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

Quantitative observations.

Counting stones.

version 1.5

Science helps us to explore and expand the edges of our knowledge.
At the edge of our knowledge we know some things incompletely.

Imagine walking into a dark room with a table.

It's not always enough to know that a table exists in the room.
Before we try to set a box on the table
we need to know the limits of our knowledge.

How many inches exist in the width of the table.
How many feet exist in the distance between table and door.

Where we can say for certain the table exists,
where we can say for certain it doesn't,
and where we are uncertain.

Measurements are how we clearly express
the extent and limits of our knowledge.

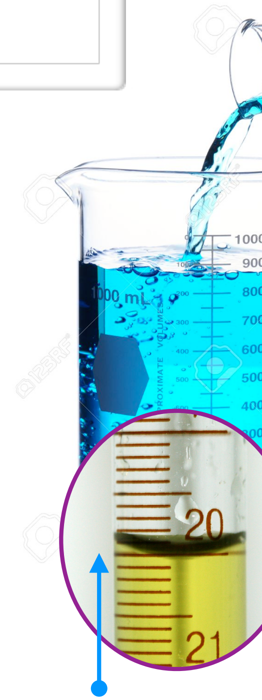
Ch01

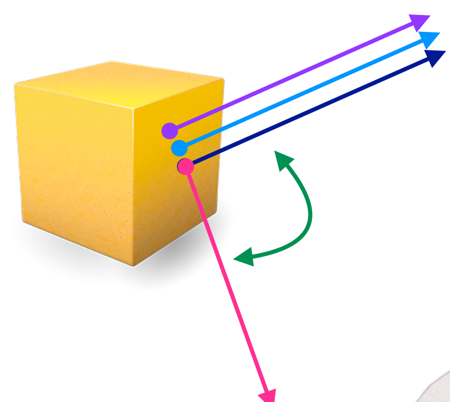
Measurement

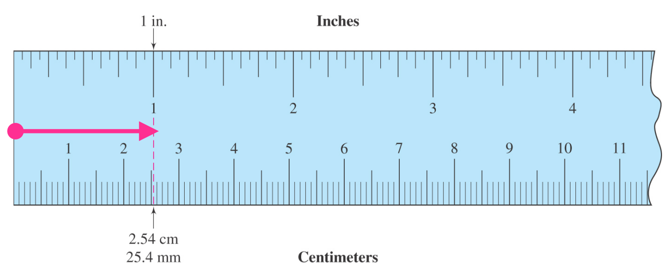
- Dimension
  - Quantifying Properties
  - Unit Standards
    - Imperial Units
  - Taking Measurements
    - Exact Numbers
    - Instrumentation
      - Precision & Accuracy
- Representation
  - Value
    - Significance & Uncertainty
      - Recording & Interpreting
    - Scientific Notation
    - Calculator Use
  - Unit
    - Seven SI Standard Units
    - SI Unit Prefixes
    - Derived SI Units
      - Density

unit

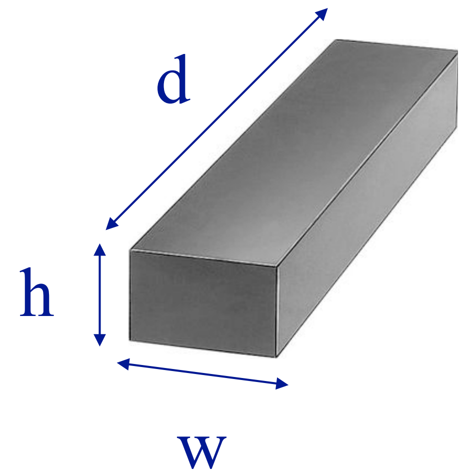
- Conversion
  - Conversion Factors
    - Within a dimension
      - Scaling a measurement
      - Bridging unit systems
    - Between dimensions
      - Jumping dimensions
  - Dimensional Analysis
    - Linking conversion factors
    - Justifying a claimed equivalence







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

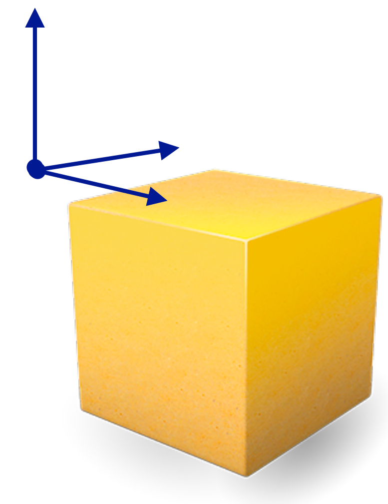
— Webster

Dimension

- Before we can measure, we need to consider the direction or dimension of the measurement.
- The property we are measuring.

- We can observe a sample extending in…
  - Height
  - Width
  - Depth

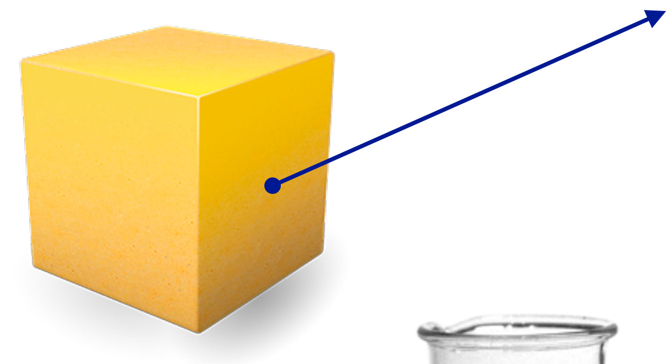
- Understanding samples of matter requires us to consider new dimensions.
  - Mass
  - Volume
  - Color
  - Temperature
    - These are the some of the dimensions we measure to empirically describe matter.



Measurement

- A measurement is a quantitative observation.
  (How far something extends into a particular dimension.)

- 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 answers: “how many?”
  - Label (the unit) — the non-numeric part answers: “of what?”

value

unit

53 gallons

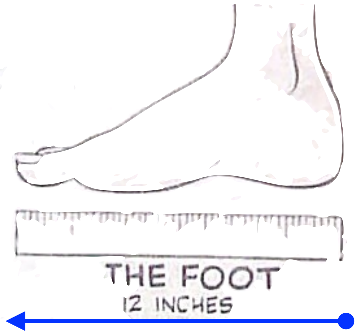
the measurement

65.7 mph

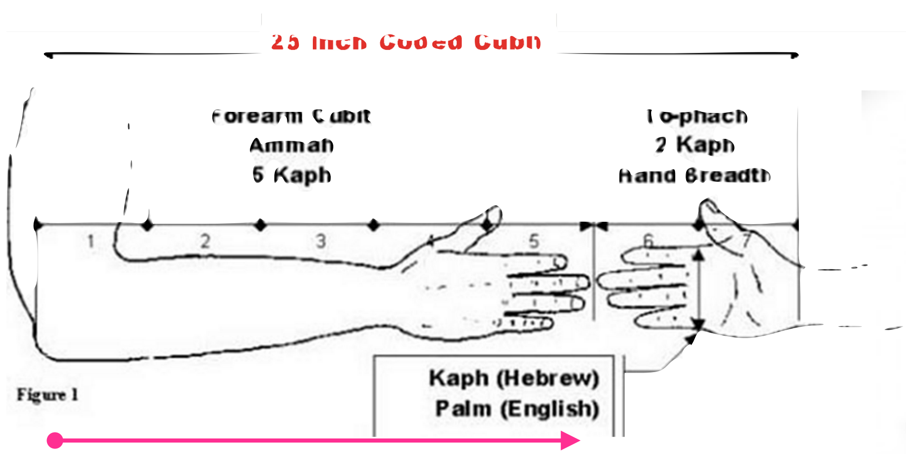
21.5 °C

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.

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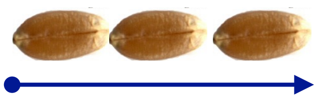

unit

- Conversion
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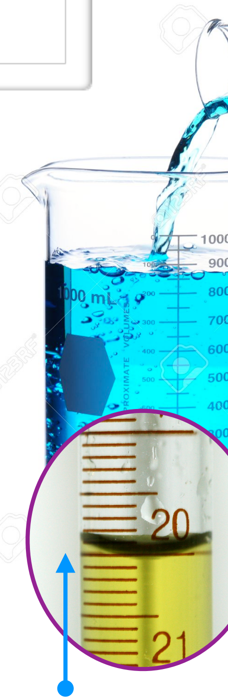
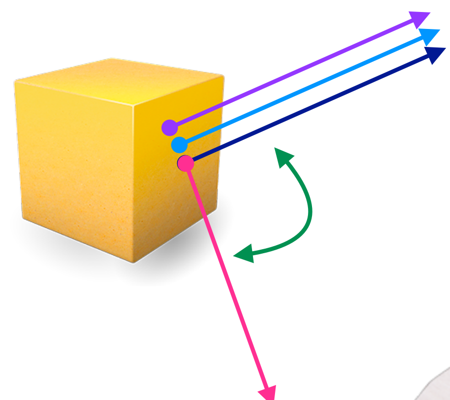
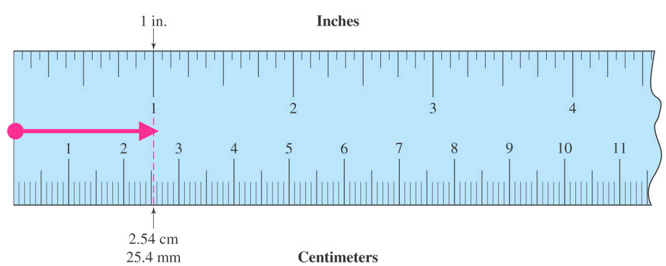




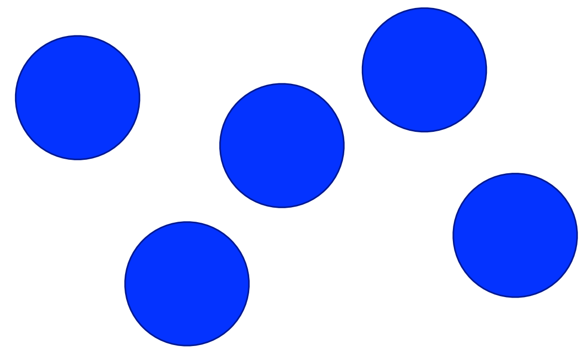


Exact Measurements

- When we make observations in the lab, we will try to report our observations quantitatively.
- When you are able to count discreet objects, your measurements will be exact.
    - How many dots on the page? 5 dots.
    - How many eggs in the box? 4 eggs.
    - How many people in the crowd? 5 people.

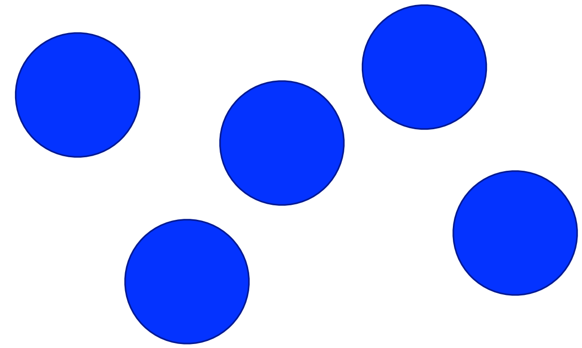
  - There is no uncertainty in these measurements. It's either 4 or 5.
  - We can be certain it's nothing in between.

- Measurements arrived at by counting operations are exact.



Exact Measurements

- Measurements arrived at by counting operations are exact.
- Defined measurements are also exact.
- One foot measures 12 inches. Exactly.
  - No foot, anywhere in the universe, contains even slightly more or less than exactly twelve inches.
  - *Because that's how a foot is defined.*



12 inches = 1 foot

$$12\frac{in}{ft}$$

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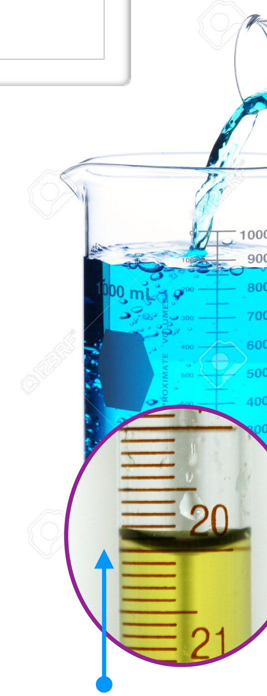
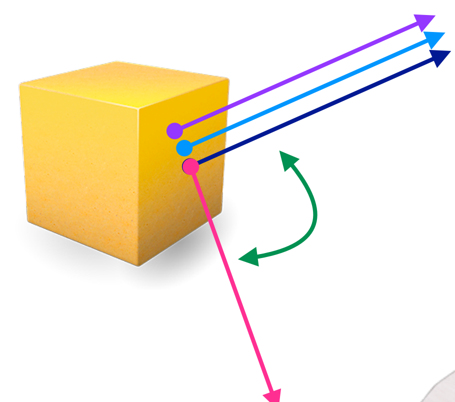
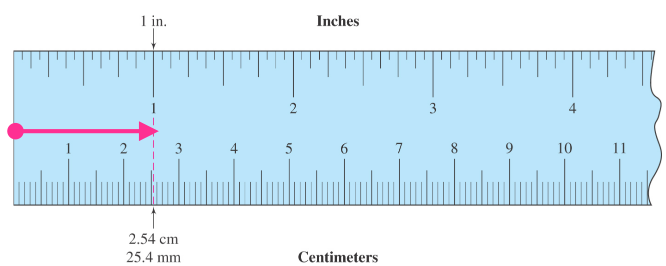






Precision

- Most measurements are not exact.
- When we try to determine how many grams or centimeters are in a penny, there is a limit to how certain we can be about that measurement.
- We could say that width contains…

1) The penny is 30 millimeters wide.

2) The penny is 31 millimeters wide.

3) The penny is 31.2 millimeters wide.

4) The penny is 31.2358053 millimeters wide.

Increasing Precision

Precision is the exactness or detail of a measurement.

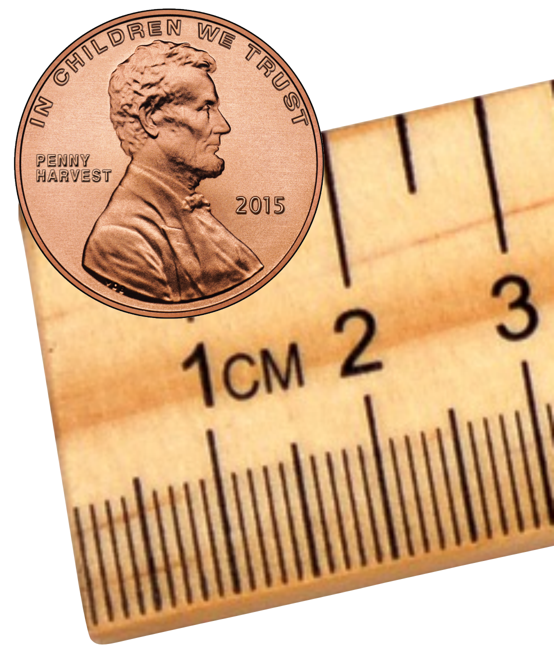
Precision is how many digits (figures) are in the measurement.

