Ch01

If you are enrolled
or on the wait list–sign
the roll sheet!
If you are trying to add the
class, add your name!

Measurement

Counting stones.

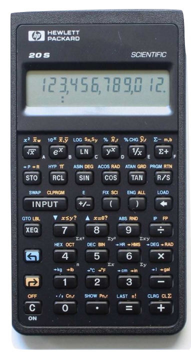
Quantitative observation.

version 1.5

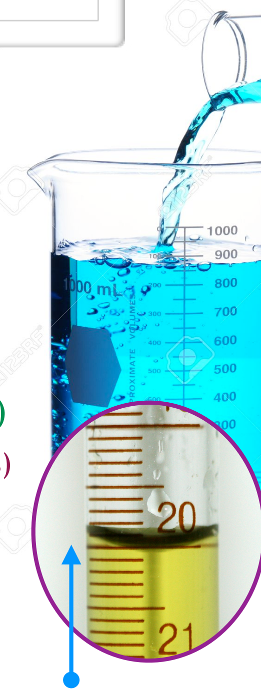
Ch01

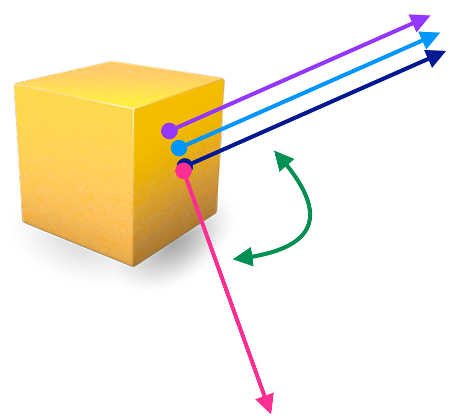
Measurement

- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes



- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions





Dimension

Dimension

noun di·men·sion

: a measurement in one direction

(such as the distance from the ceiling to the floor in a room)

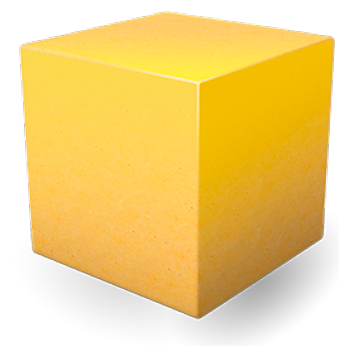
: a part of something

: one of the factors making up a complete personality or entity

— Webster

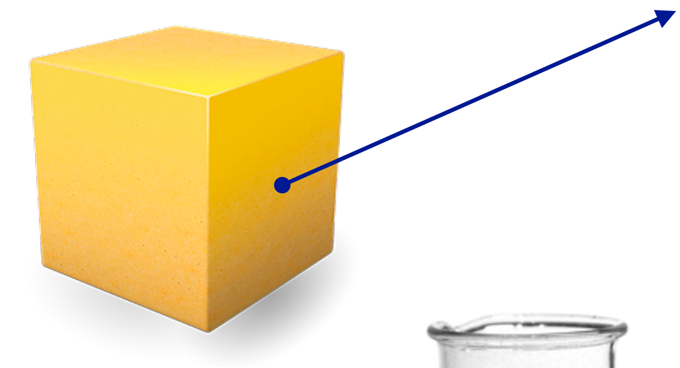
Dimension

- To quantify our observations we put numbers what we find in each dimension.
- We can observe it's:
  - Height
  - Width
  - Length
- There are more dimensions to consider in understanding samples of matter.
  - Mass
  - Volume
  - Color
  - Temperature
    - These are the some of the dimensions we measure to empirically describe matter.



Measurement

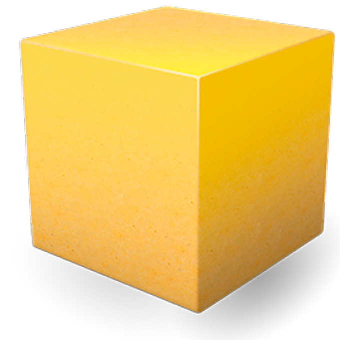
- A measurement is a quantitative observation.
- A measurement is an observation of how many of something exists in that dimension.
  - How many inches exist in it’s length.
  - How many pounds exist in it’s mass.
  - How many degrees exist in it’s temperature.
- For that measurement to mean something we need to agree on a what we’re counting in each dimension.
  - One of that something is a unit.
  - Unit means “single” of something.



unit	unit	unit

Measurement

- A measurement is a quantitative observation.
  - Quantitative means expressed in numbers.



- Measurements have two parts:
  - Factor (the value) — the numeric part
  - Label (the unit) — the non-numeric part

value

unit

53 gallons

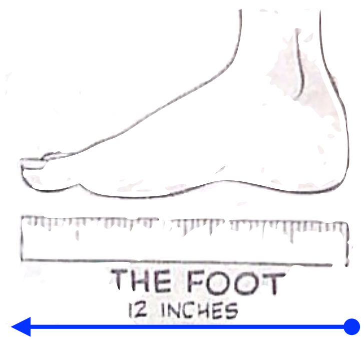
the measurement

65.7 mph

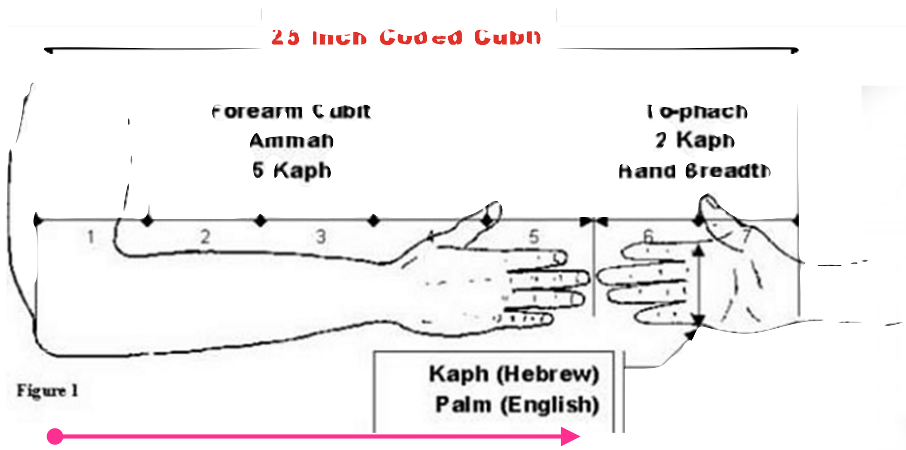
21.5 °C

1,213 feet

Units



- The measurement won't mean something to anyone else (or to us a later time) if the size of that unit isn't the same.
- To share out observations, we need to agree on a standard for that unit.
- Units of measurement were originally based on physical objects.
  - The foot (based on a king's foot)
  - The cubit (based on a tradesman's forearm)
  - The hand (based on the hand)
  - The stone (based on a stone)
- Agreeing on the village "stone" is how people became a village.

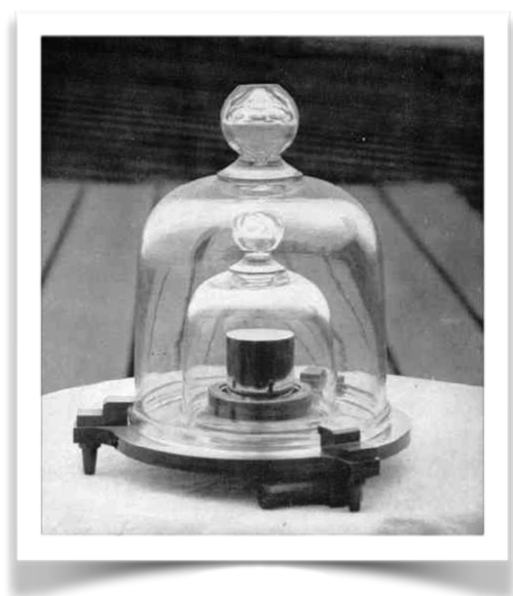


Imperial Units

- Between 1815 and 1914, a period of time called the imperial century, around 10,000,000 square miles of territory and roughly 400 million people were added to the British Empire.
- Commerce, military, scientific, and other efforts were coordinated and shared across the empire by agreeing on a single standard of units.
- The imperial units included
  - For mass, pound sterling
  - For volume, imperial gallon
  - For length, inch
  - All of which were all based on the standard of a single grain of wheat.
    - 1 inch = 3 grains long
    - 1 British sterling (the coin of the realm) was made to weigh 32 grains
    - 1 ounce = 20 sterling
    - 1 pound = 12 ounce
    - 1 gallon = 8 pounds of wine
- All measurement across that empire came down to figuring out how many grains of wheat were in a length, weight, or volume.

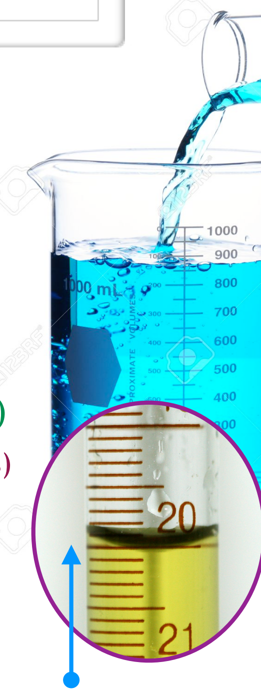
Other Unit Standards

- Over time those standards were replaced with more carefully managed units.
- England maintained a golden ruler.
- France kept the definitive pound under a bell jar.
  - But measurement is still finding the number of standard units in the dimension being considered.
  - It's still about counting how many times the village stone fits in the thing you're measuring.

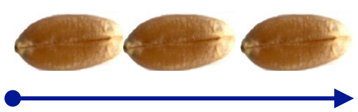


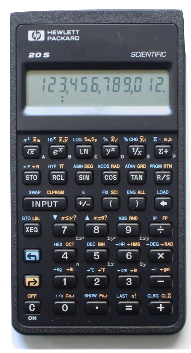
Ch01

Measurement

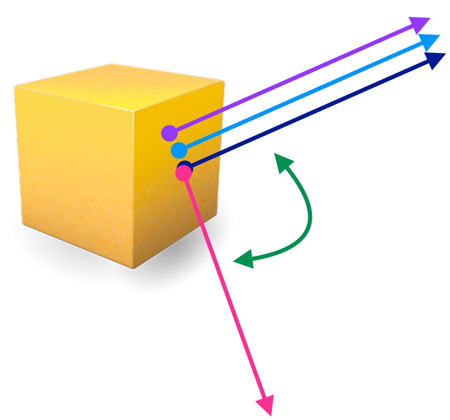


- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions



Scientific Notation

- Some values we want to record are very large or very small.
- A drop of water contains 1,500,000,000,000,000,000,000 particles of water.
- A particle of neon has a width of 0.000 000 007 0 cm.
- Standard notation works by representing multiples of 10 or tenths in a value as zeroes.
  - Either on the right or left of the decimal point.

