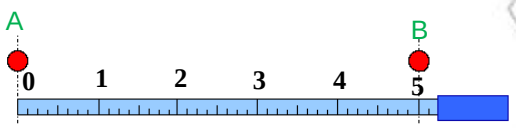
UNIT 1

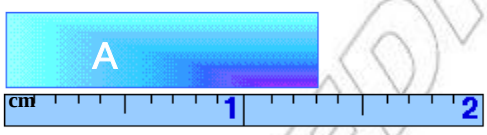
PHYSICS AND MEASUREMENT

Unit outcomes: **After completing this unit you should be able to:**

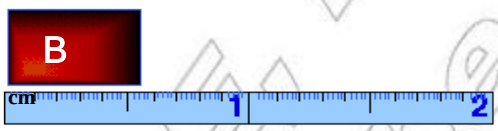
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **search for patterns or relationships in experimental data.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**



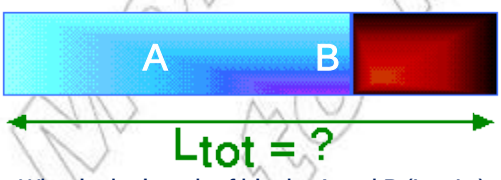
a) What is the distance between A and B?



b) What is the length of block A (L_A = ?)



c) What is the length of block B (L_B = ?)



d) What is the length of blocks A and B ($L_A + L_B$) = ?

Introduction

In the lower grades you learnt about science in general. For example, environmental science and integrated science. In this and next grades you will learn about physics, chemistry and biology separately. In this unit you will learn what physics is and about measurement.

Activity 1.1

Discuss the following questions in a group.

i. What is science? What does science deal with?

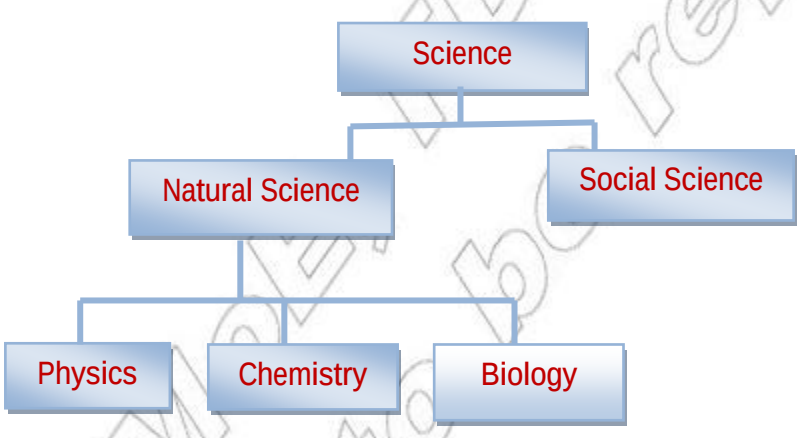
ii. What are the major branches of science?

Science is a systematized knowledge arising from observation, study and experimentation.

In a simple term, science is the study of the world around us. It deals with the knowledge of the world around us. The major classifications of science are given in chart 1.

- What are the two categories of science?
- Name the three branches of natural sciences?

Chart 1. Classification of science



1.1 Definition of Physics

a) Meaning of physics

Physics is defined in different ways. The following is one definition of physics. Physics is a way of observation of the world around us. Through observation we understand our world and how objects in the world behave (laws of nature). Physics is simply the science of observation and measurement.

Activity 1.2

i. From the explanations given above, describe in your own words what physics is.
ii. What do we call the person who studies physics?

The word 'Physics' has its origin in the Greek word meaning 'nature'.

Hence, physics is the branch of natural science. It is the study of the nature of matter, energy and their interactions. A person who studies physics is called physicist.

Isaac Newton (1643-1727) discovered the laws of motion and law of gravity.

Michael Faraday (1791-1867), discovered the generation of electr-icity from magnetism. He built the 1st dynamo.

