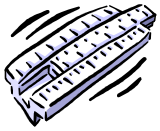


Measurements

Significant Figures

Rounding

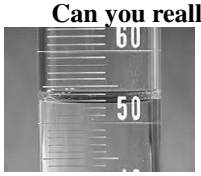
LPT

There is no such thing as a perfect measurement

All measurements have errors
Calculators display meaningless digits

Reporting 10^{-10} values
Data only good to 10^{-1}

Can you really measure 0.000000001 ml?

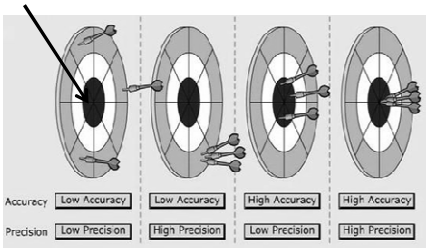


For this graduate Cylinder:
Doubtful digit: tenth place (52.9 ml), so
Any digit past tenths place is meaningless
Any digit past tenths place is invalid
Any digit past tenths place is fraud

LPT

Random Measurements

True Value



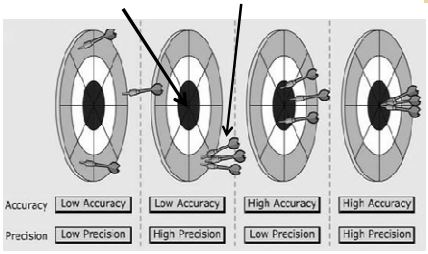
Values not clustered and do not represent true value

LPT

Precise Measurements

True Value

Systematic Error

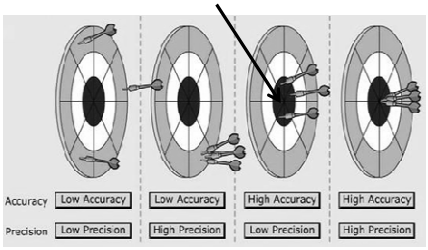


Values clustered, but do not represent true value

LPT

Accurate Measurements

True Value

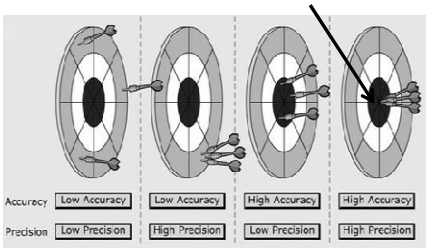


Values average to true value

LPT

Accurate & Precise Measurements

True Value



Values clustered and represent true value

LPT

Significant Figures:

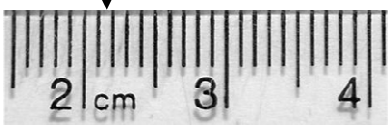
Indicate the degree of certainty (*precision*) in a measured quantity
or
in a calculated result

All the digits that are known
plus
the first uncertain digit (*doubtful digit*) in a measurement

LPT

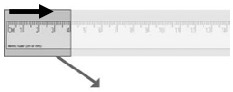
All measurements have a doubtful (estimated) digit

Somewhere between 2.1 and 2.2
(2.16 cm)



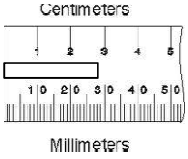
LPT

Reported Digits Convey Measurement Quality



Always estimate to
One decimal place
beyond measuring device marks

2.9 cm Implies ruler has 0 marks between 2 & 3; 9 is doubtful
2.94 cm Implies ruler has 10 marks between 2 & 3; 4 is doubtful



LPT

Lab Measurements

Distance (cm) measurements: 2 decimal digits

Mass measurements: all decimal digits

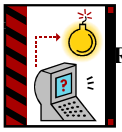
Volume (ml) measurements: 1 or 2 decimal digits (depends on cylinder markings)

LPT

Never Round Data

Always record digits displayed
On instruments, last digit displayed is doubtful

If multiple measurements are used in calculations:
errors in measurements are multiplied (propagated)
magnitude of error may exceed ability to measure
large error invalidates the experiment



Round Only after last calculation is completed

LPT

Certain & Doubtful Digits

	Certain	Doubtful
15.25 cm	15.2	5
894.22 g	894.2	2
1.7 L	1	7
36.94 mL	36.9	4
3.1 mg	3	1

Always last digit to the right in a measurement

LPT

Exact Numbers

Numbers that are determined by counting or by definition ("per" expressions (conversion factors) are exact)

contain no uncertainty
have infinite (∞) or unlimited significant figures.

