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UNIT 1

MEASUREMENT

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Learning Objectives

After completing this lesson, students will be able to

- understand the fundamental and derived quantities and their units.
- know the rules to be followed while expressing physical quantities in SI units.
- get familiar with the usage of scientific notations.
- know the characteristics of measuring instruments.
- use vernier caliper and screw gauge for small measurements.
- find the weight of an object using a spring balance.
- know the importance of accurate measurements.

Introduction

Measurement is the basis of all important scientific study. It plays an important role in our daily life also. While finding your height, buying milk for your family, timing the race completed by your friend and so on, you need to make measurements. Measurement answers questions like, how long, how heavy and how fast? Measurement is about assigning a number to a characteristic of an object or event which can be compared with other objects or events. It is defined as the determination of the size or magnitude of a quantity. In this lesson you will learn about units of measurements and the characteristics of measuring instruments.

1.1 Physical Quantities and Units

1.1.1 Physical quantities

Physical quantity is a quantity that can be measured. Physical quantities can be classified into two: fundamental quantities and derived quantities. Quantities which cannot be expressed in terms of any other physical quantities are called fundamental quantities. Example: Length, mass, time, temperature etc. Quantities which can be expressed in terms of fundamental quantities are called derived quantities. Example: Area, volume, density etc.

Physical quantities have a numerical value and a unit of measurement (say, 3 kilogram). Suppose you are buying 3 kilograms of vegetable in a shop. Here, 3 is the numerical value and kilogram is the unit. Let us study about units now.

1.1.2 Units

A unit is a standard quantity with which the unknown quantities are compared. It is defined as a specific magnitude of a physical quantity that has been adopted by law or convention. For example, feet is the unit for measuring length. That means, 10 feet is equal to 10 times the definite pre-determined length, called feet.

Earlier, different unit systems were used by people from different countries. Some of the unit systems followed earlier are given below in Table 1.1.

Table 1.1 Unit systems of earlier times

System	Length	Mass	Time
CGS	centimetre	gram	second
FPS	foot*	pound	second
MKS	metre	kilogram	second

* foot is the singular of feet

At the end of the Second World War there was a necessity to use worldwide system of measurement. Hence, SI (International System of Units) system of units was developed and recommended by General Conference on Weights and Measures at Paris in 1960 for international usage.

1.2 SI System of Units

SI system of units is the modernised and improved form of the previous system of units. It is accepted in almost all the countries. It is based on a certain set of fundamental units from which derived units are obtained by proper combination. There are seven fundamental units in the SI system of units. They are also known as base units and they are given in Table 1.2.

The units used to measure the fundamental quantities are called fundamental units and the units which are used to measure the derived quantities are called derived units.

Table 1.2 Fundamental quantities and their units

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

With the help of these seven fundamental units, the units for other derived quantities are obtained and their units are given below in Table 1.3.

1.3 Fundamental Units

1.3.1 Length

Length is the extent of something between two points. The SI unit of length is metre. One metre is the distance travelled by light through vacuum in 1/29,97,92,458 second.

Table 1.3 Derived quantities and their units

S.No	Physical quantity	Expression	Unit
1	Area	length × breadth	m^2
2	Volume	area × height	m^3
3	Density	mass / volume	kgm^{-3}
4	Velocity	displacement / time	ms^{-1}
5	Momentum	mass × velocity	$kgms^{-1}$
6	Acceleration	velocity / time	ms^{-2}
7	Force	mass × acceleration	$kgms^{-2}$ or N
8	Pressure	force / area	Nm^{-2} or Pa
9	Energy (work)	force × distance	Nm or J
10	Surface tension	force / length	Nm^{-1}

In order to measure very large distance (distance of astronomical objects) we use the following units.

- Astronomical unit
- Light year
- Parsec

Astronomical unit (AU): It is the mean distance of the centre of the Sun from the centre of the Earth. 1 AU = 1.496×10^{11} m (Figure 1.1).

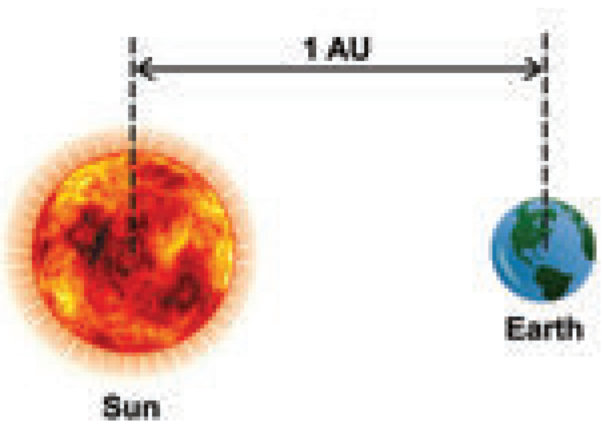


Figure 1.1 Astronomical unit

Light year: It is the distance travelled by light in one year in vacuum and it is equal to 9.46×10^{15} m.

Parsec: Parsec is the unit of distance used to measure astronomical objects outside the solar system.

1 Parsec = 3.26 light year.

Table 1.4 Larger units

Larger units	In metre
Kilometre (km)	10^3 m
Astronomical unit (AU)	1.496×10^{11} m
Light year (ly)	9.46×10^{15} m
Parsec (pc)	3.08×10^{16} m

DO YOU KNOW?

The nearest star alpha centauri is about 1.34 parsec from the sun. Most of the stars visible to the unaided eye in the night sky are within 500 parsec distance from the sun.

To measure small distances such as distance between two atoms in a molecule, size of the nucleus and wavelength etc. we use submultiples of ten. These quantities are measured in Angstrom unit (Table 1.5).

Table 1.5 Smaller units

Smaller units	In metre
Fermi (f) *	10^{-15} m
Angstrom (Å)*	10^{-10} m
Nanometre (nm)	10^{-9} m
Micron (micrometre μ m)	10^{-6} m
Millimetre (mm)	10^{-3} m
Centimetre (cm)	10^{-2} m

* Unit outside SI system and still accepted for use.

1.3.2 Mass

Mass is the quantity of matter contained in a body. The SI unit of mass is kilogram (kg). One kilogram is the mass of a particular international prototype cylinder made of platinum-iridium alloy, kept at the International Bureau of Weights and Measures at Sevres, France.

The units gram (g) and milligram (mg) are the submultiples of ten (1/10) of the unit kg. Similarly quintal and metric tonne are multiples of ten (× 10) of the unit kg.

1 g = 1/1000 × 1 kg = 0.001 kg

1 mg = 1/1000000 × 1 kg = 0.000001 kg

1 quintal = 100 × 1 kg = 100 kg

1 metric tonne = 1000 × 1 kg = 10 quintal

Atomic mass unit

Mass of a proton, neutron and electron can be determined using atomic mass unit (amu).

1 amu = $(1/12)^{th}$ of the mass of C^{12} atom.

More to Know

Mass of 1 m*l* of water = 1g

Mass of 1*l* of water = 1kg

Mass of the other liquids vary with their density.

1.3.3 Time

Time is a measure of duration of events and the intervals between them. The SI unit of time is second. One second is the time required for the light to propagate 29,97,92,458 metres through vacuum. It is also defined as 1/86, 400^{th} part of a mean solar day. Larger units for measuring time are day, month, year and millennium etc. 1 millenium = 3.16×10^9 s.

1.3.4 Temperature

Temperature is the measure of hotness or coldness of a body. SI unit of temperature is kelvin (K). One kelvin is the fraction (1/273.16) of the thermodynamic temperature of the triple point of water (The temperature at which saturated water vapour, pure water and melting ice are in equilibrium). Zero kelvin (0 K) is commonly known as absolute zero. The other units for measuring temperature are degree celsius (°C) and fahrenheit (F).

1.4 Unit Prefixes

Unit prefixes are the symbols placed before the symbol of a unit to specify the order of magnitude of the quantity. They are useful to express very large and very small quantities. k (kilo) is the unit prefix in the unit, kilometer. A unit prefix stands for a specific positive or negative power of 10. Some unit prefixes are given in Table 1.6.

Table 1.6 Unit prefixes

Power of 10	Prefix	Symbol
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

The physical quantities vary in different proportion like from 10^{-15} m being the diameter of nucleus to 10^{26} m being the distance between two stars and 9.11×10^{-31} kg being the mass of electron to 2.2×10^{41} kg being the mass of the milky way galaxy.

1.5 Rules and Conventions for writing SI Units and their Symbols

1. The units named after scientists are not written with a capital initial letter. E.g. newton, henry, ampere and watt.
2. The symbols of the units named after scientists should be written by the initial capital letter. E.g. N for newton, H for henry, A for ampere and W for watt.
3. Small letters are used as symbols for units not derived from a proper noun. E.g. m for metre, kg for kilogram.
4. No full stop or other punctuation marks should be used within or at

the end of symbols. E.g. 50 m and not as 50 m.

5. The symbols of the units are not expressed in plural form. E.g. 10 kg not as 10 kgs.
6. When temperature is expressed in kelvin, the degree sign is omitted. E.g. 283 K not as 283° K (If expressed in celsius scale, degree sign should be included e.g. 100°C not as 100 C, 108° F not as 108 F).
7. Use of solidus (/) is recommended for indicating a division of one unit symbol by another unit symbol. Not more than one solidus is used. E.g. ms^{-1} or m/s. J/K/mol should be $JK^{-1}mol^{-1}$.
8. The number and units should be separated by a space. E.g. 15 $kgms^{-1}$ not as 15 $kgms^{-1}$.
9. Accepted symbols alone should be used. E.g. ampere should not be written as amp and second should not be written as sec.
10. The numerical values of physical quantities should be written in scientific form. E.g. the density of mercury should be written as 1.36×10^4 kgm^{-3} not as 13600 kgm^{-3}.

1.6 Vernier Caliper and Screw Gauge

In our daily life, we use metre scale for measuring lengths. They are calibrated in cm and mm. The smallest length which can be measured by metre scale is called least count. Usually the least count of a scale is 1 mm. We can measure the length of objects upto 1 mm accuracy with this scale. By using vernier caliper we can have an accuracy of 0.1 mm and with screw gauge we can have an accuracy of 0.01 mm.

1.6.1 Description of Vernier caliper

The Vernier caliper consists of a thin long steel scale graduated in cm and mm called main scale. To the left end of the main scale an upper and a lower jaw are fixed perpendicular to the bar. These are named as fixed jaws. To the right of the fixed jaws, a slider with an upper and a lower moveable jaw is fixed. The slider can be moved or fixed to any position using a screw. The Vernier scale is marked on the slider and it moves along with the movable jaws and the slider. The lower jaws are used to measure the external dimensions and the upper jaws are used to measure the internal dimensions of the objects. The thin bar attached to the right side of the Vernier scale is used to measure the depth of hollow objects.

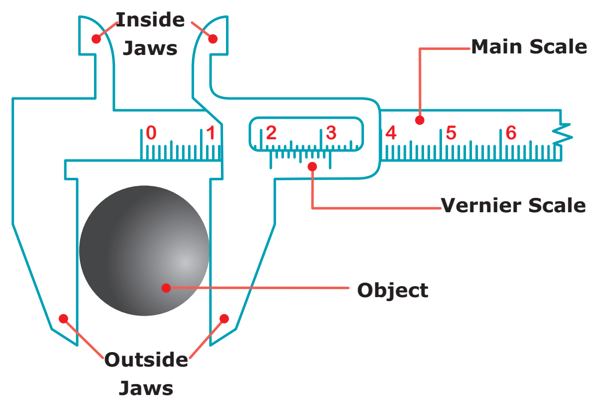


Figure 1.2 Vernier Caliper

1.6.2 Usage of Vernier caliper

The first step in using the Vernier caliper is to find out its least count, range and zero error.

a) Least count

Least count of the instrument (L.C)

$$= \frac{\text{Value of one main scale division}}{\text{Total number of vernier scale division}}$$

The main scale division will be in centimeter, further divided into millimetre. The value of the smallest main scale division is 1 mm. In the Vernier scale there will be 10 divisions.

$$\therefore \quad L.C = \frac{1mm}{10} = 0.1mm = 0.01cm$$

b) Zero error

Unscrew the slider and move it to the left, such that both the jaws touch each other.

Check whether the zero marking of the main scale coincides with that of the zero of the vernier scale. If they coincide then there is no zero error. If they do not coincide with each other, the instrument is said to possess zero error. Zero error may be positive or negative. If the zero of a vernier is shifted to the right of main scale, it is called positive error. On the other hand, if the zero of the vernier is shifted to the left of the zero of main scale, then the error is negative.

Positive zero error

Figure 1.3 shows the positive zero error. From the figure you can see that zero of the vernier scale is shifted to the right of the zero of the main scale. In this case the reading will be more than the actual reading. Hence, this error should be corrected. In order to correct this error, find out which vernier division is coinciding with any of the main scale divisions. Here, fifth vernier division is coinciding with a main scale division. So, positive zero error = +5 × LC = +5 × 0.01 = 0.05 cm and the zero correction is negative. Hence, zero correction is –0.05 cm.

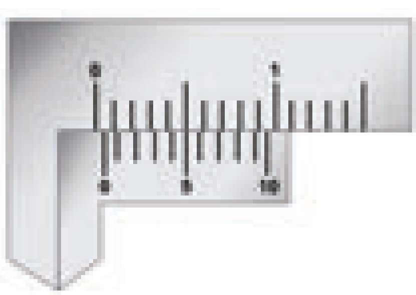


Figure 1.3 Positive zero error

Problem 1

Calculate the correct reading, if the main scale reading is 8 cm, vernier coincidence is 4 and positive zero error is 0.05 cm.

Solution:

Correct reading = 8 cm + (4 × 0.01cm) – 0.05 cm

= 8 + 0.04 – 0.05 = 8 – 0.01 = 7.99 cm

Negative zero error

Now look at the Figure 1.4. You can see that the zero of the vernier scale is shifted to the left of the zero of the main scale. So, the obtained reading will be less than the actual reading. To correct this error we should first find which vernier division is coinciding with any of the main scale divisions, as we found in the previous case. In this case, you can see that sixth line is coinciding. To find the negative error, we can count backward (from 10). Here, the fourth line is coinciding. Therefore, negative zero error = –4 × LC = –4 × 0.01 = –0.04 cm. Then zero correction is positive. Hence, zero correction is +0.04 cm.

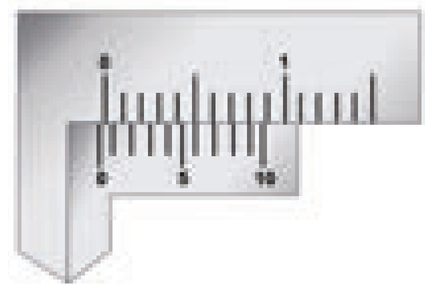


Figure 1.4 Negative zero error

Problem 2

The main scale reading is 8 cm and vernier coincidence is 4 and negative zero error is 0.02 cm. Then calculate the correct reading:

Solution:

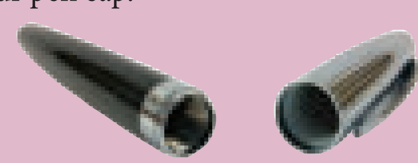
Correct reading = 8 cm + (4 × 0.01 cm) + (0.02 cm)

= 8+0.04+0.02 = 8.06 cm.

We can use Vernier caliper to find different dimensions of any familiar object. If the length, width and height of the object can be measured, volume can be calculated. For example, if we could measure the inner diameter of a beaker (using appropriate jaws) as well as its depth (using the depth probe) we can calculate its inner volume.

Activity 1

Using Vernier caliper find the outer diameter of your pen cap.



1.6.3 Digital Vernier caliper

We are living in a digital world and the digital version of the vernier callipers are available nowadays. Digital Vernier caliper (Figure 1.5) has a digital display on the slider, which calculates and displays the measured value. The user need not manually calculate the least count, zero error etc.

Figure 1.5 Digital Vernier caliper

1.7 Screw Gauge

Screw gauge is an instrument that can measure the dimensions upto 1/100th of a millimetre or 0.01 mm. With the screw gauge it is possible to measure the diameter of a thin wire and thickness of thin metallic plates.

1.7.1 Description of screw gauge

The screw gauge consists of a U shaped metal frame. A hollow cylinder is attached to one end of the frame. Grooves are cut on the inner surface of the cylinder through which a screw passes (Figure 1.6). On the cylinder parallel to the axis of the screw there is a scale which is graduated in millimetre. It is called Pitch Scale (PS). One end of the screw is attached to a sleeve. The head of the sleeve (Thimble) is divided into 100 divisions and it is called the Head scale.

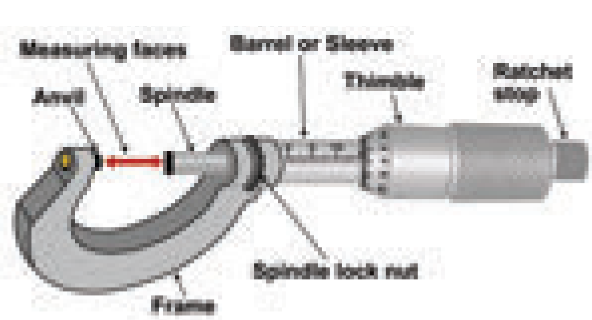


Figure 1.6 Screw gauge

The end of the screw has a plane surface (Spindle). A stud (Anvil) is attached to the other end of the frame, just opposite to the tip of the screw. The screw head is provided with a ratchat arrangement (safety device) to prevent the user from exerting undue pressure.

1.7.2 Using the screw gauge

The screw gauge works on the principal that when a screw rotates in a nut, the distance moved by the tip of the screw is directly proportional to the number of rotations.

a) Pitch of the screw

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The pitch of the screw is the distance moved by the tip of the screw for one complete rotation of the head. It is equal to 1 mm in typical screw gauges.

$$\text{Pitch of the screw} = \frac{\text{Distance moved by the Pitch}}{\text{No. of rotations by Head scale}}$$

b) Least count of a screw gauge

The distance moved by the tip of the screw for a rotation of one division on the head scale is called the least count of the screw gauge.

Least count of the instrument (L.C.)

$$= \frac{\text{Value of one smallest pitch scale reading}}{\text{Total number of Head scale division}}$$

$$LC = \frac{1}{100} = 0.01 \text{ mm}$$

c) Zero Error of a screw gauge

When the movable stud of the screw and the opposite fixed stud on the frame area brought into contact, if the zero of the head scale coincides with the pitch scale axis there is no zero error.

Positive zero error

When the movable stud of the screw and the opposite fixed stud on the frame are brought into contact, if the zero of the head scale lies below the pitch scale axis, the zero error is positive (Figure 1.7). Here, the 5th division of the head scale coincides with the pitch scale axis. Then the zero error is positive and is given by,

Z.E = + (n × LC) where 'n' is the head scale coincidence. In this case, Zero error = + (5 × 0.01) = 0.05mm. So the zero correction is – 0.05 mm.

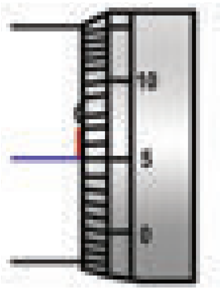


Figure 1.7 Positive Zero Error

Negative zero error

When the plane surface of the screw and the opposite plane stud on the frame are brought into contact, if the zero of the head scale lies above the pitch scale axis, the zero error is negative (Figure 1.8). Here, the 95^{th} division coincides with the pitch scale axis. Then the zero error is negative and is given by,

$$ZE = -(100 - n) \times LC$$
$$ZE = -(100 - 95) \times LC$$
$$= -5 \times 0.01$$
$$= -0.05 \text{ mm}$$

The zero correction is + 0.05mm.

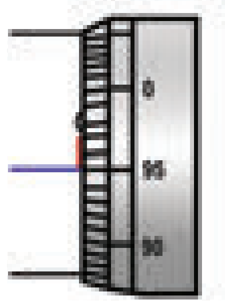


Figure 1.8 Negative Zero Error

Activity 2

Determine the thickness of a single sheet of your science textbook with the help of a Screw gauge.

1.8 Measuring Mass

We commonly use the term 'weight' which is actually the 'mass'. Many things are measured in terms of 'mass' in the commercial world. The SI unit of mass is kilogram (kg). In any case, the units are based on the items purchased. For example, we buy gold in gram or milligram, medicines in milligram, provisions in gram and kilogram and express cargo in tonnes.

Can we use the same instrument for measuring the above listed items? Different measuring devices have to be used for items of smaller and larger masses. In this section we will study about some of the instruments used for measuring mass.

DO YOU KNOW?

The shell of an egg is 12% of its mass. A blue whale can weigh as much as 30 elephants and it is as long as 3 large tour buses.

Common (beam) balance

A beam balance compares the sample mass with a standard reference mass (Standard reference masses are 5g, 10g, 20g, 50g, 100g, 200g, 500g, 1kg, 2kg, 5kg). This balance can measure mass accurately up to 5g (Figure 1.9).

Figure 1.9 Common beam balance

Physical balance

This balance is used in labs and is similar to the beam balance but it is a lot more sensitive and can measure mass of an object correct to a milligram (Figure 1.10).

The standard reference masses used in this physical balance are 10 mg, 20 mg, 50 mg, 100 mg, 200 mg, 500 mg, 1 g, 2g, 5 g, 10 g, 20 g, 50 g, 100g, and 200 g.

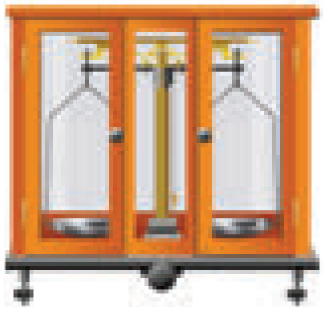


Figure 1.10 Physical balance

Digital balance

Nowadays, for accurate measurements digital balances are used, which measure mass accurately even up to a few milligrams, the least value being 10 mg (Figure 1.11). This electrical device is easy to handle and commonly used in jewellery shops and labs.

Figure 1.11 Digital balance

Activity 3

With the resources such as paper plates, tea cups, thread and sticks available at home make a model of an ordinary balance. Using standard masses find the mass of some objects.

Spring balance

This balance helps us to find the weight of an object. It consists of a spring fixed at one end and a hook attached to a rod at the other end. It works by 'Hooke's law' which states that the addition of weight produces a proportional increase in the length of the spring (Figure 1.12). A pointer is attached to the rod which slides over a graduated scale on the right. The spring extends according to the weight attached to the hook and the pointer reads the weight of the object on the scale.

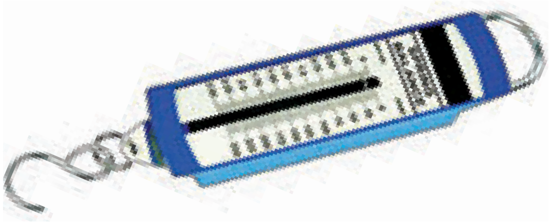


Figure 1.12 Spring balance

1.8.1 Difference between mass and weight

Mass (m) is the quantity of matter contained in a body. Weight (w) is the normal force (N) exerted by the surface on the body to balance against gravitational pull on the object. In the case of spring scale, the tension in the spring balances the gravitational pull on the object. When a man is standing on the surface of the earth or floor, the surface exerts a normal force on the body which is equivalent to gravitational force. The gravitational force acting on the object is given by 'mg'. Here, m is mass of the object and 'g' is acceleration due to gravity.

Problem 3

If a man has a mass 50 kg on the earth, then what is his weight?

Solution:

Weight (w) = mg

Mass of a man = 50 kg

His weight = 50 × 9.8

w = 490 newton

The pull of gravity on the Moon is 1/6 times weaker than that on the Earth. This causes the weight of the object on the Moon to be less than that on the Earth by six times. Acceleration due to gravity on the Moon = 1.63 ms^{-2}

If the mass of a man is 70 kg then his weight on the Earth is 686 N and on the Moon is 114 N. But his mass is still 70 kg on the Moon.

Mass	Weight
1. It is a fundamental quantity.	It is a derived quantity.
2. It has magnitude alone – scalar quantity.	It has magnitude and direction – vector quantity.
3. It is the amount of matter contained in a body.	It is the normal force exerted by the surface on the object against gravitational pull.
4. Remains the same everywhere.	Varies from place to place.
5. It is measured using physical balance.	It is measured using spring balance.
6. Its unit is kilogram.	Its unit is newton.

1.9 Accuracy in Measurements

When measuring physical quantities, accuracy is important. Accuracy represents how close a measurement comes to a true value. Accuracy in measurement is center in engineering, physics and all branches of science. It is also important in our daily life. You might have seen in jewellery shops how accurately they measure gold. What will happen if little more salt is added to food while cooking? So, it is important to be accurate when taking measurements.

Faulty instruments and human error can lead to inaccurate values. In order to get accurate values of measurement, it is always important to check the correctness of the measuring instruments. Also, repeating the measurement and getting the average value can correct the errors and give us accurate value of the measured quantity.

Points to Remember

- Quantities which cannot be expressed in terms of any other physical quantities are called fundamental quantities. Example: Length, mass, time, temperature etc.
- Quantities which can be expressed in terms of fundamental quantities are called derived quantities. Example: Area, volume and density etc.
- A unit is the fundamental quantity with which unknown quantities are compared.
- Length, mass, time, temperature, electric current, intensity and mole are the fundamental units in SI system.
- To find the length or thickness of smaller dimensions Vernier caliper and Screw gauge are used.
- Austronomical unit is the mean distance of the Sun from the center of the Earth. $1AU = 1.496 \times 10^{11}$m.
- Light year is the distance travelled by light in one year in vacuum. 1 Light year = 9.46×10^{15}m.
- Parsec is the unit of distance used to measure astronomical objects outside the solar system.
- 1 Angstrom (A°) = 10^{-10} m.
- SI Unit of volume is cubic metre or m^3. Generally volume is represented in litre (l). $1ml = 1cm^3$.
- Least count of screw gauge is 0.01 mm. Lease count of Vernier caliper is 0.01 cm.
- Common balance can measure mass accurately upto 5 g.
- Accuracy of physical balance is 10 mg.

A-Z GLOSSARY

Metre [m]	Distance light travels, in a vacuum, in $1/299792458^{th}$ of a second.
Kilogram [kg]	Mass of an international prototype in the form of a platinum-iridium cylinder kept at Sevres in France.
Second [s]	Length of time taken for 9192631770 periods of vibration of the Caesium-133 atom to occur.
Ampere [A]	It is that current which produces a specified force between two parallel wires which are 1 metre apart in a vacuum.
Kelvin [K]	It is 1/273.16th of the thermodynamic temperature of the triple point of water.
Mole [mol]	Amount of the substance that contains as many elementary units as there are atoms in 0.012 kg of carbon-12.
Candela [cd]	Intensity of a source of light of a specified frequency, which gives a specified amount of power in a given direction.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. Choose the correct one.
   a. mm< cm < m < km
   b. mm > cm > m > km
   c. km < m < cm < mm
   d. mm > m> cm> km

2. Rulers, measuring tapes and metre scales are used to measure
   a. mass b. weight
   c. time d. length

3. 1 metric ton is equal to
   a. 100 quintals b. 10 quintals
   c. 1/10 quintals d. 1/100 quintals

4. Which among the following is not a device to measure mass?
   a. Spring balance b. Beam balance
   c. Physical balance d. Digital balance

II. Fill in the blanks.

1. Metre is the unit of ________
2. 1 kg of rice is weighed by ______
3. Thickness of a cricket ball is measured by ________
4. Radius of a thin wire is measured by __________
5. A physical balance measures small differences in mass up to ______

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

1. The SI unit of electric current is kilogram.
2. Kilometre is one of the SI units of measurement.
3. In everyday life, we use the term weight instead of mass.
4. A physical balance is more sensitive than a beam balance.
5. One Celsius degree is an interval of 1K and zero degree Celsius is 273.15 K.
6. With the help of vernier caliper we can have an accuracy of 0.1 mm and with screw gauge we can have an accuracy of 0.01 mm.

IV. Match the following.

1. Length — kelvin
   Mass — metre
   Time — kilogram
   Temperature — second

2. Screw gauge — Vegetables
   Vernier caliper — Coins
   Beam balance — Gold ornaments
   Digital balance — Cricket ball

V. Assertion and reason type questions.

Mark the correct answer as:

a. Both A and R are true but R is not the correct reason.

b. Both A and R are true and R is the correct reason.

c. A is true but R is false.

d. A is false but R is true.

1. Assertion(A): The scientifically correct expression is " The mass of the bag is 10 kg"

   Reason (R): In everyday life, we use the term weight instead of mass.

2. Assertion (A): 0 °C = 273.16 K. For our convenience we take it as 273 K after rounding off the decimal.

   Reason (R): To convert a temperature on the Celsius scale we have to add 273 to the given temperature.

3. Assertion (A): Distance between two celestial bodies is measured in terms of light year.

   Reason (R): The distance travelled by the light in one year is one light year.

VI. Answer very briefly.

1. Define measurement.
2. Define standard unit.
3. What is the full form of SI system?
4. Define least count of any device.
5. What do you know about pitch of screw gauge?
6. Can you find the diameter of a thin wire of length 2 m using the ruler from your instrument box?

VII. Answer briefly.

1. Write the rules that are followed in writing the symbols of units in SI system.
2. Write the need of a standard unit.
3. Differentiate mass and weight.
4. How will you measure the least count of vernier caliper?

VIII. Answer in detail.

1. Explain a method to find the thickness of a hollow tea cup.
2. How will you find the thickness of a one rupee coin?

IX. Numerical Problems.

1. Inian and Ezhilan argue about the light year. Inian tells that it is 9.46×10^{15} m and Ezhilan argues that it is 9.46×10^{12} km. Who is right? Justify your answer.
2. The main scale reading while measuring the thickness of a rubber ball using Vernier caliper is 7 cm and the Vernier scale coincidence is 6. Find the radius of the ball.
3. Find the thickness of a five rupee coin with the screw gauge, if the pitch scale reading is 1 mm and its head scale coincidence is 68.
4. Find the mass of an object weighing 98 N.

REFERENCE BOOKS

1. Units and Measurements – John Richards. S. Chand publishing, Ram nagar, New Delhi.
2. Complete physics (IGCSE) - Oxford University press, New York.
3. Practical physics – Jerry. D. Wilson – Saunders college publishing, USA.

INTERNET RESOURCES

http://www.npl.co.uk/reference/measurement-units/

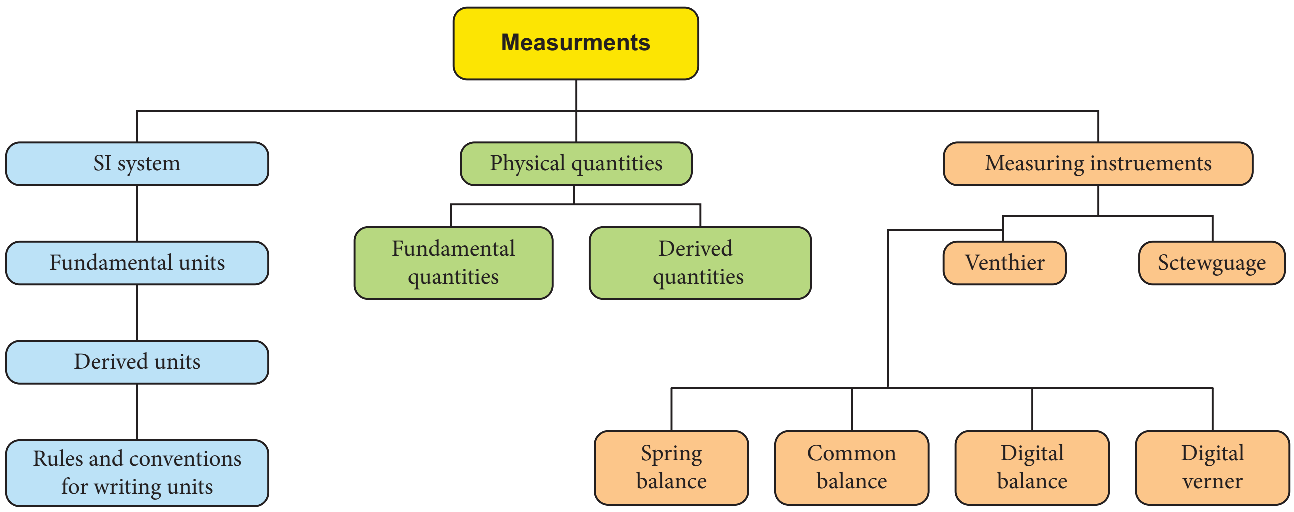
http://www.splung.com/content/sid/1/page/units

http://www.edinformatics.com/math_science/units.htm

https://www.unc.edu/~rowlett/units/dictA.html

https://study.com/academy/lesson/standard-units-of-measure.html

Concept Map



ICT CORNER

MEASUREMENT - VERNIER CALIPER

Vernier is a visual aid that helps the user to measure the internal and external diameter of the object.

This activity helps the students to understand the usage better

Step 1. Type the following URL in the browser or scan the QR code from your mobile. Youcan see"Vernier caliper" on the screen.

Step 2. The yellow colour scale is movable. Now you can drag and keep the blue colour cylinder in between. Now you can measure the dimension of the cylinder. Use the + symbol to drag cylinder and scale.

Step 3. Now go to the place where you can enter your answer. An audio gives you the feedback and you can see the answer on the screen also

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https://play.google.com/store/apps/details?id=com.ionicframework.vernierapp777926

UNIT 2

MOTION

Learning Objectives

After completing this lesson, students will be able to:

- list the objects which are at rest and which are in motion.
- understand distance and displacement.
- determine the distance covered by an object describing a circular path.
- classify uniform motion and non-uniform motion.
- distinguish between speed and velocity.
- relate accelerated and unaccelerated motion.
- deduce the equations of motion of an object from velocity – time graph.
- write the equations of motion for a freely falling body.
- understand the nature of circular motion.
- identify centripetal force and centrifugal force in day to day life.

Introduction

Motion is the change in the position of an object with respect to its surrounding. Everything in the universe is in motion. Even though an object seems to be not moving, actually it is moving because the Earth is moving around the Sun. You may see objects moving in your surrounding. Cars along the road, trains along the track and aeroplanes in the sky are all moving. These movements are one type of motion. You may see the fan rotating in the ceiling. This is another type of motion. When you are playing in swing, it moves to and fro. This is also a type of motion. Motion is described in terms of distance, speed, acceleration and time. In this lesson we will study about different types and equations of motion, displacement, velocity and acceleration.

2.1 Rest and Motion

Activity 1

Look around you. You can see many things: a row of houses, large trees, small plants, flying birds, running cars and many more. List the objects which remain fixed at their position and the objects which keep on changing their position.

In physics, the objects which do not change their position are said to be at rest, while those which change their position are said to be in motion. For example, a book lying on a table and the walls of a room are at rest. Cars and buses running on the road, birds and aeroplanes flying in air are in motion. Motion is a relative phenomenon. This means that an

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object appearing to be in motion to one person can appear to be at rest as viewed by another person. For example, trees on road side would appear to move backward for a person travelling in a car while the same tree would appear to be at rest for a person standing on the road side.

2.2 Types of Motion

In physics, motion can be classified as below.

Linear motion: Motion along a straight line.

Circular motion: Motion along a circular path.

Oscillatory motion: Repetitive to and fro motion of an object at regular interval of time.

Random motion: Motion of the object which does not fall in any of the above categories.

2.2.1 Uniform and Non-uniform motion

Uniform motion

Consider a car which covers 60 km in the first hour, 60 km in the second hour, and another 60 km in the third hour and so on. The car covers equal distance at equal interval of time. We can say that the motion of the car is uniform.

An object is said to be in uniform motion if it covers equal distances in equal intervals of time howsoever big or small these time intervals may be.

Non-uniform motion

Now, consider a bus starting from one stop. It proceeds slowly when it passes through crowded area of the road. Suppose, it manages to travel merely 100 m in 5 minutes due to heavy traffic and is able to travel about 2 km in 5 minutes when the road is clear. Hence, the motion of the bus is non-uniform i.e. it travels unequal distances in equal intervals of time.

Thus, an object is said to be in non-uniform motion if it covers unequal distances in equal intervals of time.

Activity 2

Tabulate the distance covered by a bus in a heavy traffic road in equal intervals of time and do the same for a train which is not in an accelerated motion. From your table what do you understand?

The bus covers unequal distance in equal intervals of time but the train covers equal distances in equal intervals of time.

2.3 Distance and Displacement

Consider a body moving from the point A. It moves along the path given in the Figure 2.1 and reaches the point B. The total length of the path travelled by the body from A to B is called distance travelled by the body. The length of the straight line AB is called displacement of the body.

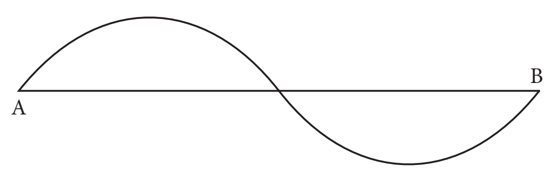


Figure 2.1 Distance and Displacement

2.3.1 Distance

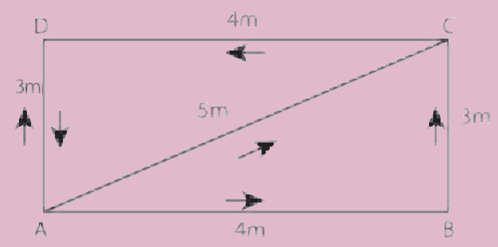
The actual length of the path travelled by a moving body irrespective of the direction is called the distance travelled by the body. It is measured in metre in SI system. It is a scalar quantity having magnitude only.

2.3.2 Displacement

It is defined as the change in position of a moving body in a particular direction. It is a vector quantity having both magnitude and direction. It is also measured in metre in SI system.

Activity 3

Observe the motion of a car as shown in the figure and answer the following questions:



Compare the distance covered by the car through the path ABC and AC. What do you observe? Which path gives the shortest distance to reach D from A? Is it the path ABCD or the path ACD or the path AD?

2.4 Speed, Velocity and Acceleration

Speed is the quantity which shows how fast the body is moving but velocity is the quantity which shows the speed as well as the direction of the moving body.

2.4.1 Speed

Speed is the rate of change of distance or the distance travelled in unit time. It is a scalar quantity. The SI unit of speed is ms^{-1}.
Speed = Distance travelled / Time taken

Problem 1

An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Solution:

Total distance travelled by the object = 16 m + 16 m = 32 m

Total time taken = 4s + 2s = 6s

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{32m}{6s} = 5.33\ ms^{-1}$$

Therefore, the average speed of the object is 5.33 ms^{-1}

Problem 2

A sound is heard 5 s later than the lightning is seen in the sky on a rainy day. Find the distance of location of lightning? Given the speed of sound = 346 ms^{-1}

Solution:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Distance = Speed × Time = 346 × 5 = 1730 m

Thus, the distance of location of lightning is 1730 m.

2.4.2 Velocity

Velocity is the rate of change of displacement. It is the displacement in unit time. It is a vector quantity. The SI unit of velocity is ms^{-1}.

Velocity = Displacement / Time taken

2.4.3 Acceleration

Acceleration is the rate of change of velocity or it is the change of velocity in unit time. It is a vector quantity. The SI unit of acceleration is ms^{-2}.

Acceleration
= Change in velocity/Time
= (Final velocity – Initial velocity)/Time
$a = (v-u)/t$

Consider a situation in which a body moves in a straight line without reversing its direction. From the above equation if $v > u$, i.e. if final velocity is greater than initial velocity, the velocity increases with time and the value of acceleration is positive.