James Prescott Joule (1818-1889) , studied the nature of heat and discovered the relationship between mechanical energy and heat energy

Marie Curie (1867-1934), won the Nobel Prize for the discovery of the elements polonium and radium.

Fig1.1 Some known physicists and their works

In order to understand, the definition of physics well, you need to have clear idea of **'matter'** and '**energy**'. Discuss with your friends and parents on the questions below and write a short note on:

Challenging Questions

i. What is matter?
ii. Some properties of matter.
iii. What is energy?
Iv. Explain how matter and energy are interrelated.

Activity 1.3

Mention at least five areas of study or topics

i. related to physics

ii. not related to physics

b) Purposes of studying physics

Physics is studied as a separate subject in grades 7 and 8 and also in secondary schools.

Activity 1.4

Discuss in a group with your friends why you study physics. Report your answers to the whole class.

The following are some specific purposes of studying physics

- Physics helps you to understand the working principles of many of your daily utensils and tools.
- Physics helps you discover some of the unknown parts of nature and makes you familiar with the modern world.
- Physics helps you to understand some of the natural phenomena in other subjects like: biology, chemistry, geology, astronomy, etc.
- Physics enables you to understand why it is difficult to walk on a smooth plane, why the electric fan moves, how the cars, airplanes, space-rockets, refrigerators, alarm-clocks, radios, televisions, etc work.

Generally studying physics helps you to:

- understand concepts, relationships, principles and laws of nature.
- do activities (experiments), to formulate and to check theories.
- describe some applications of physics on your daily life.
- solve practical problems (real life problems).
- understand the cause and effect of natural phenomenon.

c) Areas of study where physics does not address

There are areas or activities which does not require direct knowledge of physics. For example, history, civics and ethical education, politics, religion, etc. are not directly related to physics.

d) The main goal of the study of physics

The main goal of learning physics is to gain a better understanding of the world around you and the things in it. By understanding the world around you and the things in it, you discover facts. These facts form scientific concepts, theories, laws, principles and relationships. For example all objects fall towards the earth. This is a scientific fact. Corresponding to this there is a scientific law known as law of gravity; which is derived from that fact. Similarly when light falls on the surface of a mirror, it is reflected. Hence, from this fact, the law of reflection of light is derived.

Activity 1.5

Form a group with your friends and list down some examples of '*scientific facts*' and related '*scientific law*'.

Scientific facts	Scientific laws/ principles
e.g. All objects fall towards the earth	Law of gravity

e) Relationship of physics to other sciences and disciplines

There is no clear boarder line between the different branches of natural sciences. Knowledge of physics overlaps with the knowledge of chemistry, biology, astronomy, etc. For example, chemistry and physics knowledge are studied as a subject called **physical science/physical chemistry**. The following are some areas of studies where physics is combined with other science disciplines.

- **Biophysics**: combination of biology and physics.
- **Astrophysics**: combination of astronomy and physics.
- **Geophysics**: combination of geology and physics.

f) Branches of Physics

Physics is divided into different branches. Some of the branches of physics are given in Table 1.1

Table 1.1 Branches of physics

Branches	Purpose
Mechanics	Deals with motion of a physical body.
Sound	Studies production, transmission and other properties of sound.
Optics	Studies production, transmission and other properties of light.
Electricity and Magnetism	Deals with charged bodies at rest and in motion and relationship between electrical and magnetic properties of bodies.
Heat	Deals with temperature, heat transfer and exchange in molecular level.
Nuclear physics	Deals with interaction in the atomic nuclear
Astrophysics	Deals with celestial bodies like planets, stars, galaxies, etc.

Activity 1.6

Write five practical examples from your everyday life where the branches of physics are observed.

g) Relationship of physics to engineering and technology

Activity 1.7

i. What is the relation between physics and technology?
ii. What are the differences and similarities between technology and engineering?
iii. Which comes first, physics or technology?

