Unit 2
Physical Quantities

Introduction

Physics is the study of the fundamental aspects of our universe. It begins with observing phenomena and then describes these observations using mathematical tools. This process involves measuring various physical quantities using standardized scales and units. In this unit, you will learn about different types of scales, measurement techniques, the classification of physical quantities, and unit conversions.

1. Scales, Standards, and Units

Scales: A scale on a measuring device shows the amount of what is being measured. The precision of a device depends on how many markings it has. More marks mean higher precision. For example, a ruler with finer markings can measure length more precisely. Here's how to read scales:

- **Example 1**: To measure the length of an object using a ruler with markings, you might find it falls between 3.3 and 3.4 cm. By estimating, you could say the length is approximately 3.35 cm.

Standards: To ensure consistency in measurement, standards are used. For instance, in physics, we use seven basic quantities:

- **Length (l)**: Measured in meters (m).
- **Mass (m)**: Measured in kilograms (kg).
- **Time (t)**: Measured in seconds (s).
- **Temperature (T)**: Measured in kelvins (K).
- **Electric Current (I)**: Measured in amperes (A).
- **Amount of Substance (n)**: Measured in moles (mol).
- **Luminous Intensity (Iv)**: Measured in candelas (cd).

Example 2: If a measurement is reported differently by different people, it indicates a lack of standardization. For example, using a palm to measure cotton varies greatly from person to person, leading to inaccurate measurements.

2. Units and Conversion

International System of Units (SI): The SI system is a globally accepted system of measurement that standardizes units:

- **Length**: Meter (m) – 1 meter is defined as the distance light travels in a vacuum in 1/299,792,458 seconds.
- **Time**: Second (s) – Defined by the vibration period of cesium-133 atoms.
- **Mass**: Kilogram (kg) – Defined using Planck's constant.

Scientific Notation: This is used to write very large or very small numbers more easily. It is in the form d×10nd \times 10^nd×10n, where ddd is a decimal number and nnn is the exponent. For example:

- $3.24\times10^{3}=3240$
- $3.24\times10^{-3}=0.00324$

Significant Figures: These are the digits in a number that carry meaningful information about its precision. Rules for significant figures include:

- **Addition/Subtraction**: The result should have the same number of decimal places as the number with the fewest decimal places.
- **Multiplication/Division**: The result should have the same number of significant figures as the number with the fewest significant figures.

Example 3: For 6.827 (4 significant figures) rounded to 3 significant figures, it becomes 6.83.

Prefixes: Prefixes modify units to represent large or small quantities. For example:

- **kilo- (k)**: 1,000
- **centi- (c)**: 0.01
- **milli- (m)**: 0.001

Example 4: 1 kilogram (kg) is 1,000 grams (g), or 1×10^{3}g.

3. Measurement and Safety

Measurement: The process of comparing an unknown quantity to a known standard. Measurement involves:

- **Physical Quantity**: What is being measured.
- **Measuring Tools**: Instruments used.
- **Units**: Standard units for comparison.

Measuring Length: Standard unit is meter (m). Non-SI units include millimeter (mm), centimeter (cm), and kilometer (km).

Measuring Mass: Standard unit is kilogram (kg). Non-SI units include gram (g) and milligram (mg).

Measuring Time: Standard unit is second (s). Non-SI units include minute (min) and hour (hr).

Example 5: Measuring instruments such as rulers, balances, and clocks help ensure accurate measurements in everyday life and scientific research.

Classification of Physical Quantities

Introduction

In physics, understanding physical quantities involves knowing how to measure and classify different types of measurements. This includes distinguishing between fundamental and derived quantities and understanding scalar and vector quantities. This guide explains these classifications and concepts in detail.

1. Fundamental (Basic) Physical Quantities

Fundamental physical quantities are the basic measurements that cannot be described in terms of other physical quantities. They are directly measurable and form the foundation for other measurements. Each fundamental quantity has a specific unit of measurement, called a fundamental unit.

Basic Physical Quantities:

- **Length (l):** Measured in meters (m)
- **Mass (m):** Measured in kilograms (kg)
- **Time (t):** Measured in seconds (s)
- **Temperature (T):** Measured in Kelvin (K)
- **Electric Current (I):** Measured in Amperes (A)
- **Amount of Substance (n):** Measured in moles (mol)
- **Luminous Intensity (Iv):** Measured in candelas (cd)

2. Derived Physical Quantities

Derived physical quantities are obtained by combining fundamental quantities. They depend on the basic quantities for their measurement and have derived units.

Examples of Derived Physical Quantities:

- **Speed (v):** Distance per unit time, measured in meters per second (m/s)
- **Acceleration (a):** Change in velocity per unit time, measured in meters per second squared (m/s^2)
- **Area (A):** Product of length and width, measured in square meters (m^2)
- **Volume (V):** Product of length, width, and height, measured in cubic meters (m^3)
- **Density (ρ):** Mass per unit volume, measured in kilograms per cubic meter (kg/m^3)
- **Work (W):** Force applied over a distance, measured in joules (J)

3. Scalar and Vector Quantities

Physical quantities can be classified into scalar and vector quantities based on their characteristics.

- **Scalar Quantities:** These have only magnitude and no direction. Examples include:
  - **Distance**
  - **Mass**
  - **Time**
  - **Temperature**
  - **Energy**
- **Vector Quantities:** These have both magnitude and direction. Examples include:
  - **Displacement**
  - **Velocity**
  - **Acceleration**
  - **Force**

Vectors are often represented with arrows or boldface letters to indicate their direction and magnitude. For example, displacement might be represented as $\vec{d}$.

4. Unit Conversion

Unit conversion involves changing a measurement from one unit to another. This is essential for consistent communication of measurements. Conversion is done using multiplicative factors.

Examples:

- **Length Conversion:**
  - 1 meter (m) = 100 centimeters (cm)
  - 1 kilometer (km) = 1000 meters (m)
  - 1 meter (m) = 1000 millimeters (mm)
- **Mass Conversion:**
  - 1 kilogram (kg) = 1000 grams (g)
  - 1 tonne = 1000 kilograms (kg)
- **Time Conversion:**
  - 1 hour (hr) = 3600 seconds (s)
  - 1 minute (min) = 60 seconds (s)

Key Takeaways:

- **Scales** help measure physical quantities and can be precise or approximate.
- **Standards** ensure consistency in measurement across different contexts.
- **Prefixes** simplify the representation of very large or very small quantities (e.g., kilo, centi, milli).
- **Scalar quantities** have magnitude only, while **vector quantities** have both magnitude and direction.
- Conversion between units allows for standardization and comparison.