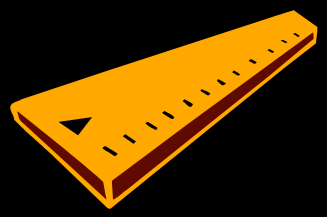
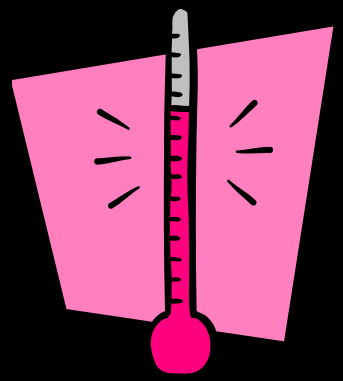
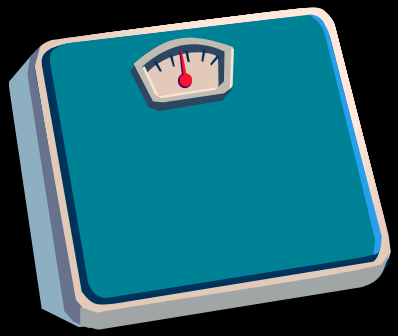


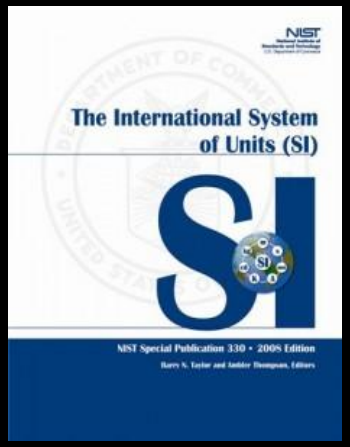


Measurements



LPT

Basic SI (Systeme International) Units

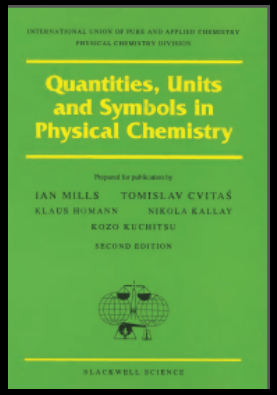


How much?

- mass = kilogram (kg)
- length = meter (m)
- time = second (s)
- chemical quantity = mole (mol)

2 Different Systems:

- kms: kilogram-meter-second (preferred)
- cgs: centimeter-gram-second (commonly used in labs)

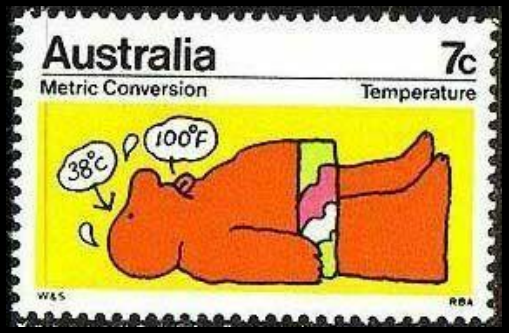


Measurement incomplete without "units"
Absolutely essential when working problems!

166 pages

Units

	English	Metric
Origin	Conquest	Convention
	Based on royalty	Based on decimal 10
Conversions	Not-uniform	Uniform
	Not-consistent	Consistent
Communication	Confuses	Facilitates
	Regional	Universal in science



LPT

Metric Prefixes

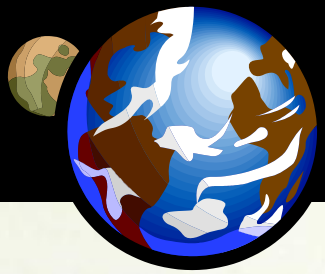


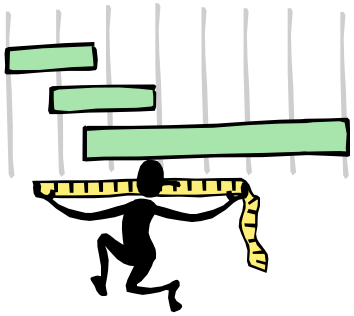
Table 3.2 Metric Prefixes*

Large Units			*Small Units*		
Metric Prefix	**Metric Symbol**	**Multiple**	**Metric Prefix**	**Metric Symbol**	**Multiple**
tera-	T	10^{12}	Unit (gram, meter, liter)		$1 = 10^{0}$
giga-	G	10^{9}	deci-	d	$0.1 = 10^{-1}$
mega-	M	$1{,}000{,}000 = 10^{6}$	**centi-**	**c**	$\mathbf{0.01 = 10^{-2}}$
kilo-	**k**	$\mathbf{1{,}000 = 10^{3}}$	**milli-**	**m**	$\mathbf{0.001 = 10^{-3}}$
hecto-	h	$100 = 10^{2}$	micro-	μ	$0.000001 = 10^{-6}$
deca-	da	$10 = 10^{1}$	nano-	n	10^{-9}
Unit (gram, meter, liter)		$1 = 10^{0}$	pico-	p	10^{-12}