You have already seen what physics is. Now, you will see what a technology is.

Technology is the use of scientific knowledge to help human beings work easier and live better and enjoy their environment more. Things such as automobiles, TV sets, radio, airplane and home tools (appliances) are the products of technology. A person who studies technology is called a **technologist.**

Technologists apply physics and mathematical knowledge and skills to produce a very useful tool.

What are the products shown in Fig 1.2?




a) **b)** **c)** **d)**

Fig1.2 Products of Technology

Engineers are technologists who design, construct and assemble products.

What are the criteria for a good technological product?

Products of engineers can be judged on six criteria. These are:

1. Is the product functioning as it should?
2. Is the product durable?
3. Is the product cost effective? Cheap?
4. How does the product affect the individual?
5. How does the product affect the society it works in?
6. How does the Product affect the environment?

Check point 1.1

1. Explain what physics is.
2. List five branches of physics.
3. What is the purpose of learning physics?
4. Describe the relation ship of physics to:
   a. Biology
   b. Chemistry
   c. Astronomy
5. List some other disciplines related to physics.
6. What is the relationship of physics and technology?
7. What are the criteria for judging of good products in engineering?

1.2 Standardization and Measurement

Activity 1.8

i. Measure the length and width of this textbook.
ii. Calculate the area of this textbook using the above measured values.
iii. Measure the height of your friend, and let your friend measure your height also.
iv. What instrument did you use?
v. How did you write the measures of the textbook and your friend's height?

Measurement

While you are doing Activity 1.8, you may come across units and numbers. These numbers by themselves means nothing. But when they are attached to some units of measurement like centimeter and meter they give you full information about your textbook and your friend's height.

i.e. - The length of this textbook is 24 centimeter.
- Its width is 17 centimeter.
- The height of your friend is 1 meter and 45 centimeters.

Measurement consists of the comparison of an unknown quantity with a known, fixed unit quantity. It consists of two parts:
i. the unit.
ii. the number indicating how many units there are in the quantity being measured.

Whenever you measure something, you simply compare two bodies. One of them being a '**standard**', and the other one being the body to be measured.

Measurement is one of the activities performed in physics. Physicists get quantitative information about objects through measurement.

Standardization

Activity 1.9

i. What traditional measuring units do you know that are used to describe length, time and mass?
ii. Are they reliable (dependable)?

In ancient times, people in Ethiopia used to measure physical quantities such as time, mass, length, etc using traditional units. They say '*Nigat*' or ' *Mishet*' as the sun rises or sets respectively. They say ' *Ekule- ken'* as the sun comes over head in the sky to measure time.

Lengths at olden days were measured in 'cubits', 'spans', 'foot' and, 'stride'.

a) Span b) Cubit

Fig 1.3 Traditional length measuring units

We still find these traditional units of length and time in our country. But they are not reliable. They do not give exact information.

Activity 1.10 *Group work*

i. Select friends who are shorter and taller than you.
ii. Compare their cubits and spans. Are they the same?
iii. What can you conclude? Are the traditional measuring units of length reliable?

Standard units are conventional units which are used to measure physical quantities scientifically.

The development of science and technology came up with the development of **standard** and **reliable** units of measurement. Scientists all over the world met together and agreed to have a standard unit that can be used through out the world. These standard units are known as **System of International Units.** In short, it is written as the **SI units**.

Physical quantities

You measured, the length, width and height of your textbook. These quantities are called physical quantities. Time and mass are also examples of phyical quanties.

Quantities that can be measured directly or indirectly are known as physical quantities.

Physical quantities are numbers with units which are used to describe physical phenomena.

The measured values of physical quantities are written in terms of a number and unit. Physical quantities and units can also be written using symbols.

Note ℓ = 24 cm, w = 17 cm

Where "ℓ" is length
"w" is width

'ℓ' and 'w' are symbols of length. The numbers 24 and 17 are numerical values 'cm' is the symbol of the unit of length called centimeter.

