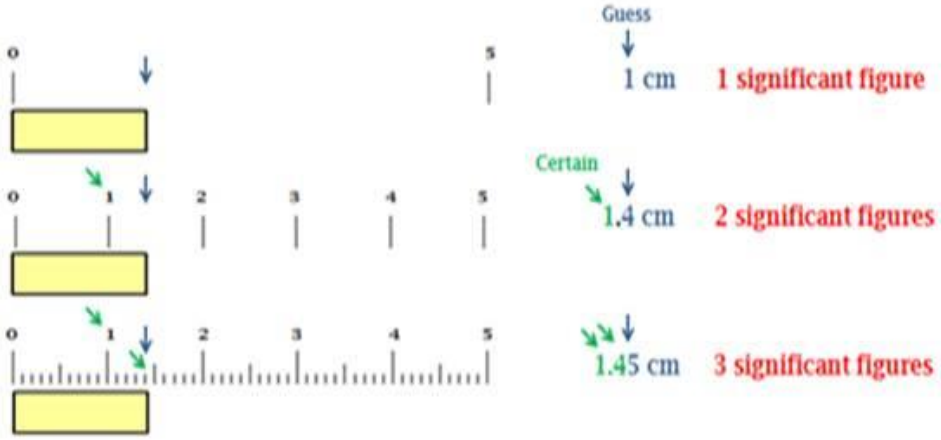
Chemistry 9-12

Measurement

Guided Inquiry with Manipulatives

By Shari Kendrick



Measurement Lesson
Teacher Notes

How I use this lesson in my classroom:

- I usually put all of the needed handouts and card sets in plastic boxes located on a bookshelf near the door. For this lesson, the boxes would contain the handout. I like to keep the task cards in boxes at the front of the room. The "Task Card Answer Sheet" is provided with the lesson.

- Students pick up the boxes when they enter the classroom. I usually let students work with up to three other students or they may work alone. More structured collaborative groups could also be set up and would work well.

- Students start at the beginning of the lesson and work their way through the lesson. I move between individuals and groups answering questions, asking higher order questions, and verbally assessing.

- The bullet symbols in the lesson serve as visual action cues to the student.
  - Indicates that the student needs to do something: get out cards, sort something, etc
  - Indicates that the student needs to make an observation
  - ? Indicates that the student needs to answer a question.

Teacher Preparation:

- ***The Handout***: I usually print several copies of the handout and laminate them. The handout may be printed in color or grayscale.

- ***The Ball Drop Activity:*** You will need several pieces of carbon paper and some small balls. Make sure that students make all of their drops from the same height.

- ***The Line Drawing Activity:*** Students will need metric rulers.

- ***The Task Cards:*** There are six different versions of the task cards. Each version is a different color. I like to attach each set together with a metal ring.

- ***The "Task Card Answer Sheet"***: Students record their answers to the task cards on the "Task Card Answer Sheet". Students should record the name of the task card set and the color of the cards on their "Task Card Answer Sheet". I usually have the students turn in the answer sheet for a grade. I give students the "Task Card Answer Sheet" along with the lesson.

- ***The Study Sheet:*** I usually provide the study sheet along with the lesson, but it could also be given out after the lesson or before a quiz.

Modifications:

This lesson has several kinesthetic and visual components. Student and teacher interactions during the lesson also ensure a strong verbal component. Because of this, it works well "as is" for on level, special education, and most 504 students. I usually modify as needed by varying the level of my questioning when interacting with students. This lesson could also be used as an introductory activity for more advanced students.

Learning Objectives (Bloom's Revised Taxonomy):

- *Remembering*

  Determine how to record the correct number of significant figures in a measurement.

- *Understanding*

  Explain the following terms: significant figures, accuracy, precision, percent error.

- *Applying*

  Calculate the percent error in measurement data.

- *Analyzing*

  Analyze data to determine its accuracy and precision.

- *Evaluating*

  Discuss how differences in measuring devices can affect the accuracy and precision of a measurement.

- *Creating*

  Illustrate the following: 1) low accuracy with high precision; 2) high accuracy with low precision; 3) low accuracy with low precision; 4) high accuracy with high precision.

