

Units And Measurement

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What is Physics?

- Physics is the branch of science that studies the nature and properties of matter and energy.
- It explores fundamental concepts such as motion, force, energy, mass, heat, light, sound, electricity, and the structure of atoms.

Need for Measurement

- To understand and describe physical phenomena accurately, we need to measure physical quantities such as length, mass, time, temperature, electric current, etc.
- A physical quantity is any measurable property of a physical system.
- **It is always expressed as:**

$$\text{Physical Quantity} = \text{Number} + \text{Unit}$$

Example:

- Length = 5 meters = 5×1 meter
- **Note:** A measurement is incomplete without specifying the unit used.

Types of Units

1. **Base (Fundamental) Units:** Units for basic physical quantities (like length, mass, time).
2. **Derived Units:** Units formed by combining base units (like speed = m/s).
3. **Supplementary Units:**
 - **Plane angle** (radian, symbol: rad):
 - **Solid angle** (steradian, symbol: sr):

Note: Both radian and steradian are dimensionless.

The International System of Units (SI)

Earlier Systems

- In the past, scientists used different unit systems:
 - **CGS System:** centimetre (cm), gram (g), second (s)
 - **FPS System (British):** foot (ft), pound (lb), second (s)

- **MKS System:** metre (m), kilogram (kg), second (s)

The SI System

- Today, the globally accepted system of units is the SI (Système Internationale d'Unités).
- It was introduced by the International Bureau of Weights and Measures (BIPM) and updated in 2018 by the General Conference on Weights and Measures.
- The SI system is used in science, engineering, and business worldwide. It follows the decimal system, so conversions are easy.

SI Base Units

- There are **seven** base units in SI. These are:

Quantity	Unit Name	Symbol
 Length	metre	m
 Mass	kilogram	kg
 Time	second	s
 Electric current	ampere	A
 Temperature	kelvin	K
 Amount of substance	mole	mol
 Luminous intensity	candela	cd

Definitions of SI Base Units (in simple terms)

1. **Metre (m):** The distance light travels in vacuum in $1/299,792,458$ seconds.
2. **Kilogram (kg):** Based on a constant of nature called the Planck constant.
3. **Second (s):** Based on the vibrations of a cesium-133 atom.
4. **Ampere (A):** Based on the elementary charge of an electron.
5. **Kelvin (K):** Based on the Boltzmann constant which relates temperature to energy.
6. **Mole (mol):** Contains exactly 6.022×10^{23} particles (Avogadro number).

7. **Candela (cd):** Measures light intensity in a particular direction.

Units for Angle Measurement

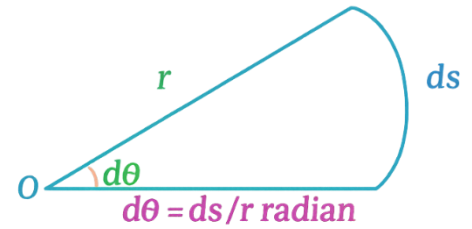
- Besides the seven base units, two other units are important for measuring angles:

A. Plane Angle (θ)

- Defined as:

$$d\theta = \frac{ds}{r}$$

- Unit: **radian (rad)**

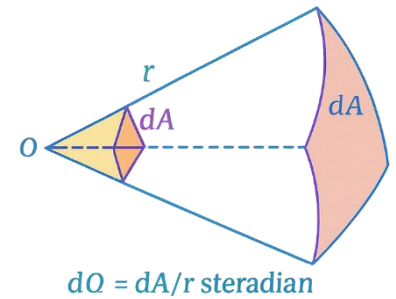


B. (b) Solid Angle (Ω)

- Defined as:

$$d\Omega = \frac{dA}{r^2}$$

- Unit: **steradian (sr)**



- Both are dimensionless quantities.

Some Units Retained for General Use (Though Outside SI)

Name	Symbol	SI Equivalent
Minute	min	60 s
Hour	h	3600 s
Day	d	86400 s
Year	y	3.156×10^7 s
Degree (angle)	°	$1^\circ = (\pi / 180)$ rad
Litre	L	$1 \text{ L} = 10^{-3} \text{ m}^3$
Tonne	t	10^3 kg
Carat	c	200 mg
Bar	bar	10^5 Pa
Curie	Ci	$3.7 \times 10^{10} \text{ s}^{-1}$
Roentgen	R	$2.58 \times 10^{-4} \text{ C/kg}$
Quintal	q	100 kg
Barn	b	10^{-28} m^2
Are	a	10^2 m^2

Hectare	ha	10^4 m^2
Standard Atmospheric Pressure	atm	$1.013 \times 10^5 \text{ Pa}$

Significant Figures

What are Significant Figures?

- Every measurement involves some error. Therefore, we must express the result in a way that reflects the **precision** of measurement.
- **Significant figures** include:
 - All digits known with certainty
 - The **first uncertain** (or doubtful) digit

Examples:

- If the time period of a pendulum is **1.62 s**, then:
 - 1 and 6 are certain
 - 2 is uncertain
 - So, **3 significant figures**
- If length is **287.5 cm**:
 - 2, 8, 7 are certain
 - 5 is uncertain
 - So, **4 significant figures**
- Reporting more digits than necessary is misleading and incorrect.

Rules for Counting Significant Figures

1. All non-zero digits are significant.
2. Zeros between non-zero digits are significant.
 - **Example:** 2.308 has 4 significant figures
3. For numbers less than 1, zeros after the decimal and before the first non-zero digit are not significant.
 - **Example:** 0.002308 → has 4 significant figures (2308)
4. Trailing zeros without a decimal point are not significant.
 - **Example:** 12300 → 3 significant figures

5. Trailing zeros in a number with a decimal point are significant.
 - **Example:** 3.500 → 4 significant figures
 - **Example:** 0.06900 → 4 significant figures
6. Change in unit does not change the number of significant figures.
 - **Example:** 2.308 cm = 0.02308 m = 23080 μm → 4 significant figures

Scientific Notation and Significant Figures

- To avoid confusion about significant zeros, we use **scientific notation**:
 - A number is written as: $a \times 10^b$
 - Here, **a** is a number between 1 and 10, and **b** is any integer.

Example:

- 4.700 m can be written as:
- 4.700×10^2 cm
- 4.700×10^3 mm
- 4.700×10^{-3} km

In scientific notation, **all digits in 'a' are significant**, so **4.700** has **4 significant figures**, regardless of the power of 10.

Order of Magnitude

- Rough estimate of a quantity's size using powers of 10.
- 10^b is the order of magnitude of 10^b

Examples:

- Diameter of Earth = 1.28×10^7 m ⇒ Order: 10^7
- Diameter of Hydrogen atom = 1.06×10^{-10} m ⇒ Order: 10^{-10}
- Earth is 17 orders of magnitude larger than a hydrogen atom.

Rules for Arithmetic Operations with Significant Figures

When doing calculations with measurements, the result should reflect the precision of the original values.

A. Multiplication & Division

- The result should have the same number of significant figures as the value with the least significant figures.



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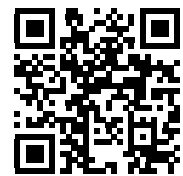


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