Part – 1: Physical Quantities, Units, Systems of Units and SI System

Learning Objectives

After studying this part, you will be able to:

- Understand the need for measurements.
- Define physical quantities.
- Differentiate between fundamental and derived quantities.
- Explain the concept of units.
- Describe different systems of units.
- Understand the SI system of units and its advantages.

1. Introduction

Physics is an experimental science. Every physical law is based on **observations** and **measurements**. To compare physical quantities accurately, a **standard unit** is essential.

For example:

- Length of a table = **2 m**
- Mass of a book = **0.75 kg**
- Time taken = **15 s**

Without units, these numerical values have no physical meaning.

2. Measurement

Definition

Measurement is the process of comparing an unknown physical quantity with a standard quantity of the same kind, called a **unit**.

For example,

If the length of a rod is **5 m**, it means the rod is five times the standard unit of length (metre).

3. Physical Quantity

Definition

A **physical quantity** is any quantity that can be **measured** and expressed by a **numerical value** along with a **unit**.

A physical quantity consists of two parts:
- Numerical value (Magnitude)
- Unit

Example:

$$\boxed{25\ m}$$

where,

- **25** = Magnitude
- **m** = Unit

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4. Types of Physical Quantities

Physical quantities are classified into two categories:

(A) Fundamental (Base) Quantities

These are independent quantities and cannot be expressed in terms of other physical quantities.

Examples:

- Length
- Mass
- Time
- Electric current
- Temperature
- Amount of substance
- Luminous intensity

(B) Derived Quantities

These quantities are obtained by combining fundamental quantities mathematically.

Examples:

- Area
- Volume
- Velocity
- Acceleration

- Force
- Momentum
- Pressure
- Energy
- Power
- Density

Example:

Velocity

$$\boxed{Velocity = \frac{distance}{time}}$$

Acceleration

$$\boxed{a = \frac{\Delta V}{\Delta t}}$$

Force

$$\boxed{F = ma}$$

---

5. Unit

Definition

A **unit** is a fixed and internationally accepted standard used to measure a physical quantity.

Example:

- metre (m)
- kilogram (kg)
- second (s)

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6. Characteristics of a Good Unit

An ideal unit should:

- Be well defined.
- Be invariable with time and place.
- Be easily reproducible.
- Be internationally accepted.
- Be convenient in size.

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7. Need for Standard Units

Without standard units:

- Measurements cannot be compared.
- Scientific communication becomes difficult.
- Experimental results become unreliable.
- International trade and technology suffer.

Therefore, scientists adopted an internationally accepted system called the **SI System**.

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8. Systems of Units

Several systems have been used historically.

System	Length	Mass	Time
CGS	centimetre (cm)	gram (g)	second (s)
FPS	foot (ft)	pound (lb)	second (s)
MKS	metre (m)	kilogram (kg)	second (s)
SI	metre (m)	kilogram (kg)	second (s)

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9. SI System of Units

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

It was adopted internationally in **1960** and is based on **seven fundamental units**.

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10. Seven SI Base Quantities

Physical Quantity	SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

Important for NEET/JEE: Learn this table exactly as given.

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11. Advantages of SI System

- Internationally accepted.
- Decimal-based system.
- Easy conversion between units.
- Uniform in all branches of science.
- Suitable for scientific research and engineering.

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12. Common Examples of Derived Units

Quantity	SI Unit
Area	m^2
Volume	m^3
Velocity	m/s
Acceleration	m/s^2
Force	newton (N)
Pressure	pascal (Pa)
Work	joule (J)
Power	watt (W)
Energy	joule (J)
Density	kg/m^3

---

13. Important Points for Board & Competitive Exams

- Every physical quantity must have a **magnitude** and a **unit**.
- SI has **7 base quantities**.
- Most quantities used in Physics are **derived quantities**.
- The **SI system** is used worldwide in science and engineering.

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14. Common Mistakes

□ Writing **Kg** instead of **kg**.

✔ Correct symbol: **kg**

□ Writing **Sec** for second.

✔ Correct symbol: **s**

□ Writing **M** for metre.

✔ Correct symbol: **m**

□ Confusing **mass** with **weight**.

