Chapter 4 - Activity 2: Scientific Measurement – Because Life is Never Certain

Introduction

Scientists are interested in the measurement of the attributes of material objects.[1] Because of this, unlike purely mathematical problems, calculations involving scientific measurements have three key characteristics.

- The uncertainty of the measurement and the importance of significant figures
- The property being measured as identified by the unit associated with a measurement
- The magnitude of the number as commonly expressed by scientific notation

Here, uncertainty does not mean "error" or "mistake." It refers to the fact when we measure the properties of real objects, there is always some physical limitation to the precision of that measurement. Here, "property" means a characteristic, quality or distinctive feature which we use to describe physical objects. For the next few Activities, we will explore the qualities of scientific measurements and master their mathematical manipulation.

Skills

At the conclusion of this Activity, you will be able to:

- Distinguish between exact and inexact numbers (2.3.1)
- Explain the relationship between uncertainty in measurement and significant figures (2.3.2)
- Determine the proper number of SF based on the precision of the measuring device (2.3.3)

Information

Pick up a piece of twine and a measuring stick. Assume that each device is 1 yard long.

Model 1: Exact and Inexact Numbers

When using a measuring device that has a marked scale (example, ruler or thermometer), the most precise measurement that can be reasonably made is 1/10 of the smallest subdivision provided.[2] This is called the 1/10th Rule of Estimating. For example, in Figure 4-1 the bottom stick has no subdivisions while the top figure is

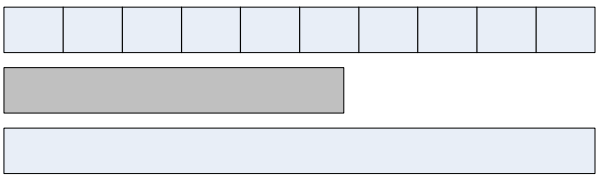

Figure 4-1

[1] "Attribute" here means a quality, property, or characteristic of matter.

[2] We use the word "precise" to express the place-value of the last digit that can be reasonably estimated. Thus, a device which allows a measurement to be approximated to the hundredths place is more precise that a device that allows a measurement to be approximated to the tenths place.

divided into tenths. Measurement of the middle figure with the bottom stick would be limited to 1/10 (or 0.1 expressed as a decimal) of the smallest subdivision which is 1. Thus, a reasonable measurement would be "approximately" 0.6. On the other hand, the top measuring stick is divided into tenths. Again, we can measure to 1/10 of the smallest subdivision. Since the smallest subdivision is 1/10, 1/10 times 1/10 is equal to 1/100 (0.01). Therefore, a reasonable measurement using the top measuring stick would be "approximately" 0.58. The word "approximately" is used because the last digit on the right of the measurement is an estimate or an approximation. That is, two people may reasonably read the last digit somewhat differently.

Using the information provided above, measure each member of your group first with the twine and then with the stick to the smallest place value possible. Do not use the stick to estimate measurements using the twine. Write down the results in the Table 4-1.

Twine	quantity	Stick	quantity
A		A	
B		B	
C		C	
D		D	
Total		Total	
Average		Average	

Table 4-1

1. How many members are in your group? _____
2. Using a calculator, determine the total height of your group? Report all digits displayed by your calculator.

   Twine: _____ Stick :_____

3. Using a calculator, what is the average height of your group? Report all digits displayed by the calculator. To find the average, add up all of the heights and divide it by the number of people measured.

   Twine: _____ Stick:_____

4. Do you consider the digit representing the number of members in your group to be exact? In other words, do you know it with complete certainty or did you have to estimate it? Use complete English sentences to explain your answer.

5. Is the number representing the total height of your group exact? Use complete English sentences to explain your answer.

6. Using correct English and in your own words, do the following.
   a. Define "exact number" and give an example of one which is different from those above.

   b. Define "inexact number" and give an example of one which is different from those above.

7. Which of the following is an exact number and which is an inexact number? Mark the appropriate line with an "X."

Item	(A) Exact	(B) Inexact
a) The number of candies in a bag		
b) The weight of a bag of candy		
c) The number of students in this class		
d) The total height of students in this class		
e) Number of days in a week		
f) Number of items in a dozen		
g) The number of inches in a foot		
h) The length of this classroom in inches		

Model 2: Uncertainty in Measurements & Significant Figures

Scientific calculations can involve both exact and inexact numbers. Exact numbers occur when we can count the individual objects involved, like the number of people in your groups, or when we define a property as having a specific value (e.g., days in a week, 12 items in a dozen, etc.). Inexact numbers are those that we obtain from any type of measurement. A measurement of a real object, as we have seen, is never 100% certain because there is always some estimating or approximating associated with it. We will use the data obtained from measuring team members to explore the consequences of uncertainty when reporting a scientific measurement.

