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Precise and accurate measurements

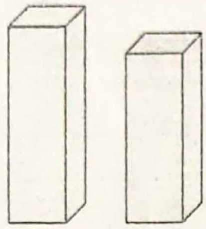
Introduction

One process which can be considered responsible for evolution of modern science, mathematics, and technology is developments in measurements. Any quantity for which a measurement system could be developed led to expanding our knowledge about the world and also led to new technologies.

Measurement, as simple a task as it may seem, gives us some values. These seemingly simple values carry a lot of information in them. In this Learning Unit, we are going to explore some details which are applicable to any measurement process through exploring measuring devices and the measurement data collected.

Task 1: Creating scales: Multiplying and Dividing

Imagine you do not have any measuring instrument handy with you. Can you compare the two blocks/objects in the diagram below?



Q1. How will you make the comparison? Can you say which one of them is taller and which one would weigh more? How did you make these conclusions?

We make Comparison by ~~observing~~ Comparing each one. Yes the 1st one is taller and also 1st one have weight more. By observing.

You might get some information about the objects being compared, with reference to each other, but we don't know the exact height or weight of the objects. To have this information, we will have to measure these quantities using some measuring instrument.

Q2. Describe what you think 'measurement' is, in your own words. Also, what exactly is it that we do, when we measure any quantity?

Measurement is to measure something by Comparing the Object / material given. when we measure any quantity we observe and Compare.

Now, suppose we want to measure the dimensions of a cuboidal object (i.e its length, breadth and height). For simplicity, we can try measuring the dimensions of a book. But you can also choose any cuboidal object of your choice eg. matchbox.

To measure its dimensions, we will need *something* to compare the lengths as before, such that the values obtained by comparing the cuboid object are multiples of that *something*. And this *something* could be anything that has a straight edge!

Q3. Can you think of some objects, other than a ruler, that we can use? What obvious feature does this object needs to have, to be able to measure the dimensions of the book?

Yes, we think of some objects, other than ruler like - Eraser, Sharpner, Matchbox, Chalk etc. SHAPE is the abvious feature.

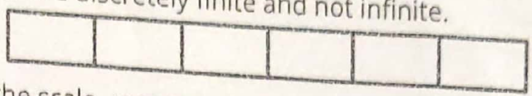
The object that you decide to use for measuring the dimensions of the cuboid, will be your reference for making a measuring instrument. You can use an eraser, a pen cap or any other suitable object. If you choose earser as reference object, any length that is equal to the length of the eraser will be 1 eraser unit. If twice then it'll be 2 eraser units and so on.

Now let's make a scale (on paper, cardboard, or any other material) using your eraser as a unit. You are free to design and develop this scale in any way you want, but like any other scale, this scale should also have markings on it for different lengths.

Q4. Where will you make the markings? Is there any other information one needs to make this scale?

We make the markings on paper ~~by~~ With the help of sharpener. NO.

In making a scale, what we are doing is making categories for lengths. Each marking on the scale defines a region and the dimensions of any object falling in the vicinity of that region, belongs to the region. For example, objects whose length is close to 1 eraser length will now belong to category of length = 1 eraser length. Similarly we can define another group of objects whose length can be defined to be 2 eraser length long. This is how the measuring will proceed. The categories that a scale creates are discretely finite and not infinite.



Once you are done making the scale, measure the dimensions of the cuboid object. One can also try using this scale to measure dimensions of different objects later.

Objects	Measurements made using the new scale			
	Length	Breadth	Height	
Book	9SU	7SU	1SU	63
Box DS	4SU	3 SU	3SU	36
Box SF	11SU	2SU	2SU	44

Table 1: Measuring cuboid objects using the new scale

Q5. Did you face any difficulties while taking the measurements? Were there some lengths you were not able to measure at all?

Yes, we face difficulties while taking the measurements. When we're measuring book then we're n't completely measure. That's we measure in scale.

Q6. Can you use this scale to measure the length of your classroom? State your reasons.

Yes but ~~NO,~~ We also didn't use this scale to measure the length of classroom. because our scale is not a perfect scale. also our scale is to small for measuring class.

Q7. Units are an important factor in any measurement. What were the units you used to measure the dimensions of the cuboidal object?

The units we used to measure is 1SU, 2SU, 3SU.......