✔ Mass is a base quantity; weight is a derived quantity.

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15. Quick Revision

- Measurement = Comparison with a standard unit.
- Physical Quantity = Magnitude + Unit.
- Two types of quantities:
  - Fundamental
  - Derived
- SI System = International System of Units.
- Number of SI base quantities = **7**.
- SI base units:
  - metre (m)
  - kilogram (kg)
  - second (s)
  - ampere (A)
  - kelvin (K)
  - mole (mol)
  - candela (cd)

Part – 2: SI Base Units, SI Prefixes and Scientific Notation

Learning Objectives

After studying this part, you will be able to:

- Understand the seven SI base units in detail.
- Learn the modern (2019) definitions of SI units.
- Use SI prefixes correctly.
- Express very large and very small numbers in scientific notation.
- Perform unit conversions using powers of ten.

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1. SI Base Units

The **International System of Units (SI)** consists of **seven base units**, from which all other units are derived.

Base Quantity	SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

---

2. Modern Definitions of SI Base Units (2019 Revision)

In 2019, the SI system was redefined based on **fundamental physical constants**, making measurements more accurate and universal.

(A) Metre (m)

Definition:

One metre is the distance travelled by light in vacuum during a time interval of

1299 792 458 second\boxed{\frac{1}{299\,792\,458}\ \text{second}}2997924581 second

---

(B) Kilogram (kg)

The kilogram is defined by fixing the numerical value of the **Planck constant (h)**.

Important Note: Earlier, the kilogram was defined using a platinum-iridium cylinder kept in France. This definition is no longer used.

(C) Second (s)

One second is defined using the radiation emitted during the transition between two hyperfine energy levels of the **Cesium-133 atom**.

(D) Ampere (A)

Defined by fixing the numerical value of the **elementary charge (e)**.

(E) Kelvin (K)

Defined using the **Boltzmann constant (k_B)**.

(F) Mole (mol)

One mole contains exactly

$$\boxed{6.02214076 \times 10^{23}}$$

specified elementary entities.

This number is called the **Avogadro constant**.

(G) Candela (cd)

Defined using the luminous efficacy of monochromatic radiation of frequency

$$\boxed{540 \times 10^{12} Hz}$$

---

3. SI Prefixes

SI prefixes are used to express very large or very small quantities conveniently.

(A) Multiples of Units

Prefix	Symbol	Factor

deca	da	10^1
hecto	h	10^2
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

(B) Submultiples of Units

Prefix	Symbol	Factor
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

4. Examples of SI Prefixes

Quantity	Standard Form
1 km	$10^3 m$
1 mm	$10^{-3} m$
1 µm	$10^{-6} m$
1 nm	$10^{-9} m$
1 pm	10^{-12}

5. Scientific Notation

Scientific notation expresses numbers in the form

$$a \times 10^n$$

where:

- $1 \leq a < 10$
- n is an integer.

Examples

$$2500 = 2.5 \times 10^3$$

$$0.000125 = 1.25 \times 10^{-4}$$

$$0.00000014 = 1.4 \times 10^{-7}$$

6. Rules for Scientific Notation

Large Numbers

Move the decimal point to the **left**.

Example:

$$4500000 = 4.5 \times 10^6$$

Small Numbers

Move the decimal point to the **right**.

Example:

$$0.0000028 = 2.8 \times 10^{-6}$$

---

7. Unit Conversion Using Powers of Ten

Example 1

Convert **5 km** into metres.

$$5 \times 10^3 = 5000\ m$$

Example 2

Convert **7 mm** into metres.

$$7 \times 10^{-3} = 0.007m$$

Example 3

Convert **12 µm** into metres.

$$12 \times 10^{-6} = 1.2 \times 10^{-5}m$$

8. Importance of Scientific Notation

Scientific notation is useful for expressing:

- Distance between galaxies.
- Radius of atoms.

- Mass of an electron.
- Speed of light.
- Avogadro number.

It makes calculations simpler and reduces errors.