*The most important prefixes are printed in **boldface.**

Metric Prefixes

kilo-
Larger; multiply by 1000



centi-
Smaller; divide by 100

milli-
Smaller; divide by 1000

Metric Conversions

1000 m = 1 km

100 cm = 1 m

1000 mm = 1 m

"per expressions"

1000 m = 1 x (1000) m

kilo = 1000

100 x (1/100) m = 1 m

centi = 1/100

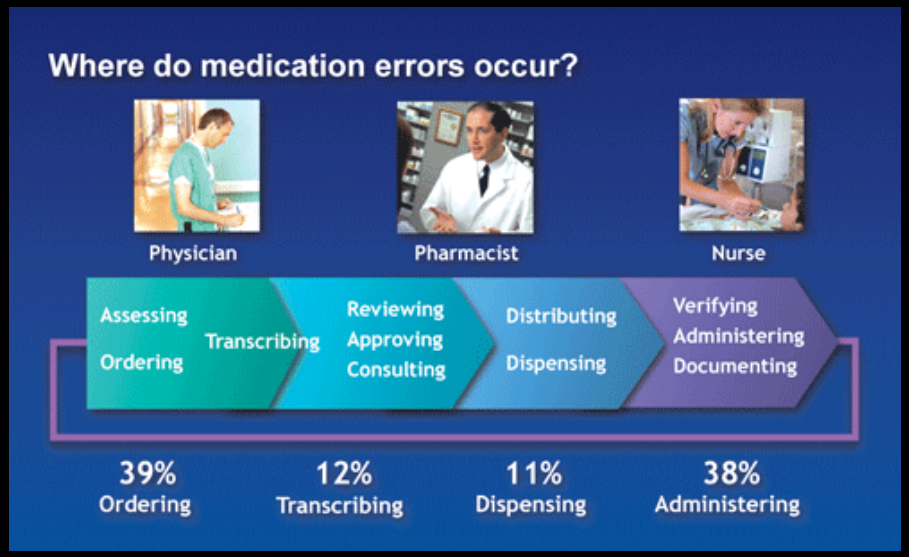
1000 x (1/1000) m = 1 m

milli = 1/1000

Same numerical value on each side of =

LPT

Correct Measurements Are Not Trivial



Improper Measurements / Calculations Can Cost Lives

1990: ~ 98,000 deaths / year from hospital errors

2016: > 440,000 deaths / year from hospital errors

Third Leading Cause of deaths in the US

~ 1.7 million non-fatal injuries

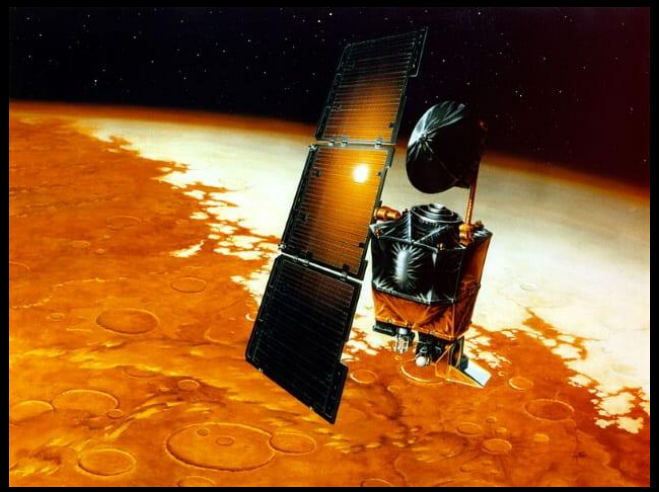
Lab Notebook Documentation Absolutely Essential

Not following procedures can be lethal

Correct Measurements Are Not Trivial

15 million doses lost:
Employees mixed wrong ingredients
$ 150 million loss

Hubble Space Telescope:
Mirror surface shape
Curve Off by 1.3 mm
(Billions $ to repair)



Mars Orbiter:
One group in km/sec
Another group in mi/hr
Orbiter Crashed:
$125 million for the orbiter

LPT

Correct Measurements Are Not Trivial

French Rail System
2000 trains too wide for
1300 Stations

Laufenberg Bridge across Rhine
Swiss-German
Measured sea level from different point
54 cm height difference when they met

Warship VASA
Builders used different length measures
Sank 20 minutes into maiden voyage

