Measurement & Uncertainty

Measurment → value & unit

value ↑ Number part

unit ↑ Type of measurment

Two systems of units

	English	SI (System International)
Length	Ft, yards, in	meter (m)
Mass	lbs, oz	kilogram (kg)
Volume	gal, guarts, floz	Liter (L)
Time	sec, min, hours	second

SI Prefixes

Giga	(G)	$\times 10^{9}$
mega	(M)	$\times 10^{6}$
Kilo	(k)	$\times 10^{3}$
Base		$\times 10^{0}$
Centi	(c)	$\times 10^{-2}$
milli	(m)	$\times 10^{-3}$
micro	(μ)	$\times 10^{-6}$
nano	(n)	$\times 10^{-9}$

How many grams

$1{,}275\ kg = ?\ g$

$\times 10^3$

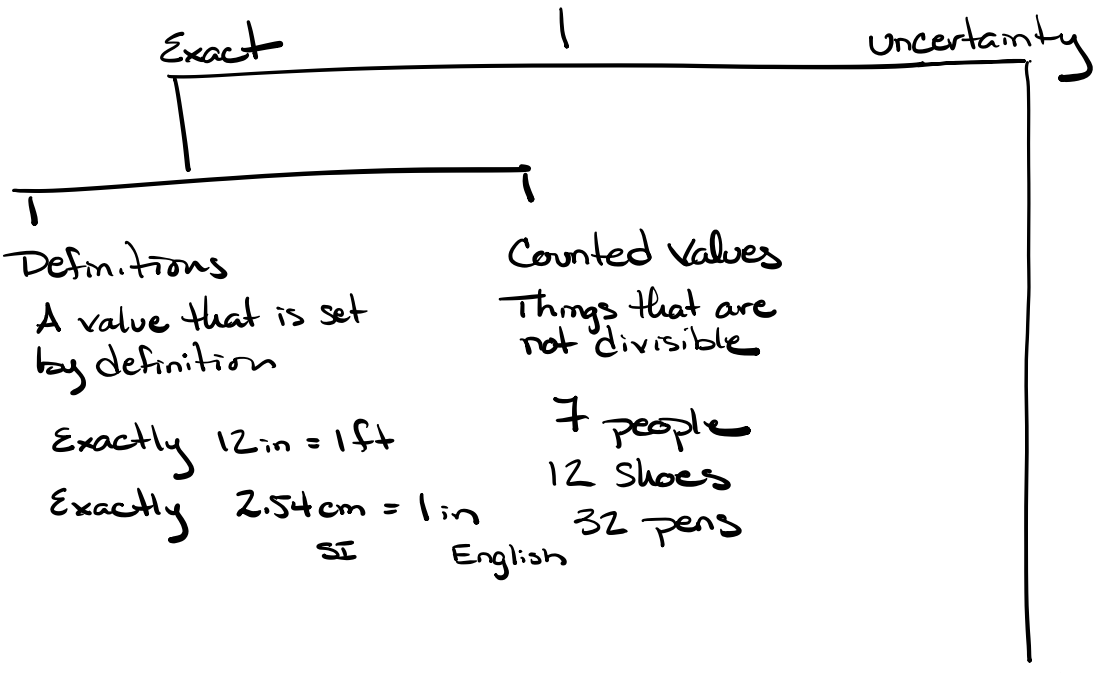
$1{,}275 \times 10^3\ g = 1{,}275{,}000\ g$

$0.731\ \mu L = ?\ L$

$\times 10^{-6}$

$= 0.731 \times 10^{-6}\ L = .000000731\ L$

Types of Values (numbers)



