UNIT 1

MEASUREMENT

Learning Objectives

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After the completion of this lesson, students will be able to:

- understand fundamental quantities and units.
- explain the system of units and measurements.
- analyse the different system of units.
- know about temperature, amount of substance, electric current and luminous intensity.
- explore the knowledge of accuracy in measurements.
- differentiate plane angle and solid angle.
- solve problems related to measurement.

Introduction

Physics is the study of nature and natural phenomena. Physics is considered as the base of all science subjects. It is based on experimental observations. The principles and observations allow us to develop a deeper understanding of nature. Scientific theories are valid, only if they are confirmed through various experiments. Theories in physics use many physical quantities that have to be measured.

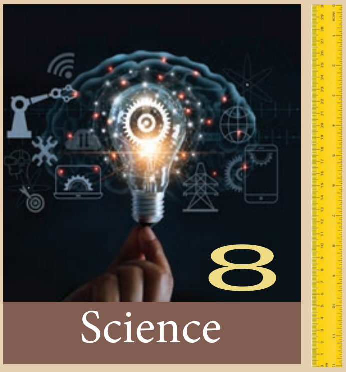
Measurement is the base of all scientific studies and experimentations. It plays a vital role in our daily life. It is the process of finding an unknown physical quantity by using a standard quantity. In this lesson, we will study about measurement in detail. We will also study about accuracy and precision, approximation and rounding off.

1.1 Unit Systems

We need three things for a perfect measurement. They are: an instrument, a standard quantity and an acceptable unit.

Activity 1

Measure the length and breadth of your science book using a ruler (scale) and compare your value with those of your friends.



Let us say that the length of the book be 30 cm. Here, the length is the physical quantity, ruler is the instrument, 30 is the magnitude and 'cm' is the unit. This process is called measurement.

In the above activity the values of all the students will not be same. Similarly, people in various parts of the world are using different systems of units for measurement. Some common systems of units are as follows.

1. FPS System (Foot for length, Pound for mass and Second for time)

2. CGS System (Centimetre for length, Gram for mass and Second for time)
3. MKS System (Meter for length, Kilogram for mass and Second for time)

DO YOU KNOW?

The 'CGS', 'MKS' and SI units are metric systems of units and 'FPS' is not a metric system. It is a British system of units.

1.2 International System of Units

In earlier days, scientists performed their experiments and recorded their results in their own system. Due to lack of communication, they couldn't organise experimental results of others. So, they planned to follow a uniform system for taking the measurements.

As you studied in the lower classes, in 1960, in the 11th General Conference on Weights and Measures at Paris in France, scientists recognised the need of using standard units for physical quantities. That was called as 'International System of Units' and is popularly known as SI System (abbreviated from the French name 'Systeme International'). Scientists, chose seven physical quantities as 'Base Quantities' and defined a 'Standard Unit' to measure each one. They are known as Base Units or Fundamental Units (Table 1.1)

Table: 1.1 Base Quantities and Units

Quantity	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

You have already studied about length, mass and time in your lower classes. Now you are going to study about the other base quantities such as temperature, current, amount of substance and luminous intensity.

DO YOU KNOW?

In December, 1998, the National Aeronautics and Space Administration (NASA), USA, launched the Mars Climate Orbiter to collect data about the Martian climate. Nine months later, on September 23, 1999, the Orbiter disappeared while approaching Mars at an unexpectedly low altitude. An investigation revealed that the orbital calculations were incorrect due to an error in the transfer of information between the spacecraft's team in Colorado and the mission navigation team in California. One team was using the English FPS system of units for calculation, while the other team was using the MKS system of units. This misunderstanding caused a loss of 125 million dollars approximately.

1.2.1 Temperature

Identify, which of the following objects are hot and which of them are cold?

Figure 1.1 Hot and Cold Objects

We see a number of objects in our daily life. Some of them are cold and some of them are hot.

