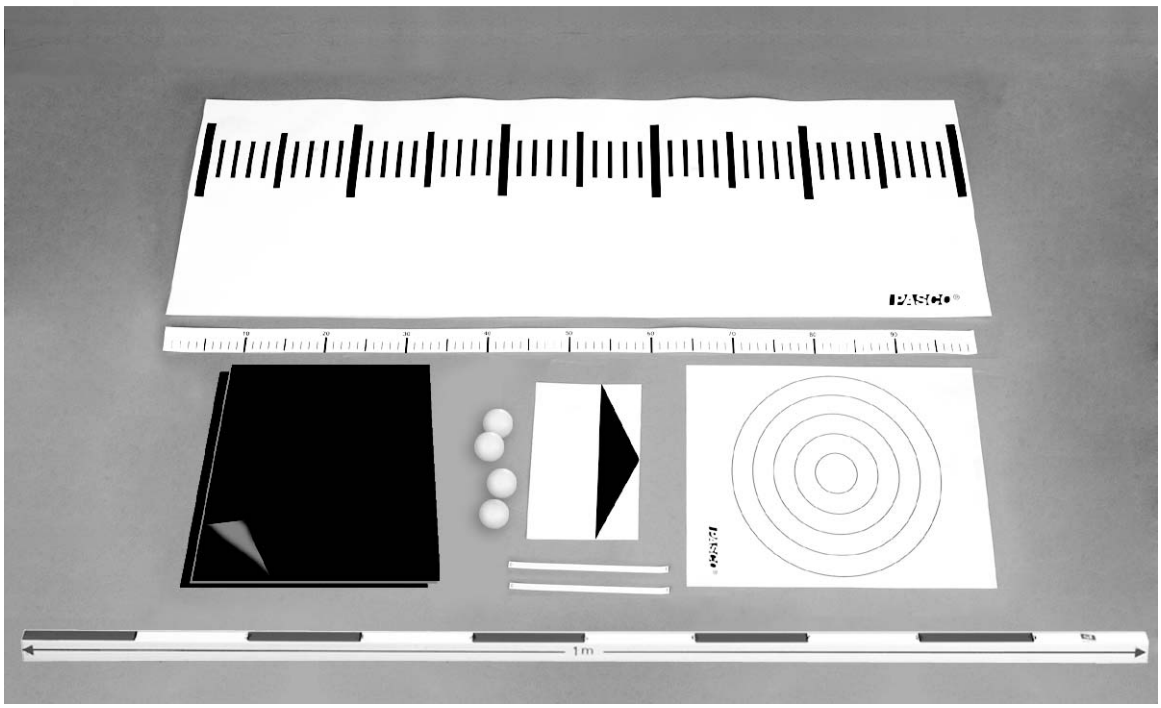
Instructions
Experiments

Instruction Manual

No. 012-08777A

Significant Figures Set

ME-9850



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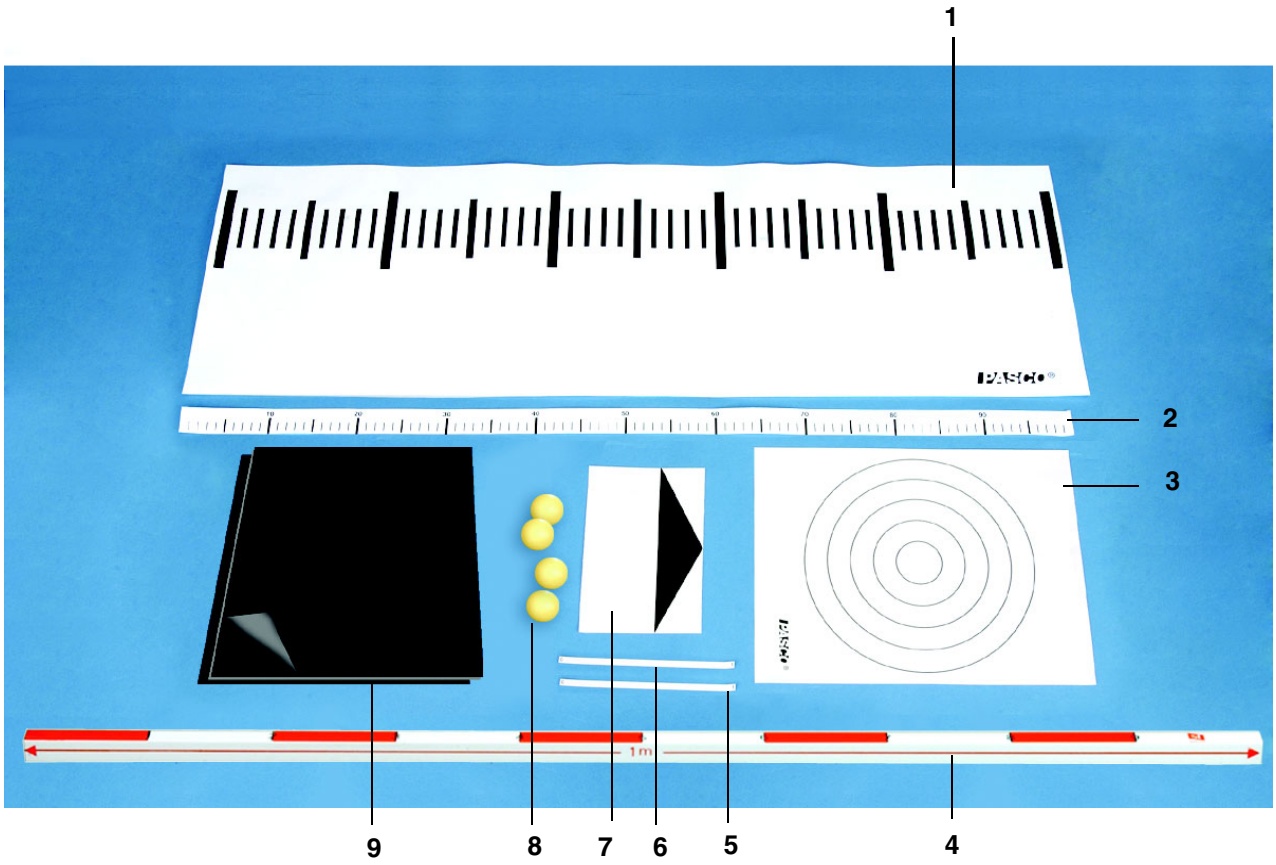
Significant Figures Set

Model No. ME-9850



Included Equipment	Replacement Part Number
1. Number line	646-08756
2. Meter stick label 80 cm/100 div	646-08757
3. Paper bull's eye (2)	012-08755
4. Four-sided Meter stick	SE-8695
5. Balance label 0-10	012-08758
6. Balance label 10 div	012-08912
7. Data pointer	646-08759
8. Plastic ball (1)	699-05120
9. Carbon paper (100 sheets)	SE-8693

Additional Equipment Required	Model Number
Sample objects: rock, wooden block, shoebox etc. (see activities)	
Triple-beam Balance	SE-8723 or SE-8707
Graduated cylinders of varying volume	
Food coloring	
Large beaker	
Tape	

Introduction

The Significant Figures Set includes a series of activities designed to engage students in the concepts of accuracy and precision. These topics, often neglected or truncated in most curricula, are essential in understanding the basics of scientific measurement. The accuracy of a measurement refers to the "closeness" of a numerical value to the actual or accepted value. The precision refers to the repeatability of a measurement. The two factors that determine the precision are the measuring instrument and the “measurer,” the person making the measurement.

The Significant Figures Set includes a laminated number line and four data pointers for classroom comparisons of measurements. Four bright plastic balls, one hundred sheets of carbon paper and eight paper bull’s eyes are provided for the engaging initial activity. In addition, four four-sided meter sticks, four meter stick labels and two sets of balance labels are included for the discovery of precision and accuracy in scientific measurements. One sheet of balance labels is marked 0 and 10, and the other is marked with 10 equal divisions.

