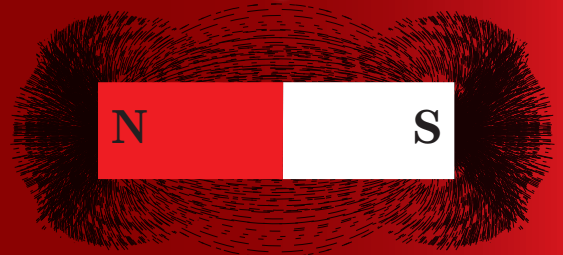
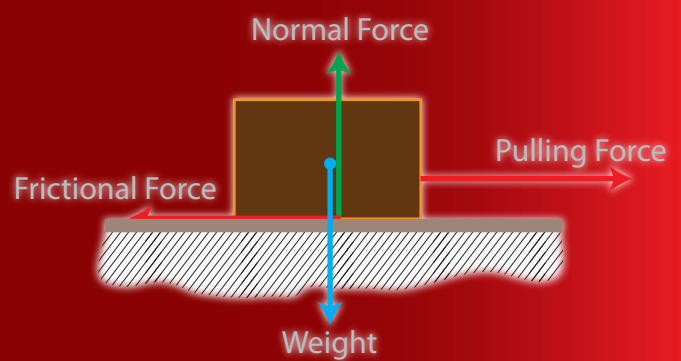




# PHYSICS

## Grade 7 Workbook



FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA  
MINISTRY OF EDUCATION AND  
JAPAN INTERNATIONAL COOPERATION AGENCY







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# How to Use This Book?

This workbook was developed for Ethiopian Grade 7 students to use. It is based on the official syllabus and the textbook. It is designed to help you understand the textbook better. Therefore, you can use it along with your textbook.

As you will see, this Workbook is organized as follows: One topic is explained in two pages (one spread). In one spread, there are "Explanations" or "Introduction" or "Definition", and then some simple "Examples". After "Examples", you will have few exercises. "Let's Exercise" gives you basic questions you have to answer to master that topic. Then comes "Let's Go Further" section where you will face some advanced problems. On some pages, you will also find "Hint!" or "Do You Know?" that helps you do the exercises or learn something new.

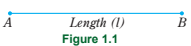
[Example of one spread]

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Physics Grade 7 Workbook

### 1.3 MEASURING PHYSICAL QUANTITY (I) – LENGTH

Length is defined as the distance between two points.



**Figure 1.1**

The distance between A and B is length from A to B.

Length is a fundamental physical quantity.

The SI unit of length is meter (m).

Non-SI units of length are centimeter (cm), millimeter (mm), kilometer (km), decimeter (dm), mile (M) etc.

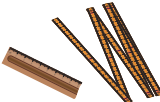
Length is a scalar physical quantity.

1 m = 100 cm  
1 dm = 10 cm  
1 cm = 10 mm  
1 km = 1000 m

1 m = 0.001 km  
1 cm = 0.01 m  
1 dm = 0.1 m

**DEVICES USED TO MEASURE LENGTH**

Devices used to measure length (instruments) are meter tape, ruler, meter stick ... etc.



**Example**

- The distance between two ends of a classroom of one side is 4 m and 8 cm. What is the length of the classroom in centimeters (cm)?
 

**How to solve it!**

First convert meter into centimeters.

1 m = 100 cm  
4 m = x  
4 m × 100 cm = 1 m × x  
x = 400 cm

And then add all centimeters (cm) together.

400 cm + 8 cm = 408 cm  
∴ Length = 408 cm
- The distance from Addis Ababa to Hawassa is 273 km. What is the length between two cities in meter?

**How to solve it!**

| Given                | Required                |
|----------------------|-------------------------|
| $l = 273 \text{ km}$ | $l = x$                 |
| 1 km = 1000 m        |                         |
| 273 km = x           |                         |
|                      | $x = 273,000 \text{ m}$ |

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Unit 1: Physics and Measurement

**Let's Exercise**

- Mention SI and non-SI units of length?
- Write instruments used to measure length.
- Convert 2 km into
  - meter
  - centimeter
  - millimeter
- Convert 5,000 mm into
  - centimeter
  - meter
  - kilometer

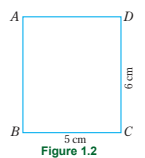
**Hint!**

1 cm = 10 mm  
1 km = 1000 m  
1 m = 100 cm

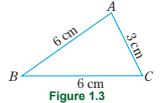


**Let's Go Further**

- A student moves starting from A and goes through B, C, D and returns to his starting point A as shown in **Figure 1.2**. What is the total length covered by the student?
- A car moves 35 km, 300 m and 500 cm in one trip. Calculate the length covered by the car in km?
- Kenenisa runs a 400 m track five times. What is the total distance covered by Kenenisa?
- A student moves from A to B then to C and returns to A as shown in **Figure 1.3**. What is the total distance/length covered by the student?
- The sum of 1 km and 1 cm = \_\_\_\_\_ meter (m).
- 2 millimeter is equal to \_\_\_\_\_ meter (m).
- 1 km + 1 m = \_\_\_\_\_ kilometer (km).



**Figure 1.2**



**Figure 1.3**

Though this is called "Workbook", you should not write your answers directly into this Workbook. Rather you should have a separate notebook at hand and write your answers in the notebook. For this reason, this Workbook does not provide enough space for your answers. Please write down your answers in your notebook.

In the last section of this Workbook, you will find answers to the exercises. After your work, you can check your answers by yourself.

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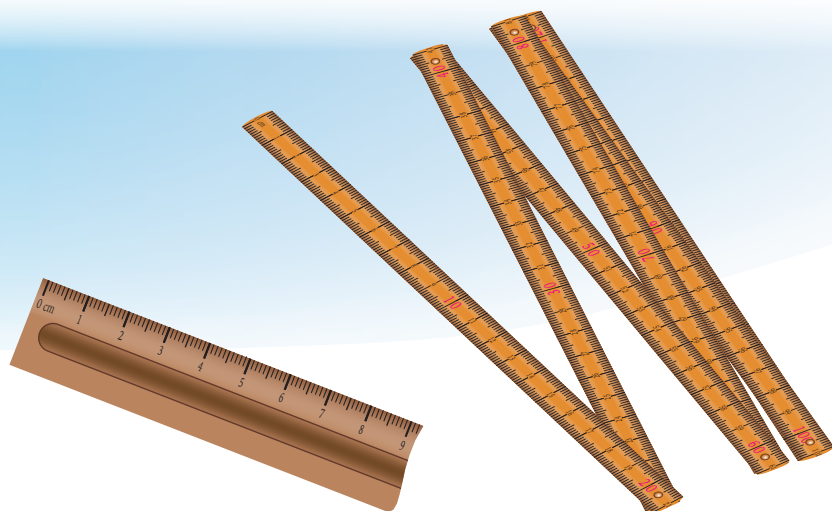
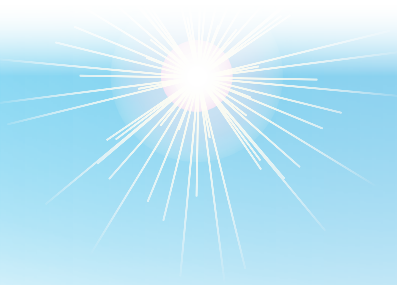
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# Unit 1

## PHYSICS AND MEASUREMENT

### Main Content

- |     |                                        |    |
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| 1.1 | Definition of Physics                  | 2  |
| 1.2 | Standardization and Measurement        | 4  |
| 1.3 | Measuring Physical Quantity (I) Length | 6  |
| 1.4 | Measuring Physical Quantity (II) Mass  | 8  |
| 1.5 | Measuring Physical Quantity (III) Time | 10 |
| 1.6 | Unit Summary                           | 12 |



## 1.1 DEFINITION OF PHYSICS

- ✓ Physics is a branch of natural science. It is the study of nature of matter, energy and their interactions.
- ✓ A person who studies physics is called *Physicist*.
- ✓ Sir Isaac Newton, Michael Faraday, James Prescott Joule and Marie Curie are some of the physicists who contributed a lot to the world by discovering scientific laws, principles and so on.
- ✓ Mechanics, Sound, Optics, Electricity and Magnetism, Heat are some branches of Physics.

### Example

Select either "True" or "False" and give your reason for the False statements.

- a) Physics is a branch of social science. (True/False)
- b) A person who studies physics is called physician. (True/False)
- c) James Prescott Joule is a physicist leaved from 1818–1889 and discovered the laws of motion. (True/False)
- d) Nuclear physics is a branch of physics which deals with interaction in the atomic nucleus. (True/False)

### How to solve it!

- a) False – Because it is a branch of natural science.
- b) False – Because it is called Physicist not Physician.
- c) False – Because he discovered the relationship between mechanical energy and heat energy.
- d) True.

### Let's Exercise

1. Select either "True" or "False" and give your reason for the False statements.
  - a) Biology is not directly related to Physics. (True/False)  
If false, reason \_\_\_\_\_.
  - b) Politics is directly related to Physics.  
If false, reason \_\_\_\_\_.

- c) Chemist is the name given to a person who study physics.  
If false, reason \_\_\_\_\_.
- d) Understanding physics helps to understand the working principles of our daily tools.  
If false, reason \_\_\_\_\_.
- e) A person who studies technology is known as technologist.  
If false, reason \_\_\_\_\_.

2. The following table shows relationships of physics with other disciplines. Fill the missing.

|                    |                       |
|--------------------|-----------------------|
| Physical-chemistry | Physics with _____.   |
| _____              | Physics with Biology. |
| Astrophysics       | Physics with _____.   |
| _____              | Physics with Geology. |

3. Fill in the missed space in the following table by relating branches of physics with the area of study.

| Branches of Physics | Area of Study (Purpose)                                                               |
|---------------------|---------------------------------------------------------------------------------------|
| _____               | Motion                                                                                |
| _____               | Production, transmission and properties of sound                                      |
| Optics              | _____.                                                                                |
| _____               | Charged bodies and relationship between electrical and magnetic properties of bodies. |
| Heat                | _____.                                                                                |
| Nuclear Physics     | _____.                                                                                |
| _____               | Celestial bodies like planets, stars etc.                                             |

## Let's Go Further

- Who is the discoverer of the generation electricity from magnetism and built the 1<sup>st</sup> dynamo?
- What are the purposes of studying Physics?
- What is the main goal of the learning of Physics?

## 1.2 STANDARDIZATION AND MEASUREMENT

Measurement consists of the comparison of an unknown quantity with known, fixed unit quantity.

It consists of two parts:

- i) The unit.
- ii) The number indication how many units there are in the quantity being measured.

Whenever you measure something, you simply compare two bodies, one of them being as standard and other one being the body to be measured. Physics get quantitative information about objects through measurement.

### STANDARD UNIT

To measure physical quantity scientifically SI units are used.

### CLASSIFICATION OF UNITS

Fundamental and derived physical quantity:

- ▶ Fundamental physical quantity – it can be measured directly.
- ▶ Derived physical quantity – it can be measured indirectly.

Scalar and vector physical quantity:

- ▶ Scalar physical quantity – it has only magnitude.
- ▶ Vector physical quantity – it has both magnitude and direction.

### Example

Classify units below into the table in the right. Cubit, ekuleken, meter, negat, second, span.

|               | SI Base Unit | Traditional Unit |
|---------------|--------------|------------------|
| <b>Length</b> |              |                  |
| <b>Time</b>   |              |                  |

### How to solve it!

Units for length are cubit, meter and span. Units for time are ekuleken, negat and second.

SI fundamental or base units are meter, kilogram, second, ampere, kelvin, candela and mole. Therefore, answers are as shown in the table to the right.

|               | SI Base Unit | Traditional Unit |
|---------------|--------------|------------------|
| <b>Length</b> | meter        | cubit, span      |
| <b>Time</b>   | second       | ekuleken, negat  |

### Let's Exercise

1. What is measurement?
2. Physical quantities are classified into two groups. What are they?
3. Which units are used to measure physical quantities scientifically?
4. What is the difference between fundamental and derived quantities?
5. What property that vector quantities have but scalar quantities do not have?
6. List down three derived physical quantities.
  - i) \_\_\_\_\_.
  - ii) \_\_\_\_\_.
  - iii) \_\_\_\_\_.
7. List examples of scalar and vector quantities in the given table below.

| Scalar Quantities | Vector Quantities |
|-------------------|-------------------|
|                   |                   |
|                   |                   |
|                   |                   |

8. List down seven fundamental quantities with their SI unit in the table given below.

| No  | Fundamental Quantities | Basic SI Units |
|-----|------------------------|----------------|
| i   |                        |                |
| ii  |                        |                |
| iii |                        |                |
| iv  |                        |                |
| v   |                        |                |
| vi  |                        |                |
| vii |                        |                |

## Let's Go Further

The density of an object is calculated as follows: the mass of the object is divided by its volume.

- a) What is the SI unit of density?
- b) Is the unit a base (fundamental) unit or a derived unit?

## 1.3 MEASURING PHYSICAL QUANTITY (I) – LENGTH

- ✓ Length is defined as the distance between two points.



**Figure 1.1**

- The distance between *A* and *B* is length from *A* to *B*.

- ✓ Length is a fundamental physical quantity.

- ✓ The SI unit of length is meter (m).

- ✓ Non-SI units of length are centimeter (cm), millimeter (mm), kilometer (km), decimeter (dm), mile (M) etc.

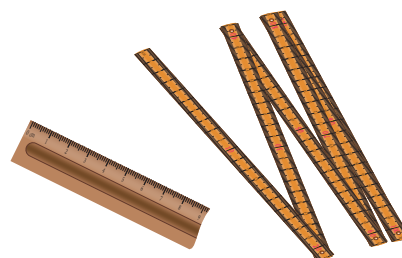
- ✓ Length is a scalar physical quantity.

$$\begin{aligned} 1 \text{ m} &= 100 \text{ cm} \\ 1 \text{ dm} &= 10 \text{ cm} \\ 1 \text{ cm} &= 10 \text{ mm} \\ 1 \text{ km} &= 1000 \text{ m} \end{aligned}$$

$$\begin{aligned} 1 \text{ m} &= 0.001 \text{ km} \\ 1 \text{ cm} &= 0.01 \text{ m} \\ 1 \text{ dm} &= 0.1 \text{ m} \end{aligned}$$

### DEVICES USED TO MEASURE LENGTH

Devices used to measure length (instruments) are meter tape, ruler, meter stick ... etc.



### Example

1. The distance between two ends of a classroom of one side is 4 m and 8 cm. What is the length of the classroom in centimeters (cm)?

#### How to solve it!

- ✓ First convert meter into centimeters.

$$\begin{aligned} 1 \text{ m} &= 100 \text{ cm} \\ 4 \text{ m} &= x \\ 4 \text{ m} \times 100 \text{ cm} &= 1 \text{ m} \times x \\ x &= 400 \text{ cm} \end{aligned}$$

- ✓ And then add all centimeters (cm) together.

$$\begin{aligned} 400 \text{ cm} + 8 \text{ cm} &= 408 \text{ cm} \\ \therefore \text{Length} &= 408 \text{ cm} \end{aligned}$$

2. The distance from Addis Ababa to Hawassa is 273 km. What is the length between two cities in meter?

#### How to solve it!

Given

$$l = 273 \text{ km}$$

Required

$$l = x$$

$$\begin{aligned} 1 \text{ km} &= 1000 \text{ m} \\ 273 \text{ km} &= x \\ x &= 273,000 \text{ m} \end{aligned}$$

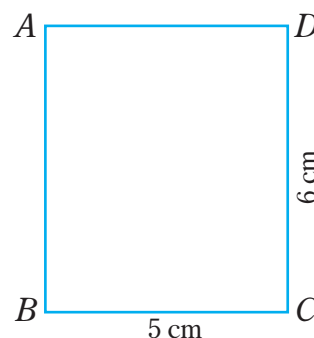
### Let's Exercise

1. Mention SI and non-SI units of length?
2. Write instruments used to measure length.
3. Convert 2 km into
  - a) meter
  - b) centimeter
  - c) millimeter
4. Convert 5,000 mm into
  - a) centimeter
  - b) meter
  - c) kilometer

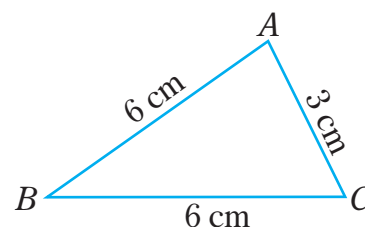


### Let's Go Further

1. A student moves starting from  $A$  and goes through  $B, C, D$  and returns to his starting point  $A$  as shown in **Figure 1.2**. What is the total length covered by the student?
2. A car moves 35 km, 300 m and 500 cm in one trip. Calculate the length covered by the car in km?
3. Kenenisa runs a 400 m track five times. What is the total distance covered by Kenenisa?
4. A student moves from  $A$  to  $B$  then to  $C$  and returns to  $B$  as shown in **Figure 1.3**. What is the total distance/length covered by the student?
5. The sum of 1 km and 1 cm = \_\_\_\_\_ meter (m).
6. 2 millimeter is equal to \_\_\_\_\_ meter (m).
7.  $1 \text{ km} + 1 \text{ m} =$  \_\_\_\_\_ kilometer (km).



**Figure 1.2**



**Figure 1.3**

## 1.4 MEASURING PHYSICAL QUANTITY (II) – MASS

Mass is the fundamental (basic) physical quantity. It is defined as the amount of matter in a body. Mass can be measured. Its measuring SI unit is *kilogram* (kg).

Mass can be measured in traditional way and scientific way.

**Traditional way** – things can be compared to guess approximate value of their masses.

### Example

Putting an already known 1 kg of one thing on one hand and butter of unknown mass on the other hand compare and approximate the mass of butter.

**Scientific way** – mass is measured in scientific way using different instruments.

Beam balance and triple beam balance are some of the mass measuring instruments.

You can measure mass of a body using the device called *beam balance*. Mass has other non-SI units. They are the *gram* (g), *milligram* (mg), *quintal* and *tonne* (t).

The SI unit kilogram is related with the non-SI units as follows.

$$\begin{array}{ll} 1 \text{ kg} = 1000 \text{ g} & 1 \text{ quintal} = 100 \text{ kg} \\ 1 \text{ kg} = 1,000,000 \text{ mg} & 1 \text{ t} = 1000 \text{ kg} \end{array}$$

You can convert (change) the SI unit into the non-SI units and vice versa.

### Example

1. A stone has a mass of 2 kg. What is the mass of the stone in grams?

#### How to solve it!

- ✓ Note, the relationship between kg and g (1 kg = 1,000 g)
- ✓ Write the conversion factor between kg and g as a fraction and multiply by 2 kg. That is,

$$\frac{1,000 \text{ g}}{1 \text{ kg}} \times 2 \text{ kg} = 2,000 \text{ g}$$

Hence, 2 kg = 2,000 g.

- ✓ The expression in the box is the conversion factor to change kg into gm.

2. A car has a mass of 450 kg. What is its mass in tonne?

### How to solve it!

- ✓ Note, relationship between kg and tonne (1 t = 1,000 kg).
- ✓ Write the conversion factor between kg and tonne as a fraction and multiply by 450 kg. That is,

$$\frac{1 \text{ t}}{1,000 \text{ kg}} \times 450 \text{ kg} = 0.45 \text{ t}$$

Hence, 450 kg = 0.45 t.

### Let's Exercise

- Change the following:
  - 25 kg into g.
  - 5 quintal into kg.
  - 4.5 t into g.
- Which one of the following is **NOT** true about mass?
  - It is the amount of matter in a body.
  - It can be measured and has an SI unit.
  - It has no SI units.
  - It is measured by a device called beam balance.
- \_\_\_\_\_ is the SI unit of mass.
- State three non-SI units of mass.
- State some of the mass measuring devices.

## Let's Go Further

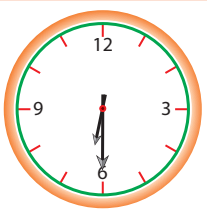
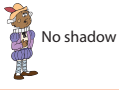
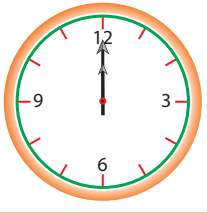
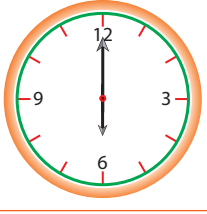
Three small iron spheres *a*, *b* and *c* have masses 40 kg, 0.5 quintal and 0.004 t respectively. Which sphere has the least mass?

## 1.5 MEASURING PHYSICAL QUANTITY (III) – TIME

Time is a fundamental physical quantity. It describes the duration between the beginning and the end of an event.

- ▶ Traditionally shadows, position of the sun, the crow of cock, etc., were used to measure time.
- ▶ Nowadays, clocks, watches, etc., are in use to measure time. These devices tell more precise time than traditional ones.

The different ways of measurement of time.

| Shadow                                                                                                                                                                     | Analogue Watch                                                                      | Digital Watch                                                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <br>     |    |    |
| <br>  |   |   |
| <br> |  |  |
| <br> |  |  |

The SI unit of time is second (s). Other non-SI units of time are minute (min), hour (h), day (d), week, month, year, etc. While measuring time, use a unit that reduces the number of digits of a measurement to the smallest possible digit.

Some unit conversion factors of time are given below.

$$1 \text{ min} = 60 \text{ s}$$

$$1 \text{ h} = 60 \text{ min}$$

$$1 \text{ d} = 24 \text{ h}$$

$$1 \text{ week} = 7 \text{ d}$$

$$1 \text{ year} = 365.25 \text{ d (365 or 366 d)}$$

## Example

Most kids start pre-school education when they are 3 years old. How many seconds is this age?