(using a ruler pennies measure to be 20 millimeters wide)

Let's talk about accuracy…

Accuracy

- Our goal is to find measurements we can believe are true.
- We trust a number if it can be verified.
- Accurate measurements are measurements that can be reproduced (and in that way verified).
- A measurement is accurate if it is consistently reproducible.



Accurate?

✓ 1) The penny has 20 millimeters in width.

✗ 2) The penny has 25 millimeters in width.

✓ 3) The penny has 19 millimeters in width.

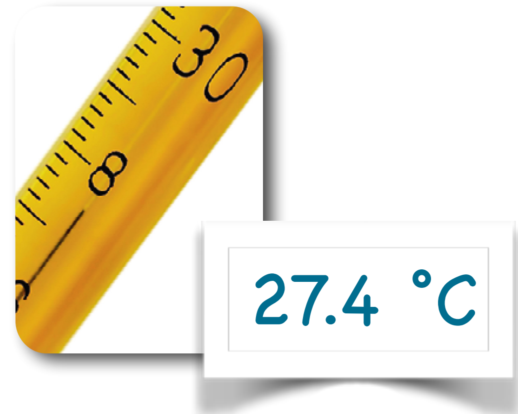
✓ 4) The penny has 19.5 millimeters in width.

✗ 5) The penny has 19.523789258 millimeters in width.

Always record the most precise measurements that is still accurate.

Taking Measurements

- Most measurements are not exact.
- Taking measurements means observing the number of units in the dimension you're considering.
- Then recording that measurement with the most precision (detail) you can offer, while still being accurate (reproducible).
- Most instruments have limits to how precisely they can offer accurate measurements.
- It's your job to know your instrument.
- We'll provide some rules to help.



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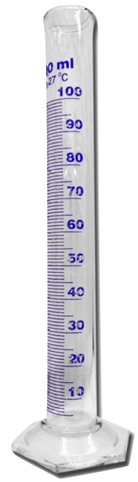
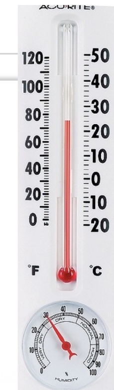




Analog

Digital


Recording Measurements

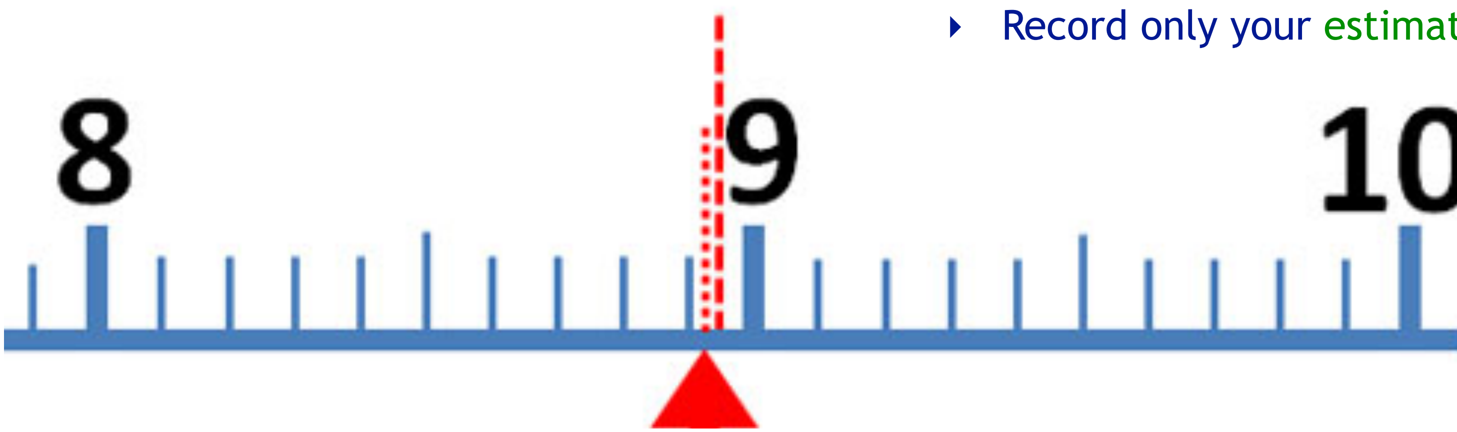
Measurements have three parts:

The part we're certain is true.

The part we're uncertain is true.

One figure that's uncertain but can be estimated.

8.94329 grams



- For a digital instrument, look for a fluctuating digit.

  (the one that flickers back and fourth between 5, 6, 7 …)
- That's where you need to estimate!
- Everything before that is certain.
- Everything after that is uncertain.
- Record only your estimate and what is certain.

- For an analog instrument, look at the divisions.

  (analog instruments are things like rulers, thermometers, flasks, etc)
- Each one has a smallest division.
- The place between the smallest divisions is where you need to estimate!
- Everything after that is uncertain.
- Record only your estimate and what is certain.

Recording Measurements

Measurements have three parts:

The part we're certain is true.

The part we're uncertain is true.

One figure that's uncertain but can be estimated.

significant | not significant

8.94|329 grams

The parts your are certain of and the estimated digit are all significant.

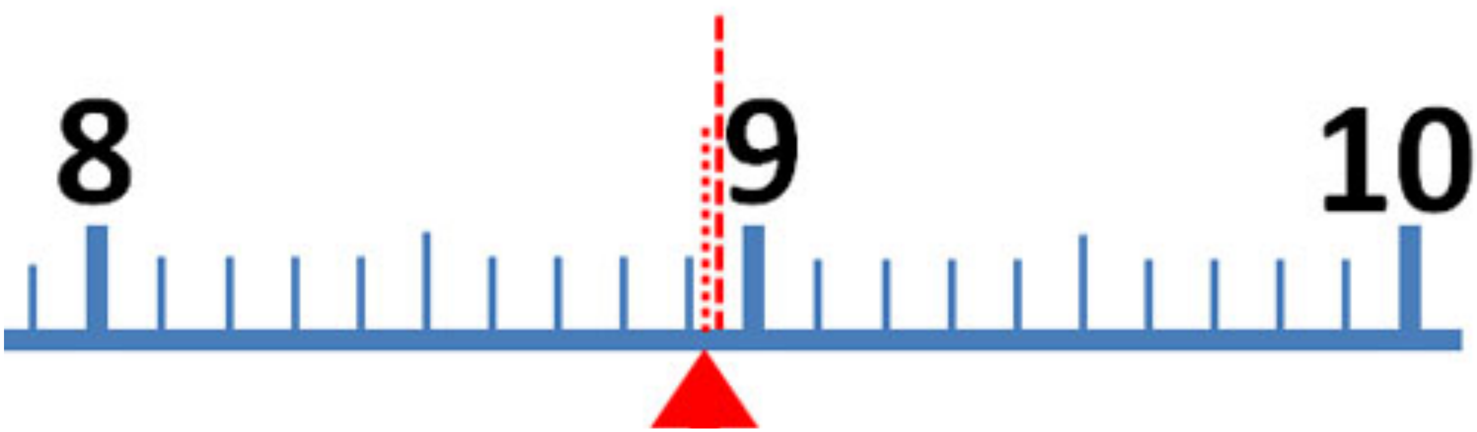
When making a measurement:

Always record all the significant digits in your observation.

This includes the estimated digit.

Record:

8.94 grams



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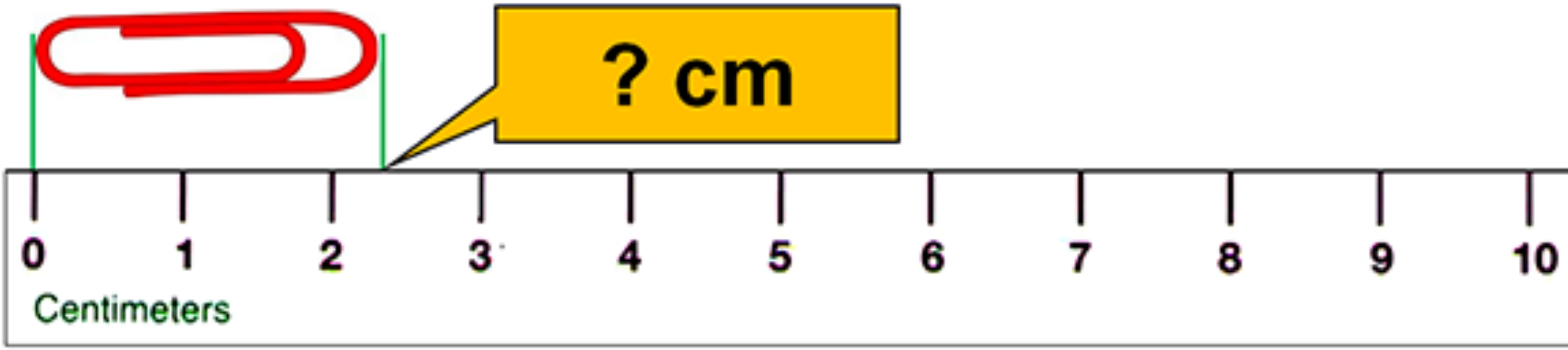
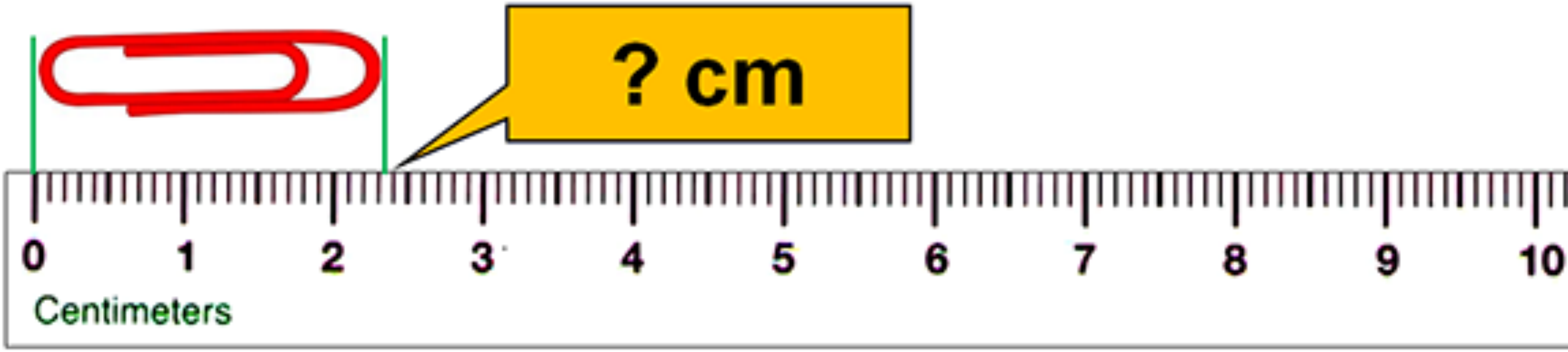


(A) 2 cm	(E) 2.5 cm	(I) 2.30 cm
(B) 3 cm	(F) 2.4 cm	(J) 2.40 cm
(C) 4 cm	(G) 2.3 cm	(K) 2.35 cm
(D) 2.9 cm	(H) 2.0 cm	(L) 2.350 cm

Recording Measurements



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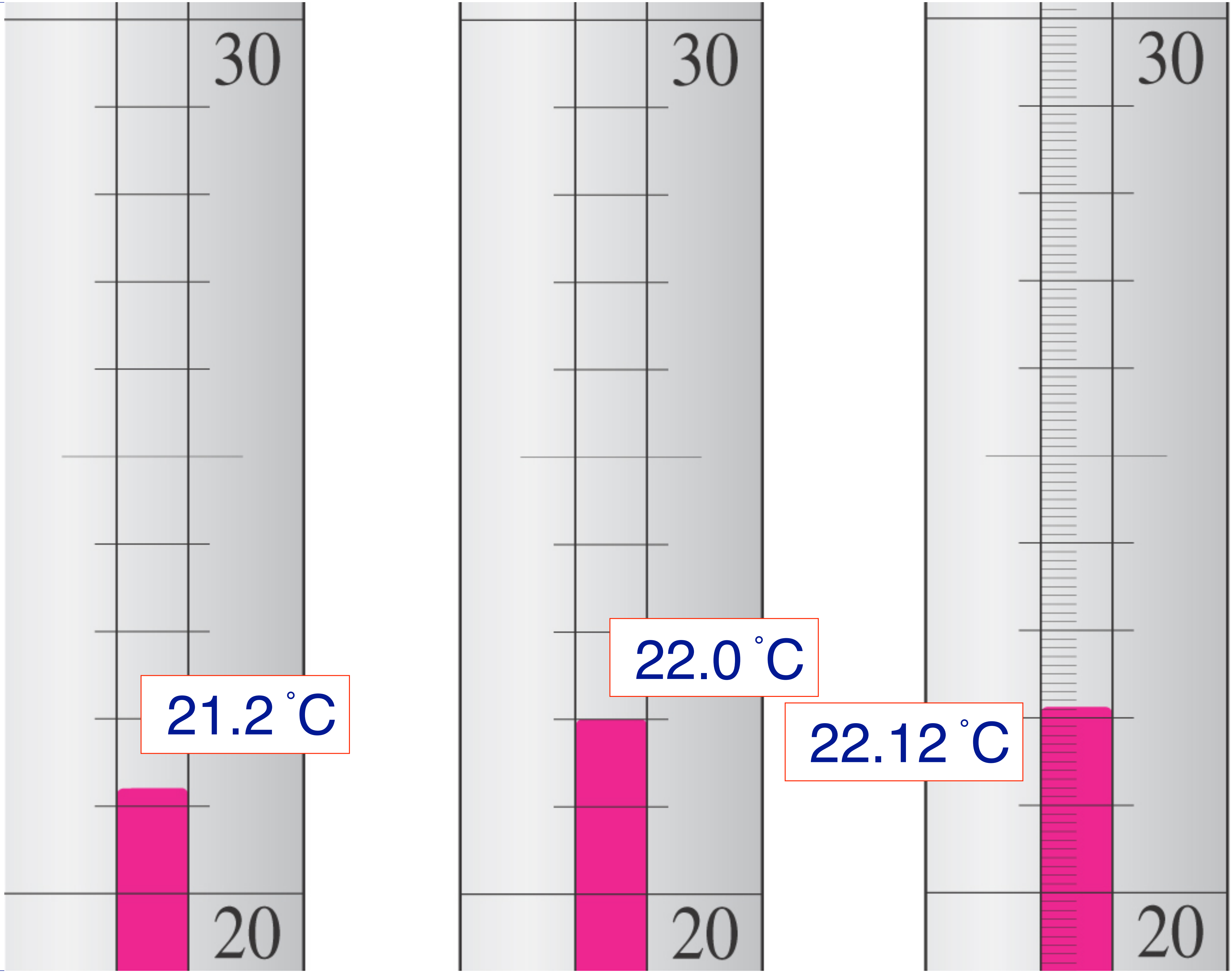
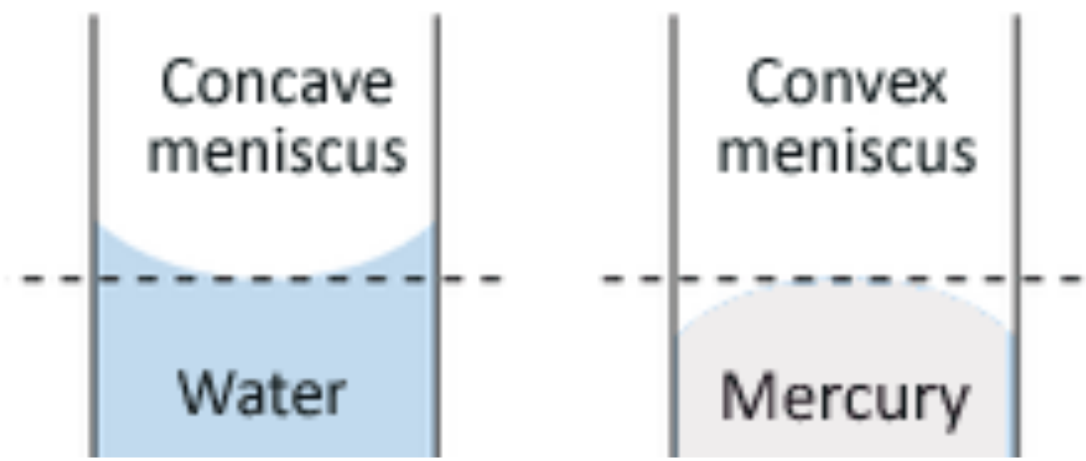
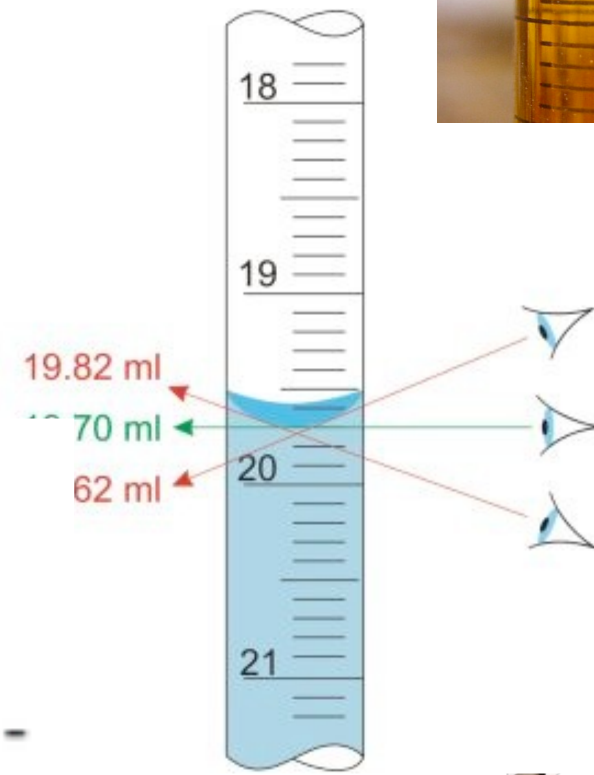