In activity 1.8, you measured directly the length and width of this textbook. But you calculated the area of it. What is the difference between the two ways of measuring things? The area of the book is calculated by combining two lengths, but not measured directly.

From this practical activity, you can see that some quantities are directly measured, while others are calculated by combining two or more measurable quantities. Hence,

Physical quantities are classified into two:

1. Fundamental physical quantities
2. Derived physical quantities.

Fundamental physical quantities: are those quantities which can be measured directly. They are not defined in terms of other physical quantities. Length, mass and time are examples of fundamental physical quantities. Fundamental physical quantities are also called basic physical quantities. The units used to measure the fundamental quantities are called basic units. You see seven basic units in Table 1.2. Can you name them?

Beside length, mass and time there are other four basic physical quantities in science. These are temperature, electric current, amount of substances and luminous intensity.

Table 1.2 The seven fundamental physical quantities

Basic quantities		Basic units	
Name	symbol	Name	Symbol
Length	ℓ	Meter	m
Time	t	Second	s
Mass	m	kilogram	kg
Temperature	T	Kelvin	K
Current	I	Ampere	A
Amount of substance	M	Mole	Mol
Luminous Intensity	-	Candela	Cd

Challenging Questions

1. What fundamental quantities are combined to give area, volume, density, speed?
2. Explain how the basic units are combined to give the derived units of force, velocity, pressure and work.

Derived physical quantities: are quantities that can be measured indirectly. They are calculated by combining two or more fundamental quantities. Area and volume are examples of derived physical quantities. The derived quantities use derived units.

Table 1.3 Some derived physical quantities.

Name	Symbol	Unit	Symbol
Area	A	square meter	m^2
Volume	V	cubic meter	m^3
Density	ρ	$\frac{\text{kilogram}}{\text{cubic meter}}$	kg/m^3
Acceleration	a	$\frac{\text{meter}}{\text{second}^2}$	m/s^2
Force	F	$\frac{\text{kilogram-meter}}{\text{second}^2}$	$kg.m/s^2$ = Newton(N)
Pressure	P	$\frac{\text{Kg.m/s.s}}{\text{square meter}}$	$\frac{kg.m/s^2}{m^2} = \frac{\text{Newton}}{\text{square meter}} = N/m^2$

Scalar and vector quantities

Some physical quantities are described completely by a number and a unit. A number with a unit is called a **magnitude**. However, other quantities have a direction attached to the magnitude. They can not be described by a number and unit only. Thus, physical quantities are grouped into two:

i. Scalar quantity
ii. Vector quantity

A scalar quantity is a physical quantity which has only a magnitude. No direction.

Time, mass, volume, density, temperature and energy are examples of a scalar quantity.

A vector quantity is a physical quantity which has both magnitude and direction.

Displacement, velocity and force are some examples of a vector quantity.

Check point 1.2

1. What is measurement?
2. What are physical quantities?
3. Describe the difference between fundamental and derived physical quantities.
4. List seven fundamental physical quantities with their SI units.
5. List some derived physical quantities.
6. How can you distinguish between scalar and vector quantities? List examples of scalar and vector quantities in the given two columns

Scalar Quantities	Vector Quantities
• _____	• _____
• _____	• _____
• _____	• _____

1.3 Measuring Length, Mass and Time

1.3.1 Measuring Length

Activity 1.11

- What is the height and width of the blackboard?
- How far is your school from your home?
- What is the inside height and width of your classroom?

When you tell the distance between your school and your home, or the height and width of your classroom, you measure length.

Length is one of the fundamental (basic) physical quantities that describes the distance between two points.

The symbol for length is "ℓ". Sometimes, we can also use other symbols such as *'b','h' and 's'*.