Measurement

By the end of this lesson, I will be able to:

- ✓ Explain the following terms: significant figures, accuracy, precision, percent error.
- ✓ Record measurements to the correct number of significant figures.
- ✓ Evaluate the accuracy and precision of data.
- ✓ Illustrate:
  - low accuracy with high precision.
  - high accuracy with low precision.
  - low accuracy with low precision.
  - high accuracy with high precision.
- ✓ Calculate the percent error of a measurement.

Ask your teacher for the handout that accompanies this lesson. You will also need a copy of a paper titled "Task Card Answer Sheet".

Part 1: Significant Figures

Look at the handout titled "Rulers".

This handout illustrates three rulers used to measure the same object.

Measure the length of the object using each ruler.

? Record your measurements in the table below. Ask three of your classmates for their measurements and record them in the table as well.

	Ruler 1 (cm)	**Ruler 2 (cm)**	**Ruler 3 (cm)**
You			
Classmate 1			
Classmate 2			
Classmate 3			

Look at the data for Ruler 1.

Circle the digits (if any) that are exactly the same for **all** of the Ruler 1 measurements. Repeat for Rulers 2 and 3.

? Were any of the digits in the Ruler 1 measurements the same for all of the measurements? Why do you think that this occurred?

? Which digits were the same for all of the Ruler 2 Measurements? Which digits were different? Why do you think that this occurred?

? Which digits were the same for all of the Ruler 3 Measurements? Which digits were different? Why do you think that this occurred?

Vocabulary!

When recording a measurement:

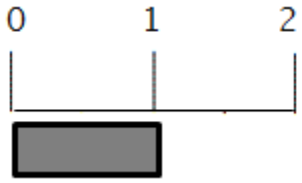
- record all certain digits.
- record one digit that must be guessed

The ***significant figures*** in a measurement are equal to all of the certain digits plus one digit that must be guessed.

? Which ruler gave you the measurement with the most significant figures?

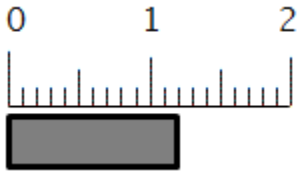
Compare the rulers and measurements shown below.

Ruler A



1.0 cm

Ruler B



1.20 cm

? What is the value of the certain digit in the measurement using Ruler A? What is the digit that was guessed?

? What are the values of the certain digits in the measurement using Ruler B? What is the digit that was guessed?

? What can you conclude about the digit that must be guessed when the measurement appears to land on a scale line?

Ask your teacher for a set of "Measurement Task Cards" and get out the "Task Card Answer Sheet".

? Answer each of the questions on Measurement Task Cards 1-8 only. **Record your answers on your "Task Card Answer Sheet".**

Part 2: Accuracy and Precision

- *Ask your teacher for carbon paper, and a ball. You will also need two pieces of blank paper.*

  - Draw a dot or "cross-hair" in the center of one of the sheets of paper. Make the same mark on the back of the paper. **Make sure the two marks are in the exact same spot on the paper.**

    Label the paper "Eyes Closed".

    Place a piece of carbon paper under the paper.

  - With your <u>eyes closed</u>, drop the ball ten times and try to hit the mark in the center of the paper. **Be sure to drop the ball from the same height each time.**

  - Draw a dot or "cross-hair" in the center of a second sheet of paper. Make the same mark on the back of the paper. **Make sure the two marks are in the exact same spot.**

    Label the paper "Eyes Open".

    Place a piece of carbon paper under the paper.

  - With your <u>eyes open</u>, drop the ball ten times and try to hit the mark in the center of the paper. **Be sure to drop the ball from the same height each time.**

  - Measure the distance in cm from each ball mark to the mark in the center of each paper.

    A ball mark that lands directly on the mark in the center of the paper should be recorded as 0.00 cm.

? Record your measurements in the table below.

Ball Drop	"Eyes Closed" Distance from Center in cm	"Eyes Opened" Distance from Center in cm
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

? Which group of data is closest to the mark in the center of the paper? (i.e Which group of data is closest to 0.00 cm?). This group of data is the most **accurate**.

Vocabulary!

The ***accuracy*** of a measurement indicates how close it is to the known or correct value.