### How to solve it!

$$1 \text{ yr} = 365.25 \text{ d}$$

$$\text{Therefore, } 3 \text{ yr} = 3 \cancel{\text{yr}} \times 365.25 \frac{\text{d}}{\cancel{\text{yr}}} = 1095.75 \text{ d}$$

$$1 \text{ d} = 24 \text{ h}$$

$$1095.75 \text{ d} = 1095.75 \cancel{\text{d}} \times 24 \frac{\text{h}}{\cancel{\text{d}}} = 26298 \text{ h}$$

$$1 \text{ h} = 60 \text{ min}$$

$$26298 \text{ h} = 26298 \cancel{\text{h}} \times 60 \frac{\text{min}}{\cancel{\text{h}}} = 1577880 \text{ min}$$

$$1 \text{ min} = 60 \text{ s}$$

$$\text{Therefore, } 1577880 \text{ min} = 1577880 \cancel{\text{min}} \times 60 \frac{\text{s}}{\cancel{\text{min}}} = 94672800 \text{ s}$$

The most suitable unit in this case is year. Thus, 3 yr has only one digit but 94672800 s has eight digits.

## Let's Exercise

- When does a tree, exposed to the sun cast:
  - the longest shadow to the east direction?
  - the longest shadow due west?
  - the shortest shadow?
- How many hours is 1 week?
- How many seconds is a day?
- Which unit of time is more convenient to express 172800 s? Why?

## Let's Go Further

- Traditional time measuring methods are not applicable at any time. When does:
  - shadow method use to guess time?
  - the crow of a cock use to guess time in Ethiopia?
- Suppose a student studies in library every day from 3:00:00 p.m. To 6:00:00 p.m. How long does she stay in the library every day?

## 1.6 UNIT SUMMARY

### I Choose the Correct Answer.

- Which one of the following is the SI unit of fundamental physical quantity?  
A. m/s                      B. m                      C. m/s<sup>2</sup>                      D. km/s<sup>2</sup>
- Which one of the following is correct about vector quantity?  
A. It has only direction.  
B. It has only magnitude.  
C. It has both magnitude and direction.  
D. It is the quantity that cannot be measured.
- Which one of the following physical quantities requires direction for its complete description?  
A. Distance                      B. Force                      C. Mass                      D. Time

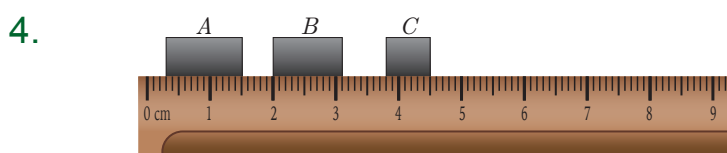


Figure 1.4

Abebe and Tolessa want to know the length of three metal bars using single ruler as shown in **Figure 1.4**. What is the total length of the metal bar?

- A. 3.00 m                      B. 3.90 m                      C. 4.36 m                      D. 4.50 m
- If the masses at both sides of the sea-saw/beam balance are equal as shown in **Figure 1.5**, what is the mass of "A" in kg?

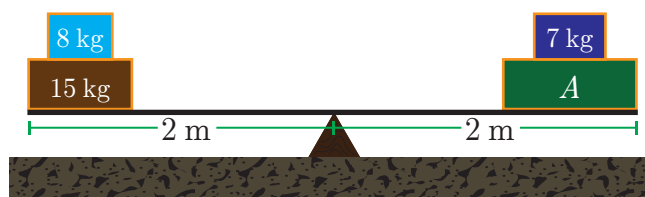


Figure 1.5

- A. 13                      C. 16  
B. 15                      D. 20

### II Give Short Answer.

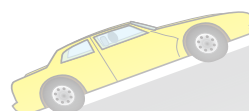
- List the disciplines overlapping with physics in some of their parts.
- Why do you study physics?
- Why derived physical quantities are different from fundamental physical quantities?
- Why do you think that measuring length is reliable?

# Unit **2**

## MOTION

### Main Content

- 2.1 Definition of Motion **14**
- 2.2 Motion along a Straight Line **16**
- 2.3 Qualitative Exploration of Constant Velocity **18**
- 2.4 Qualitative Exploration of Accelerated Motion **20**
- 2.5 Unit Summary **22**



## 2.1 DEFINITION OF MOTION

If the position changes as time passes, the object is in motion. If the position is not changing, the object is said to be at rest

Let us now talk about the position and displacement of an object such as a car moving from your house to the post office, which is 5 blocks East.



Figure 2.1

The position of an object refers to the location of the object with respect to some fixed point. In the present case, your house can be used as the fixed point from which all distances are measured. The fixed point is called a *reference point*.

If there is no change in direction during straight-line motion, that would still be motion along straight-line. For this reason, straight-line motion can be diagonal, horizontal or vertical. If you were to mention the highlights of your motion towards the center and the reverse, what comes to your mind are speed and direction of motion? Speed refers to how fast you were running and direction tells from where to where you were going.

When you described your motion on the backyard, speed (magnitude) alone cannot tell from where to where you went. It only tells whether you were slow or fast during the motion. This means that in order to provide a complete picture you must also add the direction of the motion so that the information will be completely understood.

We can represent the motion of an object that moves from one position to another by an arrow that points from the initial position to the final position. This arrow represents a physical quantity called the *displacement of the object*.

In physics, we are concerned with three types of motion: *translational*, *rotational*, and *vibrational*.

### Example

The following are examples of type of motion.

- ▶ A car moving down a highway. .... *Translational motion*
- ▶ The Earth's spin on its axis. .... *Rotational motion*
- ▶ The back-and-forth movement of a pendulum. .... *Vibrational motion*

### Example

Suppose you walk in a straight line from point  $P$  to a point  $Q$ , 2 m away from  $P$ , and then walk back along the same line to  $P$ .

- What is your displacement for the round trip?
- What distance did you travel during the round trip?

### How to solve it!

- Because your final position is the same as your initial position your displacement is zero.
- Your distance travelled is  $2\text{ m} + 2\text{ m} = 4\text{ m}$ .

### Let's Exercise

- Match the terms in column A with the statements in column B.

#### Column A

- Rectilinear motion ( )
- Vibratory motion ( )
- Curvilinear motion ( )
- Rotary motion ( )

#### Column B

- Motion about an axis
- Motion along a curved path
- Motion in a straight line
- Spiral motion
- A to and fro motion

- What do you call the condition of an object whose position is not changing? \_\_\_\_\_.
- A child in a swing performs a type of motion referred to as \_\_\_\_\_.
- The motion of blades of a fan is known as \_\_\_\_\_ motion.

## Let's Go Further

- What is the difference in the type of motion between a ball kicked off vertically and at an angle into the air?
- Suppose an object moves from an initial position  $x_i = -1.2\text{ m}$  to a final position  $x_f = -2.3\text{ m}$  without reversing its direction of travel. Show the change in the position of an object using a diagram.
- An object moves from point  $P$  at  $x = +2.3\text{ m}$  to point  $Q$  at  $x = +4.1\text{ m}$  and then to point  $R$  at  $x = +1.5\text{ m}$ .
  - What is the object's displacement after traveling from point  $P$  to  $R$ ?
  - What is the distance between the object's initial and final positions?

## 2.2 MOTION ALONG A STRAIGHT LINE

The motion of a body along a straight line is called a *rectilinear motion*.

We can represent the motion of an object that moves from one position to another by an arrow that points from the initial position to the final position. This arrow represents a physical quantity called the *displacement of the object*.



Figure 2.2

The *distance* travelled is the distance covered by a moving object along the path of its motion.

An object's *average speed* is the distance travelled divided by the time interval required to travel that distance. The quantity that gives us both the speed and the direction of travel is *velocity*. An object's average velocity is its displacement divided by the length of the time interval taken to travel displacement.

$$\text{Average speed} = \frac{\text{Distance traveled}}{\text{time taken}}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{time taken}}$$

- ✓ Distance and speed are scalar quantities.
- ✓ Displacement and velocity are vector quantities.
- ✓ SI unit of speed and magnitude of velocity is m/s. In daily life, km/h is also used.

### Example

1. Suppose you walk in a straight line from a point *P* to a point *Q*, 2 m away to the right from *P*, and then walk back 1 m along the same line directed to *P*.
  - a) What is your displacement for the round trip?
  - b) What distance did you travel during the round trip?

#### How to solve it!

- a) Because your final position is 1 m away to the right from your initial position your displacement is 1 m to the right.
  - b) Your distance travelled is  $2 \text{ m} + 1 \text{ m} = 3 \text{ m}$ .
2. In case of **example question 1**, you walked from *P* through *Q* to the final position in 10 seconds.
    - a) What is your average velocity?
    - b) What is your average speed?

**How to solve it!**

- a) The displacement you travelled is 1 m to the right. Time taken is 10 s. The average velocity is  $1/10 = 0.1$  m/s to the right.
- b) The distance you travelled is 3 m. Time taken is 10 s. The average speed is  $3/10 = 0.3$  m/s.

**Let's Exercise**

- For the following quantity, write "S" for a scalar quantity and "V" for a vector quantity.
  - Velocity \_\_\_\_\_
  - Distance \_\_\_\_\_
  - Displacement \_\_\_\_\_
  - Speed \_\_\_\_\_
- What is the average speed of a cheetah that runs 100 m in 4 s? How about if it runs 50 m in 2 s?
- What do you mean by a constant speed?
- The speedometer of a car reads 100 km/h while it is moving to the east. The speedometer of another car reads 100 km/h while it is moving to the west. Do both cars have the same velocity?
- During a certain period of time, the speedometer of a car reads a constant 60 km/h. Does this indicate a constant speed or a constant velocity?
- Suppose you travel 10 km from *P* to *Q* at 10 km/h and another 10 km from *Q* to *R* at 20 km/h. What is your average speed during the entire trip from *P* to *R*?

**Let's Go Further**

- Information about three cars travelling on a road is given as shown below.

| Cars  | Distance Travelled in m | Time Taken in s |
|-------|-------------------------|-----------------|
| Car A | 80                      | 20              |
| Car B | 70                      | 20              |
| Car C | 90                      | 20              |

- Which car is moving faster? And what is the speed?
  - Which car is moving slowest? And what is the speed?
- If a car moves with an average speed of 60 km/h for an hour, it will travel a distance of 60 km. How far would it travel if it moved at this rate:
    - for 4 h?
    - for 5 h?

## 2.3 QUALITATIVE EXPLORATION OF CONSTANT VELOCITY

The motion of a body along a straight line with constant velocity or speed in a given direction is called *uniform motion*. This can be shown in **Figure 2.3** below is moving with uniform velocity. It covers equal distance in equal intervals of time.

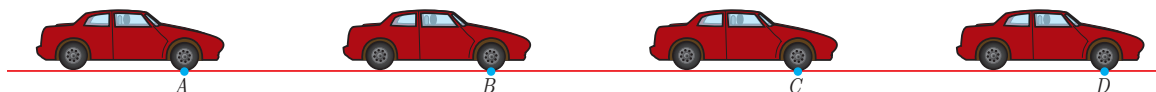


Figure 2.3

$$\vec{V} = \frac{\Delta \vec{S}}{\Delta t}, \text{ the SI unit of Velocity is 'm/s'.$$

### Example

The data on the motion of a certain body is measured and recorded in the table below.

|           |   |   |    |    |    |    |    |     |
|-----------|---|---|----|----|----|----|----|-----|
| $t$ (s)   | 0 | 1 | 2  | 3  | 4  | 5  | 6  | ... |
| $S$ (m)   | 0 | 5 | 10 | 15 | 20 | 25 | 30 | ... |
| $V$ (m/s) | 5 | 5 | 5  | 5  | 5  | 5  | 5  | ... |

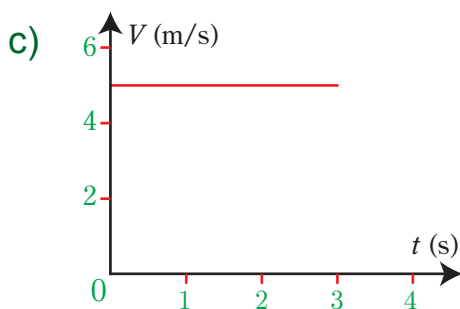
- Calculate the velocity of the body for each interval.
- What type of motion is it? Why?
- Draw the velocity-time graph.
- What is the nature of the graph?

### How to solve it!

$$\begin{aligned} \vec{V} &= \frac{\Delta \vec{S}}{\Delta t} = \frac{5 \text{ m} - 0}{1 \text{ s} - 0} = 5 \text{ m/s} \\ \vec{V} &= \frac{\Delta \vec{S}}{\Delta t} = \frac{10 \text{ m} - 5 \text{ m}}{2 \text{ s} - 1 \text{ s}} = 5 \text{ m/s} \\ \vec{V} &= \frac{\Delta \vec{S}}{\Delta t} = \frac{15 \text{ m} - 10 \text{ m}}{3 \text{ s} - 2 \text{ s}} = 5 \text{ m/s} \end{aligned}$$

⋮

- Motion with uniform velocity because the velocity (5 m/s) is constant through out the motion.



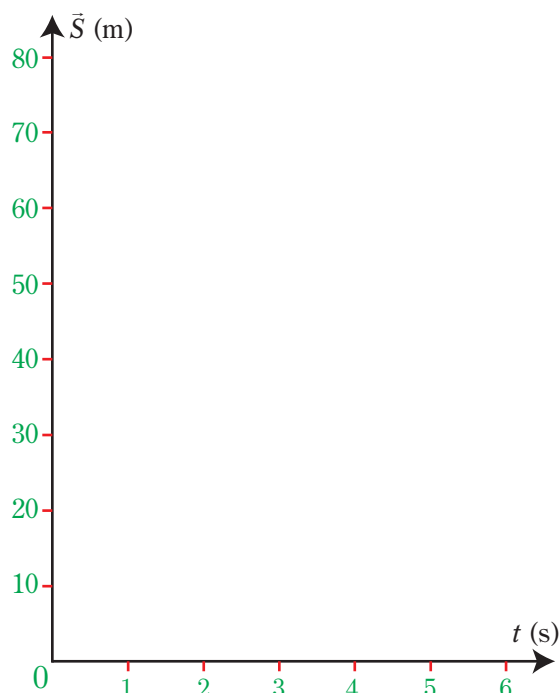
- The nature of the graph is parallel to the time axis.

### Let's Exercise

- When do you say a body is moving with uniform velocity?
  - When its speed is constant but the direction changes.
  - When its speed and direction of motion are changing.
  - When its speed increases fastly.
  - When its speed decreases fastly.
  - When its speed and direction of motion are not changing.
- In uniform motion \_\_\_\_\_ is constant.
- A bus is moving on a straight line towards north direction and covered a distance of 200 m in 4 seconds. Calculate the velocity of the bus.
- A car is moving with a speed of 40 m/s for 3 seconds in a given direction. What is the displacement of the car?
- How long does a body take to cover a distance of 100 m moving with a uniform velocity of 5 m/s?

### Let's Go Further

A car and a bus are moving on a straight line in a given direction with a speed of 20 m/s and 10 m/s respectively. Draw the displacement–time graph of the motion of the car and the bus in one graph and calculate the slopes of each graph.



**Hint!**

$$\text{Slope} = \frac{\Delta \vec{S}}{\Delta t}$$



## 2.4 QUALITATIVE EXPLORATION OF ACCELERATED MOTION

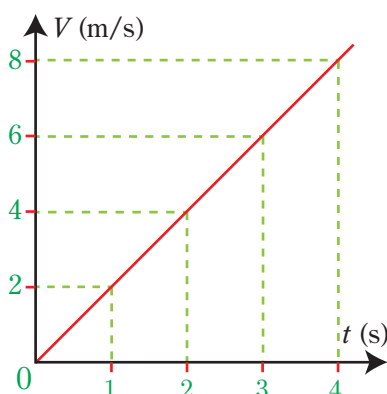
Uniformly accelerated motion is a motion that the velocity of a body changes equally for equal interval of time.

$$\text{acceleration } (\vec{a}) = \frac{v_f - v_i}{t}, \text{ where } v_f \text{—final velocity}$$

$$v_i \text{—initial velocity}$$

$$t \text{—time}$$

- ✓ Free fall is a type of uniformly accelerated motion of a body under the action of the force of gravity.
- ✓ Graphic representation of uniformly accelerated motion is shown below.



*This graph describes that the velocity changes in 2 m/s in every second.*



### Example

1. A train is moving 40 m/s starting from rest in 8 seconds. Calculate the acceleration of the train?
2. A ball is dropped from a certain height. After 2 s later it hits the ground. What is the velocity of the ball when it hits the ground? ( $g = 10 \text{ m/s}^2$ )

### How to solve it!

1. Given:

$$v_f = 40 \text{ m/s}$$

$$v_i = 0$$

$$t = 8 \text{ s}$$

Required:

$$a = ?$$

$$a = \frac{v_f - v_i}{t}$$

$$= \frac{40 \text{ m/s} - 0}{8 \text{ s}}$$

$$= 5 \text{ m/s}^2$$

2. Given:

$$v_i = 0$$

$$t = 2 \text{ s}$$

$$g = 10 \text{ m/s}^2$$

Required:

$$v_f = ?$$

$$a = \frac{v_f - v_i}{t}, \text{ since } a = g \text{ and } v_i = 0$$

$$\Rightarrow v_f = gt = 10 \text{ m/s}^2 \times 2 \text{ s}$$

$$= 20 \text{ m/s}$$

### Do You Know?

*In a free falling body the acceleration due to gravity ( $g$ ) is nearly  $10 \text{ m/s}^2$ .*

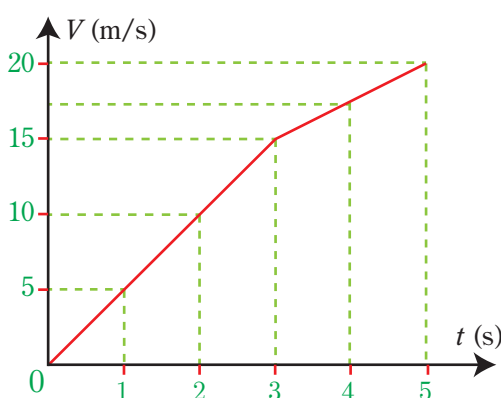


### Note:

If the velocity is decreasing uniformly, the acceleration will be negative. This motion is known as *deceleration*.

### Let's Exercise

1. A car starts from rest and travels with 20 m/s in 10 s. What is the acceleration of the car?
2. A stone is released from a certain height above the ground. If it hits the ground after 4 s, what will be the velocity of the stone just it strikes the ground? ( $g = 10 \text{ m/s}^2$ )
3. Using the graph shown below.



- a) Calculate the acceleration of the object during the first three seconds (0 – 3 seconds).
- b) Calculate the acceleration of the object during the last two seconds (3 – 5 seconds).
- c) What do you observe? (Relate the values you have got with the graph)

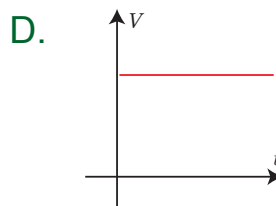
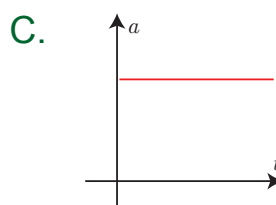
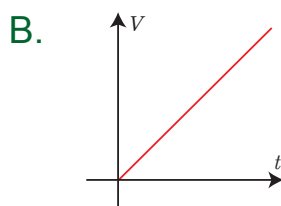
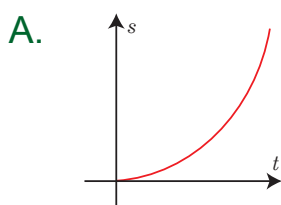
### Let's Go Further

1. A man is riding a motorbike. It speeds up 2 m/s to 10 m/s in 8 seconds uniformly:
  - a) what is the acceleration of a motorbike?
  - b) draw the velocity-time ( $v - t$ ) graph of the motion.
2. A car is moving with 20 m/s. A driver brakes as soon as he has seen a donkey in his way. Then the car stops after 5 s. Find the acceleration of this car.

## 2.5 UNIT SUMMARY

### I Choose the Correct Answer.

- If a body moves 20 m to the right and return back to its initial point on the same line, its displacement is:  
 A. 0                      B. 20 m left                      C. 20 m right                      D. 40 m left
- Which one of the following example describes vibratory motion?  
 A. The motion of a falling ball from a certain hight.  
 B. The motion of a wheel of a car.  
 C. The motion of a pendulum.  
 D. The motion of a moon around the earth.
- Which of the following graphs represents uniform motion?



### II Give Short Answer.

- The motion of an object along a straight line with a constant velocity is \_\_\_\_\_.
- The slope of distance versus time graph in uniform motion gives the magnitude of \_\_\_\_\_.
- If an athlete covers a distance of 3,000 m in 10 min. His/her average speed in m/s is \_\_\_\_\_.
- The rate of change of velocity and the rate of change of displacement are respectively \_\_\_\_\_ and \_\_\_\_\_.
- The ball is kicked to the air from the ground by the goal keeper and it came to rest after it passed half time of the football field. The type of motion that is performed by the ball is \_\_\_\_\_.
- The motion of the wheel of a singer (sewing machine) can be an example of \_\_\_\_\_.

# Unit **3**

## FORCE AND NEWTON'S LAWS OF MOTION

### Main Content

- 3.1 Force **24**
- 3.2 Measuring a Force **26**
- 3.3 Newton's First Law of Motion **28**
- 3.4 Newton's Second Law of Motion **30**
- 3.5 Weight **32**
- 3.6 Newton's Third Law (Law of Action and Reaction) **34**
- 3.7 Definition and Types of Frictional Force **36**
- 3.8 Effects of Friction **38**
- 3.9 Unit Summary **40**



## 3.1 FORCE

Force is a push or a pull exerted on a body by another body.