- Another method for representing these values is scientific notation.
  - Scientific notation keeps track of how many 10's or tenths exist using exponents.
  - (any number raised to a power, means it's multiple by itself that many times)

$$100{,}000. \quad = \quad 1 \underbrace{\times 10 \times 10 \times 10 \times 10 \times 10}_{\text{five “x 10's”}} \quad = \quad 10^5$$

five zeroes

10 to the fifth

Scientific Notation

- Some values we want to record are very large or very small.
- A drop of water contains 1,500,000,000,000,000,000,000 particles of water.
- A particle of neon has a width of 0.000 000 007 0 cm.

standard notation 27,000,000

2,700,000 x 10

270,000 x 10 x 10

27,000 x 10 x 10 x 10

$$2.7 \times \underbrace{10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10}_{\text{seven “x 10's”}}$$

scientific notation 2.7×10^7

Scientific Notation

- Some values we want to record are very large or very small.
- A drop of water contains 1.5×10^{21} particles of water.
- A particle of neon has a width of 0.000 000 007 0 cm.

$$0.1 = 10^{-1}$$

standard notation $.000092$

$$.00092 \times 10^{-1}$$

$$.0092 \times 10^{-1} \times 10^{-1}$$

$$.092 \times 10^{-1} \times 10^{-1} \times 10^{-1}$$

$$9.2 \times \underbrace{10^{-1} \times 10^{-1} \times 10^{-1} \times 10^{-1} \times 10^{-1}}_{\text{five “x 0.1’s”}}$$

scientific notation 9.2×10^{-5}

Scientific Notation

- Some values we want to record are very large or very small.
- A drop of water contains 1.5×10^{21} particles of water.
- A particle of neon has a width of 7.0×10^{-9} cm.
- Numbers expressed in scientific notation have three parts
  - The significant figures are represented as a decimal number, with the decimal always placed after the first non-zero digit.
- This is not an equation, it’s a single value (more on that coming up).

exponential term

sign

$$-4.70 \times 10^{-2} \text{ mL}$$

significand

(or decimal term or mantissa)

Scientific Notation

- Some values we want to record are very large or very small.
- A drop of water contains 1.5×10^{21} particles of water.
- A particle of neon has a width of 7.0×10^{-9} cm.
- To convert between standard notation and scientific notation:
  - Move the decimal point in the original number so that it is located after the first nonzero digit.
  - Follow the new number by a multiplication sign and 10 with an exponent (power).
  - The exponent is equal to the number of places that the decimal point was shifted.

$$0.053 \text{ mL} \longrightarrow 5.3 \times 10^{-2} \text{ mL}$$

$$320 \text{ grams} \longrightarrow 3.2 \times 10^{2} \text{ grams}$$

Scientific Notation

- Move the decimal point in the original number so that it is located after the first nonzero digit.
- Follow the new number by a multiplication sign and 10 with an exponent (power).
- The exponent is equal to the number of places that the decimal point was shifted.

0.017 °C $\longrightarrow$ 1.7×10^{-2} °C

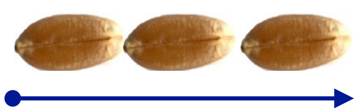
12,213 feet $\longrightarrow$ 1.2213×10^{4} feet

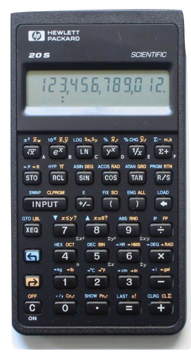
2100 gallons $\longrightarrow$ 2.1×10^{3} gallons

210.0 mph $\longrightarrow$ 2.100×10^{2} mph

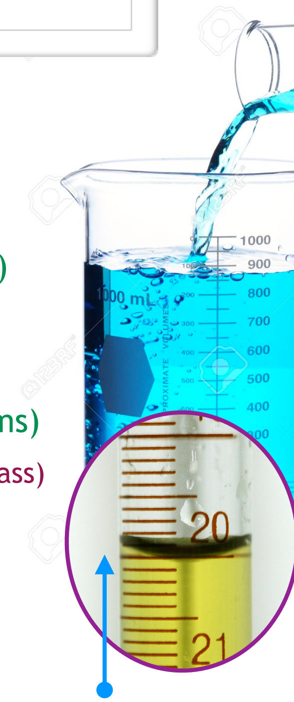
Measurement

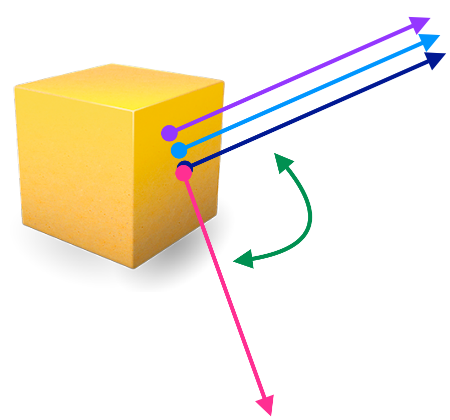
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions

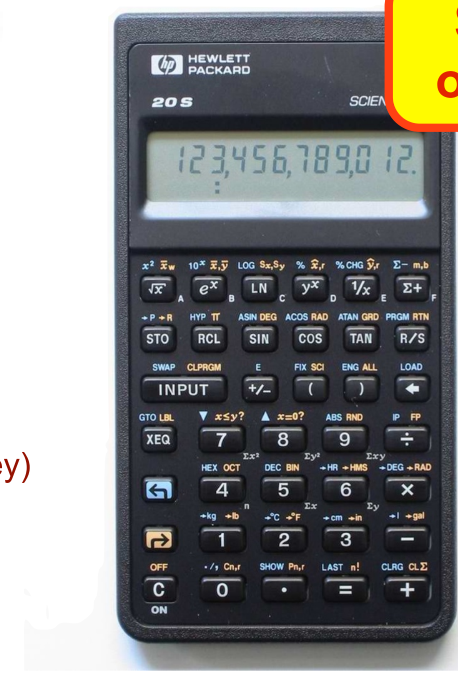




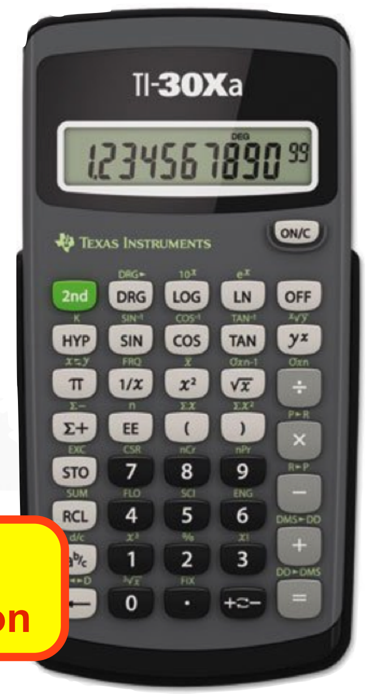
A simple scientific calculator is best.

Must do scientific notation.
(must have an EE or E or Exp key)

Cell phones/PDAs are not acceptable.



$15-35 on eBay

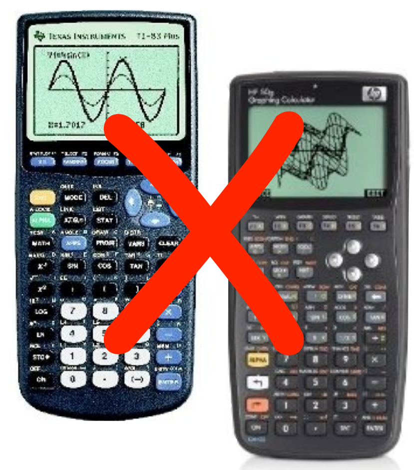


$9-15 on Amazon

Best choice:
a simple calculator with
log and scientific notation keys
- HP 20s (27s or 42s also good)
- Texas Inst TI-30Xa (least expensive)

Graphing calculators are bad — they are expensive, hard to use and will trip you up on an exam.

Don't buy one. If you already have one and <u>*know how to use it well*</u>, it's acceptable.



CAUTION:
Chem lab calculators are like boxers, they don't stay pretty for long.

<u>Do not spend big money on any calculator, it might take an acid bath tomorrow!</u>

ebay Shop by category

hp 20s | All Categories | **Search**

Related: hp 20s calculator hp 32sii hp 27s hp 22s hp 32s hp calculator hp 33s hp 35s calculator hp 32si... Include descriptio

Categories

Consumer Electronics

- Calculators
- More

Postal Stamps

- Other US Stamp Covers
- More

Collectibles

- Other Engineering Collectibles
- More

Home & Garden

- Lawnmower Parts & Accessories
- More

See all categories

Type see all

Brand see all

Size see all

Power Source see all

Condition see all

- New (127)
- Used (435)
- Not Specified (98)

Price

$ to $

All Listings | Auction | Buy It Now

Sort: **Best Match** View:

hp 20s 660 listings **Follow this search**

NEW LISTING Hewlett Packard HP 20s Scientific Calculator

$24.50

Buy It Now

HP Hewlett Packard 20 S 20S Scientific Calculator with hp slip case

$16.49 4d 20h left (Sunday, 10AM)

2 bids

Free shipping

HP Hewlett Packard 20 S 20S Scientific Calculator with hp slip case

$14.32 6d 22h left (Tuesday, 12PM)

1 bid

Free shipping

Entering Scientific Notation

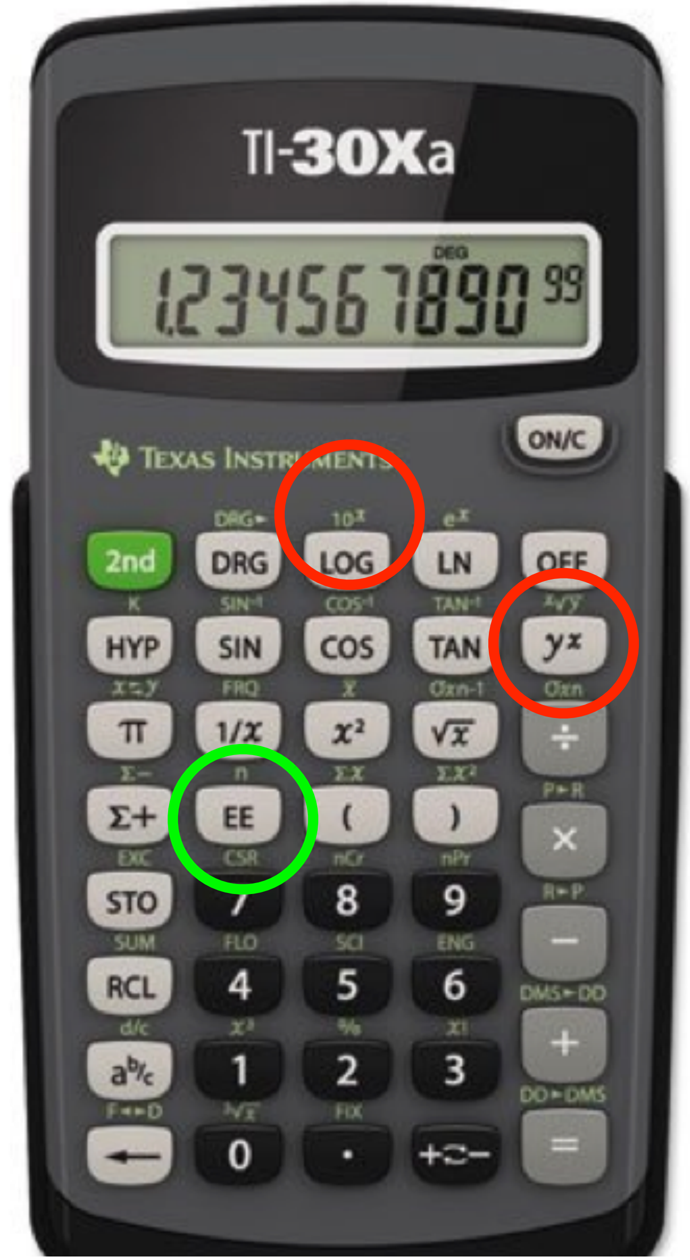
- There is one key on your calculator for entering scientific notation.
- It will have one of these symbols on it:

E, EE, Exp, or x10^X

- There are other keys that look similar, but do something different! **<u>Don't use these keys</u>**:

10^X or y^X

- You may need to use the 2nd function key or an equivalent key if the symbol appears above the key rather than on it.



