



# UNIT 1 – UNIT & MEASUREMENTS

## Units and Measurements: A Fundamental Guide

### Introduction

Units and measurements are foundational to science, engineering, trade, and daily life. They provide a standardized way to express and understand quantities, ensuring consistency and accuracy in various applications.

### 1. Definition:

- **Unit:** A specific standard used for measuring a particular physical quantity. It's a fixed magnitude of a quantity, defined and adopted by convention, with which other quantities of the same kind are compared to express their value.
- **Measurement:** The act of determining the amount or size of something. It's a comparison process, comparing an unknown quantity and a unit of measurement, resulting in a number.

### 2. Types of Measurement Systems:

- **Metric System (SI - International System of Units):**
  - Based on powers of ten.
  - Units include meters (length), kilograms (mass), and seconds (time).
- **Imperial or British System:**
  - Used primarily in the UK and USA.
  - Units include inches, feet, pounds, and gallons.

### 3. Fundamental Units in SI:

There are seven base units from which other SI units are derived:

- **Length:** Meter (m)
- **Mass:** Kilogram (kg)
- **Time:** Second (s)
- **Electric Current:** Ampere (A)
- **Thermodynamic Temperature:** Kelvin (K)
- **Amount of Substance:** Mole (mol)
- **Luminous Intensity:** Candela (cd)

### 4. Derived Units:

These are combinations of the fundamental units. Examples include:

- **Velocity:** Meters per second (m/s)
- **Force:** Newton (N), which is  $\text{kg m/s}^2$
- **Pressure:** Pascal (Pa), which is  $\text{N/m}^2$

### 5. Importance of Standardization:

- **Consistency:** Ensures that a particular quantity remains the same regardless of where or by whom it is measured.



- **Global Collaboration:** Facilitates collaboration and understanding across borders, essential for global scientific research and trade.
- **Accuracy:** Reduces the margin of error ensuring that measurements are reliable and trustworthy.

#### 6. Tools and Instruments:

Different instruments are used for different types of measurements:

- **Length:** Ruler tape measure, vernier caliper micrometer.
- **Mass:** Balance scales, electronic weighing scales.
- **Time:** Clocks, stopwatches.
- **Temperature:** Thermometers (mercury, digital).

#### Conclusion:

Units and measurement are essential in different fields, from constructing buildings and manufacturing to conducting scientific research. A clear understanding of how different quantities are measured and appropriate for them to ensures clarity and precision and a unified understanding in various application

### 1.1 Unit, physical quantities: fundamental and derived quantities and their units Systems of units: CGS, MKS and SI

#### Unit, Physical Quantities, and Systems of Units: Understanding the Foundation

##### Introduction

Units and physical quantities form the bedrock of scientific understanding and communication. By quantifying the world around us, we can express phenomena, exchange information, and delve into the intricacies of nature. Let's explore the concepts of units, fundamental and derived quantities, and the various systems of units.

#### 1. Unit and Physical Quantities:

- **Unit:** A unit is a standardized reference used to express a particular physical quantity. It provides a consistent and universal framework for measurement.
- **Physical Quantity:** A characteristic of a phenomenon that can be measured. Examples include length, mass, time, temperature, and more.

#### 2. Fundamental and Derived Quantities:

- **Fundamental Quantities:** These are basic and independent quantities that cannot be derived from other quantities. Examples include length, mass, time, and electric current.
- **Derived Quantities:** These are quantities derived from fundamental quantities using mathematical operations. Examples include velocity (derived from length and time), density (derived from mass and volume), and acceleration (derived from velocity and time).



### 3. Systems of Units:

Different systems of units are used across the world. Let's explore three prominent systems:

- **CGS System (Centimeter-Gram-Second):**
  - Primarily used in scientific research.
  - Length: Centimeter (cm), Mass: Gram (g), Time: Second (s).
- **MKS System (Meter-Kilogram-Second):**
  - Used in scientific and engineering contexts.
  - Length: Meter (m), Mass: Kilogram (kg), Time: Second (s).
- **SI System (International System of Units):**
  - Widely adopted globally.
  - Seven fundamental units: Meter (m), Kilogram (kg), Second (s), Ampere (A), Kelvin (K), Mole (mol), Candela (cd).

### 4. Benefits of Standardization:

- **Universal Communication:** A standardized system allows scientists, engineers, and people from diverse fields to communicate seamlessly.
- **Consistency:** Ensures that measurements are reproducible and understandable, regardless of location or context.
- **Precision and Accuracy:** A uniform system minimizes errors and ensures accuracy in scientific research, trade, and technology.