Instructional Goals:

1. Identify precision as the repeatability of measurements.

2. Identify accuracy as the "closeness" of measurements to an accepted value.

3. Identify how an instrument determines the precision of a measurement.

4. Identify how technique determines the precision of a measurement.

5. Make calculations that reflect the precision of each measuring instrument.

Note: In order for the collected data to vary in some degree, it is assumed that groups will collect data independently from each other.

Activity 1:
The Bull's Eye Ball Toss

Equipment Required	Part Number
Bull's eye (2)	part of ME-9850
Plastic ball	part of ME-9850
Carbon paper	part of ME-9850
Tape	

Procedure

1. Lay the sheets in this order: Bull's Eye/ Carbon Paper/Bull's Eye. Tape the top edges together so that all three remain attached. Place the sheets on the floor.
2. Decide upon a technique to drop the ball from a 2 meter height so that the ball strikes the center of the target. No other equipment may be used.
3. Drop the ball. Make sure a lab partner catches the ball after it bounces off the target.
4. Label the mark on the bottom Bull's Eye with a number "1" and your initials to indicate your first attempt.
5. Repeat steps 2 through 4 until there are 10 attempts. Make sure the same technique is used each time.
6. Blindfold a lab partner and repeat steps 3 though 5. The other lab partners may direct the blindfolded lab partner, but only from a location approximately 2 meters away from the Bull's Eye.

Post-Lab Discussion

Ask students to make a sketch of their results of the bull's eye on a white board. The teacher should gather several examples of the following: 1.) precise but not accurate results and 2.) precise and accurate results. In addition, have a couple sample bull's eyes ready in case none of the student samples have the proper results.

The discussion should channel the students toward the correct definitions of accuracy and precision.

Questions:

1. Were your results accurate? Explain.

2. Were your results precise? Explain.

3. Can the results be precise but not accurate? Explain.

4. How is dropping balls on a target similar to making a measurement?

A. What does the center of the bull's eye represent?

B. What does the spot where the ball lands represent?

C. How does the skill AND technique of the person dropping the ball influence the accuracy and precision? Why is the skill and technique of a "measurer" important in the taking of data?

Activity 2:
Length Measurements with the False Meter Stick

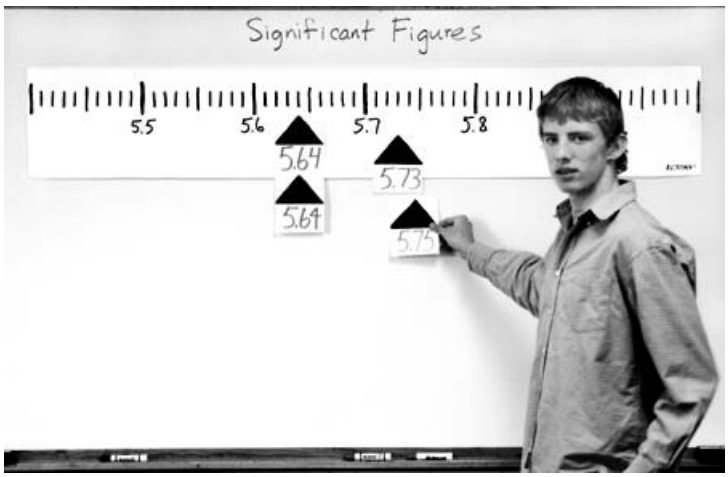
Equipment Required	Part Number
Meter stick label 80 cm/100 div	part of ME-9850
Number line	part of ME-9850
Data pointers	part of ME-9850
Sample object (for measuring)	

Before the Lab:

1. Try to find an irregular object as in the picture.
2. Place the number line on the board. Put the appropriate range of values on the number line.

Procedure

1. Measure the length of the sample object with the meter stick label. (For now, use as many digits after the decimal point as you want.)
2. Write your measurement on the data pointer. Tape the data pointer to the corresponding value on the number line.