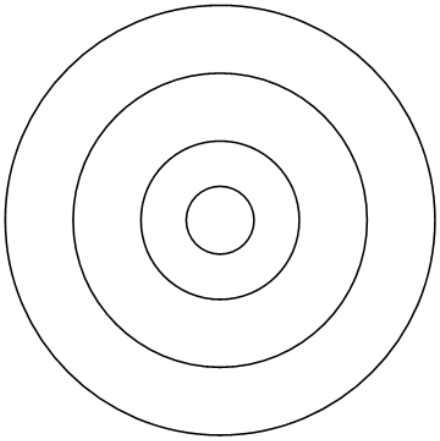
? Which group of data has measurements that are closest to each other? This group of data is the most **precise**.

Vocabulary!

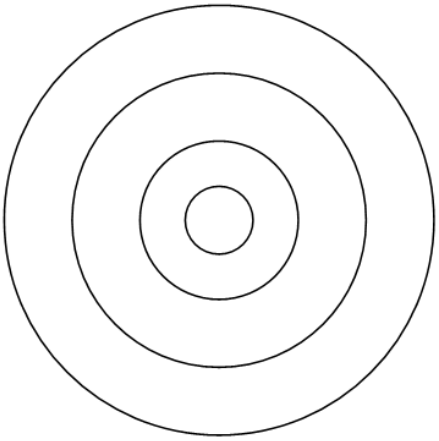
The ***precision*** of measurements indicates how close they are to each other.

? *Illustrate the indicated levels of precision and accuracy by placing six dots on each of the targets below:*

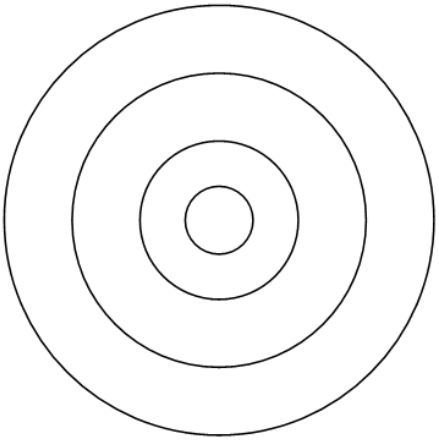
Low Accuracy
&
High Precision



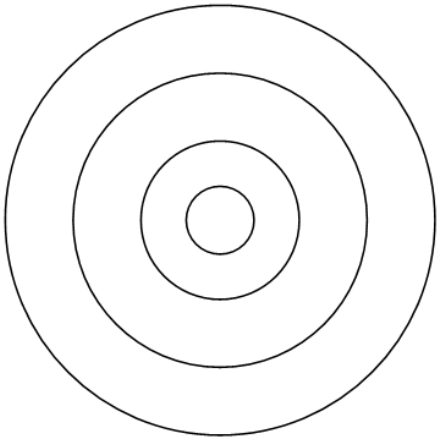
Low Accuracy
&
Low Precision



High Accuracy
&
Low Precision



High Accuracy
&
High Precision



- *Tear a piece of paper into eight smaller pieces of paper.*

  - On the first small piece of paper, draw a line that you estimate to be five cm – **do not use a ruler!** Turn the paper over so that you can't see the line you just drew.

  - Repeat on three more of the small pieces of paper. Remember! Don't use a ruler and turn over each paper when you have finished drawing the line.

  - Use a ruler to measure length of the length of the four lines that you just drew.

  - ? Record your measurements in the table below.

Line	Length of Line (cm)
1	
2	
3	
4	

  - On the remaining four small pieces of paper, repeat drawing a line that you estimate to be five cm without using a ruler. Turn each paper over after you draw the line.

  - Use a ruler to measure the length of the four new lines that you just drew.

  - ? Record your new measurements in the table below.

Line	Length of Line (cm)
5	
6	
7	
8	

? Which group of measurements is the most accurate (closest to 5.00 cm)?

? Which group of measurements is the most precise?

Part 3: Percent Error

Vocabulary!

Percent Error provides a quantitative indication of how close an experimental value is to an actual known value.

Absolute Value – make value positive

$$\% \text{ Error} = \frac{|\text{Actual Value} - \text{Experimental Value}|}{\text{Actual Value}} \times 100$$

The smaller the percent error, the closer the experimental value is to the actual value.

Look again at the second table of data that you created (Lines 5-8).

? Use the formula above to calculate the percent error for each line. The actual value will be 5.00 cm. The experimental values are the values from each of your measurements.

? What is the percent error for line five?

? What is the percent error for line six?

? What is the percent error for line seven?

? What is the percent error for line eight?