30
20
21.2 °C
30
20
22.0 °C
30
20
22.12 °C

A word about liquids…

- Liquids in thin tubes have curved surfaces.
- This curve can be up or down.
- It's caused by differences in attraction between the particles of the liquid and the container.
- A meniscus is the curved surface at the top of a liquid.
- When you read the volume of a liquid, the instrument will be calibrated so that you should read the apex of that curve.
- You should read the volume from eye level (don't raise the flask, move your head down to the surface of the counter).





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1.5782458 GRAMS

1.5783279 GRAMS

1.5782132 GRAMS

1.5783456 GRAMS

1.5781999 GRAMS

1.5783756 GRAMS

certain | uncertain

can estimate

Weight of my sample is: 1.5782 grams

The other digits are noise
-- they have no significance!

Ch01

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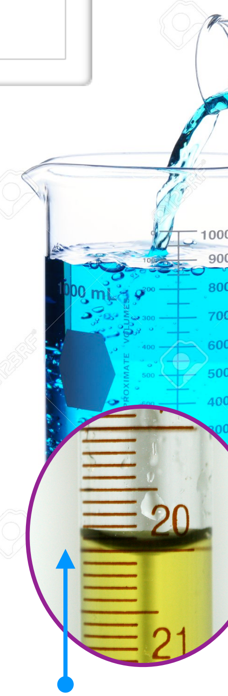

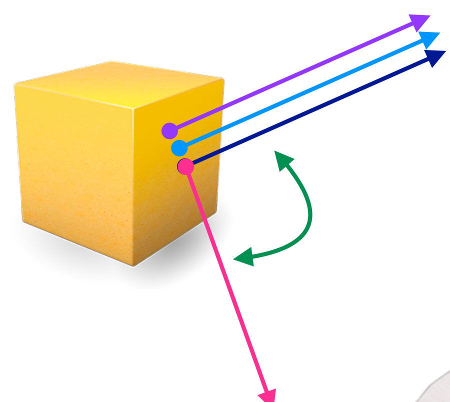

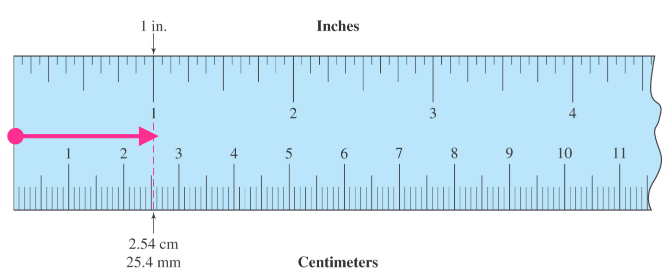

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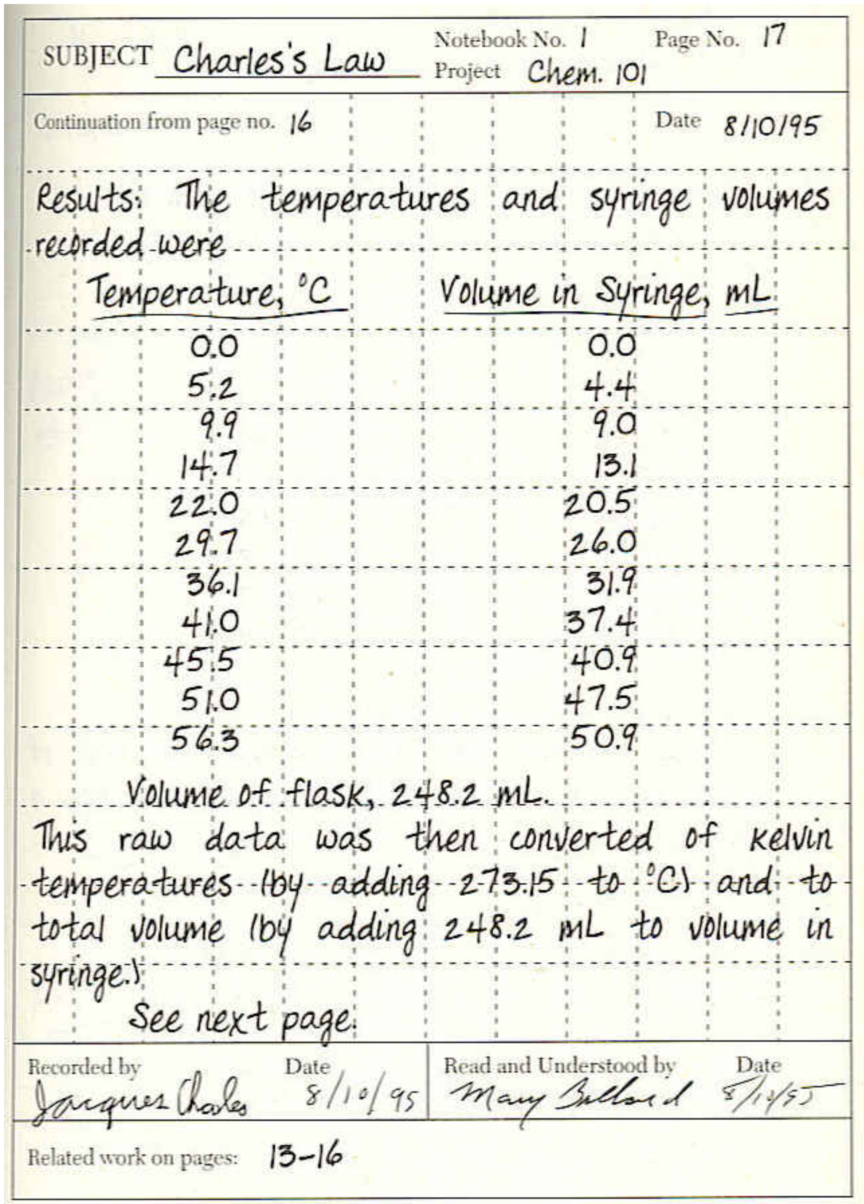
Representing Measurements



SUBJECT Charles's Law — Notebook No. 1 — Page No. 17
Project Chem. 101
Continuation from page no. 16 — Date 8/10/95

Results: The temperatures and syringe volumes recorded were

Temperature, °C	Volume in Syringe, mL
0.0	0.0
5.2	4.4
9.9	9.0
14.7	13.1
22.0	20.5
29.7	26.0
36.1	31.9
41.0	37.4
45.5	40.9
51.0	47.5
56.3	50.9

Volume of flask, 248.2 mL.

This raw data was then converted of kelvin temperatures (by adding 273.15 to °C) and to total volume (by adding 248.2 mL to volume in syringe.)

See next page.

Recorded by Jacques Charles — Date 8/10/95
Read and Understood by Mary Ballard — Date 8/11/95
Related work on pages: 13–16

- When you take a measurement you know what part to trust and what part not to.
- You know your instrument and how the measurement was taken.
- Science is a collaboration.
  - You will need to share your measurements with others and others will want to share theirs with you.
- It's important to be clear on the uncertainty in that measurement when you record it.
  - Record only the digits that are significant.

… and when you read what others recorded.

  - Trust only the digits written as significant.
- But that's not always enough.
  - There is a problem with zeroes.

A Problem with Zeroes

23,101,179 FEET

23,059,320 FEET

23,114,371 FEET

23,042,998 FEET

23,032,613 FEET

certain uncertain

23,000,013 FEET

23,000,011 FEET

23,000,002 FEET

23,000,009 FEET

23,000.001 FEET

certain uncertain

Length of sample A is: 23,000,000 feet

Length of sample B is: 23,000,000 feet

If you just see the final numbers,
you can't tell how many zeroes are significant
-- you can't tell how many zeroes to trust!

...oes

Length of sample A is: 23,000,000 feet

Length of sample C is: 23,000,000 feet

Length of sample B is: 23,000,000 feet

We need some rules to tell us how many digits to trust.

What digits to trust.

- When measurements are reported to you there may be ambiguity in whether the zeroes they contain are part of the measurement or just there to show you where the decimal point is.
- You need to be skeptical of zeroes.
- Use these rules to decide what digits you can treat as significant in a reported measurement.

1) All nonzero digits are significant.
2) A zero is significant when it is between nonzero digits.
3) A zero is not significant when it is before the first nonzero digit.
4) A zero is not significant when it is at the end of a number *without a decimal point.*

What digits "are significant"

1) All nonzero digits are significant.

6.17 °C

46.2 miles per hour

12,213 feet

175 gallons

There is no reason to write down any of those digits if the guy writing them didn't want to claim he was certain or at least making an estimate of that value.

So we assume any non zero digit is significant.

What digits "are significant"

2) A zero is significant when it is between nonzero digits.

1.07 °C

50.2 miles per hour

21,003 feet

105 gallons

None of these zeroes are needed to show where the decimal point is. The only reason to write these zeroes is to show a digit greater than 9 and less than 1.

So we assume a zero is significant when it's between two nonzero digits.

What digits "are significant"

3) A zero is not significant when it is before the first nonzero digit.

0.07 °C

.052 miles per hour

Zeroes before the first nonzero digit just exist to show us where the decimal point is. They are not significant to the measurement, they're just placeholders.

So we assume a zero is not significant when it's before the first nonzero digit.

What digits "are significant"

4) A zero is **not** significant when it is at the end of a number *without a decimal point.*

21,000 feet   100 gallons

Zeroes at the end of the number *could go either way*. They could have been measured or they could just be placeholders. We don't know, we can't trust them.

So we assume a zero at the end of a number is not significant, **UNLESS...**

What digits "are significant"

4) A zero is not significant when it is at the end of a number ***without a decimal point.***

1.00 °C

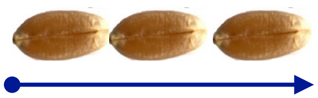
52.0 miles per hour

100. gallons

If the zeroes are not needed as placeholders or the decimal point wasn't needed, the guy must have written it for a reason — the zeroes must be significant.

So we assume a zero at the end of a number is significant, **if there is a decimal.**

Measurement



- Dimension
  - Quantifying Properties
  - Unit Standards
    - Imperial Units
  - Taking Measurements
    - Exact Numbers
    - Instrumentation
      - Precision & Accuracy
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  - Value
    - Significance & Uncertainty
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      - Density

unit

- Conversion
  - Conversion Factors
    - Within a dimension
      - Scaling a measurement
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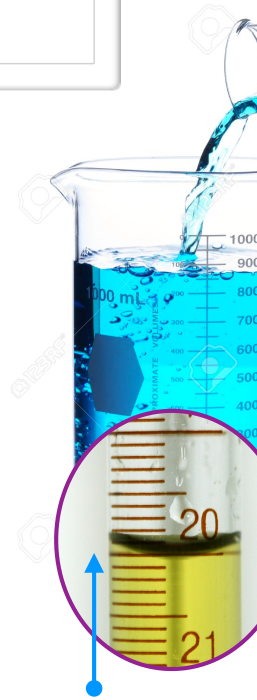

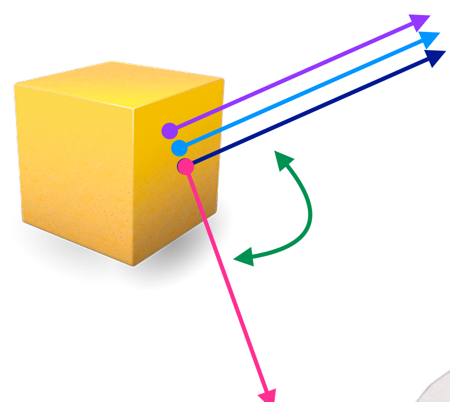

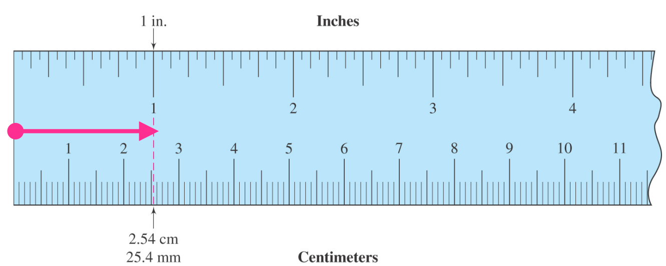

Scientific Notation

- 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)

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

five zeroes

five "x 10's"

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 x 10 x 10 x 10 x 10 x 10 x 10 x 10

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.
- Values expressed in scientific notation have three parts:
  - Sign
  - Significand
    - **The decimal is always placed after the first non-zero digit.**
  - Exponential
- But this is not an equation, it's a single value (more on that coming up).

sign

exponential term

-4.70×10^{-2} mL

significand
(or decimal term or mantissa)

In scientific notation all zeroes in the significant are necessarily significant.