Examples:

25	**6 students**
18 apples	**491 cars**
2.54 cm = 1 in	**12 in = 1 ft**
100 cm = 1 m	**1000 g = 1 kg**

Significant figures do not apply to exact numbers

LPT

Quantity	Exact or Measured	Estimated Digit
6.27 meters		
15 students		
1.94 liters		
8,295 kg		
2.54 cm ≡ 1 inch		
0.348 cm		
16		
45.0 mL		
1000 mg ≡ 1 g		

LPT

Quantity	Exact or Measured	Estimated Digit
6.27 meters	Measured	7
15 students	Exact	
1.94 liters	Measured	4
8,295 kg	Measured	5
2.54 cm ≡ 1 inch	Exact	
0.348 cm	Measured	8
16	Exact	
45.0 mL	Measured	0
1000 mg ≡ 1 g	Exact	

LPT

Significant Figures

Begin with the first nonzero digit and end with the doubtful digit.
The location of the decimal point has nothing to do with significant figures.

Nonzero digits
78.391 km (5 figures) 422.8 gal (4 figures)

Leading zeros - never
0.000391 m (3 figures) 0.00255 g (3 figures)

Captive zeros
7,503 lbs (4 figures) 100,038 cm (6 figures)

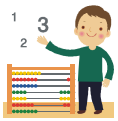
Trailing decimal point zeros
14,000 kg (2 figures) 15.60 mL (4 figures) 160. mm (3 figures)

Exact numbers -unlimited
100 cm ≡ 1 m 60 s ≡ 1 min 200 cars

LPT

How many significant figures in:

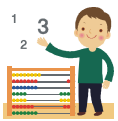
18.043 m
1,000 km
1,000. mg
0.000667 L
90.800 tons
35
35 mL
0.0500700 g
9.360 x 10^4 s
8,628,000 cm
439.00 mL
1 mL ≡ 1 cm



LPT

How many significant figures in:

18.043 m	**5**
1,000 km	**1**
1,000. mg	**4**
0.000667 L	**3**
90.800 tons	**5**
35	**-**
35 mL	**2**
0.0500700 g	**6**
9.360 x 10^4 s	**4**
8,628,000 cm	**4**
439.00 mL	**5**
1 mL ≡ 1 cm	**-**



LPT

Zeros

can be the doubtful digit
can be used to show the decimal

use scientific notation to indicate significant figures:

ex: distance between the earth and the sun is 150,000,000 km

1.5×10^8 km	**2 significant**
1.50×10^8 km	**3 significant**
1.500×10^8 km	**4 significant**

LPT

Indicate if the underlined zero is significant:

0.050800 kg	**0.008070 km**
0.050800 kg	**0.008070 km**
0.050800 kg	**0.008070 km**
0.050800 kg	**0.008070 km**
0.050800 kg	**0.008070 km**

LPT

Indicate if the underlined zero is significant:

0.050800 kg	**n**	**0.008070 km**	**n**
0.050800 kg	**n**	**0.008070 km**	**n**
0.050800 kg	**y**	**0.008070 km**	**n**
0.050800 kg	**y**	**0.008070 km**	**y**
0.050800 kg	**y**	**0.008070 km**	**y**

LPT

Re-write the quantity 40,000 mg

to show 1 sig. fig. 4×10^4 mg
to show 2 sig. fig. 4.0×10^4 mg
to show 3 sig. fig. 4.00×10^4 mg
to show 4 sig. fig. 4.000×10^4 mg

Re-write the quantity 9,340,000,000,000 ps

to show 3 sig. fig. 9.34×10^{12} ps
to show 4 sig. fig. 9.340×10^{12} ps
to show 5 sig. fig. 9.3400×10^{12} ps
to show 6 sig. fig. 9.34000×10^{12} ps

LPT

Rounding Off

Calculators may contain digits that are not significant

If the first digit to be dropped is less than 5, leave the digit before it unchanged.

If the first digit to be dropped is 5 or more, increase the digit before it by 1.