Now, based on the dimensions that you know describe the object that you have measured to other groups. Then you can discuss your findings within this group.

1) What did you discuss in groups?
2) Suppose each one of you decided on a different scale as your standard scale, would you be able to do and compare all types of measurements, or would you face some problems?
3) Now, based on the measurement, calculate the volume of cuboid. How does this value compare with others who have used the same object to measure?

...ask 2: Limits of a measuring instrument

In the previous task, we prepared our own length measuring instruments, i.e. the scale made out of eraser units, and got familiarised with some of its properties. These properties have some names designated to them. Let's see what they are called.

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 measurement of the instrument, but always from a certain minimum to a certain maximum, i.e., from 0SU to 7SU.

Q8. What is the range of the scale that you had made in Task 1?

0 Sharpener Unit to 7 sharpener Unit.

Q9. With repeated measurements one can measure any higher value, e. g., to measure 42 cm, one can use the 30 cm ruler once again. So then, what is the range of the ruler?

Q10. If the quantity we need to measure exceeds the range of the instrument, do you think we can always take repeated measurements to measure that physical quantity?

Yes

Q11. Why does one need to know the range of an instrument?

for doing repetation.

Consider any instrument, and note down the smallest value it can measure, that will give you the least count of that instrument.

Least count of an instrument is the smallest change or difference in a value that can be reliably measured using that instrument, such that all the readings recorded are multiples of this value.The smallest value indicated on the scale of an instrument (mostly zero) is not the least count.

Q12. What do you think was the least count of the scale that you prepared in the task 1?

1SU

Q13. What do you think would be the least count of the 30 cm ruler we generally use?

0.1 cm

Q14. Why does one need to know the least count of an instrument?

for measuring the accuracy of any object.

Now, that you know the terms least count and range well, look at some common measuring instruments that you can find and fill the following table.

Sr. No.	Instrument	Measured quantity	Unit	Least Count	Range
1	Scale	length	cm	0.1 cm	0cm to 30cm

2	Protector	Angle	Degree	0.1°	0° - 180°
3					
4					
5					
6					

Table 2: Range and least count of various measuring instruments

Task 3: Measuring time

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

Take a string/thread and tie a small but heavy object (eg. an eraser, potato, etc.) at one of its end. Keep the length of the pendulum (from point of rotation to the centre of heavy object), say 50 cm. Tie the pendulum to a stand.

Now, you need to measure the time it takes for one oscillation. What measuring instrument will you use to measure the time period? How will you accurately record the starting and end of one oscillation of the pendulum?

Q15. Is there any similarity in how you did length measurement and time measurement?

when time increase ~~so~~ length increase and length increase so time ~~too~~ increase.

Q16. 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?

Yes, some difference in other groups because length difference of thread.

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

Task 4: Repeating a measurement and variations obtained

In task 3, we noted down the time period for the pendulum we made. For reference, some more readings taken by student 1 and student 2, using a pendulum with same length of 50 cm, have been given below. Add your readings to this table in the last column.

Now, let's take a look at the data given below and try to analyze it.

Time taken for 1 oscillation	Student 1 (in s)	Student 2 (in s)	Your (in s)
t_1	1.40	1.44	1.38
t_2	1.40	1.40	~~1.38~~ 1.47

t₁	1.40	1.42	1.38
t₂	1.40	1.40	~~1.38~~ 1.47
t₃	1.40	1.43	~~1.38~~ 1.44

Table 3: Experimental data for time period of a pendulum

Q17. From the table, what can you say by looking at the values? Who do you think amongst students 1 and 2 performed the experiment well and why? How does your data compare with theirs?

looking at the values we observe all time period are different. student 1 performed the experiment well because our data is similar to student 1.

In the pendulum example, you might have noticed many words used by peers including correct, precise, perfect, accurate, to the point. Let us consider some more situations before we explore what meaning these words have

Q18. You buy 500 g potatoes or tomatoes. Then you are buying a silver ornament which is weighing 20 g. In which case you would be extra careful about correct weight?

we extra careful about correct weight of silver orhament.

Q19. You need to cut a 2 m long plank of wood to make a sitting bench in a park, versus you need to cut a 2 m plank to make a door which need to fit in already fixed frame in a wall. In which case you need to be extra careful in length measurement?

we need to be extra careful in 2m plank to make a door in length measurement.