If $v < u$, i.e. if final velocity is less than initial velocity, the velocity decreases with time and the value of acceleration is negative. It is called negative acceleration. Negative acceleration is called retardation or deceleration. If the acceleration has a value of $-2\ ms^{-2}$, we say that deceleration is $2\ ms^{-2}$.

2.5 Graphical representation of motion along a straight line

Plotting the distance/displacement or speed/velocity on a graph helps us to understand certain things about time and position.

2.5.1 The distance – time graph for Uniform motion

Consider the Table 2.1 which shows the distance walked by a person at different times.

Table 2.1 Uniform motion

Time (minute)	Distance (metre)
0	0
5	500
10	1000
15	1500
20	2000
25	2500

A graph is drawn by taking time along X-axis and distance along Y-axis. The graph is known as distance – time graph.

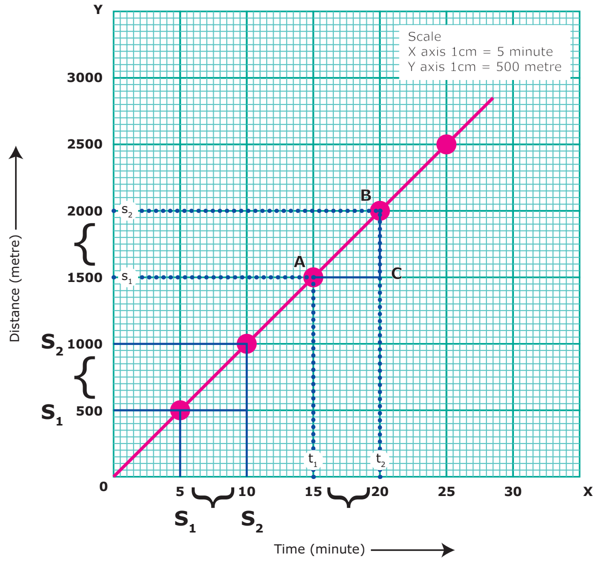


Figure 2.2 The distance – time graph for Uniform motion

When we look at the distance – time graph, we notice few things. First, it is a straight line. We also notice that the person covers equal distances in equal intervals of time. We can therefore conclude that he walked at a constant speed. Can you find the speed at which he walked, from the graph? Yes, you can. The parameter is referred as the slope of the line.

Speed = Distance covered / Time taken
= Slope of the straight line
= BC/AC (From the graph)
= 500 / 5 = 100 m/min

Steeper the slope (in other words the larger value) the greater is the speed.

Let us take a look at the distance – time graphs of three different people – Asher walking, Saphira cycling and Kanishka going in a car, along the same path (Fig 2.3). We know that cycling can be faster than walking and a car can go faster than a cycle. The distance – time graph of the three would be as given in the following graph. The slope of the line on the distance – time graph becomes steeper and steeper as the speed increases.

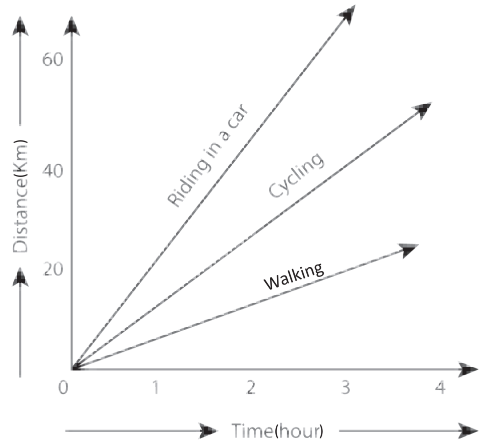


Figure 2.3 Comparison of speed

2.5.2 The distance time graph for Non-uniform motion

We can also plot the distance – time graph for accelerated motion (non-uniform motion). Table 2.2 shows the distance travelled by a car in a time interval of two seconds.

Table 2.2 Non-uniform motion

Time (second)	Distance (metre)
0	0
2	1
4	4
6	9
8	16
10	25
12	36

If we plot a graph between the distance travelled and the time taken, it would be as shown in Figure 2.4.

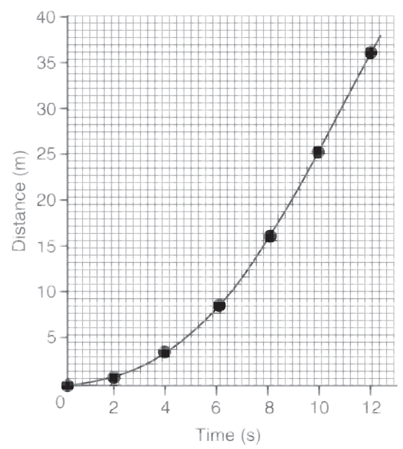


Figure 2.4 The distance time graph for Non-uniform motion

Note that the graph is not a straight line as we got in the case of uniform motion. This nature of the graph shows non–linear variation of the distance travelled by the car with time. Thus, the graph represents motion with non-uniform speed.

2.5.3 Velocity – Time graph

The variation in velocity of an object with time can be represented by velocity – time graph. In the graph, time is represented along the X – axis and the velocity is represented along the Y – axis. If the object moves at uniform velocity, a straight line parallel to X-axis is obtained. This graph shows the velocity – time graph for a car moving with uniform velocity of 40 km/hour.

We know that the product of velocity and time gives displacement of an object moving with uniform velocity. Thus, the area under the velocity – time graph is equal to the magnitude of the displacement. So, the distance (displacement), S covered by the car in a time interval of t can be expressed as,

S = AC × CD

S = Area of the rectangle ABCD (shaded portion in the graph)

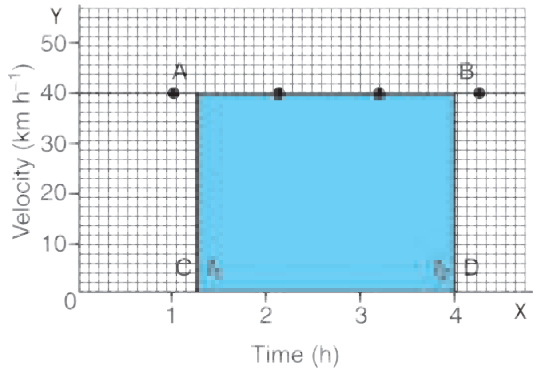


Figure 2.5 Velocity – Time graph

We can also study about uniformly accelerated motion by plotting its velocity – time graph. Consider a car being driven along a straight road. Its velocity for every 5 seconds is noted from the speedometer of the car. The velocity of the car in ms^{-1} at different instants of time is shown in the Table 2.3.

Table 2.3 Uniformly accelarated motion

Time (Second)	Velocity of the Car (ms^{-1})
0	0
5	9
10	18
15	27
20	36
25	45
30	54

In this case, the velocity – time graph for the motion of the car is shown in Figure 2.6 (straight line). The nature of the graph shows that the velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity – time graph is a straight line.

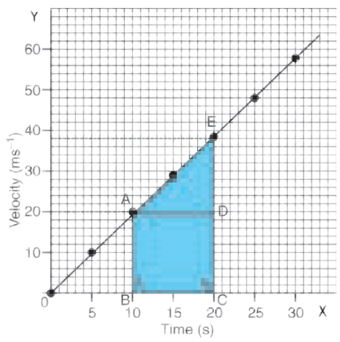


Figure 2.6 Velocity – Time graph for uniform accelaration

One can also determine the distance moved by the car from its velocity – time graph. The area under the velocity – time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time.

Since the magnitude of the velocity of the car is changing due to acceleration, the distance, S travelled by the car will be given by the area ABCDE under the velocity – time graph. That is,

S = Area ABCDE

= Area of the rectangle ABCD + Area of the triangle ADE

S = (AB × BC) + ½ (AD × DE)

Area of the quadrangle ABCDE can also be calculated by calculating the area of trapezium ABCDE. It means,

S = Area of trapezium ABCDE

= ½ × Sum of length of parallel sides × Distance between parallel sides

S = ½ × (AB + CE) × BC

In the case of non-uniformly accelerated motion, distance – time graph and velocity – time graphs can have any shape as shown in Figure 2.7.

DO YOU KNOW? The speedometer of an automobile measures the instantaneous speed of the automobile. In a uniform motion in one dimension, the average velocity is equal to instantaneous velocity. Instantaneous velocity is also called velocity or instantaneous speed or simply speed.

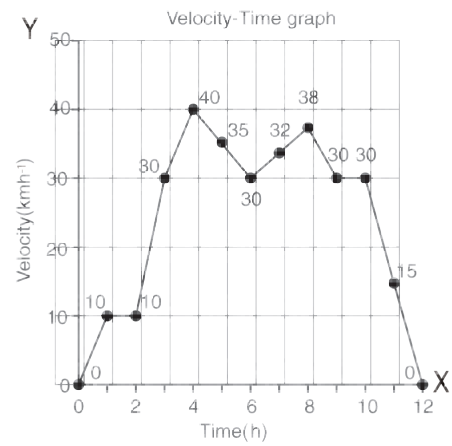


Figure 2.7 Velocity – Time graph for Non-uniform accelaration

2.6 Equations of Motion

Newton studied the motion of an object and gave a set of three equations. These equations relate displacement, velocity, acceleration and time of an object under motion. An object in motion with initial velocity, u attains a final velocity, v in time, t due to acceleration, a and reaches a distance, s. Three equations can be written for this motion.

$$v = u + at$$

$$s = ut + \frac{1}{2} a t^2$$

$$v^2 = u^2 + 2as$$

Let us try to derive these equations by graphical method.

Figure 2.8 shows the change in velocity with time for an uniformly accelerated object. The object starts from the point D in the graph with velocity, u. Its velocity keeps increasing and after time, t it reaches the point B on the graph.

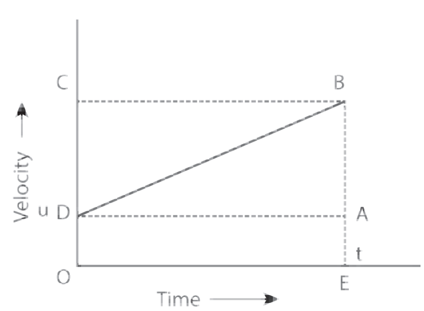


Figure 2.8 Equations of Motion

The initial velocity of the object = u = OD = EA

The final velocity of the object = v = OC = EB

Time = t = OE = DA

From the graph we know that, AB = DC

First equation of motion

By definition, Acceleration

= Change in velocity / Time

= (Final velocity – Initial velocity)/Time

= (OC – OD) / OE

= DC / OE

a = DC / t

DC = AB = at

From the graph EB = EA + AB

$$v = u + at \quad (1)$$

This is the first equation of motion.

Second equation of motion

From the graph the distance covered by the object during time, t is given by the area of quadrangle DOEB

s = Area of the quadrangle DOEB

= Area of the rectangle DOEA + Area of the triangle DAB

= (AE × OE) + (1/2 × AB × DA)

$$s = ut + \frac{1}{2} at^2 \quad (2)$$

This is the second equation of motion.

Third equation of motion

We see that the distance covered by the object during time, t is given by the area of the quadrangle DOEB. Here, DOEB is a trapezium. Then,

s = Area of trapezium DOEB

= ½ × Sum of length of parallel side × Distance between parallel sides

= ½ × (OD + BE) × OE

s = ½ × (u + v) × t

Since, a= (v – u) / t or t = (v – u)/a

s = ½ × (v + u) × (v – u)/a

$$2as = v^2 - u^2$$

$$v^2 = u^2 + 2as \quad (3)$$

This is the third equation of motion.

Problem 3

The brakes applied to a car produce an acceleration of 6 ms^{-2} in the opposite direction to the motion. If the car takes 2 s to stop after the application of brakes, calculate the distance traveled during this time.

Solution:

We have been given a = –6 ms^{-2}, t = 2s and v = 0

From the equation of motion,

$v = u + at$

$0 = u + (-6 \times 2)$

$0 = u - 12 \qquad \therefore u = 12\ ms^{-1}$

$s = ut + \frac{1}{2} at^2$

$= (12 \times 2) + \frac{1}{2}(-6 \times 2 \times 2)$

$= 24 - 12 = 12m$

Thus, the car will move 12 m before it stops after the application of brakes.

2.7 Motion of freely falling body

Activity 4

Take a large stone and a small eraser. Stand on the top of a table and drop them simultaneously from the same height. What do you observe? Now, take a small eraser and a sheet of paper. Drop them simultaneously from the same height. What do you observe? This time, take two sheets of paper having same mass and crumple one of the sheets into a ball. Now, drop the sheet and the ball from the same height. What do you observe?

From Activity 4, you can observe that, both the stone and the eraser reach the surface of the earth almost at the same time. When you drop the eraser and paper, the eraser reaches first and the sheet of paper reaches later. You can also observe that the paper crumpled into a ball reaches ground first and plain sheet of paper reaches later, although they have equal mass. Do you know the reason? When all these objects are dropped in the absence of air medium (vacuum), all would have reached the ground at the same time. In air medium, air offers some resistance to the motion of freely falling objects. But, it is negligibly small when compared to the gravitational pull acting on the stone and rubber. Hence, they reach the ground at the same time.

It can be seen from these activities that the magnitude of air resistance depends on the area of objects exposed to air. We know that an object experiences acceleration during free fall. This acceleration experienced by an object is independent of mass. This means that all objects hollow or solid, big or small, should fall at the same rate.

The equation of motion for a freely falling body can be obtained by replacing 'a' in equations with g, the acceleration due to gravity. For a freely falling body which is initially at rest, u = 0. Thus we get the following equations.

$$v = gt,\ s = \frac{1}{2} gt^2,\ v^2 = 2gh$$

DO YOU KNOW?

Can a body have zero velocity and finite acceleration? Yes, when a body is thrown vertically upwards in space, at the highest point, the body has zero velocity but it has acceleration due to the gravity.

When we throw an object vertically upwards, it moves against the acceleration due to gravity. Hence, 'a' is taken to be –g and when moving downwards 'a' is taken as +g.

2.8 Uniform circular motion

Activity 5

Take a piece of thread and tie a small piece of stone at one of its ends. Rotate the stone to describe a circular path with constant speed by holding the thread at the other end. Now, release the thread and let the stone go. Can you tell the direction in which the stone moves after it is released?

If you carefully observe, on being released the stone moves along a straight line tangential to the circular path. This is because once the stone is released, it continues to move along the direction it has been moving at that instant. This shows that the direction of motion changes at every point when the stone was moving along the circular path.

When an object is moving with a constant speed along a circular path, the velocity changes due to the change in direction. Hence, it is an accelerated motion. For example, revolution of earth around the sun, revolution of moon around the earth and the tip of the second's hand of a clock are all accelarated motions.

If an object, moving along a circular path of radius, r takes time, T to come back to its starting position, then the speed, v is given by,

Speed = Circumference/Time taken

$$V = 2\pi r/T$$

2.9 Centripetal Acceleration and Centripetal Force

A body is said to be accelerated, if the velocity of the body changes either in magnitude or in direction. So, the motion of a stone in circular path with constant speed and contineous change of direction is an accelerated motion. In this case, there must be an acceleration acting along the string directed inwards, which makes the stone to move in circular path.

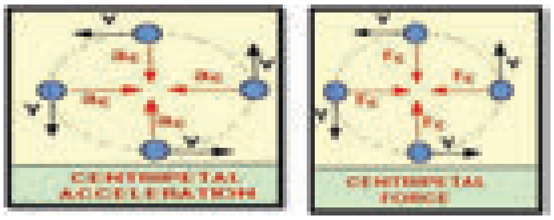


Figure 2.9 Centripetal acceleration and Centripetal force

This acceleration is known as centripetal acceleration and the force is known as centripetal force. Since the centripetal acceleration is directed radially towards the centre of the circle, the centripetal force must act on the object radially towards the centre.

Let us consider an object of mass m, moving along a circular path of radius r, with a velocity, v. Its centripetal acceleration is given by

$$a = v^2/r$$

The magnitude of centripetal force is given by,

$$F = \text{Mass} \times \text{Centripetal acceleration}$$
$$F = mv^2/r$$

Problem 4

A 900 kg car moving at 10 ms^{-1} takes a turn around a circle with a radius of 25 m. Determine the acceleration and the net force acting upon the car.

Solution:

When the car turns around circle, it experiences centripetal acceleration, $a = \frac{v^2}{r}$

$$a = \frac{(10)^2}{25} = \frac{100}{25} = 4\ ms^{-2}$$

Net force acting upon the car,

$$F = m\,a = 900 \times 4 = 3600\ N$$

DO YOU KNOW? Any force like gravitational force, frictional force, magnetic force, electrostatic force etc., may act as a centripetal force.

2.10 Centrifugal Force

Activity 6

Take a piece of rope and tie a small stone at one end. Hold the other end of the rope and rotate it such that the stone follows a circular path.

Do you experience any pull or push in your hand?

In this activity, a pulling force that acts away from the centre is experienced. This is called as centrifugal force. Force acting on a body away from the centre of circular path is called centrifugal force. Thus, centrifugal force acts in a direction which is opposite to the direction of centripetal force. Its magnitude is same as that of centripetal force. The dryer in a washing machine is an example for the application of centrifugal force.

DO YOU KNOW? When you go for a ride in a merry-go-round in amusement parks, you will experience an outward pull as merry-go round rotates about vertical axis. This is due to centrifugal force.

Points to Remember

- Motion is a change of position, which can be described in terms of the distance moved or the displacement.
- Motion of an object could be uniform or non-uniform depending on its velocity.
- Speed of an object is the distance covered per unit time and velocity is the displacement per unit time.
- The acceleration of an object is the change in velocity per unit time.
- The motion of an object at uniform acceleration can be described with the help of three equations, namely:

  $v = u + at$; $s = ut + ½ at^2$; $v^2 = u^2 + 2as$
- For a freely falling body, the acceleration, a is replaced by g.
- An object under uniform circular motion experiences centripetal force.
- Centrifugal force acts in a direction which is opposite to the direction of the centripetal force.

A-Z GLOSSARY

Motion	An object's change in its position.
Distance	Length an object has covered during its motion.
Displacement	Change in the position of an object measuring from its starting position to the final position only.
Speed	Rate of motion at which the object moves (distance/time).
Velocity	Speed of an object in a particular direction.
Acceleration	Change in magnitude or direction of velocity.
Circular motion	Movement of an object along the circumference of a circle or rotation along a circular path.
Centripetal force	Force which acts on a body moving in a circular path and directed towards the centre.
Centrifugal force	Force, arising from the body's inertia, which appears to act on a body moving in a circular path and is directed away from the centre.
Gravity	Force of attraction between an object and the centre of Earth, due to their masses.

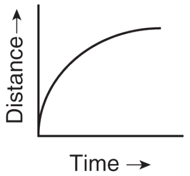
TEXTBOOK EXERCISES

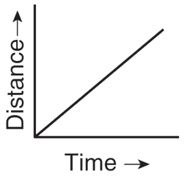
I. Choose the correct answer.

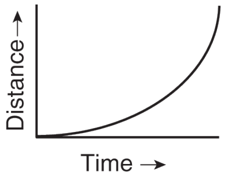
1. The area under velocity – time graph represents the
   a) velocity of the moving object.
   b) displacement covered by the moving object.
   c) speed of the moving object.
   d) acceleration of the moving object.

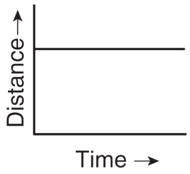
2. Which one of the following is most likely not a case of uniform circular motion?
   a) Motion of the Earth around the Sun.
   b) Motion of a toy train on a circular track.
   c) Motion of a racing car on a circular track.
   d) Motion of hours' hand on the dial of the clock.

3. Which of the following graph represents uniform motion of a moving particle?

a) 

b) 

c) 

d) 

4. The centrifugal force is
   a) a real force.
   b) the force of reaction of centripetal force.
   c) a virtual force.
   d) directed towards the centre of the circular path.

II. Fill in the blanks.

1. Speed is a ___________ quantity whereas velocity is a __________ quantity.
2. The slope of the distance – time graph at any point gives ___________
3. Negative acceleration is called _________
4. Area under velocity – time graph shows _____________

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

1. The motion of a city bus in a heavy traffic road is an example for uniform motion.
2. Acceleration can get negative value also.
3. Distance covered by a particle never becomes zero but displacement becomes zero.
4. The velocity – time graph of a particle falling freely under gravity would be a straight line parallel to the x axis.
5. If the velocity – time graph of a particle is a straight line inclined to X-axis then its displacement – time graph will be a straight line.

IV. Assertion and reason type questions.

Mark the correct choice as:

a. If both assertion and reason are true and reason is the correct explanation of assertion.

b. If both assertion and reason are true but reason is not the correct explanation of assertion.

c. If assertion is true but reason is false.

d. If assertion is false but reason is true.

1. Assertion: The accelerated motion of an object may be due to change in magnitude of velocity or direction or both of them.

   Reason: Acceleration can be produced only by change in magnitude of the velocity. It does not depend the direction.

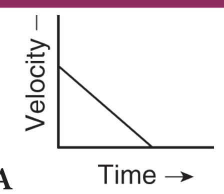
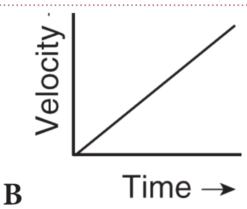
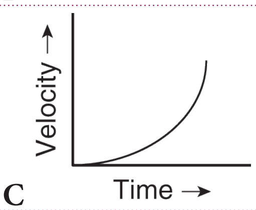
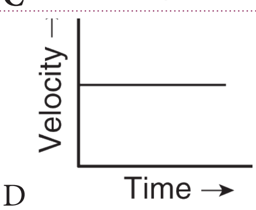
2. Assertion: The Speedometer of a car or a motor-cycle measures its average speed.

   Reason: Average velocity is equal to total displacement divided by total time taken.

3. Assertion: Displacement of a body may be zero when distance travelled by it is not zero.

   Reason: The displacement is the shortest distance between initial and final position.

V. Match the Following.

List I	List II
1. Motion of a body covering equal distances in equal interval of time	 A
2. Motion with non uniform acceleration	 B
3. Constant retardation	 C
4. Uniform acceleration	 D

VI. Answer briefly.

1. Define velocity.
2. Distinguish distance and displacement.
3. What do you mean by uniform motion?
4. Compare speed and velocity.
5. What do you understand about negative acceleration?
6. Is the uniform circular motion accelerated? Give reasons for your answer.
7. What is meant by uniform circular motion? Give two examples of uniform circular motion.

VII. Answer in detail.

1. Derive the equations of motion by graphical method.
2. Explain different types of motion.

VIII. Exercise Problems.

1. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 ms^{-2}, with what velocity will it strike the ground? After what time will it strike the ground?
2. An athlete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 m and 20 s?
3. A racing car has a uniform acceleration of 4 ms^{-2}. What distance it covers in 10 s after the start?

REFERENCE BOOKS

1. Advanced Physics by: M. Nelkon and P. Parker, C.B.S publications, Chennai
2. College Physics by: R.L.Weber, K.V. Manning, Tata McGraw Hill, New Delhi.
3. Principles of Physics (Extended) - Halliday, Resnick & Walker, Wiley publication, New Delhi.

INTERNET RESOURCES

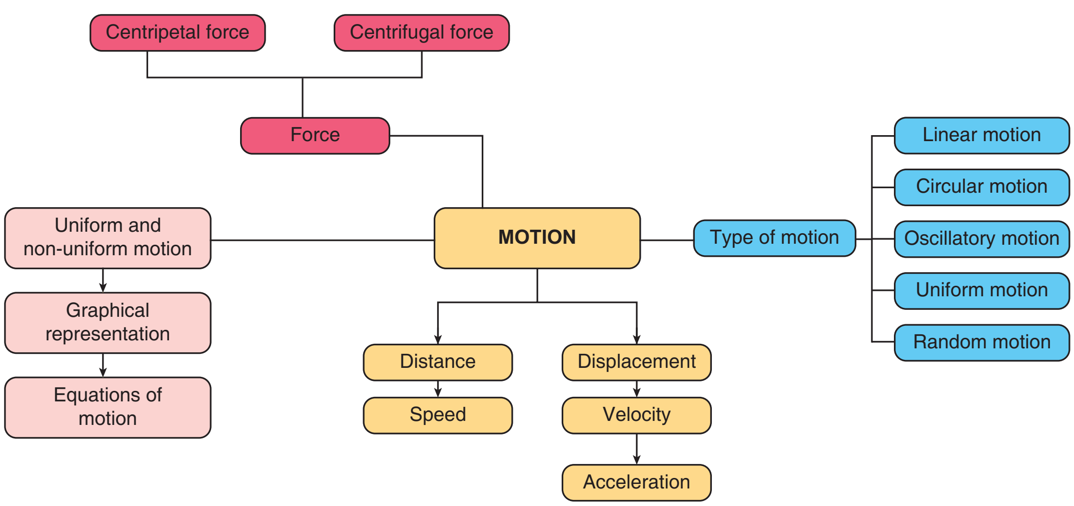
http://www.ducksters.com/science/physics/motion_glossary_and_terms.php

http://www.physicsclassroom.com/Class/1DKin/U1L1d.cfm

http://www.physicsclassroom.com/Class/1DKin/U1L1e.cfm

https://brilliant.org/wiki/uniform-circular-motion-easy/Centrifugal force

Concept Map



ICT CORNER

FORCE AND MOTION

Newton's second law says a force acting on the object either change it's direction or acceleration or both. F=ma

This activity proves that:

Step 1. Type the following URL in the browser or scan the QR code from your mobile.Youcan see a wheel barrow full of load on the screen. Below that you can see two sets of people also.

Step 2. Place different number of peoples on both the side of the rope. Click go. According to the force given by the people the wheel barrow moves to anyone of the side. If the number of people is equal on both the sides the load will not move.

Step 3. By changing the number of people you can see the force and motion.

https://phet.colorado.edu/en/simulation/forces-and-motion-basics

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UNIT 3

FLUIDS

G8JNLI

Learning Objectives

After completing this lesson, students will be able to

- define pressure in terms of weight.
- explain the variation of pressure with respect to depth in a fluid.
- learn the fact that liquid exerts an upward force on objects immersed in it.
- calculate the density of a liquid when pressure and altitude are given.
- learn the formula for finding the relative density of an object and apply the same.
- understand the behaviour of floating bodies.

Introduction

A small iron nail sinks in water, whereas a huge ship of heavy mass floats on sea water. Astronauts have to wear a special suit while traveling in space. All these have a common reason called 'pressure'. If the pressure increases in a solid, based on its inherent properties, it experiences tension and ultimately deforms or breaks. In the case of fluids it causes them to flow rather than to deform. Although liquids and gases share some common characteristics, they have many distinctive characteristics on their own. It is easy to compress a gas whereas liquids are incompressible. Learning of all these facts helps us to understand pressure better. In this lesson you will study about pressure in fluids, density of fluids and their application in practical life.

3.1 Thrust and Pressure

Pushing a pin into a board by its head is difficult. But pushing it by the pointed end is easy. Why? Have you ever wondered why a camel can run in a desert easily? Why a truck or a motorbus has wider tyre? Why cutting tools have sharp edges? In order to answer these questions and understand the phenomena involved, we need to learn about two interrelated physical concepts called thrust and pressure.

Activity 1

Stand on loose sand. Your feet go deep into the sand. Now, lie down on the sand. What happens? You will find that your body will not go that deep into the sand. Why?

In both the cases of the above activity, the force exerted on the sand is the weight of your body which is the same. This force acting perpendicular to the surface is called thrust. When you stand on loose sand, the force is acting on an area equal to the area of your feet. When you lie down, the same force acts on an area of your whole body, which is larger than the area of your feet. Therefore, the effect of thrust, depends on the area on which it acts.

The effect of thrust on sand is larger while standing than while lying.

The force per unit area acting on an object concerned is called pressure. Thus, we can say thrust on an unit area is pressure.

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area of contact}}$$

For the same given force, if the area is large pressure is low and vice versa. This is shown in Figure 3.1.

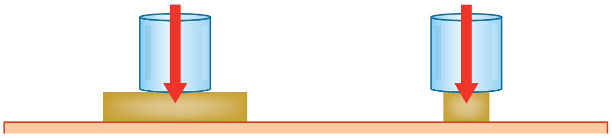


Figure 3.1 Pressure depends on area of application

In SI units, the unit of thrust is newton (denoted as N). The unit of pressure is newton per square metre or newton metre^{-2} (denoted as Nm^{-2}). In the honour of the great French scientist, Blaise Pascal, 1 newton per square metre is called as 1 pascal denoted as Pa. 1 Pa = 1 N m^{-2}

DO YOU KNOW? If a single nail pricks our body it is very painful. How is it possible for people to lie down on a bed of nails, still remain unhurt? It is because, area of contact is more.

Problem 1

A man whose mass is 90 kg stands on his feet on a floor. The total area of contact of his two feet with the floor is 0.036 m^2 (Take, g = 10 ms^{-2}). How much is the pressure exerted by him on the floor?

Solution:

The weight of the man (thrust),

$F = mg = 90\text{ kg} \times 10\text{ m s}^{-2} = 900\text{ N}$

$$\text{Pressure, } P = \frac{F}{A} = \frac{900\text{ N}}{0.036\text{ m}^2} = 25000\text{ Pa}$$

3.2 Pressure in Fluids

All the flowing substances, both liquids and gases are called fluids. Like solids, fluids also have weight and therefore exert pressure. When filled in a container, the pressure of the fluid is exerted in all directions and at all points of the fluid. Since the molecules of a fluid are in constant, rapid motion, particles are likely to move equally in any direction. Therefore, the pressure exerted by the fluid acts on an object from all directions. It is shown in Figure 3.2. Pressure in fluids is calculated as shown below.

$$\text{Fluid Pressure} = \frac{\text{Total force exerted by the fluid}}{\text{Area over which the force is exerted}} = \frac{F}{A}$$

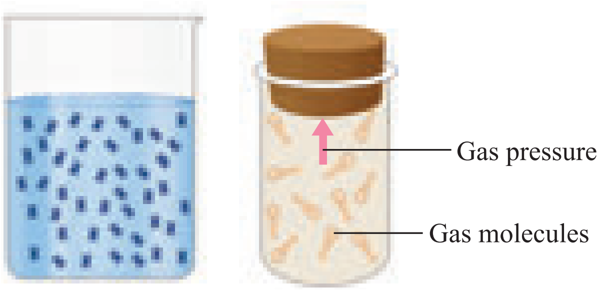


Figure 3.2 Collision of molecules gives rise to pressure

We shall first learn about the pressure exerted by liquids and then learn about the pressure exerted by gases.

3.2.1 Pressure due to liquids

The force exerted due to the pressure of a liquid on a body submerged in it and on the walls of the container is always perpendicular to the surface. In Figure 3.3(a), we can see the pressure acting on all sides of the vessel.

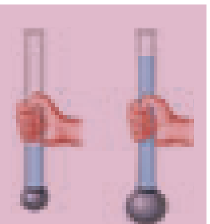
When an air filled balloon is immersed inside the water in a vessel it immediately comes up and floats on water. This shows that water (or liquid) exerts pressure in the upward direction. It is shown in Figure 3.3(b).


(a) (b) (c)

Figure 3.3 Pressure due to fluids

Similarly, liquid pressure acts in lateral sides also. When a bottle having water is pierced on the sides we can see water coming out with a speed as in Figure 3.3(c). This is because liquid exerts lateral pressure on the walls the container.

Activity 2



Take a transparent plastic pipe. Also take a balloon and tie it tightly over one end of the plastic pipe. Pour some water in the pipe from the top. What happens? The balloon tied at the bottom stretches and bulges out. It shows that the water poured in the pipe exerts a pressure on the bottom of its container.

3.2.2 Factors determining liquid pressure in liquids

Pressure exerted by a liquid at a point is determined by,

(i) depth (h)

(ii) density of the liquid (ρ)

(iii) acceleration due to gravity (g).

Activity 3

Take a large plastic can. Punch holes with a nail in a vertical line on the side of the can as shown in figure. Then fill the can with water. The water may just dribble out from the top hole, but with increased speed at the bottom holes as depth causes the water to squirt out with more pressure.

From this activity we can infer that pressure varies as depth increases. But, it is same at a particular depth independent of the direction.

Activity 4

Take two liquids of different densities say water and oil to a same level in two plastic containers. Make holes in the two containers at the same level. What do you see? It can be seen that water is squirting out with more pressure than oil. This indicates that pressure depends on density of the liquid.

3.2.3 Pressure due to a liquid column

A tall beaker is filled with liquid so that it forms a liquid column. The area of cross section at the bottom is A. The density of the liquid is ρ. The height of the liquid column is h. In other words the depth of the water from the top level surface is 'h' as shown in Figure 3.4.

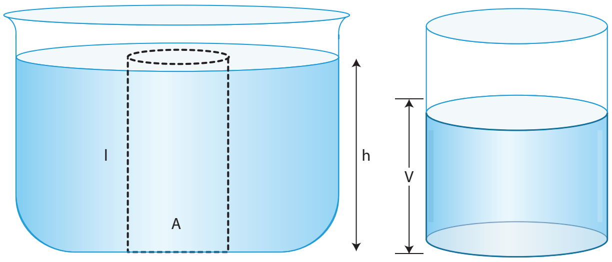


Figure 3.4 Pressure due to a liquid column

We know that, thrust at the bottom of the column (F) = weight of the liquid.

Therefore, F = mg (1)

We can get the mass of the liquid by multiplying the volume of the liquid and its density.

Mass, m = ρ V (2)

Volume of the liquid column, V

= Area of cross section (A) × Height (h) = Ah (3)

Substituting (3) in (2)

Mass, m = ρAh (4)

Substituting (4) in (1)

Force = mg = ρAhg

$$\text{Pressure, } P = \frac{\text{Thrust (F)}}{\text{Area (A)}} = \frac{mg}{A} = \frac{\rho(Ah)g}{A} = \rho hg$$

∴ Pressure due to a liquid column, P = hρg

This expression shows that pressure in a liquid column is determined by depth, density of the liquid and the acceleration due to gravity. Interestingly, the final expression for pressure does not have the term area A in it. Thus, pressure in liquid depends on depth only.

Problem 2

Calculate the pressure exerted by a column of water of height 0.85 m (density of water, ρ_w = 1000 kg m^{-3}) and kerosene of same height (density of kerosene, ρ_k = 800 kg m^{-3})

Solution:

Pressure due to water = $h\rho_w g$

= 0.85 m × 1000 kg m^{-3} × 10 m s^{-2} = 8500 Pa.

Pressure due to kerosene = $h\rho_k g$

= 0.85 m × 800 kg m^{-3} × 10 ms^{-2} = 6800 Pa.

3.3 Atmospheric pressure

Earth is surrounded by a layer of air up to certain height (nearly 300 km) and this layer of air around the earth is called atmosphere of the earth. Since air occupies space and has weight, it also exerts pressure. This pressure is called atmospheric pressure. The atmospheric pressure we normally refer is the air pressure at sea level.

Figure 3.5 shows that air gets 'thinner' with increasing altitude. Hence, the atmospheric pressure decreases as we go up in mountains. On the other hand air gets heavier as we go down below sea level like mines.

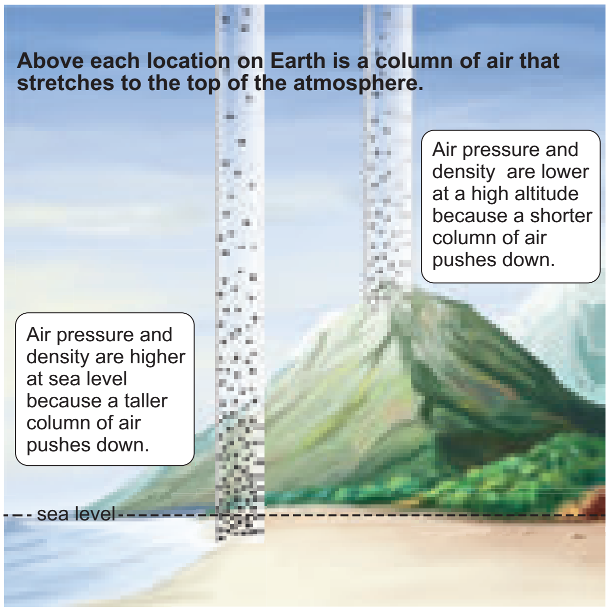
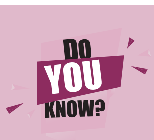


Figure 3.5 Atmospheric pressure acts like a column



Human lung is well adapted to breathe at a pressure of sea level (101.3 k Pa). As the pressure falls at greater altitudes, mountain climbers need special breathing equipments with oxygen cylinders. Similar special equipments are used by people who work in mines where the pressure is greater than that of sea level.

3.3.1 Measurement of atmospheric pressure

The instrument used to measure atmospheric pressure is called barometer. A mercury barometer, first designed by an Italian Physicist Torricelli, consists of a long glass tube (closed at one end, open at the other) filled with mercury and turned upside down into a container of mercury. This is done by closing the open end of the mercury filled tube with the thumb and then opening it after immersing it in to a trough of mercury (Fig. 3.6).

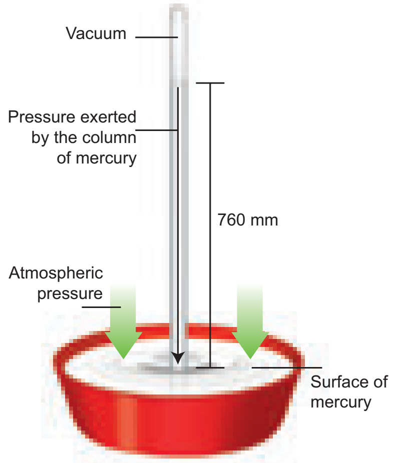


Figure 3.6 Mercury barometer

The barometer works by balancing the mercury in the glass tube against the outside air pressure. If the air pressure increases, it pushes more of the mercury up into the tub and if the air pressure decreases, more of the mercury drains from the tube. As there is no air trapped in the space between mercury and the closed end, there is vacuum in that space. Vacuum cannot exert any pressure. So the level of mercury in the tube provides a precise measure of air pressure which is called atmospheric pressure. This type of instrument can be used in a lab or weather station.

On a typical day at sea level, the height of the mercury column is 760 mm. Let us calculate the pressure due to the mercury column of 760 mm which is equal to the atmospheric pressure. The density of mercury is 13600 kg m^{-3}.

Pressure, P = hρg

$= (760 \times 10^{-3} m) \times (13600\ kgm^{-3}) \times (9.8\ ms^{-2})$

$= 1.013 \times 10^5$ Pa.

This pressure is called one atmospheric pressure (atm). There is also another unit called (bar) that is also used to express such high values of pressure.

1 atm = 1.013×10^5 Pa.

1 bar = 1×10^5 Pa.

Hence, 1 atm = 1.013 bar.

Expressing the value in kilopascal gives 101.3 k Pa. This means that, on each 1 m^2 of surface, the force acting is 1.013 k N.

Problem 3

A mercury barometer in a physics laboratory shows a 732 mm vertical column of mercury. Calculate the atmospheric pressure in pascal. [Given density of mercury, $\rho = 1.36 \times 10^4\ kg\ m^{-3}$, $g = 9.8\ m\ s^{-2}$]

Solution:

Atmospheric pressure in the laboratory,

$P = h\rho g = 732 \times 10^{-3} \times 1.36 \times 10^4 \times 9.8$

$= 9.76 \times 10^4$ Pa (or) 0.976×10^5 Pa

3.3.2 Gauge pressure and absolute pressure

Our daily activities are happening in the atmospheric pressure. We are so used to it that we do not even realise. When tyre pressure and blood pressure are measured using instruments (gauges) they show the pressure over the atmospheric pressure. Hence, absolute pressure is zero-referenced against a perfect vacuum and gauge pressure is zero-referenced against atmospheric pressure.

