. if the measurement is more accurate that the value implies). The last 3 zeros are just place holders.
1201500m	5. sig. figs. the 0 between the 2 and the 5 is significant
100.0m	4. sig. fig. We do not normally record measurements with a terminating zero AFTER the decimal place UNLESS it is significant
0.0013200m	5. sig. figs. The leading zeros are not significant, they are place holders. The last two digits are part of the measurement.
$150\tilde{0}0$ m	4. sig. fig. The ***tilde*** above the second zero indicates the number is accurate to the tens or decametres.

Q: Why are the leading or trailing zeros not considered significant?
A: In general, leading and trailing zeros are just placeholders and are not generated from the measurement itself.

Example:
Consider the following situation. You are given a piece of wood that is exactly one meter long but has no markings on it. You are then asked to measure the length of the room using this as your tool. You find the room is approximately 3.5 meters. Now since your meter stick has no markings, the last digit of your measurement is really a guess and is the least reliable digit.

It is easy to see that this number has 2 significant figures, but consider what happens if you convert the measurement to millimetres

$$3.5m \rightarrow 3500mm$$

The reading is now 3500 millimetres, however, it is misleading to assume the trailing zeros are significant because the tool use to make the measurement is only accurate to the half meter. Therefore $3500mm$ is only accurate to 2 sig. figs, the trailing zero are simply placeholders.

Rounding: Rounding is a relatively simple procedure however, special rules appy for rounding numbers terminating with 5

Rules

1. If the largest digit to be rejected is greater than 5, the last unrejected number is rounded up

   Example: rounding 5.637 to 3 sig figs. becomes 5.64

2. If the largest digit to be rejected is less than 5, the last unrejected number remains the same

   Example: rounding 4.6337 to 3 sig. figs. becomes 4.63

3. In the case where the last rejected digit is 5 and followed by no other non zero digits, the number will be rounded up or down to ensure the rounded value is an even number.

   Example: rounding 3.65 to 2 sig figs. becomes 3.6
   rounding 3.55 to 2 sig figs. becomes 3.6
   rounding 3.5500 to 2 sig figs. becomes 3.6
   rounding 3.651 to 2 sig figs. becomes 3.7

Q: So why do we have this 0.5 rule anyway? Why not just always round up?
A: Rounding always introduces some error. If you are always rounding up the 0.5 values, you will skew the data always in one direction.

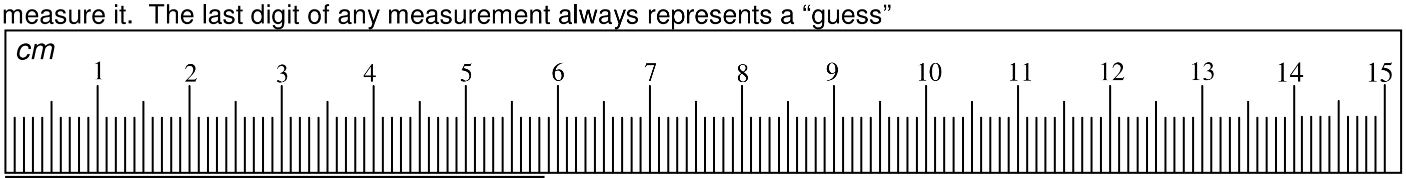
Example: Consider the following value set.
[1.5, 2.5, 3.5, 4.5]

using the simplified rounding model of rounding up values terminating with 5, we get the following set of values [2,3,4,5]. Now consider the sum of these values: 14

Using the proper rounding method we get a slightly different number set [2,2,4,4]. Now consider the sum of this value set: 12

If we consider the sum of the original value set before round it is evident the second method is more accurate. [1.5+2.5+3.5+4.5=12]

Calculations Involving Measured Quantities: The accuracy of a measured quantity is based on the tool used to measure it. The last digit of any measurement always represents a "guess"



Consider the length of the line above. The maximum resolution of the ruler is the **mm**, however, we can get a more accurate result by approximating to the closest **tenth of a mm**.

For the line above we can approximate its length to be approximately **5.85cm**. By inspection, we can see that **5.85cm** is a much closer approximation to the length of the line than **5.8cm** or **5.9cm** are.

Rule: When making measurements with any tool, always estimate your measurement to the closest tenth of the smallest scale indicated on the tool.

Note: The final digit in any measured value is the estimated tenth of the scale. Although it is technically a guess, the digit is considered to be significant. Therefore, in our above example, the measured value of 5.85 cm is accurate to **3 sig. figs** where the ".5" is the least reliable digit.

