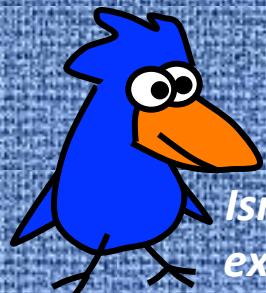
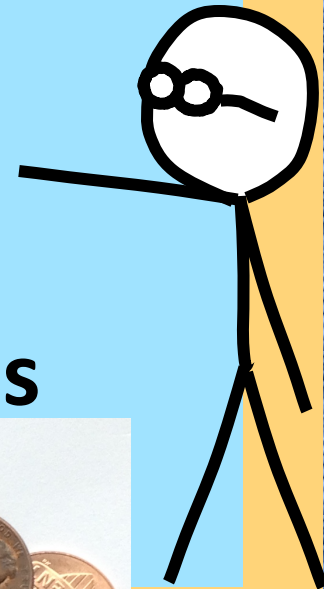


# Experiment 1

27 August 2019


## Making Measurements and the Density of Pennies



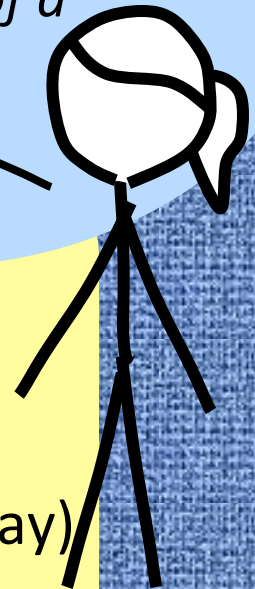
*Isn't this  
exciting!*



# Objectives: Learn to make the best possible laboratory measurements.



*Today we will become familiar with some critical lab skills like picking the best glassware for measurements and making good measurements. We will talk about significant figures, and rounding.*



*We will collect data and use it to obtain a meaningful result – the density of a metal.*

## Overview:

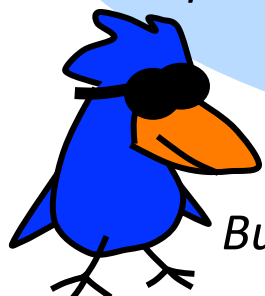
1. How to use these pre-lab presentations.
2. Making good measurements
3. Precision, accuracy, significant figures
4. Procedure for today (summary of what we do today)
5. Density of pennies
6. Your lab report

# 1. How to use these pre-lab presentations.

## Format of each experiment in the lab manual:

1. Background (or Introduction)
2. Procedure
3. Calculations, Analysis, etc.

*Before we get started with Experiment 1, let's buzz a bit about the lab manual and these presentations. Each experiment in the lab manual has three parts as you see in this box. These pre-lab presentations do the same. We try to provide a simple, more concise alternative to the first section (Background). If this works for you, you can skip the Background section in the lab manual.*



*Buzz. Buzz.*

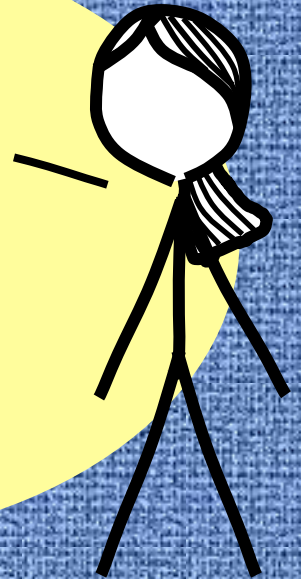
*Most of the time, we will closely follow the Procedure from the lab manual. Today... not so much. (See Slide 26.)*

*And finally, we take you through the calculations and you should follow along with what we are doing.*

# 1. How to use these pre-lab presentations.



*Each week, we introduce you to the experiment and this should help you write the **Introduction** before coming to lab.*



*Slide 2 always lists the objectives. These are the talking points for your Introduction.*



**Info for Introduction**

*Looking back to Slide 2 – you can see that we should mention something about making good measurements, precision, accuracy and significant figures and finally density. As you flip through this presentation, look for these bright yellow signs for more info for your Introduction.*

Uh-huh.



# 1. How to use these pre-lab presentations.

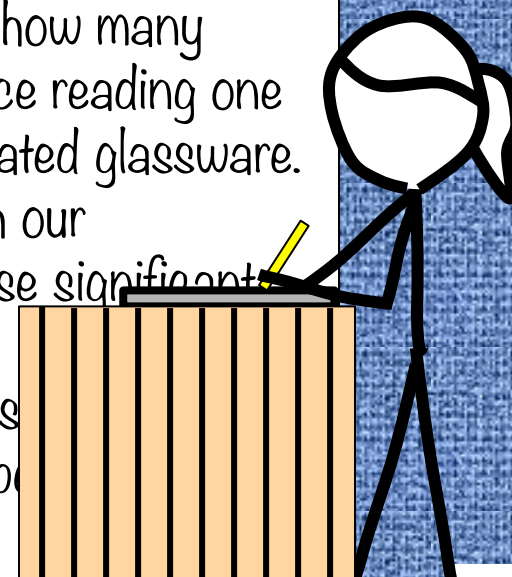


*Introductions usually run about a half-page. They should be in your own words and cover all pertinent topics. Here is an Introduction for Experiment 1. Yours could look somewhat similar but in your own words. Notice how all of the “talking points” were addressed, but only as a preview?*

## Introduction.

This week in lab we will use various glassware, balances and rulers in order to compare how accurately each one makes measurements. We will practice making good measurements and will learn how many significant figures each measurement gives. We will practice reading one more number in between two lines on a ruler or with graduated glassware. We will encounter examples of precision and accuracy with our measurements. In our calculations, we will review how to use significant figures correctly.

We will determine the density of pennies using a slope and volume measurements that we will plot so that the slope is the density.



# 1. How to use these pre-lab presentations.

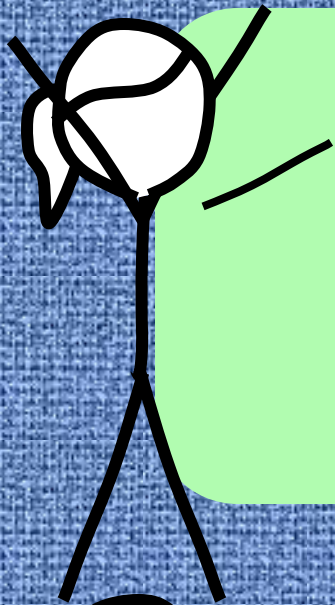
*These presentations introduce you to the experiment, so you can usually skip the Background/Introduction section from the lab manual and go straight to the Procedure (once we are in lab). These presentations are tailored to go with Dr Mattson's lectures, using the same vocabulary and approaches you've seen in lecture.*

*The pre-lab presentations also provide an overview of the procedure followed each week, however, they lack the detail that the lab manual gives.*

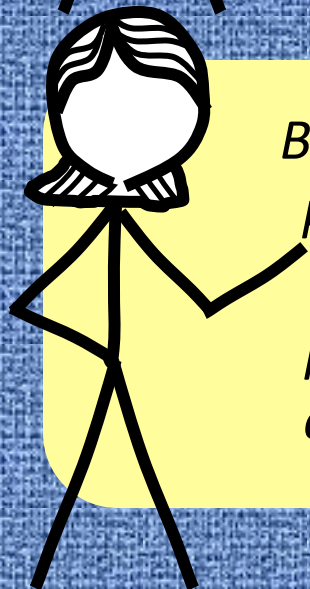
*So we generally follow the **Procedure** section in the lab manual carefully. Usually, word for word. (But as I mentioned, today is different.)*



# 1. How to use these pre-lab presentations.



*These pre-lab presentations always walk you through the calculations in a way that is easy to follow. (The lab manual expects you will refer back to the lab manual's introduction for this.)*