For pressures higher than atmospheric pressure,
absolute pressure = atmospheric pressure + gauge pressure

For pressures lower than atmospheric pressure,
absolute pressure = atmospheric pressure – gauge pressure

We have seen that liquid column exerts pressure. So the pressure inside the sea will be more. This is more than twice the atmospheric pressure. Parts of our body, especially blood vessels and soft tissues cannot withstand such high pressure. Hence, scuba divers always wear special suits and equipment to protect them (Fig. 3.7).

Figure 3.7 Scuba divers with special protecting equipment

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In petrol bunks, the tyre pressure of vehicles is measured in a unit called psi. It stands for pascal per inch, an old system of unit for measuring pressure.

3.4 Pascal's Law

Pascal's principle is named after Blaise Pascal (1623-1662), a French mathematician and physicist. The law states that the external pressure applied on an incompressible liquid is transmitted uniformly throughout the liquid. Pascal's law can be demonstrated with the help of a glass vessel having holes all over its surface. Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions (Fig. 3.8). This principle is applied in various machines used in our daily life.

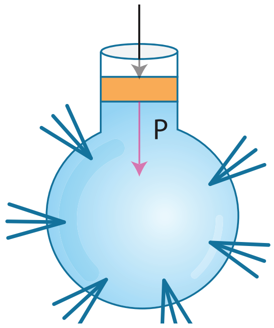

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Figure 3.8 Demonstration of Pascal's Law

3.4.1 Hydraulic press

Pascal's law became the basis for one of the important machines ever developed, the hydraulic press. It consists of two cylinders of different cross-sectional areas as shown in Figure 3.9. They are fitted with pistons of cross-sectional areas "a" and 'A'. The object to be lifted is placed over the piston of large cross-sectional area A. The force F_1 is applied on the piston of small cross-sectional area 'a'. The pressure P produced by small piston is transmitted equally to large piston and a force F_2 acts on A which is much larger than F_1.

Pressure on piston of small area 'a' is given by,

$$P = \frac{F_1}{A_1} \qquad (1)$$

Applying Pascal's law, the pressure on large piston of area A will be the same as that on small piston. Therefore, $P = \frac{F_2}{A_2}$ (2)

Comparing equations (1) and (2),we get $\frac{F_1}{A_1} = \frac{F_2}{A_2}$. or $F_2 = F_1 \times \frac{A_2}{A_1}$

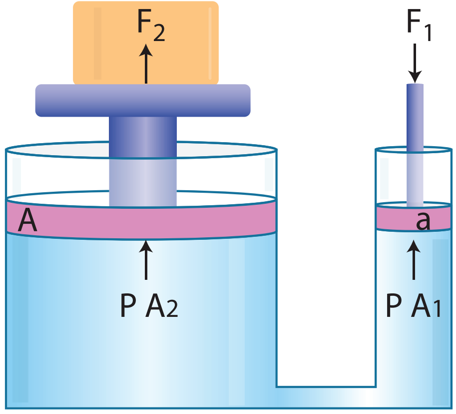

Figure 3.9 Hydraulic press

Since, the ratio $\frac{A_2}{A_1}$ is greater than 1, the force F_2 that acts on the larger piston is greater than the force F_1 acting on the smaller piston. Hydraulic systems working in this way are known as *force multipliers*.

Problem 4

A hydraulic system is used to lift a 2000 kg vehicle in an auto garage. If the vehicle sits on a piston of area 0.5 m^2, and a force is applied to a piston of area 0.03 m^2, what is the minimum force that must be applied to lift the vehicle?

Given: Area covered by the vehicle on the piston $A_1 = 0.5\ m^2$

Weight of the vehicle, $F_1 = 2000\ kg \times 9.8\ m\ s^{-2}$

Area on which force F_2 is applied, $A_2 = 0.03\ m^2$

Solution:

$P_1 = P_2$; $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ and $F_2 = \frac{F_1}{A_1} A_2$;

$F_2 = (2000 \times 9.8)\frac{0.03}{0.5} = 1176\ N$

3.5 Density

Activity 5

Take two identical flasks and fill one flask with water to 250 cm^3 mark and the other with kerosene to the same 250 cm^3 mark. Measure them in a balance. The flask filled with water will be heavier than the one filled with kerosene. Why? The answer is in finding the mass per unit volume of kerosene and water in respective flasks.

To understand density better, let us assume that the mass of the flask be 80 g. So, the mass of the flask filled with water is 330 g and the mass of flask filled with kerosene is 280 g. Mass of water only is 250 g and kerosene only is 200 g. Mass per unit volume of water is 250/250 cm^3. This is 1g/cm^3. Mass per unit volume of kerosene is 200 g/250 cm^3. This is 0.8 g/cm^3. The result 1 g/cm^3 and 0.8 gcm^3 are the densities of water and kerosene respectively. *Therefore, the density of a substance is the mass per unit volume of a given substance.*

The SI unit of density is kilogram per meter cubic (kg/m^3) also gram per centimeter cubic (g/cm^3). The symbol for density is rho (ρ).

3.5.1 Relative Density

We can compare the densities of two substances by finding their masses. But, generally density of a substance is compared with the density of water at 4 °C because density of water at that temperature is 1g/cm^3. Density of any other substance with respect to the density of water at 4 °C is called the relative density. Thus relative density of a substance is defined as ratio of density of the substance to density of water at 4 °C. Mathematically, relative density (R.D),

$$= \frac{\text{Density of the substance}}{\text{Density of water at 4 °C}}$$

We know that, Density $= \frac{\text{Mass}}{\text{Volume}}$

∴ Relative density

$$= \frac{\text{Mass of the substance/Volume of the substance}}{\text{Mass of water/Volume of water}}$$

Since the volume of the substance is equal to the volume of water,

Relative density

$$= \frac{\text{Mass of certain volume of substance}}{\text{Mass of equal volume of water (at 4°C)}}$$

Thus, the ratio of the mass of a given volume of a substance to the mass of an equal volume of water at 4°C also denotes relative density.

3.5.2 Measurement of relative density

Relative density can be measured using Pycnometer also called density bottle. It consists of ground glass stopper with a fine hole through it. The function of the hole in a stopper is that, when the bottle is filled and the stopper is inserted, the excess liquid rises through the hole and runs down outside the bottle. By this way the bottle will always contain the same volume of whatever the liquid is filled in, provided the temperature remains constant. Thus, the density of a given volume of a substance to the density of equal volume of referenced substance is called relative density or specific gravity of the given substance. If the referenced substance is water then the term specific gravity is used.

3.5.3 Floating and sinking

Whether an object will sink or float in a liquid is determined by the density of the object compared to the density of the liquid. If the density of a substance is less than the density of the liquid it will float. For example a piece of wood which is less dense than water will float on it. Any substance having more density than water (for example, a stone), will sink into it.

Problem 5

You have a block of a mystery material, 12 cm long, 11 cm wide and 3.5 cm thick. Its mass is 1155 grams. (a) What is its density? (b) Will it float in a tank of water, or sink?

Solution:

(a) $\text{Density} = \dfrac{\text{Mass}}{\text{Volume}} = \dfrac{1155\text{g}}{12\text{ cm} \times 11\text{ cm} \times 3.5\text{ cm}}$

$= \dfrac{1155\text{ g}}{462\text{ cm}^3}$

$= 2.5\text{ g cm}^{-3}$

(b) The mystery material is denser than the water. So it sinks.

3.5.4 Application of principle of flotation

Hydrometer

A direct-reading instrument used for measuring the density or relative density of the liquid is called hydrometer. Hydrometer is based on the principle of flotation, i.e., the weight of the liquid displaced by the immersed portion of the hydrometer is equal to the weight of the hydrometer.

Hydrometer consists of a cylindrical stem having a spherical bulb at its lower end and a narrow tube at its upper end. The lower spherical bulb is partially filled with lead shots or mercury. This helps hydrometer to float or stand vertically in liquids. The narrow tube has markings so that relative density of a liquid can be read directly.

The liquid to be tested is poured into the glass jar. The hydrometer is gently lowered in to the liquid until it floats freely. The reading against the level of liquid touching the tube gives the relative density of the liquid.

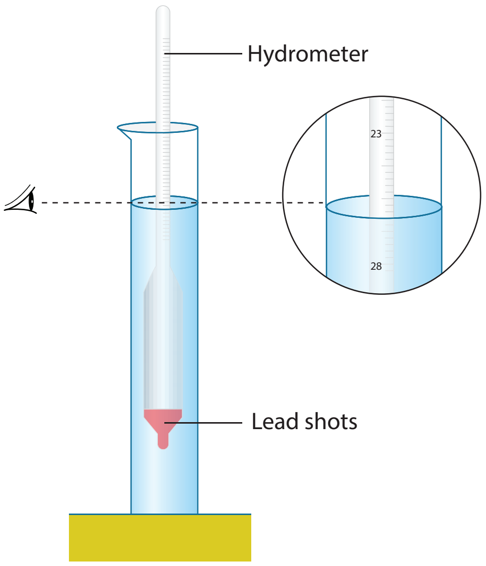

Figure 3.10 Hydrometer

Hydrometers may be calibrated for different uses such as lactometers for measuring the density (creaminess) of milk, saccharometer for measuring the density of sugar in a liquid and alcoholometer for measuring higher levels of alcohol in spirits.

Lactometer

One form of hydrometer is a lactometer, an instrument used to check the purity of milk. The lactometer works on the principle of gravity of milk.

The lactometer consists of a long graduated test tube with a cylindrical bulb with the graduation ranging from 15 at the top to 45 at the bottom. The test tube is filled with air. This air chamber causes the instrument to float. The spherical bulb is filled with mercury to cause the lactometer to sink up to the proper level and to float in an upright position in the milk.

Inside the lactometer there may be a thermometer extending from the bulb up into the upper part of the test tube where the scale is located. The correct lactometer reading is obtained only at the temperature of 60 °F. A lactometer measures the cream content of milk. More the cream, lower the lactometer floats in the milk. The average reading of normal milk is 32. Lactometers are used at milk processing units and dairies.

3.6 Buoyancy

We already saw that a body experiences an upward force due to the fluid surrounding, when it is partially or fully immersed in to it. We also know that pressure is more at the bottom and less at the top of the liquid. This pressure difference causes a force on the object and pushes it upward. This force is called buoyant force and the phenomenon is called buoyancy (Fig.3.11).

Most buoyant objects are those with a relatively high volume and low density. If the object weighs less than the amount of water it has displaced (density is less), buoyant force will be more and it will float (such object is known as positively buoyant). But, if the object weighs more than the amount of water it has displaced (density is more), buoyant force is less and the object will sink (such object is known as negatively buoyant).

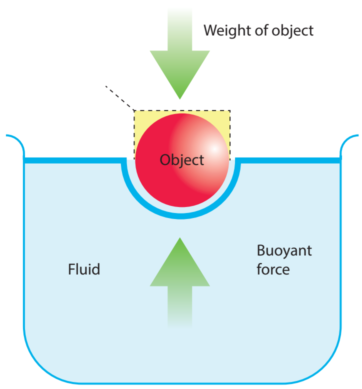

Figure 3.11 Buoyant force

> **DO YOU KNOW?** Salt water provides more buoyant force than fresh water, because, buoyant force depends as much on the density of fluids as on the volume displaced.

3.6.1 Cartesian diver

Cartesian diver is an experiment that demonstrates the principle of buoyancy. It is a pen cap with clay. The Cartesian diver contains just enough liquid that it barely floats in a bath of the liquid; its remaining volume is filled with air. When pressing the bath, the additional water enters the diver, thus increasing the average density of the diver, and thus it sinks.

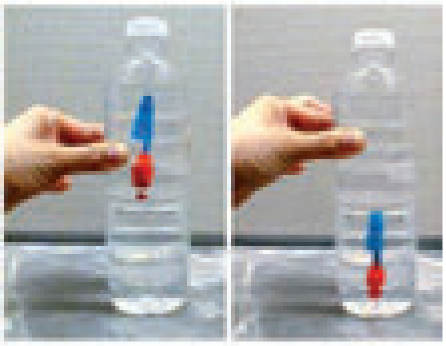

Figure 3.12 Cartesian diver

3.7 Archimedes' Principle

Archimedes principle is the consequence of Pascal's law. According to legend, Archimedes devised the principle of the 'hydrostatic balance' after he noticed his own apparent loss in weight while sitting in his bath. The story goes that he was so enthused with his discovery that he jumped out of his bath and ran through the town, shouting 'eureka'. Archimedes principle states that 'a body immersed in a fluid experiences a vertical upward buoyant force equal to the weight of the fluid it displaces'.

When a body is partially or completely immersed in a fluid at rest, it experiences an upthrust which is equal to the weight of the fluid displaced by it. Due to the upthrust acting on the body, it apparently loses a part of its weight and the apparent loss of weight is equal to the upthrust.

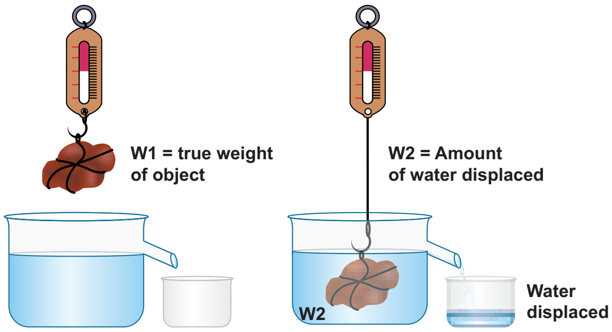

Figure 3.13 Upthrust is equal to the weight of the fluid displaced

Thus, for a body either partially or completely immersed in a fluid,

Upthrust = Weight of the fluid displaced

= Apparent loss of weight of the body.

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Apparent weight of an object

= True weight of an object in air
– Upthrust (weight of water displaced)

3.8 Laws of flotation

Laws of flotation are:

1. The weight of a floating body in a fluid is equal to the weight of the fluid displaced by the body.
2. The centre of gravity of the floating body and the centre of buoyancy are in the same vertical line.

The point through which the force of buoyancy is supposed to act is known as centre of buoyancy. It is shown in Figure 3.14.

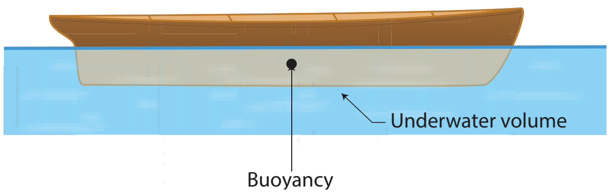


Figure 3.14 Centre of buoyancy

DO YOU KNOW? Flotation therapy uses water that contains Epsom salts rich in magnesium. As a floater relaxes, he or she is absorbing this magnesium through the skin. Magnesium helps the body to process insulin, which lowers a person's risk of developing Type 2 Diabetes.

Points to Remember

- The force which produces compression is called thrust. Its S.I. unit is newton.
- Thrust acting normally to a unit area of a surface is called pressure. Its S.I. unit is pascal.
- The pressure exerted by the atmospheric gases on its surroundings and on the surface of the earth is called atmospheric pressure. 1 atm is the pressure exerted by a vertical column of mercury of 76 cm height.
- Barometer is an instrument used to measure atmospheric pressure.
- The upward force experienced by a body when partly or fully immersed in a fluid is called upthrust or buoyant force.
- Cartesian diver is an experiment which demonstrates the principle of buoyancy and the ideal gas law.
- Pascal's law states that an increase in pressure at any point inside a liquid at rest is transmitted equally and without any change, in all directions to every other point in the liquid.
- Archimedes' principle states that when a body is partially or wholly immersed in a fluid, it experiences an up thrust or apparent lose of weight, which is equal to the weight of the fluid displaced by the immersed part of the body.
- Density is known as mass per unit volume of a body. Its S.I. unit is kg m^{-3}.
- Relative density is the ratio between the density of a substance and density of water. Relative density of a body is a pure number and has no unit.
- Hydrometer is a device used to measure the relative density of liquids based on the Archimedes' principle.
- Lactometer is a device used to check the purity of milk by measuring its density using Archimedes' principle.

A-Z GLOSSARY

Altitude Vertical distance in the up direction.

Astronaut Person who is specially trained to travel into outer space.

Axes Simple machine to cut, shape and split wood.

Deformation	Changes in an object's shape or form due to the application of a force or forces.
Iceberg	Large piece of ice floating in water.
Hydraulic systems	Device that uses fluids and work under the fluid pressure to control valves.
Incompressible	No change in volume if a pressure is applied.
Meteorological	Weather condition.
Piston	Movable disc fitted inside a cylinder.
Propellers	Fan that transmits power in the form of thrust by rotation.
Syringe	Simple pump made of plastic or glass to inject or withdraw fluid.
Therapy	Treatment given for healing sickness.
Velocity	Speed of an objects with direction.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. The size of an air bubble rising up in water
   (a) decreases
   (b) increases
   (c) remains same
   (d) may increase or decrease

2. Clouds float in atmosphere because of their low
   (a) density (b) pressure
   (c) velocity (d) mass

3. In a pressure cooker, the food is cooked faster because
   (a) increased pressure lowers the boiling point.
   (b) increased pressure raises the boiling point.
   (c) decreased pressure raises the boiling point.
   (d) increased pressure lowers the melting point.

4. An empty plastic bottle closed with an airtight stopper is pushed down into a bucket filled with water. As the bottle is pushed down, there is an increasing force on the bottom. This is because,
   (a) more volume of liquid is dispaced.
   (b) more weight of liquid is displaced.
   (c) pressure increases with depth.
   (d) All the above.

II. Fill in the blanks.

1. The weight of the body immersed in a liquid appears to be ________ than its actual weight.
2. The instrument used to measure atmospheric pressure is ___________.
3. The magnitude of buoyant force acting on an object immersed in a liquid depends on ___________ of the liquid.
4. A drinking straw works on the existence of ___________.

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

1. The weight of fluid displaced determines the buoyant force on an object.
2. The shape of an object helps to determine whether the object will float or not.
3. The foundations of high-rise buildings are kept wide so that they may exert more pressure on the ground.
4. Archimedes' principle can also be applied to gases.
5. Hydraulic press is used in the extraction of oil from oil seeds.

IV. Match the following.

Density	-	$h\rho g$
1 gwt	-	Milk
Pascal's law	-	$\frac{\text{Mass}}{\text{Volume}}$
Pressure exerted by a fluid	-	Pressure
Lactometer	-	980 dyne

V. Answer in brief.

1. On what factors the pressure exerted by the liquid depends on?
2. Why does a helium balloon float in air?
3. Why it is easy to swim in river water than in sea water?
4. What is meant by atmospheric pressure?
5. State Pascal's law.

VI. Answer in detail.

1. With an appropriate illustration prove that the force acting on a smaller area exerts a greater pressure.
2. Describe the construction and working of mercury barometer.
3. How does an object's density determine whether the object will sink or float in water?
4. Explain the construction and working of a hydrometer with diagram.
5. State the laws of flotation.

VII. Assertion and reason type questions.

Mark the correct answer as:

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If assertion is false but reason is true.

1. **Assertion:** To float, body must displace liquid whose weight is equal to the actual weight.

   Reason: The body will experience no net downward force in that case.

2. **Assertion:** Pascal's law is the working principle of a hydraulic lift.

   Reason: Pressure is thrust per unit area.

VIII. Numerical Problems.

1. A block of wood of weight 200 g floats on the surface of water. If the volume of block is 300 cm^3, calculate the upthrust due to water.
2. Density of mercury is 13600 kg m^{-3}. Calculate the relative density.
3. The density of water is 1 g cm^{-3}. What is its density in S.I. units?
4. Calculate the apparent weight of wood floating on water if it weighs 100g in air.

IX. Higher Order Thinking Skills.

1. How high does the mercury barometer stand on a day when atmospheric pressure is 98.6 kPa?
2. How does a fish manage to rise up and move down in water?
3. If you put one ice cube in a glass of water and another in a glass of alcohol, what would you observe? Explain your observations.
4. Why does a boat with a hole in the bottom would eventually sink?

REFERENCE BOOKS

1. Fundamentals of Physics - By David Halliday and Robert Resnick.
2. I.C.S.E Concise Physics - By Selina publisher.
3. Physics - By Tower, Smith Tuston & Cope.

INTERNET RESOURCES

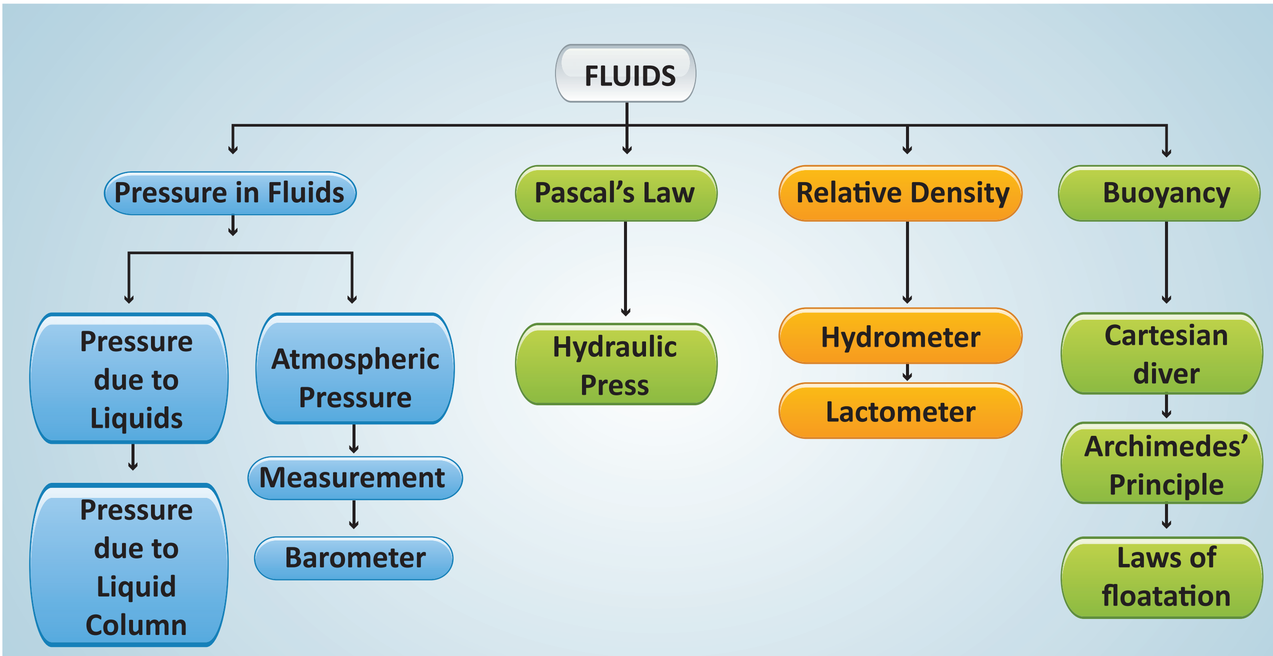
https://www.teachengineering.org/lessons/view/cub_airplanes_lesson04

http://www.cyberphysics.co.uk/topics/earth/atmosphr/atmospheric_pressure.htm

http://discovermagazine.com/2003/mar/featscienceof

http://northwestfloatcenter.com/how-flotation-can-help-your-heart/

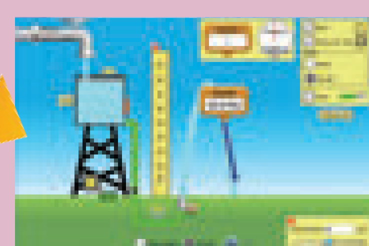
Concept Map



ICT CORNER

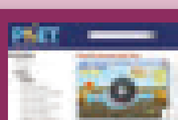
Fluid

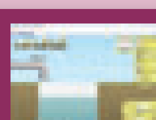
Experiment with Fluid Pressure and Flow using virtual simulator.

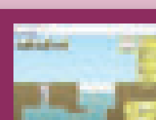


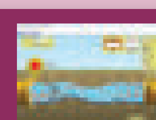
Steps

- Type the given URL to reach "pHET Simulation" page and download the "java" file of "Fluid Pressure and Flow".
- Open the "java" file. Open the water tap and observe the "Pressure" fluctuations by increasing "Fluid density" and "Gravity".
- Select the third picture and drop down a weight scales to transform weight into pressure.
- Switch to "Flow" tab from the top to simulate fluid motion under a given shape and pressure. Click the "red" button to drop dots into the fluid and alter the pipe shape by dragging the yellow holders.


Step1


Step2


Step3


Step4

Fluid Pressure and Flow Simulator

URL: https://phet.colorado.edu/en/simulation/fluid-pressure-and-flow or Scan the QR Code.

*Pictures are indicative only

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UNIT 4

ELECTRIC CHARGE AND ELECTRIC CURRENT

BLE4NF

Learning Objectives

After completing this lesson, students will be able to:

- understand the electric charge, electric field and Coulomb's law.
- explain the concepts of electric current, voltage, resistance and Ohm's law.
- draw electrical circuit diagrams for series and parallel circuits.
- explain the effects of electric current like. heating or thermal effect, chemical effect, and magnetic effect.
- understand direct and alternating currents.
- know the safety aspects related to electricity.

Introduction

Like mass and length, electric charge also is a fundamental property of all matter. We know that matter is made up of atoms and molecules. Atoms have particles like electrons, protons and neutrons. By nature, electrons and protons have negative and positive charge respectively and neutrons do not have charge. An electric current consists of moving electric charges. Electricity is an important source of energy in the modern times. In this lesson, we will study about electric charges, electric current, electric circuit diagram and the effects of electric current.

4.1 Electric charges

Inside each atom there is a nucleus with positively charged protons and chargeless neutrons and negatively charged electrons orbiting the nucleus. Usually there are as many electrons as there are protons and the atoms themselves are neutral.

If an electron is removed from the atom, the atom becomes positively charged. Then it is called a positive ion. If an electron is added in excess to an atom then the atom is negatively charged and it is called negative ion.

When you rub a plastic comb on your dry hair, the comb obtains power to attract small pieces of paper, is it not? When you rub the comb vigorously, electrons from your hair leave and accumulate on the edge of the comb. Your hair is now positively charged as it has lost electrons and the comb is negatively charged as it has gained electrons.

4.1.1 Measuring electric charge

Electric charge is measured in coulomb and the symbol for the same is C. The charge of an electron is numerically a very tiny value. The charge of an electron (represented as e) is the fundamental unit with a charge equal to 1.6×10^{-19} C. This indicates that any charge (q) has to be an integral multiple (n) of this fundamental unit of electron charge (e).

$q = ne$. Here, n is a whole number.

Problem 1

How many electrons will be there in one coulomb of charge?

Solution:

Charge on 1 electron, $e = 1.6 \times 10^{-19}$ C

$q = ne$ or $n = q/e$

∴ number of electrons in 1 coulomb

$$= \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons}$$

Practically, we have μC (micro coulomb), nC (nano coulomb)and pC (pico coulomb) as units of electric charge.

$1\ \mu C = 10^{-6}$ C, $1 nC = 10^{-9}$ and $1 pC = 10^{-12}$C

Electric charge is additive in nature. The total electric charge of a system is the algebraic sum of all the charges located in the system. For example, let us say that a system has two charges +5C and –2C. Then the total or net charge on the system is, (+5C) + (–2C) = +3C.

DO YOU KNOW?

Electrostatic forces between two point charges obey Newton's third law. The force on one charge is the action and on the other is reaction and vice versa.

4.1.2 Electric force

Among electric charges, there are two types of electric force (F): one is attractive and the other is repulsive. The like charges repel and unlike charges attract. **The force existing between the charges is called as 'electric force'.** These forces can be experienced even when the charges are not in contact.

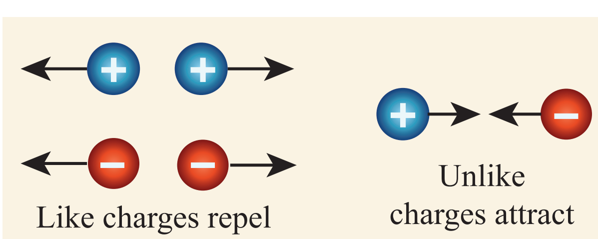

Figure 4.1 Electrostatic forces

4.1.3 Electric field

The region in which a charge experiences electric force forms the 'electric field' around the charge. Often electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed (Fig. 4.2). The direction of the electric field is the direction of the force that would act on a small positive charge. Therefore the lines representing the electric field are called 'electric lines of force'. **The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field.** Electric lines of force are imaginary lines. The strength of an electric field is represented by how close the field lines are to one another.

For an isolated positive charge the electric lines of force are radially outwards and for an isolated negative charge they are radially inwards.

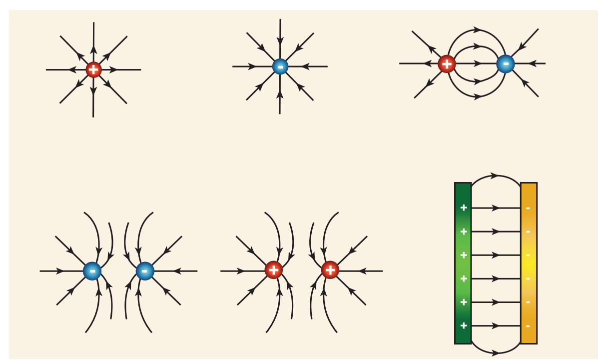

Figure 4.2 Electric lines of force

Electric field at a point is a measure of force acting on a unit positive charge placed at that point. A positive charge will experience force in the direction of electric field and a negative charge will experience in the opposite direction of electric field.

4.1.4 Electric potential

Though there is an electric force (either attractive or repulsive) existing among the charges, they are still kept together, is it not?. We now know that in the region of electric charge there is an electric field. Other charges experience force in this field and vice versa. There is a work done on the charges to keep them together. This results in a quantity called 'electric potential'.

Electric potential is a measure of the work done on unit positive charge to bring it to that point against all electrical forces.

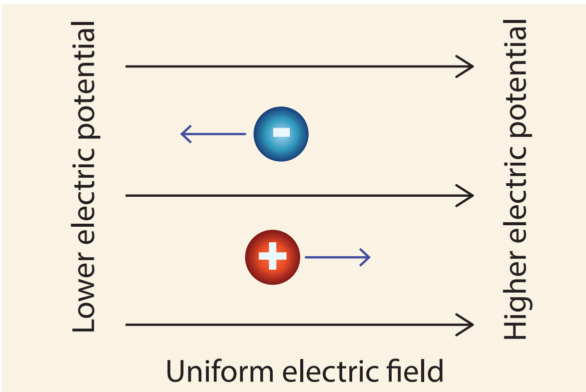

Figure 4.3 Electric potential and Electric field

4.2 Electric current

When the charged object is provided with a conducting path, electrons start to flow through the path from higher potential to lower potential region. Normally, the potential difference is produced by a cell or battery. When the electrons move, we say that an electric current is produced. That is, an electric current is formed by moving electrons.

4.2.1 Direction of current

Before the discovery of the electrons, scientists believed that an electric current consisted of moving positive charges. Although we know this is wrong, the idea is still widely held, as the discovery of the flow of electrons did not affect the basic understanding of the electric current. The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'. This is depicted in Figure 4.4.

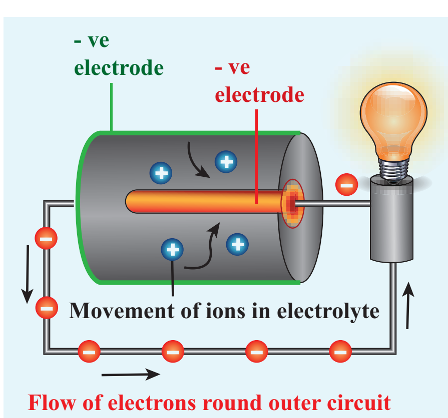

Figure 4.4 Electric current

In electrical circuits the positive terminal is represented by a long line and negative terminal as a short line. Battery is the combination of more than one cell (Fig. 4.5).

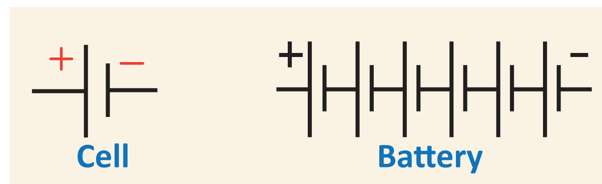

Figure 4.5 Cell and battery

4.2.2 Measurement of electric current

We can measure the value of current and express it numerically. **Current is the rate at which charges flow past a point on a circuit.** That is, if q is the quantity of charge passing through a cross section of a wire in time t, quantity of current (I) is represented as,

$$I = q/t$$

The standard SI unit for current is ampere with the symbol A. Current of 1 ampere means that there is one coulomb (1C) of charge passing through a cross section of a wire every one second (1 s).

1 ampere = 1 coulomb / 1 second (or)
$1\ A = 1\ C / 1\ s = 1Cs^{-1}$

Ammeter is an instrument used to measure the strength of the electric current in an electric circuit.

The ammeter is connected in series in a circuit where the current is to be found. . The current flows through the positive (+) red terminal of ammeter and leaves from the negative (–) black terminal.

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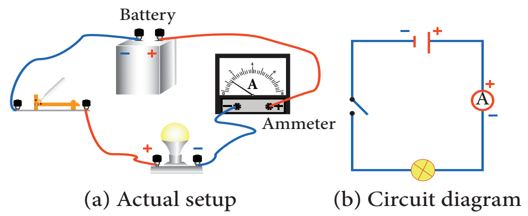


Figure 4.6 Ammeter in a circuit

Problem 2

If, 25 C of charge is determined to pass through a wire of any cross section in 50 s, what is the measure of current?

Solution:

I = q / t = (25 C) / (50 s) = 0.5 C/s = 0.5 A

Problem 3

The current flowing through a lamp is 0.2A. If the lamp is switched on for one hour, what is the total electric charge that passes through the lamp?

Solution:

I = q / t; q = I x t

1hr = 1 × 60 × 60 s = 3600 s

q = I × t = 0.2 A × 3600 s = 720 C

4.2.3 Electromotive force (e.m.f)

Imagine that two ends of a water pipe filled with water are connected. Although filled with water, the water will not move or circle around the tube on its own. Suppose, you insert a pump in between and the pump pushes the water, then the water will start moving in the tube. Now the moving water can be used to produce some work. We can insert a water wheel in between the flow and make it to rotate and further use that rotation to operate machinery.

BLHZQ3

Likewise if you take a circular copper wire, it is full of free electrons. However, they are not moving in a particular direction. You need some force to push the electrons to move in a direction. The water pump and a battery are compared in Figure 4.7.

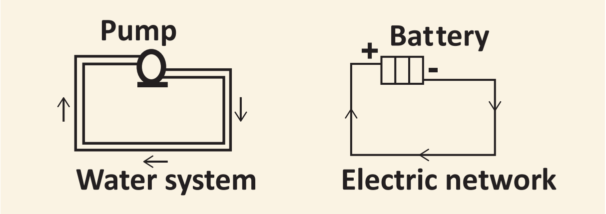


Figure 4.7 Battery is analogues to water pump

Devices like electric cells and other electrical energy sources act like pump, 'pushing' the charges to flow through a wire or conductor. The 'pumping' action of the electrical energy source is made possible by the 'electromotive force' (e.m.f). The electromotive force is represented as (ε). The e.m.f of an electrical energy source is the work done (W) by the source in driving a unit charge (q) around the complete circuit.

ε = W/q where, W is the work done. The SI unit of e.m.f is joules per coulomb (JC^{-1}) or volt (V). In other words **the e.m.f of an electrical energy source is one volt if one joule of work is done by the source to drive one coulomb of charge completely around the circuit.**

Problem 4

The e.m.f of a cell is 1.5 V. What is the energy provided by the cell to drive 0.5 C of charge around the circuit?

Solution:

ε = 1.5 V and q = 0.5 C

ε = W/q; W = ε × q;

Therefore W = 1.5 × 0.5 = 0.75 J

4.2.4 Potential difference (pd)

One does not just let the circuit connect one terminal of a cell to another. Often we connect, say a bulb or a small fan or any other electrical device in an electric circuit and use the electric current to drive them. This is how a certain amount of electrical energy provided by the cell or any other source of electrical energy is converted into other form of energy like light, heat, mechanical and so on. For each coulomb of charge passing through the light bulb (or any appliances) the amount of electrical energy converted to other forms of energy depends on the potential difference across the electrical device or any electrical component in the circuit. The potential difference is represented by the symbol V.

$$V = W/q$$

where, W is the work done, i.e., the amount of electrical energy converted into other forms of energy measured in joule and q is amount of charge measured in coulomb. The SI unit for both e.m.f and potential difference is the same i.e., volt (V).

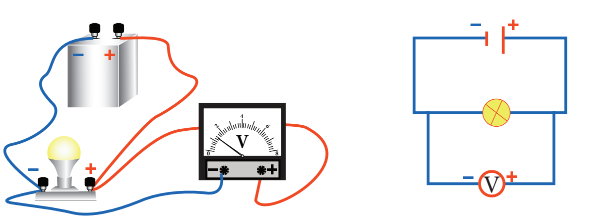
Problem 5

A charge of 2×10^4 C flows through an electric heater. The amount of electrical energy converted into thermal energy is 5×10^6 J. Compute the potential difference across the ends of the heater.

Solution:

$V = W/q$ that is 5×10^6 J / 2×10^4 C = 250 V

Voltmeter is an instrument used to measure the potential difference. To measure the potential difference across a component in a circuit, the voltmeter must be connected in parallel to it. Say, you want to measure the potential difference across a light bulb, you need to connect the voltmeter as given in Figure 4.8.



(a) Actual setup (b) Circuit diagram

Figure 4.8 Connection of voltmeter in a circuit

Note the positive (+) red terminal of the voltmeter is connected to the positive side of circuit and the negative (–) black terminal is connected to the negative side of the circuit across a component (light bulb in the above illustration).

4.2.5 Resistance

The Resistance (R) is the measure of opposition offered by the component to the flow of electric current through it. Different electrical components offer different electrical resistance.

Metals like copper, aluminium etc., have very much negligible resistance. That is why they are called good conductors. On the other hand, materials like nicrome, tin oxide etc., offer high resistance to the electric current. We also have a category of materials called insulators; they do not conduct electric current at all (glass, polymer, rubber and paper). All these materials are needed in electrical circuits to have usefulness and safety in electrical circuits.

The SI unit of resistance is ohm with the symbol (Ω). **One ohm is the resistance of a component when the potential difference of one volt applied across the component drives a current of one ampere through it.**

We can also control the amount of flow of current in a circuit with the help of resistance. Such components used for providing resistance are called as 'resistors'. The resistors can be fixed or variable.

Figure 4.9 Circuit symbol for resistor

Fixed resistors have fixed value of resistance, while the variable resistors like rheostats can be used to obtain desired value of resistance (Fig. 4.9).

Note: Difference between e.m.f and potential difference:

As both e.m.f and potential difference are measured in volt, they may appear the same. But they are not. The e.m.f refers to the voltage developed across the terminals of an electrical source when it does not produce current in the circuit. Potential difference refers to the voltage developed between any two points (even across electrical devices) in an electric circuit when there is current in the circuit.