When we measure length of an object, we are comparing it with a standard length that scientists have agreed to. The SI unit of length is METER (m). There are also other non-SI units of length. These are centimeter (cm), millimeter (mm) and kilometer (km).

a) Ruler

b) Tape Measure

c) Carpenter Rule

d) Vernier Caliper

Fig 1.4 Length measuring instruments

Activity 1.12

Form a group with your classmates and do the following activities.

- Measure the length of different bodies using half meter ruler (50cm) and, write the length of the bodies using symbols.
- Estimate the
  a) Width of the blackboard
  b) Thickness of your physics textbook
  c) Width of the door of your classroom without using instrument.
- Now, measure the above quantities using length measuring instrument and compare with the estimated values.

Table 1.4 Relationship between meter and other non- SI units	
1 meter (m)	1000 millimeters (mm)
1 meter (m)	100 centimeters (cm)
1000 meters (m)	1 kilometer (km)
1 meter (m)	0. 001kilometers (km)
1 millimeter (mm)	0. 001 m
1 centimeter (cm)	0.01 m
1 kilometer (km)	1000 m

Example 1.1

The distance between two electric poles measures 100 meters. What is this distance in: a. centimeter b. kilometer

N.B *Use Table 1.4*

Given

ℓ = 100 m (distance)

Solution

a) Since 1 m = 100 cm

Then 100 m = ?

$$\Rightarrow \text{'}\ell\text{' in cm} = \frac{100\text{cm} \times 100\cancel{\text{m}}}{1\cancel{\text{m}}}$$

ℓ = 10,000 cm

b) 1 m = 0. 001 km

100 m =?

$$\therefore \text{'}\ell\text{' in km} = \frac{100\cancel{\text{m}} \times 0.001\text{km}}{1\cancel{\text{m}}}$$

ℓ = 0. 1km

Challenging Questions

Write down the suitable unit of length you need to use to measure:

i. The distance between your school and your home.
ii. The thickness of your physics book.
iii. Your height.

1.3.2 Measuring Mass

So far you learnt how to measure length. Length is fundamental physical quantity in physics. The other important physical quantity you need to study is mass.

> Mass is a fundamental physical quantity. It is defined as the amount of matter contained in a body.

There are two ways of measuring the mass of a body.

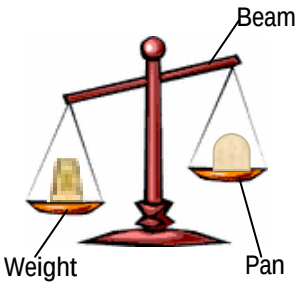
i. Traditional way:-

In traditional way things can be compared to each other to guess the approximate value of the mass of the bodies.

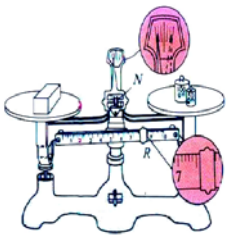
Note: A traditional instrument does not tell us the exact value of the mass of a body.

ii. Scientific way

In scientific way a mass is measured using an instrument called a **beam balance**. A beam balance consists of uniform beam having two pans suspended from each of its ends. Fig 1.5 show different mass measuring instruments. Tell where these instruments are used in our daily life.



a) Locally made beam balance



b) Beam balance

c) Triple beam balance

Fig 1.5 Mass measuring Instruments

Activity 1.13

- Have you ever tried to measure the mass of a body using a beam balance?
- Visit a shop in your living area. Write down the procedures the shopkeeper uses to measure the mass of a body using a beam-balance. Report your observations to your class.

The body to be measured is placed in one of the pans and a known **Standard mass** is placed in the other pan until a horizontal balance is obtained. At this moment the unknown masses of the body equals the standard masses.

The SI unit of mass is the kilogram (kg). Other non- SI units can also be used to measure masses. Some examples are given in Table 1.5.

Table 1.5 Relationship between units of mass

1000 kilogram	1 ton
100 kilogram	1 quintal
1 kilogram	1000 grams
1 gram	0.001 kg
1 milligram	0.001 gram

Activity 1.14

i. Estimate without instruments the masses of the following bodies.
   a. Grade 7 Physics text book b. One stick of chalk c. One duster
ii. Now measure the masses of the above estimated bodies using a beam balance.
iii. Compare the estimated and measured values and calculate the differences. Give reasons for the differences.