*Bring your laptop and have this presentation available during lab. So when it's time to perform the calculations, you can refer to the presentation.*

*Not every lab will have calculations, but they all have some sort of analysis of how things went.*



*Let's go!*



## 2. Making good measurements.

*So this week we are making good measurements?*

*What about great measurements?*

*Good (great) measurements start with the proper glassware – or equipment such as balances.*

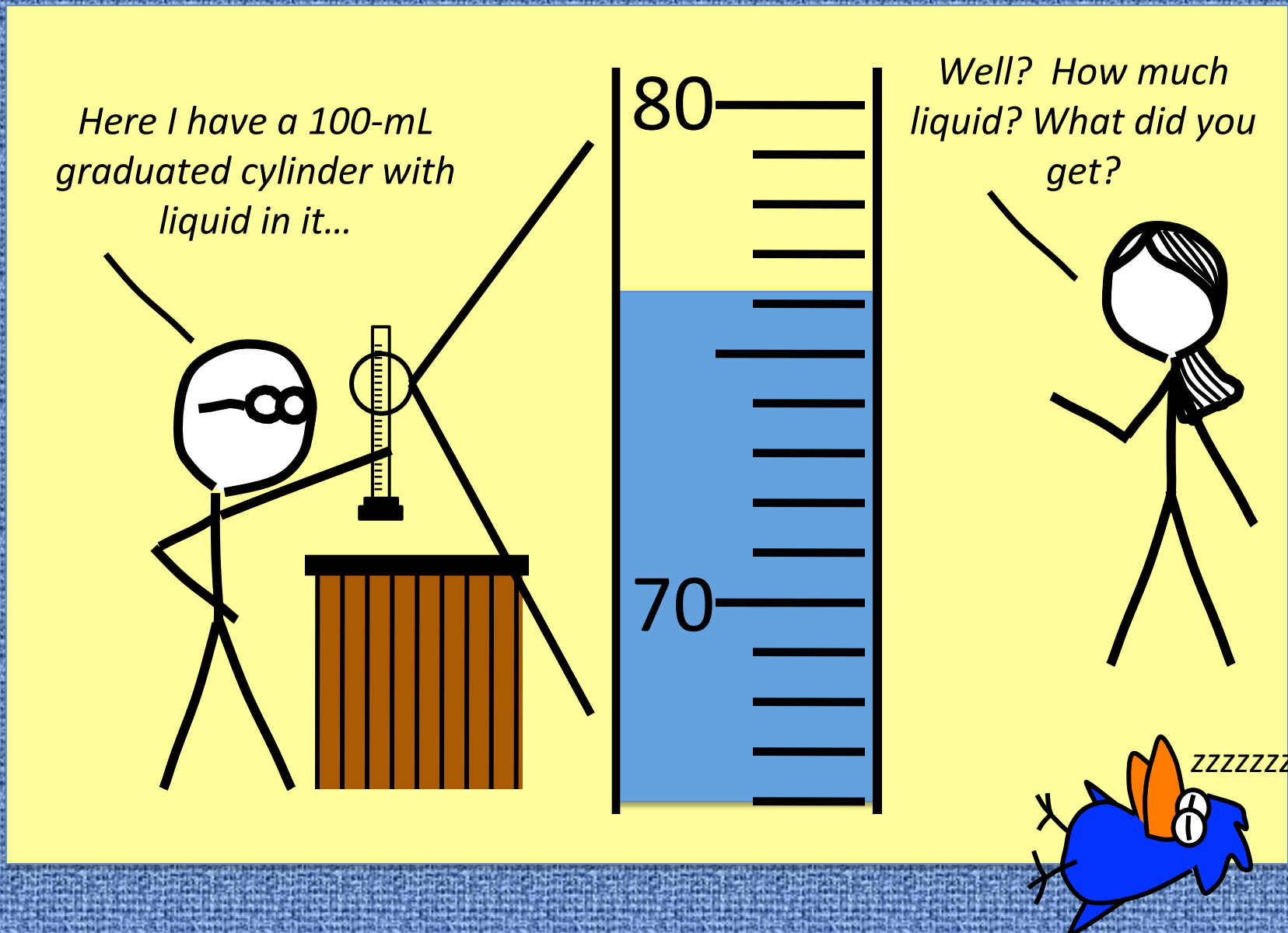
*The beaker (that you have your foot in) is not very accurate. The volumetric flask is very accurate – exactly 100.0 mL. Hint: The word volumetric in the name says it's accurate.*

*See that yellow sign in the corner? That's a hint that there is info on this slide for your introduction. Perhaps something about accuracy and glassware?*

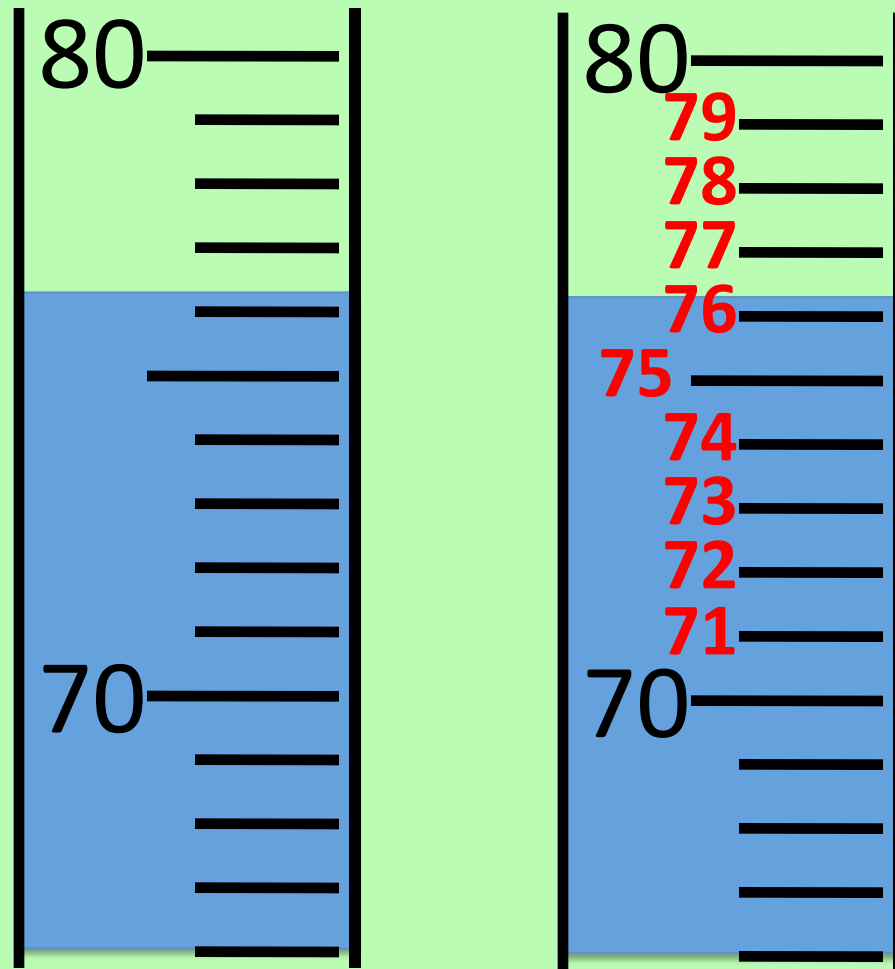


**Info for  
Introduction**

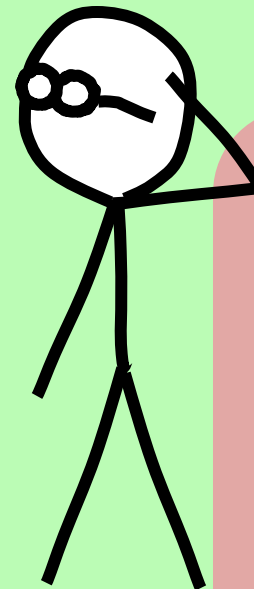
## 2. Making good measurements.