4.3 Electric circuit diagram

To represent an electrical wiring or solve problem involving electric circuits, the circuit diagrams are made.

The four main components of any circuits namely, (i) cell, (ii) connecting wire, (iii) switch and (iv) resistor or load are given above. In addition to the above many other electrical components are also used in an actual circuit. A uniform system of symbols has been evolved to describe them. It is like learning a sign language, but useful in understanding circuit diagrams. Some common symbols in the electrical circuit are shown in Table 4.1.

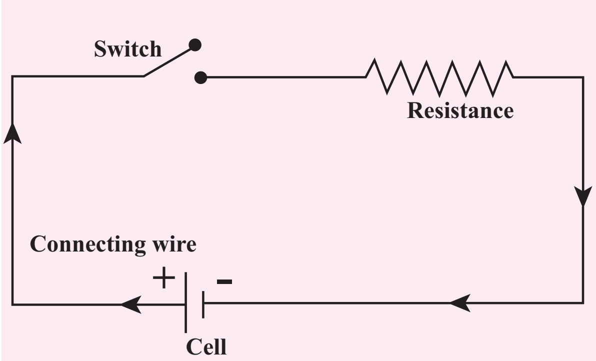
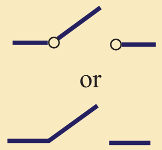
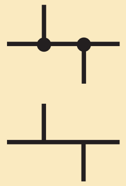
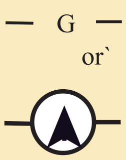
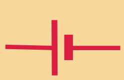
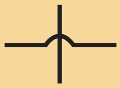
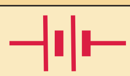
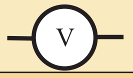
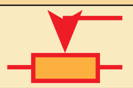
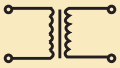
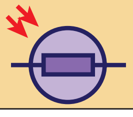
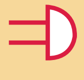


Figure 4.10 Typical electric circuit

Activity 1

Take a condemned electronic circuit board in a TV remote or old mobile phone. Look at the electrical symbols used in the circuit. Find out the meaning of the symbols known to you.

Table 4.1 Common symbols in electrical circuits

Symbol	Device	Symbol	Device	Symbol	Device
	Switch		Wires joined		galvanometer
	Cell		Wires crossed		ammeter
	Battery		Fixed resistor		Voltmeter
	D .c . power supply		variable resistor` (rheostat)		Two-way switch
	A.c. power supply		fuse		Earth connector
	Light bulb		Coil of wire		capacitor
	Potentiometer		transformer		thermistor
	light-depemdent resistor (LDR)		Semiconductor diode		bell

4.3.1 Different electrical circuits

Look at the two circuits, shown in Figure 4.11. In Figure A two bulbs are connected in series and in Figure B they are connected in parallel. Let us look at each of these separately.

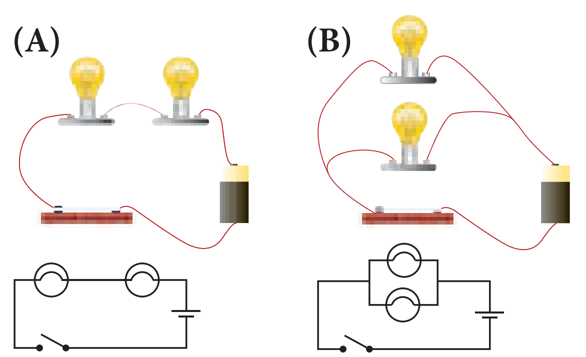


Figure 4.11 Series and parallel connections

Series circuits

Let us first look at the current in a series circuit. In a series circuit the components are connected one after another in a single loop. In a series circuit there is only one pathway through which the electric charge flow. From the above we can know that the current I all along the series circuit remain same. That is in a series circuit the current in each point of the circuit is same.

Parallel circuits

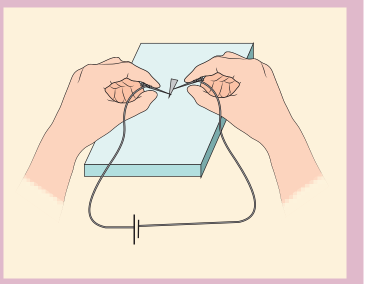
In parallel circuits, the components are connected to the e.m.f source in two or more loops. In a parallel circuit there is more than one path for the electric charge to flow. In a parallel circuit the sum of the individual current in each of the parallel branches is equal to the main current flowing into or out of the parallel branches. Also, in a parallel circuit the potential difference across separate parallel branches are same.

4.4 Effects of electric current

When current flows in a circuit it exhibits various effects. The main effects are heating, chemical and magnetic effects.

4.4.1 Heating effect

Activity 2



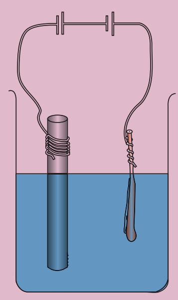
Cut an arrow shaped strip from aluminium foil. Ensure that the head is a fine point. Keep the arrow shaped foil on a wooden board. Connect a thin pin to two lengths of wire. Connect the wires to the terminals of electric cell, may be of 9V. Press one pin onto the pointed tip and other pin at a point about one or two mm away. Can you see that the tip of aluminium foil starts melting?

Caution: The heating effect and the chemical effect experiments have to be performed only with a dc cell of around 9V. Students at any cost **should not use** the main domestic electric supply which is a 220V ac voltage. If it is used it will give a heavy electric shock leading to a severe damage to our body.

When the flow of current is 'resisted' generally heat is produced. This is because the electrons while moving in the wire or resistor suffer resistance. Work has to be done to overcome the resistance which is converted in to heat energy. **This conversion of electrical energy into heating energy is called 'Joule heating'** as this effect was extensively studied by the scientist Joule. This forms the principle of all electric heating appliances like iron box, water heater, toaster etc. Even connecting wires offer a small resistance to the flow of current. That is why almost all electrical appliances including the connecting wires are warm when used in an electric circuit.

4.4.2 Chemical effect

Activity 3



Take a beaker half filled with copper sulphate solution. Take a carbon rod from a used dry cell. Wind a wire on its upper end. Take a thick copper wire, clean it well and flatten it with a hammer. Immerse both the copper wire and carbon rod in the copper sulphate solution. Connect the carbon rod to the negative terminal of an electric cell and copper wire to the positive terminal of the cell. Also ensure that the copper and the carbon rod do not touch each other, but are close enough. Wait and watch. After some time you would find fine copper deposited over the carbon rod. This is called as electroplating. This is due to the chemical effect of current.

So far we have come across the cases in which only the electrons can conduct electricity. But, here when current passes through electrolyte like copper sulphate solution, both the electron and the positive copper ion conduct electricity. **The process of conduction of electric current through solutions is called 'electrolysis'. The solution through which the electricity passes is called 'electrolyte'.** The positive terminal inserted in to the solution is called 'anode' and the negative terminal 'cathode'. In the above experiment, copper wire is anode and carbon rod is cathode.

DO YOU KNOW?

Extremely weak electric current is produced in the human body by the movement of charged particles. These are called synaptic signals. These signals are produced by electro-chemical process. They travel between brain and the organs through nervous system.

4.4.3 Magnetic effect of electricity

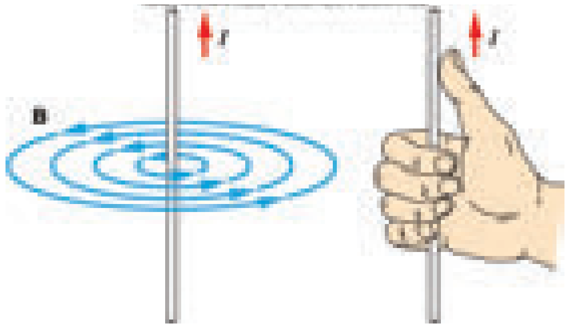


Figure 4.12 Direction of current and magnetic field

A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current. This is called magnetic effect of current. The discovery of the scientist Oersted and the 'right hand thumb rule' are detailed in the chapter on Magnetism and Electromagnetism in this book.

Direction of current is shown by the right hand thumb and the direction of magnetic field is shown by other fingers of the same right hand (Fig. 4.12).

4.5 Types of current

There are two distinct types of electric currents that we encounter in our everyday life: direct current (dc) and alternating current (ac).

4.5.1 Direct current

We know current in electrical circuits is due to the motion of positive charge from higher potential to lower potential or electron from lower to higher electrical potential. Electrons move from negative terminal of the battery to positive of the battery. Battery is used to maintain a potential difference between the two ends of the wire. Battery is one of the sources for dc current. The dc is due to the unidirectional flow of electric charges. Some other sources of dc are solar cells, thermocouples etc. The graph depicting the direct current is shown in Figure 4.13.

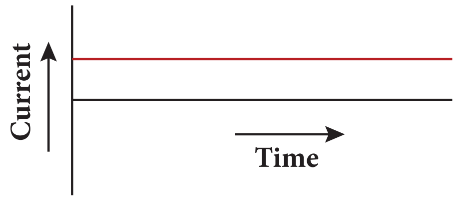


Figure 4.13 Wave form of dc

Many electronic circuits use dc. Some examples of devices which work on dc are cell phones, radio, electric keyboard, electric vehicles etc.

4.5.2 Alternating current

If the direction of the current in a resistor or in any other element changes its direction alternately, the current is called an alternating current. The alternating current varies sinusoidally with time. This variation is characterised by a term called as frequency. **Frequency is the number of complete cycle of variation, gone through by the ac in one second.** In ac, the electrons do not flow in one direction because the potential of the terminals vary between high and low alternately. Thus, the electrons move to and fro in the wire carrying alternating current. It is diagrammatically represented in Figure 4.14.

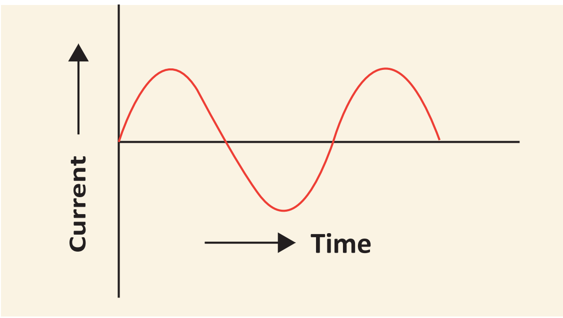


Figure 4.14 Wave form of ac

Domestic supply is in the form of ac. When we want to use an electrical device in dc, then we have to use a device to convert ac to dc. **The device used to convert ac to dc is called rectifier.** Colloquially it is called with several names like battery eliminator, dc adaptor and so on. The device used to convert dc into ac is called inverter. The symbols used in ac and dc circuits are shown in Figure 4.15.

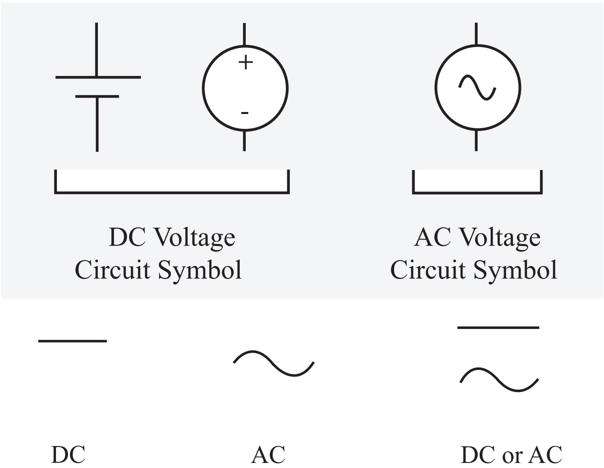


Figure 4.15 The symbol used in ac and dc circuit diagrams

4.5.3 Advantages of ac over dc

The voltage of ac can be varied easily using a device called transformer. The ac can be carried over long distances using step up transformers. The loss of energy while distributing current in the form of ac is negligible. Direct current cannot be transmitted as such. The ac can be easily converted into dc and generating ac is easier than dc. The ac can produce electromagnetic induction which is useful in several ways.

4.5.4 Advantage of dc

Electroplating, electro refining and electrotyping can be done only using dc. Electricity can be stored only in the form of dc.

In India, the voltage and frequency of ac used for domestic purpose is 220 V and 50 Hz respectively where as in United States of America it is 110 V and 60 Hz respectively.

4.6 Dangers of electricity and precautions to be taken

The following are the possible dangers as for as electric current is concerned.

Damaged insulation: Do not touch the bare wire. Use safety glows and stand on insulating stool or rubber slippers while handling electricity.

Overload of power sockets: Do not connect too many electrical devices to a single electrical socket.

Inappropriate use of electrical appliances: Always use the electrical appliances according to the power rating of the device like ac point, TV point, microwave oven point etc.

Environment with moisture and dampness: Keep the place, where there is electricity, out of moisture and wetness as it will lead to leakage of electric current.

Beyond the reach of children: The electrical sockets are to be kept away from the reach of little children who do not know the dangers of electricity.

DO YOU KNOW?

Resistance of a dry human body is about 1,00,000 ohm. Because of the presence of water in our body the resistance is reduced to few hundred ohm. Thus, a normal human body is a good conductor of electricity. Hence, precautions are required while doing electrical work.

Points to Remember

- Electric charge is a fundamental property of all matter.
- Like charges repel and unlike charges attract.
- Electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed.
- Electric current flows from higher electric potential to lower electric potential.
- The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'.
- The opposition to the flow of current is called resistance.
- The SI unit of resistance is ohm with the symbol Ω.
- The four main components of any circuit are: cell, connecting wire, switch and resistor.
- In a parallel circuit there is more than one path for the electric charge to flow.
- The main effects when current flows in a circuit are heating, chemical and magnetic effects.
- There are two distinct types of electric currents that we encounter in our everyday life: direct current (dc) and alternating current (ac).

A-Z GLOSSARY

Electric charge	It is the fundamental property of matter.
Electric field	The region around a charge in which another charge experiences electric force.
Electric lines of force	The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field.
Electric potential	Measure of the work done on unit positive charge to bring it to that point against all electrical forces.
Electric current	Electric current is the rate at which charges flow across a conductor in a circuit.
Ammeter	An instrument used for measuring the amount of electric current.
e.m.f	Work done by the electrical energy source in driving a unit charge around the complete circuit.

Voltmeter	An instrument used to measure the potential difference.
Resistance	The measure of opposition offered by the component to the flow of electric current through it.
Resistors	Components used for providing resistance.
Electrolyte	The solution through which electric current flows.
Anode	The positive terminal in the electrolyte.
Cathode	The negative terminal in the electrolyte.
Alternating current	Current in a resistor or in any other element which changes its direction alternately.

TEXTBOOK EXERCISES

BLHVRQ

I. Choose the correct answer.

1. In current electricity, a positive charge refers to,
   a) presence of electron
   b) presence of proton
   c) absence of electron
   d) absence of proton

2. Rubbing of comb with hair
   a) creates electric charge
   b) transfers electric charge
   c) either (a) or (b)
   d) neither (a) nor (b)

3. Electric field lines ______ from positive charge and ______ in negative charge.
   a) start; start   b) start; end
   c) start: end   d) end; end

4. Potential near a charge is the measure of its ______ to bring a positive charge at that point.
   a) force   b) abiility
   c) tendency   d) work

5. Heating effect of current is called,
   a) Joule heating   b) Coulomb heating
   c) Voltage heating   d) Ampere heating

6. In an electrolyte the current is due to the flow of
   a) electrons
   b) positive ions
   c) both (a) and (b)
   d) neither (a) nor (b)

7. Electroplating is an example for
   a) heating effect   b) chemical effect
   c) flowing effect   d) magnetic effect

8. Resistance of a wire depends on,
   a) temperature   b) geometry
   c) nature of material   d) all the above

II. Match the following.

1.	Electric charge	(a) ohm
2.	Potential difference	(b) ampere
3.	Electric field	(c) coulomb
4.	Resistance	(d) newton per coulomb
5.	Electric current	(e) volt

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

1. Electrically neutral means it is either zero or equal positive and negative charges.
2. Ammeter is connected in parallel in any electric circuit.
3. The anode in electrolyte is negative.
4. Current can produce magnetic field.

IV. Fill in the blanks.

1. Electrons move from ________ potential to ________ potential.
2. The direction opposite to the movement of electron is called ________ current.
3. The e.m.f of a cell is analogues to ________ of a pipe line.
4. The domestic electricity in India is an ac with a frequency of ________ Hz.

V. Conceptual questions.

1. A bird sitting on a high power electric line is still safe. How?
2. Does a solar cell always maintain the potential across its terminals constant? Discuss.
3. Can electroplating be possible with alternating current?

VI. Answer the following.

1. On what factors does the electrostatic force between two charges depend?
2. What are electric lines of force?
3. Define electric field.
4. Define electric current and give its unit.
5. State Ohm's law.
6. Name any two appliances which work under the principle of heating effect of current.
7. How are the home appliances connected in general, in series or parallel. Give reasons.
8. List the safety features while handling electricity.

VII. Exercises.

1. Rubbing a comb on hair makes the comb get – 0.4C. (a) Find which material has lost electron and which one gained it. (b) Find how many electrons are transferred in this process.
2. Calculate the amount of charge that would flow in 2 hours through an element of an electric bulb drawing a current of 2.5 A.
3. The values of current (I) flowing through a resistor for various potential differences V across the resistor are given below. What is the value of resistor?

I (ampere)	0.5	1.0	2.0	3.0	4.0
V (volt)	1.6	3.4	6.7	10.2	13.2

[Hint: plot V-I a graph and take slope]

REFERENCE BOOKS

Fundamentals of Physics - K.L Gomber andK. L.Gogia

Concepts of Physics - H.C Verma

General Physics - W.L. Whiteley

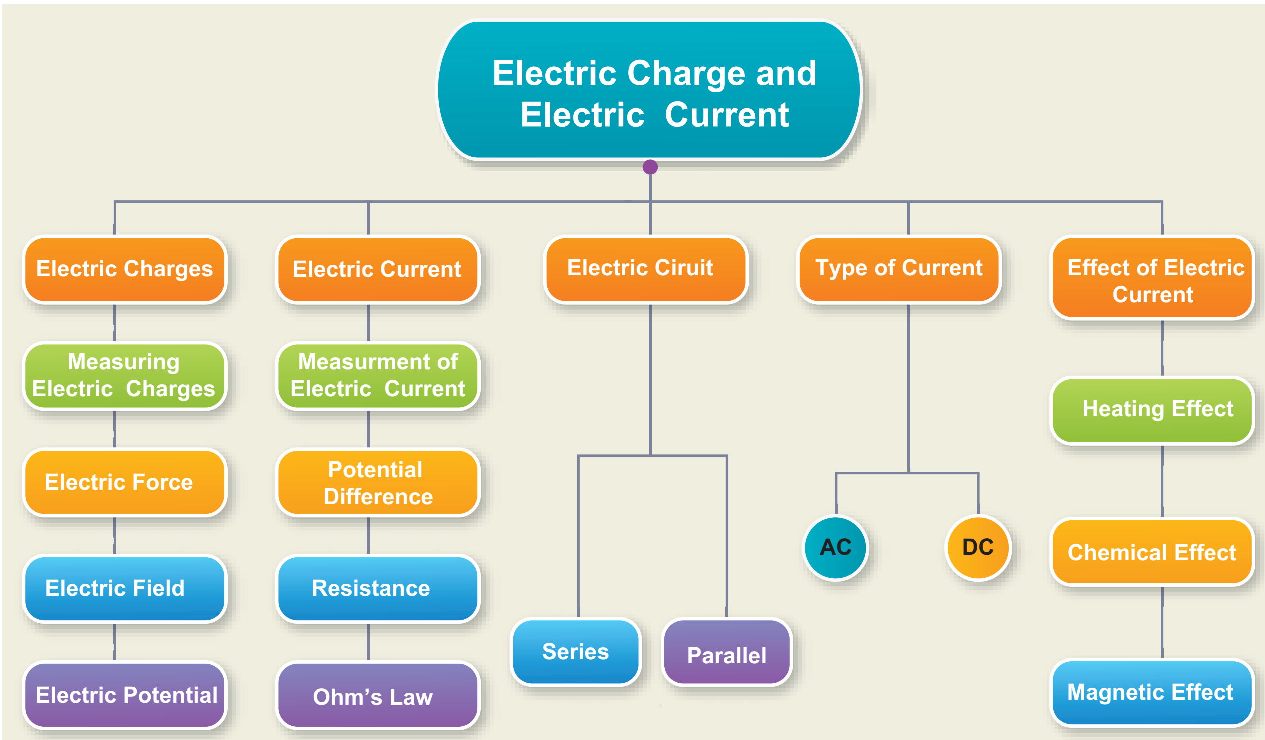
INTERNET RESOURCES

http://www.qrg.northwestern.edu/projects/vss/docs/propulsion/1-what-is-an-ion.html

https://www.explainthatstuff.com/batteries.html

https://www.woodies.ie/tips-n-advice/how-the-fusebox-works-in-the-home-new

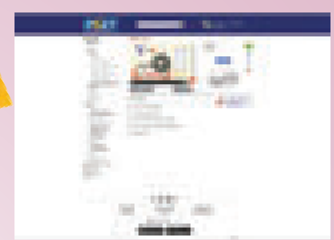
Concept Map



ICT CORNER

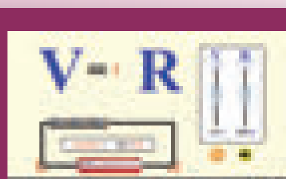
Ohm's Law Verification

This activity enables to learn the relationship between current and potential difference.

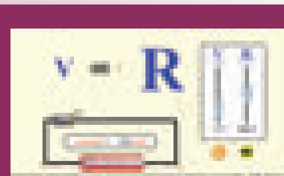


Step 1

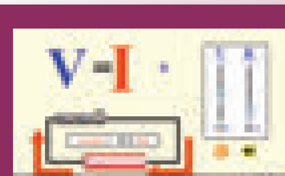
- Type the URL link given below in the browser OR scan the QR code.
- You can vary the value of **V** and **R** to know the change the **current flowing across the conductor**
- On the right you can do the changes in V and R to learn the variations.



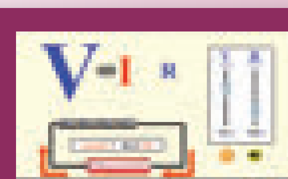
Step1



Step2



Step3



Step4

Browse in the link:

URL: https://phet.colorado.edu/en/simulation/ohms-law

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*Pictures are indicative only

UNIT 5

MAGNETISM AND ELECTROMAGNETISM

Learning Objectives

BH6RTD

After completing this lesson, students will be able to

- understand the concept of magnetic field.
- know the properties of magnetic field lines.
- calculate the force exerted on a current carrying conductor in a magnetic field.
- understand the force between two parallel current carrying conductors.
- know the concept of electromagnetic induction and apply it in the case of generators.
- appreciate how voltage can be increased or decreased using transformers.
- understand the applications of electromagnet and apply the knowledge in constructing devices using electromagnets.

Introduction

Have you ever played with magnets? Do you wonder why it attracts iron? Magnets are always attractive objects for the humans. In fact famous scientist Einstein has mentioned that he was always attracted by magnets in his childhood. In the olden days magnets were used in the ships. Captains of the ships effectively used the magnets to identify the direction of the ship in the sea.

There are two kinds of magnets that we can see around us: Natural magnet and Artificial magnet. Natural magnets exist in the nature. These kind of magnets can be found in rocks and sandy deposits in various parts of the world. The strongest natural magnet is lodestone magnetite.

The magnetic property in the natural magnets is permanent. It never gets destroyed. The lodestones were used to make compasses in the olden days. Artificial magnets are made by us. The magnets available in the shops are basically artificial magnets. In this lesson we shall study about properties of magnets, magnetic effect of current, electromagnetic induction and applications of electromagnets.

5.1 Magnetic field (B)

Activity 1

Put a magnet on a table and place some paper clips nearby. If you push the magnet slowly towards the paper clips, there will be a point at which the paper clips jump across and stick to the magnet. What do you understand from this?

From the above activity we notice that magnets have an invisible field all around them which attracts magnetic materials. In this space we can feel the force of attraction or repulsion due to the magnet. Thus, magnetic

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field is the region around the magnet where its magnetic influence can be felt. It is denoted by B and its unit is Tesla.

The direction of the magnetic field around a magnet can be found by placing a small compass in the magnetic field (Fig 5.1).

Figure 5.1 Compass showing direction of magnetic field

Magnetic field can penetrate through all kinds of materials, not just air. The Earth produces its own magnetic field, which shields the earth's ozone layer from the solar wind and it is important for navigation also.

5.2 Magnetic Field Lines

A magnetic field line is defined as a curve drawn in the magnetic field in such a way that the tangent to the curve at any point gives the direction of the magnetic field. They start at north pole and ends at south pole. In Figure 5.2, the arrow mark indicates the direction of magnetic field at points A, B and C. Note carefully that the magnetic field at a point is tangential to the magnetic field lines.

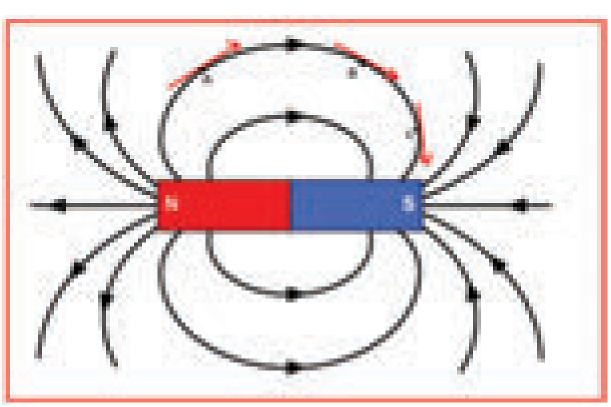

Figure 5.2 Magnetic field lines

5.2.1 Magnetic flux

Magnetic flux is the number of magnetic field lines passing through a given area (Fig. 5.3). It is denoted by ϕ and its unit is weber (Wb).

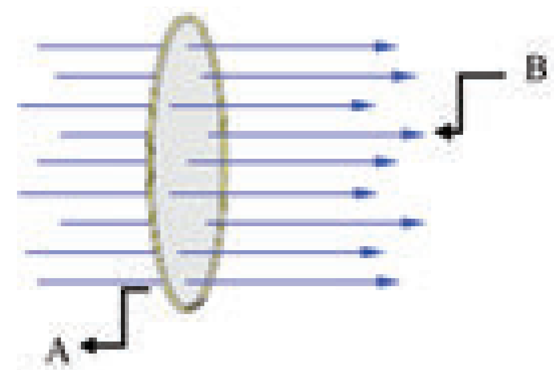

Figure 5.3 Magnetic flux

The number of magnetic field lines crossing unit area kept normal to the direction of field lines is called magnetic flux density. It is shown in Figure 5.4. Its unit is Wb/m^2

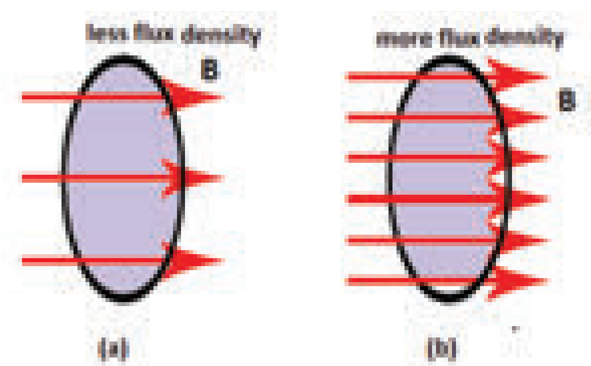

Figure 5.4 Magnetic flux density

DO YOU KNOW? Some sea turtles (loggerhead sea turtle) return to their birth beach many decades after they were born, to nest and lay eggs. In a research, it is suggested that the turtles can perceive variations in magnetic parameters of Earth such as magnetic field intensity and remember them. This memory is what helps them in returning to their homeland.

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5.2.2 Properties of magnetic lines of force

- Magnetic lines of force are closed, continuous curves, extending through the body of the magnet.
- Magnetic lines of force start from the North Pole and end at the South Pole.
- Magnetic lines of force never intersect.
- They will be maximum at the poles than at the equator.
- The tangent drawn at any point on the curved line gives the direction of magnetic field.

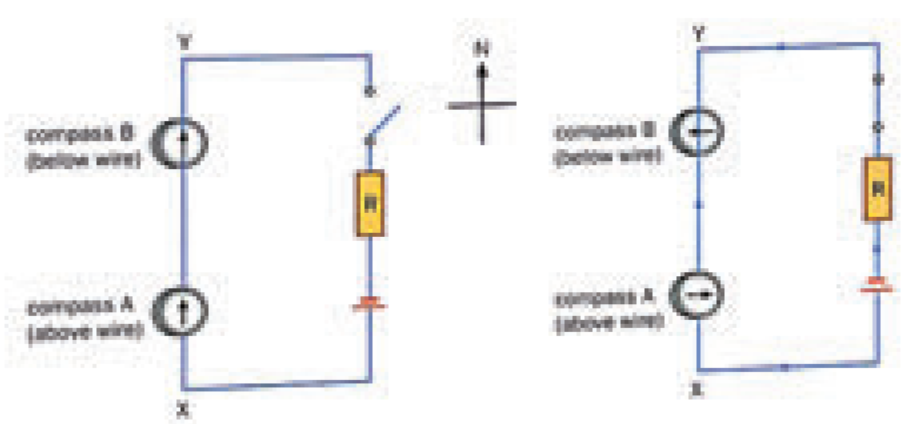
5.3 Magnetic effect of current

It was on 21st April 1820, Hans Christian Oersted, a Danish Physicist was giving a lecture. He was demonstrating electrical circuits in that class. He had to often switch on and off the circuit during the lecture. Accidentally, he noticed the needle of the magnetic compass that was on the table. It deflected whenever he switched on and the current was flowing through the wire. The compass needle moved only slightly, so that the audience didn't even notice. But, it was clear to Oersted that something significant was happening. He conducted many experiments to find out a startling effect, the magnetic effect of current.

Oersted aligned a wire XY such that they were exactly along the North-South direction. He kept one magnetic compass above the wire at A and another under the wire at B. When the circuit was open and no current was flowing through it, the needle of both the compass was pointing to north. Once the circuit was closed and electric current was flowing, the needle at A pointed to east and the needle at B to the west as shown in Figure 5.5. This showed that current carrying conductor produces magnetic field around it.

The direction of the magnetic lines around a current carrying conductor can be easily understood using the right hand thumb rule. Hold the wire with four fingers of your right hand with thumbs-up position. If the direction of the current is towards the thumb then the magnetic lines curl in the same direction as your other four fingers as shown in Figure 5.6. This shows that the magnetic field is always perpendicular to the direction of current.

The strength of the magnetic field at a point due to current carrying wire depends on: (i) the current in the wire, (ii) distance of the point from the wire, (iii) the orientation of the point from the wire and (iv) the magnetic nature of the medium. The magnetic field lines are stronger near the current carrying wire and it diminishes as you go away from it. This is represented by drawing magnetic field lines closer together near the wire and farther away from the wire.



(a) no deflection when there is no current (b) deflection when there is curret

Figure 5.5 Current produces magnetic field

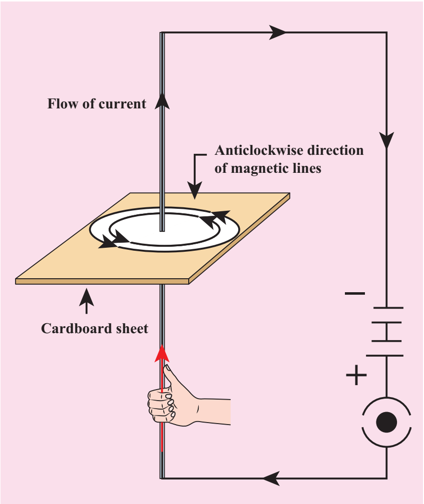


Figure 5.6 Right hand thumb rule

5.4 Force on a current carrying conductor in a magnetic field

H.A.Lorentz found that a charge moving in a magnetic field, in a direction other than the direction of magnetic field, experiences a force. It is called the magnetic Lorentz force. Since charge in motion constitutes a current, a conductor carrying moving charges, placed in magnetic field other than the direction of magnetic field, will also experience a force and can produce motion in the conductor.

Activity 2

Take a cardboard and thread a wire perpendicular through it. Connect the wire such that current flows up the wire. Switch on the circuit. Let the current flow. Place a magnetic compass on the cardboard and mark the position. Now move magnet and mark the new position. If you join all the points you will find that it is a circle. Reverse the direction of the current, you will find the magnetic circles are clockwise.

From this activity, we infer that current carrying wire has a magnetic field perpendicular to the wire (by looking at the deflection of the compass needle in the vicinity of a current carrying conductor). The deflection of the needle implies that the current carrying conductor exerts a force on the compass needle. In 1821, Michael Faraday discovered that a current carrying conductor also gets deflected when it is placed in a magnetic field. In Figure 5.7, we can see that the magnetic field of the permanent magnet and the magnetic field produced by the current carrying conductor interact and produce a force on the conductor. The view perpendicular to the direction of current is shown in Figure 5.8.

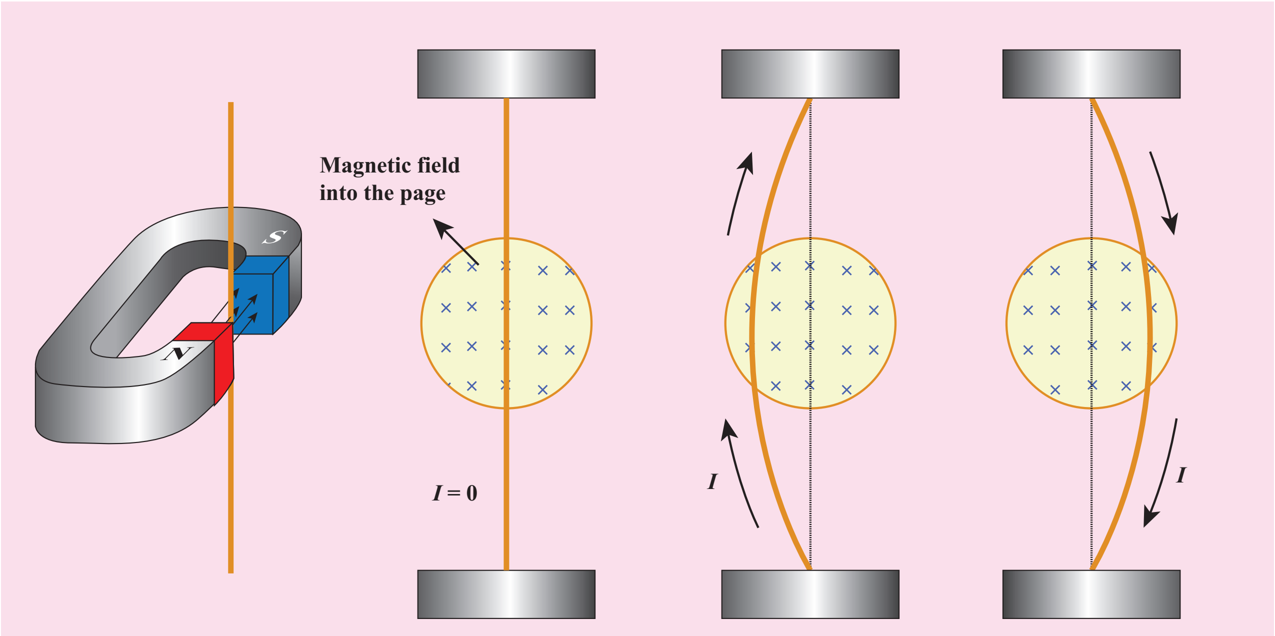


Figure 5.7 Deflection of current carrying wire in magnetic field

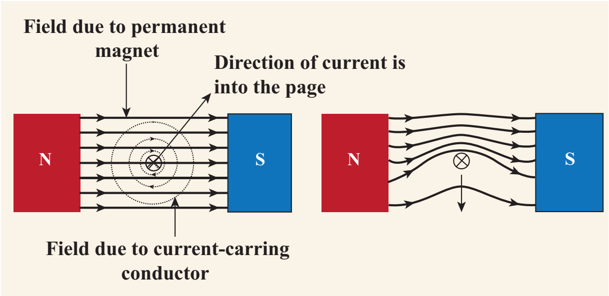


Figure 5.8 Force on a current carrying conductor kept in magnetic field

If a current, I is flowing through a conductor of length, L kept perpendicular to the magnetic field B, then the force F experienced by it is given by the equation,

F = I L B

The above equation indicates that the force is proportional to current through the conductor, length of the conductor and the magnetic field in which the current carrying conductor is kept.

Note: The angle of inclination between the current and magnetic field also affects the magnetic force. When the conductor is perpendicular to the magnetic field, the force will be maximum (=BIL). When it is parallel to the magnetic field, the force will be zero.

The force is always a vector quantity. A vector quantity has both magnitude and direction. It means we should know the direction in which the force would act. The direction is often found using what is known as Fleming's Left hand Rule (formulated by the scientist John Ambrose Fleming).

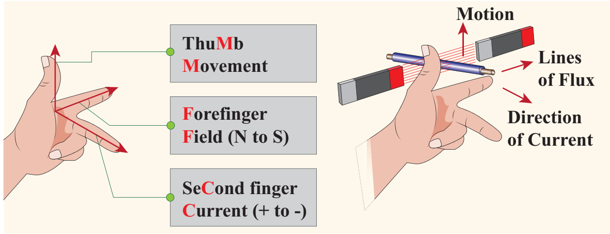


Figure 5.9 Fleming's left hand rule

The law states that while stretching the three fingers of left hand in perpendicular manner with each other, if the direction of the current is denoted by the middle finger of the left hand and the second finger is for direction of the magnetic field, then the thumb of the left hand denotes the direction of the force or movement of the conductor (Fig. 5.9)

Problem 1

A conductor of length 50 cm carrying a current of 5 A is placed perpendicular to a magnetic field of induction 2×10^{-3} T. Find the force on the conductor.

Solution:

Force on the conductor = ILB

$= 5 \times 50 \times 10^{-2} \times 2 \times 10^{-3}$

$= 5 \times 10^{-3}$ N

Problem 2

A current carrying conductor of certain length, kept perpendicular to the magnetic field experiences a force F. What will be the force if the current is increased four times, length is halved and magnetic field is tripled?

Solution:

F = I L B = (4I) × (L/2) × (3 B) = 6 F

Therefore, the force increases six times.

5.5 Force on parallel current carrying conductors

We have seen that a current carrying conductor has a magnetic field around it. If we place another conductor carrying current parallel to the first one, the second conductor will experience a force due to the magnetic field of the first conductor. Similarly, the first conductor will experience a force due to the magnetic field of the second conductor. These two forces will be equal in magnitude and opposite in direction.

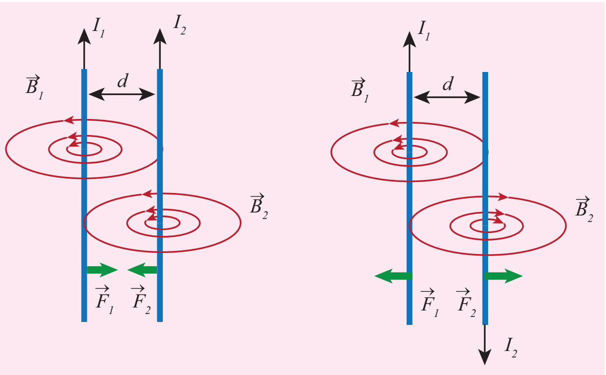


Figure 5.10 Attractive and repulsive force on current carrying wires

Using Fleming's left hand rule we can find that the direction of the force on each wire would be towards each other when the current in both of them are flowing in the same direction, i.e., the wires would experience an attractive force. However, if the direction of the flow of current is in opposite direction, then the force on each of the wire will be in opposite direction. These are shown in Figure 5.10 and the perpendicular view of the same is shown in Figure 5.11.