Entering Scientific Notation

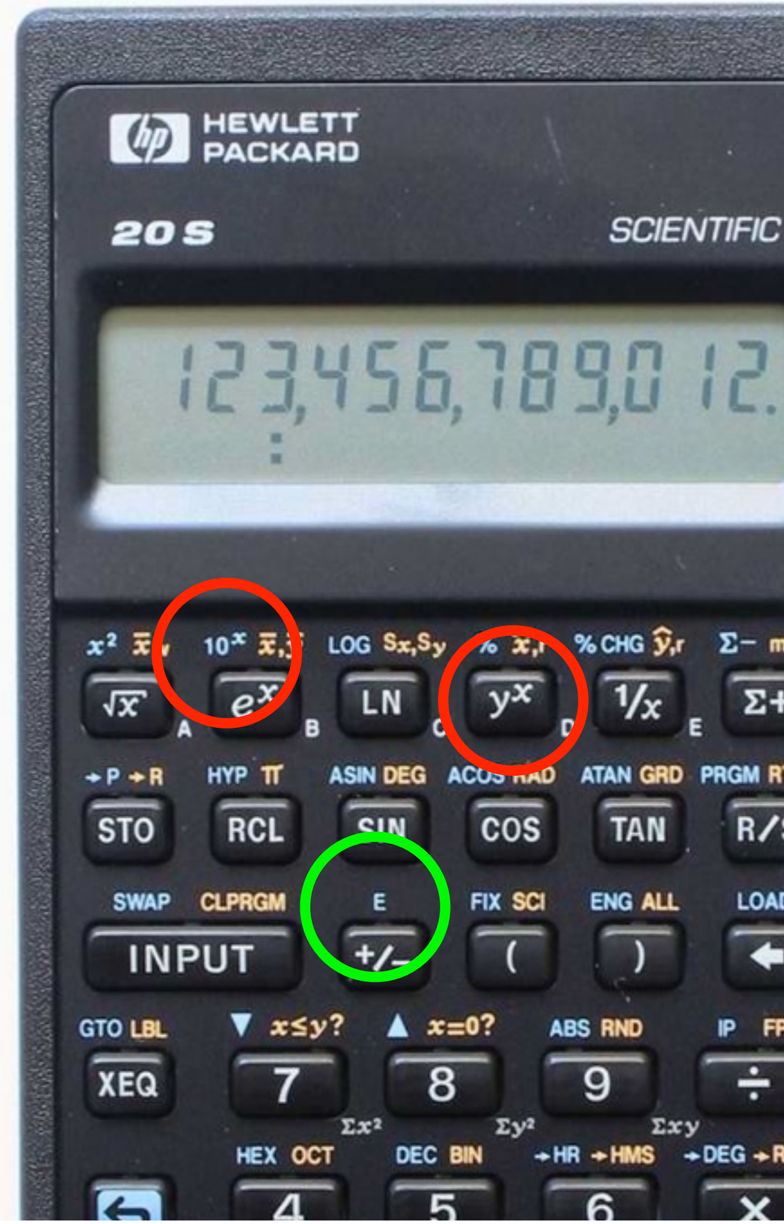
- There is one key on your calculator for entering scientific notation.
- It will have one of these symbols on it:

$$\text{E, EE, Exp, or } x10^X$$

- There are other keys that look similar, but do something different! **<u>Don't use these keys</u>**:

$$10^X \text{ or } y^X$$

- You may need to use the 2nd function key or an equivalent key if the symbol appears above the key rather than on it.



Checking your calculator

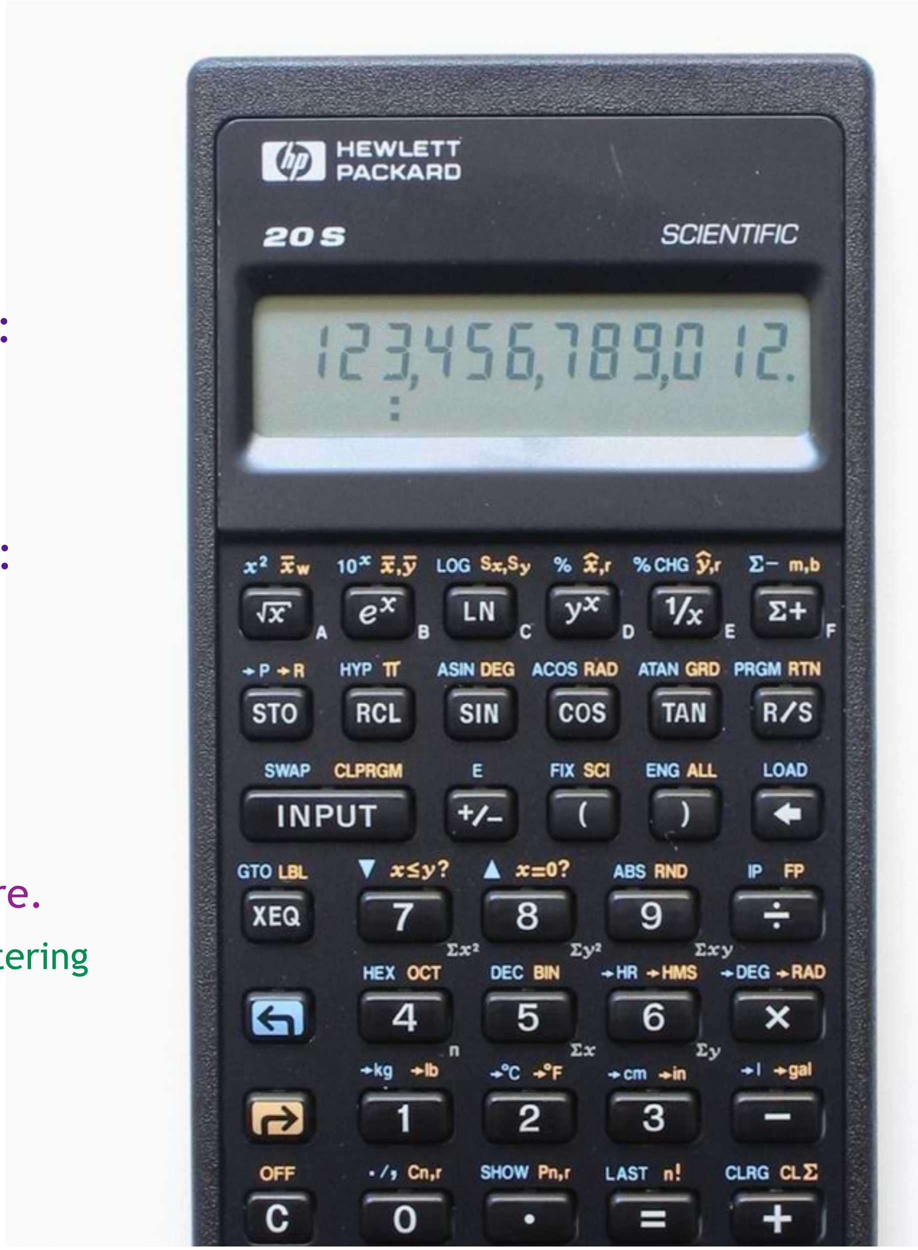
- Enter 2.5 x 10^4 into your calculator.
- To do this type “2.5 E 4” and then hit enter or equals. Look at the result.
- You did it right if your your calculator responds:

  25000 or 2.5E4 or 2.5 ^{4}

- You made a mistake if your calculator responds:

  250000 or 2.5E5 or 2.5 ^{5}

  - You typed “2.5 x 10 E 4”
    — that adds an extra 10, which shouldn’t be there.
    - Do not use the multiplication key when you’re entering scientific notation.
    - You’re putting in a single value, not an equation.



Checking your calculator

- Divide 20.8 by $5\text{x}10^3$ with your calculator.
- To do this type "20.8 ÷ 5E3" and then hit enter or equals. Look at the result.
- You did it right if your your calculator responds:

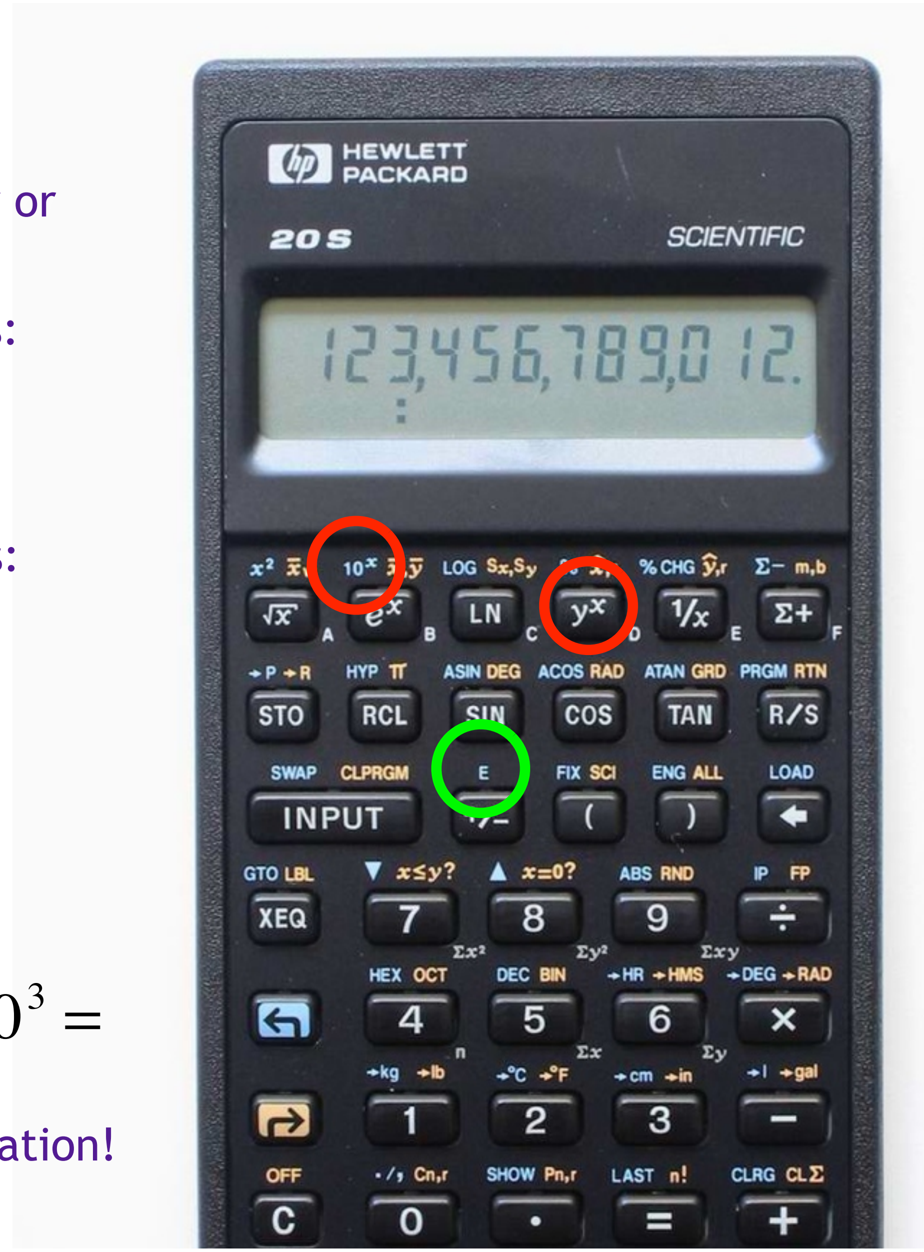
0.00416 or 4.16E-3

- You made a mistake if your calculator responds:

4,160

  - You used the wrong key.
    - You wanted to do this: $\dfrac{20.8}{5\times10^3}=$
    - You told your calculator to do this: $\dfrac{20.8}{5}\times10^3=$

There is only one key that works for scientific notation!