? Which of the four lines was the most accurate?

Return again to the set of "Measurement Task Cards" and get out the "Task Card Answer Sheet".

? Answer the questions on cards 9-12 of the Measurement Task Cards set.

Record your answers on your "Task Card Answer Sheet".

Measurement
Study Sheet – Page 1
Vocabulary

Significant Figures: all of the certain digits in a measurement plus one digit that must be guessed

Accuracy: how close a measurement is to a known or correct value

Precision: how close measurements are to each other

Percent Error: a quantitative indication of how close an experimental value is to a known actual value – the smaller the percent error, the more accurate the result

$$\% \text{ error} = \frac{|\text{ actual value} - \text{experimental value }|}{\text{actual value}} \times 100$$

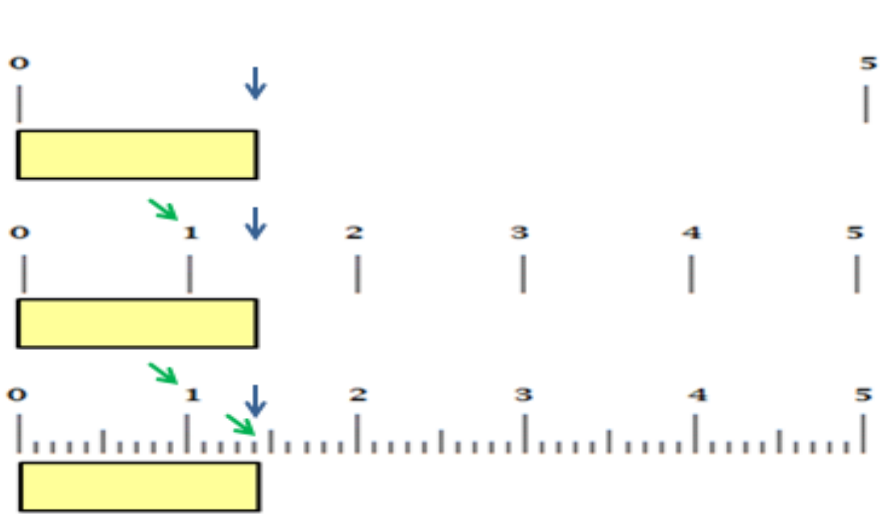
Actual Value: a correct or known value

Experimental Value: a value that is determined in an experiment

Measurement

Study Sheet – Page 2

Significant Figures and Measurement



Percent Error

absolute value symbols

$$\% \text{ Error} = \frac{|\text{actual value} - \text{experimental value}|}{\text{actual value}} \times 100$$

actual value: 3.18 g

experimental value: 5.00 g

$$\% \text{ Error} = \frac{|3.18 - 5.00|}{3.18} \times 100 = \frac{1.82}{3.18} \times 100 = 57.23\%$$

Accuracy & Precision

Actual Value: 5.55

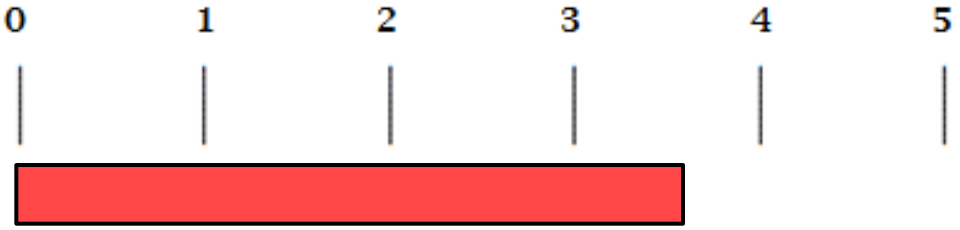
Precise, Accurate	Precise, Not Accurate
5.55	7.67
5.54	7.67
5.55	7.66