Post-Lab Discussion

Present the ACCEPTED value for the length of the sample. Show its location (if possible) on the number line. Direct the discussion to show that measurements that are not accurate can be precise as long as they are repeatable.

Questions:

1. Were your results accurate? Explain.

2. Were your results precise? Explain.

3. Can the results be precise but not accurate? Explain.

4. Explain how the "meter tape" that was used in this activity influences the accuracy.

5. Explain how the "meter tape" that was used in this activity influences the precision.

Activity 3:
Length Measurements with the True Meter Stick

Equipment Required	Part Number
Four-sided meter stick	part of ME-9850
Sample object (for measuring)	

Before the Lab:

1. Try to find an object of standard length that is easy to measure like the width of a sheet of paper.
2. Allow students to use as many significant figures as possible. (Do not discuss or use the term "significant figures.")
3. Write the following data table on the board.

Group #	Length (cm)
1	
2	
3	
4	
5	
6	
7	
8	

Procedure

1. Measure the length of the object (in meters) with the meter stick. Use as many digits after the decimal point as you can read.
1. Write your measurement on the board.

Post-Lab Discussion

The discussion should lead students to the conventional understanding of significant figures as the number of digits that can be read with certainty plus an estimated digit. This would be an appropriate time to discuss parallax with the students.

This would also be an appropriate time to discuss the role of zeroes in significant figures.

Place Holder Rule or Leading Zeroes

Zeroes that serve as placeholders are NOT significant.

Example: .003 g contains only one significant figure, the "3."

Right-Right Rule or Trailing Zeroes

Zeros to the right of the decimal AND to the right of the last significant figure are significant.

Example: 1.400 m contains four significant figures.

Decimal Rule (Used for Whole Numbers)

If a decimal is NOT included for a whole number, rightmost zeroes are NOT significant.

Example: 2300 km contains two significant figures.

If a decimal is included for a whole number, rightmost zeroes are significant.

Example: 2300. km contains four significant figures.

Note: Sometimes a line is written above a zero to identify that it is significant.

Example: 23$\overline{0}$0 km contains three significant figures.

Sandwich Rule

Zeroes in between other significant figures are significant.

Example: 20.03 g contains four significant figures.

Questions:

1. In this activity, a meter stick was used to make measurements. Make a list of techniques necessary to insure optimum precision when using a meter stick.

Sample values: .145 m .144 m .146 m .144 m

2. How many digits can you read with certainty?

3. Which digit is uncertain?

4. For the following measurements underline the digits that are known with certainty and circle the digits that are estimated.

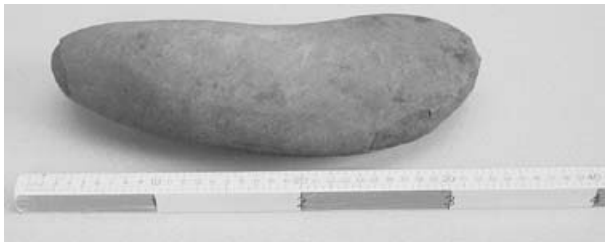
4.35 m .009340 g 3400 km 1.38×10^3 m/s

Activity 4a:
Length Measurements with the Four-Sided Meter Stick

Equipment Required	Part Number
Four-sided meter stick	part of ME-9850
Number line	part of ME-9850
Data pointer	part of ME-9850
Sample object (for measuring)	

Before the Lab:

1. Organize the lab groups so that different groups measure the object with different sides of the four-sided meter stick.
2. Place the number line on the board. Put the appropriate range of values on the number line. Use values that represent the most precise values on the four-sided meter stick.



3. Review significant figures: the number of digits that are certain plus one more estimated digit.

Procedure

1. Measure the sample object using only the side of the four-scale meter stick assigned to you by your teacher. Use significant figures.
2. Write your measurement on the data pointer.
3. Tape the data pointer to the corresponding value on the number line.