Checking your calculator

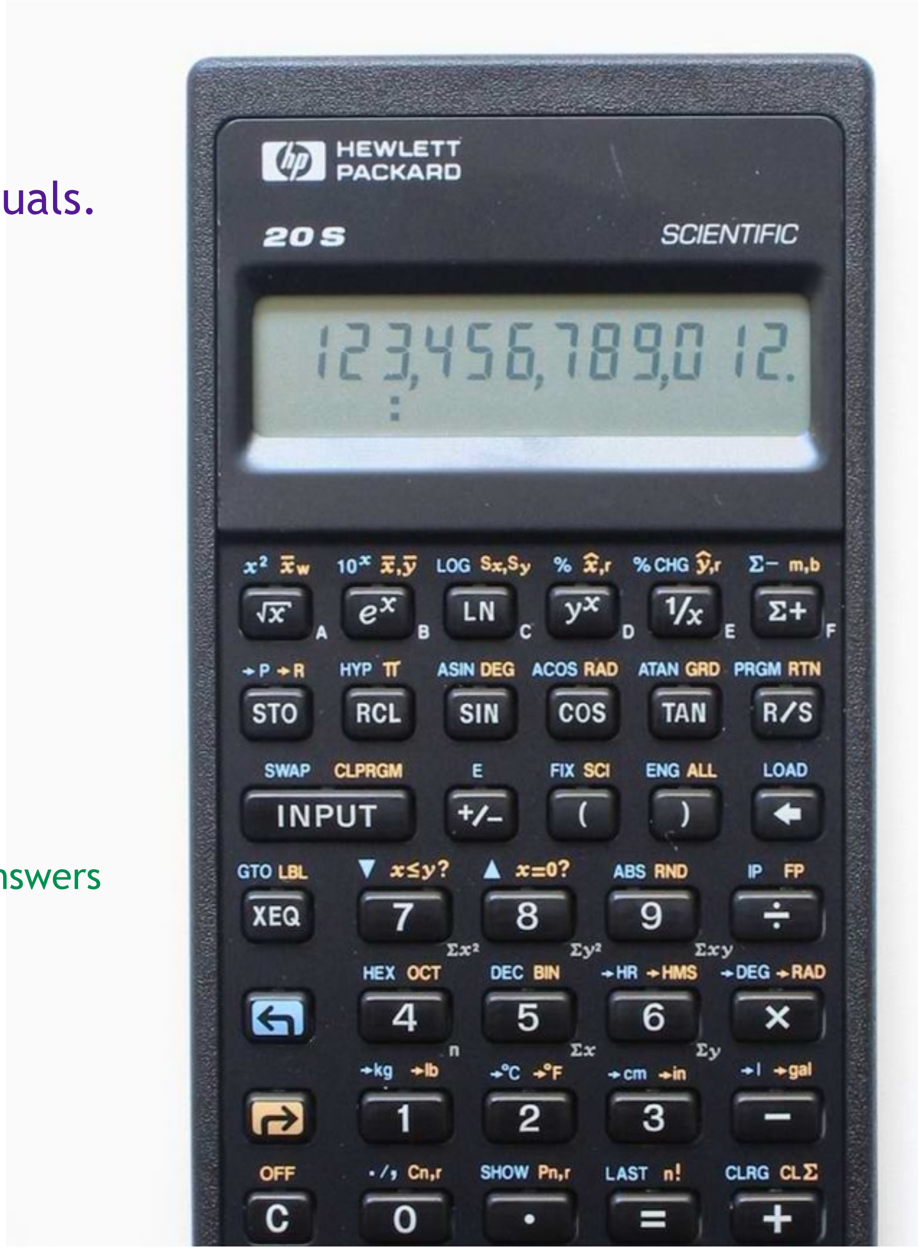
- Divide 1 by 3 with your calculator.
- To do this type “1 ÷ 3” and then hit enter or equals. Look at the result.
- You’re good if your your calculator responds:

0.333333333333

- If you get less than a full screen of 3’s or:

1/3

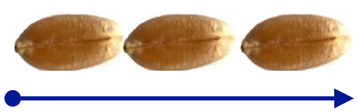
  - Your calculator is in the wrong mode.
    - Your calculator is set to display values in a way that will cause you to loose data and get wrong answers on an exam.
    - Ask me how to fix this!

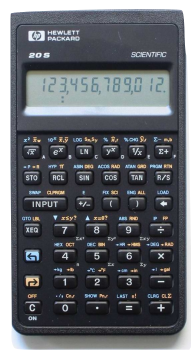


Ch01

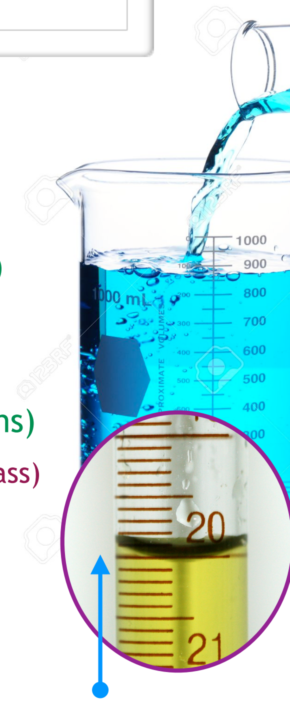
Measurement

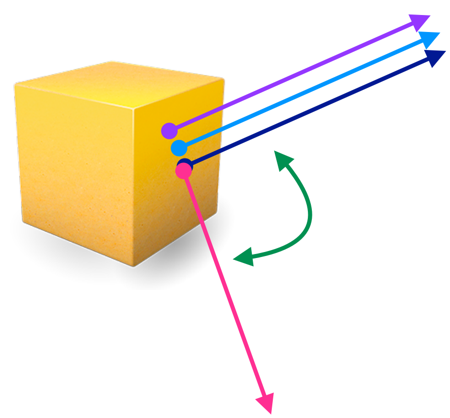
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions

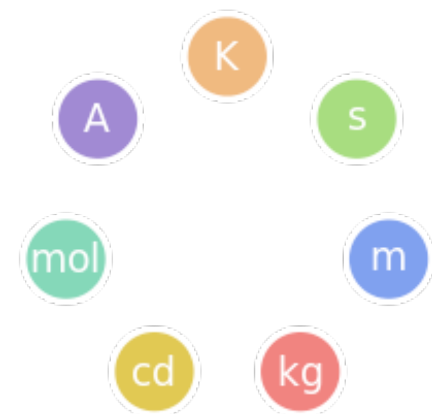




Système International (SI) Units

- Imperial Units are based on halves. Our math is based on tenths.
- The standards of imperial units are physical objects.
- To improve on this standard of units, another unit system was developed.
- The SI system was launched in 1960 as the result of an initiative that started in 1948.
- The SI system has seven base units as it's standard.
    - meter
    - kilogram
    - second
    - kelvin
    - mol
    - ampere
    - candela
  - Six of these seven units are based on physical constants — so no "village" stone is required.
  - The Kg is the one exception. A prototype Kilogram is still maintained in Paris France.

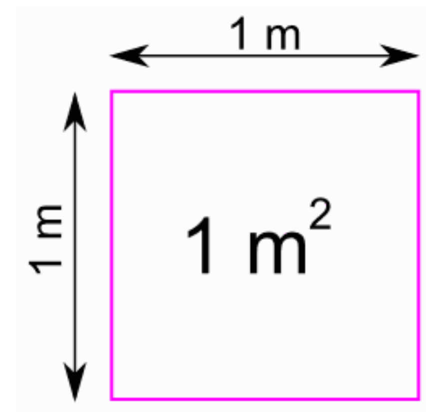
International System of Units

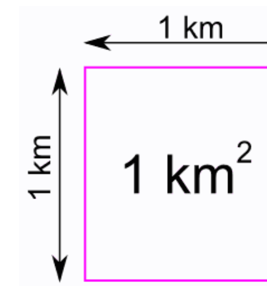


Derived SI Units

- With only seven standard units we can measure properties in thousands of physical dimensions.
- One reason for this is we can derive new units from the those seven standard units.
- For example:
  - There is no standard unit of measure for area.
    - We derive the unit meter squared (m^2) from the standard unit meter (m).
    - We don't need a village stone to compare meter squared units to, because we can build our own from a perfect meter.

$$1\ m^2 = 1\ m \times 1\ m$$





	SI derived unit	
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
mass density	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
amount-of-substance concentration	mole per cubic meter	mol/m^3
luminance	candela per square meter	cd/m^2
mass fraction	kilogram per kilogram, which may be represented by the number 1	kg/kg = 1

Named Derived SI Units

SI derived unit			
radian [a]	rad	-	$m \cdot m^{-1} = 1$ [b]
steradian [a]	sr [c]	-	$m^2 \cdot m^{-2} = 1$ [b]
hertz	Hz	-	s^{-1}
newton	N	-	$m \cdot kg \cdot s^{-2}$
pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
joule	J	N·m	$m^2 \cdot kg \cdot s^{-2}$
watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
coulomb	C	-	s·A
volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
weber	Wb	V·s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
degree Celsius	°C	-	K
lumen	lm	cd·sr [c]	$m^2 \cdot m^{-2} \cdot cd = cd$
lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
becquerel	Bq	-	s^{-1}
gray	Gy	J/kg	$m^2 \cdot s^{-2}$
sievert	Sv	J/kg	$m^2 \cdot s^{-2}$
katal	kat		$s^{-1} \cdot mol$

- Twenty two of the derived SI units have been named and given their own symbols.
- SI units not capitalized.
- The first letter in their symbols are capitalized, only if the unit was named after person.

  - Example:

$$1 \text{ hertz} = 1 \text{ Hz} = 1 \text{ s}^{-1} = \frac{1}{\text{s}}$$

I'll let you know which of these units you will be responsible for as we encounter them.

Base Units of SI

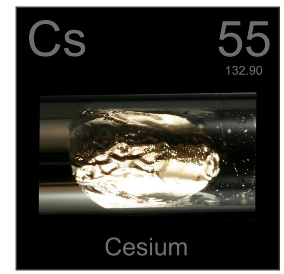
The SI (system international) system provides units for just about everything we measure. All those units are built on just seven fundamental (base) units — standard units.

Length	meter	(m)
Mass	kilogram	(kg)
Time	second	(s)
Temperature	kelvin	(K)
Count	mole	(mol)
Current	ampere	(A)
Brightness	candela	(cd)

Meter : The meter is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

Kilogram : The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

Second : The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.

