Linear Measurement

Experiment (1)

1.1 Background.

1.2 The Vernier Caliper and the Micrometer.
Experiment one

Objectives

- Understand some important concepts in measurements such as accuracy, precision, error and uncertainty.
- Know how to use the Linear Measurement tools such as: Vernier Caliper and Micrometer.

1.1 Background

Accuracy

Accuracy refers to the agreement between a measurement and the true or correct value. If a clock strikes twelve when the sun is exactly overhead, the clock is said to be accurate. The measurement of the clock (twelve) and the phenomena it is meant to measure (The sun located at zenith) are in agreement. Accuracy cannot be discussed meaningfully unless the true value is known or is knowable. (Note: The true value of a measurement can never be known)

Accuracy refers to the agreement of the measurement and the true value and does not tell you about the quality of the instrument. The instrument may be of high quality and still disagree with the true value. In the example above it was assumed that the purpose of the clock is to measure the location of the sun as it appears to move across the sky. However, in our system of time zones the sun is directly overhead at twelve O'clock only if you are at the center of the time zone. If you are at the eastern edge of the time zone the sun is directly overhead around 11:30, while at the western edge the sun is directly overhead at around 12:30. So at either edge the twelve O'clock reading does not agree with the phenomena of the sun being at the local zenith and we might complain that the clock is not accurate. Here the accuracy of the clock reading is affected by our system of time zones rather than by any defect of the clock.

In the case of time zones however clocks measure something slightly more abstract than the location of the sun. We define the clock at the center of the time zone to be correct if it matches the sun, we then define all the other clocks in that time zone to be correct if they match the central clock. Thus a clock at the Eastern edge of a time zone that reads 11:30 when the sun is overhead would still be accurate since it agrees with the central clock. A clock that read 12:00 would not be accurate at that time. The idea to get used to here is that accuracy only refers to the agreement between the measured value and the expected value and that this may or may not say something about the quality of the measuring instrument. A stopped clock is accurate at least once each day.
**Precision**

Precision refers to the repeatability of measurement. It does not require us to know the correct or true value. If each day for several years a clock reads exactly 10:17 AM when the sun is at the zenith, this clock is very precise. Since there are more than thirty million seconds in a year this device is more precise than one part in one million! That is a very fine clock indeed! You should take note here that we do not need to consider the complications of edges of time zones to decide that this is a good clock. The true meaning of noon is not important because we only care that the clock is giving a repeatable result.

![Figure (1.1)](image)

**Error**

Error refers to the disagreement between a measurement and the true or accepted value. You may be amazed to discover that error is not that important in the discussion of experimental results. This statement certainly needs some explanation.
Experiment one

As with accuracy, you must know the true or correct value to discuss your error. But consider what science is about. The central objective is to discover new things. If they are new, then we do not know what the true value is ahead of time. Thus it is not possible to discuss our error. You might raise the possibility that the experiment has a defective component or incorrect assumption so that an error is made. Of course the scientist is concerned about this. Typically there has been much discussion with other scientists and a review of the methods to try to avoid exactly this possibility.

However, if an error occurs we simply will not know it. The true value has not yet been established and there is no other guide. The good scientist assumes the experiment is not in error. It is the only choice available. Later research, attempts by other scientists to repeat the result, will hopefully reveal any problems, but the first time around there is no such guide.

Students in science classes are in an artificial situation. Their experiments are necessarily repetitions of previous work, so the results are known. Because of this students learn a poor lesson about science. Students often are very conscious of error to the point where they assume it happens in every experiment. This is distracting to the project of becoming a scientist. If you want to benefit most from your laboratory experiences, you will need to do some judicious pretending.

**Uncertainty**

Uncertainty of a measured value is an interval around that value such that any repetition of the measurement will produce a new result that lies within this interval. This uncertainty interval is assigned by the experimenter following established principles of uncertainty estimation.

Uncertainty, rather than error, is the important term to the working scientist. In a sort of miraculous way uncertainty allows the scientist to make completely certain statements. Here is an example to see how this works.

Let us say that your classmate has measured the width of a standard piece of notebook paper and states the result as 8.53 ± 0.08 inches. By stating the uncertainty to be 0.08 inches your classmate is claiming with confidence that every reasonable measurement of this piece of paper by other experimenters will produce a value not less than 8.45 inches and not greater than 8.61 inches.
Experiment one

Suppose you measured the length of your desk, with a ruler or tape measure, and the result was one meter and twenty centimeters (L = 1.20 m). Now the true length is not known here, in part because you do not have complete knowledge of the manufacture of the measuring device, and because you cannot see microscopically to confirm that the edge of the table exactly matches the marks on the device. Thus you cannot discuss error in this case. Nevertheless you would not say with absolute certainty that L = 1.20 m.

