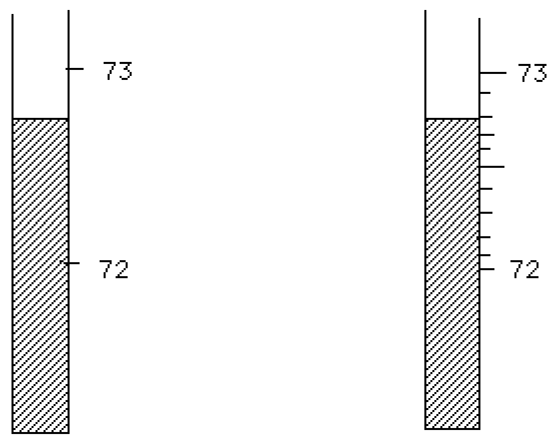
Significant Digits

Scientists, in their investigations into the laws of nature, are constantly taking measurements. They measure temperatures, frequencies, intensities, masses, volumes, velocities, and a vast array of other quantities. Inherent in the process of measuring is the concept of error**.** All measured quantities will have in them, some degree of error, or uncertainty. The error may be the fault of the person doing the measuring, especially if he or she is not adept at using the measuring instrument, but it is more likely that the error in a measurement is due to the lack of precision in the measuring tool or instrument that the measurer is using. For example, suppose we were measuring liquid volume using the following two graduated cylinders.



Cylinder A **Cylinder B**

Using graduated cylinder **A**, what is the best measurement of volume we can get? Graduated cylinder **A** tells us that the volume is 72 mL *plus a little bit*. It is this "little bit" that introduces the error because there are no lines on the scale to enable us to more exactly read what the volume is. We have to make a best guess. The best we can do therefore, is to guess or estimate the last digit in the measurement and record it as about 72.7 mL. Even though we guessed at the last digit, our recorded volume is more precise than if we had just written what we were sure of and recorded it as 72. So the number of digits in this measurement consists of two that we are sure of and one that is a best guess (or of which we are uncertain), for a total of ***three significant digits.***

Using graduated cylinder **B**, what is the best measurement of volume we can get? Graduated cylinder **B** is a little more precise. It has intervals between 72 and 73 which enable us to be certain down to a tenth of a millilitre. The graduated cylinder tells us that the volume is 72.7 mL *plus a little bit*. Here is that "little bit" again. It is a smaller bit that we had on graduated cylinder **A**, but we still have to make a best guess, and estimate the last digit in the measurement. This volume could be recorded as 72.78 mL where the last digit is our estimated figure. So the number of digits in this measurement consists of three of which we are certain and one (the last one) of which we are uncertain, for a total of ***four significant digits***.

Therefore:

1. When recording a measurement, you must use enough digits to indicate the degree of uncertainty in the measurement. The number of digits it takes to do this are called significant digits.

2. The number of significant digits in a measurement equals the number of digits known precisely plus one that is uncertain.

Special Note:

Temperature measurements are treated differently than other measurements with regard to significant digits. When you make a temperature measurement in degrees Celsius, count the number of digits after the decimal point and then add three more significant digits to that number. For example if you measure 8.7ºC, the number of significant digits is 4; the 7 counts as one and then add three more. The reasoning is as follows.

Thermometers can be marked using a number of different scales. Three main scales are Celsius, Kelvin, and Fahrenheit. Any measurement can be converted to the other two scales using a mathematical formula. Since temperature in degrees Celsius can be converted to Kelvin by adding 273.15, temperature measurements made in Celsius have more significant digits than other measurements. For example, the temperature of a sample of water is measured to be 8.7ºC by one student using a thermometer calibrated in degrees Celsius. Another student using a thermometer calibrated in Kelvin measures the same sample to be 306.9 K. The number of significant digits must be the same since they both had the first decimal place as an estimated number. So both measurements have four significant digits.

Since all measurements have intrinsic errors, we must learn how to deal with these errors when we add, subtract, multiply or divide these measured quantities by other measured quantities. There are two things to learn

1. How to determine the number of significant digits in a measured quantity. When you are reading or using a measurement someone else has made, how do you know how many of the given numbers are significant?
2. The rules for dealing with uncertainty when mathematical operations are performed using measured quantities. If you have to add, subtract, multiply or divide two or more measured quantities, how do you know how many numbers should be in the answer?