Not Precise, Accurate	Not Precise, Not Accurate
5.57	7.67
5.55	8.02
5.53	6.11

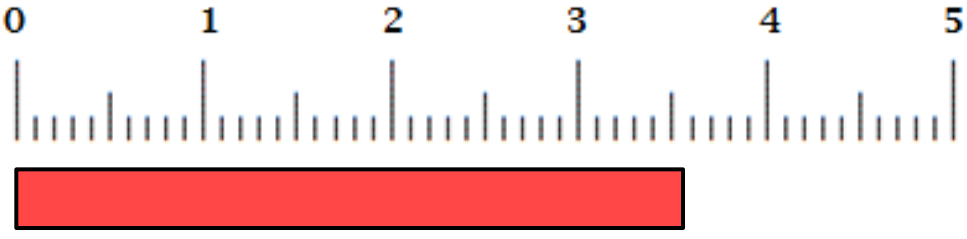
Rulers

Ruler 1

Ruler 2



Ruler 3



Task Card Answer Sheet

Measurement Task Card Answers

Card Color _____

1	2	3	4
5	6	7	8
9	10	11	12

Measurement- Answers

By the end of this lesson, I will be able to:

- ✓ Explain the following terms: significant figures, accuracy, precision, percent error.
- ✓ Record measurements to the correct number of significant figures.
- ✓ Evaluate the accuracy and precision of data.
- ✓ Illustrate:
  - low accuracy with high precision.
  - high accuracy with low precision.
  - low accuracy with low precision.
  - high accuracy with high precision.
- ✓ Calculate the percent error of a measurement.

Ask your teacher for the handout that accompanies this lesson. You will also need a copy of a paper titled "Task Card Answer Sheet".

Part 1: Significant Figures

Look at the handout titled "Rulers".

This handout illustrates three rulers used to measure the same object.

Measure the length of the object using each ruler.

? Record your measurements in the table below. Ask three of your classmates for their measurements and record them in the table as well.

Example only – answers will vary

	Ruler 1 (cm)	Ruler 2 (cm)	Ruler 3 (cm)
You	4	3.6	3.57
Classmate 1	4	3.7	3.56
Classmate 2	3	3.7	3.57
Classmate 3	3	3.8	3.58

Look at the data for Ruler 1.

Circle the digits (if any) that are exactly the same for **all** of the Ruler 1 measurements. Repeat for Rulers 2 and 3.

? Were the digits in the Ruler 1 measurements the same for all of the measurements? Why do you think that this occurred?

No, they were not the same because the numbers had to be guessed.

? Which digits were the same for all of the Ruler 2 Measurements? Which digits were different? Why do you think that this occurred?

The one's place digit ("3") is the same for all of the measurements. The tenth place digit has differences. The tenth place digit had to be guessed.

? Which digits were the same for all of the Ruler 3 Measurements? Which digits were different? Why do you think that this occurred?

The one's place digit ("3") and the tenth place digit ("5") are the same for all of the measurements. The hundredth place digit has differences. The hundredth place digit had to be guessed.

Vocabulary!

When recording a measurement:

- record all certain digits.
- record one digit that must be guessed

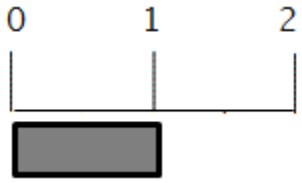
The ***significant figures*** in a measurement are equal to all of the certain digits plus one digit that must be guessed.

? Which ruler gave you the measurement with the most significant figures?

ruler 3

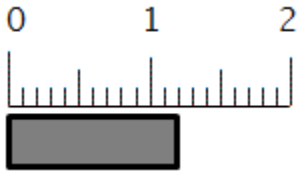
Compare the rulers and measurements shown below.

Ruler A



1.0 cm

Ruler B



1.20 cm

? What is the value of the certain digit in the measurement using Ruler A? What is the value of the digit that was guessed?

The value of the certain digit is "1". The value of the digit that was guessed is "0".

? What are the values of the certain digits in the measurement using Ruler B? What is the value of the digit that was guessed?

The values of the certain digits are "1" and "2". The value of the digit that was guessed is "0".

? What can you conclude about the digit that must be guessed when the measurement appears to land on a scale line?

When a measurement appears to land directly on a line, the digit that is guessed is "0".

Ask your teacher for a set of "Measurement Task Cards" and get out the "Task Card Answer Sheet".

? Answer each of the questions on Measurement Task Cards 1-8 only. **Record your answers on your "Task Card Answer Sheet".**

Part 2: Accuracy and Precision

- *Ask your teacher for carbon paper, and a ball. You will also need two pieces of blank paper.*

  - Draw a dot or "cross-hair" in the center of one of the sheets of paper. Make the same mark on the back of the paper. **Make sure the two marks are in the exact same spot on the paper.**

    Label the paper "Eyes Closed".