### 5. Examples of Derived Units:

- Force: Newton (N) -  $\text{kg m/s}^2$ .
- Pressure: Pascal (Pa) -  $\text{N/m}^2$ .
- Energy: Joule (J) - N m.

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### Conclusion:

Units and physical quantities form the vocabulary of science and engineering, enabling us to comprehend and explore the intricacies of the universe. Whether through fundamental quantities, derived quantities, or the systems of units we employ, the language of measurement transcends borders and disciplines, fostering collaboration and unlocking the mysteries of our world.

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## 1.2 Scalar and Vector Physical Quantities

### Scalar and Vector Physical Quantities: Understanding the Differences

#### Introduction

In the realm of physics and mathematics, physical quantities are classified into two fundamental categories: scalar and vector. These classifications are pivotal in understanding how quantities behave and interact in various contexts.



### Scalar Quantities

Scalar quantities are those that are fully described by a single numerical value (magnitude) and a unit. They have magnitude but no direction. Scalar quantities do not consider factors such as orientation or position.

Examples of Scalar Quantities:

- **Mass:** A body's mass is described solely by its magnitude (e.g., 5 kg).
- **Temperature:** A temperature reading, like 30°C, is scalar, as it does not indicate direction.
- **Time:** 2 hours is a scalar quantity, considering only its magnitude.

### Vector Quantities

Vector quantities possess both magnitude and direction, making them more complex than scalars. Vectors are used to describe quantities that have both a size and an associated direction in space.

Examples of Vector Quantities:

- **Displacement:** The change in position of an object is vectorial as it includes direction (e.g., 10 meters east).
- **Velocity:** Speed in a specific direction, like 50 km/h north.
- **Force:** A push or pull, characterized by its magnitude and the direction in which it acts.

### Key Differences:

#### 1. Nature:

- Scalar quantities are described solely by magnitude.
- Vector quantities have both magnitude and direction.

#### 2. Mathematical Representation:

- Scalar quantities are represented by a single numerical value.
- Vector quantities require both magnitude and direction for representation.

#### 3. Operations:

- Scalar quantities can be added, subtracted, multiplied, or divided by ordinary arithmetic rules.
- Vector quantities undergo vector addition and subtraction, taking direction into account.

#### 4. Physical Examples:

- Scalar: Mass, temperature, time.
- Vector: Displacement, velocity, acceleration.



### Vector Addition:

When dealing with vector quantities, addition involves both magnitude and direction. For instance, if you walk 5 meters north and then 3 meters east, the resultant displacement is a vector with a magnitude of  $\sqrt{5^2 + 3^2} = 5.83$  meters and an angle relative to the north direction.

### Conclusion:

Scalar and vector quantities are the building blocks of physics, forming the foundation for various calculations and analyses. Understanding their distinctions is crucial for accurately interpreting and solving problems involving quantities with or without direction. Whether calculating speed or plotting trajectories, the differentiation between scalar and vector quantities is at the core of comprehending the physical world.

1.3 Dimensions, dimensional formula, Applications of dimensional analysis; correctness of physical equations, conversion factor for interconversion of units in different systems of units.

### Dimensions, Dimensional Formula, and Dimensional Analysis: Navigating the Language of Physics

#### 1. Dimensions:

In physics, the term 'dimension' refers to the nature and type of physical quantity. It indicates which aspect of a phenomenon is being quantified. Common dimensions include length [L], mass [M], time [T], temperature [θ], and electric current [I].

#### 2. Dimensional Formula:

The dimensional formula provides a representation of the physical quantity in terms of its basic dimensions. For example:

- **Velocity:** Given by distance/time, its dimensional formula is  $[L][T]^{-1}$ .
- **Force:** Given by mass x acceleration, its dimensional formula is  $[M][L][T]^{-2}$ .

#### 3. Applications of Dimensional Analysis:

- **Checking Consistency:** Dimensional analysis ensures the correctness of physical equations by verifying that both sides of an equation have the same dimensions.
- **Converting Units:** By comparing the dimensions of a physical quantity in two different unit systems, one can derive conversion factors.
- **Deriving Relationships:** If the form of a physical relationship is unknown, dimensional analysis can provide insights into its potential structure, based on the principles of homogeneity.