Variations in multiple measurements of same object

Q.20 A lady purchased a *payal* (a feet anklet) made of silver from a village goldsmith, which weighted 21.3 g. She paid to the goldsmith for that mass of silver. But after coming out of goldsmith's shop, she double checked the mass from a different shop in the village where it weighed 21.4 g. She then went to her home in a citywhere goldsmith in another shop weighed the payal and the mass was found to be 22.1 g.

Why do you think the mass of the same ornament was different in three different shops. How can one decide what is the correct value of mass?

Because of device are error.

The variation in multiple measurements of same object is understood using two ideas: precision and accuracy.

A classic way of demonstrating the difference between precision and accuracy is with a dartboard. Think of the center (also known as bulls-eye) of a dartboard as the true value. The closer darts land to the center (the desired or true value), the more accurate they are.

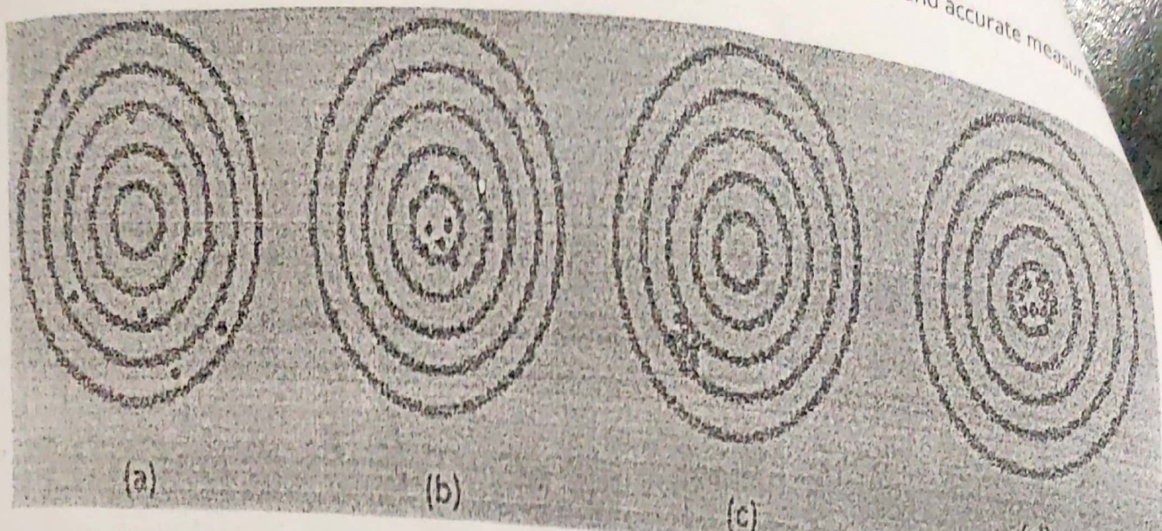


Figure 1: A classic example of using a dartboard to explain concepts of accuracy and precision

Q21. So, if the target is always hit at the same place all the time, the player is said to be precise. Which of the cases above (among a-d) seem more precise to you, and which less?

(d) is more precise and (a) is less precise.

Q22. But the player is only accurate when those precise hits are at the center. Now, which one is more accurate and which less?

d is more accurate and (a) is less accurate.

In the dart board game, we can easily talk about accuracy, because we know where we have to hit to get the best result. But during experiments or real life measurements, one doesn't really know what the bull's eye is! Similar to the simple pendulum experiment. The aim is to find the time period for 1 oscillation. But one can never be sure what the correct answer for that is! And many factors affect the result of any experiment and deviate it from the true value causing errors.

Thus, the goal of an experimenter is not getting accurate value, but to think about all the factors that can cause errors and trying to reduce them as much as possible to get the best result out of any setup. And if the same experiment is repeated at different time or place or by different people and the result are same, then that value is accepted as the correct value. But over time, if someone realises the existence of some other error causing factor and changes the experiment to reduce that error, a new result will be obtained. This result if found reproducible, be considered as the new correct result.