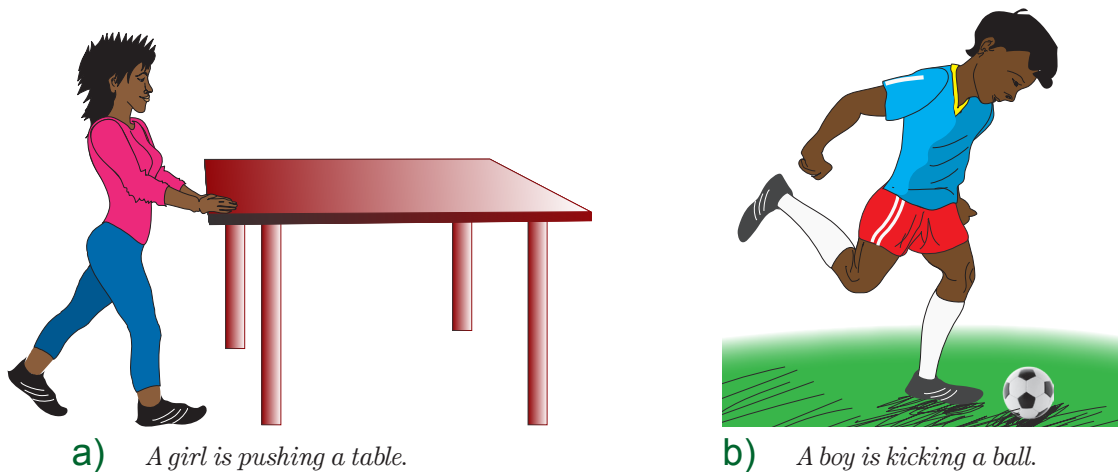


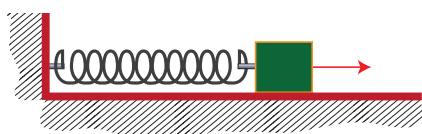
Figure 3.1

### TYPE OF FORCES

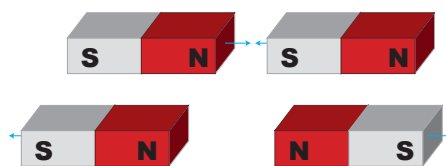
Forces are classified into two categories known as

i) *contact forces*, and

ii) *non-contact forces*



a) *Example of contact force*  
A force is exerted by stretched or compressed spring.



b) *Example of non-contact force*  
Attraction and repulsion force of magnets.

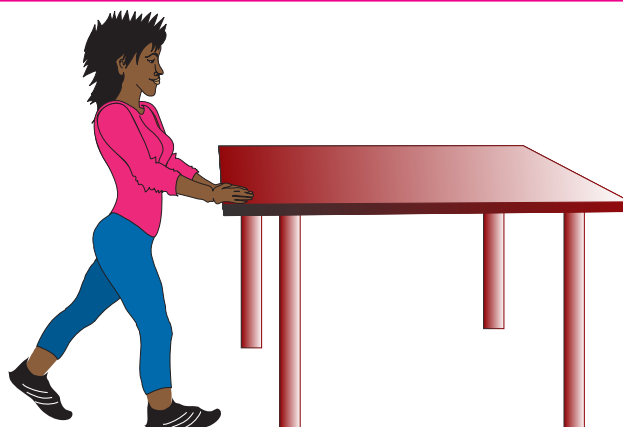
Figure 3.2

### EFFECTS OF FORCE

- i) It changes the shape and size of the objects.
- ii) It changes the magnitude or direction of motion of the objects.

### Example

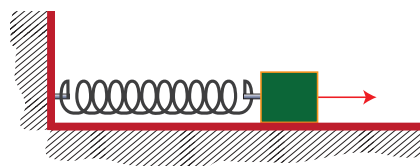
Forces are classified into two categories known as contact forces and non-contact forces. Classify the following forces into contact and non-contact force.



a) Force to push a table.



- b) Force to make a ball fall after being thrown up.



- c) Force to stretch a string.

### How to solve it!

- a) Hands and the table are touching each other. ( $\Rightarrow$  Contact force)
- b) The ball is not touching anything. ( $\Rightarrow$  Non-contact force)
- c) The spring and the object are touching each other. ( $\Rightarrow$  Contact force)

### Let's Exercise

Fill in the blank space.

1. Force is technical term in \_\_\_\_\_.
2. When you kick a ball, tear a paper and hold your exercise book, you apply \_\_\_\_\_.
3. Forces are classified into two categories known as \_\_\_\_\_ and \_\_\_\_\_ forces.
4. A force exerted by compressed or stretched spring is an example of \_\_\_\_\_ force.
5. Gravitational force is an example of \_\_\_\_\_ force.

## Let's Go Further

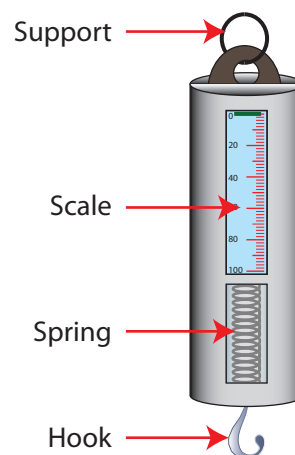
Identify the following forces whether they are contact or non-contact forces.

1. Magnetic force. ( )
2. Electrical force. ( )
3. Frictional force. ( )
4. Force exerted on a box placed on a floor. ( )
5. Force that is pushing a table. ( )
6. Force that is stretching a spring. ( )

## 3.2 MEASURING A FORCE

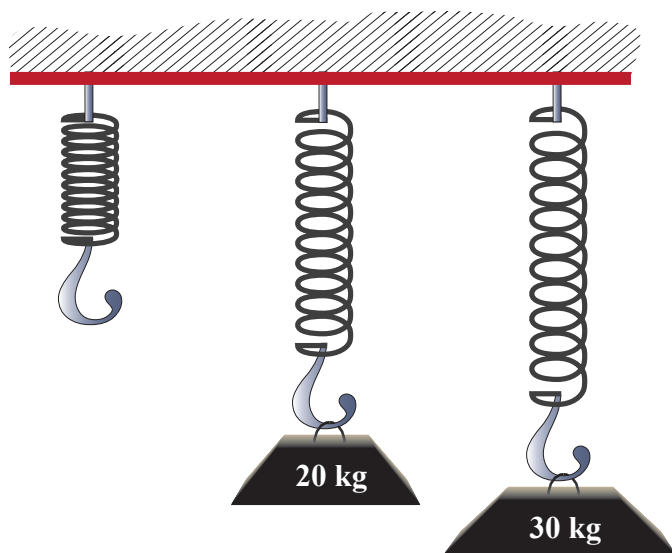
Force is measured using an instrument called *spring balance* or *Newton meter*. **Figure 3.3** to the right shows a structure of a spring balance.

If you hang 1 kg weight to the hook of the spring balance, the gravity is  $1 \times g$  N ( $g$  is the acceleration due to gravity and  $g = 10 \text{ m/s}^2$ ). Therefore the gravity is  $1 \times 10 = 10$  N. The spring balance indicates 10 N.

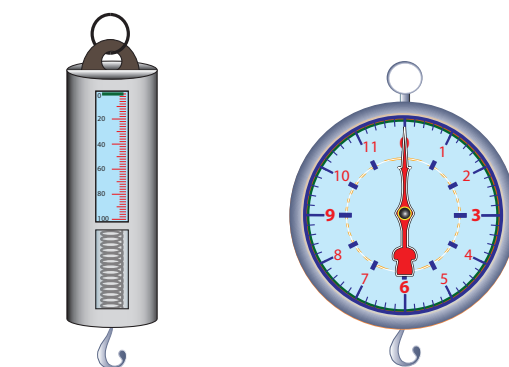


**Figure 3.3**

- ✓ When a mass is suspended from its end, it stretches.
- ✓ The amount of stretch depends on the weight or force.
- ✓ The larger the weight is suspended, the more the spring stretches.
- ✓ Force has both magnitude and direction. Hence, force is a vector quantity. The instrument indicates the magnitude.



**Figure 3.4**



*Instruments of measuring force*

**Figure 3.5**

As illustrated in **Figure 3.4** above, different forces are suspended on the spring. For example, 20 kg and 30 kg weights are suspended. 30 kg weight stretches the spring more than 20 kg weight.

The SI unit of force is Newton (N).

### Example

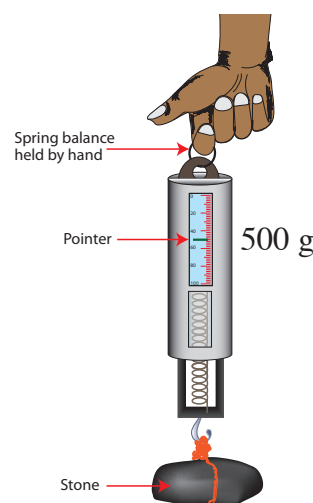
A student measured stone's weight using a spring balance as shown in **Figure 3.6** to the left. The spring balance indicates 500 g. What is the weight in newton? (Use  $g = 10 \text{ m/s}^2$ )

### How to solve it!

The mass of the stone is  $500 \text{ g} \Rightarrow m = 0.5 \text{ kg}$ .

Therefore, the weight will be

$$F = mg = 0.5 \times 10 = 5 \text{ N}$$



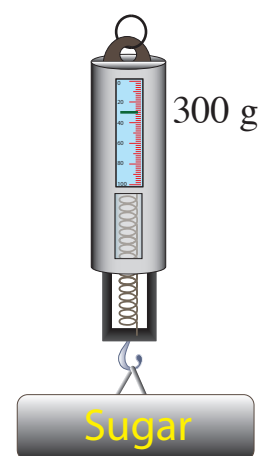
**Figure 3.6**

### Let's Exercise

1. The instrument used to measure force is \_\_\_\_\_.
2. The amount of stretch depends on the \_\_\_\_\_.
3. The larger the weight is suspended the more the spring \_\_\_\_\_.
4. Force has both \_\_\_\_\_ and \_\_\_\_\_.
5. Force is a \_\_\_\_\_ physical quantity.

## Let's Go Further

1. What will happen the length of the spring, if the force is increase from 8 N to 10 N?
2. What is the SI unit of force?
3. What instrument is used to measure force?
4. A student measured a weight of sugar using a spring balance as shown in **Figure 3.7**. The spring balance indicates 300 g. What is the weight in Newton? (Take  $g = 10 \text{ m/s}^2$ )



**Figure 3.7**

### 3.3 NEWTON'S FIRST LAW OF MOTION

**Newton's 1<sup>st</sup> law of motion:** states that an object at rest remains at rest and a body in a motion continues its motion with a constant speed to a specific direction unless unbalanced force acts on it.

The property of matter to resist change in state of motions is called *inertia*.

**Mass:** is a measure of inertia.

Inertia of a moving body depends on the mass of the body that means larger mass have more inertia than small mass. If small car and big car moving with the same speed the two cars do not stop at the same time, the biggest car is difficult to stop but the small car stops easily.

#### Example

If two objects of mass 10 kg and 6 kg are given, which object has greater resistance to change in its state of motions?

#### How to solve it!

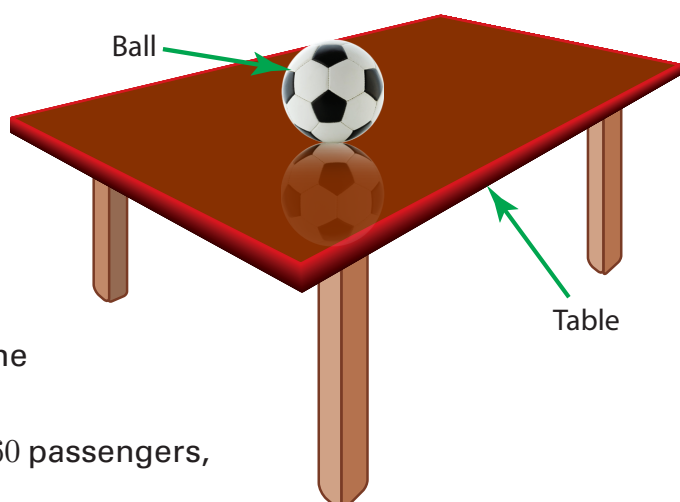
The 10 kg object has greater mass and has greater inertia.

#### Let's Exercise

1. Given two objects of mass 50 kg and 5 kg, from the two objects which one has the largest or greater inertia?
2. If we add the mass of the two objects stated in **Question 1** above, the resistance to change in its state of motion increases or decreases?
3. If a moving car stops suddenly, the passengers in the car fall forward, this is due to \_\_\_\_\_.
4. Abebe is 50 kg and Kasahun is 45 kg, they carry 10 kg and 15 kg objects, respectively. From the two:  
a) who has greater inertia?                      b) who has less inertia?

## Let's Go Further

1. If two cars of mass 500 kg and 1000 kg moving in opposite direction which car has more inertia? Why?
2. From **Figure 3.8** , if a table is suddenly pushed to the right, what would happen to the ball on the table.
  - A. Remain at rest.
  - B. Move to the right.
  - C. Move to the left.
  - D. Nothing is happened.
3. Consider the following conditions given from (a) to (d) and answer the question (i) – (iii).
  - a) Let a car of 4000 kg with 60 passengers, each of which is 50 kg.
  - b) A car of 6000 kg.
  - c) Two oxen 4000 kg and 3500 kg.
  - d) A loader of 8000 kg carrying 4000 kg car.
  - i) Which one have greater inertia?
  - ii) Which one has less inertia?
  - iii) List the inertia of **a**, **b**, **c** and **d** from high to low in order.
4. What is Newton's first law states?
5. State law of inertia.
6. Why a moving body follows forward when we stop it suddenly?



**Figure 3.8**

### 3.4 NEWTON'S SECOND LAW OF MOTION

Newton's second law of motion describes a relation which states that acceleration of a body is directly proportional to the force applied on it. More over, the acceleration is inversely proportional to mass of a body on which the force is applied.

It is mathematically expressed as:

$$\text{Acceleration } (\vec{a}) = \frac{\text{Force } (\vec{F})}{\text{Mass } (m)}$$

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

1 N is the force needed to give an acceleration of  $1 \text{ m/s}^2$  to mass of 1 kg.

In Newton's 2<sup>nd</sup> law, you will learn how to measure the magnitude of a force required to bring a given body to rest or set in motion.

The SI unit of acceleration is  $\text{m/s}^2$ .

#### Example

If a force of 20 N is required to move a block of mass 5 kg. Calculate the acceleration of a block caused by the force.

#### How to solve it!

Given:

$$F = 20 \text{ N}, m = 5 \text{ kg}$$

Required:

$$\vec{a} = ?$$

$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{20 \text{ N}}{5 \text{ kg}} = 4 \text{ m/s}^2 \end{aligned}$$

#### Let's Exercise

1. State the relationship between mass and force.
2. From the formula  $\vec{a} = \frac{\vec{F}}{m}$ , derive (write) the formula for 'F' and 'm'.
3. Explain the relation between mass and acceleration of a body.
4. A car is accelerated by  $2 \text{ m/s}^2$  when a force of 200 N is applied on it, then calculate the mass of the car.

5. Abera pulls a car of mass 500 kg through a distance of 10 m with the acceleration of  $1 \text{ m/s}^2$ . What is the force with which Abera pulls the car?

## Let's Go Further

- A mass of 5 kg body is accelerating by  $2 \text{ m/s}^2$  when 10 N force is applied on it.
  - What is the acceleration of a body if the force is not changed and mass is doubled?
  - What is the acceleration of a body if the force is not changed and mass is halved?
- Figure 3.9, shows that two objects of different masses  $m_1$  setting over  $m_2$ , and they are fixed.  $m_2$  is on the floor surface.

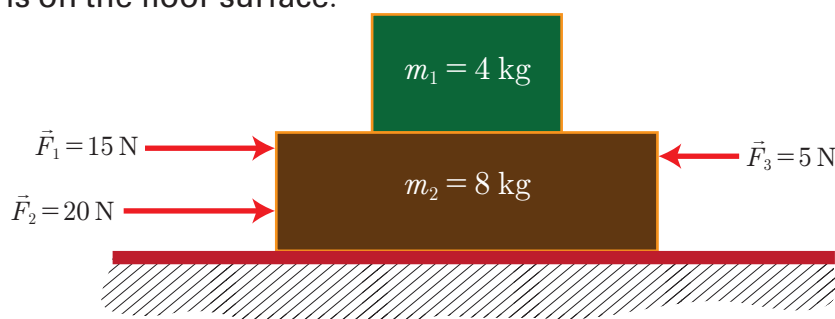


Figure 3.9

From Figure 3.9 above:

- calculate the acceleration of  $m_1$  and  $m_2$ .
  - explain the direction of motion of  $m_1$  and  $m_2$  with the reason.
  - what is the direction of the acceleration of the body?
- 3.
- 

Figure 3.10

The three objects in Figure 3.10, above A, B and C are listed with the forces acting on them. Thus, the total force acting on:

- object A is \_\_\_\_\_.
- object B is \_\_\_\_\_.
- object C is \_\_\_\_\_.

## 3.5 WEIGHT

Mass and weight are two different quantities that can easily confuse students. Mass is the amount of matter in a body, and it can be expressed in kilogram (kg) while weight is the pull of the earth on an object, and it is measured and expressed in Newton (N).

The mass of a body characterizes its inertia and the mass of a given body is the same everywhere even if it is on the moon. An object which has a mass of 10 kg on earth also has a mass of 10 kg on the moon.

On the other hand, the weight of an object is the gravitational force exerted on it by the Earth or other massive body. Since on the moon the magnitude of the gravitational force is  $\frac{1}{6}$  of that on earth, the weight on the moon is  $\frac{1}{6}$  of that on the earth.

Weight is a kind of force, so weight is a vector quantity, whereas mass is a scalar quantity.

### Example

Write mass or weight on the right column for the expression listed under left column.

|    | Expression                      | Mass/Weight |
|----|---------------------------------|-------------|
| 1. | Force                           |             |
| 2. | Measured in kilogram            |             |
| 3. | Measured in Newton              |             |
| 4. | Decreases as you go to the moon |             |
| 5. | No change as you go to the moon |             |

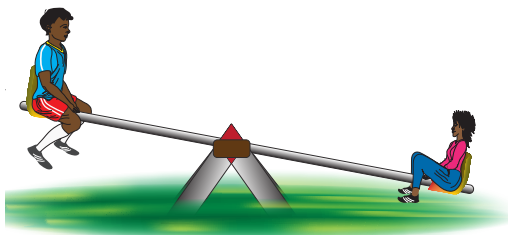
### How to solve it!

1. Weight is a kind of force. ( $\Rightarrow$  Weight)
2. Kilogram is a unit of mass. ( $\Rightarrow$  Mass)
3. Newton is a unit of force. Weight is a kind of force. ( $\Rightarrow$  Weight)
4. On the moon the weight is  $\frac{1}{6}$  of that on earth. ( $\Rightarrow$  Weight)
5. Mass is the same everywhere. ( $\Rightarrow$  Mass)

**Let's Exercise**

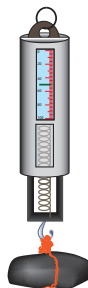
Which of the following shows the mass/weight?

a)



---

c)



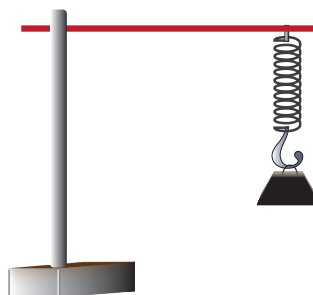
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b)



---

d)



---

**Let's Go Further**

1. How do you relate mass and weight? Let an object has a mass of 4 kg. What is its weight?
2. Suppose an object weighing 500 N on earth is taken to the Moon. Answer the following questions based on the information given above. (Take:  $g_E = 10 \text{ m/s}^2$ )
  - i) What is the mass of the object:
    - a) on the moon?
    - b) on the earth?
  - ii) What is its weight on the moon? (Hint:  $g_{\text{Moon}} = 1/6 g_E$ )

## 3.6 NEWTON'S THIRD LAW (LAW OF ACTION AND REACTION)

Newton's third law of motion deals with two equal and opposite forces acting on two different bodies. For example, when you push a wall with your hand, the wall also pushes your hand. These two forces are equal in magnitude, but the directions are opposite.



Figure 3.11

The next is another example, when you place a book on a table, the book pushes down the table by a force equal to its weight. At the same time the table pushes the book upward by an equal magnitude of force. These paired forces are called *action and reaction forces*.

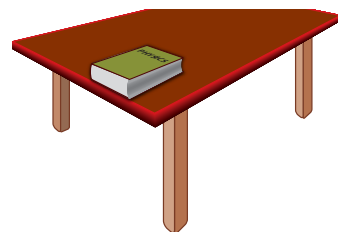


Figure 3.12

**Newton's Third Law of Motion:** Every action force is accompanied with reaction force which has equal magnitude but opposite in direction.

$$\vec{F}_A = -\vec{F}_R, \text{ where } \vec{F}_A - \text{Action force,} \\ \vec{F}_R - \text{Reaction force}$$

When a body exerts a force on another body, the second body also exerts an equal force on the first body in opposite direction.