Some times we may say that two objects are equally hot or cold. But, there will be some difference in their hotness or coldness. How do you decide, which is hotter and which is colder? You need a reliable quantity to decide the degree of hotness or coldness of an object. That quantity is 'temperature'.

Temperature is a physical quantity that expresses the degree of hotness or coldness of a substance. Heat energy given to a substance will increase its temperature. Heat energy removed from a substance will lower its temperature.

Temperature is defined as a measure of the average kinetic energy of the particles in a system. The SI unit of temperature is kelvin. Thermometers are used to measure the temperature directly. Usually, thermometers are calibrated with some standard scales. Celsius, Fahrenheit, Kelvin are the most commonly used scales to measure temperature.

Activity 2

From the news paper or television, collect the highest and lowest temperature experienced in your nearest town or city for a week and record the values in a tabular column. Does this data remain same throughout the year?

1.2.2 Electric Current (I)

Flow of electric charges, in a particular direction is known as 'electric current'. The magnitude of electric current is the amount of electric charges flowing through a conductor in one second.

$$\text{Electric current} = \frac{\text{Amount of electric charge}}{\text{time}}$$

$$I = \frac{Q}{t}$$

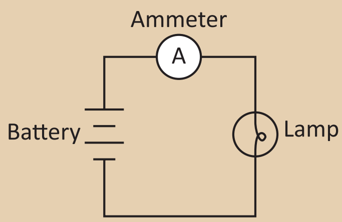
Electric charge is measured in coulumb. The SI unit of electric current is *ampere* and it is denoted as A.

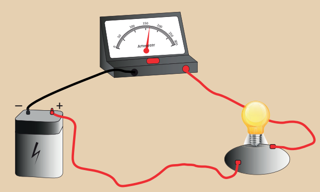
If one coulomb of charge is flowing through a conductor in one second, then, the amount of current flowing is said to be one ampere. Ammeter is the device used to measure 'electric current' (Fig 1.2).

Figure 1.2 Ammeter

Activity 3

Connect a battery, an ammeter and a lamp in series as shown in the figure. Note the ammeter reading. It is the amount of current flowing in the circuit.





Problem 1

If 2 coulomb of charge flows through a circuit for 10 seconds, calculate the current.

Solution

Charge (Q) = 2 C; Time (t) = 10 s

$$I = \frac{Q}{t} = \frac{2}{10} = 0.2 \text{ A}$$

1.2.3 Amount of Substance

Amount of substance is a measure of the number of entities (particles) present in a substance. The entity may be an atom, molecule, ion, electron or proton etc.

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Generally, the amount of substance is directly proportional to the number of atoms or molecules.

Can you count the number of copper coins in the picture? We can count them easily. But, can you count the number of copper atoms in a coin? It is very difficult to count the number of atoms because they are not visible. The number of atoms or molecules in a substance is measured in mole. It is a SI uinit.

Figure 1.3 Copper coins

Mole is defined as the amount of substance, which contains 6.023×10^{23} entities. It is denoted as 'mol'.

More to Know

The number 6.023×10^{23} is also known as Avogadro Number.

1.2.4 Luminous Intensity

Figure 1.4 Photometer in day to day life

Have you seen these scenes on the television? What is the umpire doing? He is checking the intensity of light by using an instrument. The measure of the power of the emitted light, by a light source in a particular direction, per unit solid angle is called as luminous intensity. The SI unit of luminous intensity is candela and is denoted as 'cd'.

The light emitted from a common wax candle is approximately equal to one candela. Luminous intensity is measured by 'photometer' (Luminous Intensity Meter) which gives the luminous intensity in terms of candela directly.

Figure 1.5 Photometer

Info bits

Luminous flux or Luminous power is the measure of the perceived power of light. Its SI unit is 'lumen'.

One lumen is defined as the luminous flux of the light produced by the light source that emits one candela of luminous intensity over a solid angle of one steradian.

Apart from the seven fundamental units, we have two more units known as derived units, we will study about them now.