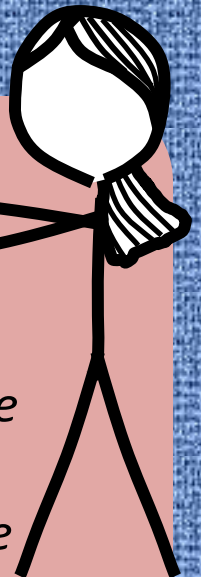
## 2. Making good measurements.



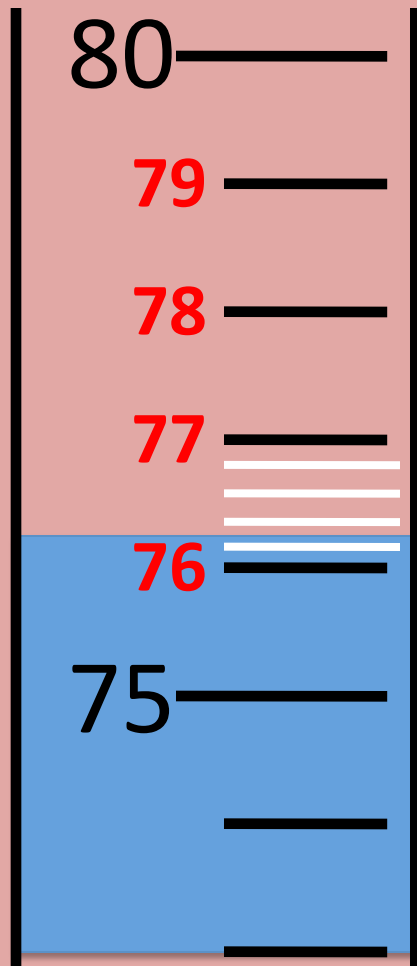
*Ahhh, it's  
between 76 and  
77 mL...*



*But we can  
estimate one  
more place  
between the  
two lines.*

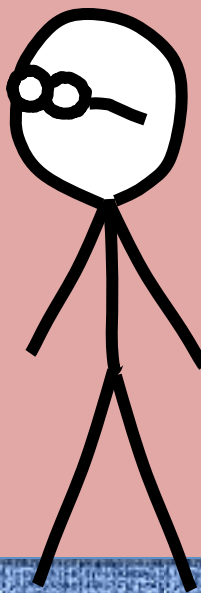


## 2. Making good measurements.



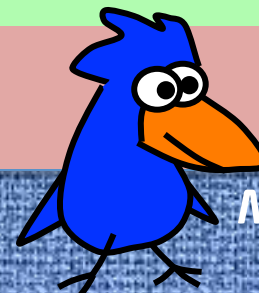
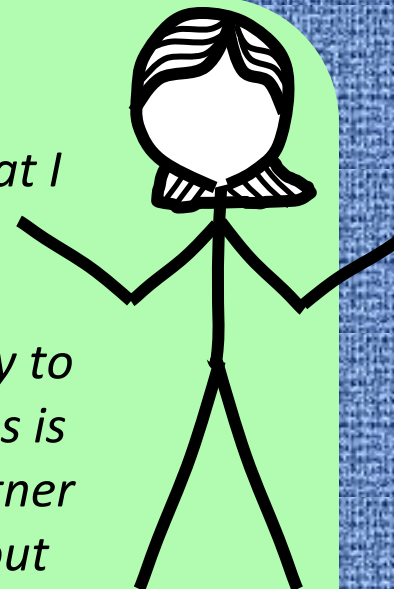
*Ok. I estimate it  
as 76.3 mL...*

— 76.8  
— 76.6  
— 76.4  
— 76.2



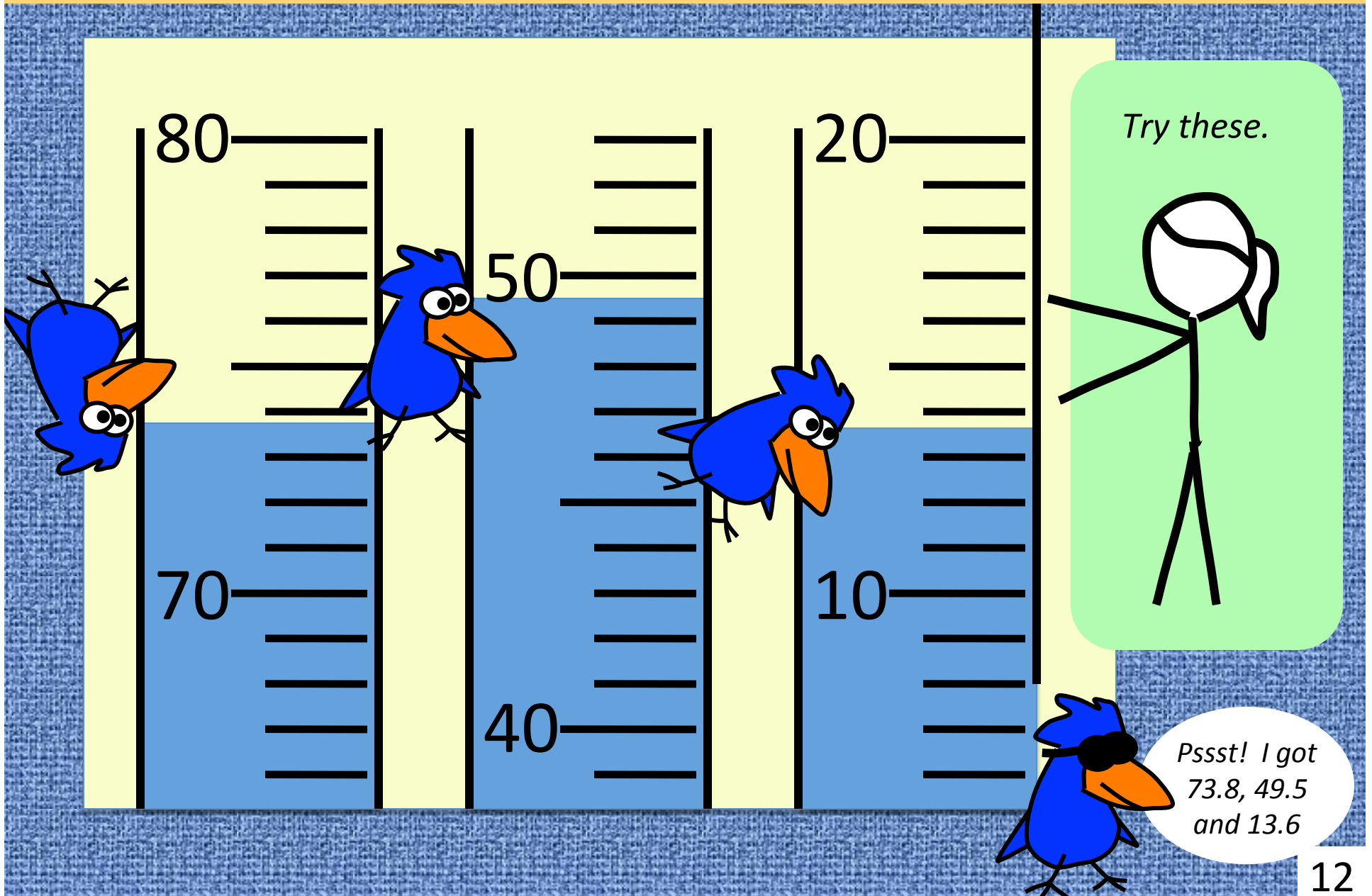
*Yeah, that's what I  
got too.*

*Hint: A good way to  
prevent mistakes is  
for each lab partner  
to read it without  
saying it out loud and  
then compare results.*