Post-Lab Discussion

The discussion should lead students to express the fact that the measuring instrument contributes to the precision of the measurement.

Have students observe the number line.

Show them that the value of "5" above means that the only significant figure is uncertain. The value may be as low as "4" or as high as "6." Whereas, the value of "4.6" is uncertain to the tenths place. The value may be as low as "4.5" or as high as "4.7."

Questions:

1. How does the side of the four-sided meter stick influence the precision of your measurement?

2. How does the side of the four-sided meter stick influence the accuracy of your measurement?

3. Five different students take the following measurements of the same object:
1.0 m 1.45 m 1.5 m 1.4530 m 1.46 m

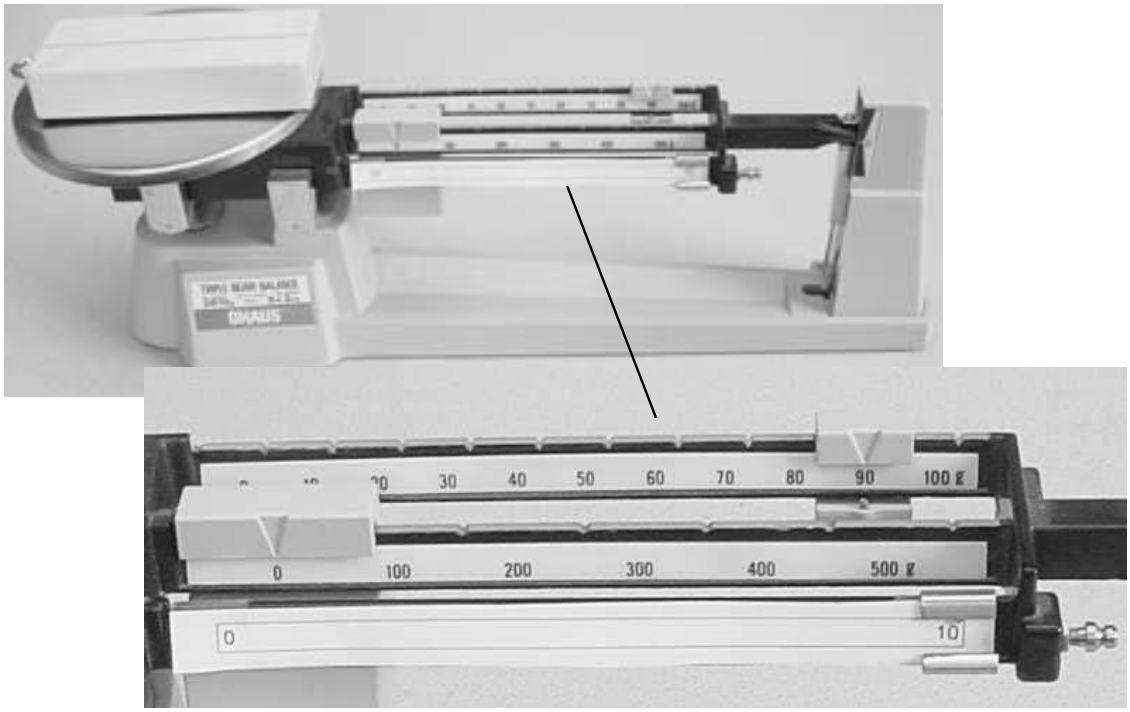
A. Why are the measurements different?

B. Which one is correct? (trick question)

Activity 4b:
Mass Measurements with Imprecise Labels on a Balance

Equipment Required	Part Number
Balance labels	part of ME-9850
Data pointer	part of ME-9850
Number line	part of ME-9850
Balance	SE-8723 or SE-8707
Sample object	

Before the Lab:



1. Cut one of the labels from the sheet of labels for each balance.
2. Tape the labels to the most precise beam of the balance.
3. Organize the lab groups so that different groups measure the object with different labels.
4. Place the number line on the board. Put the appropriate range of values on the number line.
5. Review significant figures: the number of digits that are certain plus one more that is estimated.