LPT

Correct Measurements Are Not Trivial

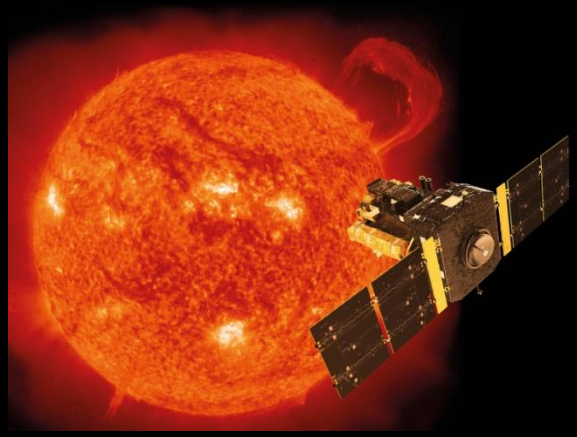
Spain's S-80 Sub (2003)
Misplaced decimal in specifications
770 tons too heavy
Added length to compensate for too heavy
Result: too long to fit naval base
1 billion Euro total cost / per sub
More than twice original cost

Disney Japan Space Mountain
Error in length conversion
Wrong axle size
Cars derailed
1 dead, 10 injured

Correct Measurements Are Not Trivial

Sochi Biathon Track
40 m too short

Amsterdam Subsidies to the poor
Sent out € 188 million instead of 18.8



SOHO satellite lost communications
Improper Metric to English conversions

Gilmli Glider
Ran out of fuel @ 40,000 feet
Wrong units for fuel calculation

LPT

Doing the Math

Measurements are two parts:

4.78 cm

Numeral

Unit

Addition / Subtraction

Quantities MUST HAVE the same units

Can't do:

Apples + oranges

km + m

miles + gal

Multiplication / Division

Numbers & units separately multiplied or divided

Doing the Math

$$345\ \text{m} \times \frac{1\ \text{km}}{1000\ \text{m}} = 0.345\ \text{km}$$

To "cancel" units:

Numerator (top) of first term
Same as
Denominator (bottom) of next term

LPT

Key to Solving Problems

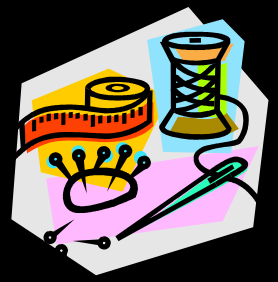
Process:

- Write Given or Known (Left side of =)
- Write Wanted (Right side of =)
- Select "per expression" to cancel given unit
- If units same on left and right of = , do the math
- If units not the same, add another per expression
- Continue "linear string" until units same on both sides of the =
- Once units correct, solve as a single linear string calculation

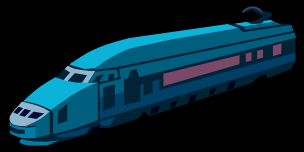
Let the units drive the solution

LPT

Measurements Allow Commerce

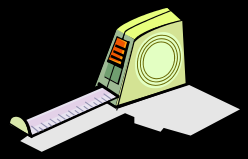


Magna Charta - 1215 (King John)
  Reissued 1216, 1217, & 1225 (King Henry)
US Constitution - 1787
French Revolution - 1789 to 1799
Metric System in France - 1801
System International - 1875



LPT

Standards Allow Different Cultures To Interact



You can measure desk distance in “pencil lengths”
Another can measure distance in “book lengths”

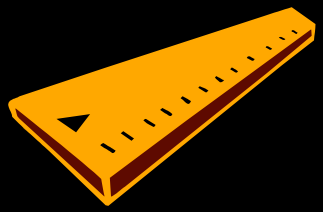
Can trade fabrics for money using different measurements

If both have conversion factor to an international standard (m)

Example:

10 pencil lengths per meter
4 book lengths per meter

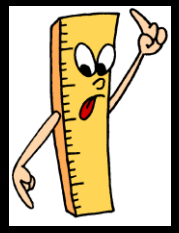
10 pencil lengths = 4 book lengths
2.25 pencil lengths = 1 book length



Measurements Lab

LPT

The Lab Today (Work in Pairs)