Round ONLY at the end of calculations

5.324657894
3 significant = 5.32
4 significant = 5.325
5 significant = 5.3247

LPT

Problems

Round 5.43 g 0.0448 m to 2 sig. figs.
5.4 g 0.045 m

Round each of the following to 3 significant figures:

16.8477 L	**16.8 L**
5.6732 g	**5.67 g**
0.14986 L	**0.150 L**
861.85 kg	**862 kg**
4.203×10^4 km	**4.20×10^4 km**
5.09810×10^{-3} mm	**5.10×10^{-3} mm**
0.00318756 m	**0.00319 m**
0.09025011 cm^3	**0.0903 cm^3**

LPT

Calculations - Multiplication & Division

Round answer to the smallest number of sig. fig. in any factor

4.62 m x 3.1 m = 14.322 m^2 (14 m^2)

248.37 in x $\frac{2.54\ cm}{in}$ = 630.8598 cm (630.86 cm)

$\frac{6.230\ g}{8.12\ mL}$ x 5 = 3.836207 g / mL (3.84 g / mL)

Failure to round to correct number of digits: Major factor in loss of exam points!

LPT

Calculations - Addition & Subtraction

Round off the answer to the first column that has a doubtful digit

2.22	cm	15.85	g
3.9	cm	- 9.4052	g
+ 8.9382	cm	6.4448	g
15.0582	cm	(6.44	g)
(15.1	cm)		

Failure to round to correct number of digits: Major factor in loss of exam points!

LPT

Calculate to the correct number of significant figures

$\frac{2.2745\ g}{3.40\ cm \times 8.1\ cm \times 7.090\ cm}$ = 0.0116487 g/cm^3 (0.012 g/cm^3)

95.34 cm^3 x $\frac{21.3\ g}{cm^3}$ = 2030.74 g (2030 g)

58.953 g x $\frac{mL}{0.877\ g}$ = 67.2212 mL (67.2 mL)

$\frac{36.0059\ g}{13.3\ cm^3}$ = 2.70721 g/cm^3 (2.71 g/cm^3)

95.202	g	42.75	g
12.33	g	- 40.8356	g
+ 40.9556	g	1.9144	g (1.91 g)
148.4876	g (148.49)		

LPT

Calculation with Many Conversions

Physiologists suggest that people "burn" 15.0 kcals climbing a flight of stairs and 5.0 kcals descending a flight of stairs. If 3500 kcals represents a pound of fat, how many pounds of fat are lost during a 15 week semester using the stairs (instead of an elevator) for a CEM 101 class that meets on the third floor twice a week?

$$\frac{20.0\ \text{kcal}}{\text{story}} \times \frac{3\ \text{stories}}{\text{day}} \times \frac{2\ \text{days}}{\text{week}} \times \frac{15\ \text{weeks}}{\text{semester}} \times \frac{\text{pounds fat}}{3500\ \text{kcal}} = ? \ \frac{\text{lbs fat}}{\text{semester}}$$

LPT

Calculation with Many Conversions

Physiologists suggest that people "burn" 15.0 kcals climbing a flight of stairs and 5.0 kcals descending a flight of stairs. If 3500 kcals represents a pound of fat, how many pounds of fat are lost during a 15 week semester using the stairs (instead of an elevator) for a CEM 101 class that meets on the third floor twice a week?

$$\frac{20.0\ \text{kcal}}{\text{story}} \times \frac{3\ \text{stories}}{\text{day}} \times \frac{2\ \text{days}}{\text{week}} \times \frac{15\ \text{weeks}}{\text{semester}} \times \frac{\text{pounds fat}}{3500\ \text{kcal}} = 0.514 \ \frac{\text{lbs fat}}{\text{semester}}$$

LPT

Calculation with Many Conversions

A sprinter does the 100.0 meter dash in 10.1 seconds. What is this speed in miles per hour?

Start with Given and Wanted:

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} = ?\ \text{mi / hr}$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{1\ \text{inch}}{2.54\ \text{cm}} \times \frac{1\ \text{foot}}{12\ \text{in}} \times \frac{1\ \text{mile}}{5{,}280\ \text{ft}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = ?\ \text{mi / hr}$$

Units the same on both sides of equal sign; do the math:

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{1\ \text{inch}}{2.54\ \text{cm}} \times \frac{1\ \text{foot}}{12\ \text{in}} \times \frac{1\ \text{mile}}{5{,}280\ \text{ft}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = 22.1479\ \text{mi/ hr}$$

LPT

Calculation with Many Conversions

A sprinter does the 100.0 meter dash in 10.1 seconds. What is this speed in miles per hour?