Connection between Electricity and Magnetism:

Before 18th century people thought that magnetism and electricity were separate subjects of study. After Oersted's experiment the electricity and magnetism were united and became a single subject called 'Electromagnetism'.

When there is current, the magnetic field is produced and the current carrying conductor behaves like a magnet. You may now wonder how was it possible for a lodestone to behave like a magnet when there was no current passing through it. Only in the twentieth century, we understood that the magnetic property arises due to the motion of electrons in the lodestone. In the circuit the electrons flow from negative of the battery to positive of the battery and constitutes current. As a result it produces magnetic field. In natural magnets and artificial magnets that we buy in shops, the electrons move around the nucleus constitutes

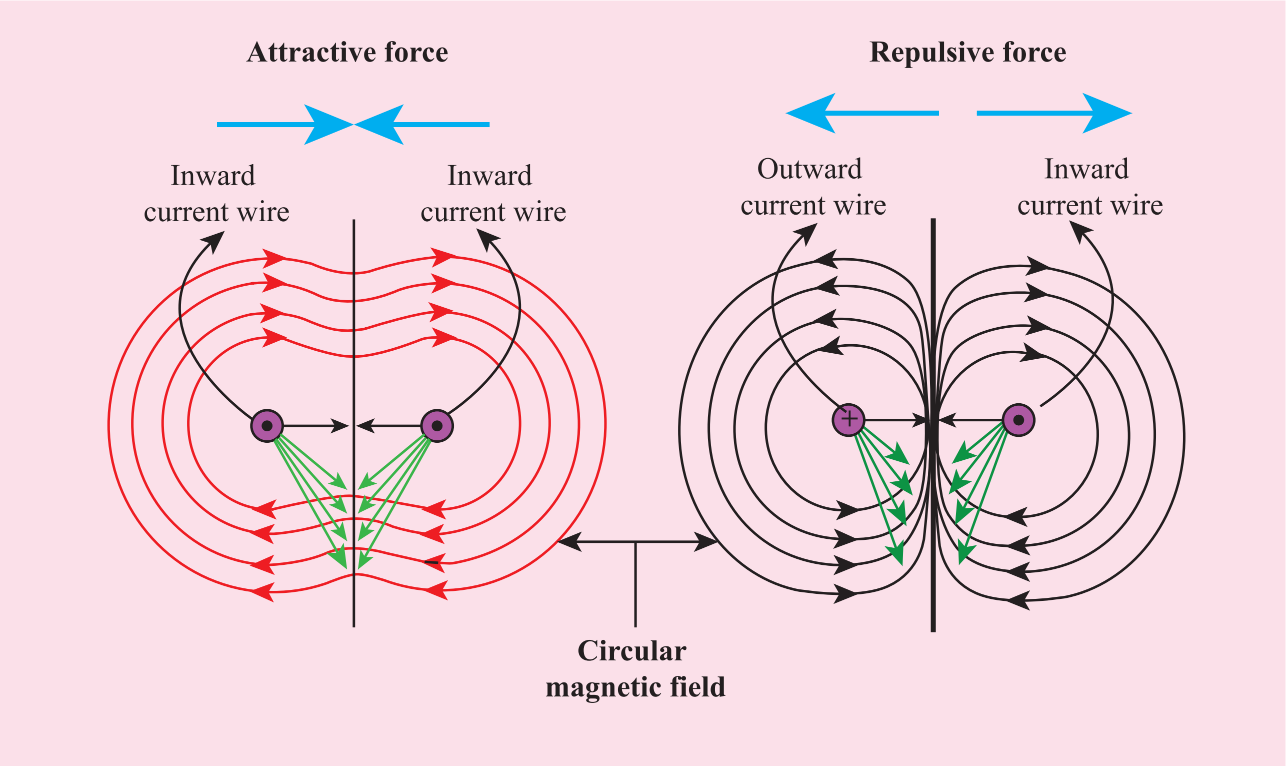


Figure 5.11 Force on current carrying conductors when viewed perpendicular to the direction of current

current which leads to magnetic property. Here, every orbiting electron in its orbit is like a current carrying loop. Even though in all the materials electrons orbit around the nucleus, only for certain special type of material called magnetic material the motion of electrons around the nucleus gets added up and as a result we have permanent magnetic field.

5.6 Electric motor

An electric motor is a device which converts electrical energy into mechanical energy. Electric motors are crucial in modern life. They are used in water pump, fan, washing machine, juicer, mixer, grinder etc. We have already seen that when electric current is passed through a conductor placed normally in a magnetic field, a force is acting on the conductor and this force makes the conductor to move. This is harnessed to construct an electric motor.

To understand how a motor works, we need to understand how a current carrying coil experiences a turning effect when placed inside a permanent magnetic field.

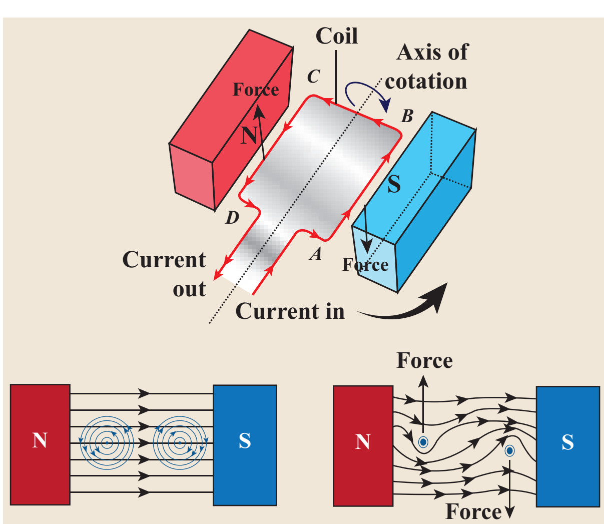


Figure 5.12 Turning effect in a coil

In Figure. 5.12, a simple coil is placed inside two poles of a magnet. Now look at the current carrying conductor segment AB. The direction of the current is towards B, whereas in the conductor segment CD the direction is opposite. As the current is flowing in opposite directions in the segments AB and CD, the direction of the motion of the segments would be in opposite directions according to Fleming's left hand rule. When two ends of the coil experience force in opposite direction, they rotate.

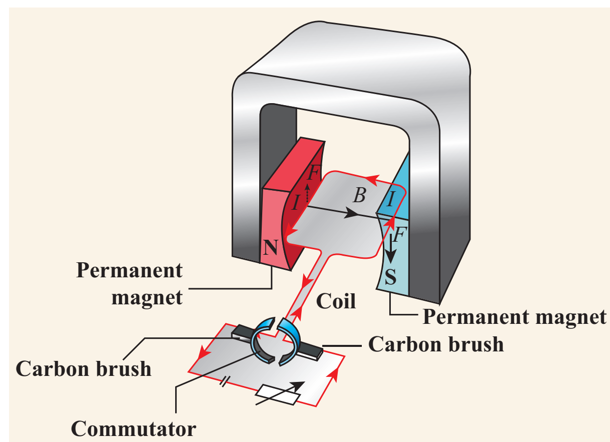


Figure 5.13 Principle of electric motor

If the current flow is along the line ABCD, then the coil will rotate in clockwise direction first and then in anticlockwise direction. If we want to make the coil rotate in any one direction, say clockwise, then the direction of the current should be along ABCD in the first half of the rotation and along DCBA in the second half of the rotation. To change the direction of the current, a small device called split ring commutator is used.

When the gap in the split ring commutator is aligned with terminals X and Y, there is no flow of current in the coil. But, as the coil is moving, it continues to move forward bringing one of the split ring commutator in contact with the carbon brushes X and Y. The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil.

The speed of rotation of coil can be increased by:

i. increasing the strength of current in the coil.
ii. increasing the number of turns in the coil.
iii. increasing the area of the coil and
iv. increasing the strength of the magnetic field.

5.7 Electromagnetic Induction

When it was shown by Oersted that magnetic field is produced around a conductor carrying current, the reverse effect was also attempted. In 1831, Michael Faraday explained the possibility of producing an e.m.f across the conductor when the magnetic flux linked with the conductor is changed. In order to demonstrate this, Faraday conducted few experiments.

5.7.1 Faraday's experiments

Experiment 1

In this experiment, two coils were wound on a soft iron ring (separated from each other). The coil on the left is connected to a battery and a switch K. A galvanometer is attached to the coil on the right. When the switch is put 'on', at that instant, there is a deflection in the galvanometer. Likewise, when the switch is put 'off', again there is a deflection – but in the opposite direction. This proves the generation of current.

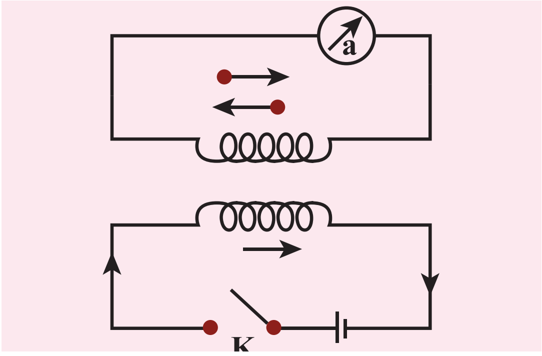


Figure 5.14 Electromagnetic induction in a current carrying coil

Experiment 2

In this experiment, current (or voltage) is generated by the movement of the magnet in and out of the coil. The greater the number of turns, the higher is the voltage generated.

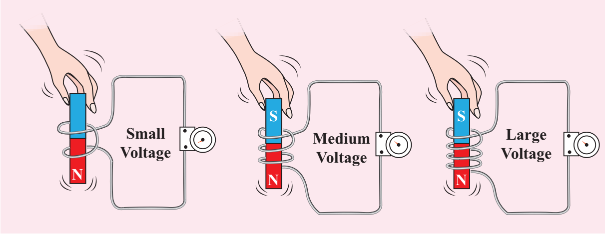


Figure 5.15 Electromagnetic induction by moving the magnet

Experiment 3

In this experiment, the magnet is stationary, but the coil is moved in and out of the magnetic field (indicated by the magnetic lines of force). Here also, current is induced.

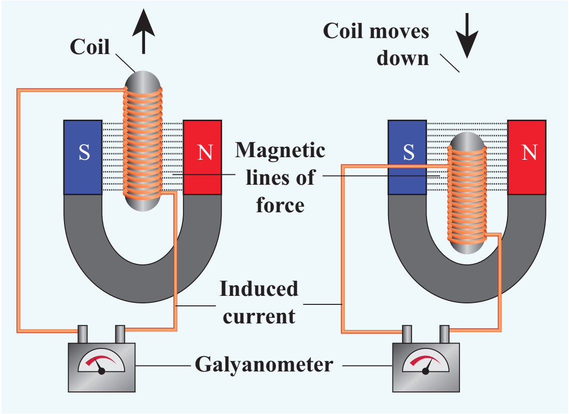


Figure 5.16 Electromagnetic induction by moving the coil

All these observations made Faraday to conclude that whenever there is a change in the magnetic flux linked with a closed circuit an emf is produced and the amount of emf induced varies directly as the rate at which the flux changes. This emf is known as induced emf and the phenomenon of producing an induced emf due to change in the magnetic flux linked with a closed circuit is known as electromagnetic induction.

Note: The direction of the induced current was given by Lenz's law, which states that the induced current in the coil flows in such a direction as to oppose the change that causes it. The direction of induced current can also be given by another rule called Fleming's Right Hand Rule.

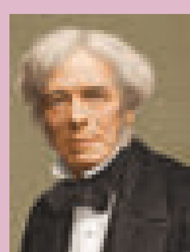
Activity 3

Create your own electromagnet

You are given a long iron nail, insulation coated copper wire and a battery. Can you make your own electromagnet?

Know Your Scientist

Michael Faraday (22nd Sep,1791–25th Aug, 1867) was a British Scientist who contributed to the study of electromagnetism and electrochemistry. His main discoveries include the principles underlying electromagnetic induction, diamagnetism and electrolysis.



5.7.2 Fleming's Right Hand Rule

Stretch the thumb, fore finger and middle finger of your right hand mutually perpendicular to each other. If the fore finger indicates the direction of magnetic field and the thumb indicates the direction of motion of the conductor, then the middle finger will indicate the direction of induced current. Fleming's Right hand rule is also called 'generator rule'.

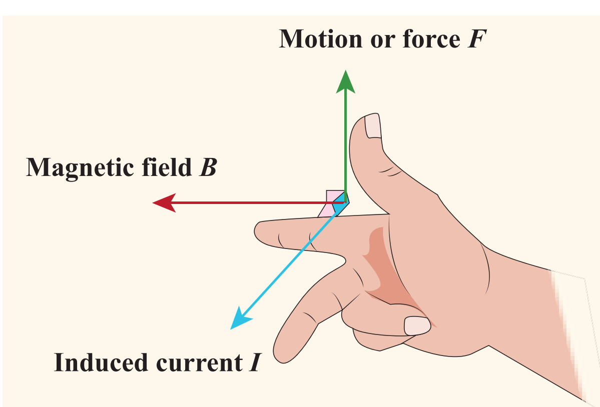


Figure 5.17 Fleming's right hand rule

5.8 Electric generator

An alternating current (AC) generator, as shown in Figure 5.18, consists of a rotating rectangular coil ABCD called armature placed between the two poles of a permanent magnet. The two ends of this coil are connected to two slip rings S_1 and S_2. The inner sides of these rings are insulated. Two conducting stationary brushes B_1 and B_2 are kept separately on the rings S_1 and S_2 respectively. The two rings S_1 and S_2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field. Outer ends of the two brushes are connected to the external circuit.

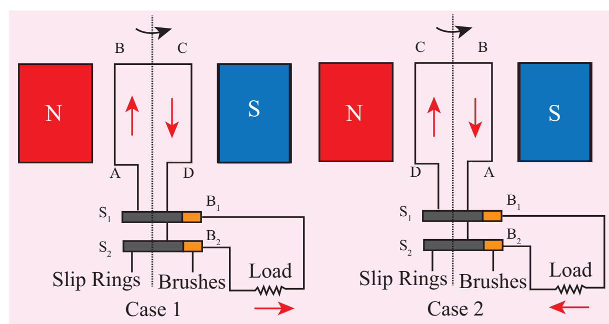


Figure 5.18 AC generator

When the coil is rotated, the magnetic flux linked with the coil changes. This change in magnetic flux will lead to generation of induced current. The direction of the induced current, as given by Fleming's Right Hand Rule, is along ABCD in the coil and in the outer circuit it flows from B_2 to B_1. During the second half of rotation, the direction of current is along DCBA in the coil and in the outer circuit it flows from B1 to B2. As the rotation of the coil continues, the induced current in the external circuit is changing its direction for every half a rotation of the coil.

To get a direct current (DC), a split ring type commutator must be used. With this arrangement, one brush is at all times in contact with the arm moving up in the field while the other is in contact with the arm moving down. Thus, a unidirectional current is produced. The generator is thus called a DC generator (Figure 5.19).

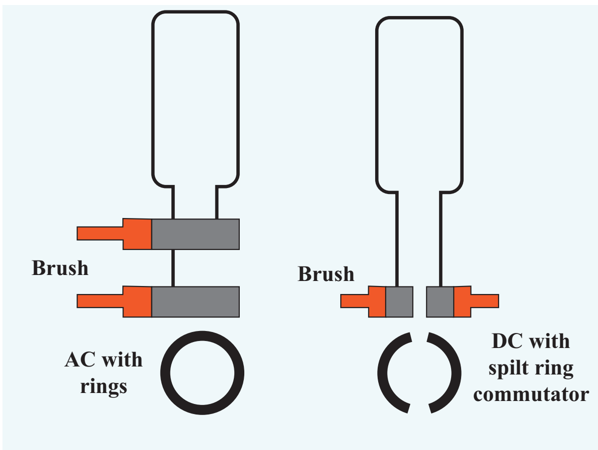


Figure 5.19 Comparison of AC and DC generators

5.9 Transformer

Transformer is a device used for converting low voltage into high voltage and high voltage into low voltage. It works on the principle of electromagnetic induction. It consists of primary and secondary coil insulated from each other. The alternating current flowing through the primary coil induces magnetic field in the iron ring. The magnetic field of the iron ring induces a varying emf in the secondary coil.

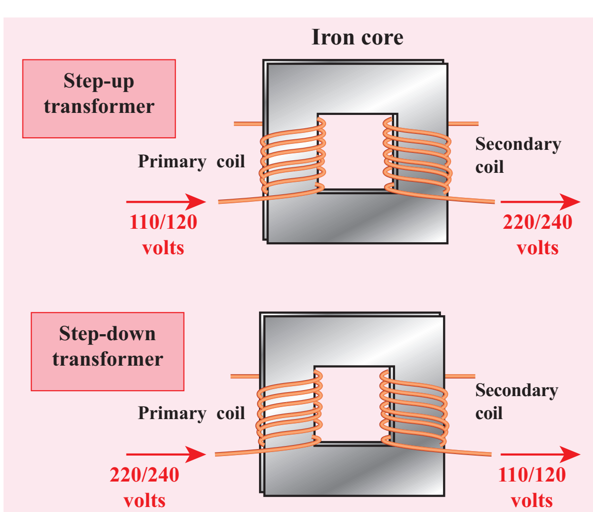


Figure 5.20 Step up and step down transformers

Depending upon the number of turns in the primary and secondary coils, we can step-up or step-down the voltage in the secondary coil as shown in Figure 5.20.

Step up transformer: The transformer used to change a low alternativing voltage to a high alternating voltage is called a step up transformer. ie Vs > Vp. In a step up transformer, the number of turns in the secondary coil is more than the number of turns in the primary coil (Ns > Np).

Step down transformer: The transformer used to change a high alternating voltage to a low alternating voltage is called a step down transformer (Vs < Vp). In a step down transformer, the number of turns in the secondary coils are less than the number of turns in the primary coil (Ns < Np).

DO YOU KNOW? A step up transformer increases the voltage but it decreases the current and vice versa. Basically there will be loss of energy in a transformer in the form of heat, sound etc.

The formulae pertaining to the transformers are given in the following equations.

$$\frac{\text{Number of primary turns } N_p}{\text{Number of secondary turns } N_s} = \frac{\text{Primary voltage } V_p}{\text{Secondary voltage } V_s}$$

$$\frac{\text{Number of secondary turns } N_s}{\text{Number of primary turns } N_p} = \frac{\text{Primary current } I_p}{\text{Secondary current } I_s}$$

A transformer cannot be used with the direct current (DC) source because, current in the primary coil is constant (ie. DC). Then there will be no change in the number of magnetic field lines linked with the secondary coil and hence no emf will be induced in the secondary coil.

Problem 3

The primary coil of a transformer has 800 turns and the secondary coil has 8 turns. It is connected to a 220 V ac supply. What will be the output voltage?

Solution:

In a transformer, $E_s / E_p = N_s / N_p$

$E_s = N_s / N_p \times E_p$

$= 8/800 \times 220 = 220/100 = 2.2$ volt

5.10 Applications of Electromagnets

Electromagnetism has created a great revolution in the field of engineering applications. In addition, this has caused a great impact on various fields such as medicine, industries, space etc.

5.10.1 Speaker

Inside the speaker, an electromagnet is placed in front of a permanent magnet. The permanent magnet is fixed firmly in position whereas the electromagnet is mobile. As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed. This means that it is in turn attracted to and repelled from the permanent magnet vibrating back and forth. The electromagnet is attached to a cone made of a flexible material such as paper or plastic which amplifies these vibrations, pumping sound waves into the surrounding air towards our ears.

5.10.2 Magnetic Levitation Trains

Magnetic levitation (Maglev) is a method by which an object is suspended with no support other than magnetic fields. In maglev trains two sets of magnets are used, one set to repel and push the train up off the track, then another set to move the floating train ahead at great speed without friction. In this technology, there is no moving part. The train travels along a guideway of magnets which controls the train's stability and speed using the basic principles of magnets.

Figure 5.21 Magnetic Levitation Trains

5.10.3 Medical System

Nowadays electromagnetic fields play a key role in advanced medical equipments such as hyperthermia treatments for cancer, implants and magnetic resonance imaging (MRI). Sophisticated equipments working based on electromagnetism can scan even minute details of the human body.

Figure 5.22 MRI Scanning machine

Many of the medical equipments such as scanners, x-ray equipments and other equipments also use the principle of electromagnetism for their functioning.

Points to Remember

- When current passes through a wire a magnetic field is set up around the wire. This is called magnetic effect of current.
- The space surrounding a bar magnet in which its influence in the form of magnetic force can be detected, is called magnetic field.
- The path along which a free magnetic north pole will move in a magnetic field is called magnetic field lines.
- The magnetic field set up by a current carrying conductor is always at right angles to the direction of flow of current.
- Two parallel wires carrying current in the same directions attract each other.
- Two parallel wires carrying current in the opposite directions repel each other.
- Direction of the force in a current carrying conductor is determined by Fleming's Left Hand Rule.
- Electric motor is a device which converts electrical energy into mechanical energy.
- The phenomenon of producing induced current in a closed circuit due to the change in magnetic field in the circuit is known as electromagnetic induction.
- Direction of induced current in a conductor is determined by Fleming's Right Hand Rule.
- Electric generator is a device used to convert mechanical energy into electrical energy.
- Electric generator works on the principle of electromagnetic induction.
- Transformer converts low alternating current to high alternating current and vice versa.

A-Z GLOSSARY

Magnetic field	The region surrounding a magnet in which the force of the magnet can be detected.
Magnetic line of force	The path followed by a magnetic needle in a magnetic field.
Dynamo	Device which converts mechanical energy into electrical energy.
Motor	Device which converts electrical energy into mechanical energy.
Electromagnetic induction	The phenomenon of producing an induced emf due to change in the magnetic lines of forces associated with a conductor.
Transformer	Device which converts low alternating current to high alternating current and vice versa.
MRI	Devise used to obtain images of the internal parts of our body.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. Which of the following converts electrical energy into mechanical energy?
   a) Motor b) Battery
   c) Generator d) Switch

2. Transformer works on
   a) AC only b) DC only
   c) Both AC and DC

3. The part of the AC generator that passes the current from the armature coil to the external circuit is
   a) field magnet b) split rings
   c) slip rings d) brushes

4. The unit of magnetic flux density is
   a) Weber
   b) weber/metre
   c) weber/meter^2
   d) weber . meter^2

II. Fill in the blanks.

1. The SI Unit of magnetic field induction is ________.
2. Devices which is used to convert high alternating current to low alternating current is ________.
3. An electric motor converts ________.
4. A device for producing electric current is ________.

III. Match the following.

1. Magnetic material	(a) Oersted
2. Non-magnetic material	(b) Iron
3. Current and magnetism	(c) Induction
4. Electromagnetic induction	(d) Wood
5. Electric generator	(e) Faraday

IV. State whether true or false. If false, correct the statement.

1. A generator converts mechanical energy into electrical energy.
2. Magnetic field lines always repel each other and do not intersect.
3. Fleming's Left hand rule is also known as Dynamo rule.
4. The speed of rotation of an electric motor can be increased by decreasing the area of the coil.
5. A transformer can step up direct current.
6. In a step down transformer the number of turns in primary coil is greater than that of the number of turns in the secondary coil.

V. Answer in brief.

1. State Fleming's Left Hand Rule.
2. Define magnetic flux density.
3. List the main parts of an electric motor.
4. Draw and label the diagram of an AC generator.
5. State the advantages of ac over dc.
6. Differentiate step up and step down transformer.
7. A portable radio has a built in transformer so that it can work from the mains instead of batteries. Is this a step up or step down transformer? Give reason.
8. State Faraday's laws of electromagnetic induction.

VI. Answer in detail.

1. Explain the principle, construction and working of a dc motor.
2. Explain two types of transformer.
3. Draw a neat diagram of an AC generator and explain its working.

REFERENCE BOOKS

Advanced Physics by Keith Gibbs – Cambridge University Press.

Principles of physics (Extended) – Halliday Resnick and Walker. Wiley publication, New Delhi.

Fundamental University Physics – M. Alonso, E. J. Finn Addimon Wesley (1967)

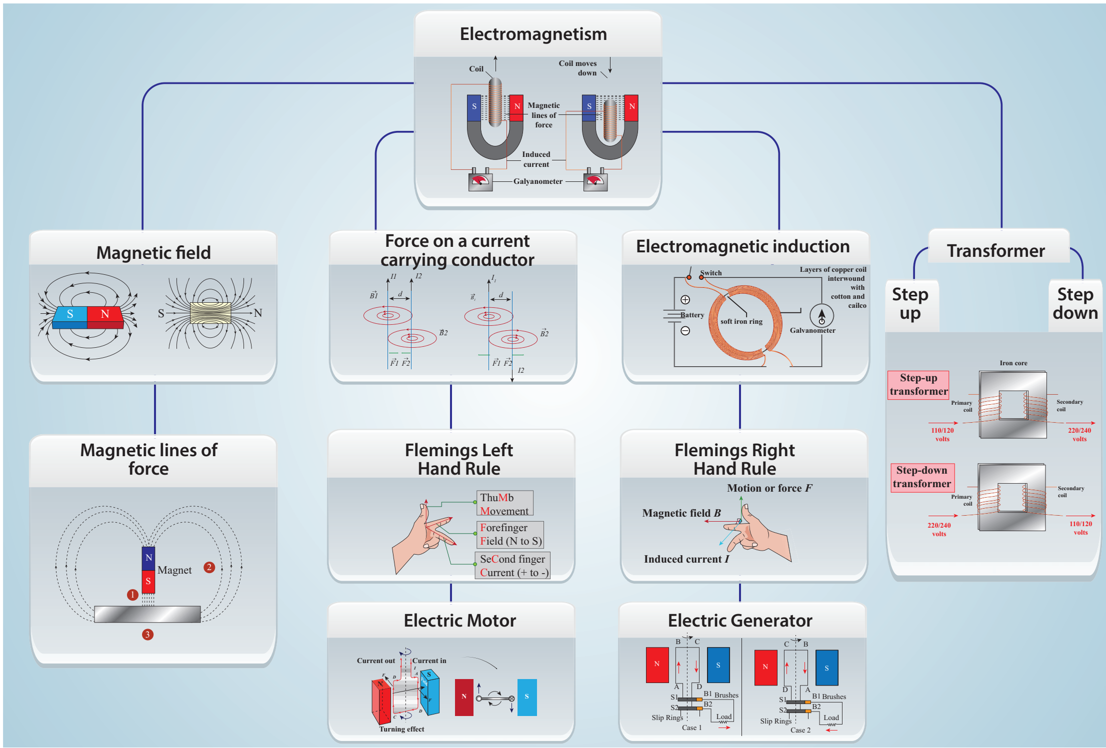
INTERNET RESOURCES

www.physicsabout.com

https://science.howstuffworks.com

http://arvindguptatoys.com/films.html

Concept Map



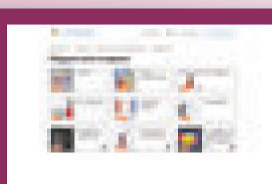
ICT CORNER

Magnetism and Electromagnetism

Explore this activity to know about the various properties in magnetism

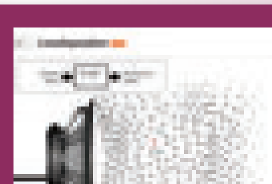
Steps

- Copy and paste the link given below or type the URL in the browser. Click the option **Magnet and Compass**.
- You can find six activities and three videos related to magnets and loudspeaker.
- Click any one of the six activities to simulate and understand the process.
- Click any one of the three videos to understand the concepts related to loudspeaker and magnets. Try all the other activities and videos as well.



Step1

Step2



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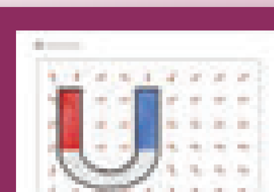

Step4

Browse in the link:

URL: http://www.edumedia-sciences.com/en/node/75-magnetism

*Pictures are indicative only

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UNIT 6

LIGHT

EL6BCC

Learning Objectives

After completing this lesson, students will be able to:

- apply the laws of reflection for plane mirrors and spherical mirrors.
- draw ray diagrams to find the position and size of the image for spherical mirrors.
- distinguish between real and virtual images.
- apply the mirror equation to calculate position, size and nature of images for spherical mirrors.
- identify the direction of bending when light passes from one medium to another.
- solve problems using Snell's law.
- predict whether light will be refracted or undergo total internal reflection.

Introduction

Light is a form of energy which travels as electromagnetic waves. The branch of physics that deals with the properties and applications of light is called *optics*. In our day to day life we use number of optical instruments. Microscopes are inevitable in science laboratories. Telescopes, binoculars, cameras and projectors are used in educational, scientific and entertainment fields.

In this lesson, you will learn about spherical mirrors (concave and convex). Also, you will learn about the properties of light, namely reflection and refraction and their applications.

6.1 Reflection of Light

Light falling on any polished surface such as a mirror, is reflected. This reflection of light on polished surfaces follows certain laws and you have studied about them in your lower classes. Let us study about them little elaborately here.

6.1.1 Laws of reflection

Consider a plane mirror MM′ as shown in Figure 6.1. Let AO be the light ray incident on the plane mirror at O. The ray AO is called incident ray. The plane mirror reflects the incident ray along OB. The ray OB is called reflected ray. Draw a line ON at O perpendicular to MM′. This line ON is called normal.

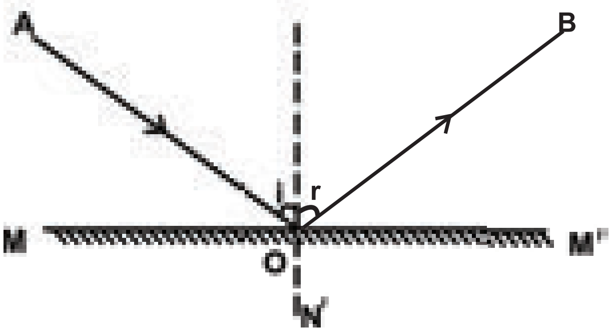

Figure 6.1 Plane mirror

The angle made by the incident ray with the normal (i = *angle* AON) is called angle of incidence. The reflected ray OB makes an angle (r = angle NOB) with the normal and this is called angle of reflection. From the figure you can observe that the angle of incidence is equal to the angle of reflection. i.e., $\angle i = \angle r$. Also, the incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane. These are called the laws of reflection. Laws of reflection are given as:

- The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
- The angle of incidence is equal to angle of reflection.

DO YOU KNOW? The most common usage of mirror writing can be found on the front of ambulances, where the word "AMBULANCE" is often written in very large mirrored text.

6.1.2 Lateral inversion

You might have heard about inversion. But what is lateral inversion? The word lateral comes from the Latin word *latus* which means side. Lateral inversion means sidewise inversion. It is the apparent inversion of left and right that occurs in a plane mirror.

Why do plane mirrors reverse left and right, but they do not reverse up and down? Well, the answer is surprising. Mirrors do not actually reverse left and right and they do not reverse up and down also. What actually mirrors do is reverse inside out.

Look at the image below (Figure 6.2) and observe the arrows, which indicate the light ray from the object falling on the mirror. The arrow from the object's head is directed towards the top of the mirror and the arrow from the feet is directed towards the bottom. The arrow from left hand goes to the left side of the mirror and the arrow from the right hand goes to the right side of the mirror. Here, you can see that there is no switching. It is an optical illusion. Thus, the apparent lateral inversion we observe is not caused by the mirror but the result of our perception.

Figure 6.2 Lateral inversion

6.2 Real and Virtual Image

If the light rays coming from an object actually meet, after reflection, the image formed will be a real iamage and it is always inverted. A real image can be produced on a screen.

When the light rays coming from an object do not actually meet, but appear to meet when produced backwards, that image will be virtual image. The virtual image is always erect and cannot be caught on a screen (Figure 6.3).

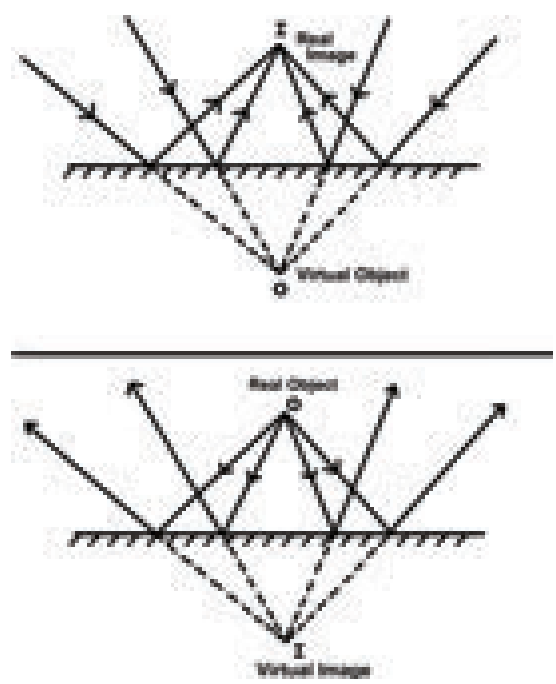

Figure 6.3 Real and virtual image

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Activity 1

Stand before the mirror in your dressing table or the mirror fixed in a steel almirah. Do you see your whole body? To see your entire body in a mirror, the mirror should be atleast half of your height. Height of the mirror= Your height/2.

6.3 Curved Mirrors

We studied about laws of reflection. These laws are applicable to all types of reflecting surfaces including curved surfaces. In your earlier classes, you have studied that there are many types of curved mirrors, such as spherical and parabolic mirrors. The most commonly used type of curved mirror is spherical mirror.

6.3.1 Spherical mirrors

In curved mirrors, the reflecting surface can be considered to form a part of the surface of a sphere. Such mirrors whose reflecting surfaces are spherical are called spherical mirrors.

In some spherical mirrors the reflecting surface is curved inwards, that is, it faces towards the centre of the sphere. They are called concave mirrors. In some other mirrors, the reflecting surface is curved outward. They are called convex mirror.

6.3.2 Image formed by spherical mirrors

Activity 2

Hold a concave mirror in your hand (or place it in a stand). Direct its reflecting surface towards the sun. Direct the light reflected by the mirror onto a sheet of paper held not very far from the mirror. Move the sheet of paper back and forth gradually until you find a bright, sharp spot of light on the paper. Position the mirror and the paper at the same location for few moments. What do you observe? Why does the paper catches fire?

We saw that the parallel rays of sun light could be focused at a point using a concave mirror. Now let us place a lighted candle and a white screen in front of the concave mirror. Adjust the position of the screen. Move the screen front and back. Note the size of the image and its shape. You can see a small and inverted image.

Slowly bring the candle closer to the mirror. What do you observe? As you bring the object closer to the mirror the image becomes bigger. Try to locate the image when you bring the candle very close to the mirror. Are you able to see an image on the screen? Now look inside the mirror. What do you see? An erect magnified image of the candle is seen. In some positions of the object an image is obtained on the screen. However, at some positions of the object no image is obtained. It is clear that the behaviour of the concave mirror is much more complicated than the plane mirror.

However, with the use of geometrical technique we can simplify and understand the behaviour of the image formed by a concave mirror. In the case of plane mirror, we used only two rays to understand how to get full image of a person. But, for understanding the nature of image formed by a spherical mirrors we need to look at four specific rules.

6.3.3 Rules for the construction of image

To find the position and nature of the image formed by a spherical mirror, we need to know the following rules.

Rule 1: A ray passing through the centre of curvature is reflected back along its own path (Figure 6.4).

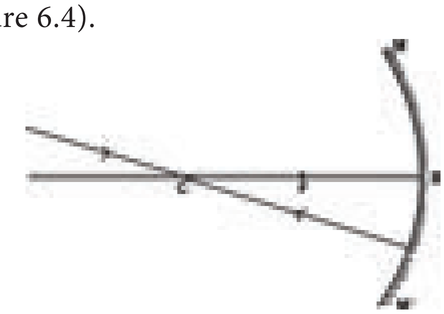

Figure 6.4 Ray passing through centre of curvature

Rule 2: A ray parallel to the principal axis passes through or appears to be coming from the principal focus (in case of convex mirror) after reflection (Figure 6.5).

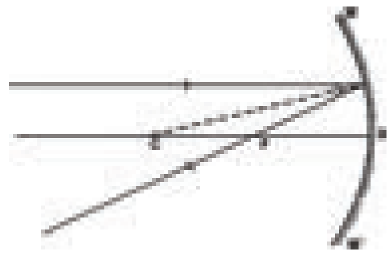

Figure 6.5 Ray parallel to prinicpal axis

Rule 3: A ray passing through the focus gets reflected and travels parallel to the principal axis (Figure 6.6).

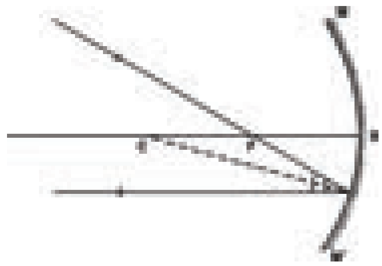

Figure 6.6 Ray travelling through the principal focus

Rule 4: A ray incident at the pole of the mirror gets reflected along a path such that the angle of incidence (APC) is equal to the angle of reflection (BPC) (Figure 6.7).

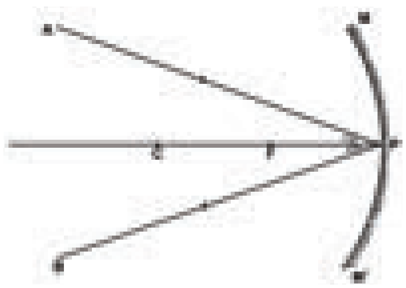

Figure 6.7 Angle of incidence equal to angle of reflection

6.4 Concave Mirror

6.4.1 Image Formation

We shall now find the position, size and nature of image by drawing the ray diagram for a small linear object placed on the principal axis of a concave mirror at different positions.

Case–I: When the object is far away (at infinity), the rays of light reaching the concave mirror are parallel to each other (Figure 6.8a).

Position of the Image: The image is formed at the principal focus F.

Nature of the Image: It is real, inverted and highly diminished in size.

Case–II: When the object is beyond the centre of curvature (Figure 6.8b).

Position of the image: Between the principal focus F and centre of curvature C.

Nature of the image: Real, inverted and smaller than object.

Case – III: When the object is at the centre of curvature (Figure 6.8c).

Position of the image: The image is at the centre of curvature itself.

Nature of the image: It is real, inverted and same size as the object.

Case – IV: When the object is in between the centre of curvature C and principal focus F (Figure 6.8d).

Position of the image: The image is beyond C

Nature of the image: It is real inverted and magnified.

Case – V: When the object is at the principal focus F (Figure 6.8e).

Nature of the image: No image can be captured on the screen nor any virtual image can be seen.

Case – VI: When the object is in between the focus F and the pole P (Figure 6.8f).

Position of the image: The image is behind the mirror.

Nature of the image: It is virtual, erect and magnified.