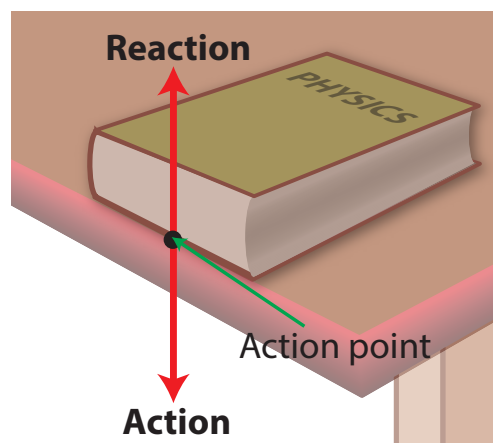
### Example

Indicate action and reaction forces in **Figure 3.12** shown above.

#### How to solve it!

Let us consider the **cross sectional diagram** of the book and the table and indicate the two forces.

- ✓ Action force acts at surface of the table downward.
- ✓ Reaction force acts at surface of the book upward.



### Let's Exercise

#### I Fill in the Blank Space.

1. For every action force there is reaction force which is equal in magnitude and opposite in \_\_\_\_\_.
2. Action and reaction forces are \_\_\_\_\_ in magnitude and \_\_\_\_\_ in direction.
3. If an action force is (equal to) 500 N due south, the reaction force is (equal to) \_\_\_\_\_.

#### II Write True or False for the Following Statements.

4. Action and reaction forces have different magnitude.
5. Action and reaction forces act on two different bodies.
6. If the direction of an action force is due East, the direction of the reaction force has to be due West.

#### III Give Short Answer.

7. Describe the direction of action and reaction forces for the motion of launching space ship shown below.



## Let's Go Further

A monkey on a small boat with a lot of oranges threw them in a certain direction. As a result the boat started to move.

- a) What is the direction of motion of the boat?
- b) What is the reason for the motion of the boat?

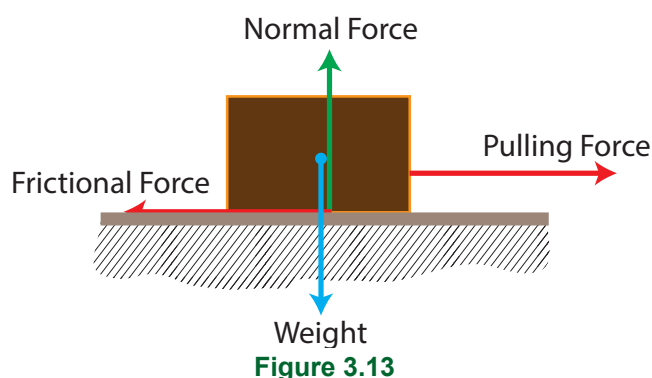
### 3.7 DEFINITION AND TYPES OF FRICTIONAL FORCE

Frictional force is a force that oppose or resist the motion of two bodies that are in contact. Frictional force is important in our day to day activities. For example, we need frictional force to ride a bicycle, to walk, to sit and so on.

Frictional force depends on:

- ▶ the roughness of the surface in contact, and
- ▶ the normal force.

When an object lies on a horizontal surface, the normal force is equal in magnitude with the weight of the object.



There are two types of frictional force namely static frictional force and kinetic frictional force.

Static frictional force is a force that oppose the motion of an object at rest. Whereas kinetic frictional force is a force that is constantly opposing the motion of an object.

Frictional force is proportional to the normal force, i.e.,  $F_s \sim N$  and  $F_k \sim N$

$F_s = \mu_s N$  and  $F_k = \mu_k N$ , Where  $F_s$  – static frictional force  
 $F_k$  – kinetic frictional force  
 $\mu_s$  and  $\mu_k$  are coefficient of static and kinetic frictional force respectively.

#### Note That:

The value of  $\mu_s$  and  $\mu_k$  are positive and usually less than one.

## Example

1. An object having a mass of 20 kg lies on a horizontal surface. What is the magnitude of:
  - a) the normal force, and
  - b) the weight of the object?

### How to solve it!

Since the object lies on a horizontal surface the magnitude of the normal force and the weight is the same, that means

$$\text{Weight} = mg$$

$$\text{Weight} = 20 \text{ kg} \times 9.8 \text{ m/s}^2 = 192 \text{ N}$$

Therefore, Normal Force ( $F_N$ ) = 192 N

2. In **Figure 3.14**, if the mass of the object is 10 kg and the coefficient of static friction is 0.1, what is the magnitude of static friction?

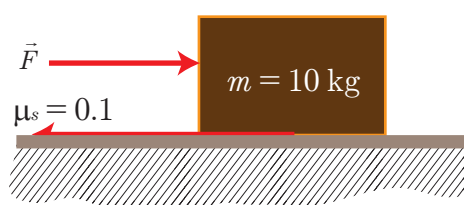


Figure 3.14

### How to solve it!

Using the formula,

$$F_s = \mu_s F_N$$

$$F_s = \mu_s (mg)$$

$$F_s = 0.1 \times 10 \times 9.8 = 9.8 \text{ N}$$

## Let's Exercise

The force of static friction between a body of mass 60 kg and a horizontal surface is measured as 200 N. What is the coefficient of static frictional force?

## Let's Go Further

Both coefficient of static and kinetic frictional force are unit less. Prove it.

## 3.8 EFFECTS OF FRICTION

Friction is very important.

In our daily life, we have both advantage and disadvantage for friction.

| Advantages of Friction                                                         | Disadvantages of Friction                                     |
|--------------------------------------------------------------------------------|---------------------------------------------------------------|
| <input checked="" type="checkbox"/> We can walk on the road.                   | <input checked="" type="checkbox"/> Wastage of energy.        |
| <input checked="" type="checkbox"/> Cars can move and stop by using tire.      | <input checked="" type="checkbox"/> Wearing out of a surface. |
| <input checked="" type="checkbox"/> We can use brake to stop cars or bicycles. | <input checked="" type="checkbox"/> Generating heat.          |

It is important to reduce friction. Friction cannot be eliminated completely, but can be reduced to the minimum value.

### METHODS OF REDUCING FRICTION

- ☒ Making a surface smooth.
- ☒ Lubrication.
- ☒ Rolling bodies.

### Example

Among the following situation which is advantage of effect of friction, put tick mark (✓) on the given spaces.

- a) A man walks on a level ground. ( )
- b) A car turns around a square asphalt road. ( )
- c) Hinges of an old door is difficult to move. When the door was opened the hinges made a noise. ( )

### How to solve it!

- a) The people cannot walk without friction. Therefore, friction is important. It is advantage (✓).
- b) If friction is absent, its inertia will take the car straight forward and can not change its direction. Therefore, friction is helpful. It is advantage (✓).
- c) The hinges of the door have large friction. Frequent motion of hinges causes rise in temperature on them. It is disadvantage. To reduce friction, the hinges have to be lubricated with oil.

### Let's Exercise

- Among the following situation does friction take an important role? If it does, put tick mark (✓) on the given spaces.
  - Letters are written on a blackboard with chalk. ( )
  - Bicycle is moved by using tire on a road. ( )
  - A large box is carried by a hand cart with wheels. ( )
  - In a car engine, the piston is vibrating rapidly. ( )
- Fill in the blanks.
  - Friction is reduced by \_\_\_\_\_ with grease.
  - If there were no friction, walking would be \_\_\_\_\_.
  - The force of friction produces \_\_\_\_\_ that deforms the parts of machine.
- State the factors in which frictional force depends on.

### Let's Go Further

- A 80 kg physics teacher pushes a 1 kg physics textbook on a 22 kg physics demo table. ( $g = 10 \text{ m/s}^2$ )
  - If the teacher needs to apply a force of 5.0 N to start the book sliding, what is the coefficient of static friction between the book and the table?
  - If the teacher needs to apply a force of 4.0 N to keep the book sliding at constant 0.3 m/s across the table, what is the coefficient of kinetic friction between the book and the table?
- Draw a force diagram of situation above.
- Figure 3.15** shows, the forces acting on a motorcycle as it travel on a flat road.
  - Two of the forces have effects that cancel each other out. Which two? Explain your answer?
  - Which one is the friction? Explain your answer.

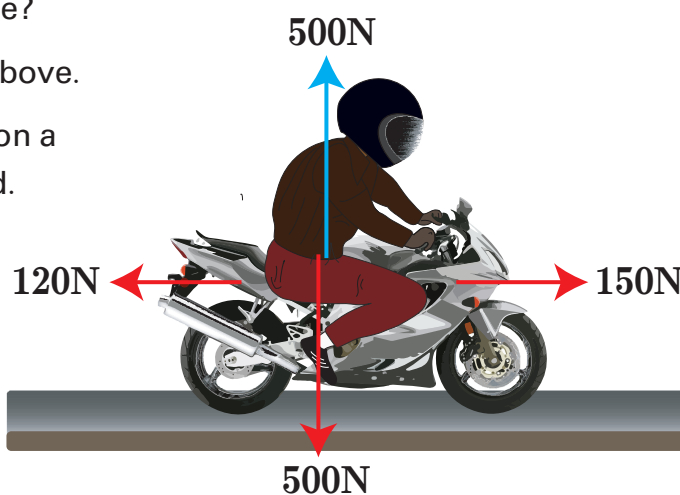


Figure 3.15

## 3.9 UNIT SUMMARY

### I Choose the Correct Answer.

- Kebede run 400 m around a track on football field. What type of path did he performed in his motion?
  - Curvilinear
  - Rectilinear
  - Rotary
  - Vibrating
- A boy wants to buy a 3.5 kg sugar from a shop. Then the shop keeper uses a pan balance to measure the sugar. If the shop keeper puts a 1 kg, 2 kg and  $x$  kg standard masses in one pan and exactly balances the 3.5 kg sugar. What is the value of the standard mass  $x$ ?
  - 0.5 kg
  - 1 kg
  - 2 kg
  - 3.5 kg
- Which one of the following measuring device and SI unit of force are correctly paired?
  - Beam balance, kilogram
  - Spring balance, kilogram
  - Beam balance, Newton
  - Spring balance, Newton
- Which of the following forces can be an example of contact force?
  - Electrical force
  - Frictional force
  - Magnetic force
  - Gravitational force

### II Give Short Answer.

- Mass of four different bodies are given in the table below. Which body has the largest inertia?

| Body | Mass (kg) | Speed (m/s) |
|------|-----------|-------------|
| $X$  | 20        | 50          |
| $Y$  | 30        | 40          |
| $Z$  | 40        | 30          |
| $W$  | 50        | 20          |

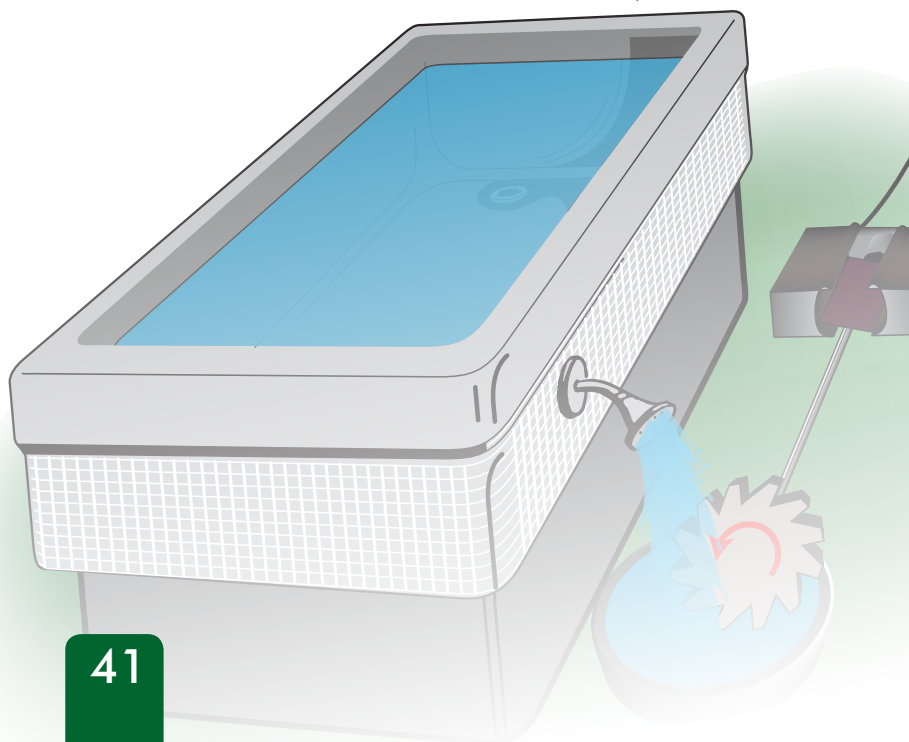
- How do you relate mass and inertia? Explain.
- What is the instrument used to measure force?
- State the law of inertia.

# Unit 4

## WORK, ENERGY AND POWER

### Main Content

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- 4.2 Definition of Energy 44
- 4.3 Kinetic Energy and Potential Energy 46
- 4.4 Transformation and Conservation of Energy 48
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## 4.1 WORK

In our society, both physical and non-physical activities are considered as *work*. However, in physics work is said to be done when energy is transformed from one form to another.

The amount of work done can be calculated using the equation:

$$\text{Work done} = \text{Force} \times \text{Displacement (along the direction of force)}$$

$$W = F \times \vec{S}$$

The SI unit of work is Joule (J).

$$1 \text{ J} = 1 \text{ N m}$$

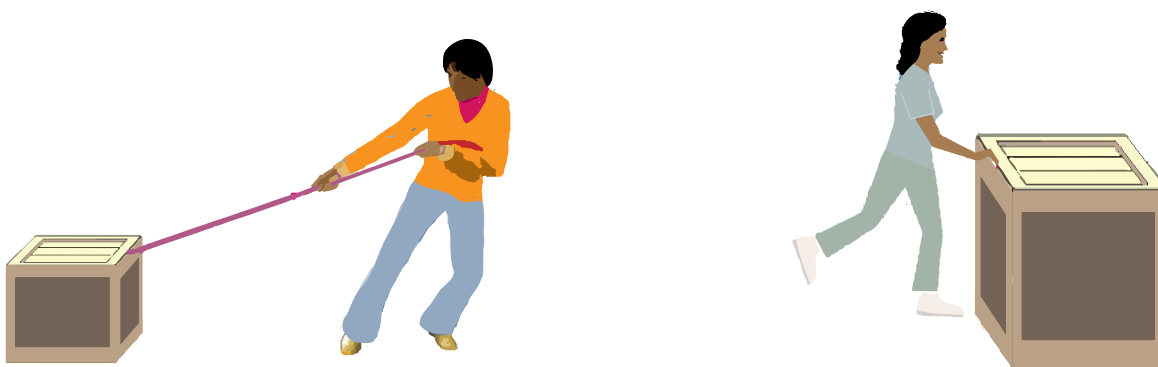


Figure 4.1

### Example

How much work is done in lifting 5 kg bag of Teff to a 1.5 m height?

**How to solve it!**

Given:

$$m = 5.0 \text{ kg}, h = 1.5 \text{ m}$$

Required:

$$\text{Work done (} W \text{)} = ?$$

In this case,  $F = \text{weight of the mass}$  and  $s = h = 1.5 \text{ m}$

$$F = mg, \text{ but } g = 10 \text{ m/s}^2$$

$$= 5.0 \text{ kg} \times 10 \text{ m/s}^2$$

$$= 50 \text{ N}$$

$$W = \text{Weight} \times \text{Height}$$

$$= 50 \text{ N} \times 1.5 \text{ m}$$

$$= 75 \text{ N} \cdot \text{m}$$

$$= 75 \text{ J}$$

Therefore, 75 J of work is done against gravity in lifting 5.0 kg bag of Teff on to 1.5 m height.

### Let's Exercise

1. What is the SI unit of work?
2. Is work done by a gravitational force to increase potential energy on an object?
3. Suppose a block is drag straight forward on a flat surface. The block has moved 20 m by applying 500 N force. Calculate the work done by the force against friction.

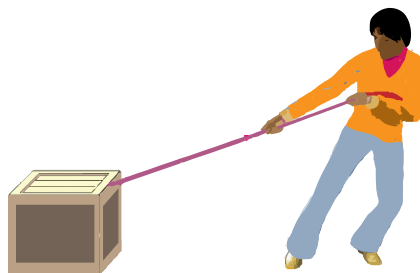


Figure 4.2

### Let's Go Further

1. In pushing a cart forward, if the force is doubled by what factor does the work change?
2. Suppose a force acting on a cart by a man being the same force, if the distance ( $S$ ) in moving a cart forward is halved ( $\frac{1}{2}S$ ), by what factor does the energy transformed by the man change?

**Do You Know?**

*Work done and energy transformed are equivalent.*

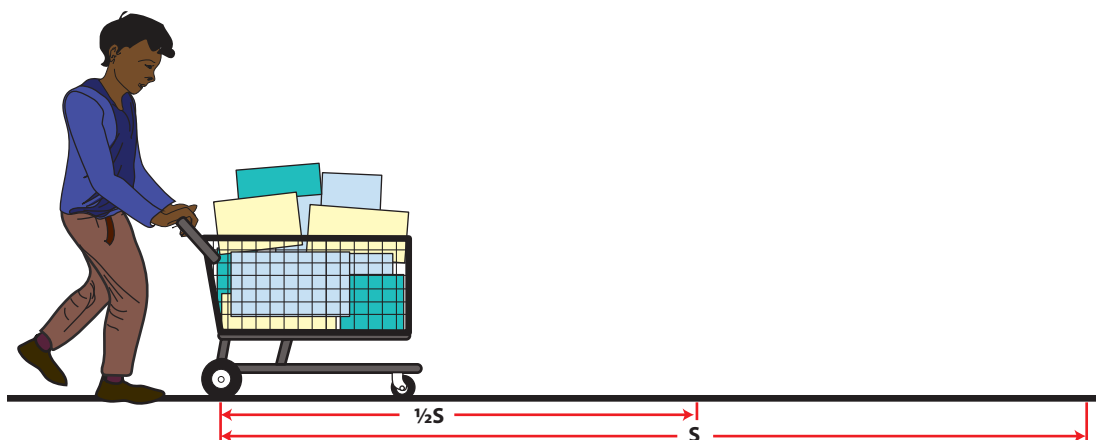


Figure 4.3

## 4.2 DEFINITION OF ENERGY

**Energy** is a property that objects possess. The fact that a body possesses energy means that it has ability to do work. Thus, the energy of a body is equal to the quantity of work that the body can do.

Energy is the capacity to do work. It is a scalar quantity and its SI unit is Joule (J).

In this world, there are different forms of energy. Some of them are Mechanical energy, Electrical energy, Chemical energy, Nuclear energy, Solar energy, Heat energy, and Sound energy.

### Note That:

Energy is transferred from one form into another.

**Mechanical energy** is the energy possessed by an object due to its *motion* and *position*.

There are two types of mechanical energy.

- i) Kinetic Energy (K.E.)
- ii) Potential Energy (P.E.)



### Example

Among the following concepts, if the concept of energy is correct, put tick mark (✓) on the given spaces, if not leave it as it is.

- a) A body is capable of doing work without possessing energy. ( )
- b) Energy is a scalar quantity. ( )
- c) The quantity of work that the body can do is equal to the energy of the body. ( )

### How to solve it!

- a) A body cannot do work unless it possess energy. So it is incorrect.
- b) Energy is a physical quantity with only magnitude. So it is scalar quantity.
- c) Energy of a body is equal to the amount of work that the body can do, it is correct.

### Let's Exercise

1. Define what energy mean?
2. Write at least three forms of energy.
3. What is the SI unit of energy?
4. Which forms of energy have abundance sources of energy relative to the other forms of energy.
5. Explain briefly what mechanical energy is.
6. List the two types of mechanical energy.

## Let's Go Further

1. There is a spring on a table (**Figure 4.4**). When an object is put on the spring, the spring shrinks and stops the motion after a while. Does shrunk spring have energy? If it has energy, what type of energy is it?

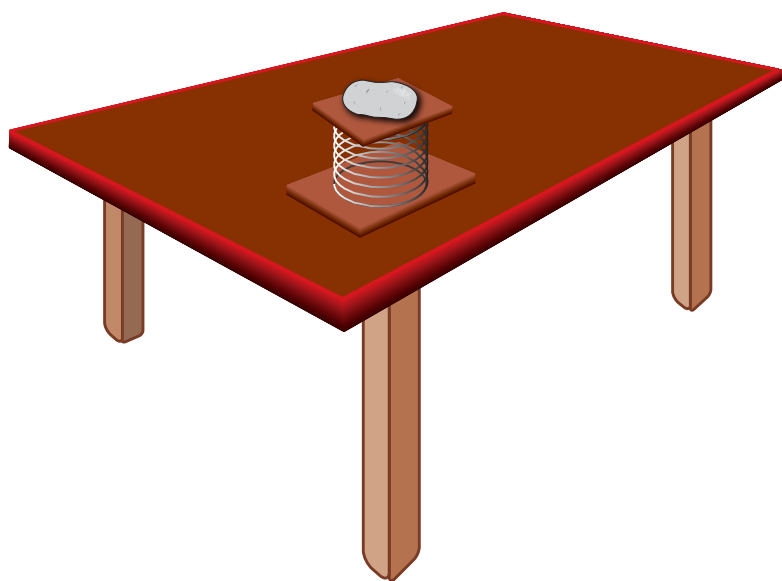


Figure 4.4

2. A hydroelectric plant needs dam to generate electricity. A hydroelectric plant which has huge dam which reserves large amount of water generates huge power otherwise it generate relatively less power. Why?

## 4.3 KINETIC ENERGY AND POTENTIAL ENERGY

An object of mass " $m$ " at a vertical height " $h$ " above the ground has a gravitational potential energy ( $G.P.E.$ ) of " $mgh$ ".

