

L.1 MEASUREMENT IN SCIENCE AND TECHNOLOGY

1. Introduction to Measurement

Measurement is the process of comparing an unknown quantity with a known fixed quantity of the same kind, called a unit. It is one of the most fundamental activities of science and forms the backbone of all scientific and technological progress. Without accurate measurement, it would be impossible to describe, compare, or reproduce observations.

Lord Kelvin famously remarked that when we can measure what we are speaking about and express it in numbers, we know something about it — but when we cannot measure it, our knowledge remains meagre and unsatisfactory. This highlights how measurement converts qualitative knowledge into precise, quantitative knowledge.

Importance of Measurement in Daily Life

- Cooking and food preparation — measuring ingredients accurately.
- Shopping — measuring weight, length, or volume of goods purchased.
- Construction and engineering — measuring dimensions for buildings, roads, and machines.
- Medicine — measuring dosage, body temperature, blood pressure, etc.
- Sports — measuring distance, time, and speed of athletes.
- Scientific research — every experimental observation depends on precise measurement.

2. Historical Development of Measurement Systems

In ancient times, people used parts of the human body and everyday objects as units of measurement because these were readily available, even though they lacked accuracy and uniformity.

Traditional (Non-Standard) Units

Traditional Unit	Description
Cubit	Length from elbow to the tip of the middle finger
Hand span	Distance from the tip of the thumb to the tip of the little finger with the hand stretched
Foot	Length of a human foot
Angul (Digit)	Width of a finger, used in ancient India
Paces/Steps	Used to measure distance while walking
Heartbeat	Used as a rough unit of time

Limitations of Body-Based Units

- They vary from person to person, so results were not the same everywhere.
- They lacked precision needed for scientific and trade purposes.
- There was no way to reproduce them exactly at a different time or place.
- Different regions/countries developed their own systems (FPS, CGS, MKS), creating confusion in trade and science.

To remove this confusion, scientists across the world agreed upon a single, universally acceptable system of units — the International System of Units (SI), adopted in 1960 by the General Conference on Weights and Measures (CGPM).

3. Physical Quantities and Units

A physical quantity is any quantity that can be measured, such as length, mass, time, temperature, etc. Every measurement consists of two parts: a numerical value (magnitude) and a unit.

Example: The length of a table is 2 metres. Here, 2 is the numerical value and metre is the unit.

Fundamental (Base) and Derived Quantities

Fundamental quantities are those which do not depend on any other quantity for their measurement, e.g., length, mass, time, temperature, electric current, luminous intensity, and amount of substance. Derived quantities are obtained by combining two or more fundamental quantities, e.g., area, volume, speed, density, and force.

4. The International System of Units (SI)

The SI system consists of seven base (fundamental) units from which all other (derived) units are obtained. It is accepted worldwide because it is coherent, decimal-based, and easily scalable using prefixes.

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

Some Common Derived Units

Derived Quantity	SI Unit	Symbol
Area	square metre	m ²

Derived Quantity	SI Unit	Symbol
Volume	cubic metre	m ³
Speed/Velocity	metre per second	m/s
Density	kilogram per cubic metre	kg/m ³
Force	newton	N (kg·m/s ²)
Pressure	pascal	Pa (N/m ²)
Energy/Work	joule	J (N·m)

Advantages of the SI System

- It is a coherent system — all units are logically inter-related.
- It is a decimal system, making conversion between units easy (multiples of 10).
- It is universally accepted, removing confusion in international trade and scientific communication.
- It is scalable — very large and very small quantities can be expressed conveniently using prefixes.

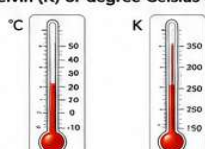
5. SI Prefixes

SI prefixes are used with base units to express very large or very small quantities conveniently, without writing too many zeros.