Example 1.2

1. In one of the pans of a beam balance the masses 1kg, 500g, 30g, 0.6g are placed to measure the mass of unknown body. What should be the mass of the body on the other side of a pan if they are in balance?

Given **Required**

m = 1kg, 500 g, 30 g, 0.6 g total mass = ?

Solution

m = the sum of the given masses
= 1kg + 500g + 30g + 0.6g (change 1kg into g)
= 1000g + 500g + 30g + 0.6g
= 1530.6g or
= 1.53 kg

2. Abel and Zehara want to sit at the two ends of a SEE-SAW having equal distances from the pivot as shown in Fig.1.6. Zehara is 37 kg, and Abel is 29 kg. What additional mass (m_x) should Abel carry in order to balance the SEE-SAW.

Fig 1.6 See-Saw

Given	Required	Solution
$m_A = 29$ kg $m_Z = 37$ kg	$m_x = ?$	$m_A + m_X = m_Z$ $29kg + m_X = 37kg$ $m_X = 37kg - 29kg$ $= 8$ kg

Check point 1.3

1. What is a length? Name the measuring device of a length.
2. State the SI unit of length and some common non-SI units. Explain their relationship.
3. What is a mass? Name some measuring devices of a mass.
4. State the SI unit of mass and other commonly used non- SI units of mass. Explain their relationship.
5. What is time? Mention the measuring devices of time.
6. Write the relationship between SI unit of time and other commonly used non-SI units of time.

1.3.3 Measuring Time

What is time? The sun rises in the east in the morning and sets in the west in the evening. How long does the sun take to rise and set? People use the sunrise and sunset as a time measuring device. It is called **sundial**.

Time is a fundamental physical quantity. It describes the duration between the beginning and end of an event.
The SI unit of time is second (s). The symbol for time is 't'.

Activity 1.15

Discuss: how the sun rise and sun set is used to measure the time of a day.
Draw a diagram of sundial at different times of the day.

a) Watch

b) Stopwatch

c) Digital watch

Fig 1.7 Time measuring devices

A clock and watch are the modern instruments used to measure time. Can you explain how the time measuring instruments indicated in Fig 1.7 are read?
To measure very small or large intervals of time, there are other non- SI units of time. These are minute (min), hour (hr), day, etc.

Activity 1.16

i. Measure the beat of your heart using a wrist watch (digital watch). Express it using symbols of quantity of time and unit of time.
ii. Tell your friends and teacher how you did your activity.

Relationships between SI units and non- SI units of time:

Activity 1.17

i. Have you ever noticed the relationships between hour, minute and second? What are the relationships?

ii. Take a day (24 hrs) and list down activities you do through out the day.

Time	Activity
Morning 12:00	
1:00	
2:00	
etc.	

Are you using your time wisely? Compare your time with your friends time. Who are not using the day wisely? Discuss with your friends.

Some wrist watches have an hour hand, a minute hand and a second hand. Can you define hour, minute and second using a wristwatch from your experiences?

- As the second hand completes one cycle, the minute hand moves one unit.(1 minute)
- As the minute hand completes one cycle the hour hand moves one unit (one hour).
- As the hour hand completes one cycle, we say 12 hours.