*Mistakes cost  
points.*

## 2. Making good measurements.



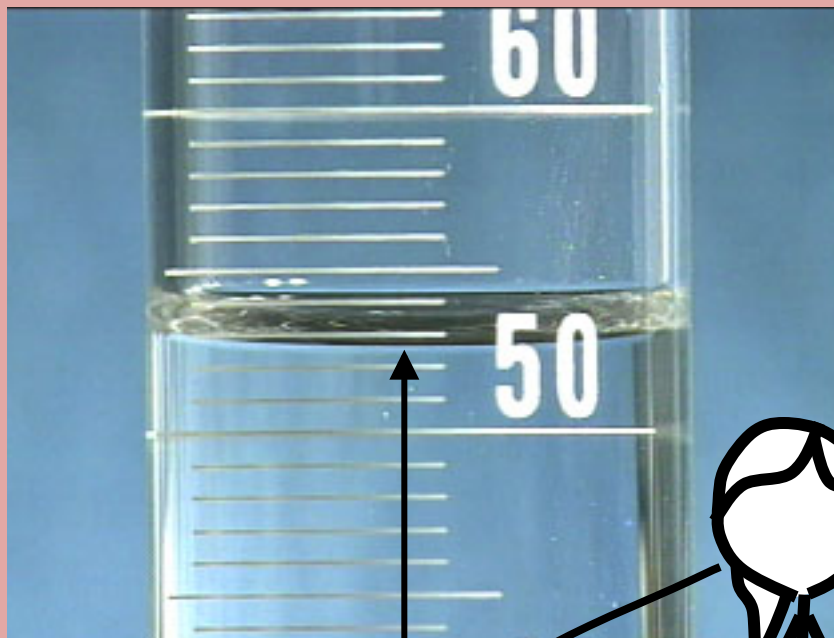
## 2. Making good measurements.

*10-mL graduated cylinders work the same except we can read to the hundredths place.*

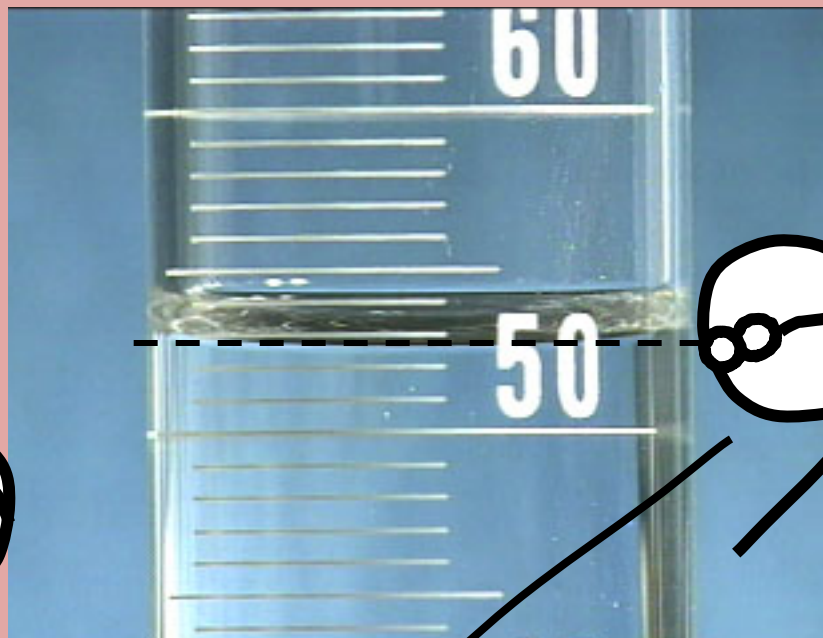
*Try these.*

*Pssst! I got 3.08 and 8.73. Milliliters, that is.*

## 2. Making good measurements.



*Real water forms a meniscus – we read from the bottom of the meniscus.*



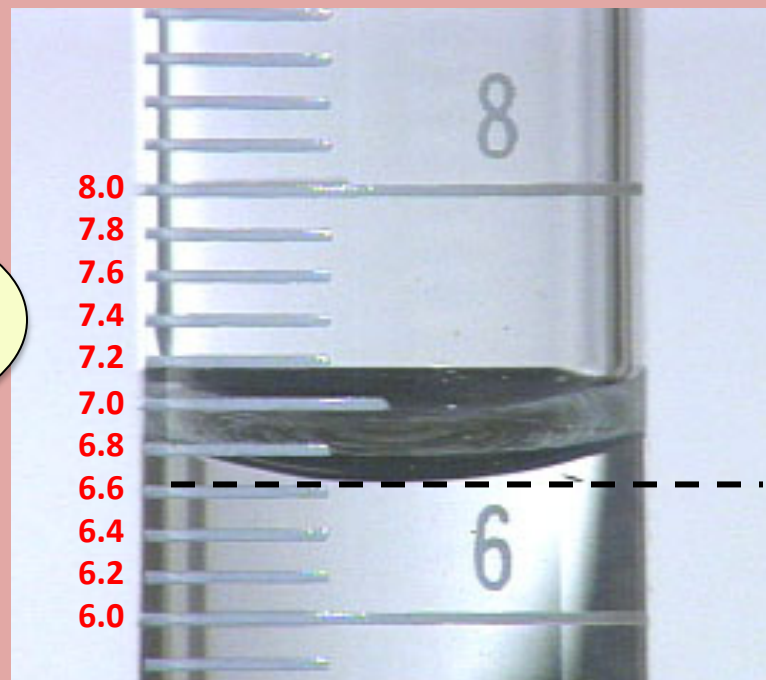
*...Aaaah... between 52 and 53... Closer to 53... Sort of 8/10 closer to 53... so... I get 52.8 mL*

Photo credit: [http://www.austincc.edu/biocr/1406/labm/ex2/images/graduated\\_cylinder.jpg](http://www.austincc.edu/biocr/1406/labm/ex2/images/graduated_cylinder.jpg)

## 2. Making good measurements.




*Try this...*



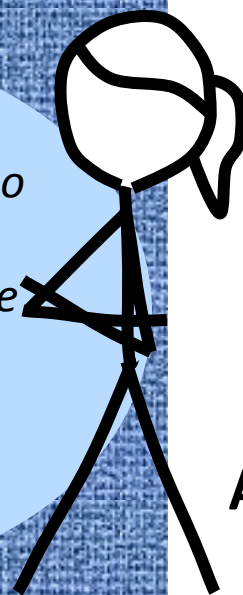
*...without  
help, or...*

*...with help.*


### 3. Precision, accuracy and significant figures.



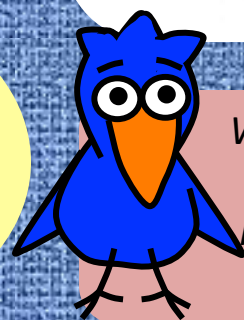
**PRECISION** has two definitions. In our textbook, precision refers to how well a set of independent measurements agree with one another.



In lab, **PRECISION** also refers to how many significant figures the measurement gives. So it has two definitions.



We could measure the mass of a penny multiple times, for example, using various pocket balances that read to the hundredths place.



These data look pretty good. They are all similar so that suggests precision of the first kind.

The mass of a 2017 penny

Trial 1	2.76 g
Trial 2	2.74 g
Trial 3	2.73 g
Trial 4	2.74 g

Average 2.743 g



We certainly expect uncertainty in the last decimal place.