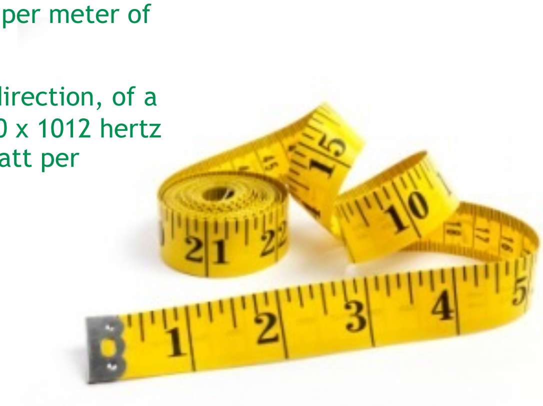


Kelvin : The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Mole : The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is “mol."

Ampere : The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 x 10-7 newton per meter of length.

Candela : The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.



For Exam #1 you are responsible for the first four: m, kg, s, and K
Moles will be introduced later.
We won’t be making use of the other two.

SI Prefixes

kilo means "x1000" or "$x10^3$"

1 kg = 1 x1000 g = 1000 g

2 kg = 2 x1000 g = 2000 g

micro means "$x10^{-6}$"

1 μs = 1 $x10^{-6}$ s = 10^{-6} s

7.3 μs = 7.3 $x10^{-6}$ s = 7.3 $x10^{-6}$ s

milli means "$x10^{-3}$"

1 mm = 1 $x10^{-3}$ m = 10^{-3} m

2.43 $x10^5$ mm = 2.43 $x10^5$ $x10^{-3}$ m
= 2.43 x 10^2 m

- There are twenty prefixes in the SI system to allow scaling the base units.
- A SI prefix is a unit prefix that precedes a basic unit of measure to indicate a decadic (x10) multiple or fraction of the unit.
- Each prefix has a unique symbol that is prepended to the unit symbol.
- For example:
  - The prefix kilo- may be added to gram to indicate multiplication by one thousand; one kilogram is equal to one thousand grams.
  - The prefix milli- may be added to metre to indicate division by one thousand; one millimetre is equal to one thousandth of a metre.

SI Prefixes

- You are responsible for knowing prefixes Giga through Femto and being able to convert between them.

kilo means "x1000" or "x10^3"

1 kg = 1 x1000 g = 1000 g

2 kg = 2 x1000 g = 2000 g

micro means "x10^{-6}"

1 μs = 1 x10^{-6} s = 10^{-6} s

7.3 μs = 7.3 x10^{-6} s = 7.3 x10^{-6} s

milli means "x10^{-3}"

1 mm = 1 x10^{-3} m = 10^{-3} m

2.43 x10^5 mm = 2.43 x10^5 x10^{-3} m
= 2.43 x 10^2 m

exa	E	x 1,000,000,000,000,000,000	x 10^{18}
peta	P	x 1,000,000,000,000,000	x 10^{15}
tera	T	x 1,000,000,000,000	x 10^{12}
giga	G	x 1,000,000,000	x 10^9
mega	M	x 1,000,000	x 10^6
kilo	k	x 1,000	x 10^3
deci	d	x 0.1	x 10^{-1}
centi	c	x 0.01	x 10^{-2}
milli	m	x 0.001	x 10^{-3}
micro	μ	x 0.000001	x 10^{-6}
nano	n	x 0.000000001	x 10^{-9}
pico	p	x 0.000000000001	x 10^{-12}
femto	f	x 0.000000000000001	x 10^{-15}
atto	a	x 0.000000000000000001	x 10^{-18}

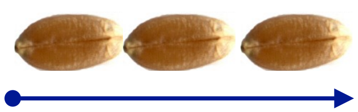
Mega & micro are both six (3+3)

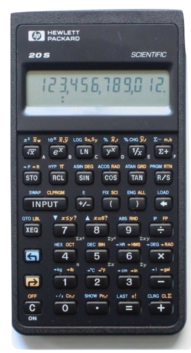
nine nano

fifteen femto

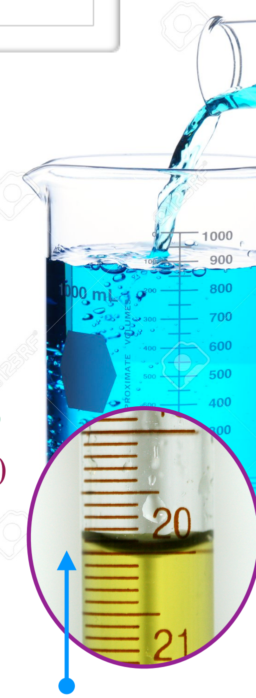
Measurement

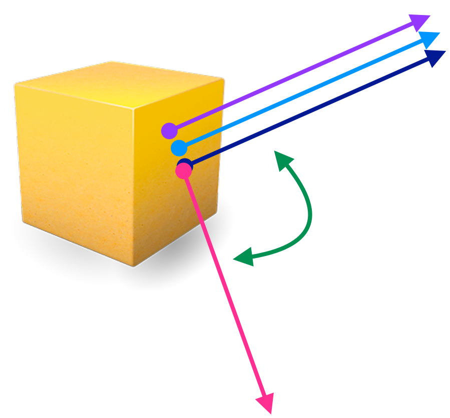
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





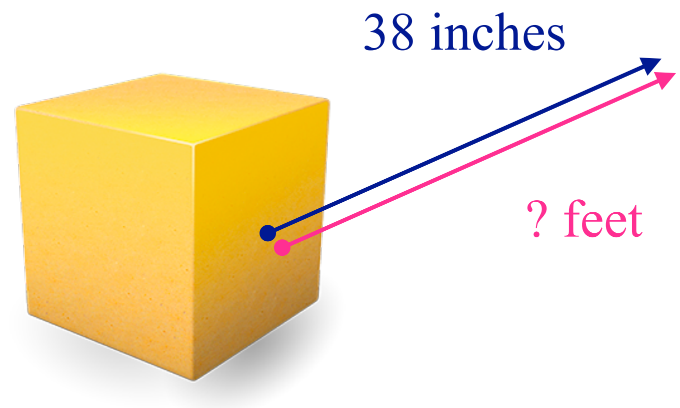
- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions





Converting Measurements

- We'll take measurements in one set of units and later need them in another.
- It might just be simpler to consider then on a different scale.
- For example, we may measure a sample in inches and then want to know how many feet are contained in the length of that sample.
  - If a length is 38 inches, how many feet is it?



- Intuitively you know how to do this:
- But this justification is insufficient for a science class.

38 ÷ 12 = 3.2 ft

- You need to provide more than the "answer" you need to expose the details of your justification so we can share your confidence in that answer.
- In this way we can "know" that answer, the same way you do.

Conversion Factors

- Conversion factors are a tool for "trading" units.
  - They can be used to convert a measurement, in one set of units, into a measurement of that same quantity, but in another set of units.
- Using conversion factors exposes the relationship by which you link those units and the math by which you process that conversion.
- Conversion factors are based on equivalences.
  - There are different ways we can determine an equivalence.
  - How we determine the equivalence determines how many significant figures exist in the conversion factor.
    - Measurement (has finite significant figures)
    - Counting (has infinite significant figures)
    - Definitions (has infinite significant figures)
    - Proofs (depends on what we use to prove it)
- The conversion factors we build are equal to unity.

an equivalence

$$12 \text{ inches} = 1 \text{ ft}$$

$$\frac{12 \text{ inches}}{12 \text{ inches}} = \frac{1 \text{ ft}}{12 \text{ inches}}$$

$$1 = \frac{1 \text{ ft}}{12 \text{ inches}}$$

one conversion factor

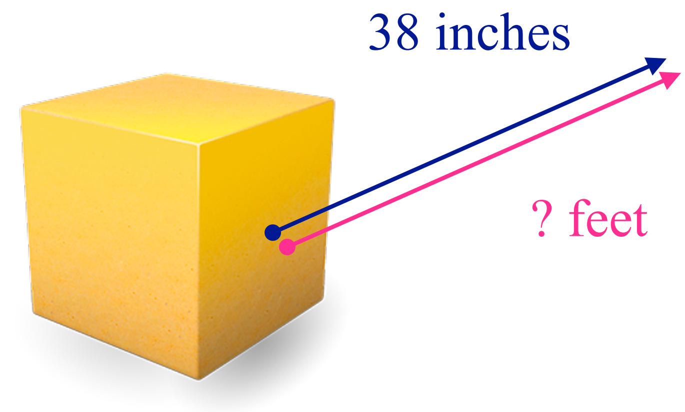
$$\frac{12 \text{ inches}}{1 \text{ ft}} = \frac{1 \text{ ft}}{1 \text{ ft}}$$

$$12 \frac{\text{inch}}{\text{ft}} = 1$$

another conversion factor

Applying Conversion Factors

- A factor is something you multiply a number by to produce another number.
- Since conversion factors are equal to unity, they don't change the quantity measured.
- The conversion allows you to determine the number for that quantity in the new units.



$$38 \text{ inches} = \boxed{\ ?\ } \text{ ft.}$$

$$38 \text{ inches} \cdot 1 =$$

$$38 \text{ inches} \cdot \frac{1 \text{ ft}}{12 \text{ inches}} \approx 3.16666 \text{ ft}$$

2 s.f. ∞ s.f.

$$= \boxed{3.2 \text{ ft}}$$

2 s.f.

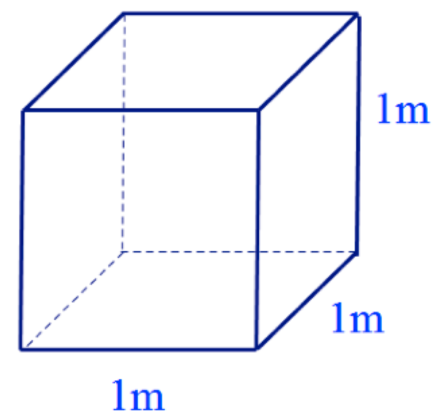
Be sure to:

Show units.

Consider significant figures.

Liters

- The SI unit of volume is the derived unit m^3.
- The liter (L) is not an SI unit, but is a very useful unit for liquid volumes.
- A liter is defined as equal to 1/1000th of a cubic meter.
- On the laboratory scale it’s more convenient to work with 1/1000th of a liter, a milliliter (mL).
- Most of our measuring tools will be calibrated for milliliters (mL).

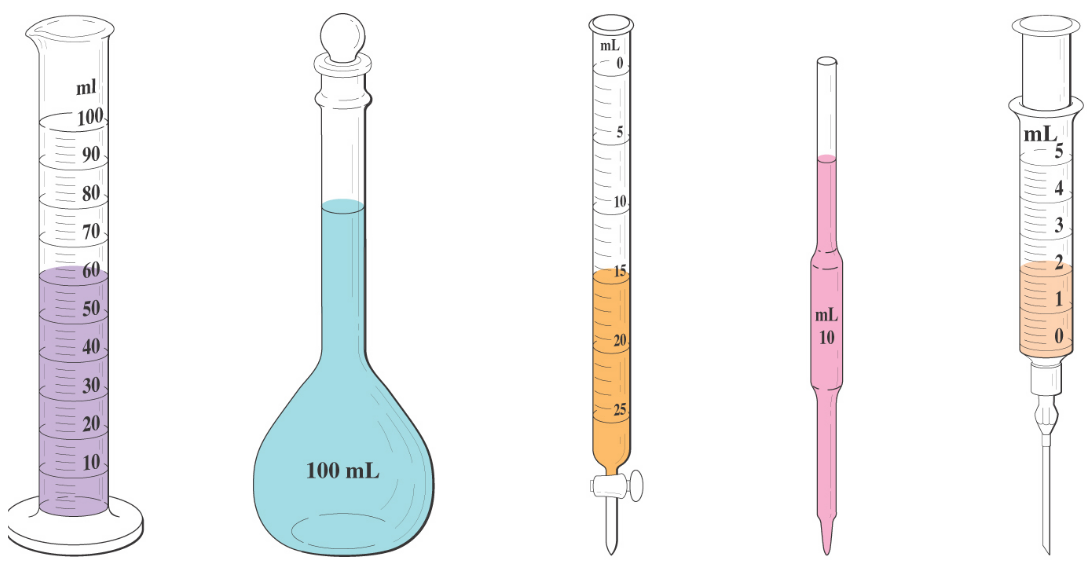


$1\ m^3 = 1000\ L$

by Definition

$1\ mL = 10^{-3}\ L$

by Definition



Graduated cylinder | Volumetric flask | Buret | Pipet | Syringe

Conversion Factor: 1 cm^3 → 1 mL (exact)

- A milliliter (mL) is exactly equal to 1 cm^3
- That's not a definition, it's determined by a proof.
  - We justify it with algebra.
- You are responsible for knowing this equivalence.
- It will come in handy when we need to convert between those units.
  - You may need to prove (build) other conversion factors as we go along.