Supposed a stone whose  $G.P.E.$  30 J is dropped.



Its  $G.P.E.$  is 30J at the heighest position



Its  $G.P.E.$  is 15J at the mid position



Its  $G.P.E.$  is 0J at the bottom position

$G.P.E. = mgh$ ; where,  $m = \text{mass}$

$g = \text{acceleration due to gravity}$

$h = \text{height}$

### Example

What is the gravitational potential energy of a 5 kg stone at the top of 10 m high building? (Use  $g = 10\text{m/s}^2$ )

### How to solve it!

Given:

$$m = 5 \text{ kg}, h = 10 \text{ m}, g = 10 \text{ m/s}^2$$

Required:

$$G.P.E. = ?$$

$$G.P.E. = mgh$$

$$= 5 \text{ kg} \times 10 \frac{\text{m}}{\text{s}^2} \times 10 \text{ m}$$

$$= 500 \text{ kg} \cdot \frac{\text{m}^2}{\text{s}^2}$$

Answer, a 5 kg stone placed at a 10 m high building has a  $G.P.E.$  of 500 J.

## KINETIC ENERGY

Kinetic energy is the energy in a body due to its speed.

An object of mass " $m$ " travelling at a velocity " $v$ " has a kinetic energy of  $\frac{1}{2} mv^2$ .

**Example**

A ball of 3 kg is traveling at a speed of 4 m/s. What is its kinetic energy?

**How to solve it!**

Given:

$$m = 3 \text{ kg}, v = 4 \text{ m/s}$$

Required:

$$K.E. = ?$$

$$\begin{aligned} K.E. &= \frac{1}{2}mv^2 \\ &= \frac{1}{2} \times 3 \text{ kg} \times (4 \text{ m/s})^2 \\ &= \frac{3}{2} \times 16 \text{ kg} \cdot \text{m/s}^2 \cdot \text{m} \\ &= 24 \text{ N} \cdot \text{m} \\ &= 24 \text{ J} \end{aligned}$$

A ball of mass 3 kg traveling at 4 m/s has a kinetic energy of 24 J.

**Let's Exercise**

1. A monkey is on the top of 15 m tall tree. If the monkey's mass is 10 kg, how much gravitational potential energy does it have at the top of the tree.  
(Use the bottom of the tree as zero height and  $g = 10 \text{ m/s}^2$ .)
2. A motor cycle has a mass of 100 kg and it is traveling at a speed of 60 m/s. What is the kinetic energy of the motorcycle?

**Do You Know?**

- ✓ In a freely falling body the sum of the kinetic energy and the gravitational potential energy is constant.
- ✓ If there is no dissipative force, kinetic energy is maximum at a position where gravitational potential energy is minimum and the vice versa.

**Let's Go Further**

The maximum potential energy of a pendulum at the highest position is 2000 J. What are the values of its kinetic energy and potential energy at the bottom of the pendulum?

## 4.4 TRANSFORMATION AND CONSERVATION OF ENERGY

In our daily life, we use different forms of energy. Energy change (transformation) is needed to enable people, machines, computers and other devices to do work.

A form of energy can be changed into other forms of energy.

### Example

- ✓ When a ball is thrown upward, *K.E.* (Kinetic Energy) is converted into *P.E.* (Potential Energy).
- ✓ In a flashlight, chemical and electrical energy is converted into light and heat energy.

### TRANSFORMATION OF ENERGY OF FALLING OBJECT

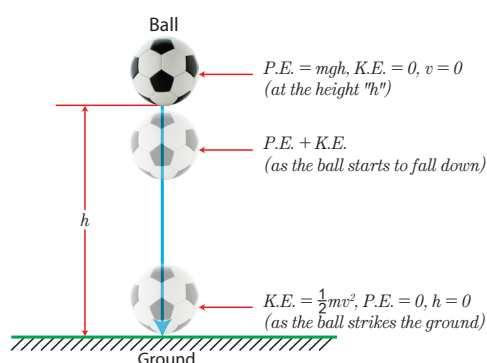


Figure 4.5: Falling Object

### TRANSFORMATION OF MECHANICAL ENERGY IN SIMPLE PENDULUM

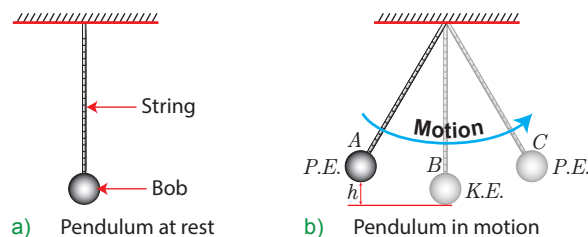


Figure 4.6: Pendulum

### Let's Exercise

1. An object placed at the top of the building has \_\_\_\_\_ energy.
2. A falling objects has \_\_\_\_\_ and \_\_\_\_\_ energy.
3. At position "A" a bob **Figure 4.6 (b)** has \_\_\_\_\_ energy.

## Let's Go Further

1. Why falling objects has both *K.E.* and *P.E.*?
2. Why the energy of an object at the top is equal to the energy at the bottom?

The law of conservation of energy is one of the universal law of nature and it is stated as follows:

*"Energy is neither created nor destroyed."* It only transforms from one form to another forms.

## ENERGY OF FALLING WATER

The mechanical energy ( $M.E.$ ) that a body possesses exists as potential energy ( $P.E.$ ) or kinetic energy ( $K.E.$ ) or both.

- ✓ Falling water is a main source of hydroelectric energy.
- ✓ When the water reaches the turbine blades it has only kinetic energy ( $M.E. = K.E.$ ).

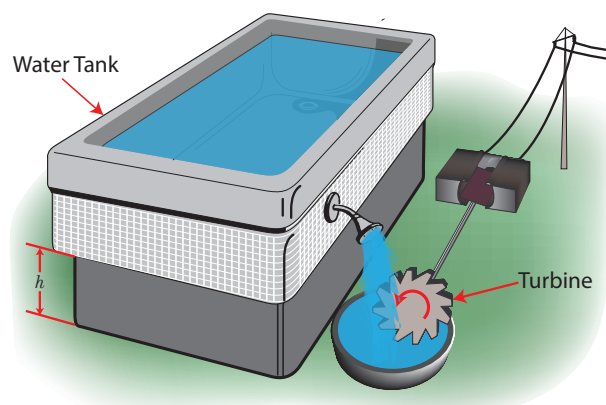


Figure 4.7: Water turbine

The water at the intake tower have only a potential energy due to its position ( $M.E. = P.E.$ ). When the water passes through the pipe its energy is the sum of both  $K.E.$  and  $P.E.$  That is,

$$M.E. = P.E. + K.E.$$

Energy of falling water shows that the total  $M.E.$  of the system remains constant.

## WIND ENERGY

A giant wind mill called *wind turbine* with two or more blades mounted on a tall tower can drive an electrical generator attached to it. This is done when the wind with a kinetic energy rotates the blades.

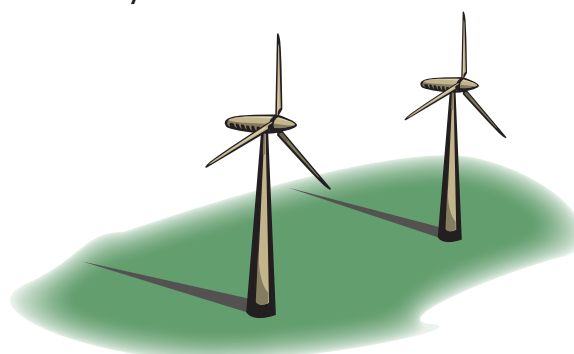


Figure 4.8: Wind mill

### Let's Exercise

1. Falling water is the main source of \_\_\_\_\_ energy.
2. When the water passes through the pipe placed at the height " $h$ " in Figure 4.7 its energy is the sum of \_\_\_\_\_ and \_\_\_\_\_ energy.

## Let's Go Further

1. What form of energy does wind have?
2. State the law of conservation of energy.
3. Explain the different form of energy possessed by falling object from a certain height.

## 4.5 POWER

Power is defined as the rate of doing work or the rate of energy expended.

$$\text{Power} = \frac{\text{Work done}}{\text{time taken}} = \frac{\text{Energy transferred}}{\text{time taken}}$$

$$P = \frac{W}{t}, \text{ where } P - \text{power}$$

$W$  – work done

$t$  – time taken

As work and energy are scalar quantities, power is also a scalar quantity.

### Example

A machine lifts a 20 kg mass to a height of 30 m in 2 s. Calculate the power developed by the machine. (Take  $g = 10 \text{ m/s}^2$ )

### How to solve it!

Given:

$$m = 20 \text{ kg}, h = 30 \text{ m}, g = 10 \text{ m/s}^2$$

Required:

$$P = ?$$

$$P = \frac{\text{Energy transferred}}{\text{time taken}} \text{ but, energy transferred} = \text{P.E.} = mgh$$

Thus,

$$\begin{aligned} \text{Power (P)} &= \frac{mgh}{t} \\ &= \frac{20 \text{ kg} \times 10 \text{ m/s}^2 \times 30 \text{ m}}{2 \text{ s}} \\ &= \frac{6000 \text{ kg m}^2/\text{s}^2}{2} = 3000 \text{ W} \end{aligned}$$

### Let's Exercise

1. Define power?
2. Power is \_\_\_\_\_ quantity?
3. A machine lifts 20 kg mass to a height of 2 m in 2 s, calculate the power developed by the machine. (Use  $g = 10 \text{ m/s}^2$ )

## UNITS OF POWER

The SI unit of power is Watt (W) which is equal to  $\frac{\text{Joule}}{\text{Second}}$ .

$$1 \text{ W} = 1 \text{ J/s}$$

When larger quantities of power are involved. We can use kilowatt (kW) and megawatt (MW). Where,

$$1 \text{ kW} = 1,000 \text{ W}$$

$$1 \text{ MW} = 1,000,000 \text{ W}$$

### Let's Exercise

1. The SI unit of power is \_\_\_\_\_.
2. Convert 2 MW to W.
3. 5 kW is \_\_\_\_\_ Watt (W).
4. What is the power of an electric "Mitad"? Which transfers 4 kJ of electric energy in 2 seconds.
5. A 50 kg man runs up a stair case reaches the next floor at a height of 4 m in 4 seconds. What is the power developed by him?

## Let's Go Further

1. Abdi displaces block of 10 kg mass to a 8 m height in 2 minutes. Tola displaces the same block of mass to the same height in 4 minutes. Who has more power? Abdi or Tola? Explain it.
2. A full bucket of water weights 5 kg and a water well is 4 m deep. A girl draws the water from the well. It takes 2 minutes to draw a full bucket of water from the well. What is the power of the task? (Take  $g = 10 \text{ m/s}^2$ )
3. Calculate the power of a pump that can lift 200 liters of water through a vertical height of 11 m in 5 seconds. (1 liter of water is 1 kg)

## 4.6 UNIT SUMMARY

### I Choose the Correct Answer.

1. Suppose a box is pulled by a force  $F$  along a level surface through a distance  $S$  as shown in **Figure 4.9** below. Which one of the following gives defining equation of work?

- A.  $W = \text{Force} \times \text{Distance}$   
 B.  $W = \text{Force} \times \text{Displacement}$   
 C.  $\text{Work} = \frac{\text{Force}}{\text{Displacement}}$   
 D.  $\text{Work} = \frac{\text{Force}}{\text{Distance}}$



**Figure 4.9**

2. If Adane kicks a 200 g of ball with a speed of 5 m/s. What will be the kinetic energy of the ball?  
 A. 2500 J                      B. 1000 J                      C. 2.5 J                      D. 1 J
3. How high should one raise a 5 kg wood block to increase its gravitational potential energy by 250 J?  
 A. 0.2 m                      B. 5 m                      C. 10 m                      D. 50 m
4. Machine "A" and "B" lifted a mass up to a certain height. The following table shows the mass, height and time taken, respectively. What is the power of machine "A" and "B"? (Take:  $g = 10 \text{ m/s}^2$ )

- A. 160 W and 120 W  
 B. 5,000 W and 800 W  
 C. 20,000 W and 18,000 W  
 D. 24,000 W and 1,500 W

|               | Machine |       |
|---------------|---------|-------|
|               | A       | B     |
| Mass lifted   | 50 kg   | 80 kg |
| Height raised | 40 m    | 80 m  |
| Time taken    | 4 s     | 80 s  |

### II Give Short Answer.

5. An object is raised from the ground. What type of energy does the object possess due to its position?
6. A moving car along a level surface has an energy called \_\_\_\_\_.
7. The energy produced when a falling water hits the turbine of a generator is called \_\_\_\_\_.
8. A loader lifts a 500 kg stone at a height of 8 m in 2 seconds. The power developed by the loader is \_\_\_\_\_. (Take  $g = 10 \text{ m/s}^2$ )

# Unit **5**

## SIMPLE MACHINES

### Main Content

|     |                                                                   |    |
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## 5.1 DEFINITION OF MACHINES

In everyday language, the term “machine” is used to refer any mechanical device that is used to accomplish a task faster than that, it would be done without the machine.

In science, there is no difference between machines and tools or devices. We use different tools in our daily activities to make our work easier.

*Knife, scissors, screw, bottle opener, axle, lever, pulley, hammer and wedge ... etc are some machines or tools which make our work easier.*

*“A machine is any device which helps us to do work easily.”*

### *Why do we use machines?*

To discuss this question, we use the terms:

**Effort (E)** is the force exerted on the machine by an external body like a human being.

**Load (L)** is the force exerted by a machine on an object to be lifted or moved.

People use machines at least for one of the following purposes, these are:

- ▶ to multiply force — a force multiplier,
- ▶ to multiply speed (distance) — a speed multiplier or a distance multiplier,
- ▶ to change direction — a direction changing machine.

### **Example**

If you raise a load of 400 N by an effort of 40 N, by how much amount you were able to exert your original effort. And what type of machine you have used.

### **How to solve it!**

The ratio of the load lifted 400 N and the effort force 40 N applied on the machine will gives how many times the original effort is increased that is

$$\frac{\text{Load}}{\text{Effort}} = \frac{400 \text{ N}}{40 \text{ N}} = 10 \text{ times of the original effort.}$$

Such machine we have used is a force multiplier.

**Let's Exercise**

1. Define the terms of
  - a) Effort
  - b) Load
  - c) Machine
2. Fill in the blank with appropriate word.
  - a) The device that change only the direction of force is known as \_\_\_\_\_.
  - b) \_\_\_\_\_ is a force applied on a machine.

**Let's Go Further**

---

1. Describe three purposes of using simple machines?
    - i) \_\_\_\_\_
    - ii) \_\_\_\_\_
    - iii) \_\_\_\_\_
  2. Do you know how to define the force ratio of a machine i.e., the force exerted by a machine (load) output force to the input force (effort)?
  3. Can you define the term obtained from the ratio of distance moved by the effort and the distance moved by the load?
  4. A machine raises a load to 2 m, when the effort is moved by 8 m. What is the velocity ratio of the machine?
  5. A load of 360 N is moved by applying an effort of 60 N to a machine. What is the mechanical advantage of the machine?
-

## 5.2 DEFINITION OF MECHANICAL ADVANTAGE, VELOCITY RATIO AND EFFICIENCY

- ✓ **Mechanical Advantage (M.A.)** of a machine is a physical quantity that tells us the number of times a machine multiplies the effort.

$$M.A. = \frac{\text{Load (L)}}{\text{Efforts (E)}}, \quad M.A. = \frac{L}{E}$$

- ✓ **Velocity Ratio (V.R.)** is defined as the ratio of the distance moved by the effort to the distance moved by load.

► Velocity ratio is also called *ideal mechanical advantage (IMA)*.

► If friction is negligible (zero), then  $V.R. = M.A.$

$$V.R. = \frac{\text{Distance moved by the effort (S}_E\text{)}}{\text{Distance moved by the load (S}_L\text{)}}; \quad V.R. = \frac{S_E}{S_L}$$

- ✓ **Efficiency ( $\eta$ )** of machine is the ratio of the output work ( $W_o$ ) to input work ( $W_i$ ).

$$\eta = \frac{W_o}{W_i} \times 100\% \quad \text{where } W_o = L \times S_L \\ W_i = E \times S_E$$

### Example

1. A load of 200 N is moved upward by 50 N effort to a machine what is the mechanical advantage of the machine?

**How to solve it!**

Given:

Required:

$$L = 200 \text{ N}$$

$$M.A. = ?$$

$$M.A. = \frac{L}{E} = \frac{200 \text{ N}}{50 \text{ N}} = 4$$

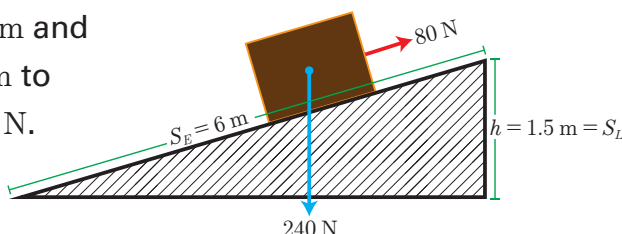
► M.A. is unit less.

► M.A. = 4, means the machine multiplied the effort by 4.

2. A load of 240 N is placed at the bottom of an inclined plane of height 1.5 m and pushed through a distance of 6 m to the top by applying a force of 80 N.

a) What is work on the load?

b) What is work on effort?



**Figure 5.1**

c) What is the efficiency?

### How to solve it!

a) Work on the load

$$\begin{aligned} W_o &= L \times S_L \\ &= 240 \text{ N} \times 1.5 \text{ m} \\ &= 360 \text{ J} \end{aligned}$$

b) Work on the effort

$$\begin{aligned} W_i &= S \times S_E \\ &= 80 \text{ N} \times 6 \text{ m} \\ &= 480 \text{ J} \end{aligned}$$

d) What is wastage energy?

c) Efficiency

$$\begin{aligned} \eta &= \frac{W_o}{W_i} \times 100\% \\ &= \frac{360 \text{ J}}{480 \text{ J}} \times 100\% \\ &= 75\% \end{aligned}$$

d) Wastage

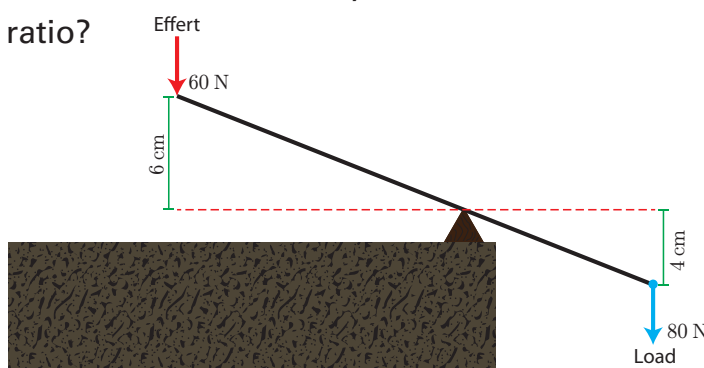
$$\begin{aligned} \text{Wastage} &= W_i - W_o \\ &= 480 \text{ J} - 360 \text{ J} \\ &= 120 \text{ J} \end{aligned}$$

## Let's Exercise

1. What is the mechanical advantage of a machine, if 40 N force is applied to move a load of 120 N?
2. If the load is moved by 200 cm and effort is moved by 400 cm in a certain machine what is the velocity ratio?

3. Consider the following lever in **Figure 5.2** and find.

- a) M.A.
- b) V.R.
- c) Work out put
- d) Work in put
- e) Efficiency



**Figure 5.2**

4. What is the mechanical advantage of a single fixed pulley ideally?
5. What is the velocity ratio of a single fixed pulley?
6. A single fixed pulley is used to \_\_\_\_\_.
7. What is the mechanical advantage of a single movable pulley? If friction is negligible?

### Hint!

$$\begin{aligned} \eta &= \frac{W_o}{W_i} \times 100\%, \\ \frac{W_o}{W_i} &= \frac{L \times S_L}{E \times S_E} = \frac{L}{E} \times \frac{S_L}{S_E} = \frac{l/E}{s/S_L} = \frac{M.A.}{V.R.} \\ \therefore \eta &= \frac{M.A.}{V.R.} \times 100\% \end{aligned}$$



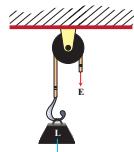
## Let's Go Further

1. The mechanical advantage of a machine is 3, what amount of effort is needed to lift a load of 180 N?
2. The mechanical advantage of a machine is 3 and the velocity ratio is 4. What is the efficiency of the machine and what percent of energy is wasted?

## 5.3 TYPES OF SIMPLE MACHINES

Simple machine is a device that changes the direction or magnitude of a force. A simple machine uses single applied force (effort) to do work against single load (force).

The following table shows the types of simple machines with practical examples.

| Nº | Types of Simple Machine | Practical Example                                                                    |
|----|-------------------------|--------------------------------------------------------------------------------------|
| 1  | Lever                   |    |
| 2  | Pulley                  |    |
| 3  | Inclined Plane          |    |
| 4  | and Axle                |    |
| 5  | Screw                   |  |
| 6  | Wedge                   |  |

### Example

1. A load of 720 N is moved by applying an effort of 120 N. What is the mechanical advantage of a machine?

#### How to solve it!

The mechanical advantage of lever is the ratio of load to effort.

$$M.A. = \frac{L}{E},$$

where *M.A.* – Mechanical Advantage  
*L* – Load      *E* – Effort

#### Given

$$L = 720 \text{ N},$$

$$E = 120 \text{ N}$$

#### Required

$$M.A. = ?$$

$$M.A. = \frac{L}{E} = \frac{720 \text{ N}}{120 \text{ N}} = 6$$

2. In **Figure 5.3**, shown below, the length of the plane is 6 m and the height is 1 m. What is the velocity ratio of the inclined plane?