### 3. Precision, accuracy and significant figures.

**The mass of a 2017 penny using pocket balances**

Trial 1 2.76 g  
Trial 2 2.74 g  
Trial 3 2.73 g  
Trial 4 2.74 g

**Average 2.743 g**



**Info for  
Introduction**

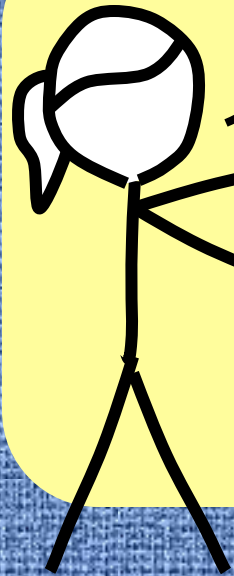
*Using analytical balances we get one or two extra places past the decimal point – better precision (of the second kind)*

**The mass of the same 2017 penny using different analytical balances**

Trial 1 2.763 g  
Trial 2 2.751 g  
Trial 3 2.729 g  
Trial 4 2.744 g

**Average 2.7468 g**

### 3. Precision, accuracy and significant figures.

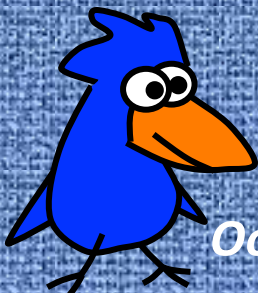
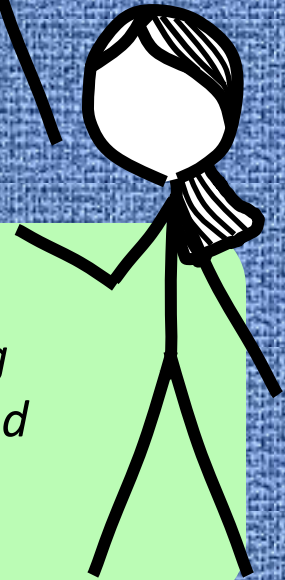


**ACCURACY** refers to how well the values compare to the actual true value, assuming it is known.

If the four trials were made by four people using four different balances, and the data were consistent, we would be pretty certain of the accuracy.



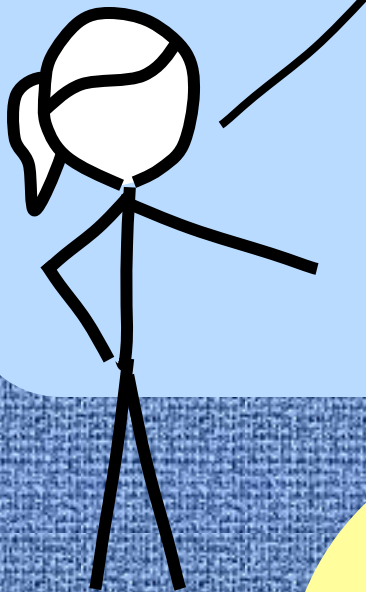
Suppose four people used the same balance – and maybe it is not working right. Or suppose one person measured a volume four times but was doing it wrong. Accuracy is not certain.



*Ooops.*

### 3. Precision, accuracy and significant figures.

*That brings us to significant figures  
and the rules for adding,  
subtracting, multiplying, and  
dividing them.*



*How many significant figures are  
present in each of these values?*

**18.99**

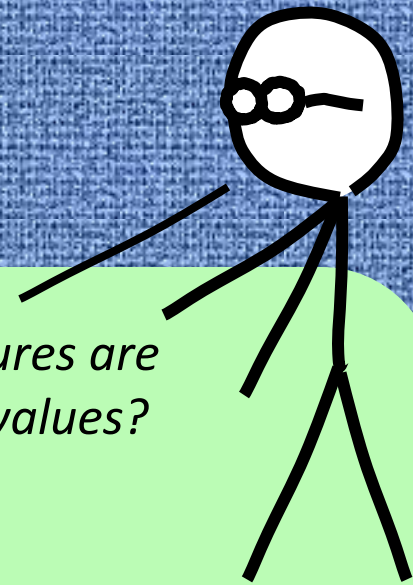
**0.0042**

**0.01610**

**12.002**

**47000**

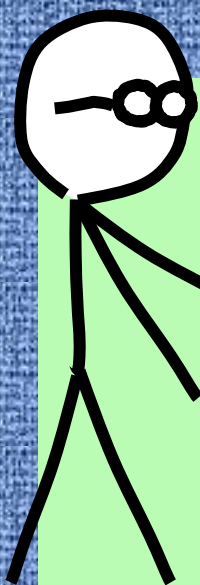
**100.**



*Ooo ooo!  
Ask me! I'm  
a numbers  
bird.*



### 3. Precision, accuracy and significant figures.



*How did you do?*

**18.99** (FOUR)  
**0.0042** (TWO)  
**0.01610** (FOUR)  
**12.002** (FIVE)  
**47000** (TWO)  
**100.** (THREE)

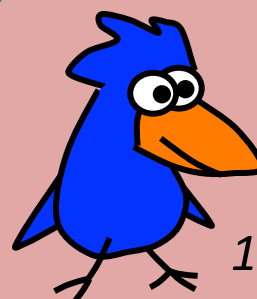
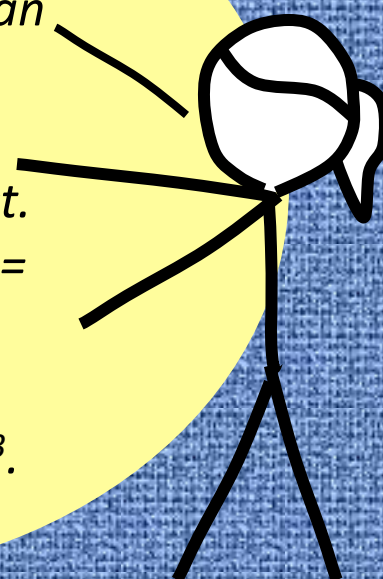


*Here are a two examples of conversions that are not exact – both have five sig figs:*

$1 \text{ L} = 1.0567 \text{ qt}$   
 $1 \text{ pound} = 453.59 \text{ g}$

Info for  
Introduction

*Moving along, numbers that are **defined** have an infinite number of significant figures because they are exact. For example, 1 dozen = 12, or  $1 \text{ m} = 100 \text{ cm}$ . And my personal favorite:  $1 \text{ mL} = 1 \text{ cm}^3$ .*



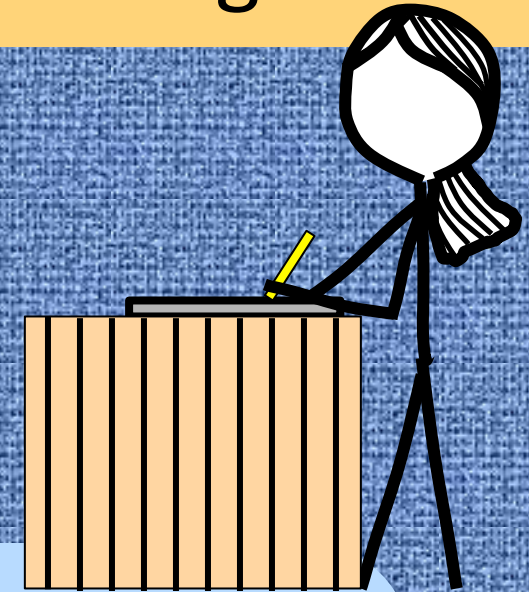
*Here are two bizarre exact conversions (by definitions):*

$1 \text{ inch} = 2.54 \text{ cm exactly}$   
 $1 \text{ cal} = 4.184 \text{ J exactly}$

### 3. Precision, accuracy and significant figures.

*The rule for adding or subtracting numbers is trickier than the rule for multiplying or dividing... We'll start with tricky.*