1.2.5 Plane angle

Plane angle is the angle made at the intersection of two straight lines or intersection of two planes. The SI unit of plane angle is 'radian' and is denoted as 'rad'.

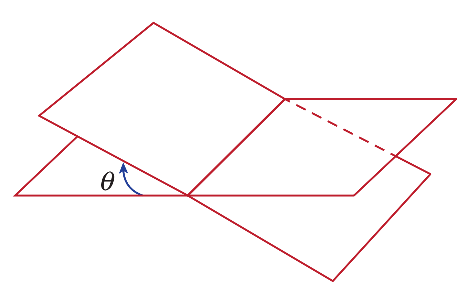

Figure 1.6 Plane angle

Radian is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle (Fig 1.7).

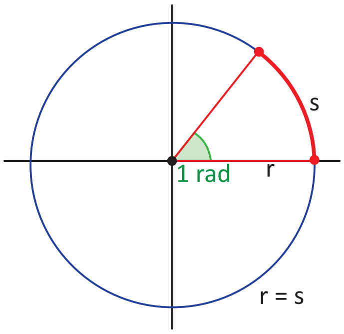

Figure 1.7 Radian

π radian = 180°

$1 \text{ radian} = \frac{180°}{\pi}$

Problem 2

Convert 60° into radian.

Solution

We know that,

$1° = \frac{\pi}{180}$

$60° = \frac{\pi}{\cancel{180}_3} \times \cancel{60} = \frac{\pi}{3}$ radian

Problem 3

Convert $\frac{\pi}{4}$ into degrees.

Solution

We know that,

π radian = 180°

$\frac{\pi}{4} \text{ radian} = \frac{180}{4} = 45°$

1.2.6 Solid angle

Solid angle is the angle formed by three or more planes intersecting at a common point. It can also be defined as 'angle formed at the vertex of the cone'. The SI unit of solid angle is 'steradian' and is denoted as 'sr'.

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Steradian is the solid angle at the centre of a sphere subtended by a portion whose surface area is equal to the square of the radius of the sphere.

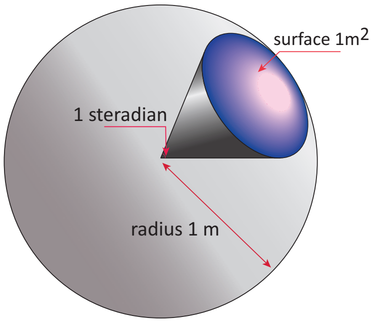

Figure 1.8 Steradian

DO YOU KNOW?

Until 1995, plane angle and solid angle were classified under supplementary quantities. In 1995, they were shifted to derived quantities.

Table 1.2 Difference between plane angle and solid angle

Plane Angle	Solid Angle
It is the angle made at the point of intersection of two lines or planes.	It is the angle by the intersection of three or more planes at a common point.
It is two dimensional.	It is three dimensional.
Its unit is radian.	Its unit is steradian.

1.3 Clocks

Clocks are used to measure time intervals. So many clocks are being used from the ancient time. Scientists have modified the mechanism of the clocks everytime to obtain accuracy.

1.3.1 Types of clock based on display

There are two types of clocks based on display. They are:

1. Analog clocks
2. Digital clocks

1. Analog clocks

Analog clocks look like a classic clock. It has three hands to show the time.

Hours hand

It is short and thick. It shows 'hour'.

Minutes hand

It is long and thin. It shows 'minute'.

Seconds hand

It is long and very thin. It shows 'second'. It makes one rotation in one minute and 60 rotations in one hour.

Analog clocks can be driven either mechanically or electronically.

Figure 1.9 Analog clock

Activity 4

Make a model of an analog clock using card board.

2. Digital clocks

A **digital clock** displays the time directly. It shows the time in numerals or other symbols. It may have 12 hours or 24 hours display. Recent clocks are showing date, day, month, year, temperature etc. Digital clocks are often called as electronic clocks.

Figure 1.10 Digital clock

Activity 5

Make a model of a digital clock using match sticks on a card board, with date and time.