$1\ cm^3 = 1\ mL$ (exactly)

justified by Proof

(a mathematical proof)

$c = 10^{-2}$

$m = 10^{-3}$

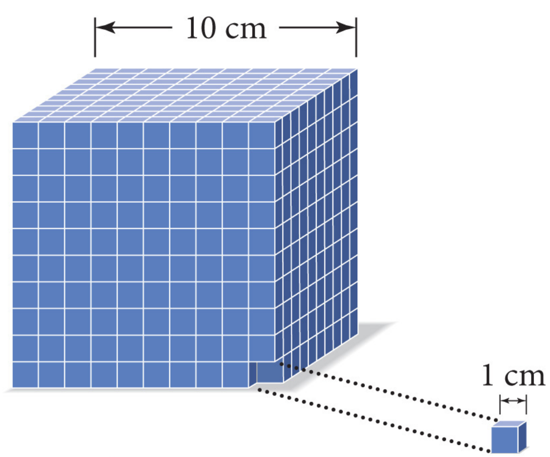
$$
\begin{aligned}
1\ cm^3 &= 1\ cm^3 \\
&= 1\ (10^{-2}\ m)^3 \\
&= 1\ (10^{-2})^3\ (m)^3 \\
&= 1\ (10^{-6})\ (m)^3 \\
&= 10^{-6}\ m^3 \\
&= 10^{-3} \times 10^{-3}\ m^3 \\
&= 10^{-3} \times 1\ L \\
1\ cm^3 &= 1\ mL
\end{aligned}
$$

$1\ m^3 = 1000\ L$

justified by Definition

$1\ m^3 = 10^3\ L$

$10^{-3}\ m^3 = 1\ L$

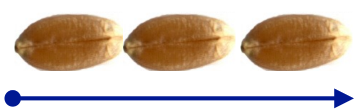


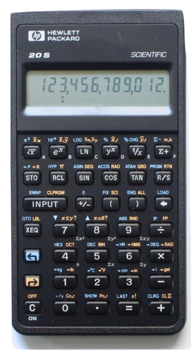
A 10 cm cube contains 1000 1 cm cubes.

Ch01

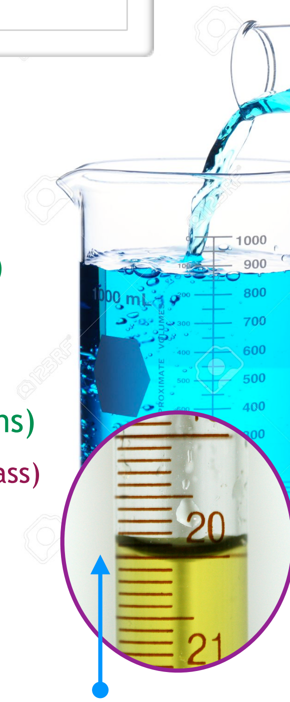
Measurement

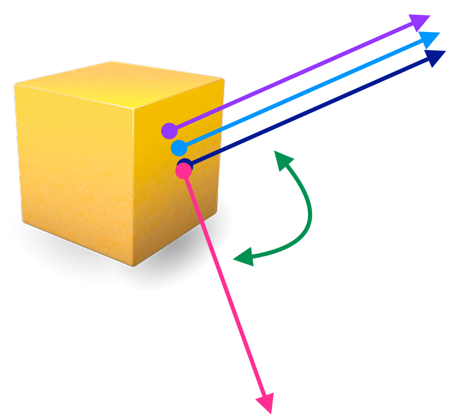
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





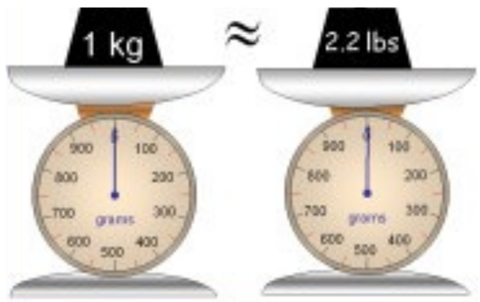
- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions



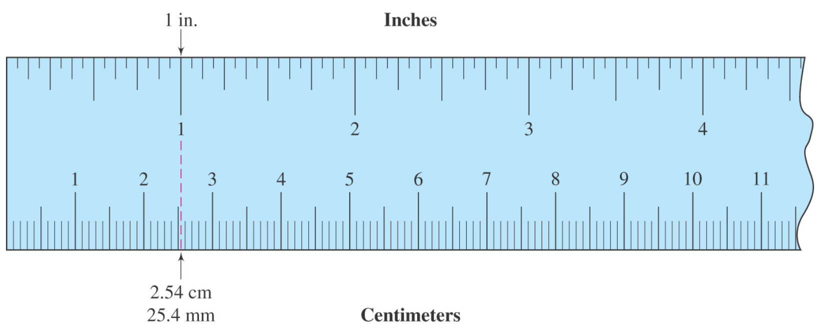


Converting Between Systems

- There is usually no defined link between different unit systems.
- To bridge different systems someone literally has to measure one unit of the old system in the new system.
  - For example:
    - A kilogram measures 2.2 lbs (2 significant figures).
    - A quart measures 0.946 L (3 significant figures).

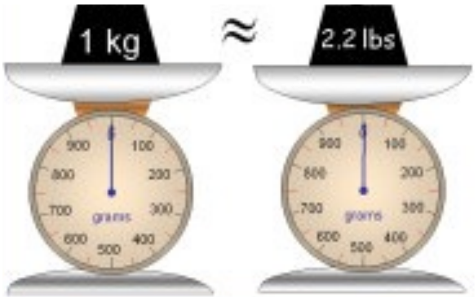


- One important exception is the conversion between an inch and a centimeter.
  - In 1959 we got tired of that limitation and the entire imperial system of length measurement was redefined.
  - As of 1959, and inch is defined to be 2.54 cm (exactly).



Conversion Factor: 1 kg → 2.2 lbs (measured)

- How many kg are in 92.7 lbs?



$$92.7\ \text{lbs} \cdot \frac{1\ \text{kg}}{2.2\ \text{lbs}} = 46.13636\ \text{kg}$$

3 s.f. 2 s.f

$$= \boxed{42\ \text{kg}}$$

- How many lbs are in 178 kg?

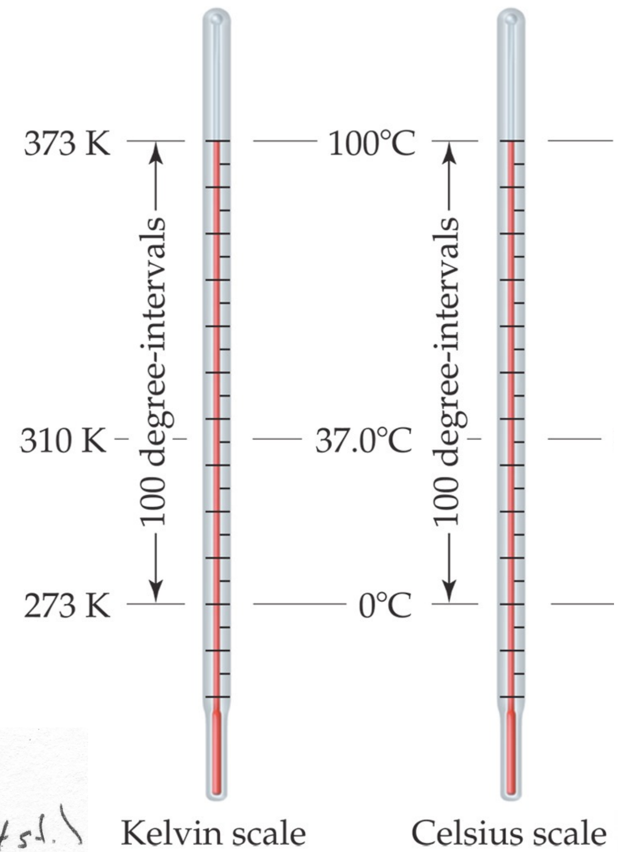
$$178\ \text{kg} \cdot \frac{2.2\ \text{lbs}}{1\ \text{kg}} = 391.6\ \text{lbs}$$

3 s.f. 2 s.f.

$$= \boxed{4.0 \times 10^{2}\ \text{lbs}}$$

Temperature

- Managing temperature measurements uses a different kind of conversion.
  - Celsius and Kelvin are different (but related) measurements.
    - It's a long story, we'll talk about it more in a future chapter.
- 1 degree Celsius is the same size as 1 degree Kelvin — but they have a different zero value.
  - To convert to Kelvin add 273.15 to the Celsius temperature.
  - To convert to Celsius subtract 273.15 from the Kelvin temperature.
- Watch significant figures!
- Addition and subtraction are tricky with sig figs.
  — *always use long hand to find the precision!*



$$\begin{array}{rll} & 900.00\ ^\circ C & (5\ s.f.) \\ + & 273.15 & (5\ s.f.) \\ \hline & 1{,}173.15\ K & (6\ s.f.) \end{array}$$

$$\begin{array}{rll} & 298.2\ K & (4\ s.f.) \\ - & 273.15 & (5\ s.f.) \\ \hline & 25.05 & \\ = & 25.1\ ^\circ C & (3\ s.f.) \end{array}$$

Conversion Factors You are Responsible For

Length	2.54 cm = 1 inch (exact)
Mass	1 kg = 2.2 lbs (not exact)
Time	60 sec = 1 min; 60 min = 1 hr; 24 hr = 1 day; 365 day = 1 year (all exact)
Temperature	K temp = add 273.15 to ˚C temp (not exact) (we will talk about Fahrenheit in ch 3)
Count	(coming soon)
Volume	1 cm^3 = 1 mL (exact)

giga	G	x 1,000,000,000	x 10^{9}
mega	M	x 1,000,000	x 10^{6}
kilo	k	x 1,000	x 10^{3}
deci	d	x 0.1	x 10^{-1}
centi	c	x 0.01	x 10^{-2}
milli	m	x 0.001	x 10^{-3}
micro	μ	x 0.000001	x 10^{-6}
nano	n	x 0.000000001	x 10^{-9}
pico	p	x 0.000000000001	x 10^{-12}
femto	f	x 0.000000000000001	x 10^{-15}