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9. Important Constants

Quantity	Value
Speed of light (c)	$3.0 \times 10^8 m/s$
Planck constant (h)	$6.626 \times 10^{-34} Js$
Avogadro constant (N_A)	$6.022 \times 10^{23} mol^{-1}$
Elementary charge (e)	$1.602 \times 10^{-19} C$

---

10. Common Mistakes

☐ Writing **KM** instead of **km**

✔ Correct: **km**

☐ Writing **M** for milli

✔ **m = milli**, **M = mega**

☐ Confusing **μ (micro)** with **m (milli)**

- milli = 10^{-3}
- micro = 10^{-6}

---

11. Exam-Oriented Tips

- Memorize all **seven SI base units**.
- Learn SI prefixes from **tera (101210^{12}1012)** to **femto (10−1510^{-15}10−15)**.
- Practice converting numbers into scientific notation.
- Revise powers of ten regularly.

---

12. Quick Revision

- SI has **7 base units**.
- Scientific notation: $a \times 10^n, where\ 1 \leq a < 10$
- kilo = 10^3
- mega = 10^6
- giga = 10^9

- milli = 10^{-3}
- micro = 10^{-6}
- nano = 10^{-9}
- pico = 10^{-12}
- femto = 10^{-15}

Part – 3: Dimensions, Dimensional Formula and Dimensional Analysis

Learning Objectives

After studying this part, you will be able to:

- Define dimensions and dimensional formula.
- Write dimensional formulae of important physical quantities.
- Understand the principle of dimensional homogeneity.
- Apply dimensional analysis to derive equations and check their correctness.
- Know the limitations of dimensional analysis.

---

1. Dimensions

Definition

The **dimensions** of a physical quantity are the powers of the fundamental quantities required to express that physical quantity.

The seven SI base quantities are:

- Length (L)
- Mass (M)
- Time (T)
- Electric Current (I)
- Thermodynamic Temperature (Θ)
- Amount of Substance (N)
- Luminous Intensity (J)

Note: In Class XI Mechanics, we mainly use **M, L, and T**.

---

2. Dimensional Formula

A **dimensional formula** represents a physical quantity in terms of the powers of the base quantities.

General form:

$$[M^a L^b T^c]$$

where a, b, and c are called **dimensional exponents**.

---

3. Dimensional Equation

A dimensional equation expresses the equality of dimensions on both sides of a physical equation.

Example:

For force,

$$F = ma$$

Dimensions of mass:

$$[M]$$

Dimensions of acceleration:

$$[LT^{-2}]$$

Therefore,

$$[F] = [MLT^{-2}]$$

---

4. Dimensional Formulae of Important Physical Quantities

Physical Quantity	Formula	Dimensional Formula
Length	—	[L]
Mass	—	[M]
Time	—	[T]
Area	$l \times b$	$[L^2]$
Volume	$l \times b \times h$	$[L^3]$
Velocity	s/t	$[LT^{-1}]$
Acceleration	v/t	$[LT^{-2}]$
Momentum	mv	$[MLT^{-1}]$
Force	ma	$[MLT^{-2}]$
Work/Energy	Fs	$[ML^2T^{-2}]$
Power	W/t	$[ML^2T^{-3}]$
Pressure	F/A	$[ML^{-1}T^{-2}]$
Density	m/V	$[ML^{-3}]$
Frequency	$1/T$	$[T^{-1}]$

---

5. Derived Examples

Note: Know the formula of given physical quantity or their SI units, then convert its SI units in basic quantities' unit and then write the dimensional formula in power of M, L, T, A, K whichever may the case be.

(A) Velocity

$$velocity = \frac{displacement}{time} = \frac{L}{T}$$

$$[v] = [LT^{-1}]$$

(B) Acceleration

$$acceleration = \frac{velovity}{time} = \frac{v}{T} = \frac{LT^{-1}}{T}$$

$$[a] = [LT^{-2}]$$

(C) Force

$$F = ma = MLT^{-2}$$

$$[F] = [MLT^{-2}]$$

(D) Work

$$W = Fs = MLT^{-2} \times L$$

$$[W] = [ML^2T^{-2}]$$

(E) Power

$$P = \frac{W}{t} = \frac{ML^2T^{-2}}{T}$$

$$[P] = [ML^2T^{-3}]$$

6. Principle of Dimensional Homogeneity

Statement

In any correct physical equation, the dimensions of all terms must be the same. Any equation may be separated by +, >, <, + or - , will have same dimensions both sides.
Example:

$$s = ut + \frac{at^2}{2}$$

So, either $s = ut, or\ s = at^2\ or\ ut = at^2$ (1/2 is dimensionless.)
Dimensions of ut:

$$[LT^{-1}] \times [T] = [L]$$

Dimensions of at^2:

$$[LT^{-2}][T^2] = [L]$$

Dimensions of s = L
Hence,

$$LHS = RHS$$

The equation is dimensionally correct.

7. Applications of Dimensional Analysis

(A) To Check the Correctness of an Equation

Example:

$$v = u + at$$

Dimensions:

- $v = [LT^{-1}]$
- $u = [LT^{-1}]$
- $at = [LT^{-2}][T] = [LT^{-1}]$

Hence, the equation is dimensionally correct.

(B) To Derive a Formula**

Suppose,

$$T \propto l^a g^b$$

Using dimensions, the powers a and b can be determined.

This method is frequently used in mechanics.

(C) To Find Dimensions of Constants

If an equation contains a constant, dimensional analysis helps determine its dimensions.

(D) To Convert Units

Dimensions help convert one system of units into another.

---

8. Limitations of Dimensional Analysis

Dimensional analysis **cannot**:

1. Determine numerical constants such as 2, π, 1/2 etc.
2. Distinguish between quantities having the same dimensions (e.g., work and torque).
3. Derive equations involving trigonometric, exponential or logarithmic functions.
4. Indicate whether additional dimensionless terms are present.

---

9. Important Dimensionless Quantities

The following have **no dimensions**:

- Angle (radian)
- Solid angle (steradian)
- Strain
- Relative density
- Refractive index
- Coefficient of friction
- Specific gravity

---

10. Frequently Used Dimensional Formulae

Quantity	Dimensional Formula
Velocity	$[LT^{-1}]$
Acceleration	$[LT^{-2}]$
Momentum	$[MLT^{-1}]$
Force	$[MLT^{-2}]$
Energy	$[ML^2T^{-2}]$
Power	$[ML^2T^{-3}]$
Pressure	$[ML^{-1}T^{-2}]$
Density	$[ML^{-3}]$
Frequency	$[T^{-1}]$

---

11. Common Mistakes

□ Confusing **velocity** and **acceleration** dimensions.

✔ Velocity → $[LT^{-1}]$

✔ Acceleration → $[LT^{-2}]$

□ Confusing **work** and **power**.

✔ Work → $[ML^2T^{-2}]$

✔ Power → $[ML^2T^{-3}]$

□ Forgetting that **frequency** has dimensions of $[T^{-1}]$

---

12. Exam-Oriented Tips

- Memorize the dimensional formulae of all common physical quantities.
- Always check **dimensional homogeneity** before accepting an equation.
- In derivations using dimensional analysis, write each step clearly.
- Remember the limitations; they are often asked in CBSE theory questions.

13. Quick Revision

- Dimensions represent powers of base quantities.
- General dimensional formula: $[M^a L^b T^c]$
- Principle of dimensional homogeneity: **Dimensions on both sides of an equation must be identical.**
- Force → $[MLT^{-2}]$
- Energy → $[ML^2T^{-2}]$
- Power → $[ML^2T^{-3}]$
- Pressure → $[ML^{-1}T^{-2}]$
- Density → $[ML^{-3}]$
- Frequency → $[T^{-1}]$

Part – 4: Applications of Dimensional Analysis and Unit Conversion

Learning Objectives

After studying this part, you will be able to:

- Apply the method of dimensions to derive simple formulae.
- Check the dimensional correctness of equations.
- Convert units from one system to another.
- Solve dimensional analysis problems commonly asked in Board, NEET, and JEE examinations.

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1. Method of Dimensions

Dimensional analysis can be used to determine the relationship between physical quantities.

Steps

1. Assume the required quantity depends on certain variables.
2. Write the relation using unknown powers.
3. Replace each quantity by its dimensional formula.
4. Equate the powers of fundamental quantities (M, L, T).
5. Solve the equations to find the unknown powers.