*Here's how: Line up the decimal points of the numbers to be added or subtracted. This involves writing the numbers down all lined up by decimal point. Then add them up using your calculator (or your head). Chop off the answer to match the number that has the fewest places past the decimal.*



EXAMPLE 1

$$\begin{array}{r} 8.653 \\ + 94.03 \\ \hline 102.68 \end{array}$$

*See? You can easily get more (or fewer) significant figures than you started with!*

### 3. Precision, accuracy and significant figures.

Example 2

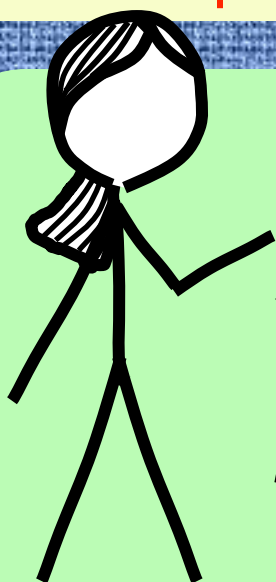
$$\begin{array}{r} 2.1 \\ + 7.422 \\ \hline 9.522 \\ 9.5 \end{array}$$

Example 3

$$\begin{array}{r} 0.0077 \\ + 1.04 \\ \hline 1.0477 \\ 1.05 \end{array}$$

Example 4

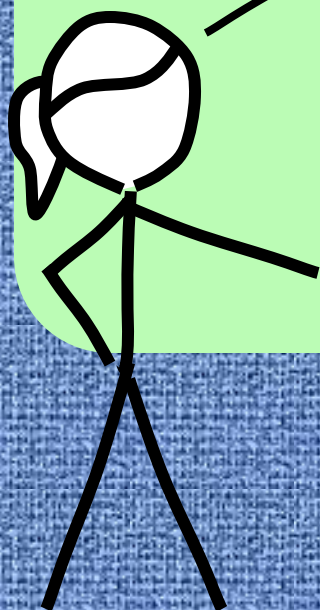
$$\begin{array}{r} 0.0027 \\ + 1.040 \\ \hline 1.0427 \\ 1.043 \end{array}$$



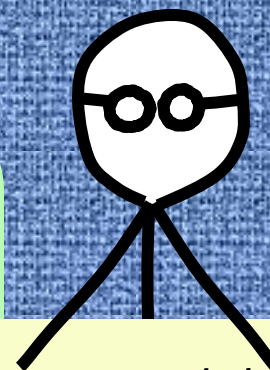
*Here are some more examples. See how we rounded in Examples 3 and 4? Also, listen up! This is important! Keep your full answer in your calculator until the very end – just keep track of how many figures your answer should have. This prevents propagating rounding errors. In Example 2, keep 9.522 for the next calculation, but remember you get only two sig figs from it in the final answer..*



### 3. Precision, accuracy and significant figures.



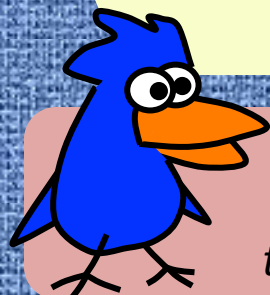
*The rule for multiplying and dividing...  
Well, we all know that rule...*



*If one number has five significant figures and the other number has only three, the product or quotient has only three – the same as the least of the participant numbers.*

**Example 1. A density problem: Suppose 2.6943 g has a volume of 1.37 mL. What is its density?**

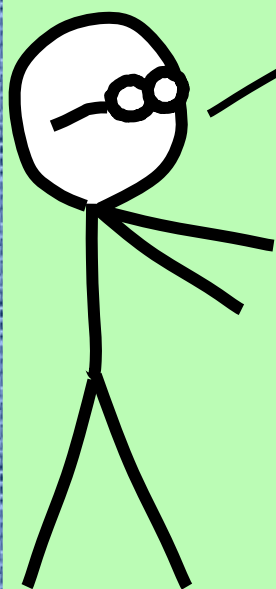
$$\text{density} = \text{mass/volume} = 2.6943 \text{ g} / 1.37 \text{ mL} \\ = 1.966642336 \text{ g/mL} \rightarrow 1.97 \text{ g/mL}$$



*Again, keep the whole number in your calculator until the end of the calculations Just remember there are supposed to be three significant figures.*

### 3. Precision, accuracy and significant figures.

**Example 2. What is the average mass of the penny from the pocket balance measurements?**



*Here we use both rules: We add up the four masses using the adding rule and then divide by 4 (an exact number this time) using the dividing rule.*

Trial 1	2.76 g
Trial 2	2.74 g
Trial 3	2.73 g
Trial 4	2.74 g

**Sum = 10.97 g**  
**4 significant figures**

Info for  
calculations

**DIVIDE  
BY 4  
(EXACT)**

**The mass of a  
2017 penny using  
pocket balance**

Trial 1	2.76 g
Trial 2	2.74 g
Trial 3	2.73 g
Trial 4	2.74 g

**Average 2.743 g**



### 3. Precision, accuracy and significant figures.

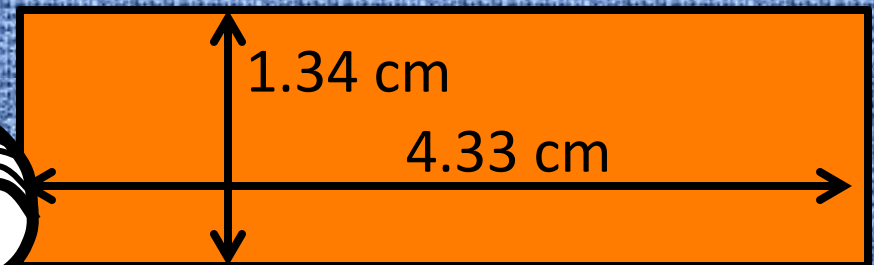
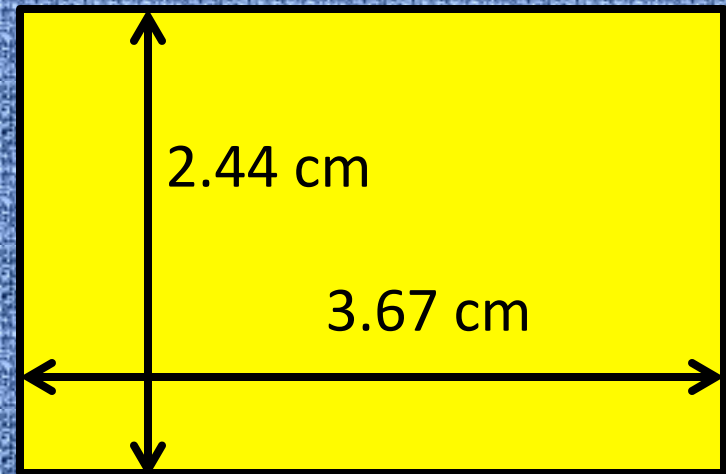
Example 3. What is the total area of these two blocks?

$$\text{Area}_{\text{yellow}} = 2.44 \text{ cm} \times 3.67 \text{ cm} \\ = 8.9548 \text{ cm}^2 \text{ (3 sf)}$$

$$\text{Area}_{\text{orange}} = 1.34 \text{ cm} \times 4.33 \text{ cm} \\ = 5.8022 \text{ cm}^2 \text{ (3 sf)}$$

$$\begin{array}{r} \text{Total area} = 8.9548 \text{ cm}^2 \\ + 5.8022 \text{ cm}^2 \\ \hline = 14.7570 \text{ cm}^2 \end{array}$$