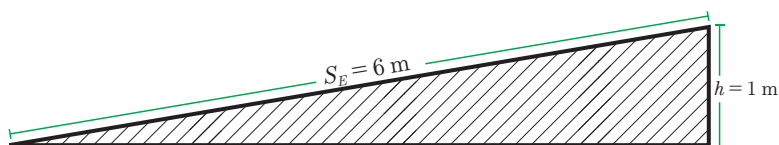


Figure 5.3

## How to solve it!

The velocity ratio of inclined plane is

$$V.R. = \frac{s}{h}, \text{ where } V.R. - \text{Velocity ratio}$$

$s$  – Length

$h$  – Height

Given:

$$s = 6 \text{ m}, h = 1 \text{ m}$$

$$V.R. = \frac{s}{h} = \frac{6 \text{ m}}{1 \text{ m}} = 6$$

Required:

$$V.R. = ?$$

## Let's Exercise

1. List the six types of simple machines.

a) \_\_\_\_\_.

d) \_\_\_\_\_.

b) \_\_\_\_\_.

e) \_\_\_\_\_.

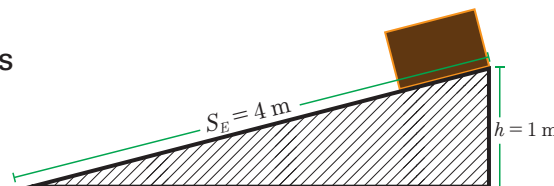
c) \_\_\_\_\_.

f) \_\_\_\_\_.

2. What is a simple machine?

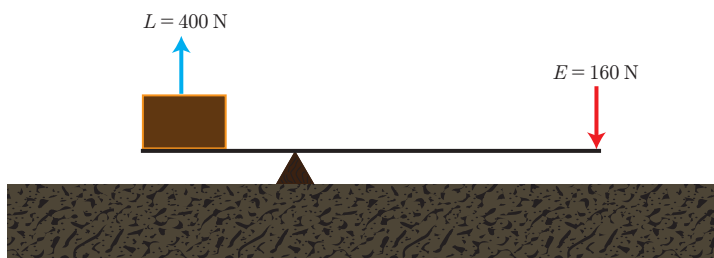
Simple machine is \_\_\_\_\_.

3. In **Figure 5.4**, the length of the plane is 4 m and the height is 1 m. What is the velocity ratio of the inclined plane?



**Figure 5.4**

4. In **Figure 5.5**, a load of 400 N is lifted by applying a force of 160 N on the lever, what is the mechanical advantage of the lever?



**Figure 5.5**

5. State:

a) 1<sup>st</sup> order lever.

b) 2<sup>nd</sup> order lever.

c) 3<sup>rd</sup> order lever.

## Let's Go Further

Define compound machine.

## 5.4 TORQUE

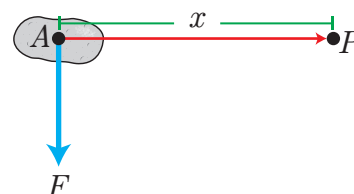
### TORQUE

A moment of force about a point is the product of the force,  $F$  and the perpendicular distance from the point to the line of action of a force. It is called *torque*.

- ✓ If a force,  $F$  acts at a point,  $A$  on a body, which is fixed at point,  $P$  as shown in **Figure 5.6**, there is turning effect (torque) about a point,  $P$ .

$$\text{Torque} = \text{Force} \times \text{Distance}$$

$$\tau = F \times x$$

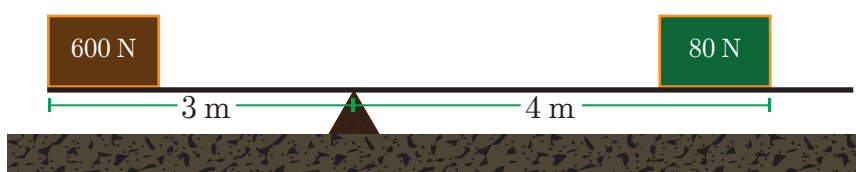


**Figure 5.6**

- ✓ The movement of force (torque) produces a turning effect (rotation) about a point,  $P$ .
- ✓ The direction of torque is either clockwise or anti-clockwise.
- ✓ The SI unit of torque is Nm. It is not joule.
- ✓ An object is said to be balanced, when the clockwise torque is equal to anti-clockwise torque.
- ✓ Torque is a vector physical quantity.

### Example

1. A 10 m long lever is used to balance a load of 600 N by a force of 80 N. When the fulcrum is located at a distance of 3 m from the load and 4 m from the effort as shown in **Figure 5.7** below.



**Figure 5.7**

Find

- a) Clockwise torque
- b) Anti-clockwise torque

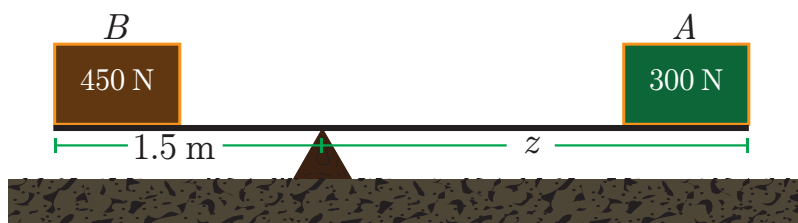
### How to solve it!

Given:  $L = 600 \text{ N}$ ,  $E = 80 \text{ N}$ ,  $S_E = 4 \text{ m}$ ,  $S_L = 3 \text{ m}$

$$\begin{aligned} \text{a) } \text{Clockwise Torque} &= E \times S_E \\ &= 80 \text{ N} \times 4 \text{ m} = 320 \text{ Nm} \end{aligned}$$

$$\begin{aligned} \text{b) } \text{Anti-clockwise Torque} &= L \times S_L \\ &= 600 \text{ N} \times 3 \text{ m} = 1800 \text{ Nm} \end{aligned}$$

2. From **Figure 5.8** given below, what is the value of  $z$  to make the load balance?



**Figure 5.8**

### How to solve it!

#### Given:

$$L_A = 300 \text{ N}, L_B = 450 \text{ N}, S_B = 1.5 \text{ m},$$

$$L_A \times S_A = L_B S_B$$

$$300 \text{ N} \times z = 450 \text{ N} \times 1.5 \text{ m}$$

$$z = \frac{450 \text{ N} \times 1.5 \text{ m}}{300 \text{ N}} = 2.25 \text{ m}$$

#### Required:

$$S_A = z = ?$$

### Let's Exercise

1. Define the term torque.
2. Is there any difference between force and torque? Explain.
3. When do we say an object is balanced?
4. What is the mathematical definition of torque?

## Let's Go Further

1. The effective torque arm between the point of application of force and the center of rotation is 32.4 cm and the force applied is 100 N. Find the torque?
2. When force is needed to develop a torque of 12.5 Nm when the torque arm is 18.5 cm?
3. What effective torque arm is needed to produce a torque of 9.82 Nm from a force of 24.5 N?

## 5.5 UNIT SUMMARY

### I Choose the Correct Answer.

- Which one of the following is **NOT** the purpose of machine?
  - Changing direction of force.
  - Multiplying speed.
  - Multiplying force.
  - Multiplying energy.
- Which of the following definition is correct?
  - $M.A.$  is distance moved by effort over distance of load.
  - $V.R.$  is load per effort.
  - Efficiency is  $M.A.$  divided by  $V.R.$
  - $V.R.$  is the ratio of  $M.A.$  to efficiency.
- The following table shows four levers with the value of the load, effort, distance of effort and distance of load from the fulcrum. Which one of the four levers has the least efficiency?

- Lever 1
- Lever 2
- Lever 3
- Lever 4

| Levers | Load (N) | Effort (N) | $S_L$ (cm) | $S_E$ (cm) |
|--------|----------|------------|------------|------------|
| 1      | 100      | 20         | 10         | 60         |
| 2      | 200      | 40         | 10         | 60         |
| 3      | 300      | 60         | 5          | 100        |
| 4      | 400      | 80         | 10         | 120        |

- Abebe uses one fixed and two moveable pulleys to lift a load as shown in **Figure 5.9**. How much is the velocity ratio ( $V.R.$ ) of this machine?

- 2
- 3
- 4
- 5

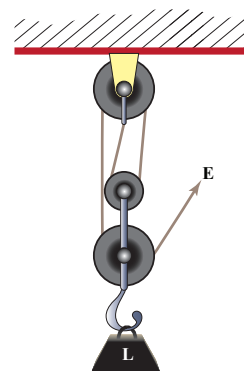


Figure 5.9

### II Give Short Answer.

- Why is the velocity ratio of a simple fixed pulley equals to 1?
- In **Figure 5.10**, the clockwise and anti-clockwise torque of the lever consequently are \_\_\_\_\_ and \_\_\_\_\_.

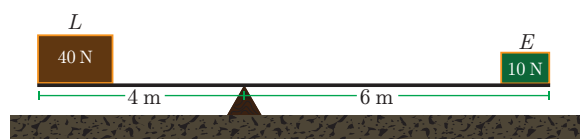


Figure 5.10

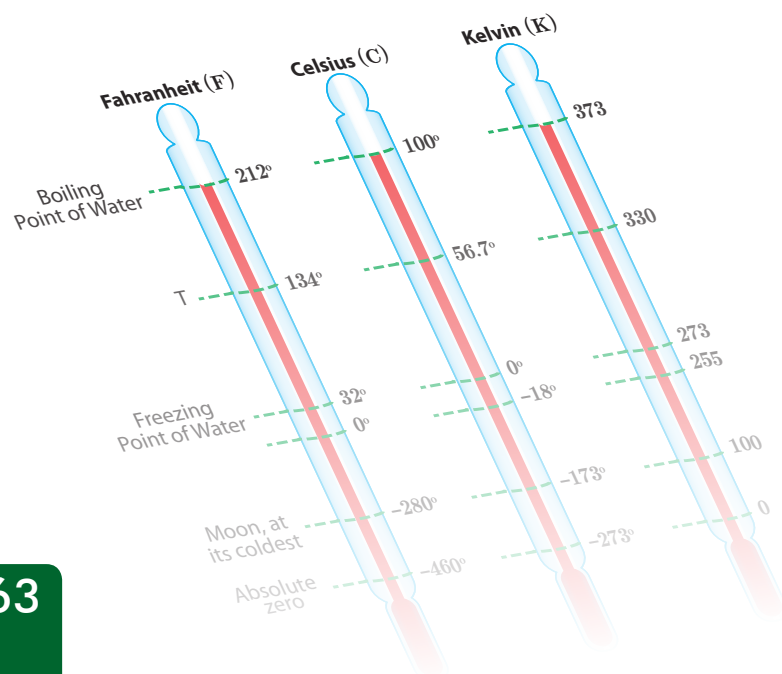
- If a machine helps to lift big load by applying small effort. The machine is said to be \_\_\_\_\_.
- What effort should be applied to move 100 N load if the machine multiplies force by 4?

# Unit 6

## TEMPERATURE AND HEAT

### Main Content

- |     |                                           |    |
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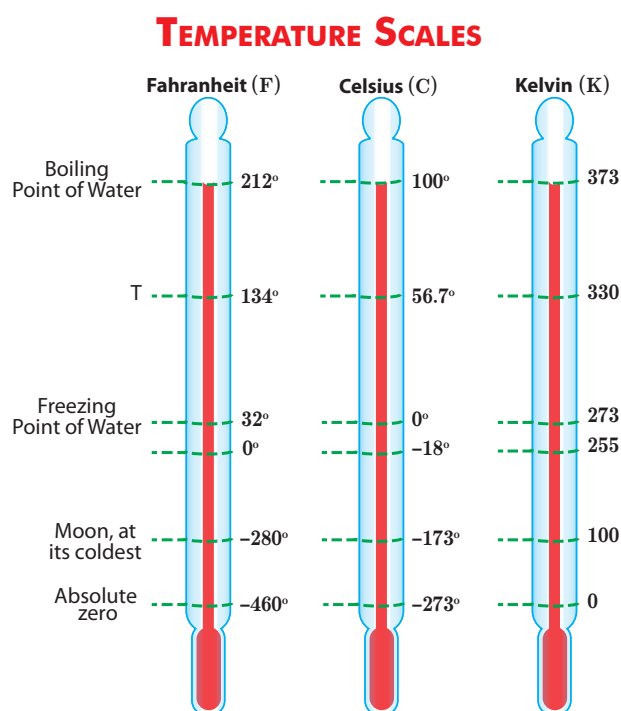
## 6.2 TEMPERATURE SCALES

These days, different temperature scales are in use. But at this level, the three most common temperature scales are discussed below. These are,

- i) Centigrade (Celsius) scale
- ii) Fahrenheit scale
- iii) Kelvin scale

In making a thermometer, the lower fixed point and the upper fixed point are taken to be the melting point of ice and the boiling point of water at sea level, respectively.

- i) **The Celsius Scale:** In this scale, the value 0 is assigned to the lower point (melting point) and the value 100 is assigned to the upper point (boiling point) of water. The space between the lower and the upper points is divided into 100 equal parts. The unit of temperature in Celsius scale is  $^{\circ}\text{C}$  (degree Celsius).
- ii) **The Fahrenheit Scale:** In this scale, the value 32 is assigned to the ice point and 212 to the boiling point. The space between the two points is divided into 180 equal parts and the unit of temperature in this scale is  $^{\circ}\text{F}$  (degree Fahrenheit).
- iii) **The Kelvin Scale:** In this scale, the ice point is assigned to be 273 and the boiling point to be 373. The space between these two points is divided into 100 equal parts. The unit of temperature in this scale is K (Kelvin). The lowest possible temperature that objects can attain is  $-273^{\circ}\text{C}$  or 0 K. This temperature is called the *absolute zero*. Kelvin (K) is also the SI unit of temperature.



**Figure 6.1:** Thermometer reading from different scales

When a thermometer is in contact with a hotter body, the mercury inside it expands and rises up the tube. The reverse occurs when the thermometer is in contact with a cooler body. The expansion and contraction of the mercury with the change in temperature determines the location of the meniscus which is the temperature reading.

### Example

1. Is there any temperature cooler than  $0^{\circ}\text{C}$ ?

#### How to solve it!

Yes, objects can attain a temperature of up to  $-273^{\circ}\text{C}$ .

2. Can an object give off heat at  $0\text{ K}$  temperature?

#### How to solve it!

An object at  $0\text{ K}$  cannot give off any energy. It has lost all its energy before it attains this minimum temperature.

### Let's Exercise

1. Which temperature unit does not have the degree symbol?
2. Which temperature scale is commonly used for scientific works?
3. Is there a limit to how cold things can get?

## Let's Go Further

1. A student claimed that the thermometers are useless because a thermometer always registers its own temperature. How would you respond?  
\_\_\_\_\_
2. A thermometer is laid out in direct sunlight and its temperature rises. In which temperature scales do we have the same change in reading of the temperature?  
\_\_\_\_\_
3. While constructing a mercury thermometer, which thermometric property of mercury is used: volume, color, or pressure?  
\_\_\_\_\_

## 6.3 CONVERSION OF TEMPERATURE SCALES

Different scales are used to measure temperature.

There are two things require to construct a temperature scale. One is the reference point, such as the temperature at which water freezes at standard atmospheric pressure. As shown below, the three scales have different values as this reference point. Water freezes at 273.15 kelvins (273.15 K), 0° Celsius (0°C) and 32° Fahrenheit (32°F). Notice that the standard terminology for the Kelvin scale avoids the use of “degrees.” Water freezes at 273.15 kelvins, not 273.15 degrees kelvin.

The other requirement is pick another reference point, such as the temperature at which water boils at standard atmospheric pressure, and established the number of degrees between this two points. This determines the magnitude of the units of scale. The Celsius and Kelvin scales both have 100 units between the freezers and boiling points of water. This means that their units are equal: a change of 1 °C equals a change of 1 K.

In contrast, there are 180 degrees between these temperature in the Fahrenheit system.

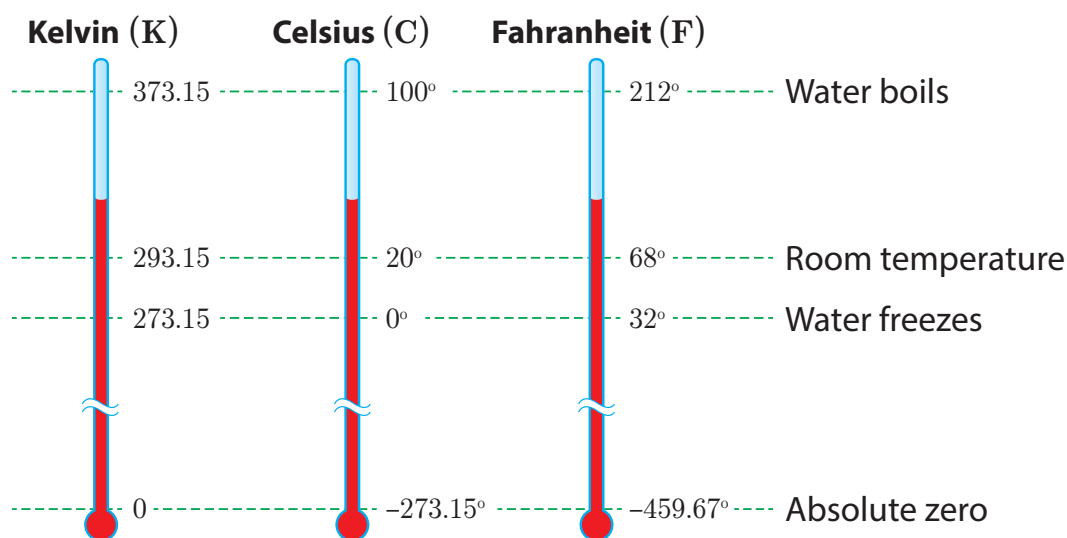


Figure 6.2

### TEMPERATURE SCALES

Kelvin, Celsius and Fahrenheit.

Water freezes at 0 °C.

Absolute zero is 0 K.

Unit of Celsius = Unit of Kelvin.

### TEMPERATURE SCALE CONVERSIONS

$$T_K = T_C + 273.15$$

$$T_C = (5/9) (T_F - 32)$$

$$T_F = (9/5) T_C + 32$$

Where,  $T_K$  – Kelvin temperature

$T_C$  – Celsius temperature

$T_F$  – Fahrenheit temperature

**Example**

Convert 98.6 °F to Celsius and kelvin.

**How to solve it!**

$$T_C = \left(\frac{5}{9}\right)(T_F - 32.0)$$

$$T_C = \left(\frac{5}{9}\right)(98.6^\circ\text{F} - 32.0)$$

$$T_C = \left(\frac{5}{9}\right)(66.6) = 37.0^\circ\text{C}$$

$$T_K = T_C + 273.15$$

$$T_K = 37.0 + 273.15 = 310.15 \text{ K}$$

**Let's Exercise**

1. What are the temperature for freezing water on the Celsius and Fahrenheit scales? For boiling water?
2. What are the temperature for freezing water and boiling water on the Kelvin temperature scales?
3. Rank in order, from the highest to the lowest, the temperature 0 K, 0°C, 0°F.
4. Room temperature is often considered to be 68°F. What is room temperature in a degree Celsius and in kelvin?
5. Convert each of the following temperature to the individual scale:
  - a) 100 K to Celsius scale, \_\_\_\_\_ °C.
  - b) 373 °C to the Fahrenheit scale, \_\_\_\_\_ °F.
  - c) 72 °F to the Celsius scale, \_\_\_\_\_ °C.
  - d) 273.15 °C to Fahrenheit scale, \_\_\_\_\_ °F.

**Let's Go Further**

1. What Celsius temperature is the same when converted to Fahrenheit? (*There is only one such temperature.*) \_\_\_\_\_ °C.
2. An iron rod is heated from 66.0 °F to 280 °F. Express the increase in temperature in Celsius. \_\_\_\_\_ °C.

## 6.4 DEFINITION AND SOURCE OF HEAT

If you touch a hot stove, energy enters your hand because the stove is warmer than your hand. When you touch a piece of ice, on the other hand, energy passes out of your hand and into the colder ice. The direction of spontaneous energy transfer is always from a warmer thing to a neighbouring cooler thing. The energy transferred from one thing to another because of a temperature difference between the things is called *heat*.

Any object that can be used to derive heat is considered as a source of heat energy. There are many sources of heat energy.

The sun is a part of our solar system. Thus, it is a natural source of heat energy. Sunlight is important for the existence of all living organisms on the planet. This form of heat energy is also called solar energy.

Fossil fuels (coal, natural gases, kerosene, etc.) and nuclear energy are non-renewable energy sources whereas wood wastes, geothermal, wind hydroelectric, biomass and solar energy are renewable energy sources.

Lit candle and fire wood are common examples of sources of heat.



Figure 6.3

### Example

Answer the following accordingly.

1. If you hold a cold can of Coca-Cola in your hand, the can will warm up and your hand will chill. Energy flows from your hand to the can. This energy that moves is called \_\_\_\_\_.
2. As with other forms of energy, heat can be measured in \_\_\_\_\_.
3. Heat refers solely to the flow of energy due to \_\_\_\_\_.
4. A metal block is heated. How do the following physical quantities change?  
*Volume, density, and mass.*

### How to solve it!

1. heat – Heat is a form of energy which transferred from hot to cold object.
2. joule – Energy is measured in joule.
3. temperature difference – If there is temperature difference heat flows.
4. When a matter is heated, volume increases and mass remains the same. Therefore, the density decreases.