However it is quite easy to imagine that you could be certain that the desk was not more than ten centimeters (~ five inches) different than your measurement. You may have experience with tape measures. And based on that experience, you are sure that your tape measure could not be stretched out by five inches compared to its proper length. If you do not have this confidence, perhaps ten inches or a foot would make you confident. After measuring you might say "This desk is not longer than 1.35 m and not shorter than 0.95 m." You could make this statement with complete confidence. The scientist would write L = 1.20 ± 0.15 m. The format is "value plus or minus uncertainty."

Notice that it is always possible to construct a completely certain sentence. In the worst case we might say the desk is not shorter than zero meters and not longer than four meters (because it would not fit the room). This measurement may be nearly useless, but it is completely certain! By stating a confidence interval for a measurement the scientist makes statements that any reasonable scientist must agree with. The skill comes in getting the confidence intervals (the uncertainty) to be as small as possible.

This is your task in the laboratory. Every measurement you make should be considered along with a confidence interval. You should then assign this uncertainty to the measurement at the time that you record the data.

Uncertainty: Having presented the example, here is the definition of uncertainty.

The uncertainty in a stated measurement is the interval of confidence around the measured value such that the measured value is certain not to lie outside this stated interval.

Uncertainties may also be stated along with a probability. In this case the measured value has the stated probability to lie within the confidence interval. A particularly common example is one standard deviation (SD) for the average of a random sample. The format "value ± 1 SD" means that if you repeat the measurement, 68% of the time your new measurement will fall in this interval.
2.2 The Vernier caliper and the micrometer

A length is measured by comparing it with some standard length such as a metre rule. Thus to measure the length of a rod, it is placed against a metre rule, and the readings of the scale markings of the rule nearest to the ends of the rod are taken. The difference in the readings is the length of the rod. In general neither end will coincide exactly with a scale marking. The fractional distance between two neighbouring scale markings of the rule overlapped by the rod has to be estimated. A little practice enables one to do this fairly accurately by eye. Greater accuracy can be attained by the use of vernier scales.

A vernier is a short scale sliding along the main scale. It enables accurate readings to be made to a fraction of a division of the main scale.

If we interested in very high accuracy we use the micrometer, which has greater accuracy than calipers.

Vernier Caliper

The Vernier Caliper is a precision instrument that can be used to measure internal and external distances extremely accurately. The example shown below is a manual caliper. Measurements are interpreted from the scale by the user. This is more difficult than using a digital vernier caliper which has an LCD digital display on which the reading appears. The manual version has both an imperial and metric scale. Manually operated vernier calipers can still be bought and remain popular because they are much cheaper than the digital version. Also, the digital version requires a small battery whereas the manual version does not need any power source.
Experiment one

The external measurement (diameter) of a round section piece of steel is measured using a vernier caliper, metric scale.

**MATHEMATICAL METHOD**

The main metric scale is read first and this shows that there are 13 whole divisions before the 0 on the hundredths scale. Therefore, the first number is 13. B. The hundredths of mm scale is then read. The best way to do this is to count the number of divisions until you get to the division that lines up with the main metric scale. This is 21 divisions on the hundredths scale.

This 21 is multiplied by 0.02 giving 0.42 as the answer (each division on the hundredths scale is equivalent to 0.02mm).

The 13 and the 0.42 are added together to give the final measurement of 13.42mm (the diameter of the piece of round section steel).

**COMMON SENSE METHOD**

Alternatively, it is just as easy to read the 13 on the main scale and 42 on the hundredths scale. The correct measurement is 13.42mm.

![Diagram of vernier caliper](image)
Experiment one

Another example:

The micrometer is a precision measuring instrument, used by engineers. Each revolution of the ratchet moves the spindle face 0.5mm towards the anvil face. The object to be measured is placed between the anvil face and the spindle face. The ratchet is turned clockwise until the object is ‘trapped’ between these two surfaces and the ratchet makes a ‘clicking’ noise. This means that the ratchet cannot be tightened anymore and the measurement can be read.

**Micrometer**

The micrometer is a precision measuring instrument, used by engineers. Each revolution of the ratchet moves the spindle face 0.5mm towards the anvil face. The object to be measured is placed between the anvil face and the spindle face. The ratchet is turned clockwise until the object is ‘trapped’ between these two surfaces and the ratchet makes a ‘clicking’ noise. This means that the ratchet cannot be tightened anymore and the measurement can be read.
Experiment one

Using the first example seen below:

Read the scale on the sleeve. The example clearly shows 12 mm divisions.

Still reading the scale on the sleeve, a further ½ mm (0.5) measurement can be seen on the bottom half of the scale. The measurement now reads 12.5mm.

Finally, the thimble scale shows 16 full divisions (these are hundredths of a mm).

The final measurement is 12.5mm + 0.16mm = 12.66

Figure (1.6)
Experiment one

**Reading and Results**

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<th>Micrometer</th>
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