Procedure

1. Measure the sample object using the balance. Use significant figures.
2. Write your measurement on the data pointer.
3. Tape the data pointer to the corresponding value on the number line.

Post-Lab Discussion

The discussion should lead students to express the fact that the measuring instrument contributes to the precision of the measurement.

Questions:

1. How does the type of label used influence the precision of your measurement?
2. How does the type of label used influence the accuracy of your measurement?
3. In this activity, a balance was used as opposed to a meter stick. When a meter stick is used, parallax influences the precision. What techniques were necessary to optimize the precision of the measurement?
4. Two scientists take a mass measurement of the same sample. The first scientist measures 4.3 g. The other scientist measures 4.30 g. Which scientist took the more precise measurement? How was this accomplished? Explain.

Activity 5:
Volume Measurements with a Graduated Cylinder

Equipment Required	Part Number
Graduated cylinders of varying volume	
Food coloring	
Assorted liquids	

Before the Lab:

1. Place colored water in each of the graduated cylinders. If possible use different liquids like soap water, oil and alcohol to vary the size of the meniscus.
2. Leave the graduated cylinders at one location in the lab.
3. Do not mention the "meniscus."
4. Review significant figures: the number of digits that are certain plus one more that is estimated.
5. Write the following data table on the board.

Group #	Sample 1 (mL)	Sample 2 (mL)	Sample 3 (mL)	Sample 4 (mL)
1 **2** **3** **4** **5** **6** **7** **8**				

Procedure

1. Measure the volume of each liquid sample. Use significant figures.
2. Record your measurements in the data table on the board.

Post-Lab Discussion

When all students are done, write the accepted values at the top of the data table. Discuss the technique students used to measure the volume. At this time describe the meniscus. Address the effect of technique as it applies to precision.

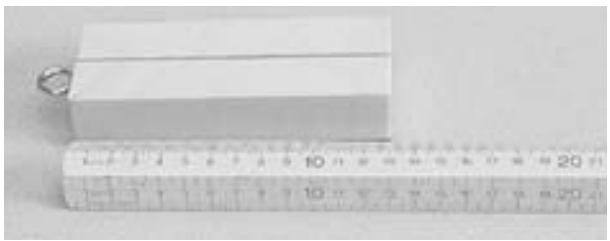
Questions:

1. Sketch the section of one of your graduated cylinders that contains the meniscus. Label the spot that must be measured.
2. Were your results precise?
3. Were your results accurate?
4. In this activity, graduated cylinders were used as opposed to a meter stick. When a meter stick is used, parallax influences the precision. Other than taking into account the meniscus, what techniques were necessary to optimize the precision of the measurement?

Activity 6a:
Volume Calculations

Equipment Required	Part Number
Four-sided meter stick	part of ME-9850
Number line	part of ME-9850
Data pointer	part of ME-9850
Sample object for measuring volume (block or box)	

Before the Lab:



1. Leave the object at one location in the lab.
2. Review significant figures: the number of digits that are certain plus one more that is estimated.
3. Write the following data table on the board.

Group #	Length (cm)	Width (cm)	Height (cm)	Volume (cm^3)
1				
2				
3				
4				
5				
6				
7				
8				

Procedure

1. Measure the length, width and height of the sample object. Use a different side of the four-sided meter stick to measure each dimension of the sample object. Record the correct number of significant figures for each measurement.
2. Calculate the volume of the object.
3. Record your data and calculations. Enter them in the data table on the board.
4. Write the volume on the data pointer. Tape the data pointer to the corresponding value on the number line.

Post-Lab Discussion

Student Presentations: Ask students to present which side of the meter stick they used and the digits they were able to keep. Have them also discuss how they maintained precision through the calculation.

Class Discussion: Have students observe the data table. Ask students what determines the precision of the volume calculation. Direct students to realize that the least precise measurement in their calculation determines the precision of the volume calculation. As a class, make any necessary changes to the calculations.