Prefix	Symbol	Multiplying Factor
Tera	T	10 ¹²
Giga	G	10 ⁹
Mega	M	10 ⁶
Kilo	k	10 ³
Hector	h	10 ²
Deca	da	10 ¹
—	—	10 ⁰ (base unit)
Deci	d	10 ⁻¹
Centi	C	10 ⁻²
Milli	M	10 ⁻³
Micro	M	10 ⁻⁶
Nano	N	10 ⁻⁹
Pico	P	10 ⁻¹²
Femto	F	10 ⁻¹⁵

Example: 1 kilometre (km) = 10^3 m = 1000 m; 1 nanometre (nm) = 10^{-9} m; 1 microgram (μ g) = 10^{-6} g

MEASUREMENTS

Length of a table is measured in metres (m).  1.25 m	Mass of an object is measured in kilograms (kg).  2.000 kg	Time is measured in seconds (s).  00:30.25	Temperature is measured in kelvin (K) or degree Celsius ($^{\circ}$C).  $^{\circ}$C K
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1. PHYSICAL QUANTITIES

Physical quantity = Numerical value $\times$ Unit

Example:

If the length of a rod is 5 metres:

- Numerical value = 5
- Unit = metre (m)
- Physical quantity = 5 m



Physical quantities are broadly classified into:

A. Fundamental quantities:

These are independent quantities, such as:

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



B. Derived quantities:

These are obtained from fundamental quantities.

Examples:

• Area = Length $\times$ Length

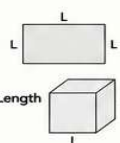
• Volume = Length $\times$ Length $\times$ Length

• Speed = Distance / Time

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

• Density = Mass / Volume

Density = $\frac{m}{V}$



2. UNITS OF MEASUREMENT

A unit is a fixed standard used for measuring a physical quantity.

The internationally accepted system of units is the International System of Units (SI).

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

3. IMPORTANCE OF MEASUREMENT



Provides accurate scientific information.



Helps in comparing different quantities.



Makes scientific results reproducible.



Essential in engineering and construction.



Helps in manufacturing and quality control.



Supports technological development.



Allows scientists to record and communicate observations precisely.

4. MEASURING INSTRUMENTS

Different physical quantities require different instruments.

Quantity	Measuring Instrument
Length	Ruler, measuring tape, vernier calipers
Mass	Beam balance, electronic balance
Time	Clock, stopwatch
Temperature	Thermometer
Electric current	Ammeter
Voltage	Voltmeter
Pressure	Barometer/manometer

5. ACCURACY AND PRECISION

Accuracy refers to how close a measured value is to the true or accepted value.

Precision refers to how close repeated measurements are to one another.

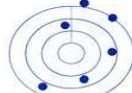
A measurement can be precise but not accurate, or accurate but not highly precise.



High accuracy
High precision
(Ideal)



Low accuracy
High precision



Low accuracy
Low precision

6. ERRORS IN MEASUREMENT

No measurement is perfectly free from error. Errors may arise because of:

- Faulty instruments
- Improper use of instruments
- Environmental conditions
- Human observation
- Incorrect reading of scales

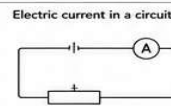


To obtain reliable results:

Measurements should preferably be repeated and appropriate instruments should be used.



MORE EXAMPLES OF MEASUREMENTS IN DAILY LIFE



6. Rules for Using SI Units

1. Symbols of units are written in lower case unless derived from a person's name (e.g., 'm' for metre, but 'N' for newton, named after Newton).
2. Unit symbols do not take a plural 's' (write 10 kg, not 10 kgs).
3. No full stop is placed after a unit symbol (except at the end of a sentence).
4. There should be a space between the numerical value and the unit symbol (e.g., 5 m, not 5m).
5. Only one prefix should be used with a unit at a time (e.g., use nm, not m μ m).
6. Symbols must not be mixed with the full names of units (write 'newton metre' or 'N m', not 'newton m').

7. Instruments Used for Measurement

Measurement of Length

- Metre scale — used for lengths ranging from 1 mm to about 1 m.
- Vernier callipers — used for more precise measurement (up to 0.01 cm); consists of a main scale and a sliding vernier scale.
- Screw gauge (micrometer) — used for very precise, small measurements such as the diameter of a wire (up to 0.001 cm).
- Measuring tape — used for measuring longer lengths such as the dimensions of a room or field.

Measurement of Mass and Time

- Physical balance / electronic balance — used to measure mass.
- Stopwatch / clock — used to measure time intervals.