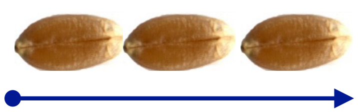
Mega & micro are both six (3+3)

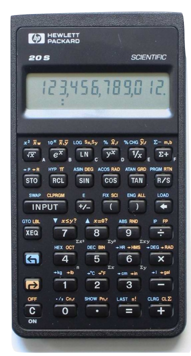
nine nano

fifteen femto

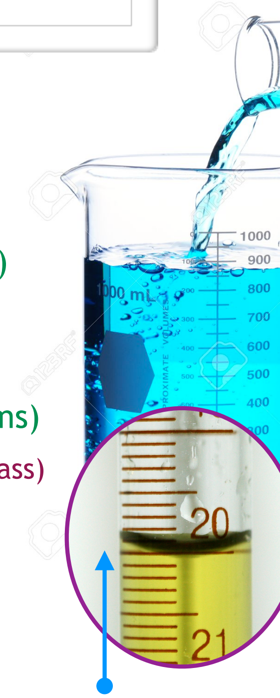
Measurement

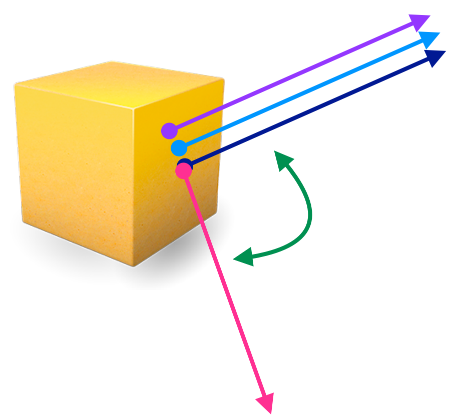
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes



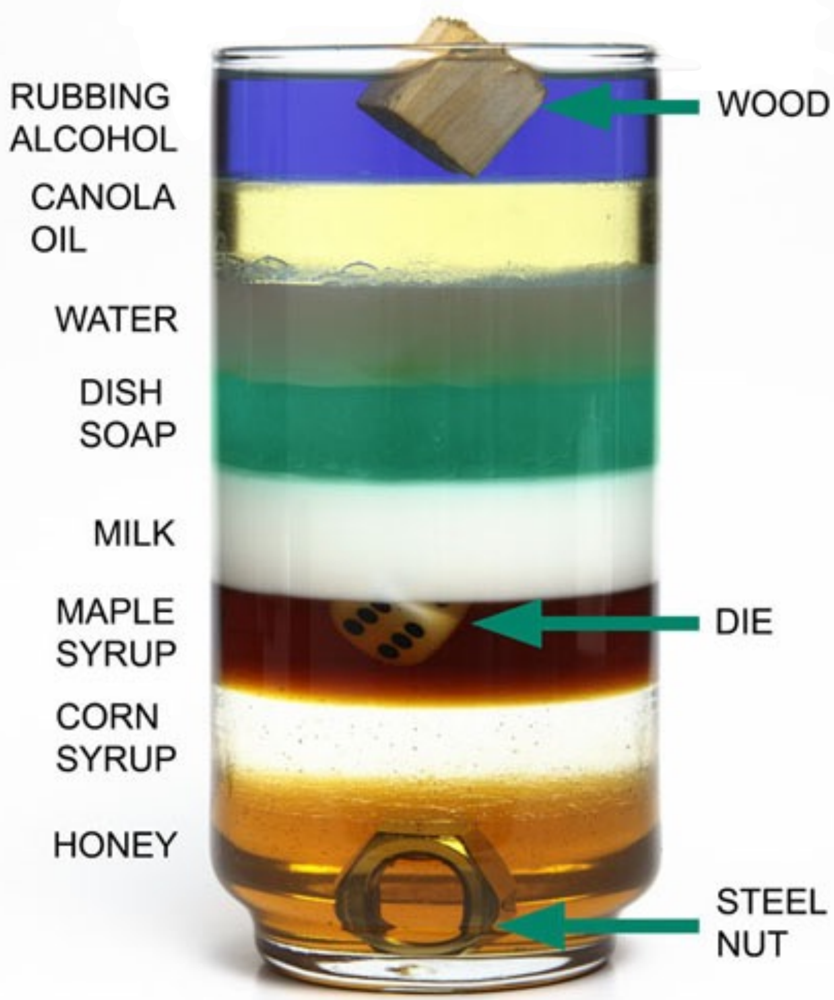


- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions





Density



- Density is an intensive physical property of a substance.
  - It's a measure of how "crowded" mass is in that substance.
- Density is defined as the mass of the substance divided by it's volume.

$$\boxed{d = \frac{\text{mass}}{\text{volume}}}$$

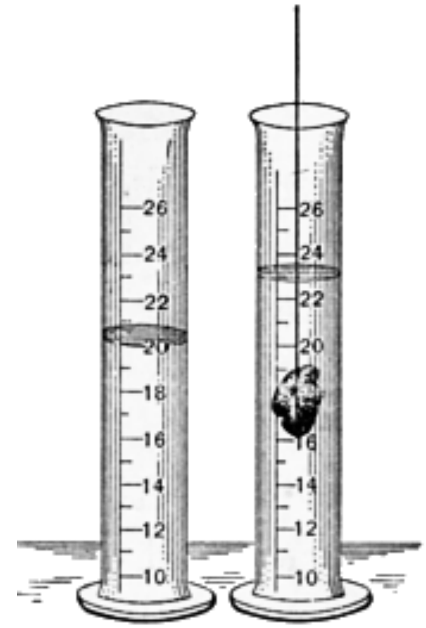
- Density is related to buoyancy, less dense substances will float on more dense substances.
- The units of density are derived units:
  - The density of solids is given in units of g/cm^3.
  - The density of liquids is usually reported in g/mL.
- We have no instrument for measuring density, it's value is calculated from measurements of other properties.

Measuring by Difference

- Iron pyrite and gold have many similar properties, but gold has a remarkably unique density.

$$d_{FeS_2} = 4.80\frac{g}{cm^3} \qquad d_{Au} = 19.30\frac{g}{cm^3}$$

- During the gold rush, prospectors would identify gold by it's density.
- They would measure the mass and volume of a nugget, then divide them to find the objects density.
- Mass was easy to measure, they'd just set the nugget on a scale.
- For the volume of a solid it's easiest to measure volume using the "difference method"
  - Measure your container (water in this case)
  - Add the thing you want to know about
  - Measure again and take the difference
- In the lab, you'll use difference method for the volume of solids.
- Some of the substances you're measure will be liquids or powders, you can't set them on a scale like a gold nugget.
- You'll use a beaker and the difference method to get the mass of substances for your experiments.



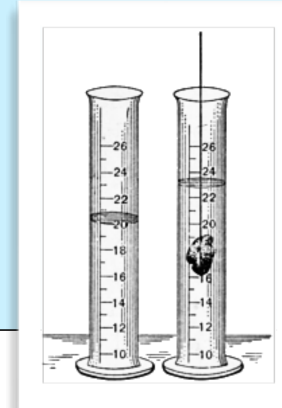
	23.5 mL	water + gold
−	20.0 mL	water alone
	3.5 mL	gold alone

	27.3 g	beaker + sample
−	19.2 g	beaker alone
	8.1 g	sample alone

Density Calculation

Gold has a density of 19.3 g/cm^3. A nugget weights 63.88 grams. If you put the nugget in 20.00 ml of water the volume rises to 23.31 ml, what is it's density?

Is the rock gold?



① Find the volume

② Find the Density

$m = 63.88\ g$
$V = 3.31\ mL$

$$\begin{array}{rl} & 23.31\ mL \\ - & 20.00\ mL \\ \hline & 3.31 \end{array}$$

$V = 3.31\ mL$

$$d = \frac{m}{V} = \frac{63.88\ g}{3.31\ mL}$$

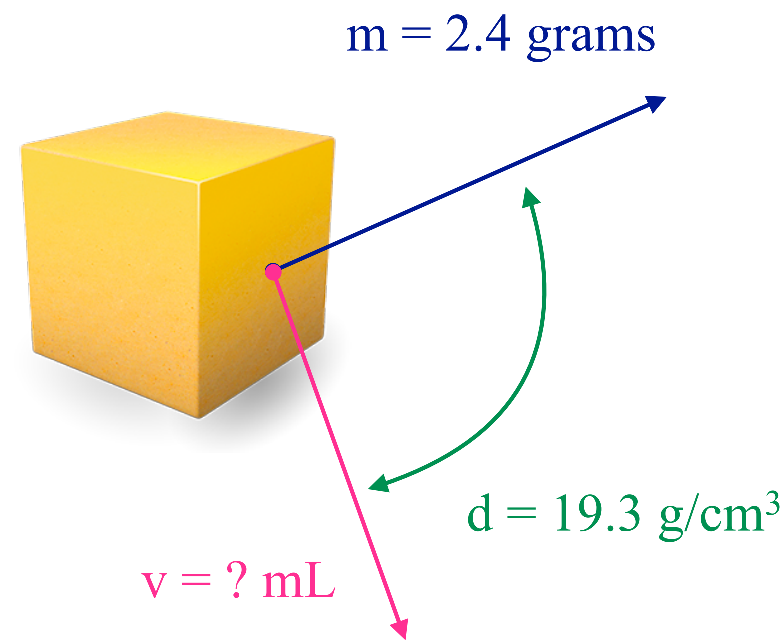
$$= 19.299094\ g/mL$$

(a) $\boxed{= 19.3\ g/mL}$

(b) $\boxed{\text{The rock is gold.}}$

Intensive Properties are Conversion Factors

- Intensive properties like density can often be used to relate extensive properties of a sample (in this case mass and volume).
- The ratio of two extensive properties can be used to determine an intensive property of a substance.
  - These conversion factors are the results of measurements, so they will have finite significant figures.



- A gold ring weighs 2.4 grams, what is it's volume? (the density of gold is 19.3 g/cm^3)

$$2.4\,g \cdot \frac{1\,cm^3}{19.3\,g} = 0.1243523\,cm^3$$

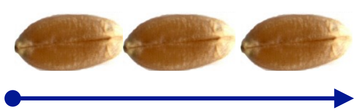
2 s.f. 3 s.f.

