

Measurements

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Basic SI (Système 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

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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

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Metric Prefixes



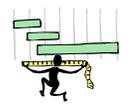
Large Units			Small Units		
Metric Prefix	Metric Symbol	Multiple	Metric Prefix	Metric Symbol	Multiple
tera-	T	10^{12}	Unit (gram, meter, liter)		$1 = 10^0$
giga-	G	10^9	deci-	d	$0.1 = 10^{-1}$
mega-	M	$1,000,000 = 10^6$	centi-	c	$0.01 = 10^{-2}$
kilo-	k	$1,000 = 10^3$	milli-	m	$0.001 = 10^{-3}$
hecto-	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.

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Metric Prefixes

kilo-
Larger; multiply by 1000



centi-
Smaller; divide by 100

milli-
Smaller; divide by 1000

Metric Conversions

$1000 \text{ m} = 1 \text{ km}$

$100 \text{ cm} = 1 \text{ m}$

$1000 \text{ mm} = 1 \text{ m}$

"per expressions"

$1000 \text{ m} = 1 \times (1000) \text{ m}$
kilo = 1000

$100 \times (1/100) \text{ m} = 1 \text{ m}$
centi = 1/100

$1000 \times (1/1000) \text{ m} = 1 \text{ m}$
milli = 1/1000

Same numerical value on each side of =

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Correct Measurements Are Not Trivial

Medication Error?
Click here for a free consultation with an attorney.



Where do medication errors occur?



Ordering	Transcribing	Dispensing	Administering
39%	12%	11%	38%

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

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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

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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

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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

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Correct Measurements Are Not Trivial



Sochi Biathlon 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



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

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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

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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



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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

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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









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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









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Measurements Lab




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The Lab Today (Work in Pairs)

I. Watch Measurements Video

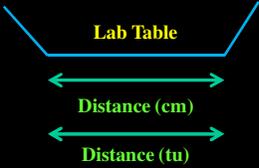
II. Lab Measurements To Be Done:

(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)



Lab Table



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

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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

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The Lab Today (Work in Pairs)

(D) Volume

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)



Meniscus

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

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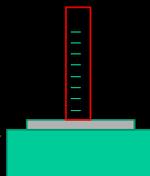
The Lab Today - Volume

150 mL Beaker



No decimal digits

50 mL Cylinder



One decimal digit

2 separate Measures

Tare Container

Add 50 mL to beaker

Add 50.0 mL to cylinder

Compare Weights

You are weighing the water (should be ~ 50 g)

Value closest to 50 g is the most accurate

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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

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