---

2. Example 1: Time Period of a Simple Pendulum

Suppose the time period T depends on:

- Length l
- Acceleration due to gravity g

Assume,
$T \propto l^a g^b$
or
$T = k l^a g^b$
where k is a dimensionless constant.

Step 1: Write Dimensions of both sides

$[T] = [L]^a [LT^{-2}]^b = [L]^{a+b} [T]^{-2b}$

Step 2: Compare Powers of L and T both sides,

For L:

$$a + b = 0$$

For T:

$$-2b = 1 \; or, b = -1/2$$

And,

$$a = -1/2$$

Hence,

T$\propto l^{1/2} g^{-1/2}\ or\ T \propto \sqrt{l/g}$

The exact expression is:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Note: The factor 2π cannot be obtained by dimensional analysis.

---

3. Example 2: Speed of a Wave on a Stretched String

Assume,

$$v \propto T^a \mu^b$$

where:

- T = Tension
- μ = Linear mass density

Using dimensional analysis,

$$\boxed{v = \sqrt{\frac{T}{\mu}}}$$

This is an important result used in **Chapter 14: Waves**.

---

4. Checking Dimensional Correctness of Equations

Example:

Verify:

$$v = u + at$$

Dimensions of each side:

- LHS: $v = [LT^{-1}]$
- RHS: $u = [LT^{-1}]\ and\ at\ = [LT^{-2}][T] = [LT^{-1}]$

All terms of both sides have the same dimensions.

Result: The equation is dimensionally correct.

---

5. Conversion of Units

If

$$n_1 u_1 = n_2 u_2$$

Then

$$n_2 = \left(\frac{n_1 u_1}{u_2}\right)$$

where:

- n = Numerical value
- u = Unit

---

6. Conversion Using Dimensions

If the dimensional formula of a quantity is

$$[M^a L^b T^c]$$

then, during unit conversion,

$$n_2 = n_1 \left(\frac{M_1}{M_2}\right)^a \left(\frac{L_1}{L_2}\right)^b \left(\frac{T_1}{T_2}\right)^c$$

This formula is especially useful for **JEE Advanced** problems.

---

7. Solved Example: Unit Conversion

Convert 72 km/h into m/s.

Solution
(72×1000) / 3600 = 20

Answer: $\boxed{20\ m/s}$

---

8. Solved Example

Convert 5 m/s into km/h.

Solution
5 × (18/5)5 = 10

Answer: $\boxed{10\ km/h}$

---

9. Limitations of Dimensional Analysis

Dimensional analysis **cannot**:

- Find numerical constants such as 2, π, or 1/2.
- Distinguish between physical quantities having the same dimensions (e.g., work and torque).
- Derive equations containing trigonometric, logarithmic, or exponential functions.
- Verify equations involving sums of different dimensionless constants.

---

10. Common Errors

□ Assuming that a dimensionally correct equation is always physically correct.

✔ Dimensional correctness is **necessary**, but **not sufficient**, for physical correctness.

□ Forgetting to compare the dimensions of **every term** in an equation.

□ Ignoring dimensionless constants while using dimensional analysis.

---

11. Exam-Oriented Tips

- Always write the assumed relation first.
- Use only **M, L, and T** unless other base quantities are involved.
- Compare exponents carefully while solving.
- Memorize the conversion:
  - **1 m/s = 3.6 km/h**
  - **1 km/h = 5/18 m/s**

---

12. Quick Revision

- Dimensional analysis helps derive simple formulae.
- It checks the dimensional correctness of equations.
- It is useful in unit conversion.
- It cannot determine numerical constants.
- A dimensionally correct equation may still be physically incorrect.

Part – 5: Errors in Measurement, Accuracy, Precision and Propagation of Errors

Learning Objectives

After studying this part, you will be able to:

- Understand the concept of measurement errors.
- Differentiate between accuracy and precision.
- Calculate absolute, relative, and percentage errors.
- Apply rules for the propagation (combination) of errors.
- Solve numerical problems based on errors.