8. Write the total height of your group you obtained by using the twine and using the stick. Be sure to report all of digits that your calculator displayed. Now, circle the digit in each of these measurements of which you are most certain is correct? That is, the one in which you are most sure of its value.
   Twine: _____ Stick:_____

9. Rewrite below the total height of your group as displayed by your calculator and then, starting from the left side of the number, circle the digit in that number which you are most uncertain is correct? That is, the one in which you are the least sure of its value.
   Twine: _____ Stick:_____

10. Using the average height as displayed by your calculator, circle the digit in that number which you are the most certain is correct?
    Twine: _____ Stick:_____

11. Using the average height as displayed by your calculator and starting from the left side of the number, circle the first digit for which you think there is some uncertainty regarding its value.
    Twine: _____ Stick:_____

Information: When reporting a scientific measurement you include only those numbers for which you are certain plus one more for which you can make a reasonable approximation. Therefore, it is critical when using any sort of measuring device that you are able to identify the first digit for which there is some degree of uncertainty, in other words, the first digit that has been approximated. In a measurement, the first estimated figure is the last "significant figure."

12. Fill-in the following blanks below in the definition of significant figure.

    The _____ uncertain figure is the _____ significant figure

Information: We assume, at a minimum, that a reported scientific measurement is uncertain to ± 1 of the last reported digit. For example, if the average height of a group is reported as 1.92 yards we assume that the measurement would vary at least ±0.01 yard which we could represent by writing: 1.92 ± 0.01 yard. This means that the true average height could reasonably be anywhere from 1.91 (1.92 – 0.01) to 1.93 (1.92 + 0.01) yard.

13. Using the information above, write down the average height of your group you obtained using the stick with the proper number of significant figures. Include the variation of the last significant figure as described above.

    The total height of your group _____.

Information: Graduated cylinders are common laboratory devices used to measure volume of a liquid. They come in many sizes. Figure 4-2 is a drawing of a 5-mL graduated cylinder; that is, capable of measuring up to 5-mL. Each of the lines represents 0.1 mL of liquid. The volume present is determined by estimating the reading where the bottom of the meniscus is located as shown by the arrow.[3]

14. Based on this information alone, to what place – units, tenths, hundredths or thousandths could this volume be estimated?

15. What is a reasonable volume to report from Figure 4-2?

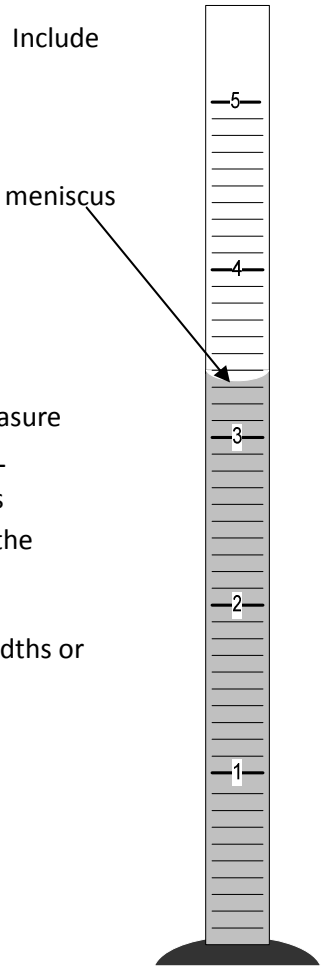

Figure 4-2

[3] A meniscus is the curved upper surface of a still liquid in a tube. It is concave (sagging down) if the liquid wets the walls of the container and it is convex (bulging up) if it does not, caused by surface tension.

16. A student measured the same volume of solution five times and found the following volumes (in mL): 4.83, 4.84, 4.81, 4.86, and 4.87.

    a. Of all of the numbers given in the sentence immediately above which, if any, is the only exact one?

    b. Give the average value for the volume as displayed by your calculator and give the average value for the volume with the appropriate number of significant figures (SF).

        Calculator value: _____

        Value with just SF: _____

Read T1.5; Complete end-of-chapter problems: 1.40 – 1.47

"T" refers to text. The digit to the left of the decimal point is the chapter number from the text while the digits to the right of the decimal point refer to the problem number.