Questions:

1. What determines the precision of the volume calculation?

2. Why is it important to use the same technique to measure each length? For example, if you remember to take into account parallax for one measurement and you do not for the other measurements, how will this effect your final volume calculation?

3. Calculate the following:

4.1 cm x 3.759 cm x 2.124 cm =

4.2 cm x 3.759 cm x 2.124 cm =

4.3 cm x 3.759 cm x 2.124 cm =

4. What digits place is uncertain in the answers?

Activity 6b:
Density Calculations

Equipment Required	Part Number
Four-sided meter stick	part of ME-9850
Data pointer	part of ME-9850
Number line	part of ME-9850
Balance labels	part of ME-9850
Balance	SE-8723 or SE-8707
Sample object for measuring volume and mass	

Before the Lab:

1. Leave the object at one location in the lab.
2. Review significant figures: the number of digits that are certain plus one more that is estimated.
3. Tape the labels to the balances.
4. Assign groups to different balances.
5. Review density with the students.

6. Write the following data table on the board.

Group #	Length (cm)	Width (cm)	Height (cm)	Mass (kg)	Volume (cm^3)	Density (kg/cm^3)
1						
2						
3						
4						
5						
6						
7						
8						

Procedure

1. Measure and record the length, width, and height of the sample object. Use a different side of the four-sided meter stick to measure each dimension of the sample object.

2. Calculate the volume of the object.

3. Measure and record the mass of the object using the balance assigned to you by your teacher.

4. Enter your measurements and calculations in the data table on the board.

5. Write the density on the data pointer. Tape the data pointer to the corresponding value on the number line.

6. The teacher will place the accepted value of the density on the number line.

Post-Lab Discussion

Ask students to present their values of length, width, height, and mass. Make sure they address the reasoning behind the precision of their measurements. Have them also discuss how they maintained precision through the calculation.

Have students observe the data table. Ask students what determines the precision of the density. Direct students to realize that the least precise measurement in their calculation determines the precision of the density. As a class, make any necessary changes to the calculations.

Questions:

1. What determines the precision of the density calculation?

2. Why is it important to use the same technique to measure each length? For example, if you remember to take into account parallax for one measurement and you do not for the other measurements, how will this effect your final density calculation?

Activity 7:
Circumference, Area, and Volume Calculations

Equipment Required	Part Number
Meter stick	
Large beaker	

Before the Lab:

1. Leave the beaker at one location in the lab.
2. Review significant figures: the number of digits that are certain plus one more that is estimated.
3. Review "circumference," "area," and "volume" for a cylinder.
4. Write the following data table on the board.

Group #	Height (cm)	Diameter (cm)	Circumference (cm)	Volume (cm^3)

Procedure

1. Measure the diameter and height of the beaker.
2. Calculate the circumference, area, and volume of the beaker.
3. Record your data and calculations. Enter them in the data table on the board.

Post-Lab Discussion

Have students observe the data table. Ask students what determines the precision of the circumference, area, and/or volume. Direct students to realize that the exact numbers (2, π) are NOT measured values (or calculated from measured values), hence they do not affect the precision of the calculation. As a class, make any necessary changes to the calculations.

Questions:

1. The diameter of a circle is 4.32 cm.

- What is the circumference?

- What is the area?