<u>Definitions</u>:

Accuracy: is indicated by the number of significant digits within a measure quantity.

Precision: is determined by the number of decimal places in a measured quantity.

Example 1: $l = 1.0890cm$

i) l has 5 sig. figs. (significant figures)
ii) l is accurate to 5 sig. figs.
iii) l is precise to the 10,000th of a cm

Example 2: $y = 240m$

i) y has 2 sig. figs. (significant figures)
ii) y is accurate to 2 sig. figs.
iii) y is precise to the decametre (or to the **tens** of metres…. NOT tenths)

Example 3: $z = 5.098 \times 10^{-2} m$

i) z has 4 sig. figs. (significant figures)
ii) z is accurate to 4 sig. figs.
iii) z is precise to the 10^{-5} m or 100000th of a m (to figure this out you can convert the number back out of scientific notation i.e. $0.05098m$)

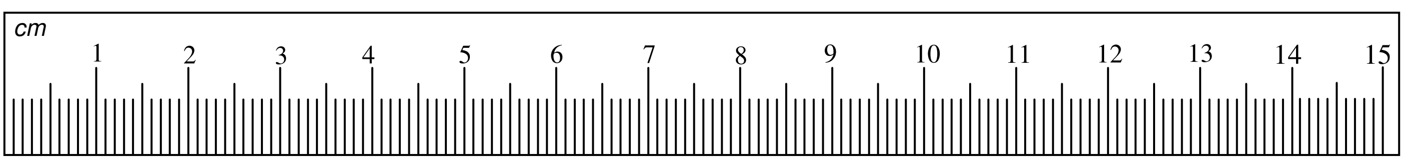
Exercise:

In each of the following examples state;

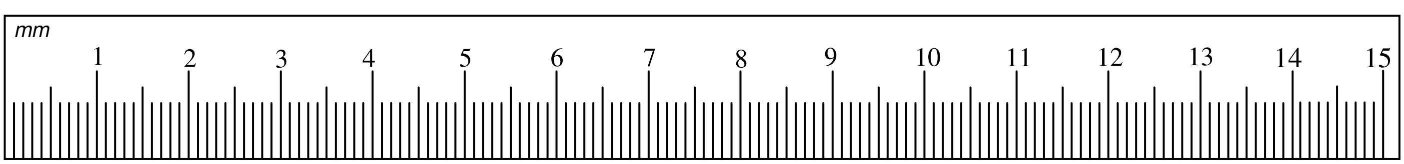
i) the number in scientific notation
ii) the number of significant figures in the measurement
iii) the accuracy of the measurement
iv) the precision of the measurement

a) $2.5m$ i) ii) iii) iv)	b) $100g$ i) ii) iii) iv)	c) $225kg$ i) ii) iii) iv)	d) $100.0km$ i) ii) iii) iv)
e) $0.009h$ i) ii) iii) iv)	f) $0.0890s$ i) ii) iii) iv)	g) $120\tilde{0}0km$ i) ii) iii) iv)	h) $23.0\times10^{-3}s$ i) ii) iii) iv)

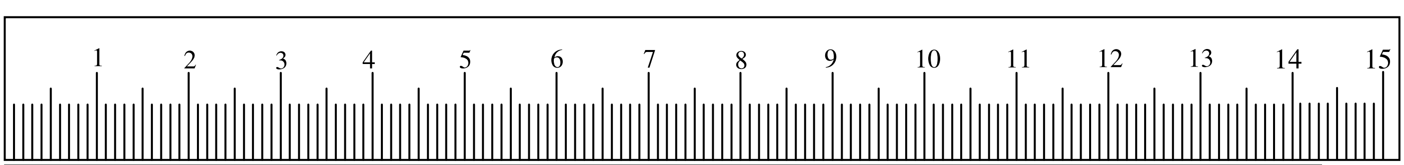
Estimate the following measurements.



Measurement:________________________________



Measurement:________________________________



Measurement:________________________________

Addition, Subtraction, Multiplication and Division of Measured Quantities

Addition and Subtraction:

- Based on the ***precision*** of the measured quantities.
- Answer should be expressed to the **same precision** of the ***least precise*** measured quantity.

Multiplication and division:

- Based on the ***accuracy*** of the measured quantities
- Answer should be expressed to the **same accuracy** of the ***least accurate*** measured quantity.