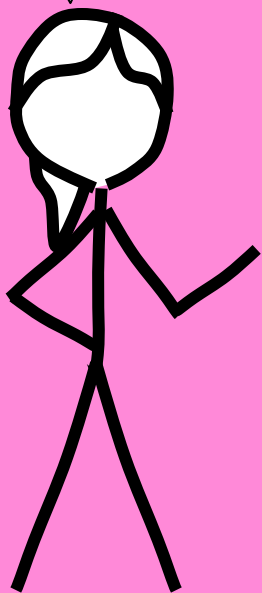
Info for  
calculations



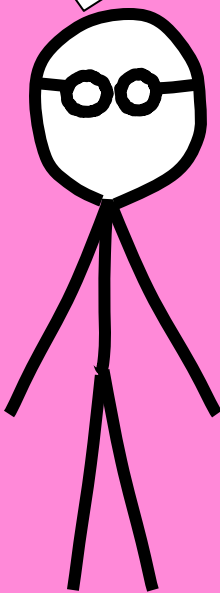
*Rounding as we go would yield 14.75 cm<sup>2</sup>. Carrying the extra numbers yields 14.76 cm<sup>2</sup> after rounding the final number – probably a better answer.*

## 4. Procedure: What we will do today

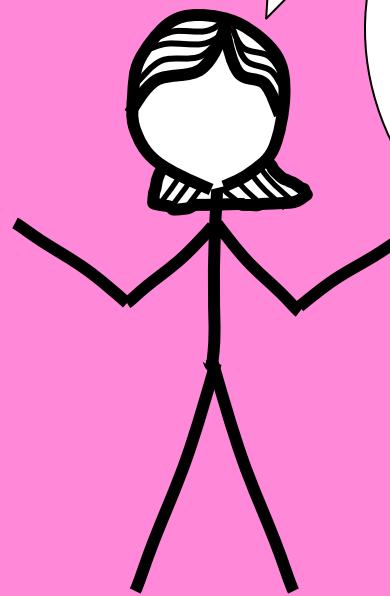
Now it's time for you to do the experiment. The TAs will help you with the lab safety part of the Procedure. You do not need to write anything in your lab notebook.



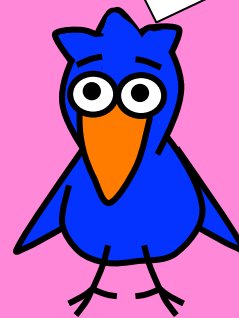
The TAs will also help you with the next two parts, Glassware and Equipment and practicing taking measurements.



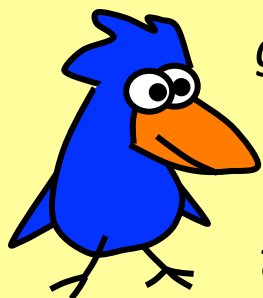
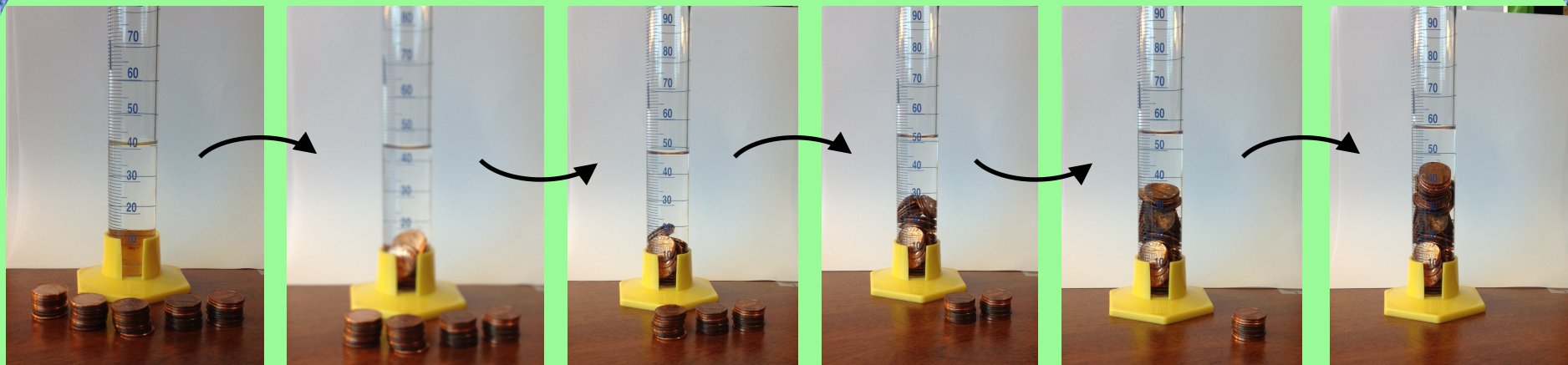
*Instead of the lab manual procedure for the density of pennies, follow the procedure on the back of the cover sheet and overviewed on the next four slides.*



Do the last part of the lab manual procedure on precision & accuracy if you have enough time. It will not be graded.



## 5. Procedure for the density experiment. (Details given on the back of the cover sheet.)



*Your experiment will look like this sequence as it goes along. Start with five piles of 10 pennies each and weigh each pile to the nearest 0.01 g. Fill a graduated cylinder with about 40 mL water. Read the volume to the nearest 0.1 mL. Add the first pile of pennies and read the volume again. Record the mass of pennies just added and the new volume. Repeat until all five piles have been added.*

## 5. Procedure for today (our density experiment)



*Follow the instructions on the back of your cover sheet to create an Excel spreadsheet with your data.*

	A	B	C	D	E	F	G
1	Trial	Number of Coins	Initial Volume	Final Volume	Volume of Coins	Mass of coins added	Total mass coins
2	1	10	40.1	44.0	3.9	27.0	27.02
3	2	20	40.1	47.7	7.6	27.6	54.60
4	3	30	40.1	51.0	10.9	27.0	81.62
5	4	40	40.1	54.9	14.8	27.1	108.74
6	5	50	40.1	58.1	18.0	27.1	135.83
7							

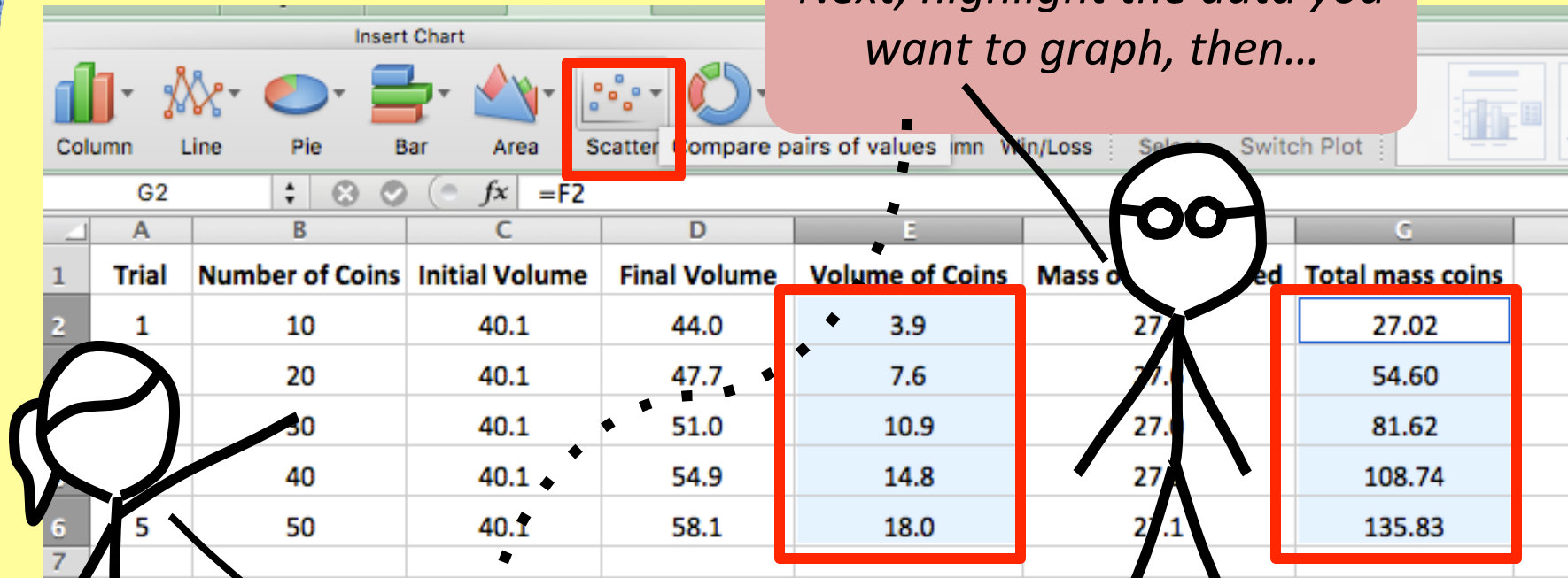
*Learn to write formulas, learn to copy and paste formulas and how to format your numbers. Help each other and ask Dr. Mattson or the TAs if you have questions.*