### Let's Exercise

1. An iron paper clip and a big iron bolt are removed from a hot oven. They are red-hot and have the same temperature. When dropped into identical containers of water of equal temperature, which one raises the water temperature more?
2. In which direction is heat transferred – from warm to cool or from cool to warm?
3. Name three fossil fuels that are used as the source of energy at power plants.

## Let's Go Further

1. Describe ways in which heat energy is produced naturally.
2. When you touch a cold surface, does cold travel from the surface to your hand or does energy travel from your hand to the cold surface? Explain.
3. Identify and evaluate different sources of heat and the environmental impacts of their use.
4. When water is heated, its volume increases. So what happens to its weight?
5. State what kinds of everyday devices convert electricity into heat and use it?

## 6.5 EFFECT OF HEATING

Some of the effects of heating a body are expansion, temperature rise and change of states.

### HEATING CAUSES EXPANSION

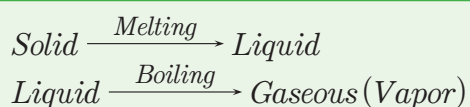
- ✓ Expansion is an increase in size of the body.
- ✓ Gases, liquids and solids, generally, expand when heated and shrink when cooled.

### HEATING CAUSES TEMPERATURE RISE

When substance is heated, the kinetic energy of the particles increase. This causes an increase in temperature of the substance. Generally, as a body receives heat, its temperature rises.

### HEATING CAUSES CHANGE OF STATE

Substances exist in three states: *Solid*, *liquid* and *gas*. For example, water exists in the solid state as ice, in the liquid state as water, and in the gaseous state as steam (vapor). All substances can exist in any of the three states under proper conditions of temperature and pressure. The transitions from one state to another are accompanied by absorption or release of heat at constant temperature. In the process of change of state:



### MELTING

When a solid is heated sufficiently it changes its state from solid to liquid, the process of changing from solid to liquid is called *melting*.

A definite temperature at which the solid body starts to melt is called the *melting point of the solid*.

### BOILING

When water is heated, bubbles of water vapor are first formed at the bottom and sides of the container. As the water is continuously heated, its temperature rises and its molecular bonds break and move farther apart. The process of changing from liquid to gas is called *boiling*.

- ✓ A definite temperature at which liquid starts to boil is called the *boiling point of the liquid*.

## EVAPORATION

Evaporation is the change from liquid to vapor at the surface of a body at any temperature. During evaporation, the molecules near the surface of the body escape into air. Evaporation causes cooling of the body.

## DIFFERENCE BETWEEN BOILING AND EVAPORATION

| Boiling                                     | Evaporation                                                          |
|---------------------------------------------|----------------------------------------------------------------------|
| ✓ Happens at boiling point.                 | ✓ Happens at any temperature.                                        |
| ✓ Happens throughout the liquid body.       | ✓ Happens on the surface of a body - solid or liquid.                |
| ✓ Does not depend on wind and surface area. | ✓ Increases in hot and windy day and where the body surface is wide. |

## Example

List the three major effects of heating.

### How to solve it!

- i) Expansion      ii) Temperature rise      iii) Change of states

## Let's Exercise

1. What is meant by evaporation?

\_\_\_\_\_.

2. Write down two differences between evaporation and boiling?

i) \_\_\_\_\_.

ii) \_\_\_\_\_.

3. What are the three states of matter?

\_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.

## Let's Go Further

What is meant by expansion effect of heating?

\_\_\_\_\_.

## 6.6 UNIT SUMMARY

### I Choose the Correct Answer.

1. The measure of hotness or coldness of a body is called \_\_\_\_\_.  
A. heat  
B. heat capacity  
C. specific heat capacity  
D. temperature
2. On a hot day, which temperature scale shows the greatest number?  
A. The Fahrenheit scale.  
B. The Kelvin scale.  
C. The Celsius scale.  
D. All scales read the same.
3. What is the temperature reading in Fahrenheit scale when the reading is  $60^{\circ}\text{C}$ ?  
A.  $134^{\circ}\text{F}$   
B.  $136^{\circ}\text{F}$   
C.  $138^{\circ}\text{F}$   
D.  $140^{\circ}\text{F}$
4. The change from liquid to vapor at the surface of lake or ocean at any temperature is called \_\_\_\_\_.  
A. Boiling  
B. Evaporation  
C. Heating  
D. Freezing

### II Give Short Answer.

5. What is the instrument used to measure temperature?
6. What is the SI unit of temperature?
7. At what point do the temperatures in Celsius and Fahrenheit scale show the same reading?
8. State the three effects of heating.

# Unit

# 7

## SOUND

### Main Content

|     |                                                  |    |
|-----|--------------------------------------------------|----|
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| 7.2 | Speed of Sound in Different Media                | 78 |
| 7.3 | Reflection of Sound                              | 80 |
| 7.4 | Unit Summary                                     | 82 |



## 7.1 DEFINITION, PRODUCTION AND TRANSMISSION OF SOUND

### Definition:

Sound is a form of energy. It is generated by a vibrating object.

*When a teacher teaches in a classroom, students sit in front line can hear more easily than students in rear sit. Why?*

Because the teacher's sound energy generated by his vocal cord is decreased as it travels.

### How to PRODUCE SOUND?

When you hit a drum with stick, the stretched plastic vibrates back and forth. Then sound is generated. This sound travels in every direction.

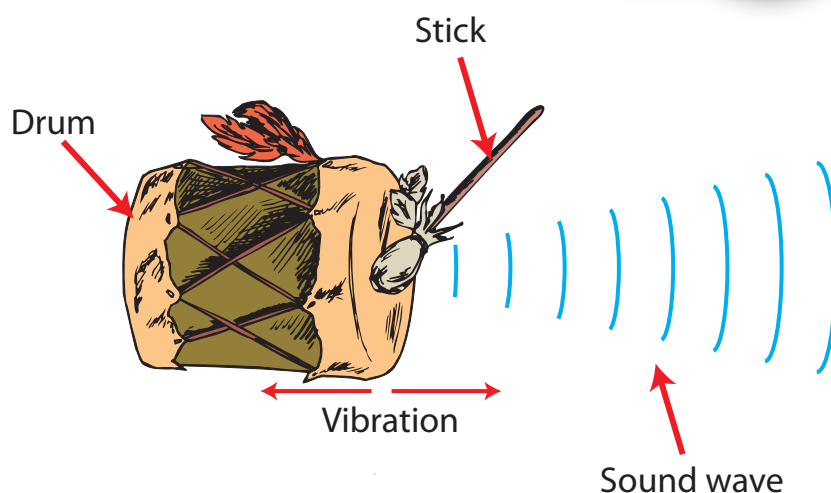
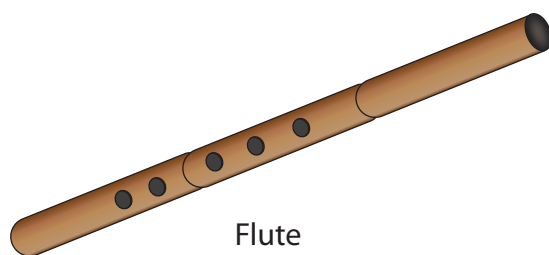


Figure 7.1

In some musical instruments, sound is produced by the vibration of air. For example, flute and saxophone.



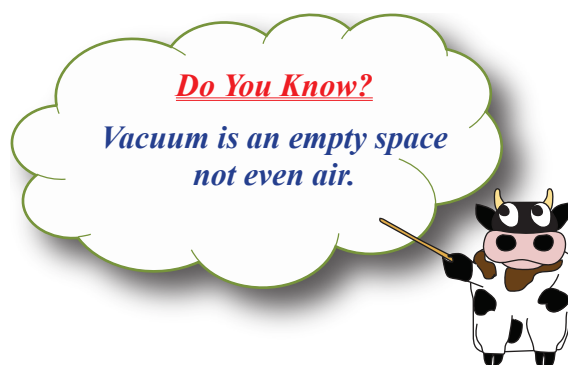
Flute  
Figure 7.2

Once sound is produced it needs a material medium to reach listener's end. And materials (i.e., solid, liquid and air (gas)) can transmit sound.

**Note:**

- ▶ Solid is better transmitter of sound than liquid and gas.
- ▶ Liquid is better transmitter of sound than gas.

Sound cannot be transmitted through vacuum.

**Note:**

To produce sound, there must be:

- ▶ a vibrating source,
- ▶ medium of transmission and
- ▶ a receiver.

**Example**

1. How can sound produced by the “Kirar”?
2. Why does sound decrease as it goes a long distance?

**How to solve it!**

1. When the player hits the stretched strings of a “Kirar”; the string starts to vibrate, the sound is produced.
2. Sound is a form of energy. When it goes a (long) distance, it loses its energy. So, it decreases.

**Let's Exercise**

1. What happen to the transmission of sound in different material? (Solids, liquids, and gases). Explain it!
2. Why is it possible to hear round corners?

**Let's Go Further**

Sound cannot travel in vacuum. Why?

## 7.2 SPEED OF SOUND IN DIFFERENT MEDIA

Sound needs material medium for its transmission. This means there is no sound in vacuum. Speed of sound depends on the nature of the material through which it travels. The speed of sound is maximum in solid and minimum in gas, whereas in liquid it is relatively moderate.

### Example

| Substances | Speed (m/s) at 0 °C |
|------------|---------------------|
| Air        | 331                 |
| Sea water  | 1450                |
| Copper     | 4998                |

On rough estimation, the speed of sound:

- ▶ in solid is about four times that of in liquid.
- ▶ in liquid is about four times that of in gas.

The speed of sound in air at any temperature ( $v_T$ ) can be calculated:

$$v_T = v_o + \frac{0.6}{1^\circ\text{C}} \times T \quad \text{where } v_o \text{ is the speed of sound at } 0^\circ\text{C} \text{ and}$$

$"T"$  is temperature in degree Celsius.

### Example

A thunder was heard 4 s after the lightning was seen. If the distance of the lightning is 1396 m away from the observer, what is the speed of sound at that temperature?

#### How to solve it!

Given:

$$t = 4 \text{ s}, s = 1396 \text{ m}$$

Required:

$$v = ?$$

$$s = vt$$

$$\Rightarrow v = \frac{s}{t} = \frac{1396 \text{ m}}{4 \text{ s}} = 349 \text{ m/s}$$

### Let's Exercise

1. The speed of sound in air at  $0^{\circ}\text{C}$  is \_\_\_\_\_ m/s.
2. When temperature increases  $1^{\circ}\text{C}$ , the speed of sound in air increases by \_\_\_\_\_ m/s.
3. The speed of sound in air at any temperature ( $v_T$ ) can be calculated by  $v_T =$  \_\_\_\_\_.
4. What is the nature of the sound?
5. Among solid, liquid and gas, in which medium sound travels the fastest?
6. Can sound be transmitted in vacuum? If not why?
7. A thunder was heard 2 sec later after the lightning is seen. If the distance of lightning is 698 m away from the observer, what is the speed of sound at that temperature?

### Let's Go Further

1. Why is the speed of sound in solid greater than that of liquid and gas? Explain based on the arrangement of particles in the three states of matter.
2. In an electric bell jar, as the air in the jar is out, the sound decreases and finally stops. Why?
3. What are the three requirements of sound?
4. Birhanu is chopping a log with an axe. His friend Challa is seeing at 2 km away from him. Challa has observed that the sound is heard after the axe is raised off the log. Why is that Challa do not hear the sound immediately while the axe hitting the log?

#### Do You Know?

*Taking the same distance from the source, the loudness of sound coming through gases, liquids and solids increases consecutively.*



## 7.3 REFLECTION OF SOUND

- ✓ When you shout in empty hall the sound bounces back from the wall and comes towards you.
- ✓ When a sound meets a boundary or an obstacle some portions of a sound are absorbed and the remaining are reflected. This reflection of sound is called an *Echo*.
- ✓ Hard substance such as wall, hall, metal. Wood, building, ... etc are good reflectors. But such as cloth, wool, ... etc, absorb sound energy a lot.
- ✓ If the reflected sound reaches you more than 0.1 second later, we can hear reflected sound as echo.

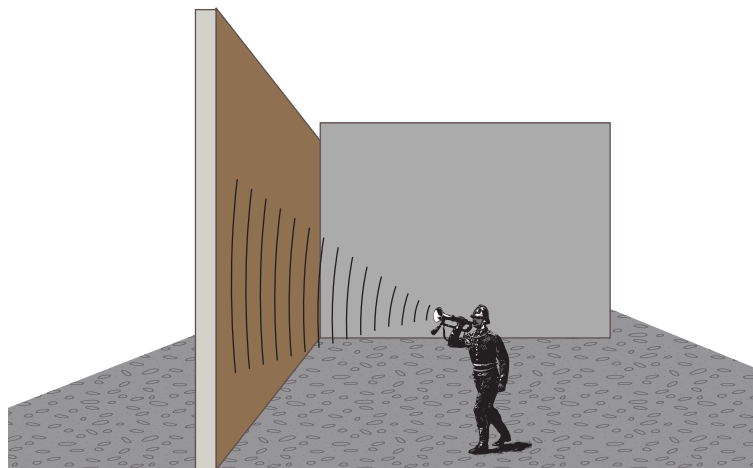


Figure 7.3

### APPLICATIONS OF ECHO SOUNDING

Since the distance travelled by the sound is the sum of the distance from the source to the reflector and back from the reflector to the source.

$$2s = vt; \quad v = \frac{2s}{t}$$

Hence, the minimum distance from the source to produce an echo is 17 m, if the speed of sound at that temperature is 340 m/s.

### Example

What is the speed of sounds at a given temperature if an echo is heard 3 s later from a mountain which is 519 m away?

## How to solve it!

Given:

$$t = 3 \text{ s}, s = 519 \text{ m}$$

Required:

$$v = ?$$

$$v = \frac{2s}{t} = \frac{2 \times 519 \text{ m}}{3 \text{ s}} = 346 \text{ m/s}$$

## Let's Exercise

1. The reflection of sound from hard surface to the source is called \_\_\_\_\_.
2. The minimum time require to hear an echo is \_\_\_\_\_ sec.
3. The minimum distance from an echo to be heard is \_\_\_\_\_ m.

## Let's Go Further

1. Classify the following materials as reflectors of sound and as absorbers of sound.

a) Hills

e) Walls

b) Buildings

f) Cloth

c) Wood

g) Wool

d) Metals

Reflectors: \_\_\_\_\_.

Observers: \_\_\_\_\_.

2. The echo produced by 850 m away cliff is heard after 5 s. What is the speed of sounds from this information?
3. What is the distance of sound at a given temperature if an echo is heard 3 s later from a mountain with the speed of 344 m/s.
4. The time taken to hear an echo from a mountain at a speed of 344 m/s and distance of 860 m away is \_\_\_\_\_.

## 7.4 UNIT SUMMARY

### I Choose the Correct Answer.

- Which one of the following is true about the sensation of hearing sound?
  - All sounds when hear are produced by vibrating.
  - The produced sound do **NOT** travel in all direction.
  - Sound is **NOT** a form of energy.
  - If sound travels in long distance it gains more energy.
- If an alarm clock is placed in a vacuum and then activated, how is the sound of alarm?
  - Sound is heard.
  - No sound is heard.
  - Sound is amplified.
  - Sound is absorbed.
- An echo is produced when sound wave is \_\_\_\_\_.
  - reflected from a surface.
  - refracted from hard surface.
  - refracted from soft surface.
  - absorbed into soft surface.
- Different media transmit sound at different speed. Which one of the following shows the correct arrangement of media in increasing order of their property to transmit sound?
  - Gas – liquid – solid.
  - Liquid – solid – gas.
  - Liquid – gas – solid.
  - Solid – gas – liquid.

### II Give Short Answer.

- Sound is produced by \_\_\_\_\_ of a body.
- Among air, steel and water in which sound travel the fastest at  $0^{\circ}\text{C}$ ? \_\_\_\_\_.
- Why do we hear sound after it collides with a hard material? \_\_\_\_\_.
- Two boys are located in front of hill as shown in **Figure 7.4**. The time taken to hear the echo of their own whistles are  $0.8\text{ s}$  for the first boy and  $1.2\text{ s}$  for the second boy. What is the distance between the two boys, if the speed of sound at that temperature is  $332\text{ m/s}$ ?

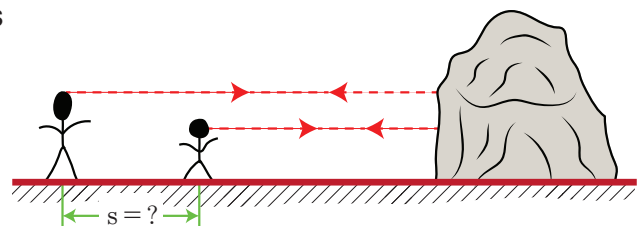


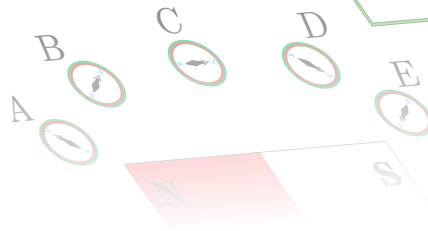
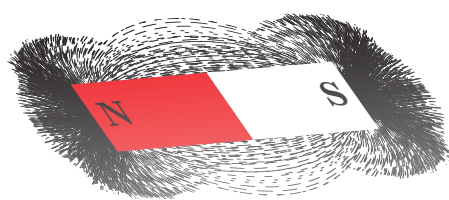
Figure 7.4

# Unit 8

## ELECTRICITY AND MAGNETISM

### Main Content

|      |                                             |     |
|------|---------------------------------------------|-----|
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## 8.1 MAGNETS (I)

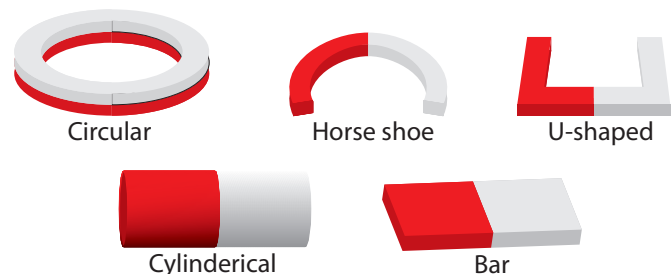
Magnet is a piece of iron that attracts substances like steel, nickel and iron material.

- ✓ Materials are classified into two: *Magnetic* and *Non-magnetic* material. Magnetic materials are the materials that can be attracted by a magnet. The non-magnetic materials are those that cannot be attracted by a magnet.

| Magnetic Materials | Non-magnetic Materials |           |
|--------------------|------------------------|-----------|
| Iron               | Wood                   | Plastic   |
| Steel              | Stone                  | Copper    |
| Nickel             | Water                  | Aluminium |
| Cobalt             | Rubber                 | Gold      |
|                    | Paper                  | Glass     |

- ✓ Magnets have different shapes as shown in **Figure 8.1**.

- ✓ Magnets have two poles at each ends. These are *North pole* and *South pole*.



**Figure 8.1**

### Example

Separate the following materials into magnetic and non-magnetic materials use (✓) for magnetic and (×) for non-magnetic materials.

- |                      |                   |
|----------------------|-------------------|
| a) Coin ( )          | e) Paper clip ( ) |
| b) Paper money ( )   | f) Pen ( )        |
| c) Nail ( )          | g) Pin ( )        |
| d) Block (Brick) ( ) |                   |

### Solution:

- ✓ Nail, pin and paper clip are made up of Iron. Therefore, they are magnetic materials.
- ✓ Paper money is made up of paper, coin is made up of copper, block (brick) is made up of cement and sand, pen is made up of plastics. Therefore, they are non-magnetic materials.

### Let's Exercise

- Bring a magnet near to the following materials and try to attract them one by one, then fill the table below by using (✓) for magnetic and (×) for non-magnetic materials.
  - Tooth pick ( )
  - Scissors ( )
  - Screw driver ( )
  - Rubber ( )
  - Bulb ( )
  - Electric wire ( )
- List five magnetic and five non-magnetic materials that you are using in your daily life (experience).

#### ***Hint!***

*Remember that the materials made from Iron, Nickel and Steel are magnetic and the rest are non-magnetic.*



### Let's Go Further

Which one of the following attracts a pin?

- A brand new nail without any special treatments.
- A nail after rubbed with a pole of a magnet in the same direction.
- A nail after rubbed with a pole of a magnet in both directions.
- A nail after rubbed with both poles of a magnet alternately.
- A brand new pencil without any special treatments.
- A pencil after rubbed with a pole of a magnet in a direction.
- A pencil after rubbed with a pole of a magnet in both directions.
- A pencil after rubbed with both poles of a magnet alternately.

#### ***Do You Know?***

*Magnets can be made by rubbing a magnetic materials with a magnet.*





- C. water bodies on its surface  
D. an ideal bar magnet in its core
3. The south pole of the ideal bar magnet inside the earth is \_\_\_\_\_.
- A. at the center of the earth  
B. near earth's north pole  
C. near earth's east pole  
D. near earth's south pole
4. Bring two bar magnets close to each other, what do you observe?  
Attraction or repulsion?

- a)  \_\_\_\_\_.
- b)  \_\_\_\_\_.
- c)  \_\_\_\_\_.
- d)  \_\_\_\_\_.

## Let's Go Further

Indicate the earth's magnet shown in the following earth's diagram.