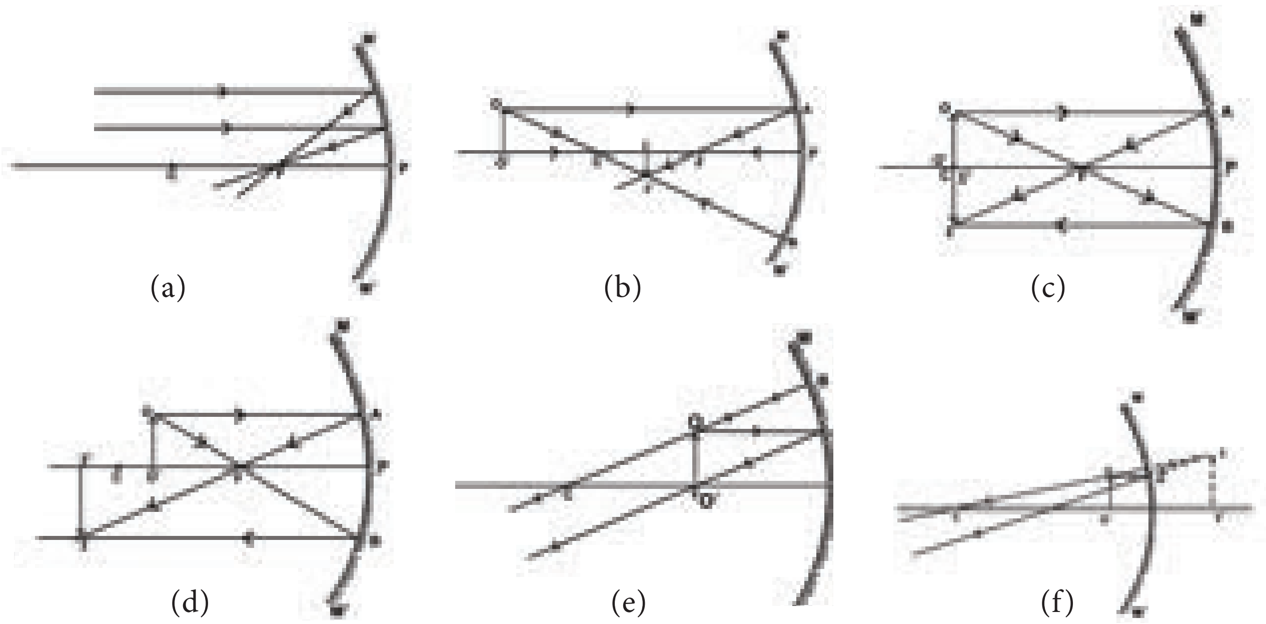

Figure 6.8 Ray diagram for the images formed by concave mirror

6.4.2 Sign convention for measurement of distances

We follow a set of sign conventions called the cartesian sign convention to measure distances in ray diagram. In this convention, the pole (P) of the mirror is taken as the origin. The principal axis is taken as the X-axis of the coordinate system (Figure 6.9).

- The object is always placed on the left side of the mirror.
- All distances are measured from the pole of the mirror.
- Distances measured in the direction of incident light are taken as positive and those measured in the opposite direction are taken as negative.
- All distances measured perpendicular to and above the principal axis are considered to be positive.
- All distances measured perpendicular to and below the principal axis are considered to be negative.

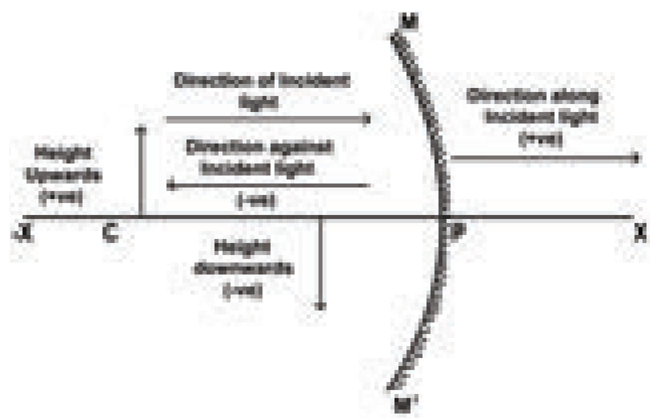

Figure 6.9 Sign convention for spherical mirrors

Table 6.1 Sign convention for spherical mirrors.

Type of mirror	u	v		f	R	Height of the object	Height of the image	
		real	virtual				real	virtual
Concave mirror	-	-	+	-	-	+	-	+
Convex mirror	-	No real image	+	+	+	+	No real image	+

6.4.3 Mirror equation

The expression relating the distance of the object (u), distance of the image (v) and the focal length (f) of a spherical mirror is called the mirror equation. It is given as:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

6.4.4 Linear magnification (m)

Magnification produced by a spherical mirror gives how many times the image of an object is magnified with respect to the object size.

It can be defined as the ratio of the height of the image (h_i) to the height of the object (h_o).

$$m = \frac{h_i}{h_o}$$

The magnification can be related to object distance (u) and the image distance (v).

$$m = -\frac{v}{u}$$

$$\therefore m = \frac{h_i}{h_o} = -\frac{v}{u}$$

Note: A negative sign in the value of magnification indicates that the image is real. A positive sign in the value of magnification indicates that the image is virtual.

Problem 1

Find the size, nature and position of the image formed when an object of size 1 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm.

Solution:

Object distance, u = –15 cm (to the left of mirror)

Image distance, v = ?

Focal length, f = –10 cm (concave mirror)

Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} + \frac{1}{-15} = \frac{1}{-10}$$

$$\frac{1}{v} - \frac{1}{15} = \frac{-1}{10}$$

$$\frac{1}{v} = \frac{-1}{10} + \frac{1}{15} = \frac{-3+2}{30} = \frac{-1}{30}$$

Thus, image distance, v = –30 cm (negative sign indicates that the image is on the left side of the mirror).

∴ Position of image is 30 cm in front of the mirror. Since the image is in front of the mirror, it is real and inverted.

To find the size of the image, we have to calculate the magnification.

$$m = \frac{-v}{u} = \frac{-(-30)}{(-15)} = -2$$

We know that, $m = \frac{h_2}{h_1}$

Here, height of the object h_1 = 1 cm

$$-2 = \frac{h_2}{1}$$

$h_2 = -2 \times 1 = -2$ cm

The height of image is 2 cm (negative sign shows that the image is formed below the principal axis).

Problem 2

An object 2 cm high is placed at a distance of 16 cm from a concave mirror which produces a real image 3 cm high. Find the position of the image.

Solution:

Height of object h_1 = 2 cm

Height of real image h_2 = –3 cm

Magnification $m = \frac{h_2}{h_1} = \frac{-3}{2} = -1.5$

We know that, $m = \frac{-v}{u}$

Here, object distance u = –16 cm

Substituting the value, we get

$$-1.5 = -\frac{v}{(-16)}$$

$$-1.5 = \frac{v}{16}$$

$$v = 16 \times (-1.5) = -24 \text{ cm}$$

The position of image is 24 cm in front of the mirror (negative sign indicates that the image is on the left side of the mirror).

6.4.5 Uses of concave mirror

Dentist's head mirror: In dentist's head mirror, a parallel beam of light is made to fall on the concave mirror. This mirror focuses the light beam on a small area of the body (such as teeth, throat etc.).

Make-up mirror: When a concave mirror is held near the face, an upright and magnified image is seen. Here, our face will be seen magnified.

Other applications: Concave mirrors are also used as reflectors in torches, head lights in vehicles and search lights to get powerful beams of light. Large concave mirrors are used in solar heaters.

DO YOU KNOW?

Stellar objects are at an infinite distance. Therefore, the image formed by a concave mirror would be diminished, and inverted. Yet, astronomical telescopes use concave mirrors.

6.5 Convex Mirror

6.5.1 Image Formation

Any two rays can be chosen to draw the position of the image in a convex mirror (Figure 6.10): a ray that is parallel to the principal axis (rule 1) and a ray that appears to pass through the centre of curvature (rule 2).

Note: All rays behind the convex mirror shall be shown with dotted lines.

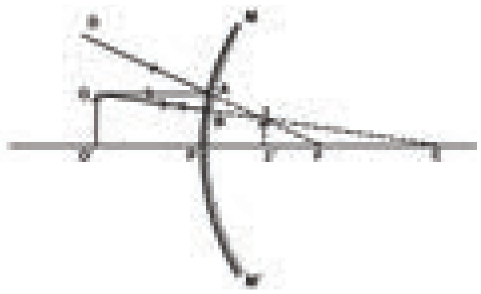

Figure 6.10 Image formation in a convex mirror

The ray OA parallel to the principal axis is reflected along AD. The ray OB retraces its path. The two reflected rays diverge but they appear to intersect at I when produced backwards. Thus II′ is the image of the object OO′. It is virtual, erect and smaller than the object.

Activity 3

Take a convex mirror. Hold it in one hand. Hold a pencil close to the mirror in the upright position in the other hand. Observe the image of the pencil in the mirror. Is the image erect or inverted? Is it diminished or enlarged? Move the pencil slowly away from the mirror. Does the image become smaller or larger? What do you observe?

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6.5.2 Uses of convex mirrors

Convex mirrors are used as rear-view mirrors in vehicles. It always forms a virtual, erect, small-sized image of the object. As the vehicles approach the driver from behind, the size of the image increases. When the vehicles are moving away from the driver, then image size decreases. A convex mirror provides a much wider field of view (it is the observable area as seen through eye / any optical device such as mirror) compared to plane mirror.

Convex mirrors are installed on public roads as traffic safety device. They are used in acute bends of narrow roads such as hairpin bends in mountain passes where direct view of oncoming vehicles is restricted. It is also used in blind spots in shops.

DO YOU KNOW? In the rear view mirror, the following sentence is written. "Objects in the mirror are closer than they appear". Why?

Problem 3

A car is fitted with a convex mirror of focal length 20 cm. Another car is 6 m away from the first car. Find the position of the second car as seen in the mirror of the first. What is the size of the image if the second car is 2 m broad and 1.6 m high?

Solution:

Focal length = 20 cm (convex mirror)

Object distance = –6m = –600 cm

Image distance v = ?

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{20} = \frac{1}{-600} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{20} - \frac{1}{-600} = \frac{1}{20} + \frac{1}{600} \quad \frac{1}{v} = \frac{30+1}{600} = \frac{31}{600}$$

$$v = \frac{600}{31} = 19.35 \text{ cm}$$

b) Size of the image

$$m = \frac{-v}{u} = -\frac{v}{(-u)} = -\frac{600}{31} \times \frac{1}{-600} = \frac{1}{31}$$

Breadth of image = $\frac{1}{31} \times 200$ cm = 6.45 cm

Height of image = $\frac{1}{31} \times 160$ cm = 5.16 cm

6.6 Speed of light

In early seventeenth century, the Italian scientist Galileo Galilee (1564-1642) tried to measure the speed of light.

In 1665, the Danish astronomer Ole Roemer first estimated the speed of light by observing one of the twelve moons of the planet Jupiter. He estimated the speed of light to be about 220,000 km per second.

DO YOU KNOW? Some organisms can make their own light too? This ability is called bioluminescence. Worms, fish, squid, starfish and some other organisms that live in the dark sea habitat glow or flash light to scare off predators.

In 1849, the first land based estimate was made by Armand Fizeau. Today the speed of light in vacuum is known to be almost exactly 300,000 km per second.

6.7 Refraction of light

Activity 4

Refraction of light at air – water interface

Put a straight pencil into a tank of water or beaker of water at an angle of 45° and look at it from one side and above. How does the pencil look now? The pencil appears to be bent at the surface of water.

This acctivity explains the refraction of light. The bending of light rays when they pass obliquely from one medium to another medium is called refraction of light. Light rays get deviated from their original path while entering from one transparent medium to another medium of different optical density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light is more in a rarer medium (low optical density) than in a denser medium (high optical density).

6.7.1 Refraction of light from a plane transparent surface

When a ray of light travels from optically rarer medium to optically denser medium, it bends towards the normal. (Figure 6.11a).

When a ray of light travels from an optically denser medium to an optically rarer medium it bends away from the normal. (Figure 6.11b).

A ray of light incident normally on a denser medium, goes without any deviation. (Figure 6.11c).

6.7.2 The laws of refraction of light

Laws of refraction, also known as Snell's law of refraction are given below as:

- The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a light of given colour and for the given pair of media.

If i is the angle of incidence and r is the angle of refraction, then

$$\frac{\sin i}{\sin r} = \text{constant}$$

This constant is called the refractive index of the second medium with respect to the first medium. It is generally represented by the Greek letter, ${}_1\mu_2$ (mew).

Note: The refractive index has no unit as it is the ratio of two similar quantities.

The refractive index of a medium is also defined in terms of speed of light in different media.

$$\mu = \frac{\text{speed of light in vacuum or air } (c)}{\text{speed of light in the medium } (v)}$$

In general, $${}_1\mu_2 = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}$$

Problem 4

The speed of light in air is 3×10^8 ms^{-1} and in glass it is 2×10^8 ms^{-1}. What is the refractive index of glass?

Solution:

$${}_a\mu_g = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2} = 1.5$$

Problem 5

Light travels from a rarer medium to a denser medium. The angles of incidence and refraction are respectively 45° and 30°. Calculate the refractive index of the second medium with respect to the first medium.

Solution:

$${}_1\mu_2 = \frac{\sin i}{\sin r} = \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2} = 1.414$$

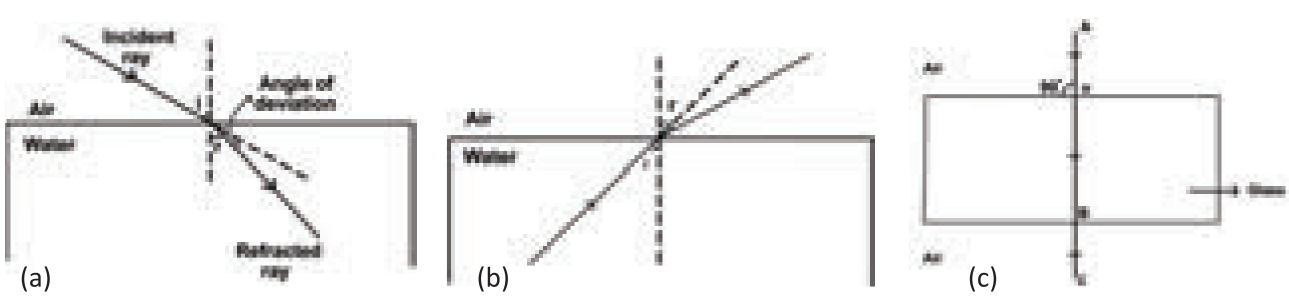

Figure 6.11 Refraction of light from a plane transparent surface

6.8 Total Internal Reflection

When light travels from denser medium into a rarer medium, it gets refracted away from the normal. While the angle of incidence in the denser medium increases the angle of refraction also increases and it reaches a maximum value of r = 90° for a particular value. This angle of incidence is called critical angle (Figure 6.12). The angle of incidence at which the angle of refraction is 90° is called the critical angle. At this angle, the refracted ray grazes the surface of separation between the two media.

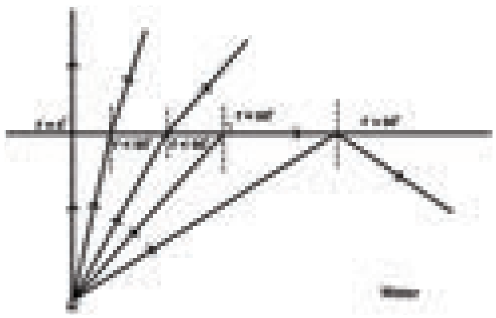

Figure 6.12 Critical angle

When the angle of incidence exceeds the value of critical angle, the refracted ray is not possible. Since r > 90° the ray is totally reflected back to the same medium. This is called as total internal reflection.

6.8.1 Conditions to achieve total internal reflection

In order to achieve total internal refelection the following conditions must be met.

- Light must travel from denser medium to rarer medium. (Example: From water to air).
- The angle of incidence inside the denser medium must be greater than that of the critical angle.

6.8.2 Total internal reflection in nature

Mirage: On hot summer days, patch of water may be on the road. This is an illusion. In summer, the air near the ground becomes hotter than the air at higher levels. Hotter air is less dense, and has smaller refractive index than the cooler air.

Thus, a ray of light bends away from the normal and undergoes total internal reflection. Total internal reflection is the main cause for the spectacular brilliance of diamonds and twinkling of stars.

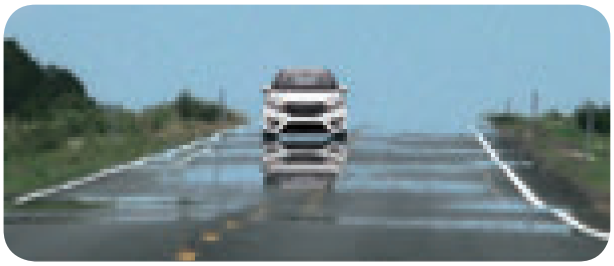

Figure 6.13 Mirage

Optical fibres: Optical fibres are bundles of high-quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. Optical fibres work on the phenomenon of total internal reflection. When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflection along the length of the fibre and finally comes out at the other end.

Optical fibres are extensively used for transmitting audio and video signals through long distances. Moreover, due to their flexible nature, optical fibers enable physicians to look and work inside the body through tiny incisions without having to perform surgery.

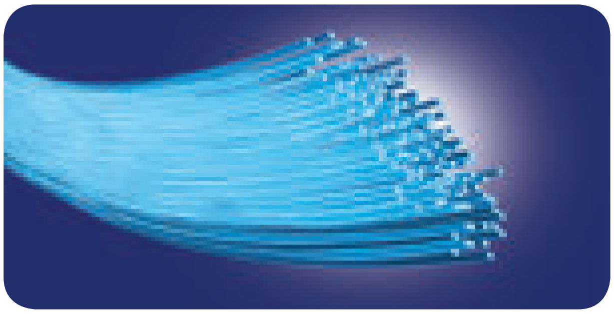

Figure 6.14 Optical fibres

DO YOU KNOW?

An Indian-born physicist Narinder Kapany is regarded as the *Father of Fibre Optics*.

Points to Remember

- Light is a form of energy which produces the sensation of sight.
- Laws of reflection: i) Angle of incidence is equal to the angle of reflection ii) The incident ray, the normal to the point of incidence and the reflected ray, all lie in the same plane.
- The distance between the pole and the principal focus of the spherical mirror is called focal length. $f = \frac{R}{2}$; where R is the radius of curvature of the mirror.
- Mirror equation: The relation between u, v and f of a spherical mirror is known as mirror formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
- Magnification: m = $\frac{\text{height of the image } h_2}{\text{height of the object } h_1}$
- Laws of refraction: The incident ray, the refracted ray and the normal to the surface separating two medium lie in the same plane. The ratio of the sine of the incident angle (∠i) to the sine of the refracted angle (∠r) is constant i.e. $\mu = \frac{\sin i}{\sin r}$ = constant
- The bending of light when it passes obliquely from transparent medium to another is called refraction.
- When the angle of incidence exceeds the value of critical angle the refracted ray is impossible. Since r > 90° refraction is impossible and the ray is totally reflected back to the same medium (denser medium). This is called as total internal reflection.

A-Z GLOSSARY

Spherical Mirror	A reflecting surface which is a part of a sphere whose inner or outer surface is reflecting.
Concave Mirror	Part of a hollow sphere whose outer part is silvered and/or inner part is the reflecting surface.
Convex Mirror	Part of a hollow sphere whose inner part is silvered and/or outer part is the reflecting surface.
Centre of curvature	The centre of the hollow sphere of which the spherical mirror forms a part.
Radius of curvature	The radius of the hollow sphere of which the spherical mirror forms a part.
Pole	The midpoint of the spherical mirror.
Aperture	The diameter of the circular rim of the mirror.
Principal axis	The normal to the centre of the mirror is called the principal axis.
Principal focus	The point on the principal axis of the spherical mirror where the rays of light parallel to the principal axis meet or appear to meet after reflection from the spherical mirror.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. A ray of light passes from one medium to another medium. Refraction takes place when angle of incidence is

   a) 0°   b) 45°   c) 90°

2. ______ is used as reflectors in torchlight.
   a) Concave mirror   b) Plane mirror
   c) Convex mirror

3. We can create enlarged, virtual images with
   a) concave mirror   b) plane mirror
   c) convex mirror

4. When the reflecting surface is curved outwards the mirror formed will be
   a) concave mirror   b) convex mirror
   c) plane mirror

5. When a beam of white light passes through a prism it gets
   a) reflected   b) only deviated
   c) deviated and dispersed

6. The speed of light is maximum in
   a) vacuum   b) glass   c) diamond

II. State whether true or false. If false, correct the statement.

1. The angle of deviation depends on the refractive index of the glass.
2. If a ray of light passes obliquely from one medium to another, it does not suffer any deviation.
3. The convex mirror always produces a virtual, diminished and erect image of the object.
4. When an object is at the centre of curvature of concave mirror the image formed will be virtual and erect.
5. The reason for brilliance of diamonds is total internal reflection of light.

III. Fill in the blanks.

1. In going from a rarer to denser medium, the ray of light bends ______________.
2. The mirror used in search light is ______.
3. The angle of deviation of light ray in a prism depends on the angle of _______.
4. The radius of curvature of a concave mirror whose focal length is 5cm is _______.
5. Large _________ mirrors are used to concentrate sunlight to produce heat in solar furnaces.

IV. Match the following.

Ratio of height of image to height of object.	Concave mirror
Used in hairpin bends in mountains.	Total internal reflection
Coin inside water appearing slightly raised.	Magnification
Mirage	Convex mirror
Used as Dentist's mirror.	Refraction

V. Assertion and reason type questions.

Mark the correct choice as:

a) If both assertion and reason are true and reason is the correct explanation.

b) If both assertion and reason are true and reason is not the correct explanation.

c) If assertion is true but reason is false.

d) If assertion is false but reason is true.

1. Assertion: For observing the traffic at a hairpin bend in mountain paths a plane mirror is preferred over convex mirror and concave mirror.
   Reason: A convex mirror has a much larger field of view than a plane mirror or a concave mirror.
2. Assertion: Incident ray is directed towards the centre of curvature of

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spherical mirror. After reflection it retraces its path.

Reason: Angle of incidence (i) = Angle of reflection (r) = 0°.

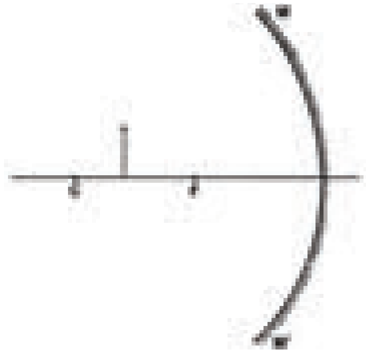
VI. Answer very briefly.

1. According to cartesion sign convention, which mirror and which lens has negative focal length?
2. Name the mirror(s) that can give (i) an erect and enlarged image, (ii) same sized, inverted image.
3. If an object is placed at the focus of a concave mirror, where is the image formed?
4. Why does a ray of light bend when it travels from one medium to another?
5. What is the speed of light in vacuum?
6. Concave mirrors are used by dentists to examine teeth. Why?

VII. Answer briefly.

1. a) Complete the diagram to show how a concave mirror forms the image of the object.

   b) What is the nature of the image?



2. Pick out the concave and convex mirrors from the following and tabulate them.

   Rear-view mirror, Dentist's mirror, Torch-light mirror, Mirrors in shopping malls, Make-up mirror.
3. State the direction of incident ray which after reflection from a spherical mirror retraces its path. Give reason for your answer.
4. What is meant by magnification? Write its expression. What is its sign for real image and virtual image?
5. Write the spherical mirror formula and explain the meaning of each symbol used in it.

VIII. Answer in detail.

1. a) Draw ray diagrams to show how the image is formed using a concave mirror, when the position of object is: i) at C ii) between C and F iii) between F and P of the mirror.

   b) Mention the position and nature of image in each case.
2. Explain with diagrams how refraction of incident light takes place from

   a) rarer to denser medium b) denser to rarer medium c) normal to the surface separating the two media.

IX. Numerical problems.

1. A concave mirror produces three times magnified real image of an object placed at 7 cm in front of it. Where is the image located? (Ans: 21 cm in front of the mirror)
2. Light enters from air into a glass plate having refractive index 1.5. What is the speed of light in glass? (Ans: 2×10^8 ms^{-1})
3. The speed of light in water is 2.25×10^8 ms^{-1}. If the speed of light in vacuum is 3×10^8 ms^{-1}, calculate the refractive index of water. (Ans: 1.33)

X. Higher Order Thinking Skills.

1. Light ray emerges from water into air. Draw a ray diagram indicating the change in its path in water.
2. When a ray of light passes from air into glass, is the angle of refraction greater than or less than the angle of incidence?
3. What do you conclude about the speed of light in diamond. if the refractive index of diamond is 2.41?

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INTERNET RESOURCES

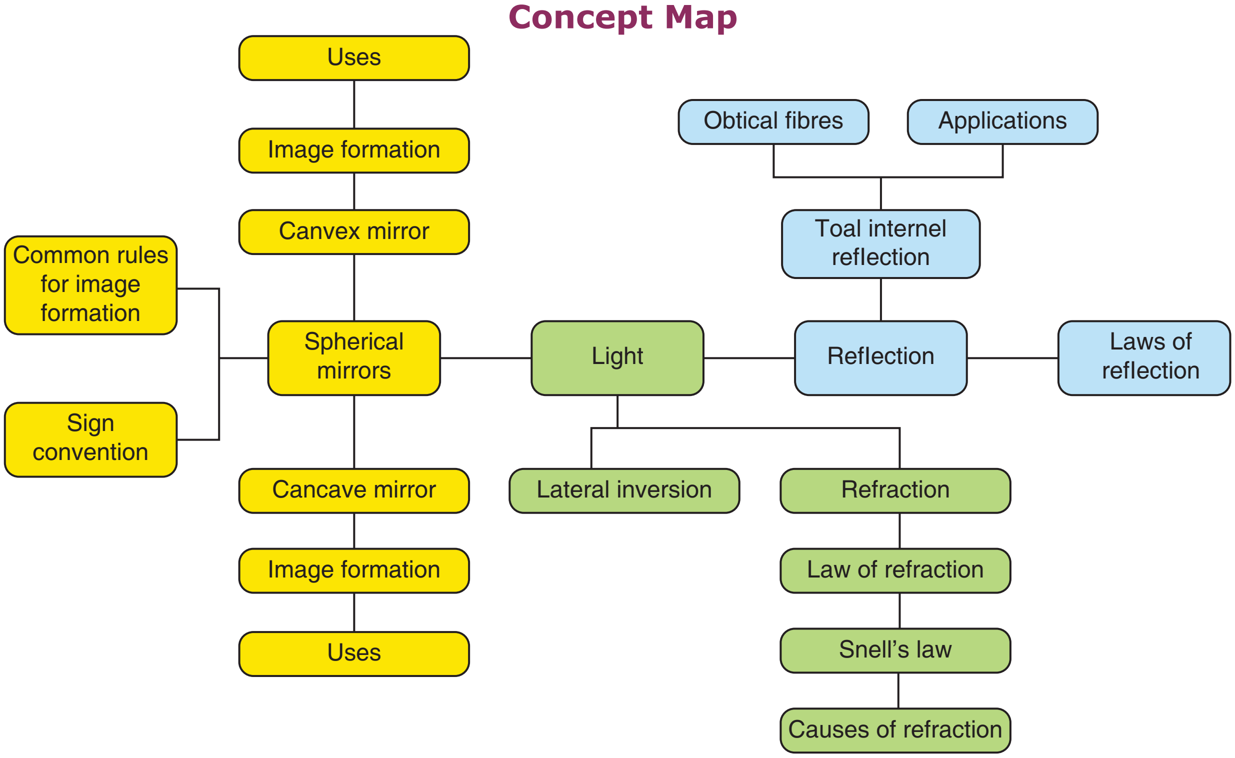
www.Physics.org

https://www.geogebra.org/m/aJuUDA9Z

http://www.animations.physics.unsw.edu.au/light/geometrical-optics/

http://www.splung.com/content/sid/4/page/snellslaw

Concept Map



ICT CORNER — LIGHT - REFRACTION

Refraction is bending of light when travel from one medium to another

This activity enable the students to learn about the different mediums and its role in refraction of light

Step 1. Type the following URL in the browser or scan the QR code from your mobile. Youcan see"Bending light" on the screen. Click intro

Step 2. Now you can see light beam from the torch. Options are there in the four corners. Select options of your choice and then press the button in the torch. You can see the phenomeno of refraction. The angles of refraction differ for different medium. You can check it with the protractor

Step 3. Next select prism. Now explore with given tools and different mediums and come out with different results

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https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

UNIT 7

HEAT

BKLGIH

Learning Objectives

After completing this lesson, students will be able to:

- understand the nature and the effects of heat.
- differentiate the conducting powers of various substances.
- list out good and bad conductors of heat and their uses.
- explain conduction using kinetic theory.
- describe the experiments to show convection in fluids.
- understand the concept of radiation.
- define specific heat capacity and thermal capacity.
- describe the concept of change of state.
- define specific latent heat of fusion and specific latent heat of vaporisation.

Introduction

All substances in our surrounding are made up of molecules. These molecules are generally at motion and posses kinetic energy. At the same time each molecule exerts a force of attraction on other molecules and so they posses potential energy. The sum of the kinetic and potential energy is called the internal energy of the molecules. This internal energy, when flows out, is called heat energy. This energy is more in hot substances and less in cold substances and flows from hot substances to cold substances. In this lesson you will study about how this heat transfer takes place. Also you will study about the effect of heat, heat capacity, change of state and latent heat.

7.1 Effects of Heat

When a substance is heated, the following things can happen.

Expansion: When heat is added to a substance, the molecules gain energy and vibrate and force other molecules apart. As a result, expansion takes place. You would have seen some space being left in railway tracks. It is because, during summer time, more heat causes expansion in tracks. Expansion is greater for liquids than solids and it is maximum in gases.

Figure 7.1 Gap in railway track

Change in State: When you heat ice cubes, they become water and water on further heating changes into vapour. So, solid becomes liquid and liquid becomes gas, when heat is added. The reverse takes place when heat is removed.

Change in Temperature: When heat energy is added to a substance, the kinetic energy of its particles increases and so the particles move at higher speed. This causes rise in temperature. When a substance is cooled, that is, when heat is removed, the molecules lose heat and its temperature falls.

Chemical changes: Since heat is a form of energy it plays a major role in chemical changes. In some cases, chemical reactions need heat to begin and also heat determines the speed at which reactions occur. When we cook food, we light the wood and it catches fire and the food particles become soft because of the heat energy. These are all the chemical changes taking place due to heat.

7.2 Transfer of Heat

Activity 1

Take a glass of water and put some ice cubes into it. Observe it for some time. What happens? The ice cubes melt and disappear. Why did it happen? It is because heat energy in the water is transferred to the ice.

Heat does not stay where we put it. Hot things get colder and cold things get hotter. Heat is transferred from one place to another till their temperatures become equal. Heat transfer takes place when heat energy flows from an object with higher temperature to an object with lower temperature (Fig. 7.2).

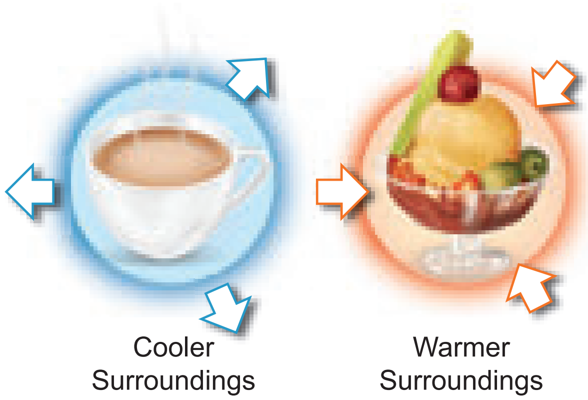


Figure 7.2 Hot and cold surroundings

DO YOU KNOW?

When a dog keeps out its tongue and breathes hard, the moisture on the tongue turns into water and it evaporates. Since, heat energy is needed to turn a liquid into a gas, heat is removed from dog's tongue. This helps to cool the body of the dog.

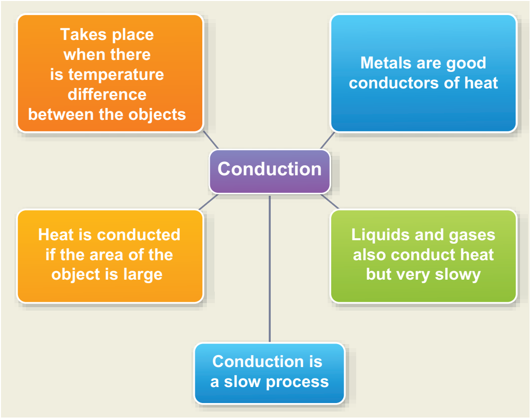
Heat transfer takes place in three ways:

i. Conduction, ii. Convection, iii. Radiation

7.2.1 Conduction

In solids, molecules are closely arranged so that they cannot move freely. When one end of the solid is heated, molecules at that end absorb heat energy and vibrate fast at their own positions. These molecules in turn collide with the neighboring molecules and make them vibrate faster and so energy is transferred. This process continues till all the molecules receive the heat energy.

The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.



Conduction in daily life

i. Metals are good conductors of heat. So, aluminium is used for making utensils to cook food quickly.

ii. Mercury is used in thermometers because, it is a good conductor of heat.

iii. We wear woolen clothes is winter to keep ourselves warm. Air, which is a bad conductor, does not allow our body heat to escape.

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Activity 2

Take metal rods of copper, aluminium, brass and iron. Fix a match stick to one end of each rod using a little melted wax. When the temperature of the far ends reach the melting point of wax, the matches drop off. It is observed that the match stick on the copper rod would fall first, showing copper as the best conductor followed by aluminum, brass and iron.

7.2.2 Convection

Activity 3

Drop a few crystals of potassium permanganate down to the bottom of a beaker containing water. When the beaker is heated just below the crystals, by a small flame, purple streaks of water rise upwards and fan outwards.

BKVCK5

In this activity, water molecules at the bottom of the beaker receive heat energy and move upward and replace the molecules at the top. Same thing happens in air also. When air is heated, the air molecules gain heat energy allowing them to move further apart. Warm air being less dense than cold air will rise. Cooler air moves down to replace the air that has risen. It heats up, rises and is again replaced by cooler air, creating a circular flow.

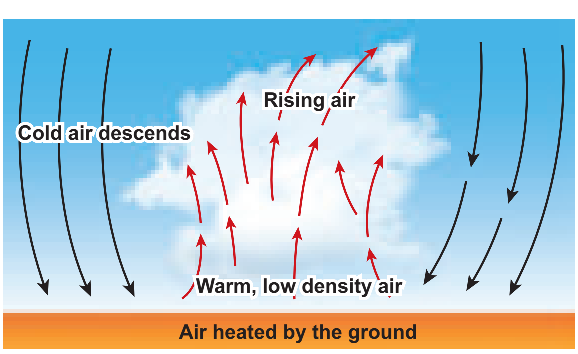

Figure 7.3 Convection in air

Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

Convection in daily life

Hot air balloons: Air molecules at the bottom of the balloon get heated by a heat source and rise. As the warm air rises, cold air is pushed downward and it is also heated. When the hot air is trapped inside the balloon, it rises.

Figure 7.4 Hot air balloon

Breezes: During day time, the air in contact with the land becomes hot and rises. Now the cool air over the surface of the sea replaces it. It is called sea breeze. During night time, air above the sea is warmer. As the warmer air over the surface of the sea rises, cooler air above the land moves towards the sea. It is called land breeze.

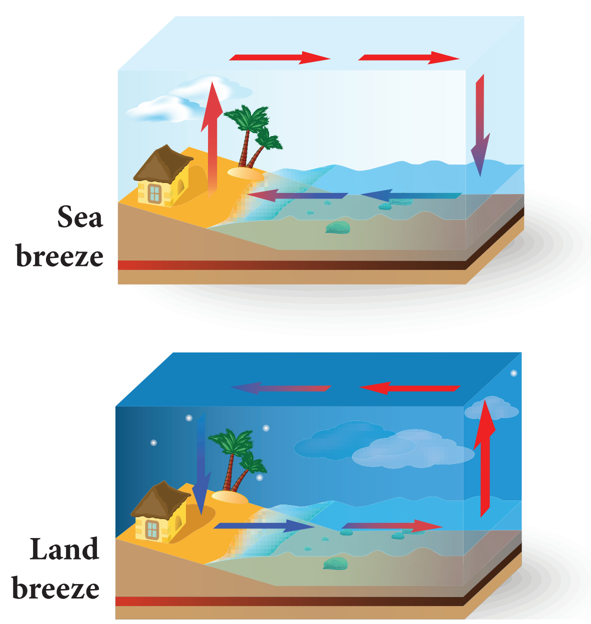

Figure 7.5 Land breeze and sea breeze

Winds: Air flows from area of high pressure to area of low pressure. The warm air molecules over hot surface rise and create low pressure. So, cooler air with high pressure flows towards low pressure area. This causes wind flow.

Chimneys: Tall chimneys are kept in kitchen and industrial furnaces. As the hot gases and smoke are lighter, they rise up in the atmosphere.

7.2.3 Radiation

Radiation is a method of heat transfer that does not require particles to carry the heat energy. In this method, heat is transferred in the form of waves from hot objects in all direction. Radiation can occur even in vacuum whereas conduction and convection need matter to be present. Radiation consists of electromagnetic waves travelling at the speed of light. Thus, radiation is the flow of heat from one place to another by means of electromagnetic waves.

Transfer of heat energy from the sun reaches us in the form of radiation. Radiation is emitted by all bodies above 0 K. Some objects absorb radiation and some other objects reflect them.

DO YOU KNOW?

While firing wood, we can observe all the three ways of heat transfer. Heat in one end of the wood will be transfered to other end due to conduction. The air near the wood will become warm and replace the air above. This is convection. Our hands will be warm because heat reaches us in the form of radiation.

Radiation in daily life

i. White or light colored cloths are good reflectors of heat. They keep us cool during summer.
ii. Base of cooking utensils is blackened because black surface absorbs more heat from the surrounding.
iii. Surface of airplane is highly polished because it helps to reflect most of the heat radiation from the sun.

7.3 Concept of Temperature

Temperature is the degree of hotness or coolness of a body. Hotter the body, higher is its temperature.

7.3.1 Unit of Temperature

The SI unit of temperature is ***kelvin*** (K). For day to day applications, ***Celsius*** (°C) is used. Temperature is measured with a thermometer.

7.3.2 Temperature scales

There are three scales of temperature.

i. Fahrenheit scale
ii. Celsius or Centigrade scale
iii. Kelvin or Absolute scale

Fahrenheit scale

In Fahrenheit scale, 32 °F and 212 °F are the freezing point and boiling point respectively. Interval has been divided into 180 parts.