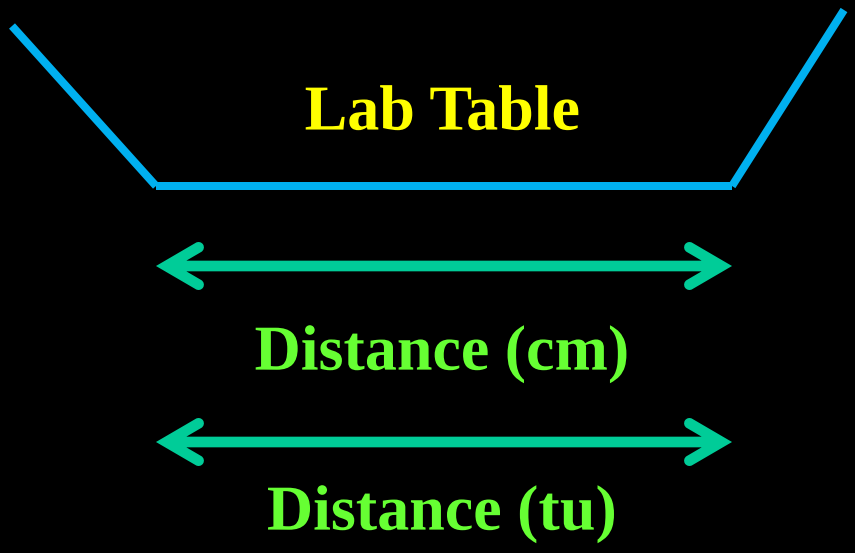


I. Watch Measurements Video

II. Lab Measurements To Be Done:

(A) Length (Comparison to reference)

Select an object as your distance "unit of measurement"
measure lab desk distance with your unit (1 decimal place)
measure lab desk distance with meter stick (2 decimal places)



Per Expression Example:
Distance = 140.00 cm
Distance = 10.0 tu
Set distances equal to each other:
10.0 tu = 140.00 cm
Divide both sides by smallest value:
1 tu = 14 cm

The Lab Today (Work in Pairs)

(B) Temperature (with thermometer (1 decimal point)

Determine the temperature of

- **tap water**
- **slush**
- **boiling water**

(C) Mass of stopper, 150 mL beaker, and watch glass (all displayed digits)

Estimate the mass of each object relative to one another.

Weigh each object (separately & together) on the balance

Sum the separate weights

Compare sum of weights to single weighing of all three objects together

Most likely the sum of 3 individual weights will be different than single weighing 'cause each measurement has errors

Summing 3 errors of measurement compared to a single value

The Lab Today (Work in Pairs)

(D)Volume

Meniscus

Always read the lowest point of the meniscus

Measure volume of water

With beaker (no decimal digits)

With graduated cylinder > 10 mL (1 decimal digit)

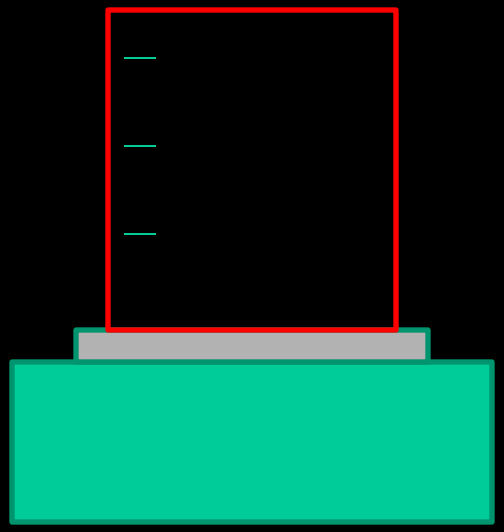
With graduated cylinder < 10 mL (2 decimal digits)

Beaker and graduate cylinder done separately

- Place container on balance
- Tare the balance (set display to zero)
- Using only marks on the beaker or cylinder
- Add 50 mL to beaker or 50.0 mL to graduate cylinder
- Read display
- Compare mass readings

The Lab Today - Volume

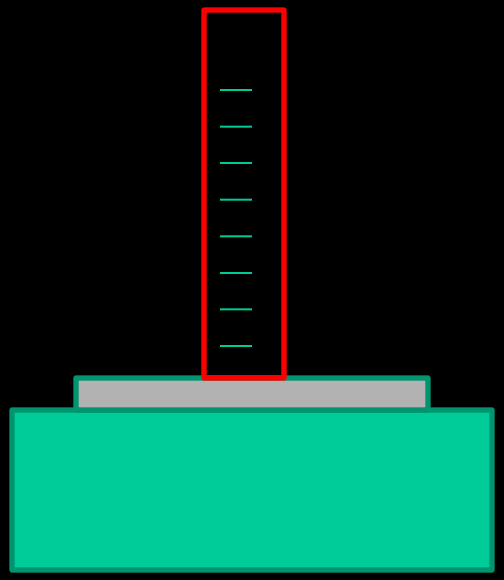
150 mL Beaker



No decimal digits

2 separate Measures
Tare Container
Add 50 mL to beaker
Add 50.0 mL to cylinder
Compare Weights

50 mL Cylinder



One decimal digit

You are weighing the water (should be ~ 50 g)
Value closest to 50 g is the most accurate

LPT

The Lab Today

III. Calculation & Results

Devise a conversion factor to convert from your units of length ➔ cm
Are masses the same when objects measured separately or together?

IV. Conclusion

What are some important things about making measurements?

V. Questions

Show work with proper sig figs and units!

Do not simply move the decimal … show linear string of fractions

c followed by any metric unit is always 1/100 of the unit, so
100 cs = 1 sec

Luke,
Use the Units

LPT

Let’s Boldly Go Explore Today’s Lab