Table 1.6 Relationship between units of time

1 hour	60 minutes
1 minute	60 seconds
1 day	24 hours
1 week	7 days
1 month	30 days
1 year	365 or 366 days

Example 1.3

1. Express the following times in minutes:
   a) 3 hours
   b) 3/4 hours
   c) 1.25 hours.

Solution

a) 1 hr = 60min

3hr = ? $\Rightarrow t = \frac{3\cancel{hr} \times 60\,\text{min}}{1\cancel{hr}}$

$= 180\ \text{min}$

b) 1hr = 60 min

$\frac{3}{4}$ hr = ? $\therefore t = \frac{\frac{3}{4}\cancel{hr} \times 60\text{min}}{1\cancel{hr}}$

$= 45\ \text{min}$

c) 1hr = 60min

1.25 hr = ? $t = \frac{1.25\cancel{hr} \times 60\,\text{min}}{1\cancel{hr}}$

$= 75\ \text{min}$

Challenging Questions

Write down what unit of time, you need to use for measuring

a. The beat of your heart.
b. The duration of one period of your class.
c. The time you take to travel from home to school.

1. How many hours, minutes and seconds are there in one day?
2. Mention some traditional ways of measuring time.
3. How many days are there in a year?
4. How old are you? Write your age in
   a. years b. months
5. Express the following times in seconds:-
   a. 75 minutes b. 2 hours c. 0.6 minutes

Summary

In this unit you learnt that:

- physics is a branch of natural science.
- physics deals with the laws of nature. Physicist is a person who studies physics.
- physics is applied to every development of science and technology.
- Mechanics, Sound, Optics, Electricity and Magnetism, Heat, Nuclear physics, and Astrophysics are different branches of physics.
- measurement is the comparison of an unknown quantity with a known one (standard unit).
- measurement of an object consists of two parts:
  i. Unit of measurement,
  ii. The numerical values of the measured object.
- standard units are conventional units which are used to measure physical quantities scientifically.
- traditional units are not reliable and not exact.
- physical quantities are quantities that can be measured directly or indirectly. They are expressed in terms of:
  i. numerical values ii. unit iii. symbol
- scalar quantities have magnitude only. Direction is not associated with them.
- vector quantities have both magnitude and direction.
- length, time, mass, temperature, current, amount of substance and luminous intensity are fundamental quantities in science. The rest are derived physical quantities expressed by combining two or more of these fundamental quantities.
  1. The SI unit of length is meter (m).
  2. The SI unit of time is second (s).
  3. The SI unit of mass is kilogram (kg).

Review Questions and Problems

I. Write true if the statement is correct and false if the statement is wrong.

1. One meter is 100 kilometer.
2. There are seven fundamental quantities in physics.
3. The device used to measure a mass of a body is kilogram.
4. If kilogram is added to kilogram then we have a derived unit.
5. m/s is a derived unit.

II. Multiple choice

1. Which one of the following is not a vector quantity?
   a) Displacement c) Force
   b) Density d) Velocity
2. Which one of the following is not a fundamental physical quantity?
   a) Time c) Force
   b) Mass d) Length
3. Which one of the following is a derived SI unit?
   a) Newton c) Kelvin
   b) Kilogram d) Second
4. 2 hr + 20 min + 60 sec are equal to _____ minutes.
   a) 120min c) 150 min
   b) 141min d) 161 min
5. Which one of the following quantities is measured by a balance?
   a) Length c) Mass
   b) Volume d) Density

III. Short answer questions

1. Why do you think that measuring length, mass and time, using traditional methods are not reliable?
2. How many centimeters are there in 9.3 m?
3. Define the following terms.
   a) Physics e) Vector
   b) Standard units f) Length
   c) Measurement g) Time
   d) Fundamental physical quantity. h) Mass

4. **A large bottle contains a number of medicinal tablets each having a mass of 250 mg. The mass of all the tablets is 0.5 kg. Calculate the number of tablets in the bottle.**

Challenging questions

1. **Meter, kilogram and second are the SI units of length, mass and time respectively. They are internationally agreed standard units. Write a descriptive note about the history, methods of determination and definition of meter, kilogram and second.**
2. **The following four SI units were named after famous scientists; Watt, Joule, Pascal and Kelvin. Find out:**
   i. **the area of physics to which each of these scientists made a significant contribution.**
   ii. **the physical quantity measured using each of the four units.**