Task 5: Need for high and low precision in measurement

Increasing precision of a measurement requires improvement in technologies and measurement methods. It may also increase costs of measurements/measuring equipments. In many case low precision measurements are also okay. Suggest which order of precision would be needed for following measurements:

1) Amount of water to be given to a healthty person for drinking: ±100 mL, ±10 mL, ±1 mL, ±0.1 mL
2) Carrots to be purchased for one family's meal: ±100 g, ±10 g, ±1 g, ±0.1 g
3) Height of wood pieces to be cut for a chair: ±10 cm, ±1cm, ±0.1 cm, 0.01 cm
4) A pair of gold earrings: ±1 g, ±0.1 g, ±0.01 g, 0.001 g
5) Time taken by a train to travel from one station to next station: ± 10 min, ± 1 min, ±10 sec, ±1 sec
6) Length of inside box of a matchbox to fit inside outer box : ± 0.5 cm, ±0.2 cm, ±0.1 cm, ±0.02 cm

Task 6 Dividing a unit into subunits- The Vernier's method (extended activity)

Vernier calliper is a useful instrument for making precise length measurements smaller than 0.1 cm. The least count of the vernier scale can be 0.01 cm depending on the making of the scales. The Vernier calliper has a main scale with markings graduated at a distance of 0.1 cm or 0.5 cm, which is fixed and does not move. A movable scale called the 'Vernier' scale is attached on the main scale. Movable scale has markings which are slightly shifted relative to the markings on the main scale by some distance depending upon the precision required from the instrument. To start making this instrument, you would need five pieces of the following shapes. Choose total length of the scale (say 10 cm or 15 cm or 20 cm).

Procedure:

Choose a length (end-to-end) for the vernier caliper (10 cm/15 cm/20 cm) & accordinly draw the parts labelled A and B on a card board/card sheet/paper. Cut them along the outer border and out of the cardsheet carefully. A will be our main scale while B will serve as the vernier scale.
After cutting out the shapes, lay part A over part B, such that the dashed lines of both the parts are aligned with each other.
Along the bottom horizontal line of part A, make markings every 1 cm, where the dashed line marks the '0' of the scale. Also add length values as 1 cm, 2 cm, 3 cm and so on on the scale.
Similarly, along the bottom horizontal line of part B (with the dashed line marking the '0' of the scale, along the edge of the main scale drawn on part A, when it is kept over part B), make markings every 0.9 cm with a range of 9 cm numbering each of them as 1(at 0.9 cm), 2(1.8 cm),....

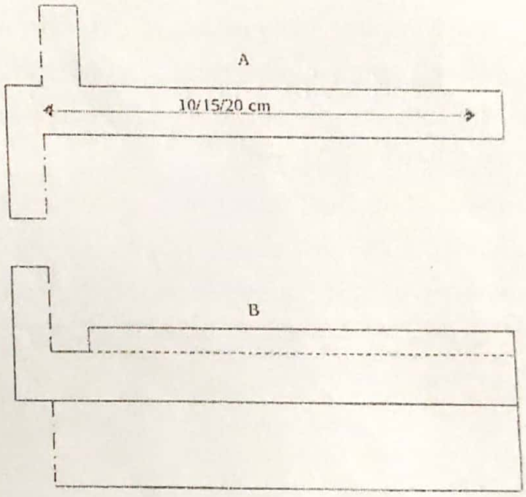


Figure 2: Outline shape for making a Vernier Caliper

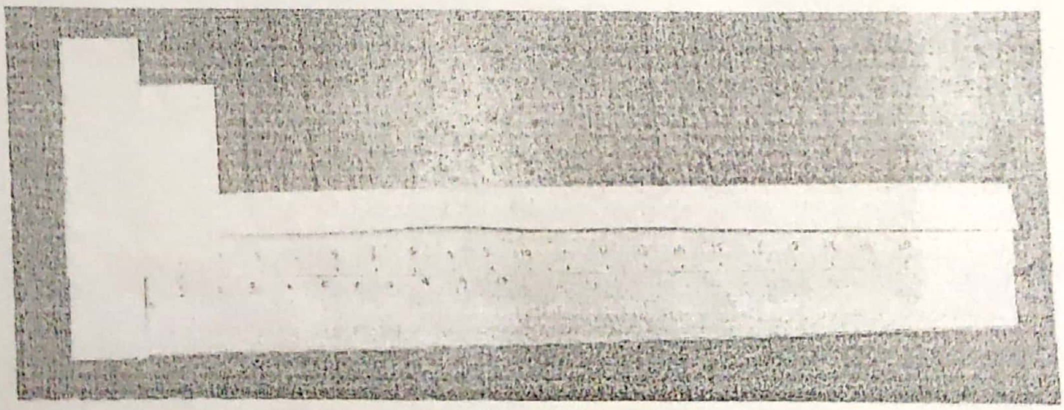


Image 1: An assembled Vernier Caliper made on paper

When the instrument(calipers) is closed or making zero measurement, the "0" marking on the

