Precise and Accurate Measurements

Overview

There are four major requirements of scientific experimentation: Procedural understanding (Planning the experiment), Recording the observations (measurements), Processing those observations (calculations, graph, etc.) and Working on errors for better results.

The core idea of this learning unit is to know the following words or concepts: Least count (never zero, not necessarily the minimum measurement of that instrument), range (not just the upper limit, single measurement), uncertainty (error), propagation of errors, various units of measurements.

Minimum Time Required: 2 sessions of minimum 40 minutes each

Type of Learning Unit: Laboratory

Pre-requisite: Brief knowledge of units of measurement, handling of common instruments like measuring scale, thermometer, etc.

Introduction

What exactly is it that we do, when we measure any quantity? We compare it with known objects/tools, assign a numerical value to the comparison and specify the quantity using a unit. Such a simple everyday task, but we don't seem to appreciate its importance.

Let us try to understand the reason behind the evolution of measurement, step by step.

Let's take a trip to stone-age and look at a caveperson who wants to make a baton similar to the one he already has. How would it go about making it?It wouldn't really go about taking any measurements. It would just make it as similar to its baton as possible. Because there is no need to for the baton to be an exact copy, and hence no need for taking any detailed measurements. Which means no need for measuring instruments. Though, it might not be so keen on making a similar baton to start with.

But if we jump from the stone-age to early civilizations, where agriculture started to become people's basic occupation, people started to experience the need for having some form of measuring technique to keep a track of the agricultural land of each person and the amount of yield. Hence people found different ways to measure length and mass. People also came up with different methods to keep track of time. And though different places had used different units, this brought some simplicity to the lives of people.

As trade of resources and information between different parts of the world increased, people realized the need of a common way of measuring quantities so as to reduce confusion and easy exchange of information. Which gave us many measuring instruments.

And as we went on to make advances in science, we realized the need for more and more accurate and precise ways of measuring quantities. As well as ways to measure quantities that are so small that they could be barely seen by naked eyes.

Just to realize for ourselves the need for such instruments let's do a task.

Materials Required

Task 1: Ruler, thick paper or cardboard, scissors (or cutter), objects having shape of cuboid (preferably a match box)

Task 2: Measuring instruments that are easily available.

Geometry' box (compass box), wrist watch, stop watch, thermometers (laboratory and clinical), syringe, measuring cylinder.

Task 3: Bob, thread, stand, stop watch (mobile), ruler.

Task 1

In this task, you will be measuring the dimensions of a cuboid so it would be great if you could select any 5 cuboid objects to measure.

Now, let's make some scales:

For this task we will need 3 different scales. One can be the 15 cm scale from your compass box, but you'll need to make 2 more. One of the 2 measuring scales has to be of length 10cm with markings at an interval of 2mm and the other one of length 20cm with markings at an interval of 5mm. Draw longer marks on every 1cm, like on any scale.

Measurements of the objects using scales of different least counts:

Using the scales that you have prepared, measure the length, breadth and height (thickness) of different objects. Remember that you cannot record an observation as a fraction of the least count i.e. if your least count is 2 mm then your measurement or observation cannot be 5 mm. Or, if you are using a scale of least count 5 mm, all readings must be in multiples of 5 mm only.

Objects	0.1			0.2			0.5		
	L	B	H	L	B	H	L	B	H

Discussion

Did you have any difficulty while measuring the selected objects? If yes, what was it?

Were you able to measure the dimensions of all chosen objects using the 3 measuring scales you made? If not what, what could be the reason?

> Scope for discussion of range of instrument

Once you have the readings, calculate the volume of one object whose all three dimensions could be recorded using all 3 scales. So you should get three values for the volume of that one object.

> Scope for discussion of Least count of an instrument

Were the three values of volume same? If not, why did the volumes of the same object come out to be different?

> Extend the discussion such that students understand the necessity of smallest possible least count.

Task 2

Now that we have somewhat familiarized with least count and range let's just briefly take a look at their definitions.

1. Least count of an instrument:

Least count of an instrument is the smallest change or difference in a value that can be reliably measured using that instrument.

The smallest value indicated on the scale of an instrument (mostly zero) is not the least count.