Celsius temperature scale

In Celsius scale, also called centigrade scale, 0°C and 100 °C are the freezing point and boiling point respectively. Interval has been divided into 100 parts. The formula to convert a Celsius scale to Fahrenheit scale is:

$$F=\frac{9}{5}C+32$$

The formula for converting a Fahrenheit scale to Celsius scale is:

$$C=\frac{5}{9}(F-32)$$

Kelvin scale (Absolute scale)

Kelvin scale is known as the absolute scale. On the Kelvin scale 0 K represents absolute zero, the temperature at which the molecules of a substance have their lowest possible energy. The solid, liquid, gaseous phases of water can coexist in equilibrium at 273.16 K. *Kelvin is defined as 1/273.16 of the triple point temperature.* The formula for converting a Celsius scale to Kelvin scale is: K = C + 273.15

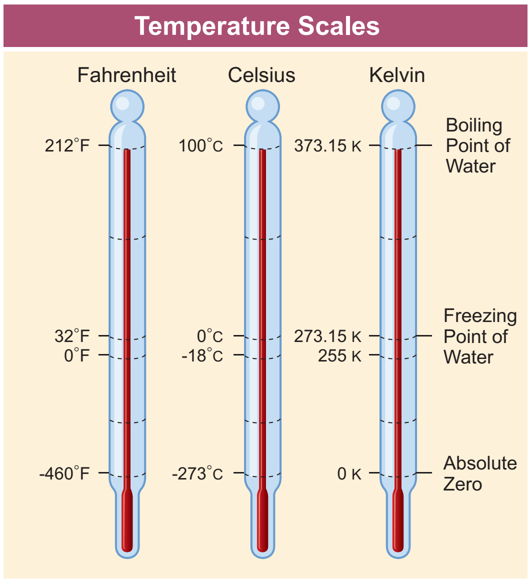

Figure 7.6 Types of temperature scales

Absolute zero

The temperature at which the pressure and volume of a gas theoretically reaches zero is called absolute zero. This is shown in Figure 7.7.

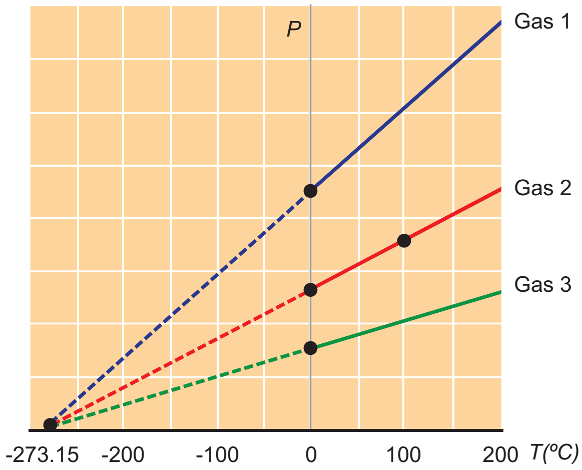

Figure 7.7 Variation of pressure (P) with temperature (T).

For all gases, the pressure extrapolates to zero at the temperature –273.15 °C. It is known as absolute zero or 0 K. Some base line temperatures in the three temperature scales are shown in Table 7.1.

Table. 7.1 Baseline temperatures in three scales.

Temperature	Kelvins (K)	Degrees Celcius (°C)	Degrees Fahrenheit (°F)
Boiling point of water	373.15	100	212
Melting point of ice	273.15	0	32
Absolute zero	0	–273	–460

Problem 1

Convert the following

i. 25 °C to Kelvin ii. 200 K to °C

Solution:

i. $T_K = T_{°C} + 273.15$

$T_K = 25 + 273.15 = 298.15$ K

ii. $T_{°C} = T_K - 273.15$

$T_{°C} = 200 - 273.15 = -73.15$ °C

Problem 2

Convert the following

i. 35° C to Fahrenheit (°F) ii. 14 °F to °C

Solution:

i. $T_{°F} = T_{°C} \times 1.8 + 32$

$T_{°F} = 25° \text{ C} \times 1.8 + 32 = 77$ °F

ii. $T_{°C} = (T_{°F} - 32)/ 1.8$

$T_{°C} = (14°\text{F} - 32)/ 1.8 = -10$ °C

7.4 Specific Heat Capacity

You might have felt that the land is cool in the morning and hot during day time. But, water in a lake will be almost at a particular temperature both in the morning as well as in the afternoon. Both are subjected to same amount of heat energy from the Sun, but they react differently. It is because both of them have different properties. In general, the amount of heat energy absorbed or lost by a body is determined by three factors.

1. Mass of the body
2. Change in temperature of the body
3. Nature of the material of the body

We can understand this from the following observations.

Observation:1

Quantity of heat required to raise the temperature of 1 litre of water will be more than the heat required to raise the temperature of 500 ml of water. If Q is the quantity of heat absorbed and m is the mass of the body, then $Q \propto m$ (7.1)

Observation: 2

Quantity of heat energy (Q) required to raise the temperature of 250 ml of water to 100°C is more than the heat energy required to raise the temperature to 50°C. Here, $Q \propto \Delta T$, where ΔT is the change in temperature of the body.

Thus, heat lost or gained by a substance when its temperature changes by ΔT is,

$$Q \propto m\Delta T$$

$$Q = mC\Delta T \qquad (7.2)$$

From the above equations, the absolute temperature and energy of a system are proportional to each other. The proportionality constant is the specific heat capacity (C) of the substance.

$$\therefore C = Q/m\Delta T$$

Thus, specific heat capacity of a substance is defined as the amount of heat required to raise the temperature of 1 kg of the substance by 1^0C or 1 K. The SI unit of specific heat capacity is $Jkg^{-1} K^{-1}$. The most commonly used units of specific heat capacity are J/kg°C and J/g°C.

Among all the substances, water has the highest specific heat capacity and its value is 4200 J/kg°K. So, water absorbs a large amount of heat for unit rise in temperature. Thus, water is used as a coolant in car radiators and factories to keep engines and other machinery parts cool. It is because of this same reason, temperature of water in the lake does not change much during day time.

Problem 3

Calculate the heat energy required to raise the temperature of 2 kg of water from 10°C to 50°C. Specific heat capacity of water is 4200 $JKg^{-1} K^{-1}$.

Solution:

Given m = 2 Kg, $\Delta T = (50 - 10) = 40$°C In terms of Kelvin, $\Delta T = (323.15 - 283.15) = 40K$, $C = 4200\ J\ Kg^{-1}\ K^{-1}$

$\therefore$ Heat energy required, $Q = m \times C \times \Delta T$
$= 2 \times 4200 \times 40 = 3{,}36{,}000$ J

DO YOU KNOW?

Water in its various form, has different specific heat capacities.

Water (Liquid state)	= 4200 $JKg^{-1} K^{-1}$
Ice (Solid state)	= 2100 $JKg^{-1} K^{-1}$
Steam (Gaseous state)	= 460 $JKg^{-1} K^{-1}$

7.5 Heat capacity or Thermal capacity

Now, you are familiar with specific heat capacity. It is the heat required to raise the temperature of a unit mass of a body by 1°C. But, heat capacity is the heat required to raise the temperature of the entire mass of the body by 1°C. Thus, heat capacity or thermal capacity is defined as the amount of heat energy required to raise the temperature of a body by 1°C. It is denoted by C'.

$$\text{Heat Capacity} = \frac{\text{Quantity of heat required}}{\text{Raise in Temperature}}$$

$$C' = Q/T$$

SI unit of heat capacity is J/K. It is also expressed in cal/°C, kcal/°C or J/°C.

Problem 4

An iron ball requires 5000 J heat energy to raise its temperature by 20 K. Calculate the heat capacity of the iron ball.

Solution:

Given, Q = 5000 J, ΔT = 20 K

$$\text{Heat Capacity, C} = \frac{\text{Heat energy required, Q}}{\text{Rise in temperature, } \Delta T}$$

$$= \frac{5000}{20} = 250\ JK^{-1}$$

7.5 Change of state

The process of changing of a substance from one physical state to another at a definite temperature is known as change of state.

For example, water molecules are in liquid state at normal temperature. When water is heated to 100°C, it becomes steam which is a gaseous state of matter. On reducing the temperature of the steam it becomes water again. If we reduce the temperature further to 0 °C, it becomes ice which is a solid state of water. Ice on heating, becomes water again. Thus, water changes its state when there is a change in temperature. There are different such processes in the change of state in matter. Figure 7.8 shows various processes of change of state.

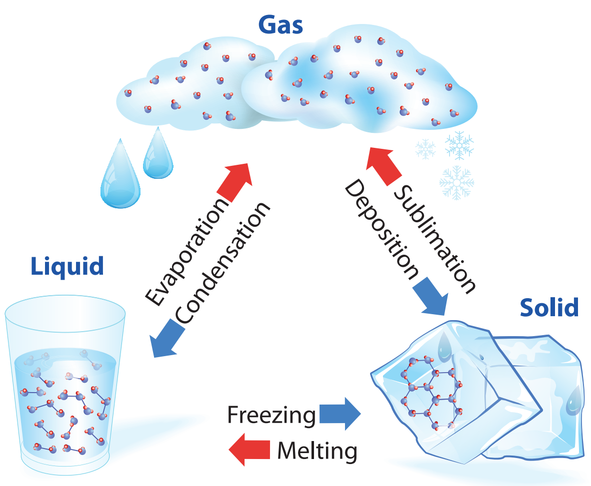

Figure 7.8 Change of state of matter

Melting – Freezing

The process in which a solid is converted to liquid by absorbing heat is called melting or fusion. The temperature at which a solid changes its state to liquid is called melting point. The reverse of melting is freezing. The process in which a liquid is converted to solid by releasing heat is called freezing. The temperature at which a liquid changes its state to solid is called freezing point. In the case of water, melting and boiling occur at 0°C.

Boiling-Condensation

The process in which a liquid is converted to vapor by absorbing heat is called boiling or vaporization. The temperature at which a liquid changes its state to gas is called boiling point. The process in which a vapor is converted to liquid by releasing heat is called condensation. The temperature at which vapour changes its state to liquid is called condensation point. Boiling point as well as condensation point of water is 100°C.

Sublimation

Some solids like dry ice, iodine, frozen carbon dioxide and naphthalene balls change directly from solid state to gaseous state without becoming liquid. The process in which a solid is converted to gaseous state is called sublimation.

Various stages of conversion of state of matter by heat with the corresponding change in temperature is shown in Figure 7.9

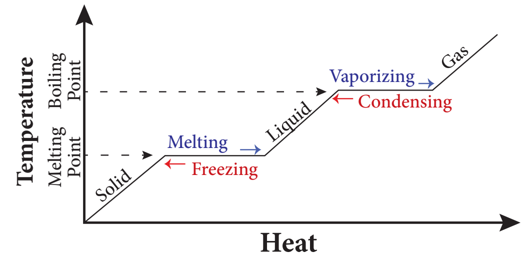

Figure 7.9 Various stages of conversion of state of matter

7.6 Latent heat

The word, 'latent' means hidden. So, latent heat means hidden heat or hidden energy. In order to understand latent heat, let us do the activity given below.

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Activity 4

Take some crushed ice cubes in a beaker and note down the temperature using thermometer. It will be 0°C. Now heat the ice in the beaker. You can observe that ice is melting to form water. Record the temperature at regular intervals and it will remain at 0°C until whole ice is converted to liquid. Now heat the beaker again and record the temperature. You can notice that the temperature will rise up to 100°C and it will retain the same even after continuous heating until the whole mass of water in the beaker is vaporized.

In the above activity, temperature is constant at 0°C until entire ice is converted into liquid and again constant at 100°C until all the ice is converted into vapor. Why? It is because, when a substance changes from one state to another, a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat. Thus, latent heat is the amount of heat energy absorbed or released by a substance during a change in its physical states without any change in its temperature.

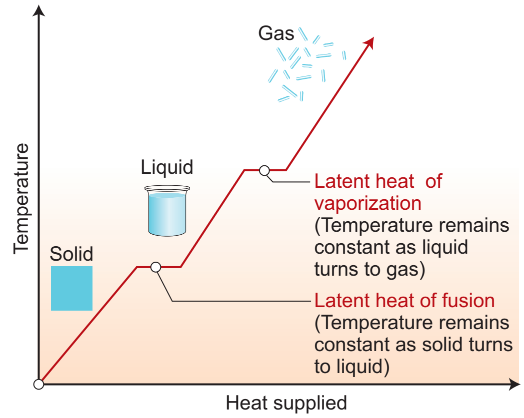

Figure 7.10 Latent heat

Heat energy is absorbed by the solid during melting and an equal amount of heat energy is liberated by the liquid during freezing, without any temperature change. It is called latent heat of fusion. In the same manner, heat energy is absorbed by a liquid during vaporization and an equal amount of heat energy is liberated by the vapor during condensation, without any temperature changes. This is called latent heat of vaporization.

Specific latent heat

Latent heat, when expressed per unit mass of a substance, is called specific latent heat. It is denoted by the symbol L. If Q is the amount of heat energy absorbed or liberated by 'm' mass of a substance during its change of phase at a constant temperature, then specific latent heat is given as L = Q/m.

Thus, specific latent heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change in temperature. The SI unit of specific latent heat is J/kg.

Problem 5

How much heat energy is required to melt 5 kg of ice? (Specific latent heat of ice = 336 Jg^{-1})

Solution:

Given, m = 5 Kg = 5000g, L = 336 Jg^{-1}

Heat energy required = m × L

= 5000 × 336

= 1680000J or 1.68×10^6 J

Problem 6

How much boiling water at 100°C is needed to melt 2 kg of ice so that the mixture which is all water is at 0°C?

[Specific heat capacity of water = 4.2 JKg^{-1} and Specific latent heat of ice = 336 Jg^{-1}].

Solution:

Given, mass of ice = 2 kg = 2000 g.

Let 'm' be the mass of boiling water required.

Heat lost = Heat gained.

$m \times c \times \Delta t = m \times L$

$m \times 4.2 \times (100 - 0) = 2000 \times 336$

$$m = \frac{2000 \times 336}{4.2 \times 100}$$

= 1600 g or 1.6 kg.

Points to Remember

- Heat is transferred from hot region to cold region.
- Heat is transferred in three forms: conduction, convection and radiation.
- Conduction takes place in solids and convection takes place in liquids and gases.
- Radiation takes place in the form of electromagnetic waves.
- There are three scales of temperature: Fahrenheit scale, Celsius or Centigrade scale and Kelvin or Absolute scale.
- Amount of heat energy absorbed or lost by a body is determined by three factors: mass of the body, change in temperature of the body, nature of the material of the body.
- The SI unit of specific heat capacity is $Jkg^{-1} K^{-1}$.
- Among all the substances, water has the highest specific heat capacity.
- SI unit of heat capacity is J/K.
- Depending upon the temperature, pressure and transfer of heat, matter is converted from one state to another.

A-Z GLOSSARY

Conduction	Process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules.
Convection	Flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.
Radiation	Flow of heat from one place to another by means of electromagnetic waves.
Temperature	It is the degree of hotness or coolness of a body.
Specific heat capacity	The amount of heat required to raise the temperature of 1 kg of the substance by 1°C or 1 K.
Heat capacity	The amount of heat energy required to raise the temperature of a body by 1°C.
Melting or fusion	Process in which a solid is converted to liquid by absorbing heat.
Freezing	Process in which a liquid is converted to solid by releasing heat.
Vaporization	Process in which a liquid is converted to vapour by absorbing heat.
Condensation	Process in which a vapor is converted to liquid by releasing heat.
Latent heat	Amount of heat energy absorbed or released by a substance during a change in its physical state without any change in its temperature.
Specific latent heat	Amount of heat energy absorbed or liberated by unit mass of substance during change of state without causing any change in temperature.

TEXT BOOK EXERCISES

I. Choose the correct answer.

1. Calorie is the unit of

a) heat b) work

c) temperature d) food

2. SI unit of temperature is

a) fahrenheit b) joule

c) celsius d) kelvin

3. Two cylindrical rods of same length have the area of cross section in the ratio 2:1. If both the rods are made up of same material, which of them conduct heat faster?
   a) Both rods b) Rod-2
   c) Rod-1 d) None of them
4. In which mode of transfer of heat, molecules pass on heat energy to neighbouring molecules without actually moving from their positions?
   a) Radiation b) Conduction
   c) Convection d) Both B and C
5. A device in which the loss of heat due to conduction, convection and radiation is minimized is
   a) solar cell b) solar cooker
   c) thermometer d) thermos flask

II. Fill in the blanks.

1. The fastest mode of heat transfer is ______.
2. During day time, air blows from ________ to ________.
3. Liquids and gases are generally ________ conductors of heat.
4. The fixed temperature at which matter changes state from solid to liquid is called ________.

III. Assertion and reason type questions.

Mark the correct choice as:

a. If both assertion and reason are true and reason is the correct explanation of assertion.
b. If both assertion and reason are true but reason is not the correct explanation of assertion.
c. If assertion is true but reason is false.
d. If assertion is false but reason is true.

1. **Assertion:** Food can be cooked faster in vessels with copper bottom.

   Reason: Copper is the best conductor of heat.

2. **Assertion:** Maximum sunlight reaches earth's surface during the noon time.

   Reason: Heat from the sun reaches earth's surface by radiation.

3. **Assertion:** When water is heated up to 100°C, there is no raise in temperature until all water gets converted into water vapour.

   Reason: Boiling point of water is 10°C.

IV. Answer briefly.

1. Define conduction.
2. Ice is kept in a double-walled container. Why?
3. How does the water kept in an earthen pot remain cool?
4. Differentiate convection and radiation.
5. Why do people prefer wearing white clothes during summer?
6. What is specific heat capacity?
7. Define thermal capacity.
8. Define specific latent heat capacity.

V. Answer in detail.

1. Explain convection in daily life.
2. What are the changes of state in water? Explain.
3. How can you experimentally prove water is a bad conductor of heat? How is it possible to heat water easily while cooking?

VI. Numerical Problems.

1. What is the heat in joules required to raise the temperature of 25 grams of water from 0 °C to 100 °C? What is the heat in Calories? (Specific heat of water = 4.18 J/g °C) **(Ans. 10450 J)**
2. What could be the final temperature of a mixture of 100 g of water at 90 °C and 600g of water at 20°C. **(Ans. 30°C)**
3. How much heat energy is required to change 2 kg of ice at 0°C into water at 20°C? (Specific latent heat of fusion of water = 3,34,000 J/kg, Specific heat capacity of water = 4200 $JKg^{-1}K^{-1}$). **(Ans. 8,36,000 J)**

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2. Tom Duncon and Heather Kenneth(2017). Cambridge IGCSE Physics, Third edition. Hodder education, London.
3. Goyal R.P., and Tripathi S.P (2016). Concise physics, Selena publishers, New Delhi.
4. Frank New Certificate Physics. Frank Bros & co, Chennai.

INTERNET RESOURCES

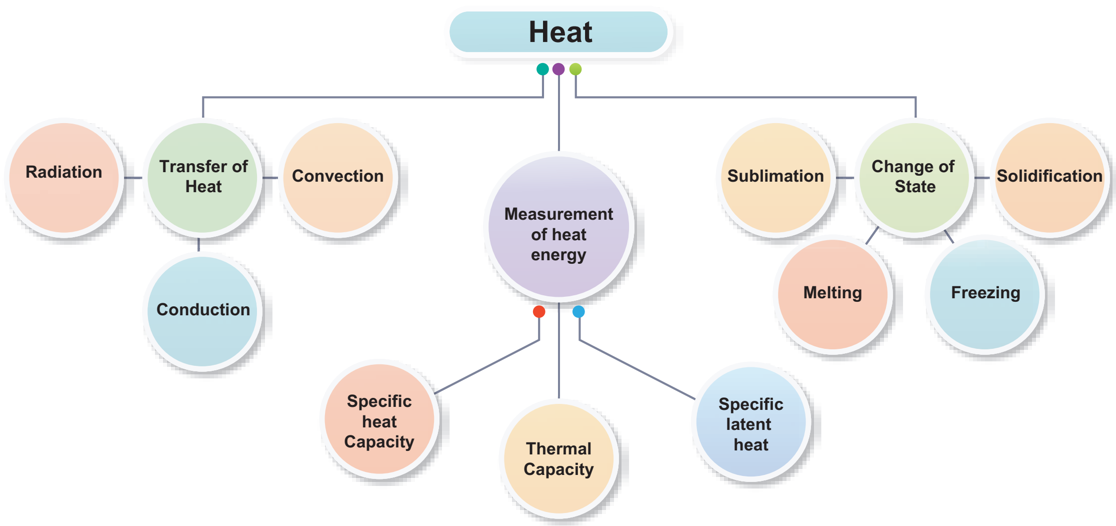
https://betterlession.com

http://www.britannica.com

http://study.com

http://www.sciencelearn.org

Concept Map



ICT CORNER — States of Matter - Effects of Heat changes

Steps

- Copy and paste the link given below or type the URL in the browser. Click the option States.
- You can find Atom & Molecules with four options – Neon, Argon, Oxygen and Water. You can also find Solid, Liquid and Gas options.
- Click any one of the Atoms & Molecules to stimulate by holding the Heat or Cool option under the simulation chamber.
- You can also try the simulation by changing the Solid, Liquid and Gas options too.
- The temperature option can be changed to Fahrenheit or Celsius.

Browse in the link:

URL: https://phet.colorado.edu/sims/html/states-of-matter/latest/states-of-matter_en.html

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*Pictures are indicative only

UNIT 8

SOUND

G9CBRG

Learning Objectives

After completing this lesson, students will be able to

- understand the properties of sound.
- know that sound requires a medium to travel.
- understand that sound waves are longitudinal in nature.
- explain the characteristics of sound.
- gain knowledge about reflection of sound.
- explain ultrasonic sound and understand the applications of ultrasonic sound.

Introduction

Sound is a form of energy which produces sensation of hearing in our ears. Some sounds are pleasant to hear and some others are not. But, all sounds are produced by vibrations of substances. These vibrations travel as disturbances in a medium and reach our ears as sound. Human ear can hear only a particular range of frequency of sound that too with a certain range of energy. We are not able to hear sound clearly if it is below certain intensity. The quality of sound also differs from one another. What are the reasons for all these? It is because sound has several qualities. In this lesson we are going to learn about production and propagation of sound along with its various other characteristics. We will also study about ultrasonic waves and their applications in our daily life.

8.1 Production of Sound

In your daily life you hear different sounds from different sources. But, have you ever thought how sound is produced? To understand the production of sound, let us do an activity.

Activity 1

Take a tuning fork and strike its prongs on a rubber pad. Bring it near your ear. Do you hear any sound? Now touch the tuning fork with your finger. What do you feel? Do you feel vibrations?

When you strike the tuning fork on the rubber pad, it starts vibrating. These vibrations cause the nearby molecules to vibrate. Thus, vibrations produce sound.

8.2 Propagation of Sound Waves

8.2.1 Sound needs a medium for propagation

Sound needs a material medium like air, water, steel etc., for its propagation. It cannot travel through vacuum. This can be demonstrated by the Bell – Jar experiment.

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An electric bell and an airtight glass jar are taken. The electric bell is suspended inside the airtight jar. The jar is connected to a vacuum pump, as shown in Figure 8.1. If the bell is made to ring, we will be able to hear the sound of the bell. Now, when the jar is evacuated with the vacuum pump, the air in the jar is pumped out gradually and the sound becomes feebler and feebler. We will not hear any sound, if the air is fully removed (if the jar has vacuum).

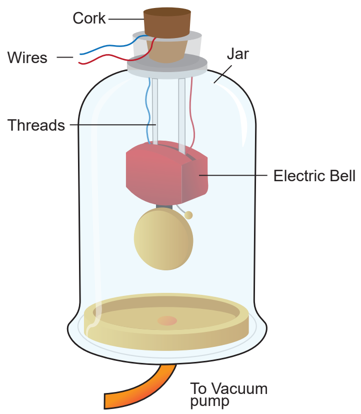

Figure 8.1 Bell-Jar experiment

8.2.2 Sound is a wave

Sound moves from the point of generation to the ear of the listener through a medium. When an object vibrates, it sets the particles of the medium around to vibrate. But, the vibrating particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is displaced from its equilibrium position. It then exerts a force on an adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches our ears. It is to be noted that only the disturbance created by a source of sound travels through the medium not the particles of the medium. All the particles of the medium restrict themselves with only a small to and fro motion called vibration which enables the disturbance to be carried forward. This disturbance which is carried forward in a medium is called wave.

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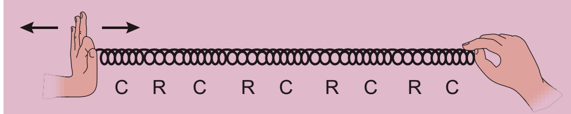
8.2.3 Longitudinal nature of sound waves

Activity 2

Take a coil or spring and move it forward and backward. What do you observe? You can observe that in some parts of the coil the turns will be closer and in some other parts the turns will be far apart. Sound also travels in a medium in the same manner. We will study about this now.



From the above activity you can see that in some parts of the coil, the turns are closer together. These are regions of compressions. In between these regions of compressions we have regions where the coil turns are far apart called rarefactions. As the coil oscillates, the compressions and rarefactions move along the coil. The waves that propagates with compressions and rarefactions are called longitudinal waves. In longitudinal waves the particles of the medium move to and fro along the direction of propagation of the wave.

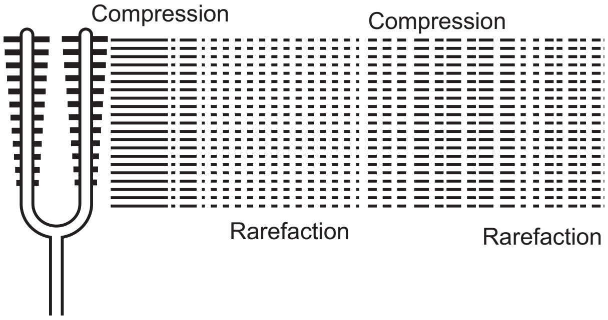


Figure 8.2 Sound is a wave

Sound also is a longitudinal wave. Sound can travel only when there are particles which can be compressed and rarefied. Compressions are the regions where particles are crowded together. Rarefactions are the regions of low pressure where particles are spread apart. A sound wave is an example of a longitudinal mechanical wave. Figure 8.2 represents the longitudinal nature of sound wave in the medium.

8.3 Characteristics of a Sound Wave

Activity 3

Listen to the audio of any musical instrument like *flute, nathaswaram, tabla, drums, veena* etc., Tabulate the differences between the sounds produced by the various sources.

A sound wave can be described completely by five characteristics namely amplitude, frequency, time period, wavelength and velocity or speed.

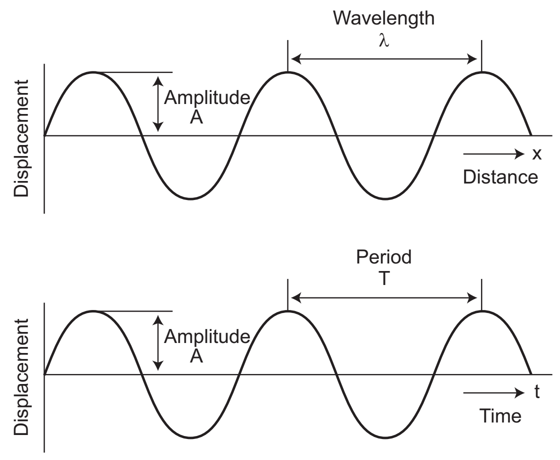


Figure 8.3 Characteristics of sound wave

Amplitude (A)

The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave. If the vibration of a particle has large amplitude, the sound will be loud and if the vibration has small amplitude, the sound will be soft. Amplitude is denoted as A. Its SI unit is meter (m).

Frequency (n)

The number of vibrations (complete waves or cycles) produced in one second is called frequency of the wave. It is denoted as n. The SI unit of frequency is s^{-1} (or) hertz (Hz). Human ear can hear sound of frequency from 20 Hz to 20,000 Hz. Sound with frequency less than 20 Hz is called infrasonic sound. Sound with frequency greater than 20,000 Hz is called ultrasonic sound. Human beings cannot hear infrasonic and ultrasonic sounds.

Time period (T)

The time required to produce one complete vibration (wave or cycle) is called time period of the wave. It is denoted as T. The SI unit of time period is second (s). Frequency and time period are reciprocal to each other ($T = \frac{1}{n}$).

Wavelength (λ)

The minimum distance in which a sound wave repeats itself is called its wavelength. In a sound wave, the distance between the centers of two consecutive compressions or two consecutive rarefactions is also called wavelength. The wavelength is usually denoted as λ (Greek letter, lambda). The SI unit of wavelength is metre (m).

Velocity or speed (v)

The distance travelled by the sound wave in one second is called velocity of the sound. The SI unit of velocity of sound is m s^{-1}.

8.4 Distinguishing different Sounds

Sounds can be distinguished from one another in terms of the following three different factors.

1. Loudness
2. Pitch
3. Timbre (or quality)

1. Loudness and Intensity

Loudness is a quantity by virtue of which a sound can be distinguished from another one, both having the same frequency. Loudness or softness of sound depends on the amplitude

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of the wave. If we strike a table lightly, we hear a soft sound because we produce a sound wave of less amplitude. If we hit the table hard we hear a louder sound. Loud sound can travel a longer distance as loudness is associated with higher energy. A sound wave spreads out from its source. As it move away from the source its amplitude decreases and thus its loudness decreases. Figure 8.4 shows the wave shapes of a soft and loud sound of the same frequency.

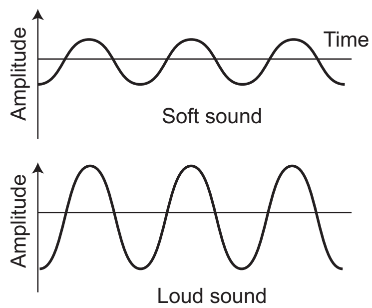

Figure 8.4 Soft and loud sound

The loudness of a sound depends on the intensity of sound wave. Intensity is defined as the amount of energy crossing per unit area per unit time perpendicular to the direction of propagation of the wave.

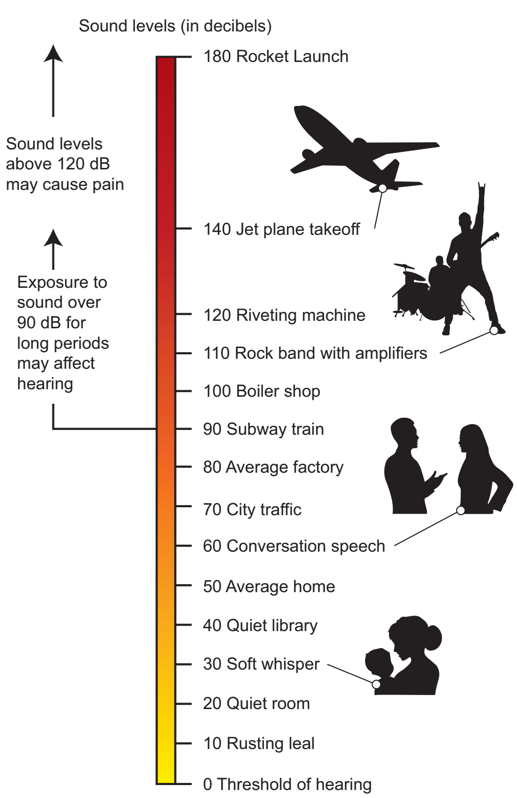

Figure 8.5 Intensity level of sound

The intensity of sound heard at a place depends on the following five factors.

i. Amplitude of the source.
ii. Distance of the observer from the source.
iii. Surface area of the source.
iv. Density of the medium.
v. Frequency of the source.

The unit of intensity of sound is decibel (dB). It is named in honour of the Scottish-born scientist Alexander Graham Bell who invented telephone.

2. Pitch

Pitch is one of the characteristics of sound by which we can distinguish whether a sound is shrill or base. High pitch sound is shrill and low pitch sound is flat. Two music sounds produced by the same instrument with same amplitude, will differ when their vibrations are of different frequencies. Figure 8.6 consists of two waves representing low pitch and high pitch sounds.

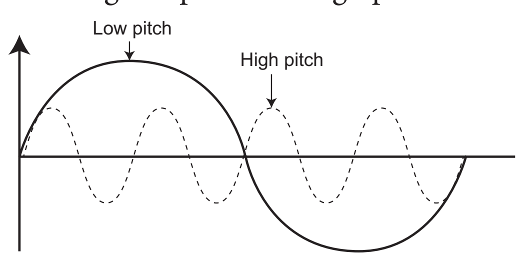

Figure 8.6 Low pitch and high pitch sounds

3. Timbre or Quality

Timbre is the characteristic which distinguishes two sounds of same loudness and pitch emitted by two different instruments. A sound of single frequency is called a tone and a collection of tones is called a note. Timbre is then a general term for the distinguishable characteristics of a tone.

8.5 Speed of Sound

The speed of sound is defined as the distance travelled by a sound wave per unit time as it propagates through an elastic medium.

$$\text{Speed (v)} = \frac{\text{Distance}}{\text{Time}}$$

If the distance traveled by one wave is taken as one wavelength (λ), and the time taken for this propagation is one time period (T), then

$$\text{Speed (v)} = \frac{\text{One wavelength } (\lambda)}{\text{One time period (T)}} \quad \text{(or)} \quad v = \frac{\lambda}{T}$$

As, $T = \frac{1}{n}$, the speed (v) of sound is also written as, $v = n\lambda$.

The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Problem 1

A sound wave has a frequency of 2 kHz and wavelength of 15 cm. How much time will it take to travel 1.5 km?

Solution:

Speed, $v = n\lambda$

Here, n = 2 kHz = 2000Hz

λ = 15 cm = 0.15 m

$v = 0.15 \times 2000 = 300\ m\ s^{-1}$

$$\text{Time (t)} = \frac{\text{Distance (d)}}{\text{Velocity (v)}}$$

$$t = \frac{1500}{300} = 5\ s$$

The sound will take 5 s to travel a distance of 1.5 km.

Problem 2

What is the wavelength of a sound wave in air at 20° C with a frequency of 22 MHz?

Solution:

$\lambda = v/n$

Here, $v = 344\ m\,s^{-1}$.

$n = 22\ MHz = 22 \times 10^6\ Hz$

$\lambda = 344/22 \times 10^6 = 15.64 \times 10^{-6}\ m = 15.64\ \mu m$.

8.5.1 Speed of sound in different media

Sound propagates through a medium at a finite speed. The sound of thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels.

The speed of sound is less in gaseous medium compared to solid medium. In any medium the speed of sound increases if we increase the temperature of the medium. For example the speed of sound in air is 330 $m\,s^{-1}$ at 0 °C and 340 $m\,s^{-1}$ at 25 °C. The speed of sound at a particular temperature in various media is listed in Table 8.1.

Table 8.1 Speed of sound in different media at 25° C.

State	Medium	Speed in $m\,s^{-1}$
Solids	Aluminum	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316
	Sulphur dioxide	213

More to Know

Sonic boom: When the speed of any object exceeds the speed of sound in air (330 $m\,s^{-1}$) it is said to be travelling at supersonic speed. Bullets, jet, aircrafts etc., can travel at supersonic speeds. When an object travels at a speed higher than that of sound in air, it produces shock waves. These shock waves carry a large amount of energy. The air pressure variations associated with this type of shock waves produce a very sharp and loud sound called the 'sonic boom'. The shock waves produced by an aircraft have energy to shatter glass and even damage buildings.

DO YOU KNOW?

Sound travels about 5 times faster in water than in air. Since the speed of sound in sea water is very large (being about 1530 m s^{-1} which is more than 5500 km/h^{-1}), two whales in the sea which are even hundreds of kilometres away can talk to each other very easily through the sea water.

8.6 Reflection of Sound

Sound bounces off a surface of solid or a liquid medium like a rubber ball that bounces off from a wall. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves. The laws of reflection are:

- The angle in which the sound is incident is equal to the angle in which it is reflected.
- Direction of incident sound, the reflected sound and the normal are in the same plane.

8.6.1 Uses of multiple reflections of sound

Musical instruments

Megaphones, loud speakers, horns, musical instruments such as nathaswaram, shehnai and trumpets are all designed to send sound in a particular direction without spreading it in all directions. In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

Figure 8.7 Megaphone or horn

Stethoscope

Stethoscope is a medical instrument used for listening to sounds produced in the body. In stethoscopes, these sounds reach doctor's ears by multiple reflections that happen in the connecting tube.

More to Know

Use of ear phones for long hours can cause infection in the inner parts of the ears, apart from damage to the ear drum. Your safety is in danger if you wear ear phones while crossing signals, walking on the roads and travelling. Using earphones while sleeping is all the more dangerous as current is passing in the wires. It may even lead to mental irritation. Hence, you are advised to deter from using earphones as far as possible.

8.7 Echo

When we shout or clap near a suitable reflecting surface such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1s.

Hence, to hear a distinct echo the time interval between the original sound and the reflected sound must be at least 0.1s. Let us consider the speed of sound to be 340 m s^{-1} at 25° C. The sound must go to the obstacle and return to the ear of the listener on reflection after 0.1 s. The total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 m s^{-1} × 0.1 s = 34 m.

Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance i.e. 17 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple

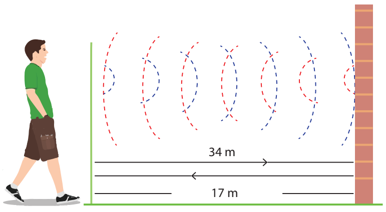

Figure 8.8 Echo

reflections. The roaring of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds at different heights and the land.

Problem 3

A man fires a gun and hears its echo after 5 s. The man then moves 310 m towards the hill and fires his gun again. If he hears the echo after 3 s, calculate the speed of sound.

Solution:

Distance (d) = velocity (v) × time (t)

Distance travelled by sound when gun fires first time, $2d = v \times 5$ (1)

Distance travelled by sound when gun fires second time, $2d - 620 = v \times 3$ (2)

Rewriting equation (2) as,

$2d = (v \times 3) + 620$ (3)

Equating (1) and (3), $5v = 3v + 620$

$2v = 620$

Velocity of sound, $v = 310\ \text{m s}^{-1}$

8.8 Reverberation

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound absorbing materials like compressed fiberboard, flannel cloths, rough plaster and draperies. The seat materials are also selected on the basis of their sound absorbing properties. There is a separate branch in physics called acoustics which takes these aspects of sound in to account while designing auditoria, opera halls, theaters etc.

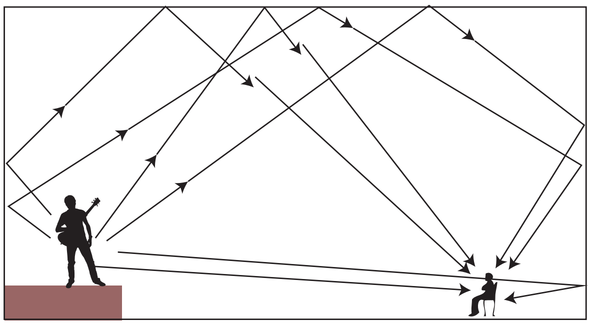

Figure 8.9 Reverberation of sound in a auditorium

8.9 Ultrasonic Sound or Ultrasound

Ultrasonic sound is the term used for sound waves with frequencies greater than 20,000 Hz. These waves cannot be heard by the human ear, but the audible frequency range for other animals includes ultrasound frequencies. For example, dogs can hear ultrasonic sound. Ultrasonic whistles are used in cars to alert deer to oncoming traffic so that they will not leap across the road in front of cars.

An important use of ultrasound is in examining inner parts of the body. The ultrasonic waves allow different tissues such as organs and bones to be 'seen' or distinguished by bouncing of ultrasonic waves by the objects examined. The waves are detected, analysed and stored in a computer. An echogram is an image obtained by the use of reflected ultrasonic waves. It is used as a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

More to Know

Animals, such as bats, dolphins, rats, whales and oil birds, use echolation, an ultrasound technique that uses echoes to identify and locate objects. Echolation allows bats to navigate through dark caves and find insects for food. Dolphins and whales emit a rapid series of underwater clicks in ultrasonic frequencies to locate their prey and navigate through water.