Definitions

A value that is set by definition

Exactly 12 in = 1 ft

Exactly 2.54 cm = 1 in

SI English

Counted Values

Things that are not divisible

7 people

12 shoes

32 pens

Measured Quantities

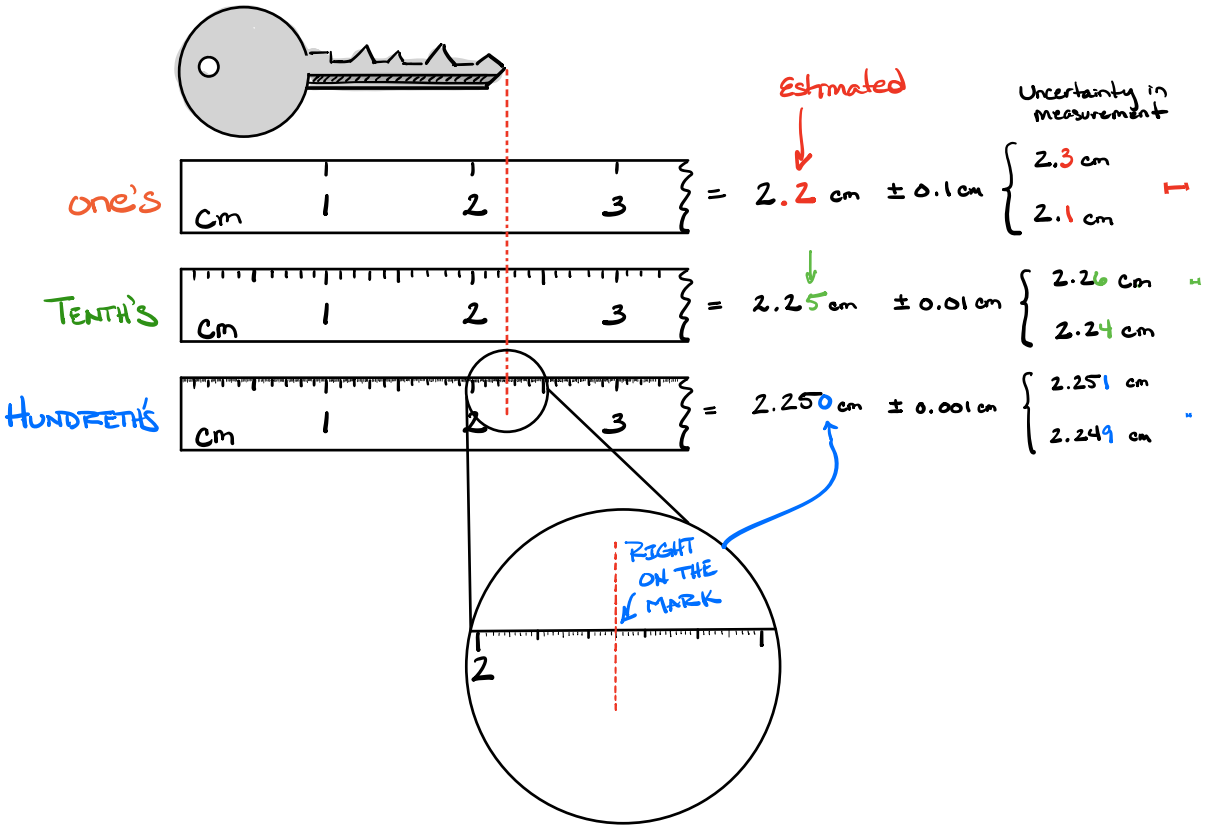
Values obtained through measurement using some sort of ruler or measuring device

± uncertainty

32 lbs ± 1 lbs

37.62 s ± 0.01 s

Uncertainty tells you how good the ruler is.

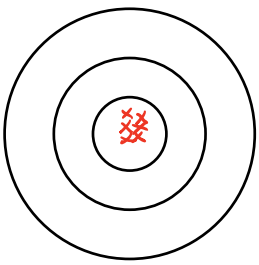


Less uncertainty = more precision

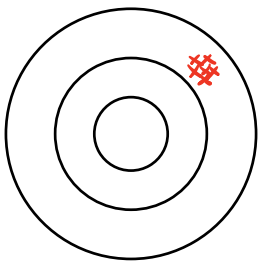
Precision = degree of uncertainty

Accuracy = How close the measurement is to the true value

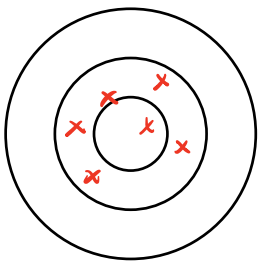
⇒ Calibration, location of the zero point.