1.3.2 Types of clock based on working mechanism

There are different types of clocks based on working mechanism. They are:

1. Quartz clock
2. Atomic clock

1. Quartz clock

These clocks are activated by 'electronic oscillations', which are controlled by a 'quartz crystal'. The frequency of a vibrating crystal is very precise. So, quartz clock is more accurate than mechanical clock. These clocks have an accuracy of one second in every 10^9 seconds.

Figure 1.11 Quartz clock

2. Atomic clock

These clocks make use of periodic vibrations occurring within the atom. These clocks have an accuracy of one second in every 10^{13} seconds. Atomic clocks are used in Global Positioning System (GPS), Global Navigation Satellite System (GLONASS) and International Time Distribution Services.

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Figure 1.12 Atomic clock

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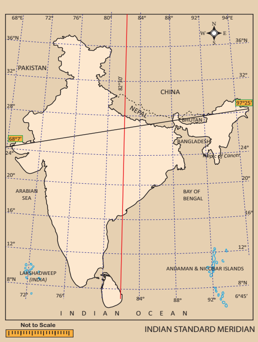
Activity 6

You may have heard about the 'Sun Dial'. Construct a sundial of your own and read out the values from morning to evening. Compare your values with modern clocks.

Greenwich Mean Time (GMT) is the mean solar time at the Royal Observatory, located at Greenwich in London. It is measured at the longitude of zero degree. The Earth is divided into 24 zones, each of a width of 15 degree longitude. These regions are called as 'Time Zones'. Time difference between two adjacent time zones is 1 hour.

Indian Standard Time (IST)



The location of Mirzapur in Uttar Pradesh is taken as the reference longitude of the Indian Standard Time. It is located at 82.5 degree longitude.

IST = GMT + 5:30 hours

1.4 Accuracy in Measurements

We have seen that measurement is the base of all experiments in science and technology. The value of every measurement contains some uncertainty. These uncertainties are called as 'errors'. Error is defined as the difference between the real value and the observed value.

While taking measurements, errors should be minimum and the measured values should be precise and accurate. Both precision and accuracy may seen to be same. But, they are not similar.

Look at the arrows shot by three persons (Fig. 1.13). In the first image all the arrows are hit at the centre. In the second image, all the arrows are hit at the same place but not at the centre. It shows that first person is precise and accurate. The second person is precious but not accurate. But, the third person is neither precise nor accurate.

Accuracy is the closeness of a measured value to the actual value or true value. Precision is the closeness of two or more measurements to each other. While making measurements, accuracy is always desired. The measured value should be close to the true value.

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1.5 Approximation

While we prepare a dish, we choose the ingredients approximately. We do not measure them accurately always. Similarly, it is not possible to set the exact value while taking measurements. Sometimes we take the approximate value. Approximation is the process of finding a number, which is

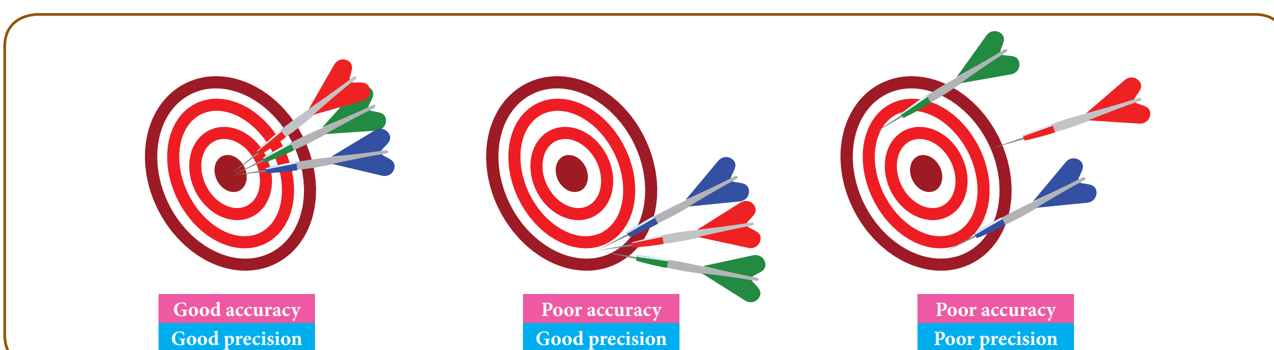

Figure 1.13 Accuracy and Precision

acceptably close to the exact value of the measurement of a physical quantity. It is an estimation of a number obtained by rounding off a number to its nearest place value.