Scientific notation expresses significant figures with more clarity.

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 mL → 5.3×10^{-2} mL

320 grams → 3.2×10^{2} 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 → 1.7×10^{-2} °C

12,213 feet → 1.2213×10^{4} feet

2100 gallons → 2.1×10^{3} gallons

210.0 mph → 2.100×10^{2} mph

Measurement

- Dimension
  - Quantifying Properties
  - Unit Standards
    - Imperial Units
  - Taking Measurements
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    - Instrumentation
      - Precision & Accuracy

unit

- Representation
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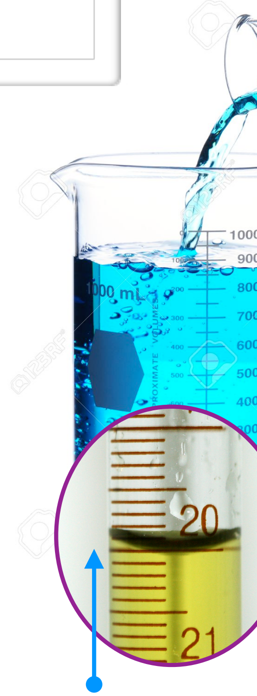
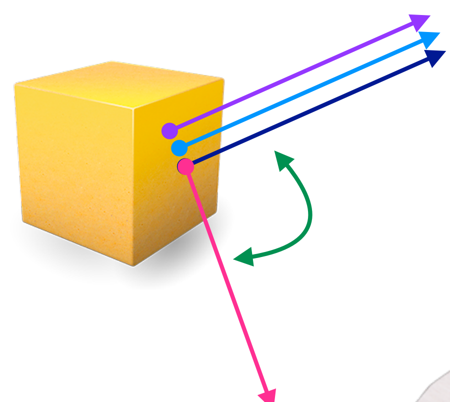
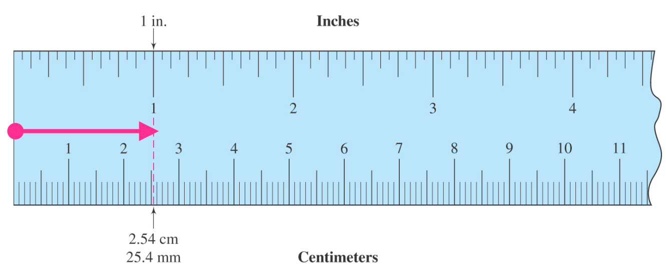
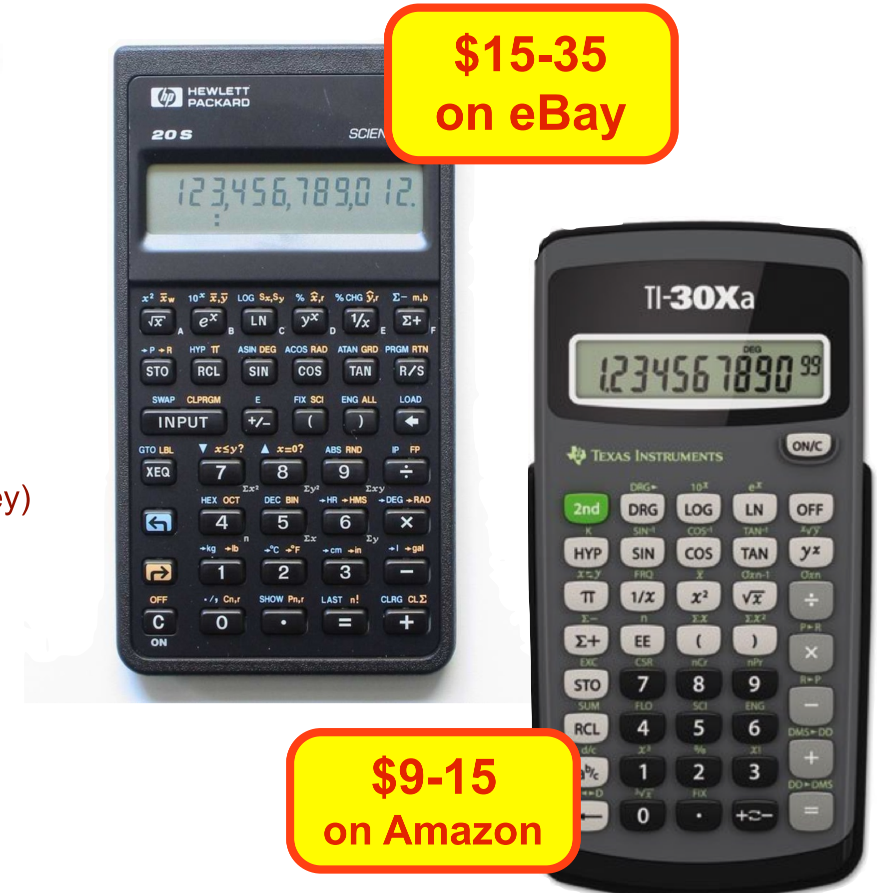






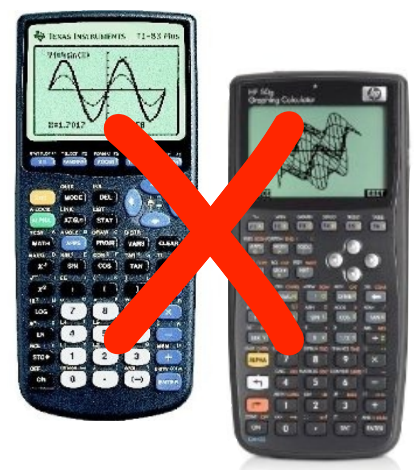
A simple scientific calculator is best.

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



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 *know how to use it well*, it's acceptable.



Cell phones/PDAs are not acceptable.

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

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

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

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1 bid

Free shipping

Entering Scientific Notation

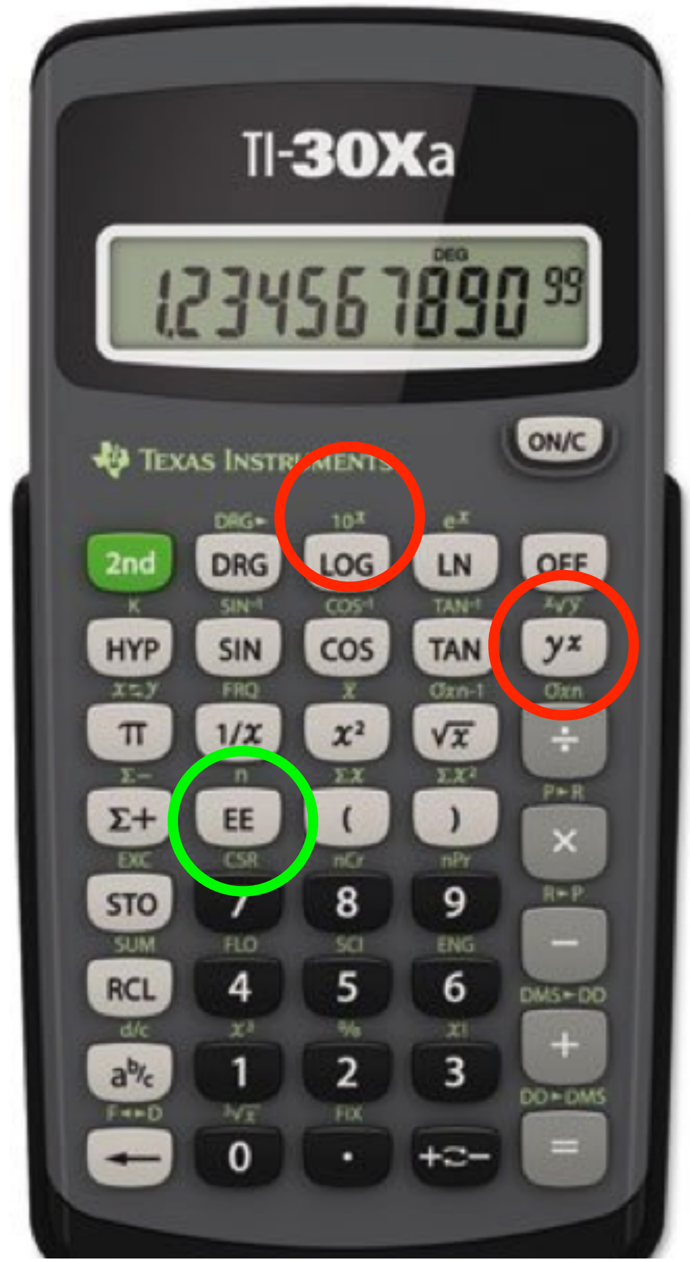
- There is one key on your calculator for entering scientific notation.
- It will have one of these symbols on it:

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.



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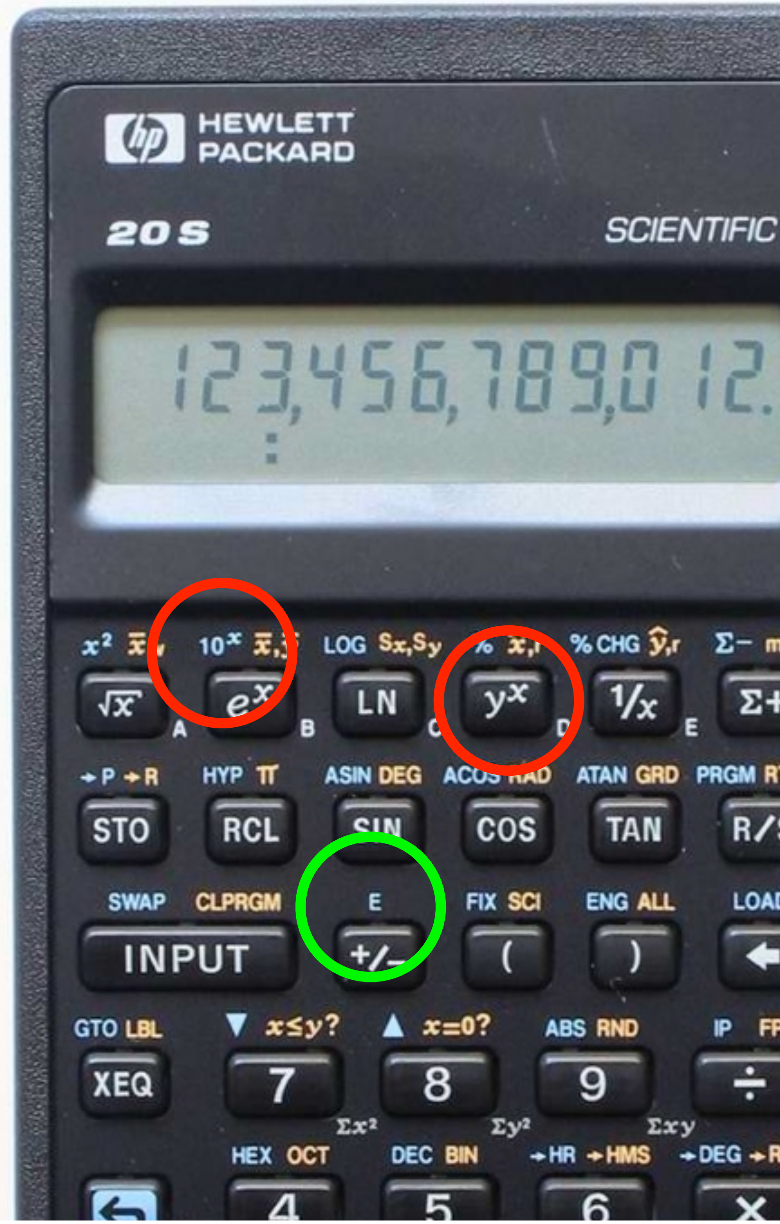


Checking your calculator

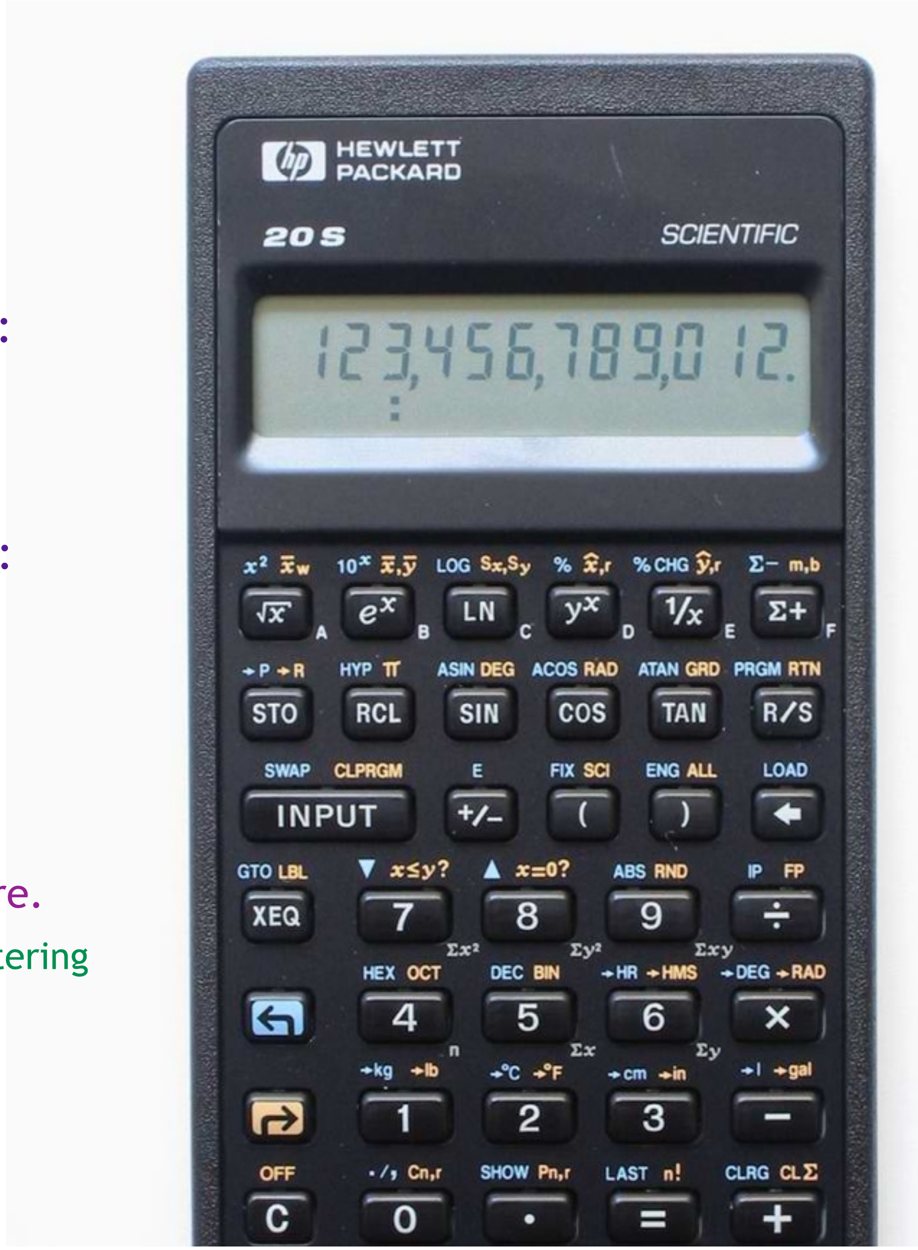
- Enter 2.5 x 10^4 into your calculator.
- To do this type “2.5 E 4” and then hit enter or equals. Look at the result.
- You did it right if your your calculator responds:

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 5x10^3 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:

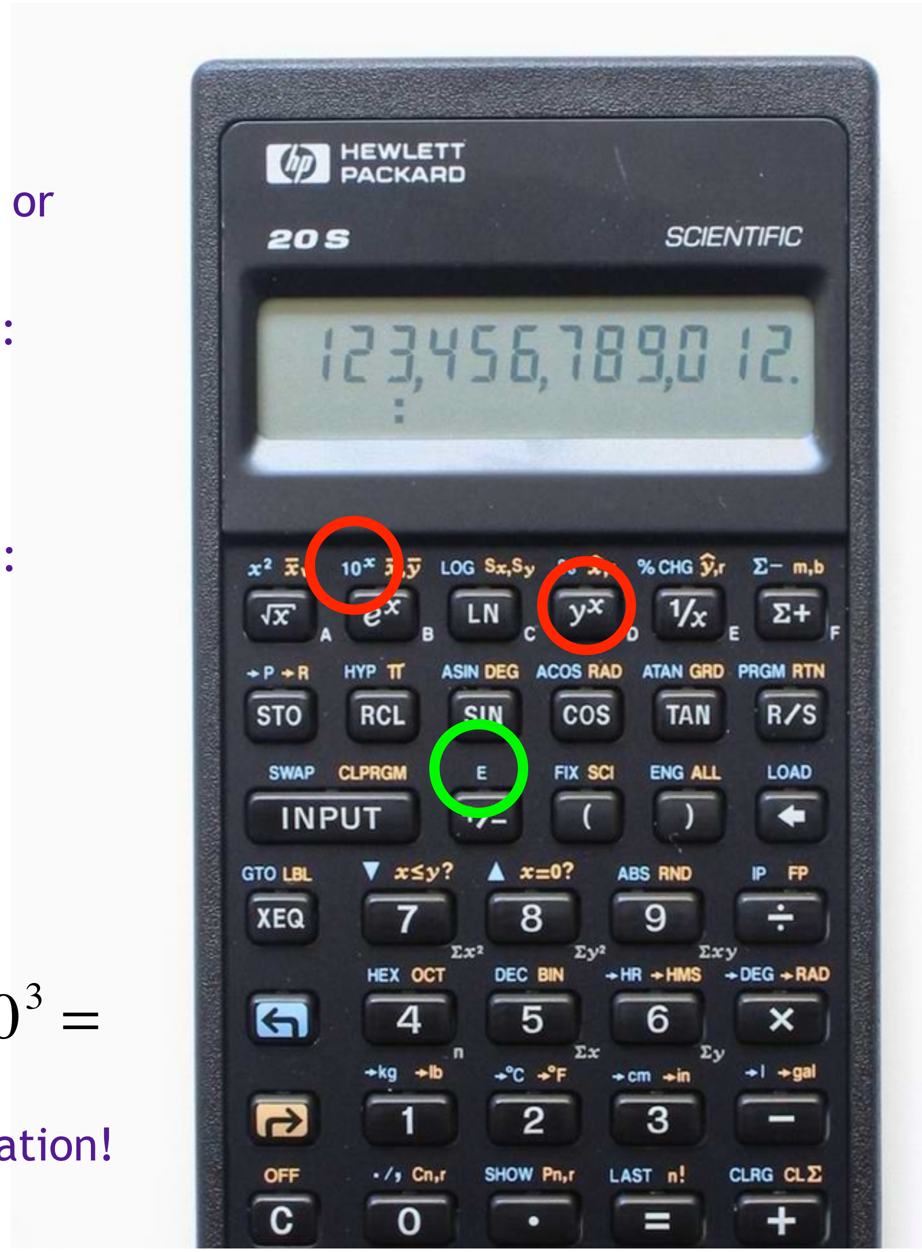
0.00416 or 4.16E-3

- You made a mistake if your calculator responds:

4,160

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

There is only one key that works for scientific notation!



Checking your calculator

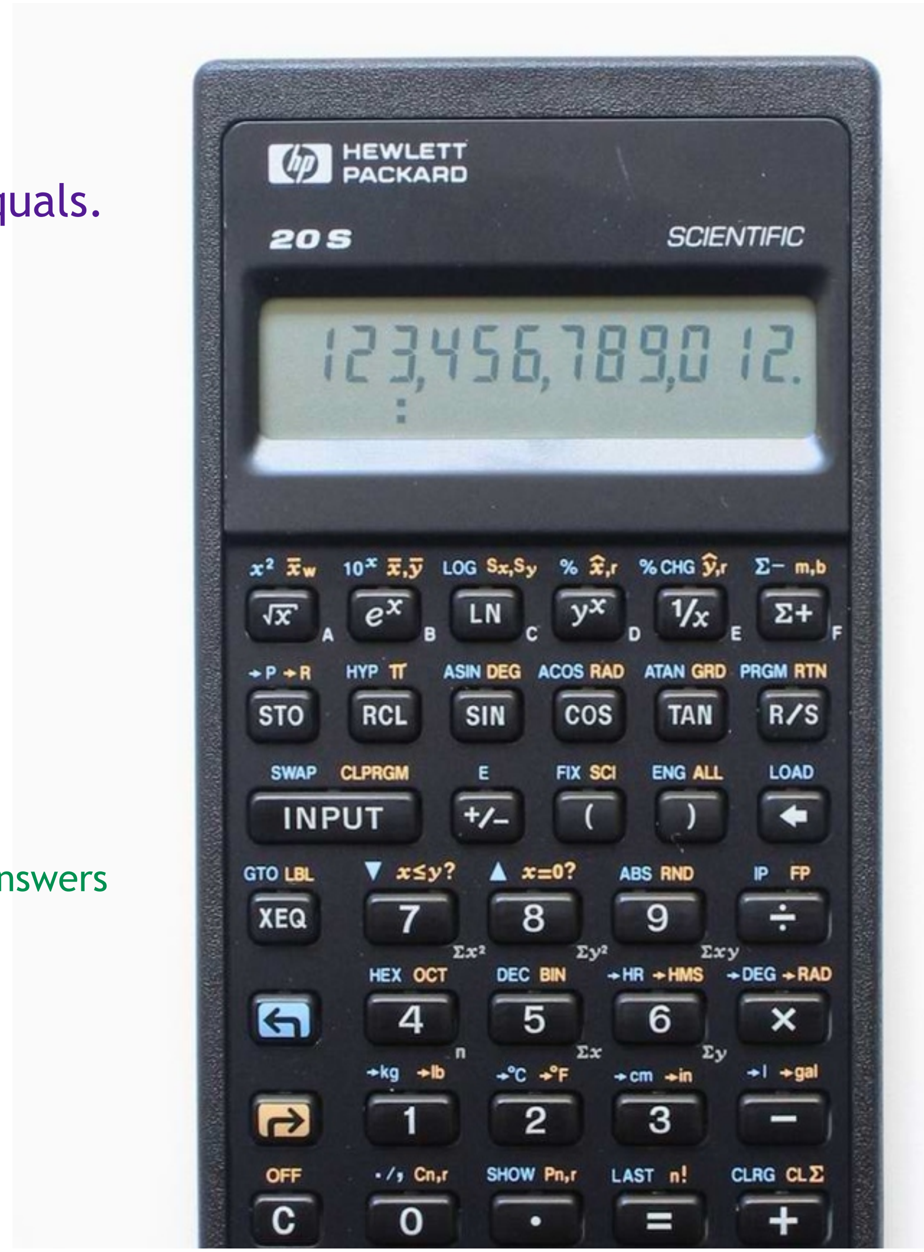
- Divide 1 by 3 with your calculator.
- To do this type “1 ÷ 3” and then hit enter or equals. Look at the result.
- You’re good if your your calculator responds:

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!



Rounding off the Noise

- Your calculator doesn't know if the number you entered is exact or a measurement with finite significant figures — there's no way of telling the calculator.
- The calculator assumes everything is exact, it assumes the 10 you typed is exactly 10 with infinite significant figures. Not 10 or 10.0 or 10.0000.
- So the calculator often reports extra digits that we know cannot be trusted.
- It is necessary to drop these extra digits so as to express the answer to the correct number of significant figures.
- When digits are dropped, the value of the last digit retained is estimated by a process known as rounding off numbers.

Rounding Off the Estimated Digit

- Rule 1. When the first digit after those you want to retain is 0,1,2,3 or 4 — that digit and all others to its right are dropped. The last digit retained is not changed.
- Rule 2. When the first digit after those you want to retain is 5, 6, 7, 8 or 9 — that digit and all others to its right are dropped. The last digit retained is increased by 1.

53

Rounding Off the Estimated Digit

- Rule 1. When the first digit after those you want to retain is 0,1,2,3 or 4 — that digit and all others to its right are dropped. The last digit retained is not changed.
- Rule 2. When the first digit after those you want to retain is 5, 6, 7, 8 or 9 — that digit and all others to its right are dropped. The last digit retained is increased by 1.

round to 3 significant figures

0.017534 → 0.0175

12,213 → 12200 or 1.22×10^4

12,257 → 12300 or 1.23×10^4

92.168246 → 92.2 or 9.22×10^1

Rounding Off the Estimated Digit

- Rule 1. When the first digit after those you want to retain is 0,1,2,3 or 4 — that digit and all others to its right are dropped. The last digit retained is not changed.
- Rule 2. When the first digit after those you want to retain is 5, 6, 7, 8 or 9 — that digit and all others to its right are dropped. The last digit retained is increased by 1.

round to 3 significant figures

100.235 → ~~100~~ 100. ✔

82,035 → ~~82,000~~ or ~~82,000.~~

8.20×10^4 ✔

Sometimes the **only** way to show the correct sig figs is with scientific notation.

So where do we round off?

to keep our sig figs accurate

- Multiplication & Division
  - The answer must contain the same number of significant figures as in the measurement that has the least number of significant figures.

$$17 \times 42 \times 6.349 = 4{,}533.186$$

$$17 \times 42 \times 6.25 = 4{,}462.5$$

2 s.f. 2 s.f. 2 s.f.

$$17 \times 42 \times 6.3 = 4{,}498.2$$

$$= 4.5 \times 10^3$$

2 s.f.

- Addition & Subtraction
  - The results of an addition or a subtraction must be expressed to the same precision as the least precise measurement.

same thing said another way:

  - The result must be rounded to the same number of decimal places as the value with the fewest decimal places.

```
   17
   42
+   6.3
-------
   65.3
```

= 65

```
   16.5
   42
+   6.3
-------
   64.8
```

+&− has different rules than ×&÷

So where do we round off?

to keep our sig figs accurate

$+$ & $-$
has different rules than
$\times$ & $\div$

- Compound Operations
  - If the equation has both multiplication/division and also has addition/subtraction carefully follow the order of operations from basic Algebra:
    - Rule 1: First perform any calculations inside parentheses.
      - Anything above or below a fraction bar is always in parenthesis.
      - Anything raised to a power is always in parenthesis.
    - Rule 2: Next perform all multiplications and divisions, working from left to right.
    - Rule 3: Lastly, perform all additions and subtractions, working from left to right.

$$\frac{a+b}{c}\times\left(a^3-d\right)$$

$$\frac{\left(a+b\right)}{c}\times\left(\left(a^3\right)-d\right)$$

Ex 1: $(53.6+79.4)\times 1.503 =$

$(53.6+79.4)\times 1.503$

$= 133.0 \times 1.503$

$= 199.899$

$= \boxed{199.9}$

$$\begin{array}{r} 53.6 \\ +\ 79.4 \\ \hline 133.0 \end{array}$$

Ex 2: $\dfrac{4{,}424}{17.9-15.7} =$

$\dfrac{4{,}424}{17.9-15.7} = \dfrac{4{,}424}{2.2}$

$$\begin{array}{r} 17.9 \\ -\ 15.7 \\ \hline 2.2 \end{array}$$

$= 2010.9$

$= \boxed{2.0\times10^3}$

Problem:

The following are measured numbers. What is the product of 190.6 and 2.3?

+ & −

has different rules than

× & ÷

Solution

4 sf. 2 s.f.

$190.6 \times 2.3 = 438.38$

keep 2 sf. drop these

$= 440$ or 4.4×10^2

Problem:

The following are measured numbers.
What is the sum of 125.17, 129 and 52.2?