#### 4. Correctness of Physical Equations:

A fundamental principle in physics is that equations must be dimensionally homogeneous, meaning the dimensions on each side of the equation must be the same. For example, in the equation  $F = ma$ , the dimensions of force  $[M][L][T]^{-2}$  on the left side are equivalent to the dimensions of mass  $\times$  acceleration on the right.

#### 5. Conversion Factor for Interconversion of Units:

When switching between unit systems, dimensional analysis provides the necessary conversion factor.

**Example:** To convert speed from kilometres per hour (km/h) to meters per second (m/s):  $100 \text{ km/h} = 27.78 \text{ m/s}$

Using dimensional analysis, this conversion factor is derived by noting that there are 1000 meters in a kilometre and 3600 seconds in an hour:

$$1 \text{ km/h} = \frac{1000 \text{ m}}{3600 \text{ s}} = 0.2778 \text{ m/s}$$

Similarly, such conversion factors can be derived for various quantities between different unit systems, like CGS to MKS or vice versa.

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#### Conclusion:

Dimensional analysis is a powerful tool in physics, lending clarity and consistency to our understanding of the natural world. By ensuring the homogeneity of equations, providing frameworks for deriving relationships, and facilitating seamless transitions between unit systems, it forms an integral part of the physicist's toolkit. Understanding the principles and applications of dimensions and dimensional analysis ensures robustness and precision in scientific investigations.

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**1.4 Errors, types of errors: instrumental, systematic and random error, estimation of errors: absolute, relative and percentage error, significant figures.**

#### Errors in Measurements: Types, Estimations, and Significance

##### Introduction

In the world of experimental and observational science, measurements rarely match true values perfectly. These deviations, known as errors, can arise from various sources. Understanding and estimating these errors is crucial for interpreting results, making informed decisions, and ensuring the reliability of data.

#### 1. Types of Errors:

- **Instrumental Error:**
  - Arise due to imperfections in measuring instruments.
  - Examples include a broken scale or a malfunctioning voltmeter.





- **Systematic Error:**
  - Consistent and predictable errors that occur due to a particular reason.
  - Often arise from flawed experimental technique or biased apparatus.
  - Example: If a stopwatch consistently lags by 0.5 seconds, it introduces a systematic error.
- **Random Error:**
  - Unpredictable errors that vary from one measurement to another.
  - Arise from unpredictable factors like sudden temperature changes or electrical fluctuations.
  - Averaging over many measurements can reduce the effects of random errors.

## 2. Estimation of Errors:

- **Absolute Error:**
  - The difference between the measured value and the true value.
  - $\Delta x = x_{\text{measured}} - x_{\text{true}}$
- **Relative Error:**
  - The ratio of the absolute error to the true value.
  - $\frac{\Delta x}{x_{\text{true}}}$
- **Percentage Error:**
  - Represents the relative error in percentage form.
  - $\% \text{Error} = \frac{\Delta x}{x_{\text{true}}} \times 100\%$

## 3. Significant Figures:

Significant figures in a number represent the digits that contribute to its precision. This includes all non-zero digits, any zeros between significant digits, and any trailing zeros in the decimal portion.

Examples:

- 1003 has four significant figures: 1, 0, 0, and 3.
- 0.00203 has three significant figures: 2, 0, and 3.

Guidelines:

1. Non-zero digits are always significant.
2. Any zeros between significant digits are significant.
3. Leading zeros are never significant.
4. Trailing zeros in a decimal number are significant.
5. All digits in the coefficient of a number written in scientific notation are significant.

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## Conclusion:

Errors are an inherent part of experimental science. By understanding their sources and types, we can adopt strategies to minimize their impact. Estimating errors enables scientists to gauge the reliability of results, while significant figures provide clarity on data precision. Together, these concepts form a framework for robust scientific inquiry, ensuring findings are reliable, interpretable, and impactful.

## 1.5 Ancient astronomical instruments: Chakra, Dhanuryatra , Yasti and Phalaka yantra.

### Ancient Astronomical Instruments: Tracing the Path of Celestial Navigation

#### Introduction

From time immemorial, the stars and skies have captivated humanity. To unravel the mysteries of the cosmos, our ancestors developed various tools and instruments. These ancient devices, particularly from civilizations like India, were precursors to modern astronomical tools. Let's delve into the intricacies of some such instruments: the Chakra, Dhanuryatra, Yasti, and Phalaka Yantra.

#### 1. Chakra:

- **Description:** The Chakra, meaning 'wheel' in Sanskrit, was a circular instrument used to measure the altitude of stars. Its design comprised a graduated circular disc with a central hole, suspended vertically.
- **Usage:** By sighting a star through the central hole, the altitude of the star could be determined based on where it intersected the disc's circumference.
- **Significance:** The Chakra was essential for determining latitudinal coordinates and was an early method for maritime navigation.