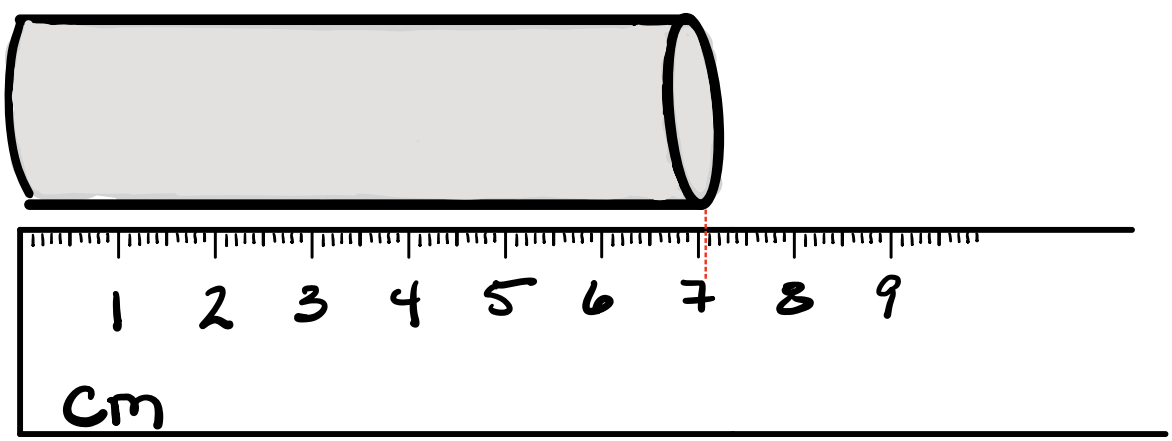
Accurate (Bulls eye)
&
Precise (Grouping)



Precise but
Calibration off
& not accurate



Accurate when
averaged, but
not precise.

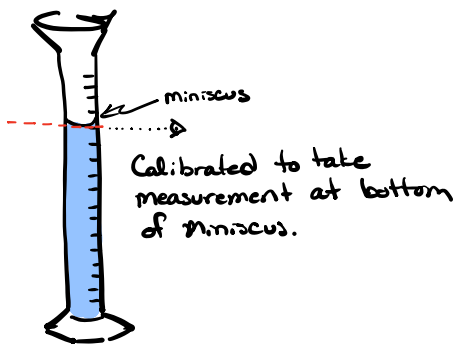


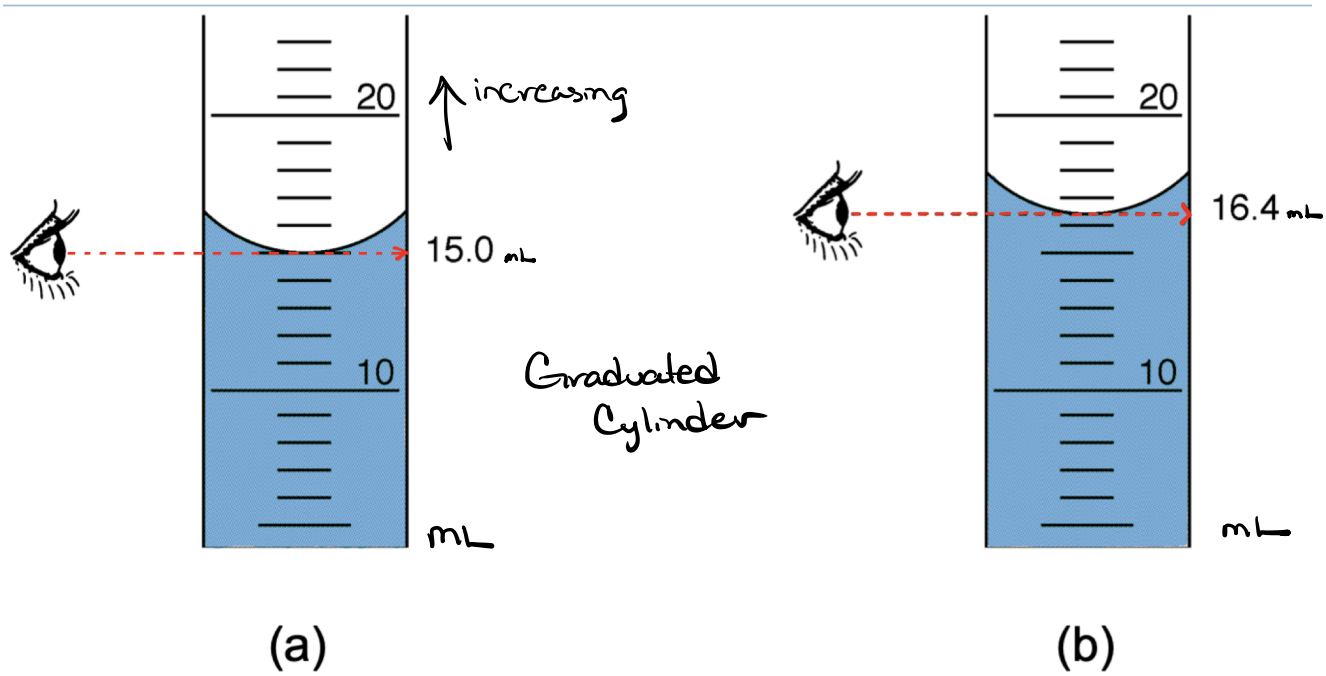
7.08 cm ± 0.01 cm
(Implied)