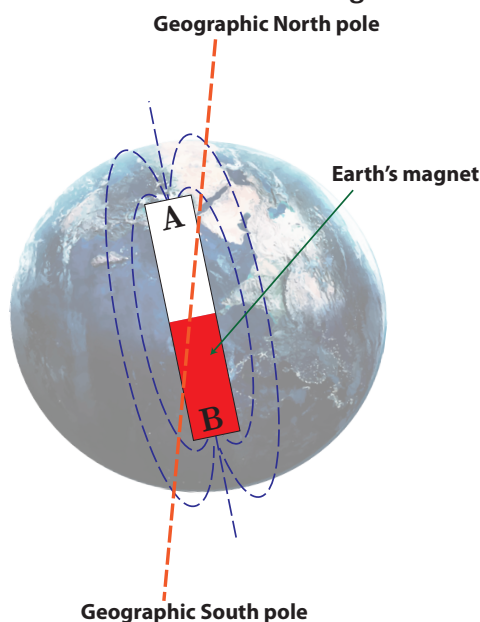


Figure 8.2

- a) A stands for \_\_\_\_\_ Magnetic pole.
- b) B stands for \_\_\_\_\_ Magnetic pole.

## 8.3 MAGNETIC LINES OF FORCE AND USES OF MAGNETS

### MAGNETIC LINES OF FORCE

Magnetic field is a region where magnetic pole exerts force. The magnetic field is represented by imaginary lines called *magnetic lines of force*.

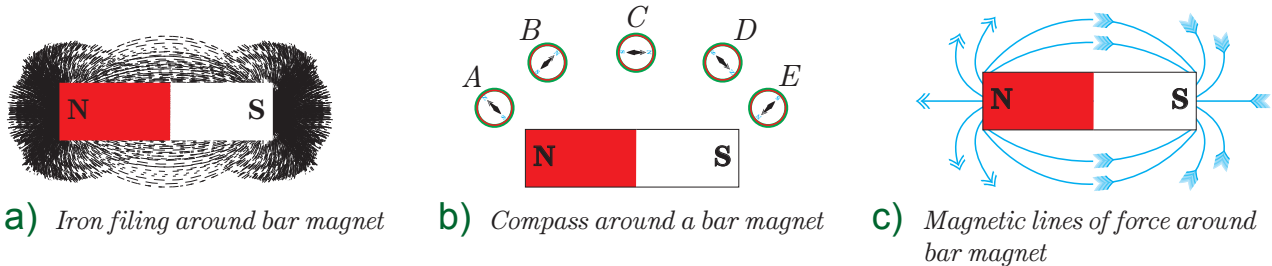


Figure 8.3: Mapping lines of Force

### PROPERTIES OF MAGNETIC LINES OF FORCE

- ✓ Magnetic lines of forces move from North pole to South pole outside the magnet.
- ✓ Magnetic lines of force never cross each other.
- ✓ Magnetic lines of force are closer at the pole.

#### Let's Exercise

1. What is magnetic field and magnetic lines of force?

\_\_\_\_\_.

2. List the properties of magnetic lines of force.

\_\_\_\_\_.

### Let's Go Further

1. Where the magnetic lines of force are closer? Why?

\_\_\_\_\_.

2. Sketch the magnetic lines of force:

- a) for a bar magnet.
- b) between two opposite magnetic poles.
- c) between two like magnetic poles.

## USES OF MAGNETS

Magnets have different applications (uses).

Some of these uses are:

- ☒ Magnets in compasses are used to indicate direction on seas, oceans, air and ground.
- ☒ They are use for lifting up iron or steel to higher places.
- ☒ They are used in construction of electric bells, motors, speakers, generators etc.
- ☒ They are used to separate magnetic substances like iron from mixture of different non-magnetic materials.

### Let's Exercise

1. List some application of magnets.

\_\_\_\_\_.

2. List some devices worked by the application of magnets.

\_\_\_\_\_.

## Let's Go Further

1. For what purpose uses magnet in a compass?

\_\_\_\_\_.

2. Why do you use magnets to separate iron from different mixture of non-magnetic materials?

\_\_\_\_\_.

3. Which one of the following uses magnets?

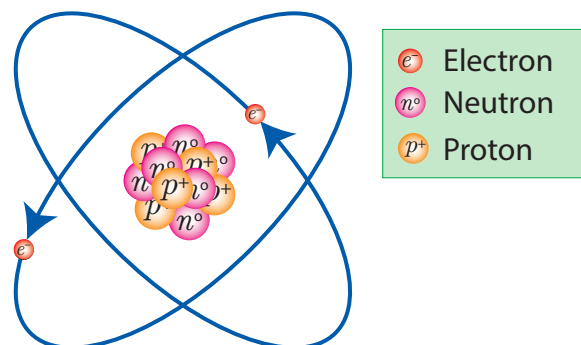
- A. Closing the door of refrigerator.
- B. Lifting water from water well.
- C. Riding a bicycle.
- D. Seeing objects at far distance.

## 8.4 ELECTROSTATICS

All Materials are made up of tiny particles called *atoms*.

An atom consists of *protons*, *electrons* and *neutrons* as shown in the **Figure 8.4**.

The protons and the neutrons are held together at the center of the atom called the *nucleus*.



**Figure 8.4**

- ▶ Electrons have negative charge.
- ▶ Protons have an equal positive charge.
- ▶ The magnitude of charge per proton is equal to that of an electron.
- ▶ Neutrons have no charge.
- ▶ Charge is a physical property of subatomic particles.

The SI unit of electronic charge is the *coulomb* (C).

$$1 \text{ C} = 1 \text{ As}$$

The charge carried by a proton and an electron is the smallest charge in nature and its magnitude is given as follows:

- ▶ Charge carried by an electron is  $-1.6 \times 10^{-19} \text{ C}$ .
- ▶ Charge carried by a proton is  $+1.6 \times 10^{-19} \text{ C}$ .

A branch of electricity that studies about charges at rest is known as *Electrostatics*.

### Example

- a) What is electric charge?
- b) What is the magnitude of charge carried by a proton?

### How to solve it!

- a) Charge is a characteristic property of subatomic particles.
- b) The magnitude of charges carried by proton is  $1.6 \times 10^{-19} \text{ C}$ .

**Let's Exercise****I Fill in the blank space.**

1. A branch of electricity that studies about charges at rest is called \_\_\_\_\_.
2. Positive charge is carried by \_\_\_\_\_.
3. Negative charge is carried by \_\_\_\_\_.
4. The magnitude of charge carried by an electron is \_\_\_\_\_.
5. The smallest charge in nature is the charge carried by an \_\_\_\_\_ and a \_\_\_\_\_.

**II Give short answer.**

6. What is the SI unit of charge?  
\_\_\_\_\_.
7. What is the sign of charge carried by a proton?  
\_\_\_\_\_.
8. What is the sign of charges carried by an electron?  
\_\_\_\_\_.
9. Write the SI unit of charge in terms of ampere and second.  
\_\_\_\_\_.

**Let's Go Further**

1. In the evening when we take off our nylon clothes we hear cracking sound and see sparks. What is the reason for this phenomenon?  
\_\_\_\_\_.
2. At normal condition, an atom is electrically neutral. What is the reason for this?  
\_\_\_\_\_.

## 8.5 METHODS OF CHARGING

A process of removing or adding electrons from or to a neutral body is called *charging*. A body can be charged in two different ways i.e., by *rubbing* and by *conduction*.

### CHARGING BY RUBBING

When two neutral bodies rubbed each other, electrons are transferred from one body to another. It means one of the bodies loses electrons while the other gains electrons.

The body which gains electrons is charged negatively and the body which loses electrons is charged positively. Thus, the process of charging a body by gaining or losing of electrons is called *charging by rubbing*.

#### Example

1. When a plastic rod is rubbed with woollen clothes, electrons are transferred from the plastic rod to woollen cloth. Then identify:
  - a) the object which is charged negatively,
  - b) the object which is charged positively, and
  - c) the method of charging.
2. Rub a glass rod with a piece of silk. Explain what happens.

#### How to solve it!

1.
  - a) Since electrons are transferred from the plastic rod, the plastic rod is charged positively i.e., number of protons are greater than number of electrons.
  - b) Since the woollen cloth is received electrons, it is charged negatively i.e., number of electrons are greater than number of protons.
  - c) Since these two bodies are charged when they rubbed each other i.e., there is a direct contact between the two objects, so the method of charging is charging by rubbing.
2. Electrons are ripped off the glass and go on to the silk. The glass is now positive and the silk is negative.

## CHARGING BY CONDUCTION

Charging a body by conduction can sometimes termed as *charging by sharing*.

When a neutral body make a contact with a charged body, electrons move from the charged body to the natural body. The process of charging a body by this way is called *charging by conduction* or *charging by sharing*.

### Example

When a negatively charged rod touch uncharged pith ball, after some times the two bodies repel each other. Answer the following questions.

1. The pith ball is charged:
  - a) positively
  - b) negatively
2. What is the methods of charging?

### How to solve it!

1. Electrons will transfer from the negatively charged rod to the pith ball and the pith ball becomes negatively charged that is why the two objects repel each other. Therefore, the pith ball is charged negatively.
2. Since the charging is takes place by sharing of electrons, the method of charging is by conduction.

### Let's Exercise

1. State the methods of charging a body.
2. When do we say a body is charged negatively or positively.

## Let's Go Further

Compare and contrast charging by rubbing and charging by sharing.

## 8.6 LAW OF ELECTROSTATICS

Static electricity is all about charges which are not free to move. This causes that they build up in one place and end with a spark or a show when they finally move.

### Example

Among the following situations write down the movement of the charges and method of charging.

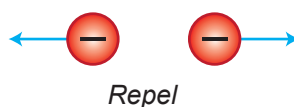
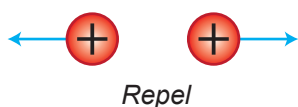
- A student rubbing an ebonite rod into silk, then he observed that the rod pulls paper pieces. \_\_\_\_\_
- A girl putting her pullover, and then she observed that her hair is moving. \_\_\_\_\_
- A student brought a rod which is negatively charged near to the other object. \_\_\_\_\_

### How to solve it!

- When two insulating materials are rubbed together, they acquire equal and opposite charges. Therefore, electrically charged objects attract small objects placed near them. This is charging by rubbing.
- Because, this left a positive static charge on one and negative static charge on the other. This is charging by rubbing.
- Because, the charged rod is negatively charged and brought near to uncharged object, the electron in this object will be pushed to the further side of the object. Only the electrons move, not the positive charges. After touching charged and uncharged objects, electrons are transferred from charged object to uncharged object. This is charging by conduction or charging by sharing.

Like charges repel, unlike charges attract each other.

Two things with opposite electric charges are attracted to each other. The two things with same electric charges repel each other. These forces get weaker the further apart the things are.



### Let's Exercise

1. State the law of electrostatic.
2. Which way the electrons are transferred depends on the two different materials involved?
3. How many kind of charges are there?
4. How many methods of charging are there given on example?

### Let's Go Further

1. Which particles move when static electricity build up, and which ones do not?
2. Describe how the machines use electricity:
  - a) Ink-jet printer?
  - b) Photocopies?
3. Explain the situation of in **Figure 8.5** below, for example, an uncharged object (the wall) attracts by a charged one (the balloon). Explain how does this happen.

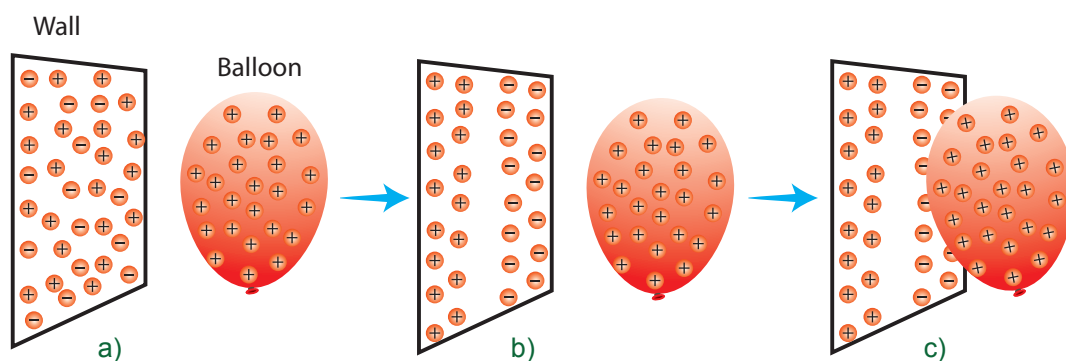


Figure 8.5

## 8.7 ELECTRIC CURRENT AND POTENTIAL DIFFERENCE

**Electric current** is the rate of flow of charge, whereas **potential difference** is difference in an electric potential between two points. Potential difference is also called *voltage*.

The symbol of an electric current is  $I$  and its SI unit is ampere (A).

The symbol of potential difference is  $P.D.$  or  $V$  and its SI unit is volt (V).

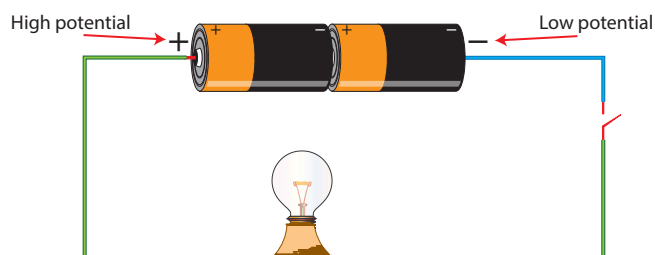
The relationship between electric current and potential difference is given by the equation:

$$\frac{V}{I} = \text{Constant}$$

Current,  $I$ , is given by the equation:

$$I = \frac{Q}{\Delta t}; \text{ where } Q - \text{is charge follow through a cross section}$$

$\Delta t$  – is the time tarvel during charge flow



**Figure 8.6**

There is potential difference in between (+) and (–) positions of the circuit. That means there is voltage.

### Example

In a big electric wire, electric charge of 4 C is flowing in 2 seconds. What is the current flowing in the wire?

#### How to solve it!

Given:

$$Q = 4 \text{ C}, \Delta t = 2 \text{ sec}$$

Required:

$$I = ?$$

$$I = \frac{Q}{\Delta t} = \frac{4 \text{ C}}{2 \text{ s}} = 2 \text{ A}$$

## SOURCES OF POTENTIAL DIFFERENCE (*P.D.*)

The charge flow in a circuit is because there is a difference in energy level between two points called *potential difference*. There are different forms of source of electricity. All the sources of electricity have *P.D.* across their terminals.

### Example

Car battery, dry cell, solar cell have *P.D.* across their terminals.

### Let's Exercise

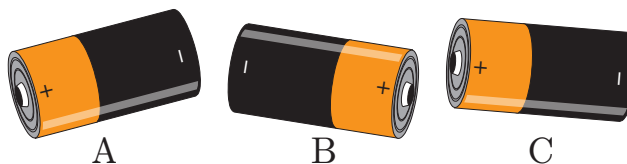
1. Give some other source of *P.D.* that you know.  
\_\_\_\_\_
2. Give one example of a rechargeable source of *P.D.*  
\_\_\_\_\_
3. Give one example of a source of *P.D.* which is used once and finally thrown away.  
\_\_\_\_\_

### Do You Know?

In rural areas solar cells are placed on the roof of a house to give electricity to the bulb in the house and make it to lit. Solar cells have least effect in pollution, they have no chemicals that pollute earth or air.

## Let's Go Further

Connect the following dry cells in a manner to get smaller or greater potential difference.



## 8.8 PRIMARY AND SECONDARY CELLS

Among the different sources of potential difference, the most widely available is *chemical cell*. It changes chemical energy into electrical energy.

Types of electric cells

- i) Primary cells
- ii) Secondary cells

### i) PRIMARY CELLS

- ☒ These cells produce current as a result of chemical changes in their various components.
- ☒ These cells cannot be recharged or used again after they are used exhaustively.
- ☒ A good example of primary cell is dry cell.
- ☒ The potential difference between the two terminals ( “+” and “-” ) of a dry cell is 1.5 V.
- ☒ When dry cells are connected end to end (in series) greater potential difference can be produced.

### ii) SECONDARY CELLS

- ☒ After they are used exhaustively they can be recharged and used again and again.
- ☒ Car battery is a typical example of these type of cells.
- ☒ These cells are also known as *storage cells* or *accumulators*.

### Example

Write the correction for the following miss understandings.

- a) We can recharge and use primary cells again after we use them.
- b) A typical example of accumulators is dry cell.
- c) Connecting dry cells in parallel enable to produce greater potential difference.
- d) Chemical cells change electrical energy to chemical energy.

**How to solve it!**

- a) Primary cells cannot be recharged and used again.
- b) A typical example of accumulators is car battery (not dry cell).
- c) To produce greater potential difference, dry cells should be connected in series (not in parallel).
- d) Chemical cells change chemical energy to electrical energy (not the reverse).

**Let's Exercise**

1. Explain how charges flow from one terminal to the other terminal for battery.

\_\_\_\_\_

\_\_\_\_\_

2. Write at least two similarity and difference between primary and secondary cells.

\_\_\_\_\_

\_\_\_\_\_

**Do You Know?**

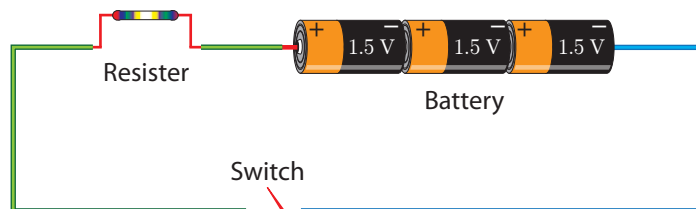
The electrical source of a mobile telephone is kind of secondary cell, that can be recharged again and again.

**Let's Go Further**

1. Give three appliances that use primary cell.
- i) \_\_\_\_\_
  - ii) \_\_\_\_\_
  - iii) \_\_\_\_\_
2. Give three examples that use secondary cells in your surroundings.
- i) \_\_\_\_\_
  - ii) \_\_\_\_\_
  - iii) \_\_\_\_\_

## 8.9 ELECTRIC CIRCUIT

Electric current needs a complete path to flow through an electric circuit. An electric circuit has a minimum of *voltage source*, *resistor*, *switch* and *connecting wires*.



**Figure 8.7:** Schematic diagram of a simple circuit

A complete path that electric current can flow through is an *electric circuit*.

The current and voltage flowing in an electric circuit are measured using instruments *ammeter* and *voltmeter* respectively.

**Table 8.1:** Elements of electric circuit and their symbols.

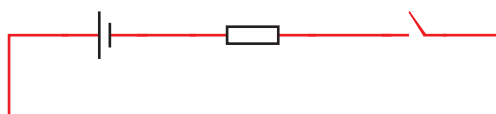
| Circuit Element | Cell | Battery | Lamp | Resistor | Voltmeter | Ammeter |
|-----------------|------|---------|------|----------|-----------|---------|
| Symbol          |      |         |      |          |           |         |

### Example

Draw a circuit diagram using symbols of one resistor, one dry cell, one switch, and connecting wires.

#### How to solve it!

Elements of an electric circuit should be connected with connecting wires which are represented by lines.



**Figure 8.8**

In an electric circuit, ammeter is connected in series with a resistor, whereas voltmeters is connected in parallel with the resistor.

### Example

Draw the proper connection of an ammeter with a battery, resistor and switch in a simple circuit using symbols.

### How to solve it!

An ammeter should be connected in series, then all elements are placed in only one pathway.

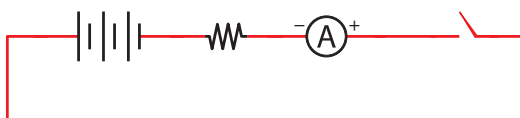


Figure 8.9

### Let's Exercise

1. Draw a simple electrical circuit using symbols of battery, bulb, switch and connecting wires.
2. Draw a correct connection of simple electrical circuit using symbols of a dry cell, resistor, voltmeter and switch.

### Do You Know?

- ✓ An open circuit is an arrangement of electrical elements but no current flow.
- ✓ Using an open circuit, one can test whether a material is electrical conductor or an insulator.

## Let's Go Further

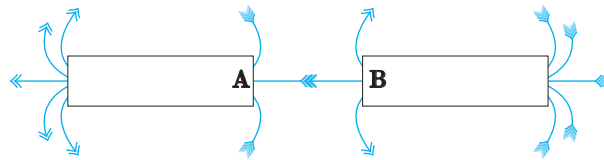
1. Draw a correct connection of a simple electric circuit that has a resistor, one ammeter, one voltmeter, switch and battery.
2. Draw a circuit diagram designed to test whether a material is conductor or insulator.

## 8.10 UNIT SUMMARY

### I Choose the Correct Answer.

1. For the magnetic field lines shown in **Figure 8.10**, what is the polarities of "A" and "B" respectively?

- A. N, N  
B. N, S  
C. S, N  
D. S, S



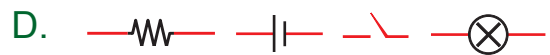
**Figure 8.10**

2. Which one of the following is **NOT** the use of magnet??
- A. To indicate direction.  
B. To separate magnetic substance.  
C. To construct electric bell.  
D. To see objects at far distance.
3. The process of charging a body by touching it with a charged body is known as charging by \_\_\_\_\_.
- A. convection  
B. induction  
C. sharing  
D. rubbing

4. Which diagram shows the forces between electric charges correctly?



5. Which one of the following groups of electric circuit elements represent resistor, battery, switch and bulb?



### II Give Short Answer.

6. The process of making magnet by stroking method is called \_\_\_\_\_.
7. The device that is used to detect the sign of charges on a body is called \_\_\_\_\_.
8. Under line only magnetic substances from the given lists of materials below.

*Iron, Steel, Gold, Wood, Copper, Nickel, Aluminium, Cobalt, Rubber.*

# Acknowledgments

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All these experts sincerely hope that this Workbook will help you with your Physics study at school and at home.

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