---

1. Errors in Measurement

Definition

An **error** is the difference between the **measured value** and the **true (accepted) value** of a physical quantity.

$$\boxed{Error = Measured\ Value - True\ Value}$$

Since the true value is usually unknown, repeated observations are used to estimate the best value.

---

2. Types of Errors

(A) Systematic Errors

These errors occur due to a definite cause and affect all measurements in the same way.

Causes

- Instrumental errors
- Calibration errors
- Zero error
- Environmental effects
- Personal bias

Examples

- A ruler with incorrect markings.
- A stopwatch running slow.
- Incorrect zero reading of a vernier caliper.

(B) Random Errors

These occur due to unpredictable variations during measurement.

Causes

- Human reaction time
- Small environmental fluctuations
- Observer estimation

Random errors can be reduced by taking a large number of readings and calculating the mean.

(C) Gross Errors

These arise due to mistakes made by the observer.

Examples:

- Wrong reading
- Wrong calculation
- Incorrect unit conversion
- Recording the wrong value

These errors should be identified and eliminated.

---

3. Accuracy and Precision

Accuracy

Accuracy is the closeness of a measured value to the true value.

A measurement is accurate if it is very close to the accepted value.

Precision

Precision refers to the closeness of repeated measurements to one another.

A set of measurements may be highly precise but not accurate if all readings are consistently shifted due to a systematic error.

Difference Between Accuracy and Precision

Accuracy	Precision
Close to the true value	Close to each other
Depends mainly on systematic errors	Depends mainly on random errors
Indicates correctness	Indicates reproducibility

4. Mean (Average) Value

If a quantity is measured n times,

$$x_1, x_2, x_3, -----, x_n$$

then the mean value is

$$\boxed{\bar{x} = \frac{x_1 + x_2 + x_3 \pm ---- x_n}{n}}$$

The mean value is taken as the best estimate of the true value.

5. Absolute Error

The absolute error in one observation is

$$\boxed{\Delta x = |x_i - \bar{x}|}$$

where:

- x_i = individual observation
- $\bar{x}$ = mean value

The **mean absolute error** is

$$\boxed{\Delta x_{mean} = \frac{\Delta x_1 + \Delta x_2 + \Delta x_3 + ------- -\Delta x_n}{n}}$$

6. Relative Error

Relative error is the ratio of the mean absolute error to the mean value.

$$\boxed{Relative\ Error = \frac{\Delta x_{mean}}{\bar{x}}}$$

It has **no unit**.

7. Percentage Error

Percentage error is obtained by multiplying the relative error by 100.

$$\boxed{\%Error = Relative\ Error\ \times 100}$$

---

8. Solved Example

The measured values of length are: 20.2 cm, 20.4 cm, 20.3 cm

Find the mean value.

Solution

$$\bar{x} = \frac{20.2 + 20.4 + 20.3}{3} = 20.3$$

Answer: $\boxed{20.3\ cm}$

---

9. Solved Example

Measured value = 100 cm, Absolute error = 0.5 cm, Find the percentage error.

Solution

$$\%Error = Relative\ Error \times 100 = \frac{\Delta x_{mean}}{\bar{x}} = \frac{0.5}{100} \times 100 = 0.5$$

Answer: $\boxed{0.5\%}$

---

10. Propagation (Combination) of Errors

Rule 1: Addition and Subtraction

If Z = A ± B, then

$$\boxed{\Delta Z = \Delta A \pm \Delta B}$$

Absolute errors are added.

Rule 2: Multiplication and Division

If Z = AB / C, then

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B} + \frac{\Delta C}{C}$$

Relative errors are added.

Rule 3: Power Rule If Z = A^n, then

$$\frac{\Delta Z}{Z} = n\frac{\Delta A}{A}$$

Rule 4: General Expression

If

$$Z = \frac{A^m B^n}{C^p}$$

Then

$$\boxed{\frac{\Delta Z}{Z} = m\frac{\Delta A}{A} + n\frac{\Delta B}{B} + p\frac{\Delta \mathrm{C}}{C}}$$

---

11. Significant Figures (Introduction)

Significant figures are the digits in a measured quantity that are known with certainty plus the first uncertain digit.