8.9.1 Applications of ultrasonic waves

- Ultrasounds can be used in cleaning technology. Minute foreign particles can be removed from objects placed in a liquid bath through which ultrasound is passed.
- Ultrasounds can also be used to detect cracks and flaws in metal blocks.

- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echo cardiography'.
- Ultrasound may be employed to break small 'stones' formed in the kidney into fine grains. These grains later get flushed out with urine.

8.10 SONAR

SONAR stands for SOund Navigation And Ranging. Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. Sonar consists of a transmitter and a detector and is installed at the bottom of boats and ships.

The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound.

Let the time interval between transmission and reception of ultrasound signal be 't'. Then, the speed of sound through sea water is $2d/t = v$.

Problem 4

A ship sends out ultrasound that returns from the seabed and is detected after 3.42 s. If the speed of ultrasound through sea water is 1531 m s^{-1}, what is the distance of the seabed from the ship?

Solution:

We know, distance = speed × time

2d = speed of ultrasound × time

$$2d = 1531 \times 3.42$$

$$\therefore d = \frac{5236}{2} = 2618\, m$$

Thus, the distance of the seabed from the ship is 2618 m or 2.618 km.

This method is called echo-ranging. Sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarine, icebergs etc.

8.11 Electrocardiogram (ECG)

The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. It can provide a wealth of useful information and remains an essential part of the assessment of cardiac patients. In ECG, the sound variation produced by heart is converted into electric signals. Thus, an ECG is simply a representation of the electrical activity of the heart muscle as it changes with time. Usually it is printed on paper for easy analysis. The sum of this electrical activity, when amplified and recorded for just a few seconds is known as an ECG.

8.12 Structure of Human Ear

How do we hear? We are able to hear with the help of an extremely sensitive device called the ear. It allows us to convert pressure variations in air with audible frequencies into electric signals that travel to the brain via the auditory nerve. The auditory aspect of human ear is discussed below.

The outer ear is called 'pinna'. It collects the sound from the surroundings. The collected sound passes through the auditory canal. At the end of the ear is eardrum or tympanic membrane. When a compression of the medium reaches the eardrum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches it. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are

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sent to the brain via the auditory nerve and the brain interrupts them as sound.

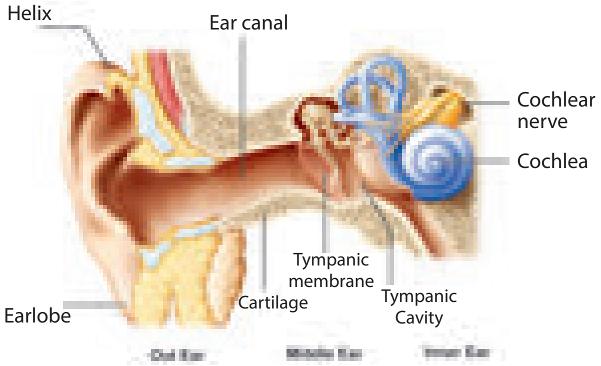


Figure 8.10 Human ear

Points to Remember

- Sound is produced due to vibration.
- Sound cannot travel through vacuum.
- Sound travels as a longitudinal wave through a material medium.
- Sound travels as successive compressions and rarefactions in the medium.
- In sound propagation, it is the energy of the sound that travels and not the particles of the medium.
- The speed (v), frequency (n), and wavelength (λ), of sound are related by the equation, $v = n\lambda$.
- The law of reflection of sound: (i) The angle of incidence, the angle of reflection and normal drawn at the point of incidence all lie in the same plane (ii) The angle of incidence (i) and the angle of reflection (r) are always equal.
- The speed of sound depends primarily on the nature and the temperature of the transmitting medium.
- For hearing distinct echo sound, the time interval between the original sound and the reflected sound must be at least 0.1 s.
- The persistence of hearing sound in an auditorium is the result of repeated reflections of sound and is called reverberation.
- The amount of sound energy passing each second through unit area is called the intensity of sound.
- The audible range of hearing for average human being is in the frequency range of 20 Hz to 20000 Hz
- Sound waves with frequencies below audible range are termed as 'Infrasonics' and those above audible range are termed as 'Ultrasonics'.
- The SONAR technique is used to determine the depth of the sea and to locate under water hills, valleys, submarines, icebergs, etc.

A-Z GLOSSARY

Amplitude	The maximum displacement of a particle.
Compressions	The region of increased pressure.
Echo	The repetition of sound caused by the reflection of sound.
Frequency	Number of waves produced in one second.
Longitudinal wave	The wave that propagates with compressions and rarefactions.
Pitch	Characteristics of sound based on frequency.
Rarefactions	The region of decreased pressure.
Reverberation	The repeated reflection that results in persistence of sound is called reverberation.
Timbre (or quality)	Characteristic which distinguishes the two sounds of same loudness and pitch emitted by two different instruments.
Time period	Time taken to produce one wave.
Ultrasonic sound	Sound waves with frequencies greater than 20,000 Hz.
Wave	The propagating disturbance that travels in a medium.
Wavelength	The minimum distance in which a sound wave repeats itself.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. Which of the following vibrates when a musical note is produced by the cymbals in a orchestra?
   a) stretched strings
   b) stretched membranes
   c) air columns
   d) metal plates
2. Sound travels in air:
   a) if there is no moisture in the atmosphere.
   b) if particles of medium travel from one place to another.
   c) if both particles as well as disturbance move from one place to another.
   d) if disturbance moves.
3. A musical instrument is producing continuous note. This note cannot be heard by a person having a normal hearing range. This note must then be passing through
   a) wax   b) vacuum
   c) water   d) empty vessel
4. The maximum speed of vibrations which produces audible sound will be in
   a) sea water   b) ground glass
   b) dry air   d) human blood
5. The sound waves travel faster
   a) in liquids   b) in gases
   c) in solids   d) in vacuum

II. Fill in the blanks.

1. Sound is a ____________ wave and needs a material medium to travel.
2. Number of vibrations produced in one second is ____________ .
3. The velocity of sound in solid is ____________ than the velocity of sound in air.
4. Vibration of object produces _________ .
5. Loudness is proportional to the square of the ____________ .
6. ____________ is a medical instrument used for listening to sounds produced in the body.
7. The repeated reflection that results in persistence of sound is called ____________ .

III. Match the following.

Tuning fork	The point where density of air is maximum.
Sound	Maximum displacement from the equilibrium position.
Compressions	The sound whose frequency is greater than 20,000 Hz.
Amplitude	Longitudinal wave.
Ultasonics	Production of sound.

IV. Answer briefly.

1. Through which medium sound travels faster, iron or water? Give reason.
2. Name the physical quantity whose SI unit is 'hertz'. Define.
3. What is meant by supersonic speed?
4. How does the sound produced by a vibrating object in a medium reach your ears?
5. You and your friend are on the moon. Will you be able to hear any sound produced by your friend?

V. Answer in detail.

1. Describe with diagram, how compressions and rarefactions are produced.
2. Verify experimentally the laws reflection of sound.
3. List the applications of sound.
4. Explain how does SONAR work?

VI. Numerical problems.

1. The frequency of a source of sound is 600 Hz. Calculate the numbner of times it vibrates in a minute?
2. A stone is dropped from the top of a tower 750 m high into a pond of water at the base of the tower. Calculate the number of seconds for the splash to be heard?
(Given g = 10 m s^{-2} and speed of sound = 340 m s^{-1})

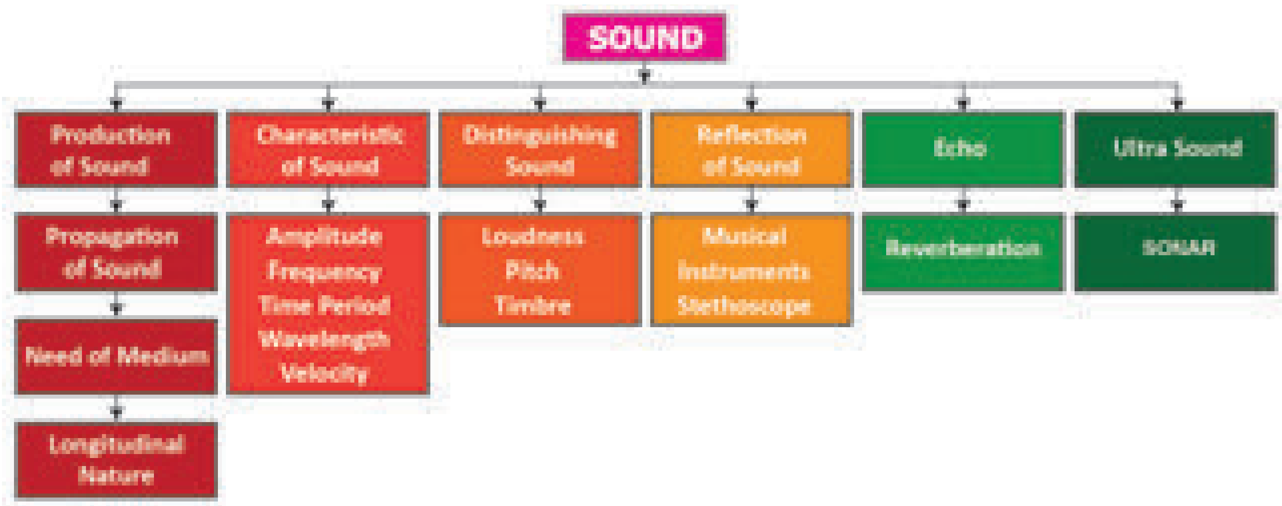
REFERENCE BOOKS

1. Applied Physics – Rajasekaran S and others – Vikas Publishing House Pvt Ltd.
2. Fundamentals of Physics – Halliday, Resnick and Walker, Wiley India Pvt Ltd. NewDelhi.

INTERNET RESOURCES

www.britannica.com/science/ultrasonics
https://www.searchencrypt.com
https://www.soundwaves.com/

Concept Map



ICT CORNER

Sound

Steps

- Type the given URL to reach "pHET Simulation" page and download the "java" file of Sound.
- Open the "java" file and plug in your headphone. Click "Audio enabled" box from right side to hear the sound waves.
- Switch the tabs from the top to simulate various properties of sound waves. Watch the longitudinal sound waves from different interfaces by altering "Frequency" and "Amplitude".
- Alter "Air Density" and observe its effect on the sound waves. Use "Reset" to repeat the experiment.

Sound Simulator

URL: https://phet.colorado.edu/en/simulation/legacy/sound or Scan the QR Code.

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UNIT 9

UNIVERSE

G9V3UR

Learning Objectives

After completing this lesson, students will be able to

- know the evolution of the universe.
- understand the building blocks of the universe.
- know more about solar system.
- know Kepler's laws of motion.
- calculate the orbital velocity and the time-period of satellites.
- know about International Space Station.

Introduction

In the earlier days, before the invention of astronomical instruments, people thought that Earth is the centre of all the objects in the space. This was known as the geocentric model, held by Greek astronomer Ptolemy (2nd Century), Indian astronomer Aryabhatta (5th Century) and many astronomers around the world. Later Polish astronomer Nicolaus Copernicus proposed the heliocentric model (helios = Sun), with Sun at the centre of the solar system. Invention of the telescope in the Netherlands, in 1608, created a revolution in astronomy. In this lesson, we will study about the building blocks of the universe, Kepler's laws of motion, time period of satellites and International Space Station (ISS).

9.1 Building block of the Universe

The basic constituent of the universe is luminous matter i.e., galaxies which are really the collection of billions of stars. The universe contains everything that exists including the Earth, planets, stars, space, and galaxies. This includes all matter, energy and even time. No one knows how big the universe is. It could be infinitely large. Scientists, however, measure the size of the universe by what they can see. This is called the 'observable universe'. The observable universe is around 93 billion light years (1 light year = the distance that light travels in one year, which is 9.4607×10^{12} km) across.

One of the interesting things about the universe is that it is currently expanding. It is growing larger and larger all the time. Not only is it growing larger, but the edge of the universe is expanding at a faster and faster rate. However, most of the universe what we think of is empty space. All the atoms together only make up around four percent of the universe. The majority of the universe consists of something scientists call dark matter and dark energy.

Activity 1

Form a team of three to four students. Prepare a poster about the astronomers.

9.1.1 Age of the Universe

Scientists think that the universe began with the start of a massive explosion called the Big Bang. According to Big Bang theory, all the matter in the universe was concentrated in a single point of hot dense matter. About 13.7 billion years ago, an explosion occurred and all the matter were ejected in all directions in the form of galaxies. Nearly all of the matter in the universe that we understand is made of hydrogen and helium, the simplest elements, created in the Big Bang. The rest, including the oxygen, the carbon, calcium, and iron, and silicon are formed in the cores of stars. The gravity that holds these stars together generally keeps these elements deep inside their interiors. When these stars explode, these fundamental building blocks of planetary systems are liberated throughout the universe.

9.1.2 Galaxies

Immediately after the Big Bang, clouds of gases began to compress under gravity to form the building blocks of galaxies. A galaxy is a massive collection of gas, dust, and billions of stars and their solar systems. Scientists believe that there are one hundred billion (10^{11}) galaxies in the observable universe. Galaxies are also in different shapes. Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular. Galaxies occur alone or in pairs, but they are more often parts of groups, clusters, and super clusters. Galaxies in such groups often interact and even merge together.

Our Sun and all the planets in the solar system are in the Milky Way galaxy. There are many galaxies besides our Milky Way. Andromeda galaxy is our closest neighboring galaxy. The Milky Way galaxy is spiral in shape.

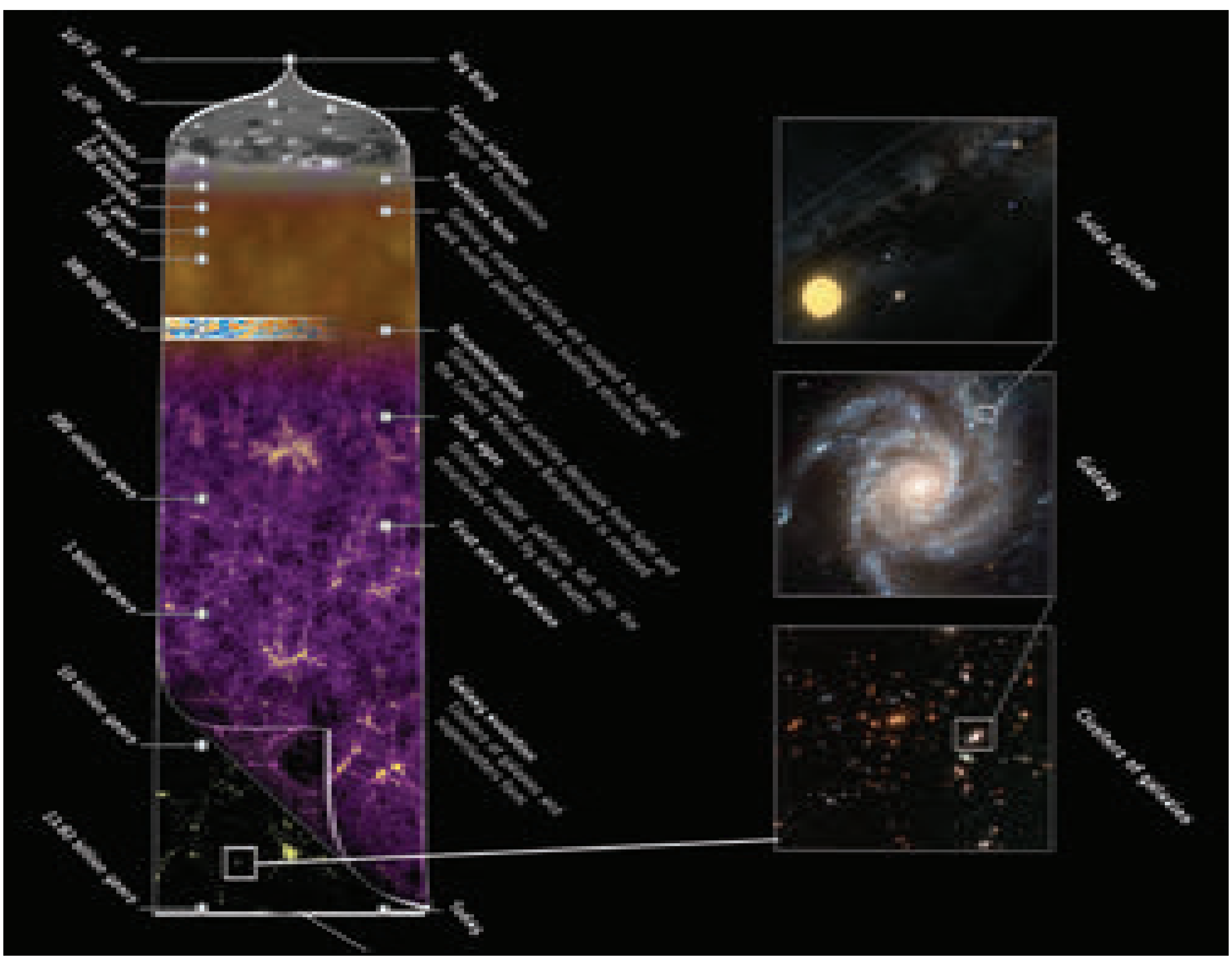

Figure 9.1 Formation of the universe

It is called Milky Way because it appears as a milky band of light in the sky. It is made up of approximately 100 billion stars and its diameter is 1,00,000 light years. Our solar system is 25,000 light years away from the centre of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the centre of the galaxy and it takes 250 million years to do that.

Figure 9.2 Milky Way Galaxy

> **DO YOU KNOW?** The distance of Andromeda, our nearest galaxy is approximately 2.5 million light-years. If we move at the speed of the Earth (30 km/s), it would take us 25 billion years to reach it!

9.1.3 Stars

Stars are the fundamental building blocks of galaxies. Stars were formed when the galaxies were formed during the Big Bang. Stars produce heat, light, ultraviolet rays, x-rays, and other forms of radiation. They are largely composed of gas and plasma (a superheated state of matter). Stars are built by hydrogen gases. Hydrogen atoms fuse together to form helium atoms and in the process they produce large amount of heat. In a dark night we can see nearly 3,000 stars with the naked eye. We don't know how many stars exist. Our universe contains more than 100 billion galaxies, and each of those galaxies may have more than 100 billion stars.

Though the stars appear to be alone, most of the stars exist as pairs. The brightness of a star depends on their intensity and the distance from the Earth. Stars also appear to be in different colours depending on their temperature. Hot stars are white or blue, whereas cooler stars are orange or red in colour. They also occur in many sizes.

A group of stars forms an imaginary outline or meaningful pattern on the space. They represent an animal, mythological person or creature, a god, or an object. This group of stars is called constellations. People in different cultures and countries adopted their own sets of constellation outlines. There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

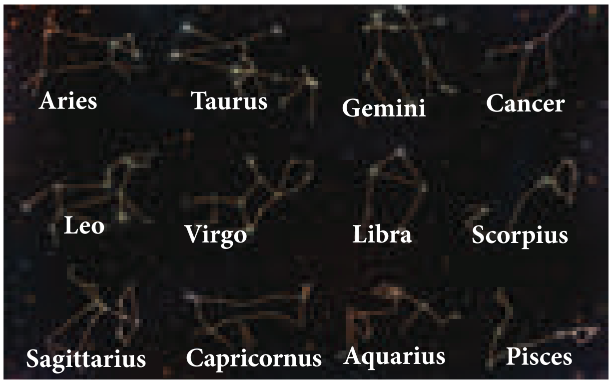

Figure 9.3 Constellations

> **Activity 2**
>
> Observe the sky keenly during night. Can you see group of stars? Can you figure out any shape? Discuss with your teachers and find out their name.

9.2 The Solar System

Sun and the celestial bodies which revolve around it form the solar system. It consists of large number of bodies such as planets, comets, asteroids and meteors. The gravitational force of attraction between the Sun and these objects keep them revolving around it.

9.2.1 The Sun

The Sun is a medium sized star, a very fiery spinning ball of hot gases. Three quarters of the

Sun has hydrogen gas and one quarter has helium gas. It is over a million times as big as the Earth. Hydrogen atoms combine or fuse together to form helium under enormous pressure. This process, called nuclear fusion releases enormous amount of energy as light and heat. It is this energy which makes Sun shine and provide heat. Sun is situated at the centre of the solar system. The strong gravitational fields cause other solar matter, mainly planets, asteroids, comets, meteoroids and other debris, to orbit around it. Sun is believed to be more than 4.6 billion years old.

Formation of the Sun

At the time of the Big Bang, hydrogen gas condensed to form huge clouds, which later concentrated and formed the numerous galaxies. Some of the hydrogen gas was left free and started floating around in our galaxy. With time, due to some changes, this free-floating hydrogen gas concentrated and paved way for the formation of the Sun and solar system. Gradually, the Sun and the solar system turned into a slowly spinning molecular cloud, composed of hydrogen and helium along with dust. The cloud started to undergo the process of compression, as a result of its own gravity. Its excessive and high-speed spinning ultimately resulted in its flattening into a giant disc.

9.2.2 Planets

A planet revolves around the Sun along a definite curved path which is called an orbit. It is elliptical. The time taken by a planet to complete one revolution is called its period of revolution.

Besides revolving around the Sun, a planet also rotates on its own axis like a top. The time taken by a planet to complete one rotation is called its period of rotation. The period of rotation of the Earth is 23 hours and 56 minutes and so the length of a day on Earth is taken as 24 hours. Table 9.1 tells about the length of a day on each planet.

Table 9.1 Length of a day on each planet

Planets	Length of a day
Mercury	58.65 days
Venus	243 days
Earth	23.93 hours
Mars	24.62 hours
Jupiter	9.92 hours
Saturn	10.23 hours
Uranus	17 hours
Neptune	18 hours

The planets are spaced unevenly. The first four planets are relatively close together and close to the Sun. They form the inner solar system. Farther from the Sun is the outer solar system, where the planets are much more spread out. Thus the distance between Saturn and Uranus is much greater (about 20 times) than the distance between the Earth and the Mars.

The four planets grouped together in the inner solar system are Mercury, Venus, Earth and Mars. They are called inner planets. They have a surface of solid rock crust and so are called terrestrial or rocky planets. Their insides, surfaces and atmospheres are formed in a similar way and form similar pattern. Our planet, Earth can be taken as a model of the other three planets.

The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system and slowly orbit the Sun are called outer planets. They are made of hydrogen, helium and other gases in huge amounts and have very dense atmosphere. They are known as gas giants and are called gaseous planets. The four outer planets Jupiter, Saturn, Uranus and Neptune have rings whereas the four inner planets do not have any rings. The rings are actually tiny pieces of rock covered with ice. Now let us learn about each planet in the solar system.

Mercury: Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. Mercury can be easily observed thorough telescope than naked eye since it is very faint and small. It always appears in the eastern horizon or western horizon of the sky.

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Venus: Venus is a special planet from the Sun, almost the same size as the Earth. It is the hottest planet in our solar system. After our moon, it is the brightest heavenly body in our night sky. This planet spins in the opposite direction to all other planets. So, unlike Earth, the Sun rises in the west and sets in the east here. Venus can be seen clearly through naked eye. It always appears in the horizon of eastern or western sky.

Activity 3

Watch the sky in the early morning. Do you see any planet? What is its name? Find out with the help of your teacher.

The Earth: The Earth where we live is the only planet in the solar system which supports life. Due to its right distance from the Sun it has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone. All these have made continuation of life possible on the Earth. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

Mars: The first planet outside the orbit of the Earth is Mars. It appears slightly reddish and therefore it is also called the red planet. It has two small natural satellites (Deimos and Phobos).

Jupiter: Jupiter is called as Giant planet. It is the largest of all planets (about 11 times larger and 318 times heavier than Earth). It has 3 rings and 65 moons. Its moon Ganymede is the largest moon of our solar system.

Saturn: Known for its bright shiny rings, Saturn appears yellowish in colour. It is the second biggest and a giant gas planet in the outer solar system. At least 60 moons are present - the largest being Titan. Titan is the only moon in the solar system with clouds. Having least density of all (30 times less than Earth), this planet is so light.

Uranus: Uranus is a cold gas giant and it can be seen only with the help of large telescope. It has a greatly tilted axis of rotation. As a result, in its orbital motion it appears to roll on its side. Due to its peculiar tilt, it has the longest summers and winters each lasting 42 years.

Neptune: It appears as Greenish star. It is the eighth planet from the Sun and is the windiest planet. Every 248 years, Pluto crosses its orbit. This situation continues for 20 years. It has 13 moons – Triton being the largest. Triton is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.

9.2.3 Other Bodies of the Solar System

Besides the eight planets, there are some other bodies which revolve around the Sun. They are also members of the solar system.

Asteroids

There is a large gap in between the orbits of Mars and Jupiter. This gap is occupied by a broad belt containing about half a million pieces of rocks that were left over when the planets were formed and now revolve around the Sun. These are called asteroids. The biggest asteroid is Ceres – 946 km across. Every 50 million years, the Earth is hit by an asteroid nearing 10 km across. Asteroids can only be seen through large telescope.

Comets

Comets are lumps of dust and ice that revolve around the Sun in highly elliptical orbits. Their period of revolution is very long. When approaching the Sun, a comet vaporizes and forms a head and tail. Some of the biggest comets ever seen had tails 160 million (16 crores) km long. This is more than the distance between the Earth and the Sun. Many comets are known to appear periodically. One such comet is Halley's Comet, which appears after nearly every 76 years. It was last seen in 1986. It will next be seen in 2062.

Meteors and Meteorites

Meteors are small piece of rocks scattered throughout the solar system. Traveling with high speed, these small pieces come closer to the Earth's atmosphere and are attracted by the gravitational force of Earth. Most of them are burnt up by the heat generated due to friction in the Earth's atmosphere. They are called meteors. Some of the bigger meteors may not be burnt completely and they fall on the surface of Earth. These are called meteorites.

Figure 9.4 Meteors and Meteorites

Satellites

A body moving in an orbit around a planet is called satellite. In order to distinguish them from the man made satellites (called as artificial satellites), they are called as natural satellites or moons. Satellite of the Earth is called Moon (other satellites are written as moon). We can see the Earth's satellite Moon, because it reflects the light of the Sun. Satellite moves around the planets due to gravity, and the centripetal force. Among the planets in the solar system all the planets have moons except Mercury and Venus.

GA4YHE

> **DO YOU KNOW?** The Sun travelling at a speed of 250 km per second (9 lakh km/h) takes about 225 million years to complete one revolution around the Milky Way. This period is called a cosmic year.

9.3 Orbital Velocity

We saw that there are natural satellites moving around the planets. There will be gravitational force between the planet and satellites. Nowadays many artificial satellites are launched into the Earth's orbit. The first artificial satellite Sputnik was launched in 1956. India launched its first satellite Aryabhatta on April 19, 1975. Artificial satellites are made to revolve in an orbit at a height of few hundred kilometres. At this altitude, the friction due to air is negligible. The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit.

The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called orbital velocity.

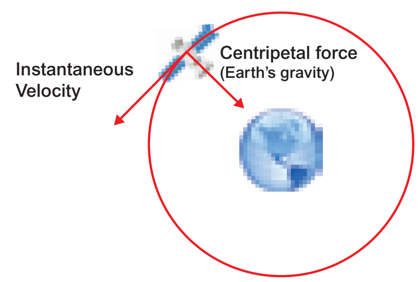

Figure 9.5 Orbital velocity

The orbital velocity of the satellite depends on its altitude above Earth. Nearer the object to the Earth, the faster is the required orbital velocity. At an altitude of 200 kilometres, the required orbital velocity is little more than 27,400 kph. That orbital speed and distance permit the satellite to make one revolution in 24 hours. Since Earth also rotates once in 24 hours, a satellite stays in a fixed position relative to a point on Earth's surface. Because the satellite stays over the same spot all the time, this kind of orbit is called 'geostationary'. Orbital velocity can be calculated using the following formula.

$$v = \sqrt{\frac{GM}{(R+h)}}$$ where,

G = Gravitational constant (6.673×10^{-11} Nm^2kg^{-2})

M = Mass of the Earth (5.972×10^{24} kg)

R = Radius of the Earth (6371 km)

h = Height of the satellite from the surface of the Earth.

Problem 1

Can you calculate the orbital velocity of a satellite orbiting at an altitude of 500 km?

Data: G = 6.673×10^{-11} SI units;

M = 5.972×10^{24} kg; R = 6371000 m;

h = 500000 m.

Solution:

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.972 \times 10^{24}}{(6371000 + 500000)}}$$

Ans: $v = 7613$ ms^{-1} or 7.613 kms^{-1}

DO YOU KNOW?

Microgravity is the condition in which people or objects appear to be weightless. The effects of microgravity can be seen when astronauts and objects float in space. Micro- means very small, so microgravity refers to the condition where gravity 'seems' to be very small.

9.4 Time period of a Satellite

Time taken by a satellite to complete one revolution round the Earth is called time period.

$$\text{Time period, } T = \frac{\text{Distance covered}}{\text{Orbital velocity}}$$

$$T = \frac{2\pi r}{v}$$

Substituting the value of v, we get

$$T = \frac{2\pi(R+h)}{\sqrt{\frac{GM}{(R+h)}}}\ .$$

Problem 2

At an orbital height of 500 km, find the orbital period of the satellite.

Solution:

$h = 500 \times 10^3$m, $R = 6371 \times 10^3$m,

$v = 7616 \times 10^3$ kms^{-1}.

$$T = \frac{2\pi(R+h)}{v} = 2 \times \frac{22}{7} \times \frac{(6371+500)}{7616}$$

$= 5.6677 \times 10^3$s = 5667 s.

This is $T \approx 95$ min

DO YOU KNOW?

All stars appear to us as moving from east to west, where as there is one star which appears to us stationary in its position. It has been named as Pole star. The pole star appears to us as fixed in space at the same place in the sky in the north direction because it lies on the axis of rotation of the Earth which itself is fixed and does not change its position in space. It may be noted that the pole star is not visible from the southern hemisphere.

Activity 4

Prepare a list of Indian satellites from Aryabhatta to the latest along with their purposes.

9.5 Kepler's Laws

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor, Tycho Brahe with three statements that described the motion of planets in a Sun-centered solar system. Kepler's efforts to explain the underlying reasons for such motions are no longer accepted; nonetheless, the actual laws themselves are still considered an accurate description of the motion of any planet and any satellite. Kepler's three laws of planetary motion can be described as below.

First Law – The Law of Ellipses

All planets revolve around the Sun in elliptical orbits with Sun at one of their foci.

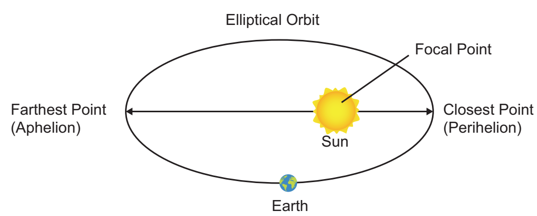

Figure 9.6 The Law of Ellipses

Second Law – The Law of Equal Areas

The line connecting the planet and the Sun covers equal areas in equal intervals of time.

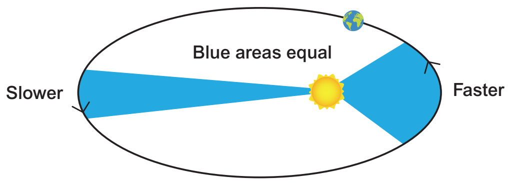

Figure 9.7 The Law of Equal Area

Third Law – The Law of Harmonies

The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the distance between sun and the planets.

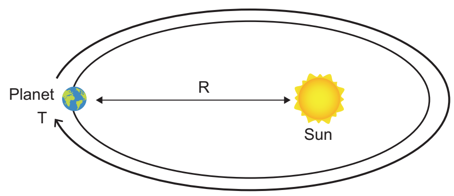

Figure 9.8 The Law of Harmonics

9.6 International Space Station

ISS is a large spacecraft which can house astronauts. It goes around in low Earth orbit at approximately 400 km distance. It is also a science laboratory. Its very first part was placed in orbit in 1998 and its core construction was completed by 2011. It is the largest man-made object in space which can also be seen from the Earth through the naked eye. The first human crew went to the ISS in 2000. Ever since that, it has never been unoccupied by humans. At any given instant, at least six humans will be present in the ISS. According to the current plan, ISS will be operated until 2024, with a possible extension until 2028. After that, it could be deorbited, or recycled for future space stations.

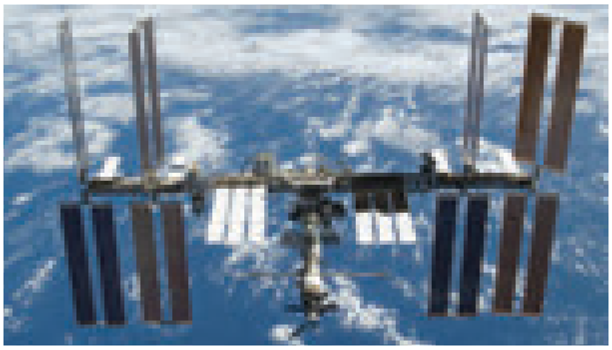

Figure 9.9 International Space Station

9.6.1 Benefits of ISS

According to NASA, the following are some of the ways in which the ISS is already benefitting us or will benefit us in the future.

Supporting water-purification efforts

Using the technology developed for the ISS, areas having water scarcity can gain access to advanced water filtration and purification systems. The water recovery system (WRS) and the oxygen generation system (OGS) developed for the ISS have already saved a village in Iraq from being deserted due to lack of clean water.

Eye tracking technology

The Eye Tracking Device, built for a microgravity experiment, has proved ideal to be used in many laser surgeries. Also, eye tracking technology is helping disabled people with limited movement and speech. For example, a kid who has severe disability in body movements can use his eye-movements alone and do routine tasks and lead an independent life.

Robotic arms and surgeries

Robotic arms developed for research in the ISS are providing significant help to the surgeons in removing inoperable tumours (e.g., brain tumours) and taking biopsies with great accuracies. Its inventors say that the robot could take biopsies with remarkable precision and consistency.

Apart from the above-mentioned applications, there are many other ways in which the researches that take place in the ISS are helpful. They are: development of improved vaccines, breast cancer detection and treatment, ultrasound machines for remote regions etc,.

9.6.2 ISS and International Cooperation

As great as the ISS' scientific achievements are, no less in accomplishment is the international co-operation which resulted in the construction of the ISS. An international collaboration of five different space agencies of 16 countries provides, maintains and operates the ISS. They are: NASA (USA), Roskosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Cananda). Belgium, Brazil, Denmark, France, Germany, Italy, Holland, Norway, Spain, Sweden, Switzerland and the UK are also part of the consortium.

Points to Remember

- The basic constituent of universe is galaxies which are really the collection of billions of stars.
- Scientists think that the universe began with the start of a massive explosion called the Big Bang.
- Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular.
- Our Sun and all the planets in the solar system are in the Milky Way galaxy.
- A group of stars forms an imaginary outline or meaningful pattern on the space, called constellations.
- The Sun and celestial bodies which revolve around it form the solar system.
- Due to its right distance from the Sun, Earth has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone.
- Millions of pieces of rocks that were left over when the planets were formed and now revolve around the Sun are called asteroids.
- A body moving in an orbit around a planet is called satellite.
- The ISS is intended to act as a scientific laboratory and observatory. Its main purpose is to provide an international lab for conducting experiments in space.

A-Z GLOSSARY

Asteroid	Small, rocky object orbiting the Sun.
Comet	A chunk of dirty, dark ice, mixed with dust which revolves around the Sun.
Constellation	A group of stars that can be seen as a pattern from Earth.
Galaxy	A group of stars, nebulae, star clusters, globular clusters and other matter.
Meteor	A meteoroid that travels through the Earth's atmosphere.
Meteorite	A meteor that hits the Earth's surface.
Milky Way	A broad band of light that looks like a trail of spilled milk in the night sky.
Moon	Any natural object which orbits a planet.
Planet	A relatively large object that revolves around a star, but which is not itself a star.
Satellite	Any object in outer space that orbits another object.
Space station	A large, manned satellite in space used as a base for space exploration.
Star	A ball of constantly exploding gases, giving off light and heat.
Universe	Everything in space, including the galaxies and stars, the Milky Way and the Solar System.

TEXTBOOK EXERCISES

GADUY2

I. Choose the correct answer.

1. Who proposed the heliocentric model of the universe?
   (a) Tycho Brahe (b) Nicolaus Copernicus
   (c) Ptolemy (d) Archimedes
2. Which of the following is not a part of outer solar system?
   (a) Mercury (b) Saturn
   (c) Uranus (d) Neptune
3. Ceres is a _______.
   (a) Meteor (b) Star
   (c) Planet (d) Astroid
4. The period of revolution of planet A around the Sun is 8 times that of planet B. How many times is the distance of planet A as great as that of planet B?
   (a) 4 (b) 5 (c) 2 (d) 3
5. The Big Bang occurred _____ years ago.
   (a) 13.7 billion (b) 15 million
   (c) 15 billion (d) 20 million

II. Fill in the blanks.

1. The speed of Sun in km/s is _______.
2. The rotational period of the Sun near its poles is ________.
3. India's first satellite is _______.
4. The third law of Kepler is also known as the Law of ________.
5. The number of planets in our Solar System is _______.

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

1. ISS is a proof for international cooperation.
2. Halley's comet appears after nearly 67 hours.
3. Satellites nearer to the Earth should have lesser orbital velocity.
4. Mars is called the red planet.

IV. Answer briefly.

1. What is solar system?
2. Define orbital velocity.
3. Define time period of a satellite.
4. What is a satellite? What are the two types of satellites?
5. Write a note on the inner planets.
6. Write about comets.
7. State Kepler's laws.
8. What factors have made life on Earth possible?

V. Answer in detail.

1. Give an account of all the planets in the solar system.
2. Discuss the benefits of ISS.
3. Write a note on orbital velocity.

VI. Conceptual questions.

1. Why do some stars appear blue and some red?
2. How is a satellite maintained in nearly circular orbit?
3. Why are some satellites called geostationary?
4. A man weighing 60 kg in the Earth will weigh 1680 kg in the Sun. Why?

VII. Numerical problems.

1. Calculate the speed with which a satellite moves if it is at a height of 36,000 km from the Earth's surface and has an orbital period of 24 hr (Take R = 6370 km)
   [Hint: Convert hr into seconds before doing calculation]
2. At an orbital height of 400 km, find the orbital period of the satellite.

REFERENCE BOOKS

1. Big Bang - By Simon Singh.
2. What are the stars? - By G. Srinivas.
3. An introduction to Astronomy - By Baidyanath Basu.

INTERNET RESOURCES

https://www.space.com/52-the-expanding-universe-from-the-big-bang-to-today.html

https://phys.org/news/2016-06-star-black-hole.html

ICT CORNER

Building Blocks of Universe

Steps

- Type the given URL to reach interactive universe and allow the browser to play “JAVA Script”, if asked.
- Click and drag the “Scale Pointer” present in the right side of the page or scroll the mouse to zoom into the universe.
- Click and drag the mouse pointer to North-South (up-down) axis to observe the fabricating structure of the galaxy.
- Zoom in on to extreme close up to view the solar system and to view the name of the objects present in the galaxy.

Interactive Universe’s

URL: http://stars.chromeexperiments.com/ or Scan the QR Code.

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