+ & −
has different rules than
× & ÷

Solution

$$
\begin{array}{r}
125.17 \\
129 \\
+\ 52.2 \\
\hline
306.37
\end{array}
$$

$$\boxed{= 306}$$

Problem:

The following are measured numbers. Calculate $\frac{15.035 - 14.966}{3.825}$

+ & − has different rules than × & ÷

Solution

$$\frac{15.035 - 14.966}{3.825} = 0.01803922$$

STEP 1:

$$\begin{array}{r} 15.035 \\ -\ 14.966 \\ \hline 0.069 \end{array}$$

STEP 2:

$$\frac{0.069}{3.825} = 0.01803922$$

$$= 0.018 \text{ or } 1.8 \times 10^{-2}$$

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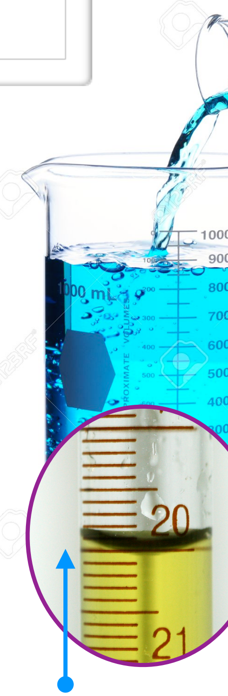
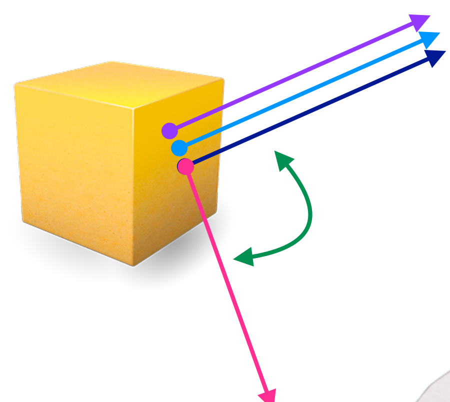
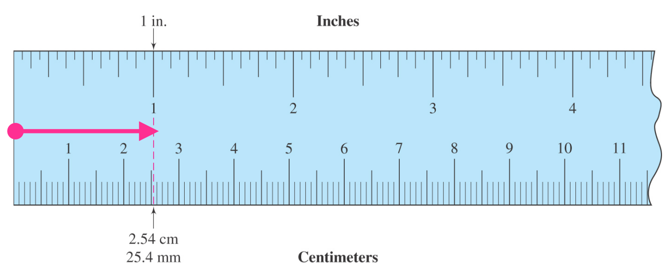




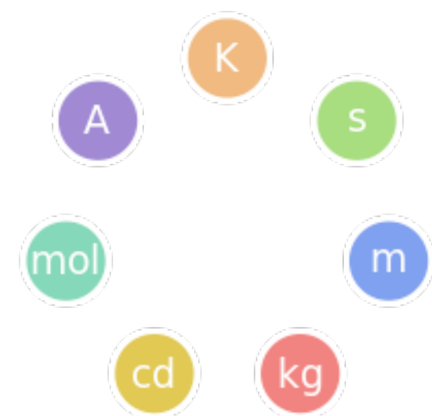


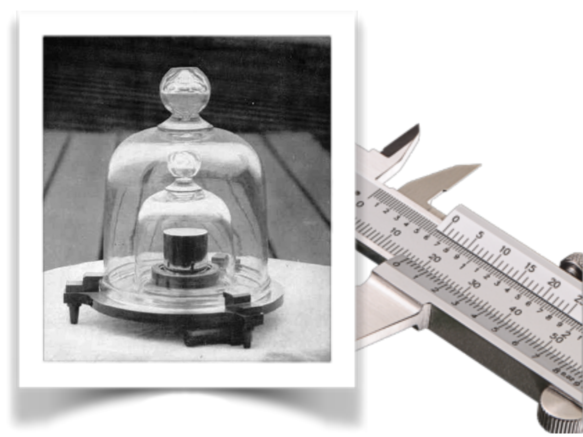
Système International (SI) Units

- 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 (length)
    - kilogram (mass)
    - second (time)
    - kelvin (temperature)
    - mol (count)
    - ampere (current)
    - candela (brightness)
  - Six of these seven units are based on physical constants — so no “village” stone is required.
  - The Kg is the one exception. A standard Kilogram is still maintained in Paris France (as of 2015).

SI

International System of Units





Base Units of SI

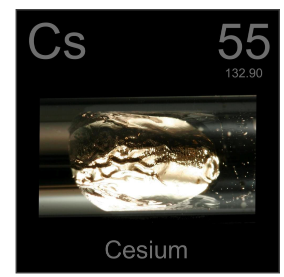
The SI (system international) system provides units for just about everything we measure. All those units are built on just seven fundamental (base) units — standard units.

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.

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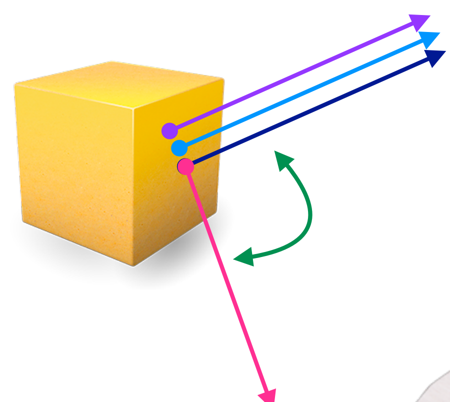
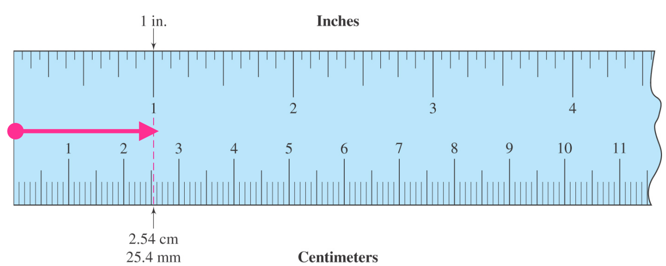




SI Prefixes

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)

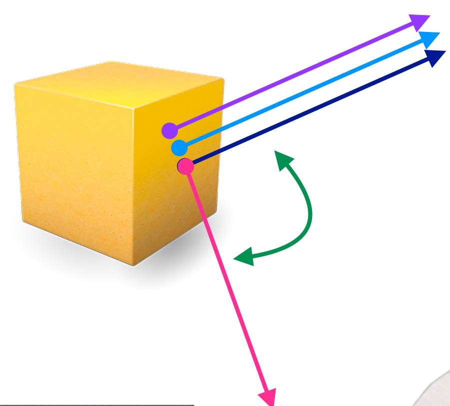
nine nano

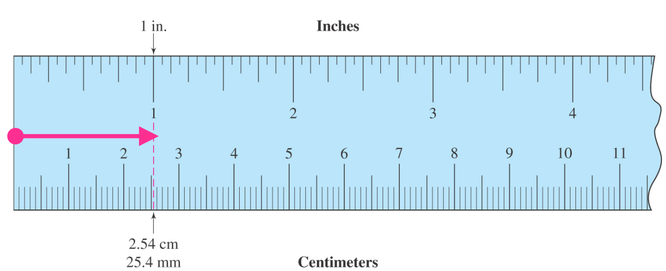
fifteen femto

Measurement

- Dimension
  - Quantifying Properties
  - Unit Standards
    - Imperial Units
  - Taking Measurements
    - Exact Numbers
    - Instrumentation
      - Precision & Accuracy
- Representation
  - Value
    - Significance & Uncertainty
      - Recording & Interpreting
    - Scientific Notation
    - Calculator Use
  - Unit
    - Seven SI Standard Units
    - SI Unit Prefixes
    - Derived SI Units
      - Density

- Conversion
  - Conversion Factors
    - Within a dimension
      - Scaling a measurement
      - Bridging unit systems
    - Between dimensions
      - Jumping dimensions
  - Dimensional Analysis
    - Linking conversion factors
    - Justifying a claimed equivalence

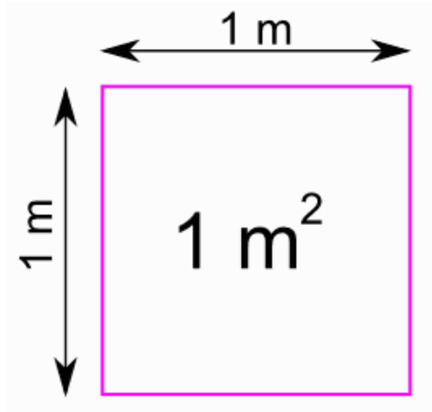




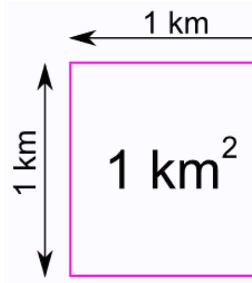
Derived SI Units

- 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.

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

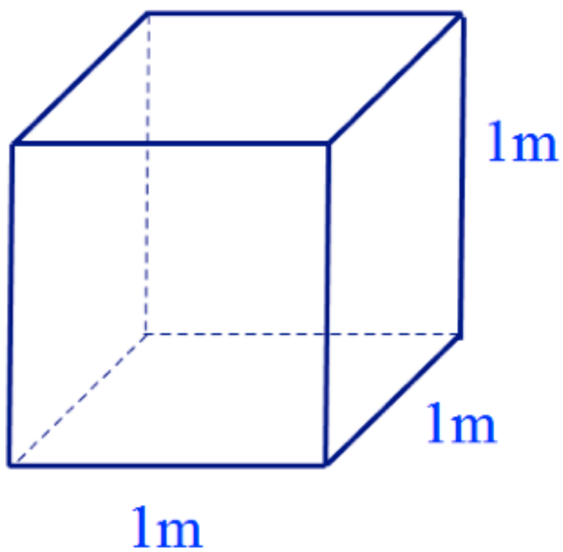


	SI derived unit	
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
mass density	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
current density	ampere per square 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



Derived SI Units

- Volume uses derived units.
- A unit of volume is a cubic meter (m^3)
  - There is no golden cubic meter.
    - We don't need one.
  - We have a perfect reference for a meter, we can always derive make that golden 1 m^3 by considering a box that is exactly 1 meter on each side.



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	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
coulomb	C	-	$s \cdot A$
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	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
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	$cd \cdot sr$ [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.

Ch01

Measurement

- Dimension
  - Quantifying Properties
  - Unit Standards
    - Imperial Units
  - Taking Measurements
    - Exact Numbers
    - Instrumentation
      - Precision & Accuracy
- Representation
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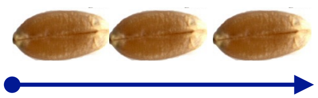

unit

- Conversion
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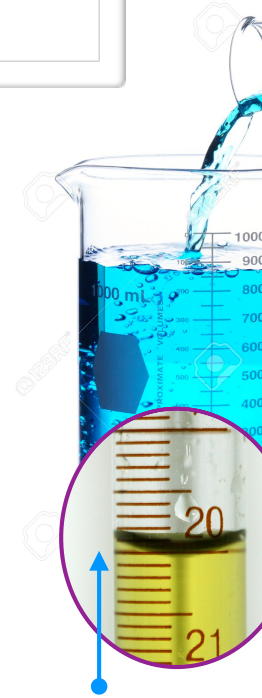
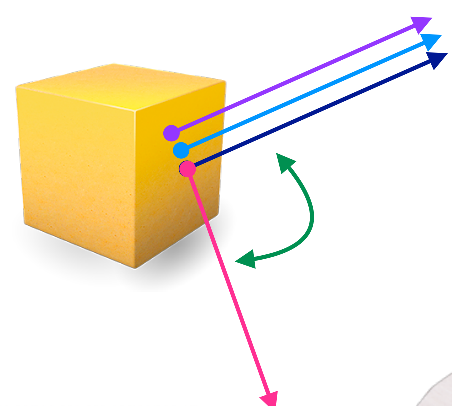
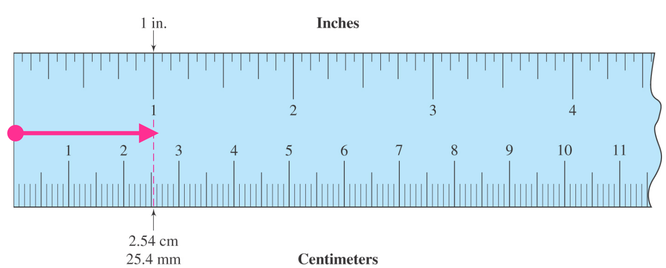
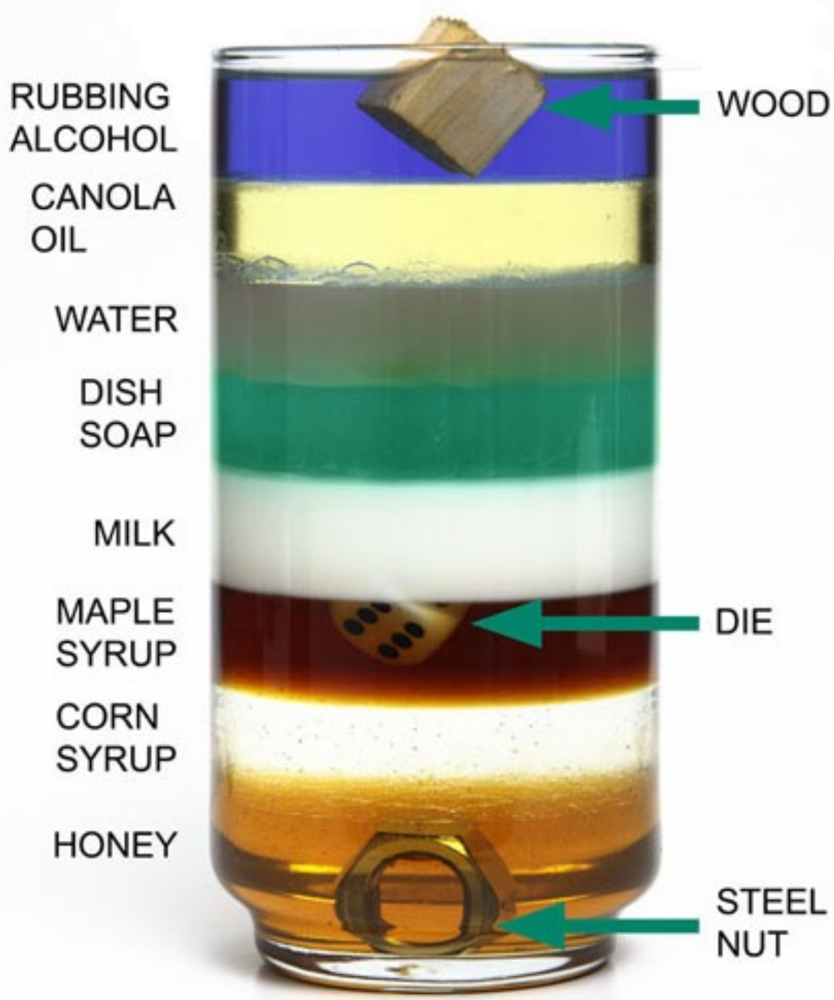






Density



- 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.

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

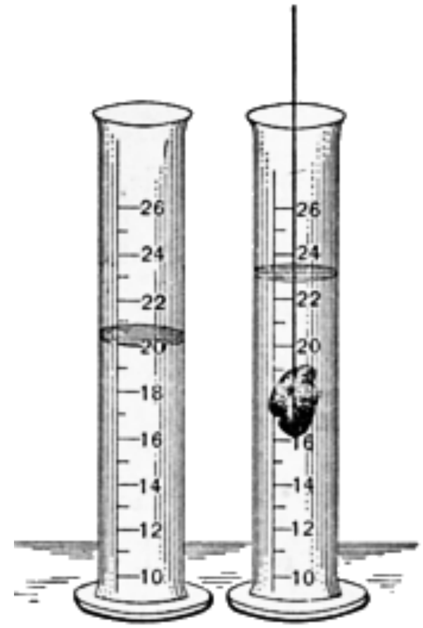
- Density is related to buoyancy, less dense substances will float on more dense substances.
- The units of density are derived units:
  - The density of solids is given in units of g/cm^3.
  - The density of liquids is usually reported in g/mL.
- We have no instrument for measuring density, it's value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

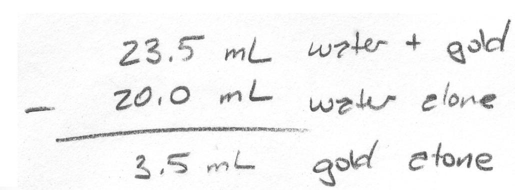
Measuring by Difference

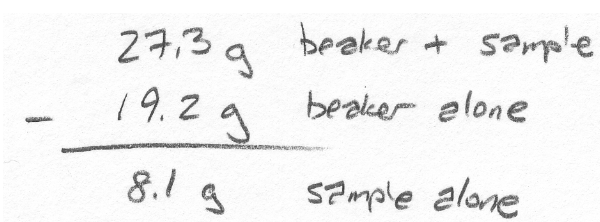
- Iron pyrite and gold have many similar properties, but gold has a remarkably unique density.