Examples

- 12.5 → 3 significant figures
- 0.00560 → 3 significant figures
- 2.000 → 4 significant figures

Note: Detailed rules for significant figures will be covered in **Part–6**.

---

12. Common Mistakes

□ Confusing **accuracy** with **precision**.

✔ Accuracy → Closeness to the true value.

✔ Precision → Closeness among repeated measurements.

□ Adding percentage errors directly in addition/subtraction.

✔ For addition/subtraction, **absolute errors** are added.

□ Forgetting that relative error is **dimensionless**.

---

13. Exam-Oriented Tips

- Learn all four propagation rules by heart.
- Use the mean value for repeated measurements.
- Practice numerical problems on percentage error.
- Be careful with units while calculating errors.

Part – 6: Significant Figures, Rounding Off and Scientific Calculations

Learning Objectives

After studying this part, you will be able to:

- Understand the concept of significant figures.
- Count significant figures correctly.
- Apply rounding-off rules.
- Perform calculations using significant figures.
- Avoid common mistakes in measurements and calculations.

---

1. Significant Figures

Definition

Significant figures are the meaningful digits in a measured quantity. They include:

- All **certain digits**, and
- The **first uncertain (estimated) digit**.

The number of significant figures indicates the precision of a measurement.

---

2. Rules for Counting Significant Figures

Rule 1: All Non-Zero Digits are Significant

Examples:

- 25.4 → **3 significant figures**
- 683 → **3 significant figures**
- 7.845 → **4 significant figures**

Rule 2: Zeros Between Non-Zero Digits are Significant

Examples:

- 1005 → **4 significant figures**
- 2.003 → **4 significant figures**
- 5.0406 → **5 significant figures**

Rule 3: Leading Zeros after decimal and before non-zero digit are Not Significant

Examples:

- 0.0052 → **2 significant figures**
- 0.00081 → **2 significant figures**
- 0.000406 → **3 significant figures**

Rule 4: Trailing Zeros After non-zero digit in a Decimal are Significant

Examples:

- 2.500 → **4 significant figures**
- 5.60 → **3 significant figures**
- 0.0800 → **3 significant figures**

Rule 5: Trailing Zeros in Whole Numbers (Without Decimal Point) are Usually Not Significant

Examples:

- 2500 → Usually **2 significant figures**
- 2500. → **4 significant figures**
- 2.500×10^3 → **4 significant figures**

---

3. Counting Significant Figures – Examples

Number	Significant Figures
15.2	3
0.0045	2
0.06020	4
5000	Usually 1
5000.	4
6.020×10^{23}	4

---

4. Rounding Off Numbers

Rule 1

If the digit to be dropped is **less than 5**, leave the previous digit unchanged.

Example:

- 8.243 → **8.24** (to 3 significant figures)

Rule 2

If the digit to be dropped is **greater than 5**, increase the previous digit by 1.

Example:

- 7.286 → **7.29**

Rule 3

If the digit to be dropped is **exactly 5**, and it is followed by non-zero digits, then preceding digit is raised by 1 whether preceding digit is even or odd..

Example:

- 4.1552 → **4.16**

Rule 4 (NCERT Convention)

If the digit to be dropped is **exactly 5** and is **not followed by any non-zero digit**:

- If the previous digit is **even**, leave it unchanged.
- If the previous digit is **odd**, increase it by 1.

Examples:

- 6.25 → **6.2** (2 is even)
- 7.35 → **7.4** (3 is odd)

---

5. Significant Figures in Calculations

(A) Multiplication and Division

The final answer should have the **same number of significant figures as the quantity with the least significant figures**.

Example

$$2.54 \times 3.1 = 7.874$$

Since **3.1** has **2 significant figures**, the answer is: $\boxed{7.9}$

(B) Addition and Subtraction

The result should have the **same number of decimal places** as the quantity with the fewest decimal places.

Example

$$12.36 + 4.2 = 16.56$$

Correct answer: = $\boxed{16.6}$

---

6. Scientific Notation and Significant Figures

Scientific notation makes the number of significant figures clear.

Examples:

- 3.20×10^4 → **3 significant figures**
- 6.022×10^{23} → **4 significant figures**
- 9.8×10^2 → **2 significant figures**

---

7. Solved Examples

Example 1

How many significant figures are there in **0.004080**?