#### 2. Dhanuryatra:

- **Description:** The term 'Dhanuryatra' translates to 'bow's journey' and was a curved instrument similar to a bow. It was often made of wood or metal.
- **Usage:** The bow's curvature was used to measure the angular distance between celestial bodies. By aligning one end with a reference point and the other end with a target celestial body, the angular separation could be gauged.
- **Significance:** Dhanuryatra provided a rudimentary but effective method to measure astronomical distances, aiding in understanding celestial mechanics.

#### 3. Yasti:

- **Description:** The Yasti, meaning 'rod' in Sanskrit, was a straight, vertical rod used as a gnomon, the part of a sundial that casts a shadow.
- **Usage:** By measuring the length and direction of the shadow cast by the Yasti, ancient astronomers could determine the time of day and the sun's declination.
- **Significance:** Beyond timekeeping, the Yasti was pivotal in understanding the Earth's tilt and the concept of equinoxes. It was one of the primary tools in ancient solar observatories.





#### 4. Phalaka Yantra:

- **Description:** The Phalaka Yantra, with 'Phalaka' meaning 'board' or 'plate', was a flat, rectangular board marked with several astronomical reference lines and circles.
- **Usage:** By placing the board in a North-South direction and using sighting rods, astronomers could measure the altitude of stars and planets, helping in their identification and tracking.
- **Significance:** The Phalaka Yantra was a precursor to the astrolabe and played a significant role in star mapping and early astronomical tables.

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#### Conclusion:

The ancient world's astronomical instruments, while rudimentary compared to today's sophisticated devices, lay the groundwork for modern astronomy. Through ingenuity and observation, these instruments unveiled the cosmos's secrets and charted humanity's course through time and space. Recognizing their contributions gives us a deeper appreciation for our ceaseless quest to understand the universe.

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#### 1.6 Applications of Vernier calipers, Screw gauge.

##### Applications of Vernier Calipers and Screw Gauges: Precision in Measurement

#### Introduction

In the realm of precision measurement, Vernier calipers and screw gauges are invaluable tools. These devices provide accurate and reliable measurements for a wide range of applications, from engineering and manufacturing to scientific research and beyond. Let's explore the practical uses of Vernier calipers and screw gauges in various fields.

#### 1. Vernier Calipers:

- **Engineering and Manufacturing:**
  - Vernier calipers are widely used in engineering to measure lengths, diameters, and thicknesses of various components and parts with high accuracy.
  - They aid in ensuring precise fits and tolerances in machinery, helping in the production of well-fitting and functional products.
- **Automotive Industry:**
  - Vernier calipers are employed to measure brake pad thickness, tire tread depth, and other critical dimensions in the automotive sector.
  - These measurements are vital for safety and optimal vehicle performance.
- **Carpentry and Woodworking:**
  - Vernier calipers can be used to measure the thickness of boards, the diameter of dowels, and other woodworking tasks.
  - They help craftsmen achieve desired dimensions and ensure precise assembly.
- **Scientific Research:**
  - In laboratories, Vernier calipers are utilized to measure the dimensions of objects like biological specimens, crystals, and various samples.
  - Accurate measurements are essential for obtaining reliable scientific data.

## 2. Screw Gauges:

- **Manufacturing and Engineering:**
  - Screw gauges are employed to measure the diameter of cylindrical objects, especially screws, bolts, and nuts.
  - Their precision ensures compatibility and safety in mechanical assemblies.
- **Microelectronics and Micromechanics:**
  - In microfabrication, screw gauges play a crucial role in measuring tiny components used in microelectromechanical systems (MEMS) and nanotechnology.
- **Quality Control:**
  - Screw gauges are extensively used in quality control procedures to ensure that manufactured parts meet specified tolerances.
  - This helps maintain consistency and reliability in products.
- **Biomedical Applications:**
  - Screw gauges are used to measure the diameter of surgical implants and medical instruments.
  - Accurate measurements are vital for ensuring compatibility and safe medical procedures.

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### Conclusion:

Vernier calipers and screw gauges stand as epitomes of precision measurement. Their applications span across diverse sectors, from manufacturing and engineering to research and healthcare. In an era driven by accuracy and technological advancement, these tools continue to serve as cornerstones in achieving meticulous measurements and exacting standards.