Start with Given and Wanted:

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} = ?\ \text{mi / hr}$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{1\ \text{inch}}{2.54\ \text{cm}} \times \frac{1\ \text{foot}}{12\ \text{in}} \times \frac{1\ \text{mile}}{5{,}280\ \text{ft}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = ?\ \text{mi / hr}$$

Units the same on both sides of equal sign; do the math:

$$\frac{100.0\ \text{m}}{10.1\ \text{sec}} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{1\ \text{inch}}{2.54\ \text{cm}} \times \frac{1\ \text{foot}}{12\ \text{in}} \times \frac{1\ \text{mile}}{5{,}280\ \text{ft}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = 22.1479\ \text{mi/ hr}$$

Round to 3 significant figures (dictated by the 10.1 sec term)

$$= 22.1\ \text{mi/ hr}$$

LPT

Calculation with Many Conversions

Insurance statistics state that a person loses 8.00 minutes of average life for each cigarette smoked. Over the next 25 years, how much life is lost on average for a person smoking 0.5 pack (10 cigarettes) a day for 25 years? Express this loss in both minutes and years.

Start with Given and Wanted:

$$\frac{10\ \text{cigarettes}}{\text{day}} = ?\text{min}$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{10\ \text{cigarettes}}{\text{day}} \times \frac{365.25\ \text{days}}{\text{year}} \times \frac{8.00\ \text{min}}{\text{cigarette}} \times 25\ \text{years} = ?\ \text{min}$$

Units the same on both sides of equal sign; do the math; round to 3 sig figs:

$$\frac{10\ \text{cigarettes}}{\text{day}} \times \frac{365.25\ \text{days}}{\text{year}} \times \frac{8.00\ \text{min}}{\text{cigarette}} \times 25\ \text{years} = ?\ \text{min}$$

Continue (without isolating) converting to years

$$\times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{1\ \text{day}}{24\ \text{hr}} \times \frac{1\ \text{year}}{365.25\ \text{days}} = ?\ \text{years}$$

LPT

Calculation with Many Conversions

Insurance statistics state that a person loses 8.00 minutes of average life for each cigarette smoked. Over the next 25 years, how much life is lost on average for a person smoking 0.5 pack (10 cigarettes) a day for 25 years? Express this loss in both minutes and years.

Start with Given and Wanted:

$$\frac{10\ \text{cigarettes}}{\text{day}} = ?\text{min}$$

"Cancel" units one at a time until left side unit = right side unit

$$\frac{10\ \text{cigarettes}}{\text{day}} \times \frac{365.25\ \text{days}}{\text{year}} \times \frac{8.00\ \text{min}}{\text{cigarette}} \times 25\ \text{years} = ?\ \text{min}$$

Units the same on both sides of equal sign; do the math; round to 3 sig figs:

$$\frac{10\ \text{cigarettes}}{\text{day}} \times \frac{365.25\ \text{days}}{\text{year}} \times \frac{8.00\ \text{min}}{\text{cigarette}} \times 25\ \text{years} = 7.31 \times 10^5\ \text{min}$$

Continue (without isolating) converting to years

$$7.31 \times 10^5\ \text{min} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{1\ \text{day}}{24\ \text{hr}} \times \frac{1\ \text{year}}{365.25\ \text{days}} = 1.39\ \text{years}$$

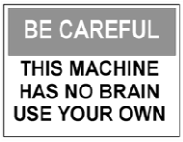
LPT

TI Specific Problem

Some TI's auto delete trailing zeros
1.300 (correct number of sig figs)
May display as 1.3
You must supply correct number of sig figs

For TI-84 Plus CE:
Mode >> Answers
Change "Auto" to "Dec"
Hit Enter

This will display all digits
User selects correct sig figs



LPT

All Calculations Must be Rounded to Appropriate Sig Figs

Failure to round to correct number of digits:
Creates Undesirable Results!

LPT