When the data are inadequate, physicists are in need of an approximation to find the solution for problems. Approximations are usually based on certain assumptions having a scientific background and they can be modified whenever accuracy is needed.

Activity 7

Calculate the approximate 'heart beat' of a man in a day (Hint: Take number of heart beats per minute as 75, approximately).

1.6 Rounding off

Calculators are widely used in day to day life to do the calculations. The result given by a calculator has too many digits. Hence, the result containing more digits should be rounded off. The technique of rounding off is used in many areas of physics.

1.6.1 Rules for rounding off

- Decide which is the last digit to keep.
- Leave it the same, if the next digit is less than 5.
- Increase it by one, if the next digit is 5 or greater than 5.

Problem 4

Round off the number 1.864 to two decimal places.

Solution

We need to round off the number to two decimal places. So, the last digit to be kept is 6. Since the next digit is less than 5, we can retain 6 as it is. So the answer is 1.86.

Problem 5

Round off the number 1.868 to two decimal places.

Solution

We need to round off the number to two decimal places. So, the last digit to be kept is 6. Since the next digit is more than 5, we should increase the second digit by one. So, the answer is 1.87.

Points to Remember

- The need of standard units for physical quantities was recognised in the 11^{th} General Conference on Weights and Measures in 1960.
- Length, mass, time, temperature, electric current, amount of substance and luminous intensity are called base quantities.
- Temperature is the measure of hotness or coldness of a substance. Its SI unit is *kelvin*.
- Electric charge is measured in coulumb and electric currect is measured in ampere.
- The SI unit of amount of substance is mole.
- Luminous intensity is measured in candela.
- Quartz clock uses the 'electronic oscillations' controlled by a 'quartz crystal'.
- Atomic clock uses the 'periodic vibrations occurring within the atom'.
- Accuracy is the closeness of a measured value to the actual value.
- Precision is the closeness of two or more measurements to each other.
- Approximation is the process of finding the solution by means of 'estimation'.

A-Z GLOSSARY

Amount of substance	Measure of number of entities (particles) present in a substance.
Calibration	Process of configuring an instrument in a particular range.
Electric current	Flow of electric charges (electrons) in a unit time.
Electronic Oscillation	Oscillations produced by an electronic circuit.
Luminous Intensity	Amount of light emitted by a light source in a particular direction per unit time.
Plane angle	Angle made at the point of intersection of two lines or planes.
Quartz Crystal	Crystal formed by Silicon and Oxygen (SiO_2).
Solid angle	Angle made at the point of intersection of three or more planes.

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TEXTBOOK EXERCISES

I. Choose the best answer.

1. Which one the following systems of unit is the British System of unit?
   a) CGS b) MKS c) FPS d) SI
2. Electric current is a ______quantity
   a) base b) supplementary
   c) derived d) professional
3. SI unit of temperature is ______
   a) celsius b) fahrenheit
   c) kelvin d) ampere
4. Luminous intensity is the intensity of ______
   a) laser light b) UV light
   c) visible light d) IR light
5. Closeness of two or more measured values is called as ______
   a) accuracy b) precision
   c) error d) approximation
6. Which one of the following statement is wrong?
   a) Approximation gives accurate value.
   b) Approximation simplifies the calculation.
   c) Approximation is very useful when little information is available.
   d) Approximation gives the nearest value only.