8. Characteristics of a Unit

to be useful, a unit must be:

- a) Relevant
- b) Convenient
- c) Well Defined

9. Significant Figures

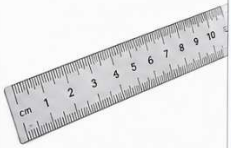
Significant figures in a measured value are the digits that carry meaningful information about the precision of the measurement. They include all certain digits plus one estimated (uncertain) digit.

Rules for Counting Significant Figures

- All non-zero digits are significant (e.g., 234 has 3 significant figures).
- Zeros between two non-zero digits are significant (e.g., 205 has 3 significant figures).

- Leading zeros (to the left of the first non-zero digit) are not significant (e.g., 0.0025 has 2 significant figures).
- Trailing zeros after a decimal point are significant (e.g., 2.500 has 4 significant figures).
- Trailing zeros in a whole number without a decimal point may or may not be significant, depending on context (e.g., 100 could have 1, 2, or 3 significant figures).

TYPES OF MEASURING INSTRUMENTS AND THEIR USES

1 MEASURING TAPE  It is used to determine the length of a physical object. It is lightweight and portable, making it easy to transport from one location to another.	2 RULER  It is used in various scenarios, such as drawing lines and measuring distances. It is beneficial to the children's school projects.	3 PRESSURE GAUGE  The pressure gauge is mainly used daily to measure air and water pressure. Hypertension patients use it as a medical device to check their blood pressure.	4 THERMOMETER  This device is used to determine the temperature of the body and its surroundings. The digital thermometer offers a faster display than traditional thermometers.	5 CLOCK  It is used to measure time and assist you in organising it while performing several jobs.
6 SPEEDOMETER  This device is typically found inside automobile vehicles. A speedometer is used to measure the speed of moving things. It is also utilised for some scientific applications outside of cars.	7 CHRONOMETER  A chronometer is used to measure the precise time at a known fixed place, particularly for navigation.	8 MEASURING CUPS  Measuring cups are mainly used for measuring food items, and bakers and cooks use them.	9 GLUCOMETER  A glucometer is a specific medical instrument used to measure blood sugar levels. Diabetic patients use it.	10 COMPASS  The architect applies this tool to draw circles. It is also employed to compute the separation between two points on a map. Even the shipbuilding and construction industries can use it.

10. Summary

- Measurement = comparing an unknown quantity with a known standard (unit).
- Ancient units were body-based and non-uniform; SI system (1960) solved this problem.
- SI has 7 base units: metre, kilogram, second, ampere, kelvin, mole, candela.
- Derived units are combinations of base units (e.g., speed = m/s).
- SI prefixes help express very large/small values conveniently.
- Vernier callipers and screw gauge give more precise length measurements than a simple scale.
- Significant figures indicate the precision/reliability of a measured value.

Multiple Choice Questions (MCQs)

1. Which of the following is NOT an SI base unit?
- (a) Metre
- (b) Kilogram
- (c) Newton
- (d) Kelvin

2. The SI unit of electric current is:

- (a) Volt
- (b) Ampere
- (c) Ohm
- (d) Watt

3. 1 kilometre is equal to:

- (a) 10 m
- (b) 100 m
- (c) 1000 m
- (d) 10000 m

4. Which instrument is used to measure very small lengths such as the diameter of a wire?

- (a) Metre scale
- (b) Measuring tape
- (c) Screw gauge
- (d) Stopwatch

5. The prefix 'micro' represents a multiplying factor of:

- (a) 10^{-3}
- (b) 10^{-6}
- (c) 10^{-9}
- (d) 10^{-12}

6. Which of these is a derived unit?

- (a) Metre
- (b) Second
- (c) Newton
- (d) Kelvin

7. The number of significant figures in 0.0025 is:

- (a) 4
- (b) 3
- (c) 2
- (d) 1

8. SI system was internationally adopted in the year:

- (a) 1945
- (b) 1960
- (c) 1975
- (d) 1990

9. 1 nanometre is equal to:

- (a) 10^{-6} m
- (b) 10^{-9} m
- (c) 10^{-12} m
- (d) 10^{-3} m

10. Which ancient unit was based on the length from the elbow to the tip of the middle finger?

- (a) Hand span
- (b) Cubit
- (c) Foot
- (d) Angul

11. The SI unit of amount of substance is:

- (a) Mole
- (b) Candela
- (c) Kelvin
- (d) Ampere

12. Vernier callipers can measure length precisely up to:

- (a) 1 cm
- (b) 0.1 cm
- (c) 0.01 cm
- (d) 0.5 cm

13. Which of the following is a fundamental quantity?

- (a) Speed
- (b) Force
- (c) Mass
- (d) Density

14. 10 μ g is equal to:

- (a) 10^{-3} g
- (b) 10^{-5} g
- (c) 10^{-1} g
- (d) 10 g

15. The correct way of writing a measured value is:

- (a) 5kg
- (b) 5 kg.
- (c) 5 kg
- (d) 5 Kgs

Answer Key

1-(c) 2-(b) 3-(c) 4-(c) 5-(b) 6-(c) 7-(c) 8-(b) 9-(b) 10-(b) 11-(a) 12-(c) 13-(c) 14-(b) 15-(c)

Very Short Answer Questions (1 Mark)

Q1. What is measurement?

Ans. Measurement is the process of comparing an unknown quantity with a known, fixed quantity of the same kind (called a unit).

Q2. What are the two essential parts of any measurement?

Ans. A numerical value (magnitude) and a unit.

Q3. Name the international system of units adopted for scientific measurement.

Ans. The International System of Units (SI).

Q4. Give one example each of a fundamental and a derived quantity.

Ans. Fundamental quantity: mass; Derived quantity: speed (or area, volume, force).

Q5. What is the SI unit of temperature?

Ans. Kelvin (K).

Q6. Name an instrument used to measure the diameter of a thin wire.

Ans. Screw gauge (micrometer).

Q7. What does the prefix 'kilo' mean?

Ans. It means a multiplying factor of 10^3 , i.e., 1000 times the base unit.

Q8. Why can't parts of the human body be used for accurate measurement?

Ans. Because they vary from person to person and cannot be reproduced exactly, making measurements inconsistent and imprecise.

Short & Long Answer Questions

Intext Questions 1.1

1. Define the term measurement by giving two examples.

Measurement is the process of comparing an unknown physical quantity with a known standard quantity of the same kind.

Examples:

1. The length of a table is measured as **2 metres (2 m)**.
2. The mass of an object is measured as **5 kilograms (5 kg)**.

2. What is a unit?

A **unit** is a fixed and standard quantity used for measuring a physical quantity.

Examples:

- Metre (m) is a unit of length.
- Kilogram (kg) is a unit of mass.
- Second (s) is a unit of time.

3. List the essential characteristics of a unit.

An ideal unit should have the following characteristics:

1. **It should be well-defined** — its value should be clear and definite.
2. **It should be invariable** — it should not change with time or place.
3. **It should be easily reproducible** — it should be possible to reproduce the unit whenever required.
4. **It should be easily accessible** — it should be convenient to use.
5. **It should be internationally accepted** — the unit should be commonly accepted and understood.
6. **It should be of convenient size** — it should neither be too large nor too small for ordinary measurements.

Intext Questions 1.2

Q1) Name the smallest unit of length during the Chandragupta Maurya period?

The smallest unit of length during the Chandragupta Maurya period was anu.

Q2) List the parts of human body which can be used for measurements.

Parts of the human body used for measurements include:

- Finger
- Hand
- Foot
- Arm
- Cubit (forearm)

Q3) Why cannot the parts of human body be used for accurate measurement?

Human body parts cannot be used for accurate measurement because their sizes differ from person to person.

Q4) In which period was ‘gaz’ introduced as a unit to measure length?

‘Gaz’ was introduced during the medieval period as a unit for measuring length.

INTEXT QUESTIONS 1.3

Q1. Differentiate between base units and derived units.

Difference between base units and derived units:

- a) **Base units:** Units of fundamental physical quantities that are independent of other units. Example: metre (m), kilogram (kg), second (s).
- b) **Derived units:** Units obtained by combining base units. Example: metre per second (m/s), newton (N), pascal (Pa).

Q2. What is the difference between mass and amount of a substance?

Difference between mass and amount of a substance:

- a) **Mass** is the quantity of matter present in an object. Its SI unit is **kilogram (kg)**.
- b) **Amount of substance** measures the number of particles (atoms, molecules, etc.) in a substance. Its SI unit is **mole (mol)**.