Ignoring leading zeros:

Digits = **4, 0, 8, 0**

Hence, $\boxed{4\ significant\ figures}$

Example 2

Round **56.7843** to **4 significant figures**.

The fifth digit is **4**, so no increase is needed.

Answer: $\boxed{56.78}$

Example 3

Round **0.009986** to **3 significant figures**.

Answer: $\boxed{0.00999}$

---

8. Scientific Measurements

Every measured quantity should include:

- Numerical value
- Unit
- Appropriate significant figures

Example: $\boxed{12.50\ cm}$

This is more precise than **12.5 cm**.

---

9. Common Mistakes

☐ Counting leading zeros as significant.

✔ Leading zeros are **never significant**.

☐ Ignoring trailing zeros after the decimal point.

✔ They are **always significant**.

☐ Using too many digits in the final answer.

✔ Always follow the significant figure rules.

---

10. Exam-Oriented Tips (★★★★★)

- Memorize all five rules for significant figures.
- Use the correct rounding-off convention.
- In multiplication/division, use the **least significant figures**.
- In addition/subtraction, use the **least number of decimal places**.
- Write answers with proper units.

---

11. Chapter-1 Summary

Key Concepts Covered

- Physical quantities and units
- SI system of units
- SI base quantities and units
- SI prefixes
- Scientific notation
- Dimensions and dimensional formulae
- Dimensional analysis
- Unit conversion
- Errors in measurement
- Accuracy and precision
- Absolute, relative, and percentage errors
- Propagation of errors
- Significant figures
- Rounding off rules

---

12. Last-Minute Revision Sheet

SI Base Units

- 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)

Important Formulae

- Velocity:

$$v = \frac{s}{t}$$

- Acceleration:

$$a = \frac{\Delta v}{\Delta t}$$

- Force:

$$F = ma$$

- Relative Error:

$$\frac{\Delta x_{mean}}{\bar{x}}$$

- Percentage Error:

$$Relative\ error\ \times 100$$

Important Dimensions

Quantity	Dimensional Formula
Velocity	$[LT^{-1}]$
Acceleration	$[LT^{-2}]$
Momentum	$[MLT^{-1}]$
Force	$[MLT^{-2}]$
Energy	$[ML^{2}T^{-2}]$
Power	$[ML^{2}T^{-3}]$
Pressure	$[ML^{-1}T^{-2}]$
Density	$[ML^{-3}]$
Frequency	$[T^{-1}]$

Chapter-1 Mind Map

```
                  Units & Measurements
                           │
     ┌─────────────────────┼──────────────────────┐
     │                     │                      │
 Physical Quantities   SI Units          Scientific Notation
     │                     │
Dimensions -------- Unit Conversion
     │
Dimensional Analysis
     │
Errors in Measurement
     │
Accuracy & Precision
     │
Absolute Error
Relative Error
Percentage Error
     │
Propagation of Errors
     │
Significant Figures
     │
Rounding Off Rules
```

Practice Numerical

1. Convert **54 km h^{-1}** into m s^{-1}.
2. Convert **15 m s^{-1}** into km h^{-1}.
3. Calculate the percentage error if the measured value is **100 cm** and the absolute error is **2 cm**.
4. Find the dimensions of work.
5. Find the dimensions of power.
6. Calculate the mean of **15.2, 15.4, 15.3, 15.5 cm**.
7. Count the significant figures in **0.02040**.
8. Find the percentage error in the area if the error in length is **3%**.
9. Find the percentage error in the volume of a cube if the error in its side is **1%**.
10. Check whether $s = ut + \left(\frac{1}{2}\right) at^2$ is dimensionally correct.

One-Day Revision Strategy

First 30 Minutes

- SI Base Units
- SI Prefixes
- Scientific Notation

Next 30 Minutes

- Dimensions
- Dimensional Formulae
- Unit Conversion

Next 30 Minutes

- Errors
- Percentage Error
- Propagation of Errors

Last 30 Minutes

- Significant Figures
- Rounding Off
- MCQs
- Numericals