II. Fill in the blanks.

1. The solid angle is measured in _______.
2. The coldness or hotness of a substance is expressed by _______.
3. _______ is used to measure electric current.
4. One mole of a substance contains _______ atoms or molecules.
5. The uncertainty in measurement is called as _______.
6. The closeness of the measured value to the original value is _______.
7. The intersection of two straight lines gives us _______.

III. State true or false. If false, correct the statement.

1. Temperature is a measure of total kinetic energy of the particles in a system.
2. If one coulomb of charge is flowing in one minute, it is called 'ampere'.
3. Amount of substance gives the number of particles present in a substance.
4. Intensity of light coming from a candle is approximately equal to one 'candela'.
5. Quartz clocks are used in GPS devices.

6. Angle formed at the top of a cone is an example for 'plane angle'.
7. The number 4.582 can be rounded off as 4.58.

IV. Match the following.

Temperature	Closeness to the actual value
Plane angle	Measure of hotness or coldness
Solid angle	Closeness to two or more measurements
Accuracy	Angle formed by the intersection of three or more planes
Precision	Angle formed by the intersection of two planes

V. Consider the statements given below and choose the correct option.

1. **Assertion:** The SI system of units is the suitable system for measurements.
   Reason: The SI unit of temperature is kelvin.
2. **Assertion:** Electric current, amount of substance, luminous intensity are the fundamental physical quantities.
   Reason: They are independent of each other.
3. **Assertion:** Radian is the unit of solid angle.
   Reason: One radian is the angle subtended at the centre of a circle by an arc of length equal to its radius.

   a. Both assertion and reason are true and reason is the correct explanation of the assertion.
   b. Both assertion and reason are true but reason is not the correct explanation of the assertion.
   c. Assertion is true, but reason is false.
   d. Both assertion and reason are false.

VI. Answer very briefly.

1. How many base quantities are included in SI system?
2. Give the name of the instrument used for the measurement of temperature.
3. What is the SI unit of luminous intensity?
4. What type of oscillations are used in atomic clocks?
5. Mention the types of clocks based on their display.
6. How many times will the 'minute hand' rotate in one hour?
7. How many hours are there in a minute?

VII. Answer briefly.

1. What is measurement?
2. Name the three scales of temperature.
3. Define - Ampere.
4. What is electric current?
5. What do you mean by luminous intensity?
6. Define - Mole.
7. What are the differences between plane angle and solid angle?

VIII. Answer in detail.

1. List out the base quantities with their units.
2. Write a short note on different types of clocks.

IX. Higher Order Thinking Question.

1. Your friend was absent to school yesterday. You are enquiring about his absence. He told that he had fever and it was measured to be 100°C. Is it possible to have 100°C fever? If he is wrong, try to make him understand.

REFERENCE BOOK

1. Units and Measurements – John Richards, S. Chand publishing, Ram nagar, New Delhi.

INTERNET RESOURCES

1. http://www.npl.co.uk/reference/measurement-units/
2. http://www.splung.com/content/sid/1/page/units

Concept Map

Measurement

- **System of Units**
  - FPS System
  - CGS System
  - MKS System
  - SI Units
- **Fundamental Quantities**
  - Temperature
  - Electric current
  - Amount of substance
  - Luminous intensity
- **Types of Clock**
  - Based on display
    - Analog
    - Digital
  - Based on working mechanism
    - Quartz clock
    - Atomic clock
- **Measured values**
  - Accuracy in Measurement
  - Approximation in Measurement
  - Round off in Measurement

ICT CORNER

Measurement

This activity enables the students to learn about the various types of Time keeping devices

Steps

- Open the Browser and type URL link given below (or) Scan the QR Code.
- Click and select the "History of time keeping devices"
- Options will be given. Select any content (Eg) Digital clock
- It gives clear understanding of the "History of time keeping devices"

Web link: https://playablo.com/Blog/5-fun-activities-to-teach-temperature-hot-and-cold-to-preschoolers/ https://en.wikipedia.org/wiki/History_of_timekeeping_devices

(or) scan the QR Code

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*Pictures are indicative only