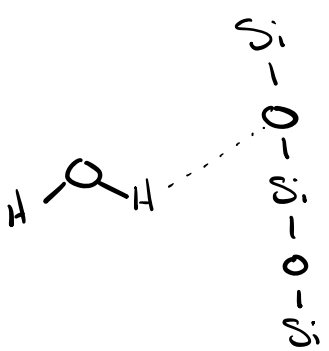
or

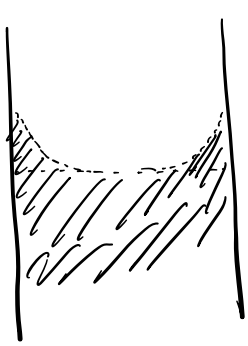
7.09 cm

Measuring liquids

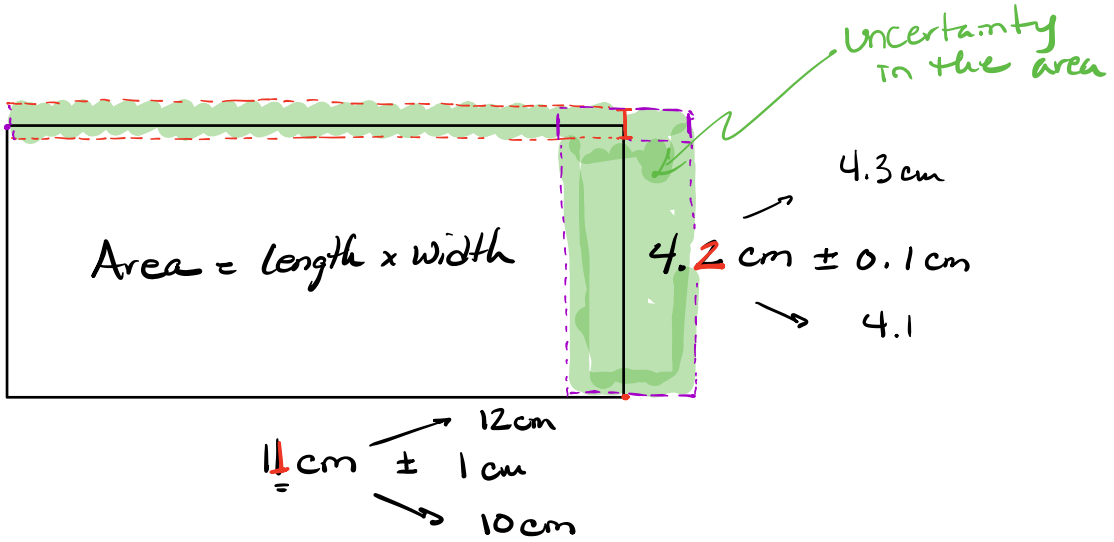








Calculation Example

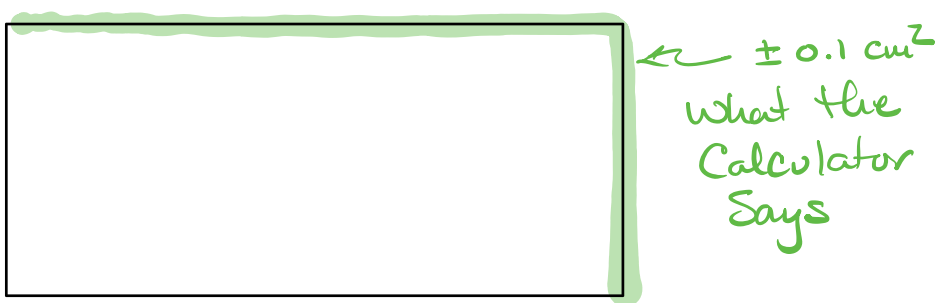


Area = $4.2\,cm \times 11\,cm = 46.2\,cm^2$

Calculator gives $46.2\,cm^2 \pm ?$

Implied uncertainty is $46.2\,cm^2 \pm 0.1\,cm^2$

↑ Super Small



How do we change the calculated result to be more consistent with the uncertainty in the measurements used?

uncertainty measurements = uncertainty in calculated result.