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

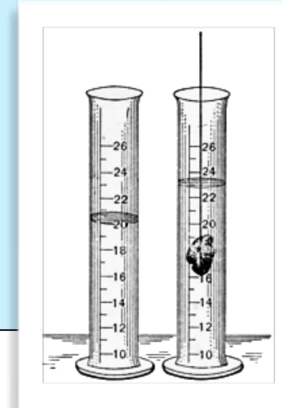
- During the gold rush, prospectors would identify gold by it's density.
- They would measure the mass and volume of a nugget, then divide them to find the objects density.
- Mass was easy to measure, they'd just set the nugget on a scale.
- For the volume of a solid it's easiest to measure volume using 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.







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?

m = 63.88 g
V = 3.31 mL

① Find the volume

$$\begin{array}{r} 23.31 \text{ mL} \\ -\ 20.00 \text{ mL} \\ \hline 3.31 \end{array}$$

V = 3.31 mL

② Find the Density

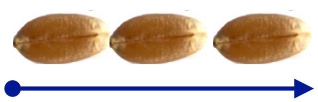
$$d = \frac{m}{V} = \frac{63.88\text{ g}}{3.31\text{ mL}}$$

$$= 19.299093\text{ g/mL}$$

(a) = 19.3 g/mL

(b) The rock is gold.

Measurement



- Dimension
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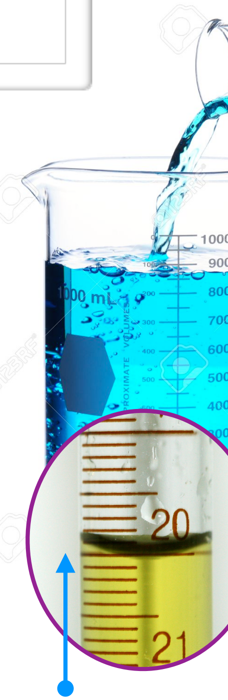
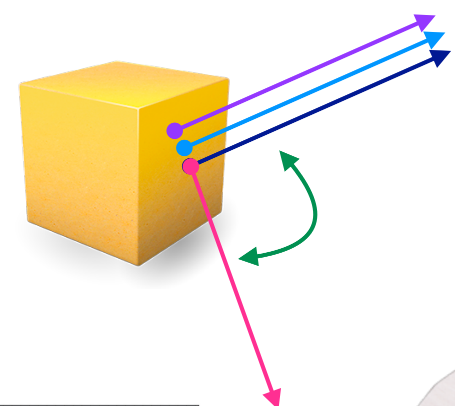
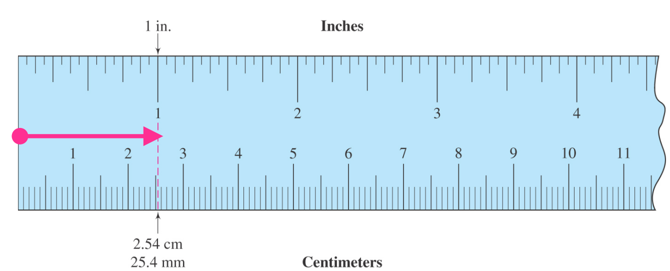
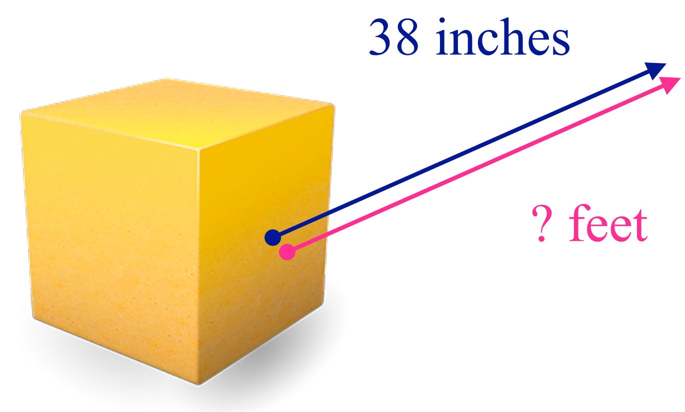




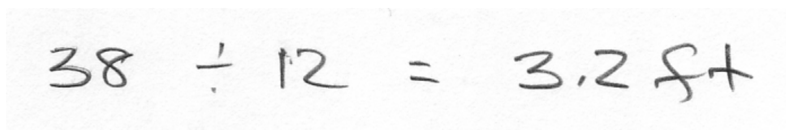


Converting Measurements

- 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.



- 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.

Using a conversion factor.

- How many feet are there in 906 inches?

75.5 inches

$$\frac{906}{12} = 75.5 \text{ inches}$$

$$906 \text{ inches} = 906 \text{ in} \cdot 1$$

$$= 906 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}}$$

$$= \boxed{75.5 \text{ in.}}$$

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

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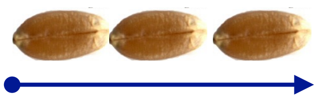

unit

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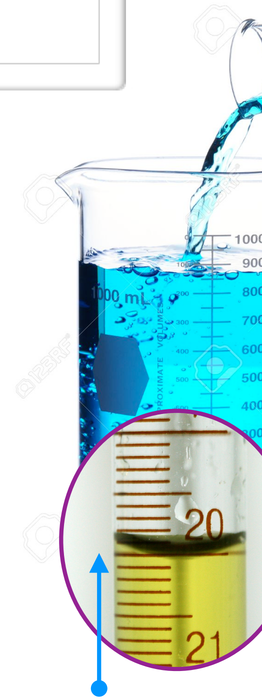
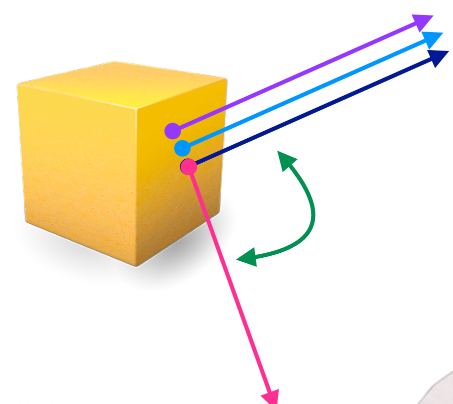
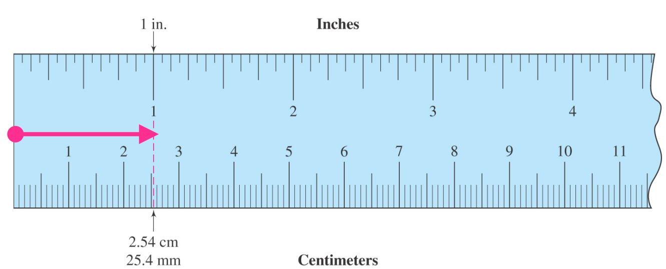
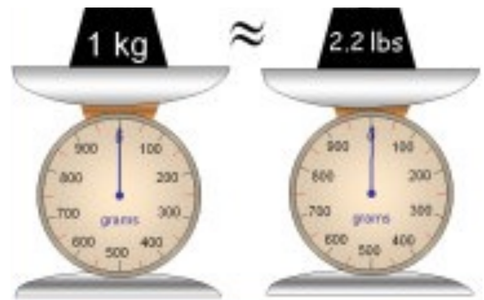




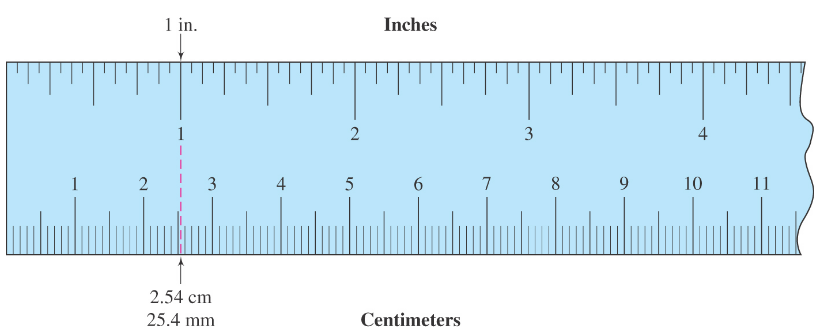


Converting Between Systems

- 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).



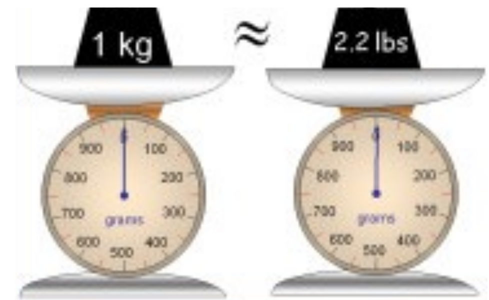
Conversion Factor: 1 kg → 2.2 lbs (measured)

- How many kg are in 92.7 lbs?

$$92.7\ \text{lbs} \cdot \frac{1\ \text{kg}}{2.2\ \text{lbs}} = 42.13636\ \text{kg}$$

3 s.f.   2 s.f.

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



- How many lbs are in 178 kg?

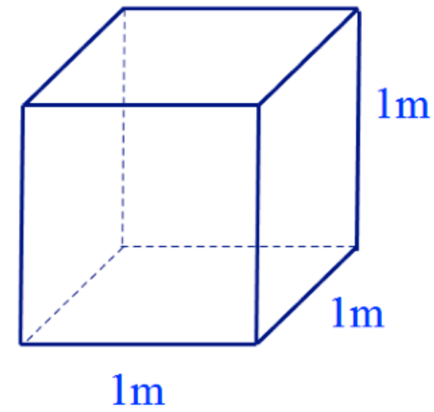
$$178\ \text{kg} \cdot \frac{2.2\ \text{lbs}}{1\ \text{kg}} = 391.6\ \text{lbs}$$

3 s.f.   2 s.f.

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

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).

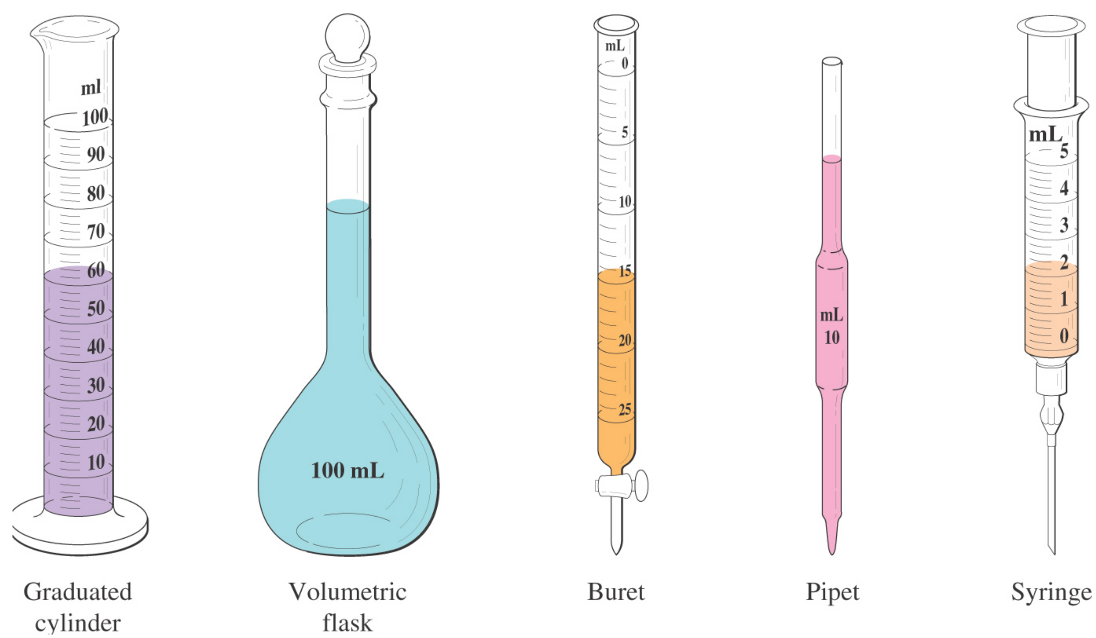


$1\ m^3 = 1000\ L$

by Definition

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

by Definition



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)

$c = 10^{-2}$

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

$m = 10^{-3}$

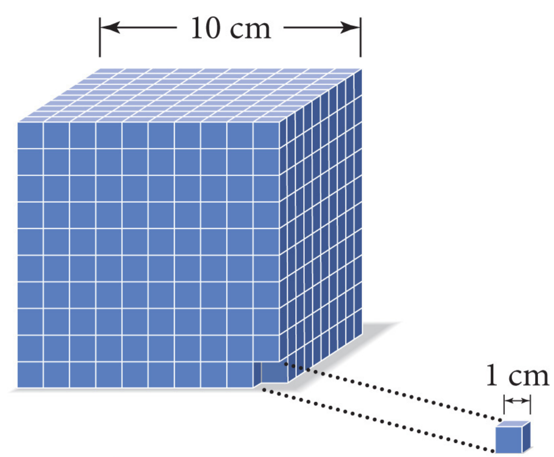
$1\ cm^3 = 1\ mL$

$1\ m^3 = 1000\ L$

justified by Definition

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

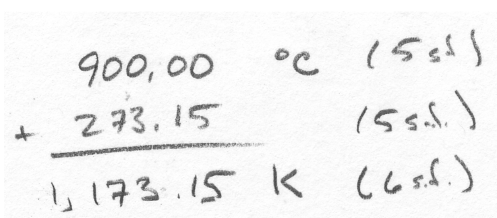
$10^{-3}\ m^3 = 1\ L$

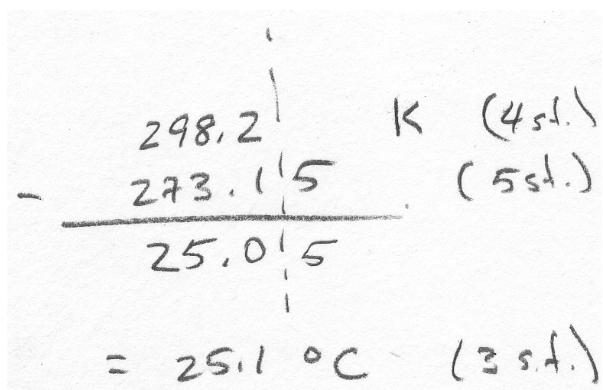


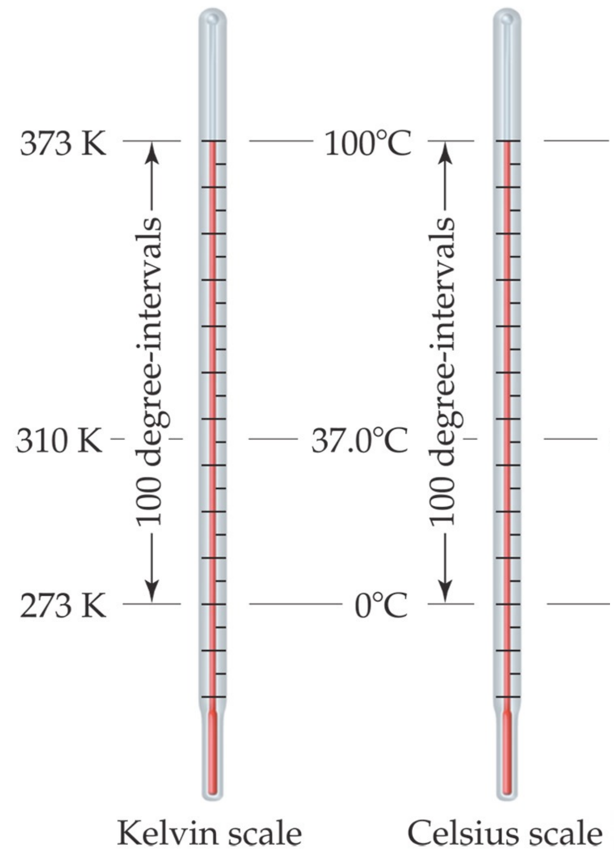
A 10 cm cube contains 1000 1 cm cubes.

