Measurement- The Foundation of Science

1.1 Introduction: What is Measurement?

Measurement is the process of comparing an unknown quantity with a known standard quantity of the same kind. Physics is based on measurement. Whether we measure the length of a classroom, the mass of a bag, or the time taken by a runner, accurate measurement is essential

Examples

- A tailor measures cloth in meters.
- A doctor measures body temperature in degree Celsius.
- A shopkeeper measures rice in kilograms.

Without proper units, these measurements would have no meaning.

Activity 1.1 Measuring the area of the classroom floor

Materials**:** Take three sticks of length l_1:l_2:l_3 = 1:2:3

Procedure:

1. Divide students in 3 groups and hand over one stick to each group.
2. Each group will measure the length and width of the classroom taking stick as one unit.

	Stick 1	**Stick 2**	**Stick 3**
Length of wall	..... units*	..... units	..... units
Breadth of wall	..... units	..... units	..... units
Area of floor	..... units^2	..... units^2	..... units^2

**the unit refers to length of the stick used for measurement*

3. Compare the length, breadth and area measured by different groups and try to generate conclusions between unit chosen and numerical values obtained by all the three groups.

This activity demonstrates that the numerical value of a quantity is inversely proportional to the size of the unit used. Thus, when a larger unit (longer stick) is used to measure the classroom floor, the numerical value obtained is smaller, and

when a smaller unit is used, the numerical value is larger.

In measurement, the physical quantity remains constant even when the unit changes.
Hence,

$$Q = n_1u_1 = n_2u_2$$

Therefore,

$$n_2 = n_1 (u_1 / u_2)$$

Activity 1.2: Let's play an estimation game

Procedure:

1. Estimate the length of the blackboard without measuring.
2. Then measure its length using a meter scale.
3. Compare the estimated and measured values. Now, calculate the inaccuracy (error) in the measurement.

1.2 Different Systems of Units

In earlier times, different regions/places used their own units of measurement, which often led to confusion and errors.

(a) CGS System

- Length: centimeter (cm)
- Mass: gram (g)
- Time: second (s)

It is mainly used in laboratory and scientific calculations.

(b) FPS System

- Length: foot (ft)
- Mass: pound (lb)
- Time: second (s)

Commonly used in the United States.

(c) MKS System

- Length: meter (m)
- Mass: kilogram (kg)
- Time: second (s)

This system later developed into the SI (**International System of Units or Système International d'Unités)** system.

Example

- The height of a person is largely measured in centimeters in India, while in some countries it is measured in feet and inches.

1.3. Need for a Common System of Units

Different systems of units caused difficulties in communication, trade, and scientific research.

Problems Without a Common System

- Confusion in international trade
- Errors in scientific calculations
- Difficulty in sharing scientific data

Example

If a scientist in India measures length in meters and another in the USA measures in feet, comparison becomes difficult unless a common unit is used.
Hence, a universal system of units was required.

Activity 1.3: Let us Compare

Materials: Ruler marked in cm and inches

Procedure:

1. Measure the length of a book using both cm and inches.
2. Compare the values and find the relation between them.

1.4. International System of Units (SI)

The International System of Units (SI) is the modern and universally accepted system of measurement.

SI Base Units

Physical Quantity	SI Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Kelvin	K
Electric Current	Ampere	A

Luminous Intensity	Candela	Cd
Amount of substance	Mole	mol

Advantages of SI Units

- Internationally accepted
- Easy to use and understand
- Based on the decimal system

Examples

- Speed of vehicles is measured in m/s or km/h
- Medicines are measured in milligrams (mg)

1.5 Conversion of Units between different Systems

Sometimes, we need to convert a measurement from one unit to another to ensure comprehension across different systems.

During unit conversion, the numerical value and the unit may change, but the magnitude of the physical quantity remains the same.

Basic Conversions

- **1 km = 1000 m**
- **1 m = 100 cm**
- **1 kg = 1000 g**
- **1 hour = 3600 s**

Examples

Q. Convert 9 km/hr into m/s.

Answer: 9 km/hr $= \frac{9 \times 1000\ m}{3600\ s} = \frac{5}{2}$ m/s

Q. Convert 1 N into gcm/s^2.

Answer: 1 kg m/s ^{2} = 1000g x 100 cm/s^2 = 10^5 gcm/s^2 = 10^5 dyne.

Quick Check

1. Name any two systems of units.
2. Why is SI system preferred over other systems?
3. Convert 250 N into gcm/s^2.
4. Convert 1000 kg/L into kg/m^3.

Check Your Understanding

1. Which of the following is not an SI unit?
   a) Meter
   b) Kilogram
   c) Second
   d) foot
2. The SI unit of mass is:
   a) Gram
   b) Kilogram
   c) Pound
   d) tonne
3. Name the system of units used internationally.
4. Why is a common system of units necessary?
5. Why is measurement necessary in physics?
6. Why was there a need for a common system of units?
7. Explain the relation: Magnitude = Numerical value × Unit
8. Why does the same classroom floor give different numerical values when measured with sticks of different lengths?

   Answer questions 9 to 11 that are based on Activity 1.1 (Measuring Classroom Floor)

   Suppose:

Stick Length	Length of Wall	Breadth of Wall
1 unit	30 units	20 units
2 units	15 units	10 units
3 units	10 units	6.6 units

9. Why are numerical values different?
10. Is the actual size of the classroom different? Why or Why not?
11. What conclusion can you draw about units and measurement from this activity?
12. Fill in the blanks
    a. Measurement is the process of comparing an unknown quantity with a _____ quantity.
    b. The SI unit of mass is _____.

c. In CGS system, the unit of length is _____.

d. 1 km = _____ m.

e. The modern internationally accepted system of units is called _____.

13. Match the following:

Column A	Column B
CGS	Kelvin
FPS	Pound
SI	International system
MKS	Meter-Kilogram-Second

14. What problems might occur if every country used its own system of units for measurement?

15. A scientist measures length in feet and another in meters. What difficulties may it lead to?

16. If 1 meter was defined differently in different countries, what would happen to international trade?

17. A shopkeeper sells rice using kilograms. A foreign customer asks for rice in pounds.

    a. Why is unit conversion necessary here?

    b. If 1 kg = 2.2 pounds, how many pounds are there in 5 kg?

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