*You and your lab partner can work together on this, but print a copy for each of you.*



## 5. Procedure for today (our density experiment)

Next, highlight the data you want to graph, then...



...pick Scatter Chart

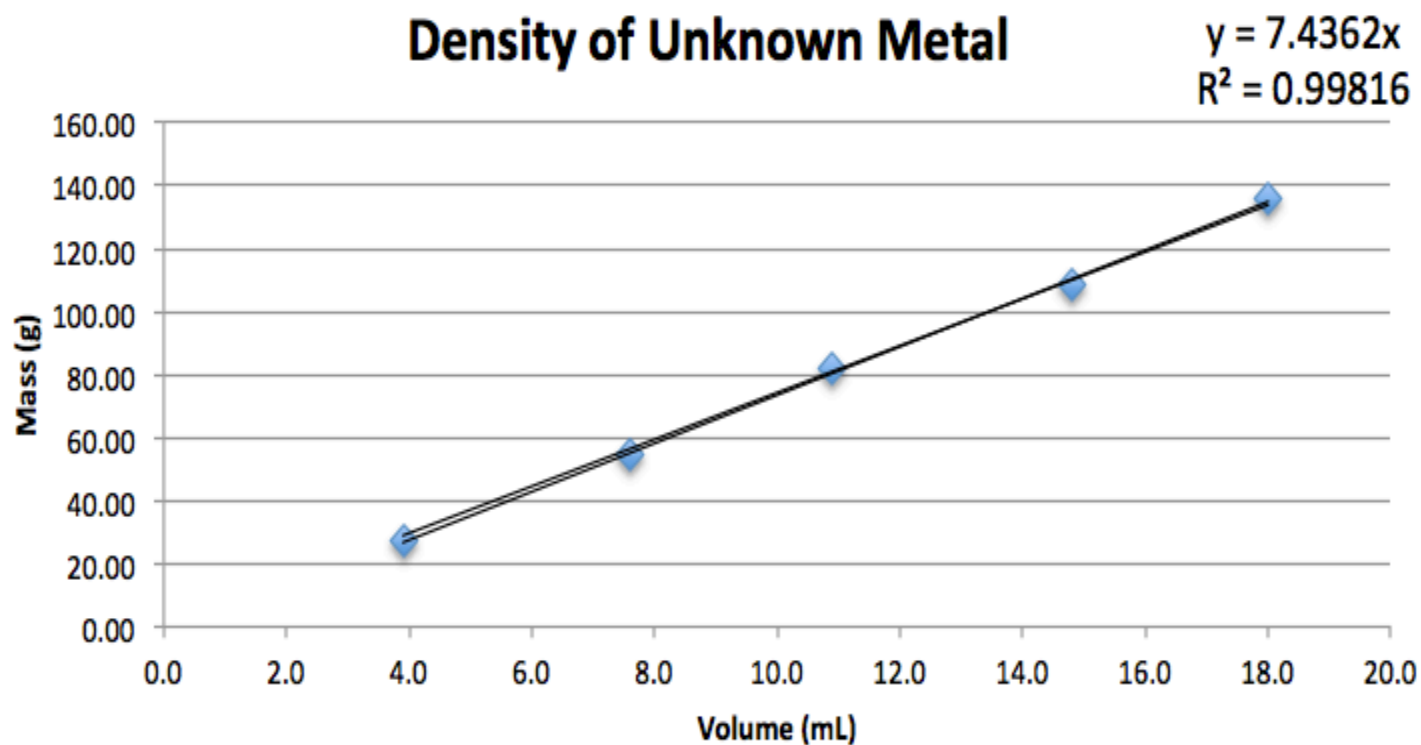
... and you'll get...

Info for  
Procedure

## 5. Procedure for today (our density experiment)

*...this graph!*

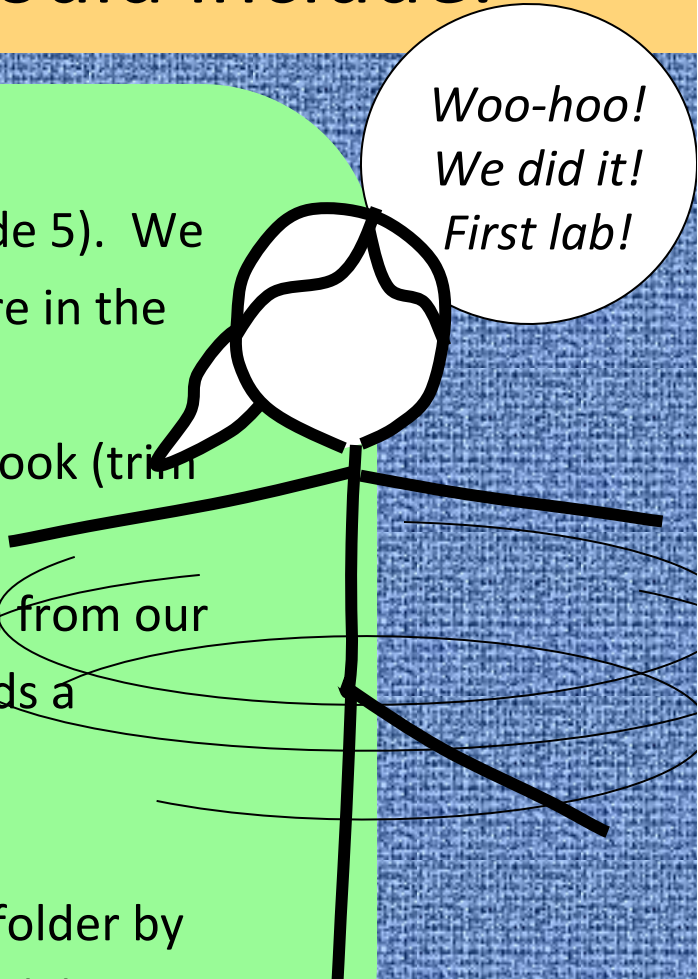
*Density is mass divided by the volume – the slope of the line!*



Info for  
Procedure

## 6. What your lab report should include.

- ① First, the cover sheet with TA initials.
- ② You now know how to write an Introduction (Slide 5). We will discuss conclusions and sources of error more in the pre-lab to Experiment 3.
- ③ Next, attach the copy pages from your lab notebook (trim off rough edges)
- ④ Last, the printed Excel x-y scatter graph and data from our density of pennies experiment. Each person needs a graph.
- ⑤ All of the above stapled together.
- ⑥ Turned in lab report (each individual) to correct folder by start of class tomorrow. Or... turn it in right after lab today. *Late labs may not be graded – see the syllabus*



Woo-hoo!  
We did it!  
First lab!

*Next week: We will need to dress for a mess.*