



Measurements



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Basic SI (Systeme International) Units

How much?

mass = kilogram (kg)

length = meter (m)

time = second (s)

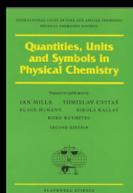
chemical quantity = mole (mol)



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

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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



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	$0.01 = 10^{-2}$
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



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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

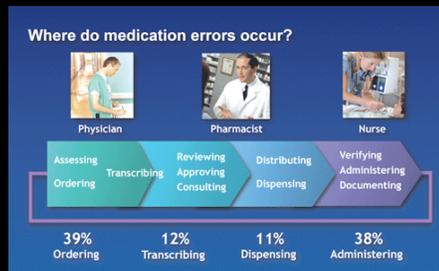


Same numerical value on each side of =

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Correct Measurements Are Not Trivial

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



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



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



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

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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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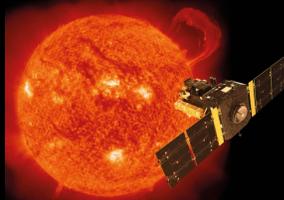
Correct Measurements Are Not Trivial



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



Gimli 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 m x $\frac{1 \text{ km}}{1000 \text{ m}} = 0.345 \text{ km}$



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

2.5 pencil lengths = 1 book length



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Measurements Lab

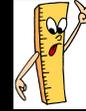


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The Lab Today (Work in Pairs)

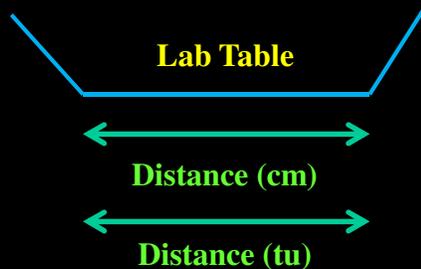
I. Watch Measurements Video



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)



Per Expression Example:

Distance = 140.00 cm

Distance = 10.0 tu

Set distances equal to each other:

$10.0 \text{ tu} = 140.00 \text{ cm}$

Divide both sides by smallest value:

$1 \text{ tu} = 14 \text{ cm}$

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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

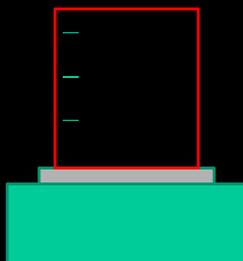
Compare mass readings

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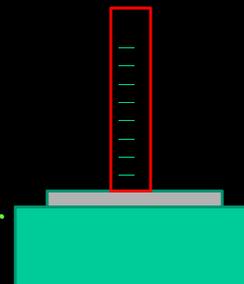
The Lab Today - Volume

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

$$100 \text{ cs} = 1 \text{ sec}$$

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A close-up photograph of Luke Skywalker wearing his iconic white helmet and goggles, looking forward with a determined expression.

**Luke,
Use the Units**

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Let's Boldly Go Explore Today's Lab



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