2. In the calculations for question 1, list your measured values and your exact values for each calculation.

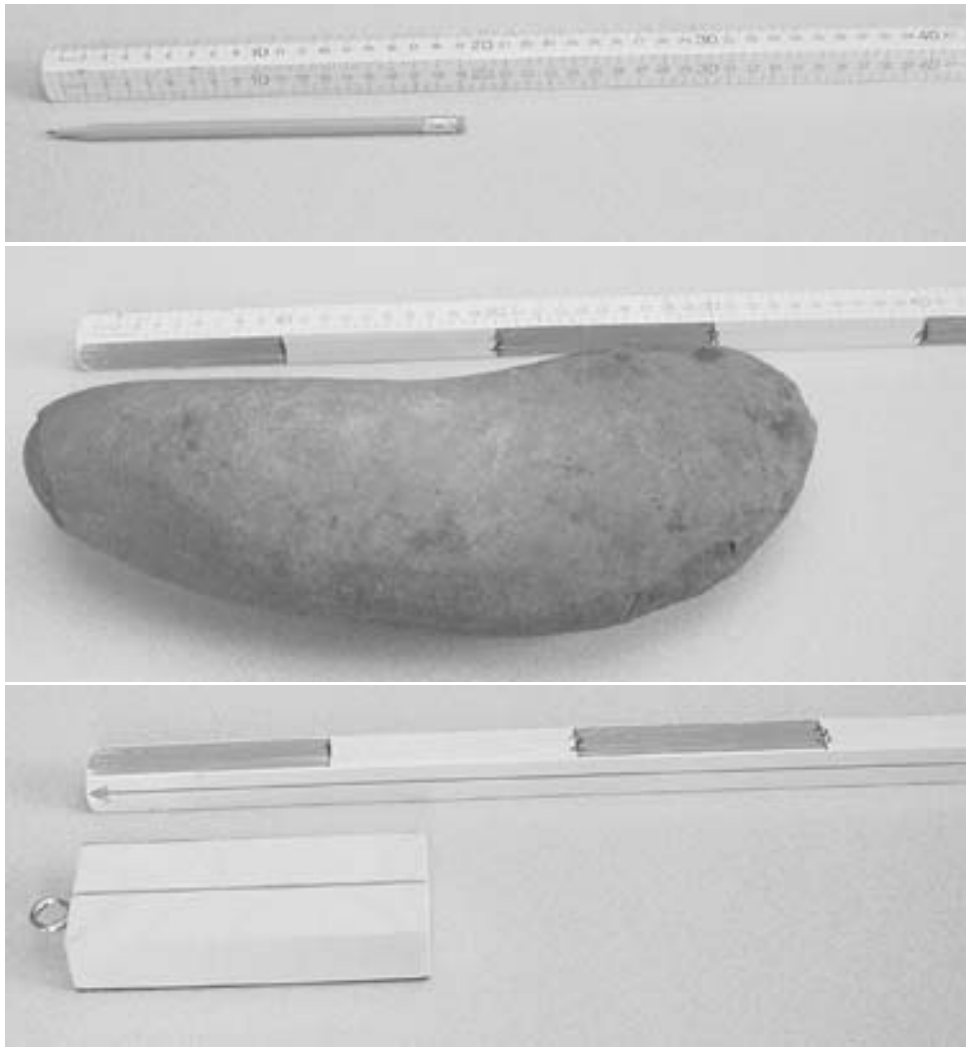
3. Which values contribute to the precision of the final calculated answer? Explain.

4. Which values do not contribute to the precision of the final calculated answer? Explain.

Activity 8:
Addition, Subtraction, and Significant Figures

Equipment Required	Part Number
Four-sided meter stick	part of ME-9850
Three different objects to measure	

Before the Lab:



1. Assign different groups to measure the length with varying precisions.
2. Place the following data table on the board:

Group #	Object 1 (cm)	Object 2 (cm)	Object 3 (cm)	Total (cm)

Procedure

1. Measure the length of each sample object using a different side of the four-sided meter stick (as assigned by your teacher).
2. Calculate the total length.
3. Record your data and calculations. Enter them in the data table on the board.

Post-Lab Discussion

Have students observe the data table. Ask students what determines the precision of the total length. Direct students to realize that the least precise measurement in their calculation determines the precision of the total length. As a class make any necessary changes to the calculations.

Questions:

1. What is the general rule for adding and subtracting measured values?
2. What is the general rule for multiplying and dividing measured values?
3. What is the general rule for "exact" numbers in the calculation of measured values?

Safety

Read the instructions before using this product. Students should be supervised by their instructors. When using this product, follow the instructions in this manual and all local safety guidelines that apply to you.

Technical Support

For assistance with any PASCO product, contact PASCO at:

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