    Place a piece of carbon paper under the paper.

  - With your <u>eyes closed</u>, drop the ball ten times and try to hit the mark in the center of the paper. **Be sure to drop the ball from the same height each time.**

  - Draw a dot or "cross-hair" in the center of a second sheet of paper. Make the same mark on the back of the paper. **Make sure the two marks are in the exact same spot.**

    Label the paper "Eyes Open".

    Place a piece of carbon paper under the paper.

  - With your <u>eyes open</u>, drop the ball ten times and try to hit the mark in the center of the paper. **Be sure to drop the ball from the same height each time.**

  - Measure the distance in cm from each ball mark to the mark in the center of each paper.

    A ball mark that lands directly on the mark in the center of the paper should be recorded as 0.00 cm.

? Record your measurements in the table below.

Ball Drop	"Eyes Closed" Distance from Center in cm	"Eyes Opened" Distance from Center in cm
1	10.75	5.22
2	14.55	3.12
3	18.45	4.98
4	21.00	6.78
5	5.77	5.34
6	24.66	7.32
7	12.96	7.23
8	8.85	4.87
9	7.32	5.35
10	26.45	6.12

Example only – answers will vary

? Which group of data is closest to the mark in the center of the paper? (i.e Which group of data is closest to 0.00 cm?). This group of data is the most **accurate**.

"Eyes Open"

Vocabulary!

The ***accuracy*** of a measurement indicates how close it is to the known or correct value.

? Which group of data has measurements that are closest to each other? This group of data is the most **precise**.

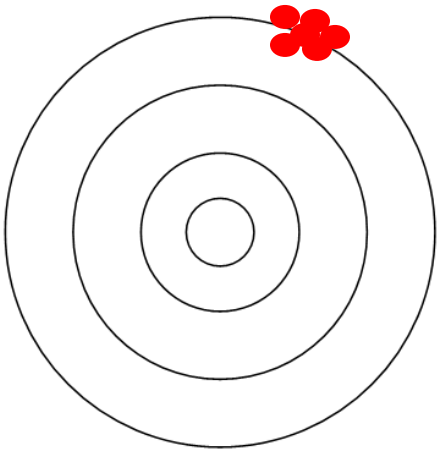
"Eyes Open"

Vocabulary!

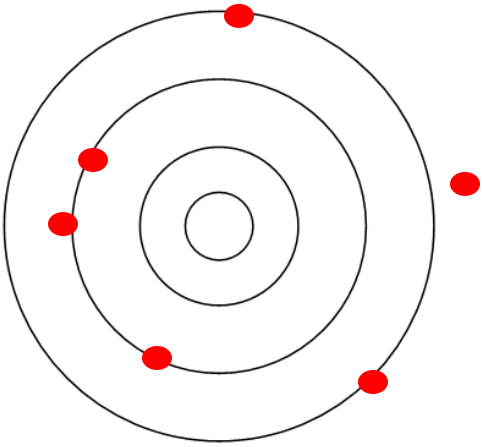
The ***precision*** of measurements indicates how close they are to each other.

? *Illustrate the indicated levels of precision and accuracy by placing six dots on each of the targets below:*

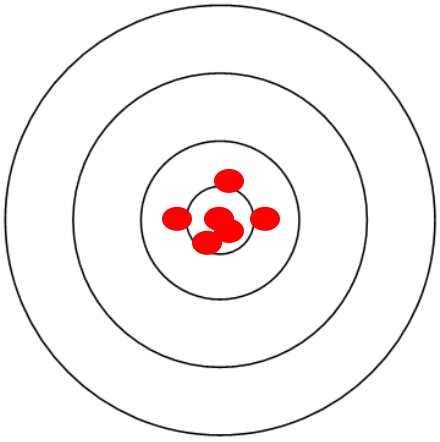
Low Accuracy
&
High Precision



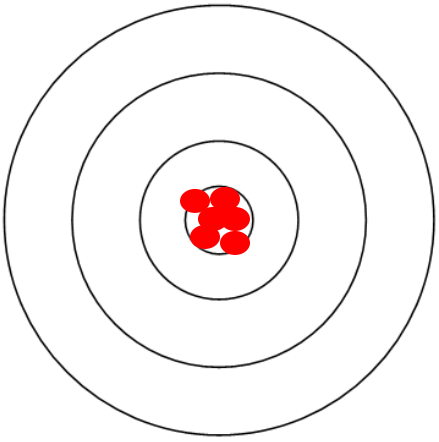
Low Accuracy
&
Low Precision



High Accuracy
&
Low Precision



High Accuracy
&
High Precision



- *Tear a piece of paper into eight smaller pieces of paper.*

  - On the first small piece of paper, draw a line that you estimate to be five cm – **do not use a ruler!** Turn the paper over so that you can't see the line you just drew.