main scale as well as the vernier scale exactly coincide with each other. The "0"th marking on the vernier scale is essentially the starting point of the vernier scale.
You can notice that the first mark on the vernier calliper is 1/10th cm or 0.1 cm short(to the left) of the first mark on the main scale. Similarly, the second marking on the vernier scale will be 2/10th cm short(to the left) of the second mark on the main scale. Similarly, the 3rd is 3/10th cm short and 8th is 8/10th cm short of the 3rd and 8th marking on main scale respectively. The 10th marking on the vernier will be 10mm or 1 cm short of the corresponding mark on the main scale and aligns 1cm to the left of the 10 cm mark on main scale i.e., coincides with the 9 cm marking on the main scale. Therefore, there are 10 divisions on the vernier scale for 9 divisions on the main scale, thus separating them by an interval of 0.1 cm.
Let's understand how this small displacement/misalignment of the markings on the two scales helps us to make fine measurements. Suppose we need to make a length measurement of an eraser of 3.5 cm in length. We need to slide the calliper to the desired length. The zero on the vernier scale will be ahead of the 3 cm mark on the main scale, which will be the main scale reading. To complete our measurement, we need to know the gap between the 3 cm on on the main scale and the coinciding division on the Vernier scale. The amount by which the zero on the vernier scale is ahead of the 3 cm mark is 0.5 cm, which 5 mm.
The first mark on the vernier scale which was earlier short by 0.1 cm will now be ahead by a net distance of more than 3 cm from the zero mark on the main scale and will not align with any marking on main scale. Similarly, the second and third mark on the vernier scale will move ahead and won't align with any marking on main scale.
However, the fifth marking on the vernier scale which was 0.5 cm short will be 0.5 cm ahead and coincide exactly with the marking on the main scale. The coincidence can be visually seen and noted by an observer. Thus, the total length of the matchbox will be 3 cm (which is 3 main scale division) + 0.5 cm (Vernier scale division) = 3.5 cm.
Thus, the instrument with a main scale least count of 1 cm or 0.1 mm along with a vernier scale could measure upto 0.1 cm which is its least count. It is thus only logical to have a vernier scale which has even more closely spaced graduations to increase the accuracy.

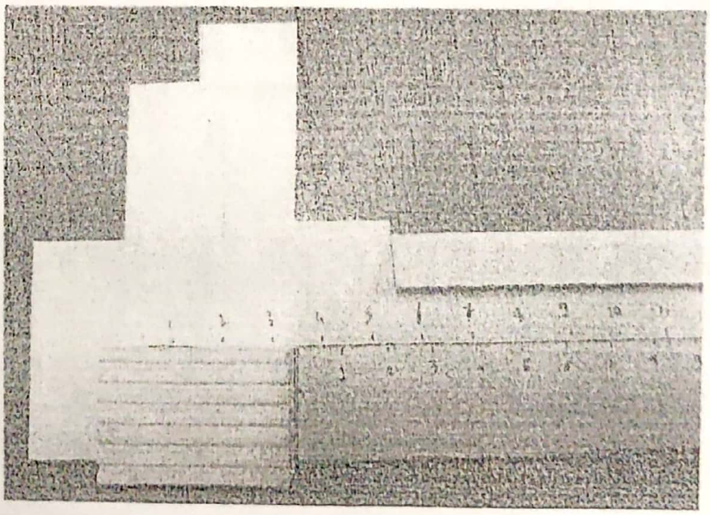


Image 2: Measuring length of an eraser using Vernier Caliper

In the above image, the 5th division on the Vernier scale is seen to be coinciding, there is no gap here. The gap of our instrument (where the eraser's length fits) is the gap between 3 main scale divison and 5 Vernier scale divison, i.e. 5 mm or 0.5 cm.