2 SF 2SF 2SF

$4.2\ cm \times 11\ cm = 46.2\ cm^2$

$= 46\ cm^2 \pm 1\ cm^2$

Calculated result must be corrected to the proper degree of uncertainty = to the uncertainty in the data used in calc.

Gratest

Significant Figures or Significant Digits

- System for estimating uncertainty in a calculation.

Rules for determining the # of Sig figs in a Value

* All about the zeros
* If a zero is part of the measurement it is Significant,
  If a zero is a placeholder for the value of the measurement it is not Significant.

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① All non-zero digits are Significant

	Sig figs
3.271 cm	4
1.69 mL	3
132,731.1 gal	7

1 SF
1,000,000 x 2400
7 SF
1,000,000.
3 SF
1.00×10^6

② Any zero flanked by non-zero's is Significant

Bound Zeros

	Sig figs	
3.021	4 SF	
100.7	4SF	
56.0023	6 SF	5.60023×10^1

③ Any zero to the right of the decimal & to the right of any non-zero digits is Significant

Trailing Zeros

32.60000	6 SF	3.26000×10^1
101.70	5 SF	
1.0200	5 SF	

④ Zero's to the right of the decimal, but to the left of the 1st non-zero are place holder values for values less than 1

$\Rightarrow$ not Significant Leading Zero's

leading zero's

$0.0125 = 1.25 \times 10^{-2}$ 3 SF

$0.00009376 = 9.376 \times 10^{-5}$ 4SF

$0.00020340 = 2.0340 \times 10^{-3}$ 5SF

⑤ Zero's to the right of the last non-zero digit and to the left of the decimal may or may not be Significant.

2100
1,000,000
1,290,000
} poorly expressed

Textbook: If the decimal is included than Zeros are Significant

2100 2 SF

2100. 4SF

How do I get 3 SF?

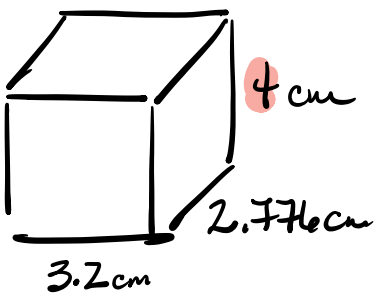
Rule #3 Trailing

2.1×10^3	2 SF	2100
2.10×10^3	3 SF	2100
2.100×10^3	4 SF	2100
2.1000×10^3	5 SF	2100.0

		# SF
①	0.0092 cm	2
②	73.050 mL	5
③	1200 gal (placeholders no decimal)	2
④	1.69200 L (part of measurement)	6
⑤	3.2000×10^2 s (part of measurement)	5 ⇐

Mult & Division

Answer to calculation is rounded to the smallest # of Sig Figs in the data.



Volume = $l \times w \times h$

1 SF, 4 SF, 2 SF

$= 4\text{cm} \times 2.776\text{cm} \times 3.2\text{cm}$

$= 35.5328\ \text{cm}^3$

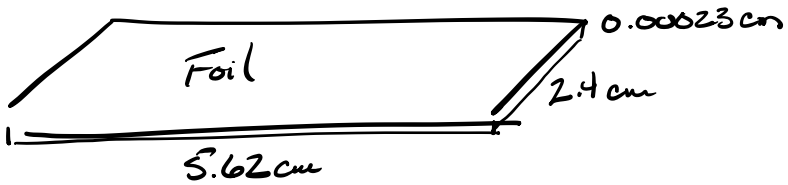
$= 40\ \text{cm}^3$

$= 4 \times 10^1\ \text{cm}^3$ — 1 SF

$40 \pm 10\ \text{cm}^3$

↑ $50\ \text{cm}^3$

↓ $30\ \text{cm}^3$



2 3 2

$0.00023\text{cm} \times 5.62\text{cm} \times 2.4\text{cm} = 0.003102224\ \text{cm}^3$