Example 1 –Precision rule

Find the total volume for the following quantities:
$95mL, 3.27mL, 2.10mL$

Using ***"old school"*** addition, line up the measured quantities such that all the decimal places line up

$$\begin{array}{r} 95 \\ 3.27 \\ +\ 2.10 \\ \hline 100.37 \end{array}$$

Rounding line

Therefore the final answer should be rounded to $100mL$

Example 2-Precision rule

Find the perimeter for the following scalene triangle:
$137cm, 2.1m, 5cm$

Notice that not all the measured quantities are in the same units. We must express each measured quantity in the same units.

$$\begin{array}{r} 137 \\ 210 \\ +\ 5 \\ \hline 352 \end{array}$$

Rounding line

Therefore the final answer should be rounded to $350cm$

Example 3 –Precision rule

Add the following time intervals, $3.02s,\ 4.5s,\ 0.05h$

Notice, one of the measured quantities is in *hours*, we'll covert hours to seconds

$$\frac{0.05h}{} \times \frac{60\min}{1h} \times \frac{60s}{1\min} = 180s$$

But, since 0.05h is expressed to 1 sig. fig., therefore 180s must be rounded to 1 sig. fig. which is 200s

$$\begin{array}{r} 3.02 \\ 4.5 \\ +\ 200 \\ \hline 207.52 \end{array}$$

Rounding line

Since the $0.05h$ is such and imprecise measurement, then our answer must reflect this fact. Therefore the final answer is just **200s**

Example 4-Accuracy rule

Find the volume of a box with the following dimensions:
$l = 2.1cm,\ w = 2.01cm,\ h = 1.09cm$

The final answer must be expressed with same number of sig. figs. as the least accurate (in this case $l = 2.1cm$ -2 sig. figs.)

$$V = 2.1 \times 2.01 \times 1.09$$

$$V = 4.60089cm^3$$

Therefore the final answer should be rounded to 2. sig. figs
$V = 4.6cm^3$

Conversions

When converting between the various units, we use a method called “multiplication by ones”

Example: convert $72km/h$ to m/s

Since the numerators and denominators are equal in each fraction, they reduce to “one”

$$x\,m/s = \frac{72km}{h}\cdot\underbrace{\frac{1000m}{1km}}\cdot\underbrace{\frac{1h}{3600s}}$$

$$= \frac{(72)(1000)(1)km\cdot h\cdot m}{(3600)(1)km\cdot h\cdot s}$$

$$= 20\,m/s$$

Common Conversions

1 mile = 5280 ft
1 km = 1000 m
1 km = 0.6214 mile
1 mile = 1760 yd
1 hour = 3600 s
1 m = 3.28 ft
1 m = 100 cm
1000 m = 0.6214 mile
1 lb = 454 g
1 in = 2.54 cm
1 L = 1.06 qt
1 year = 365.24 day

Metric Prefixes

yotta	[Y]	1 000 000 000 000 000 000 000 000	= 10^{24}	*(septillions)*
zetta	[Z]	1 000 000 000 000 000 000 000	= 10^{21}	*(sextillions)*
exa	[E]	1 000 000 000 000 000 000	= 10^{18}	*(quintillions)*
peta	[P]	1 000 000 000 000 000	= 10^{15}	*(quadrillions)*
tera	[T]	1 000 000 000 000	= 10^{12}	*(trillions)*
giga	[G]	1 000 000 000	= 10^{9}	*(billions)*
mega	[M]	1 000 000	= 10^{6}	*(millions)*
kilo	[k]	1 000	= 10^{3}	*(thousands)*
hecto	[h]	100	= 10^{2}	*(hundreds)*
deca	[da]	10	= 10^{1}	*(tens)*
		1		
deci	[d]	0.1	= 10^{-1}	*(tenths)*
centi	[c]	0.01	= 10^{-2}	*(hundredths)*
milli	[m]	0.001	= 10^{-3}	*(thousandths)*
micro	[µ]	0.000 001	= 10^{-6}	*(millionths)*
nano	[n]	0.000 000 001	= 10^{-9}	*(billionths)*
pico	[p]	0.000 000 000 001	= 10^{-12}	*(trillionths)*
femto	[f]	0.000 000 000 000 001	= 10^{-15}	*(quadrillionths)*
atto	[a]	0.000 000 000 000 000 001	= 10^{-18}	(quintillionths)
zepto	[z]	0.000 000 000 000 000 000 001	= 10^{-21}	(sextillionths)
yocto	[y]	0.000 000 000 000 000 000 000 001	= 10^{-24}	(septillions)

Web reference: http://www.ex.ac.uk/cimt/dictunit/dictunit.htm

The above site is an excellent reference for conversions between various units of measure.