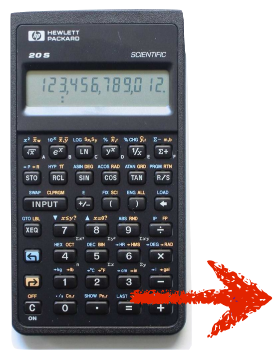
$$= \boxed{0.12\,cm^3}$$

Ch01

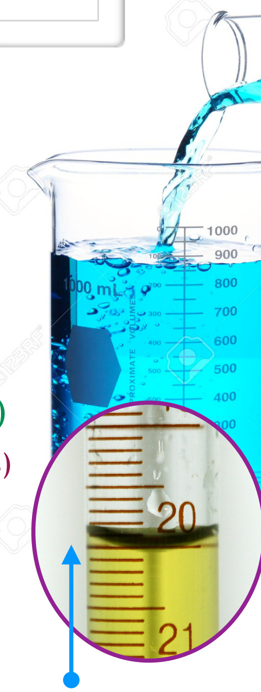
Measurement

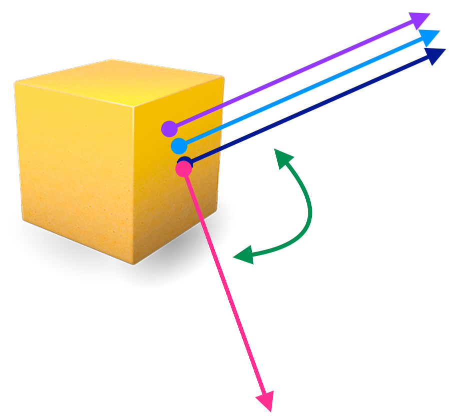
- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes





- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions





Answers aren't enough…

- When we ask you a question on an exam or homework, we rarely want only an answer.
- Answers are easy…
  - Four, true, 17.3 m, 27 gallons…
- We want knowledge. Knowledge is something that we believe is a true answer, because it can be justified.
- … and we will expect you to justify the answers that you offer as knowledge… not just toss us a guess.
- Dimensional Analysis is a tool for exposing and expressing linked dimensions.
  - It's a way to see how the different dimensions of a problem or substance.
  - It's accomplished by linking conversion factors concisely and clearly to move an observation between different dimensions of measure.
  - It's a way of exposing and sharing your reasoning, your justification, so others can share it.
    - It's a way of offering a proof of knowledge.

$$\frac{10\text{meters}}{1\ \cancel{\text{secs}}} \times \frac{60\ \cancel{\text{secs}}}{1\text{ min}} = \frac{600\text{ meters}}{1\text{ min}}$$

$$\frac{600\text{ meters}}{1\ \cancel{\text{min}}} \times \frac{60\ \cancel{\text{mins}}}{1\text{ hour}} = \frac{36{,}000\text{ meters}}{1\text{ hour}}$$

$$\frac{36{,}000\ \cancel{\text{meters}}}{1\text{ hour}} \times \frac{1\text{ km}}{1000\ \cancel{\text{meters}}} = \frac{36\text{ km}}{1\text{ hour}}$$

$$\frac{90\ \cancel{\text{miles}}}{\cancel{\text{hour}}} \ \underbrace{\frac{5280\text{ feet}}{1\ \cancel{\text{mile}}}}_{\substack{\text{conversion}\\ \text{miles}\to\text{ft}\\ \text{(exact)}}} \ \underbrace{\frac{1\ \cancel{\text{hour}}}{3600\text{ sec}}}_{\substack{\text{conversion}\\ \text{hour}\to\text{sec}\\ \text{(exact)}}} =$$

$$= 132\text{ ft/sec} = 1.3 \times 10^{2}\text{ ft/sec}$$

2 sig figs

Dimensional Analysis

- How many seconds are there in a century?

3.2 trillion seconds (an answer)

century → year → day → hr → min → sec

$$1\ \text{century} \cdot \frac{100\ \text{years}}{1\ \text{century}} \cdot \frac{365\ \text{days}}{1\ \text{yr}} \cdot \frac{24\ \text{hrs}}{1\ \text{day}} \cdot \frac{60\ \text{min}}{1\ \text{hr}} \cdot \frac{60\ \text{sec}}{1\ \text{min}}$$

∞ sf ∞ sf ∞ sf ∞ sf ∞ sf ∞ sf.

1 century = 100 years

365 days = 1 year

1 day = 24 hours.

60 min = 1 hour

60 seconds = 1 min

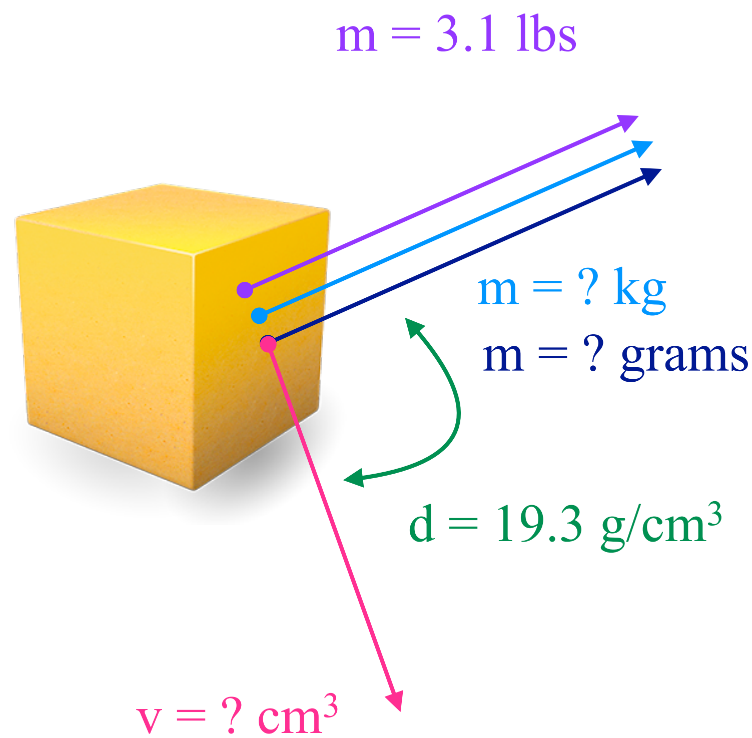
= 3,153,600,000 seconds

$$= \boxed{3.1536 \times 10^{9}\ \text{seconds}}$$

(knowledge being shared)

Dimensional Analysis

- Understanding how the properties of substances relate within and across dimensions allows chemists to make useful predictions.
- Dimensional Analysis let's us explore those relationship and share the knowledge that analysis produces.
- With dimensional analysis we can
  - move measurements between units systems, in the same dimension:
    - lbs → kg (with the measurement 1 kg = 2.2 lbs)
  - scale measurements within a unit system:
    - kg → g (with the definition k = 10^3)
  - predict the extent of related properties in different dimensions:
    - g → cm^3 (if I have the value of the property density)



Dimensional Analysis

- How many nm are there in 0.24 km?

$$0.24\,\text{Km} \cdot \frac{1\cdot 10^{3}\,\text{m}}{1\,\text{Km}} \cdot \frac{1\,\text{nm}}{1\cdot 10^{-9}\,\text{m}} \quad \boxed{= 2.4\times 10^{11}\,\text{nm}}$$

2 s.f. ∞ s.f. ∞ s.f. 2 s.f.

✦ you can link multiple factors
✦ for unit conversions always go through the base unit
✦ conversion factors within a unit system are defined

- A suitcase weights 32.4 lbs, what is the weight in grams?

$$32.4\,\text{lbs} \cdot \frac{1\,\text{kg}}{2.2\,\text{lbs}} \cdot \frac{1\cdot 10^{3}\,\text{g}}{1\,\text{kg}} = 14{,}727\,\text{g} = \boxed{1.5\times 10^{4}\,\text{g}}$$

3 s.f. 2 s.f. ∞ s.f. 2 s.f.

✦ conversion between unit systems are usually measurements — watch the significant figures!

- A pure gold pendent has a mass of 32.5 grams, what is it's volume in mL?

$$32.5\,\text{g Au} \cdot \frac{1\,\text{cm}^3\,\text{Au}}{19.30\,\text{g Au}} \cdot \frac{1\,\text{mL}}{1\,\text{cm}^3} = 1.6839\,\text{mL} = \boxed{1.68\,\text{mL Au}}$$

3 s.f. 4 s.f. ∞ s.f. 3 s.f.

✦ intensive properties are conversion factors
✦ conversion factors are reversible

Gold Rings

The price of gold is $48.91 per gram. How much would you have to spend to make seven rings that each use 0.0153 L of gold? Gold has a density of 19.3 g/mL.

Gold Rings

The price of gold is $48.91 per gram. How much would you have to spend to make seven rings that each use 0.0153 L of gold? Gold has a density of 19.3 g/mL.

2 strategy

1 sort

3 solve

4 check

Gold Rings

The price of gold is $48.91 per gram. How much would you have to spend to make seven rings that each use 0.0153 L of gold? Gold has a density of 19.3 g/mL.

$1\,g = \$48.91$

$1\text{ ring} = 0.0153\,L$

$1\,mL = 19.3\,g$

$1\,mL = 10^{-3}\,L$

Rings → L → mL → g → $

$$7\text{ rings} \cdot \frac{0.0153\,L}{1\text{ ring}} \cdot \frac{1\,mL}{10^{-3}\,L} \cdot \frac{19.3\,g}{1\,mL} \cdot \frac{\$48.91}{1\,g} =$$

$$= \$101{,}098.4373$$

$$= \$101{,}000$$

$$= \boxed{\$1.01\times10^{5}}$$

Faces in the crowd

A Blackjack shoe holds 8 decks of cards. If a casino has 92 gross of Blackjack shoes, how many royal cards (face cards) are in those shoes? (hint: a gross is a way of counting large numbers of things, there are 144 singles in a gross)

gross → shoe → deck → suit → face

3 faces = 1 suit

4 suits = 1 deck

8 decks = 1 shoe

144 singles = 1 gross

$$92 \text{ gross} \cdot \frac{144 \text{ shoe}}{1 \text{ gross}} \cdot \frac{8 \text{ deck}}{1 \text{ shoe}} \cdot \frac{4 \text{ suits}}{1 \text{ deck}} \cdot \frac{3 \text{ faces}}{1 \text{ suit}}$$

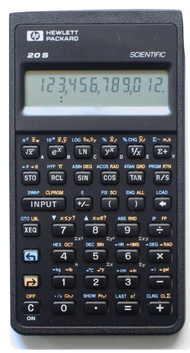
$= 1{,}271{,}808$ face cards

$\boxed{1.271808 \times 10^6 \text{ faces}}$

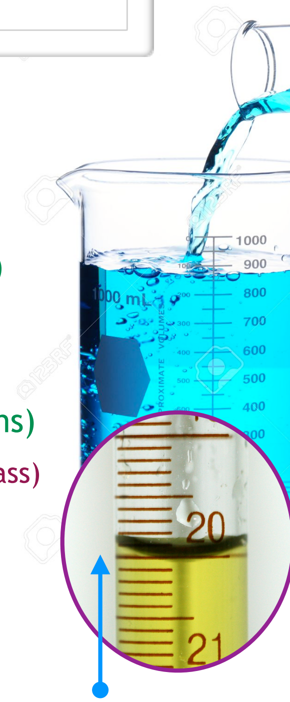
Ch01

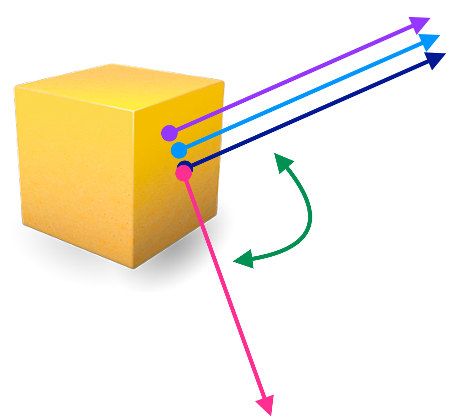
Measurement

- Dimensions
  - Measuring Properties
  - Standard Units
    - Imperial Units
- Representing Values
  - Scientific Notation
  - Calculators
    - Right calculator for this class
    - Using Scientific Notation
- Choosing Units
  - The SI Standard
  - Derived Units
    - Frequency, area, volume, speed…
  - Unit Prefixes



- Converting Factors & Labels
  - Within a dimension
    - Within the same system (scaling)
      - eg: cm → m → km
      - Volume and Liters
    - Between systems (bridging systems)
      - eg: pounds (mass) → kilograms (mass)
  - Between dimensions (bridging properties)
    - Bridging properties
      - eg: mass → volume
      - Density & Measuring by Difference
- Dimensional Analysis
  - Managing Conversions





Questions?