$= 0.0031\ \text{cm}^3$

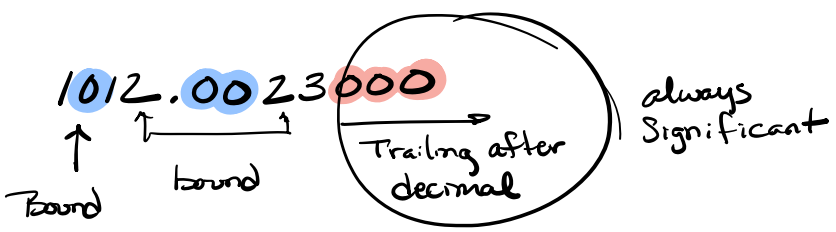
2 SF

2 3 3

$0.00023 \times 5.62 \times 2.45 = 0.00316687\ cm^3$

$= 0.0032\ cm^3$

$2.3 \times 10^{-4} \times 5.62 \times 2.45 = 3.2 \times 10^{-3}\ cm^3$



0.00629

Place holders
Leading Zeros

Never Significant

209,000

? ambiguous

2.09000×10^5

6 SF

209,000.

Bound

209,000

3 SF

Trailing to the left of decimal

2.09×10^5

Addition / Subtraction

Done by place value

	2.063	cm	4 SF	±0.001
	0.009	cm	1 SF	± 0.001
	10.1	cm	3SF	±0.1
+	8.2	cm	2SF	±0.1
	20.372	cm		

Round to place value of largest uncertainty

20.4 cm 3SF ✓

What do we do with exact values?

⟹ Exact values do not affect Sig figs.

Counted & definitions are exempt from Sig figs.

How many seconds are in 52.8 years?

3 SF

$52.8\ \text{yrs} \times \frac{365\ \text{days}}{1\ \text{year}} \times \frac{24\ \text{hr}}{1\ \text{day}} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{60\ \text{sec}}{1\ \text{min}} =$ (def. def. def. def.)

$52.8 \times 365 \times 24 \times 60 \times 60 = 1\,665\,100\,800\ \text{sec}$

$= 1.67 \times 10^9\ \text{sec}$

Apply rules in order of operation & don't Round until very end!

1st

$$\frac{(3.62\ \text{cm} + 4.7\ \text{cm}) \times 103.2\ \text{cm}}{90.3\ \text{sec}}$$

3 SF, 2 SF, 4 SF, 3 SF

Track SF

$$= \frac{8.32\ \text{cm} \times 103.2\ \text{cm}}{90.3\ \text{sec}}$$

2 SF, 4 SF, 3 SF

$$= 9.508571428571\ \text{cm}^2/\text{s}$$

$$= 9.5\ \text{cm}^2/\text{s}$$

$$\begin{array}{r} 3.62 \\ +\ 4.7 \\ \hline 8.32 \end{array}$$

2 SF 2 SF 2 SF

$5200_{cm} \times 24_{cm} = 124800\ cm^2$

$= 120000\ cm^2$

$1.2 \times 10^5\ cm^2$

~~12×10^4~~

$= 12\ cm^2$

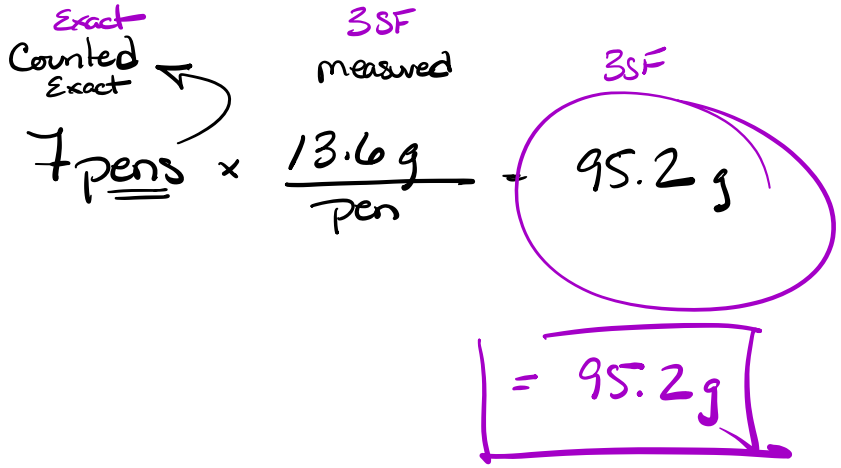
฿ 124,800.—

≈ 120,000

฿ 1.2×10^5

126300

130000


Exact
Counted
Exact
3SF
measured
3SF
7 pens
×
13.6 g / pen
=
95.2 g
= 95.2 g