Q3. Derive the unit of Pressure. (Pressure = Force/Area)

Unit of Pressure: Pressure = Force / Area

Unit of force = **newton (N)**

Unit of area = **m²**

Therefore, **Unit of pressure** = N/m² = **pascal (Pa)**

Q4. Which term of measurement is commonly used by the announcer of your favourite radio programme?

The term of measurement commonly used by a radio programme announcer is **time**, usually in **hours, minutes and seconds**.

Q5. Observe a bulb/tube light at your home for the unit measurement written on it. From Table 1.3 find out the physical quantity it measure?

A bulb/tube light commonly has a measurement such as **watt (W)** written on it. Watt measures **power**.

6. Veena, Mohindar and Alam went to market. Veena brought milk with a litre measure, Mohindar brought ribbon by a measuring mark on the table and Alam brought vegetables using stones. Which of them did not use the appropriate measurement while purchasing goods? Explain while given the names of right measurement.

Alam did not use the appropriate measurement while purchasing vegetables because stones do not provide a standard or accurate measurement.

- **Veena:** Used **litre (L)** to measure milk — appropriate.
- **Mohindar:** Used a **standard length measurement** to measure ribbon — appropriate.
- **Alam:** Should have used **kilogram (kg)** or **gram (g)** to measure vegetables, rather than stones.

INTEXT QUESTIONS 1.4

Rewrite the following measurements of length using suitable SI prefixes.

- (i) effective radius of a proton; $1.2 \times 10^{-15} \text{ m}$ _____

$$1.2 \times 10^{-15} \text{ m} = \boxed{1.2 \text{ fm}} \quad (\text{femto} = 10^{-15})$$

- (ii) radius of human red blood cell; $3.7 \times 10^{-6} \text{ m}$ _____

$$3.7 \times 10^{-6} \text{ m} = \boxed{3.7 \text{ }\mu\text{m}} \quad (\text{micro} = 10^{-6})$$

- (iii) radius of our galaxy; $6 \times 10^{19} \text{ m}$ _____

$$6 \times 10^{19} \text{ m} = \boxed{60 \text{ Em}} \quad (\text{exa} = 10^{18})$$

TERMINAL EXERCISE

1. Which of the following is not an SI unit?

- A. Metre
- B. Pound ☒
- C. Kilogram
- D. Second

Answer: B. Pound

2. If the mass of a solution is $10\ \mu\text{g}$, it is the same as:

- A. $10^{-6}\ \text{g}$
- B. $10^{-12}\ \text{g}$
- C. $10^{-9}\ \text{g}$
- D. $10^{-3}\ \text{g}$

Answer: A. $10^{-6}\ \text{g}$ ☒

Note: Strictly, $10\ \mu\text{g} = 10^{-5}\ \text{g}$. So the options in the question appear to have a printing error. If your textbook expects one of the given options, it likely intends $1\ \mu\text{g} = 10^{-6}\ \text{g}$.

3. True or False

- (i) SI units are arbitrary. — F ☒
- (ii) $1\ \text{mm}^2 = 10^{-3}\ \text{m}^2$ — F ☒
- (iii) $10^{-15}\ \text{g} = 1\ \text{mpg}$ — F ☒
- (iv) SI unit for pressure is Pascal. — T ☒

4. Represent using suitable SI prefixes

- (i) $2 \times 10^{-8}\ \text{s} = \boxed{20\ \text{ns}}$
- (ii) $1.54 \times 10^{-10}\ \text{m} = \boxed{154\ \text{pm}}$
- (iii) $1.98 \times 10^{-6}\ \text{mol} = \boxed{1.98\ \mu\text{mol}}$
- (iv) $200\ 000\ \text{kg} = \boxed{200\ \text{Mg}}$

5. Give the SI units used while buying :.

SI units used while buying

- A. Silk ribbon: metre (m)
- B. Milk: litre (L)
- C. Potatoes: kilogram (kg)

6. Give the common unit to measure our body temperature and write its SI unit

The common unit used to measure body temperature is **degree Celsius ($^{\circ}\text{C}$)**.

Its SI unit is **kelvin (K)**.

7. What are the advantages of SI units?

Advantages of SI units

- They are **internationally accepted**.
- They provide **standard and uniform measurements**.
- They make **conversion between units easy**.
- They reduce **confusion and errors**.
- They make **scientific calculations easier**.

MEER SIR ACADEMY