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.







Conversions 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) (I won't ask you about fahrenheit)
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

Ch01

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- Representation
  - Value
    - Significance & Uncertainty
      - Recording & Interpreting
    - Scientific Notation
    - Calculator Use
  - Unit
    - Seven SI Standard Units
    - SI Unit Prefixes
    - Derived SI Units
      - Density

unit

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  - Conversion Factors
    - Within a dimension
      - Scaling a measurement
      - Bridging unit systems
    - Between dimensions
      - Jumping dimensions
  - Dimensional Analysis
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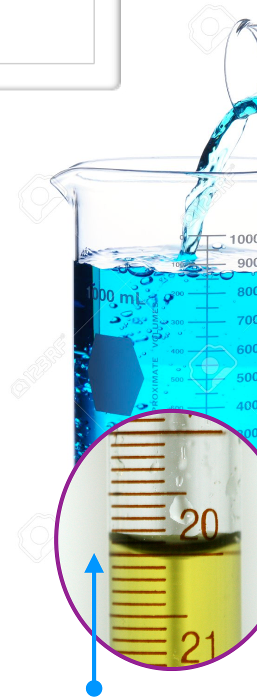
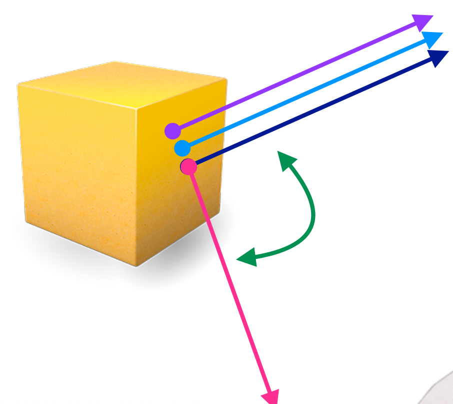
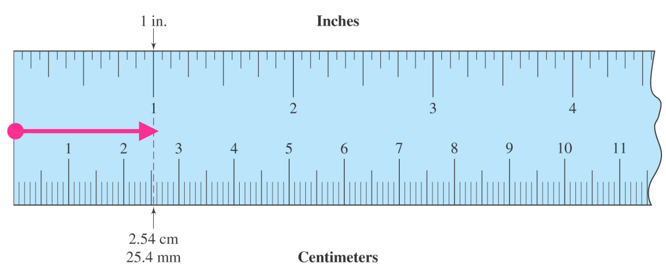
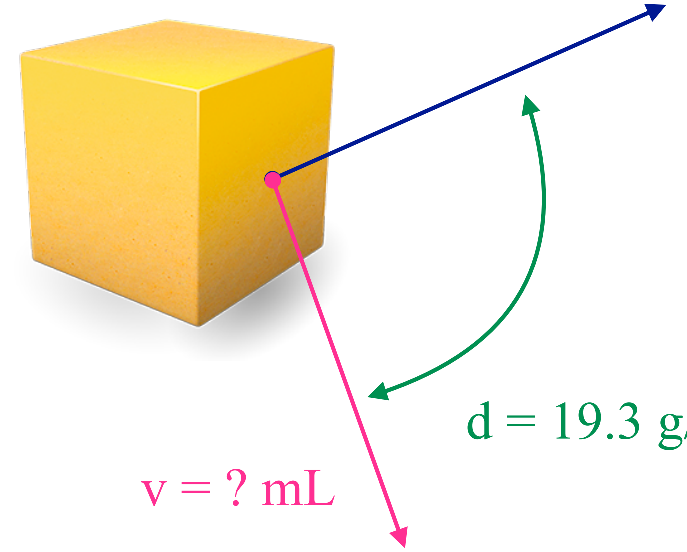






Intensive Properties as Conversion Factors

- 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

$$= 0.12\,cm^3$$

Ch01

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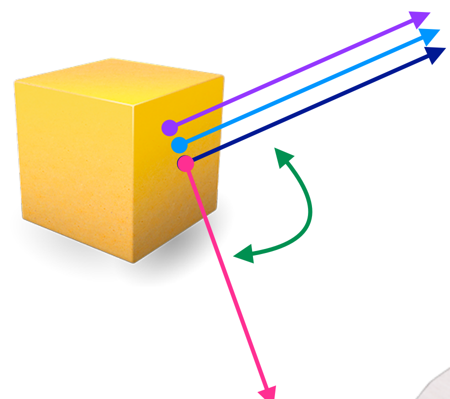
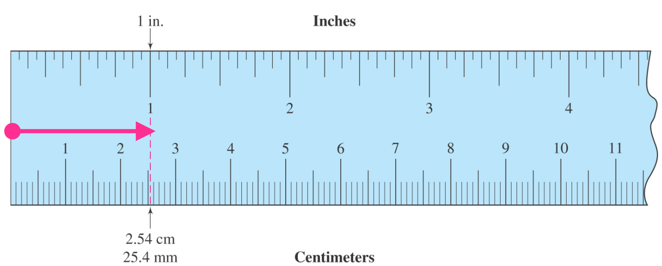
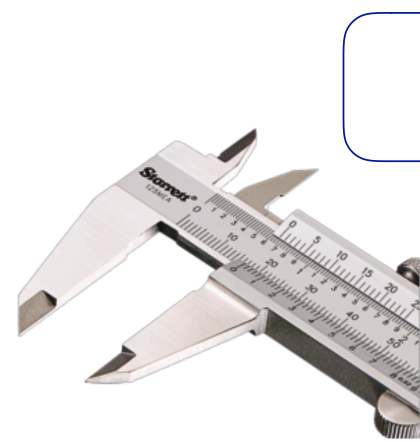






Answers aren't enough…

- 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 relate to each other.
  - 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.

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

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

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

$$\frac{90\ \cancel{\text{miles}}}{\cancel{\text{hour}}} \times \frac{5280\text{ feet}}{1\ \cancel{\text{mile}}} \times \frac{1\ \cancel{\text{hour}}}{3600\text{ sec}} =$$

conversion miles→ft (exact) | conversion hour→sec (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

Knowledge being shared

century → year → day → hr → min → sec

1 century = 100 years

365 days = 1 year

1 day = 24 hours

60 min = 1 hour

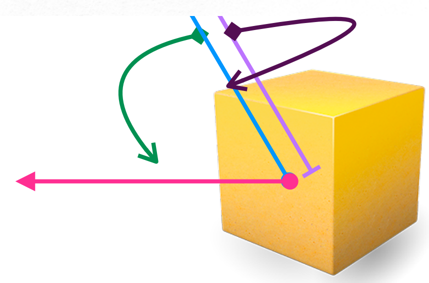
60 seconds = 1 min

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

∞ sf   ∞ sf   ∞ sf   ∞ sf   ∞ sf   ∞ sf

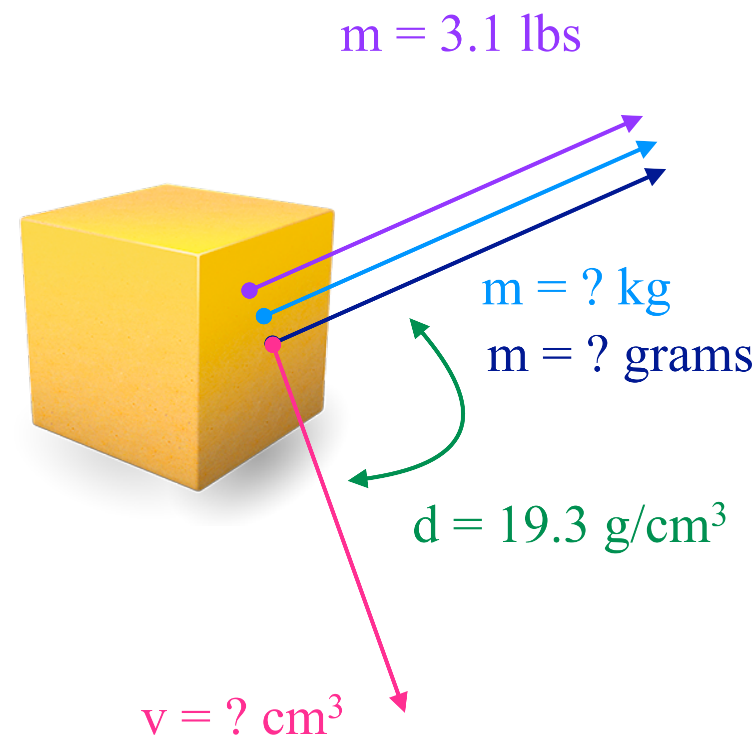
$= 3{,}153{,}600{,}000$ seconds

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



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?

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

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.

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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 → $

$$7\text{ rings} \cdot \frac{0.153\,L}{1\text{ ring}} \cdot \frac{1\,mL}{10^{-3}\,L} \cdot \frac{19.3\,g}{1\,mL} \cdot \frac{\$48.91}{1\,g} =$$

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

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

$$= \boxed{\$1.01 \times 10^5}$$

Glass Statue

Glass has a density of 2.6 g/cm^3. What's the weight in kg of a glass statue that has a volume of 42.3 in^3?

2 strategy

1 sort

3 solve

4 check

Glass Statue

Glass has a density of 2.6 g/cm³. What's the weight in kg of a glass statue that has a volume of 0.0423 m³?

$2.6\ g/cm^3$

$2.6\ g = 1\ cm^3$

$1\ kg = 10^3\ g$

$1\ cm^3 = 10^{-6}\ m^3$

① Find $m \rightarrow cm^3$ Factor

② $m^3 \rightarrow cm^3 \rightarrow g \rightarrow kg$

$1\ cm = 1\ cm$

$1\ cm = (10^{-2})\ m$

$(1\ cm)^3 = [10^{-2}\ m]^3$

$(1)^3\ cm^3 = (10^{-2})^3 (m)^3$

$1\ cm^3 = 10^{-6}\ m^3$

$$0.0423\ m^3 \cdot \frac{1\ cm^3}{10^{-6}\ m} \cdot \frac{2.6\ g}{1\ cm^3} \cdot \frac{1\ kg}{10^3\ g} = 109.98\ kg$$

3 sd, ∞ sd, 2 sd, ∞ sd,

$= 1.1 \times 10^2\ kg$

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

$\approx 1.271808 \times 10^6$ faces

Weighing an Iceberg

The volume of an iceberg can be estimated as 7,695 cubic feet. What is it's mass in kg?

(hint: 1 ft = 12 inches; 1 inch = 2.54 cm; and the density of ice is 0.917 g/cm^3)

1 ft = 12 inches
1 in = 2.54 cm
1 k = 10^3

0.917 g/cm^3

$$ft^3 \xrightarrow{(1)} in^3 \xrightarrow{(2)} cm^3 \xrightarrow{(3)} g \xrightarrow{(4)} kg$$

1 ft = 12 in
$(1\ ft)^3 = (12\ in)^3$
$1^3\ ft^3 = 12^3\ in^3$
$1\ ft^3 = 1{,}728\ in^3$

1 inch = 2.54 cm
$(1\ in)^3 = (2.54\ cm)^3$
$1^3\ in^3 = 2.54^3\ cm^3$
$1\ in^3 = 16.387064\ cm^3$

$$7695\ ft^3 \cdot \frac{1{,}728\ in^3}{1\ ft^3} \cdot \frac{16.387064\ cm^3}{1\ in^3} \cdot \frac{0.917\ g}{1\ cm^3} \cdot \frac{k}{10^3} = 199{,}812{,}589\ kg$$

4 sd. ∞ s.f. ∞ s.f. 3 sd.

2.00×10^5 kg

3 sd

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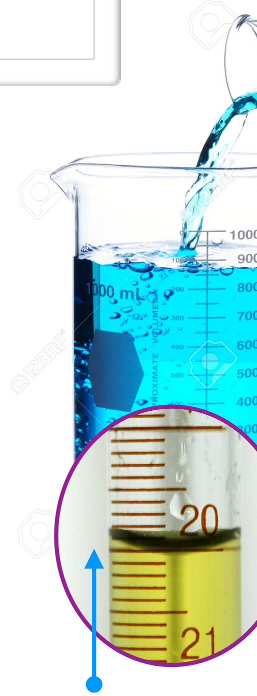

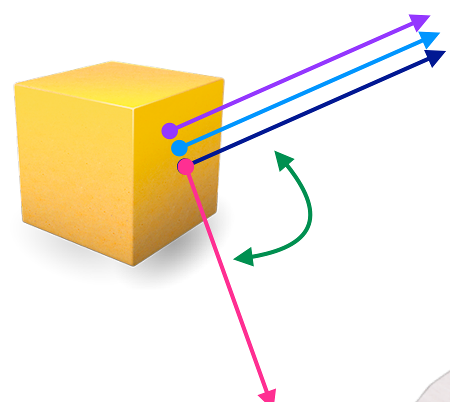

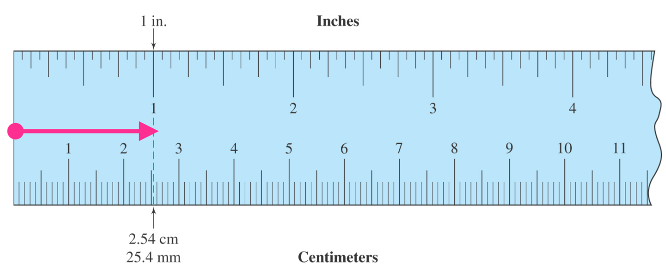

Questions?