  - Repeat on three more of the small pieces of paper. Remember! Don't use a ruler and turn over each paper when you have finished drawing the line.

  - Use a ruler to measure the length of the four lines that you just drew.

  - ? Record your measurements in the table below.

Example only – answers will vary

Line	Length of Line (cm)
1	4.42
2	3.93
3	3.85
4	4.58

  - On the remaining four small pieces of paper, repeat drawing a line that you estimate to be five cm without using a ruler. Turn each paper over after you draw the line.

  - Use a ruler to measure the length of the four new lines that you just drew.

  - ? Record your new measurements in the table below.

Example only – answers will vary

Line	Length of Line (cm)
5	5.15
6	5.10
7	5.21
8	5.00

? Which group of measurements is the most accurate (closest to 5.00 cm)?

Example only – answers will vary

The second group is the most accurate – lines 5-8.

Which group of measurements is the most precise?

The second group is the most precise – lines 5-8.

Part 3: Percent Error

Vocabulary!

Percent Error provides a quantitative indication of how close an experimental value is to an actual known value.

Absolute Value – make value positive

$$\% \text{ Error} = \frac{|\text{Actual Value} - \text{Experimental Value}|}{\text{Actual Value}} \times 100$$

The smaller the percent error, the closer the experimental value is to the actual value.

Look again at the first table of data that you created (Lines 1-4).

? Use the formula above to calculate the percent error for each line. The actual value will be 5.00 cm. The experimental values are the values from each of your measurements.

? What is the percent error for line five?

$$\% \text{ error} = \frac{|5.00 - 4.42|}{5.00} \times 100 = 11.6\%$$

Example only – answers will vary

? What is the percent error for line six?

$$\% \text{ error} = \frac{|5.00 - 3.93|}{5.00} \times 100 = 21.4\%$$

? What is the percent error for line seven?

$$\% \text{ error} = \frac{|5.00 - 3.85|}{5.00} \times 100 = 23.0\%$$

? What is the percent error for line eight?

$$\% \text{ error} = \frac{|5.00 - 4.58|}{5.00} \times 100 = 8.4\%$$

? Which of the four lines is the most accurate?

Line 8 is the most accurate because it has the lowest % error.

☝ *Return again to the set of "Measurement Task Cards" and get out the "Task Card Answer Sheet".*

? Answer the questions on cards 9-12 of the Measurement Task Cards set.

Record your answers on your "Task Card Answer Sheet".

Task Card Answers

** The last digit of the measurements will vary.
Measurements landing on the line may vary depending on the "guess".

Card #	Red	Orange	Yellow	Green	Blue	Violet
1	25.5 ml	24.0 ml	48.0 ml	43.0 ml	57.0 ml	58.0 ml
2	1.15 cm	1.50 cm	0.94 cm	2.10 cm	1.08 cm	2.28 cm
3	2.00 cm	1.82 cm	1.50 cm	0.85 cm	1.82 cm	2.00 cm
4	3.00 ml	4.00 ml	5.50 ml	5.00 ml	8.00 ml	8.00 ml
5	0.9 cm	1.4 cm	0.7 cm	1.8 cm	2.1 cm	1.6 cm
6	1.8 cm	1.8 cm	0.9 cm	1.3 cm	1.3 cm	0.9 cm
7	20.0 ml	30.0 ml	5.30 ml	5.30 ml	7.15 ml	7.15 ml
8	3.34 cm	3.80 ml	40.0ml	45.0 ml	54.8 ml	55.0 ml
9	#	#	#	#	#	#
10	11.8%	15.4%	19.2%	11.8%	9.98%	14.9%
11	38.7%	18.0%	28.2%	11.6%	18.6%	31.3%
12	$	$	$	$	$	$

Precision: how close measurements are to one another

$ Accuracy: how close a measurement is to an actual or known value

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