What do you think would be the least count of the 30 cm scale we use? _______________

Let the students explore an actual scale. There might be some students who might think that the least count of the 30 cm scale in 1 cm. Allow the students to discuss among themselves.

2. Range of an instrument:

1)If you consider any instrument, note down the value of the first marking and the last marking on it. That will give you the range of that instrument.

Here, we are not talking just about the maximum, but always from a certain minimum to a certain maximum. (From ….. to ……)

2) With repeated measurements one can measure any higher value, e. g., to measure 45 cm, one can use 30 cm ruler once again. So, what is the range of the ruler? Ask this question to the students and see their response.

Now, based on the examples discussed above as well as your experiences, fill the following table

Sr. No.	Instrument	Quantity	Unit	Least Count	Range
1					
2					
3					
4					

5					

If the students don't come up with instruments, the teacher can use the following list of instruments as a guide - measuring scale, stainless steel ruler, protractor, wrist watch, stop watch, laboratory thermometer, measuring cylinder.

A wrist watch measures the time in a cyclic order, i.e., the values get repeated after each cycle. Care should be taken while explaining the range of a digital watch as well as the analog watch. You might have to spend some time discussing the difference between a 24-hour clock and a 12-hour clock. Also, the difference in range of a stop watch and a wrist watch need to be clarified.

Task 3

Have you seen an old 'Grandfather clock'? What is its striking feature? It has a circular object suspended, which goes back and forth continuously i.e. oscillates. Have you wondered how much time it might take for that pendulum to complete one oscillation? Let's make a pendulum and try to observe that...

Now that you have a pendulum with you, how will you go about recording the time it takes for one oscillation?

Students can be asked to come up with their own procedure to take the reading; it could measure time taken just one oscillation or taking an average of time taken for 10 oscillations. Even though they would be using the same pendulum, there will be some variation in the time noted down by the students.

Was your reading the same as the other groups? Was there any difference? If yes, what could be the reason? What can be done to minimize this difference?

To have more reliable measures, an average of multiple readings can be taken.

Task 4

In task 3, we saw that even amongst the readings that you took, there was a variation. Now let's take a look at the data given below and try to analyze it. The length of the pendulum (L) is 48.6 cm.

Time taken	Bunty	Pinky
t(1)	12.0	13.5
t(2)	12.0	14.2
t(3)	12.0	13.9
t(4)	12.0	14.4
t(5)	12.0	14.0

Here you have been given the time taken for 10 oscillations, what can you say by looking at the values? According to you, who has performed the experiment well and why?

Let's check if the values are correct! Simple pendulums can be used to find the acceleration due to gravity 'g'. Do you remember its value? g = _____

Now, to calculate the value of 'g' using the two given data-sets, you can use the following formula

After calculating the value of 'g' for the given data-sets, what did you find?

Whose experiment is more correct? Pinky or Bunty ________________

The first thing one will notice on looking at the data is the precision in the readings taken by Bunty and the scatter in the readings taken by Pinky, which gives the feeling that Bunty's reading might be correct. But after 'g' is calculated, one will realize that even though Pinky's readings seemed scattered it has better accuracy than Bunty's.

Precision and accuracy both inform us about different errors in measurement and what kind of correction is needed.

Below is a link to a video that explains precision and accuracy.

https://www.ted.com/talks/matt_anticole_what_s_the_difference_between_accuracy_and_precision?language=en

> A classic way of demonstrating the difference between precision and accuracy is with a dartboard. Think of the bulls-eye (center) of a dartboard as the true value. The closer darts land to the bulls-eye, the more accurate they are.
>
> • If the darts are neither close to the bulls-eye, nor close to each other, there is neither accuracy, nor precision (a).
>
> • If all of the darts land very close together, but far from the bulls-eye, there is precision, but not accuracy (b).
>
> • If the darts are all about an equal distance from and spaced equally around the bulls-eye there is mathematical accuracy because the average of the darts is in the bulls-eye. This represents data that is accurate, but not precise (c). However, if you were actually playing darts this would not count as a bulls-eye!
>
> • If the darts land close to the bulls-eye and close together, there is both accuracy and precision (d).