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PHYSICS

2

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7th Edition

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PREFACE

Some students think that physics is too difficult a discipline to learn. This is due to a lack of discussion and demonstrations of the present day uses and practical applications of physics concepts, theories and equations.

This leaves the pupil with lack of enthusiasm, and the impression that physics has more to do with the world of the mind rather than what it really is a science. Science is a discipline, which is based in the real physical world and its foundation is practical applications and data from the physical world.

We have tried to explain the concepts in this book in the most understandable way and have taken advantage of the natural ability of young people to instantly and intuitively grasp concepts through graphics. Full colored figures and photographs support the explanations.

This book explains the phenomena related to 2nd intermediate year subjects.

This book aims to improve the level of understanding of modern physics by inclusion of the following; subjects, figures and illustrations, extensive questions and articles in an enjoyable way.

I'm grateful to all the people who have helped with this book. My special thanks to my family for their patient, support and constant encouragement.

The Authors

CONTENTS

CHAPTER 1
MEASUREMENT

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Understand measurement.
2. Describe events.
3. Compare between precision and accuracy.
4. Define the System International units.
5. Understand prefix

MEASUREMENTS

Description and Measurement

Measurement

How would you describe what you are wearing today? You might start with the colors of your outfit, and perhaps you would even describe the style. Then you might mention sizes— size 39 shoes, size 14 shirt. Every day you are surrounded by numbers. Measurement is a way to describe the world with numbers. It answers questions such as how much, how long, or how far. Measurement can describe the amount of milk in a carton, the cost of a new compact disc, or the distance between your home and your school. It also can describe the volume of water in a swimming pool, the mass of an atom, or how fast a penguin's heart pumps blood.

There are some devices that measures quantities which are used in everyday life;

Measurment Tools

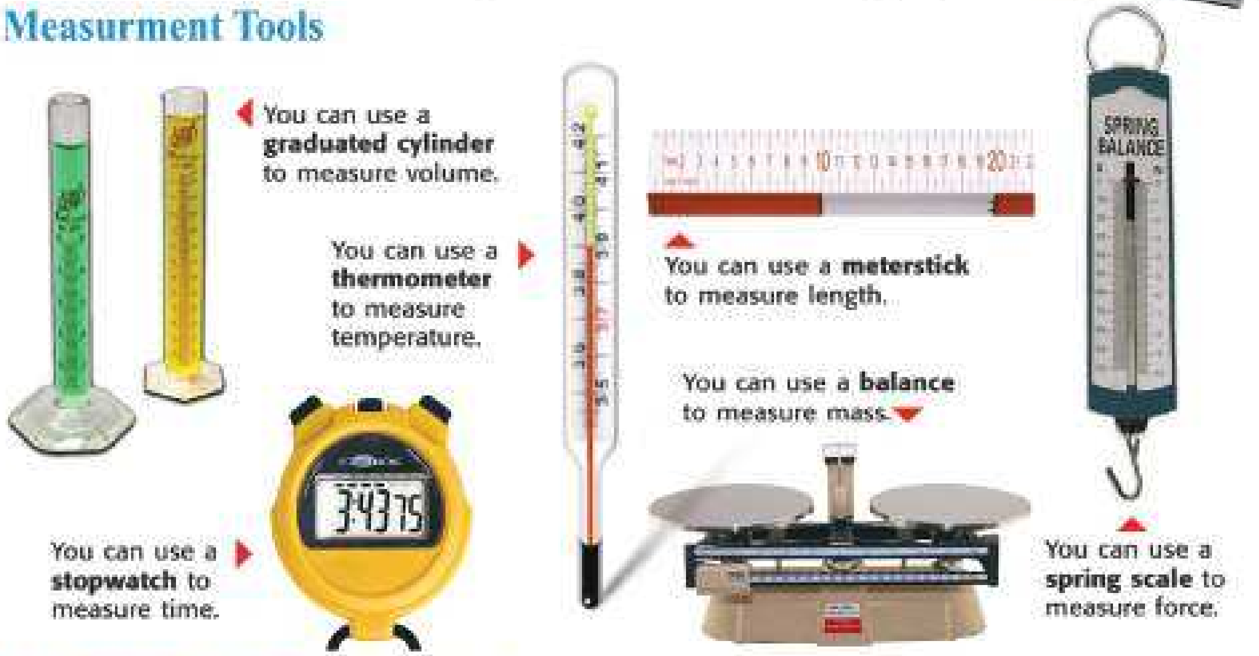


Figure (1)
Accurate measurement of distance and time is important for competitive sports like track and field. Why wouldn't a clock that measured in it.

Describing Events Measurement also can describe events such as the one shown at Figure (1) . In the 1956 summer Olympics, sprinter Betty Cuthbert of Australia came in first in the women's 200-m dash. She ran the race in 23.4 s. In the 2000 summer Olympics, Marion Jones of the United States won the 100-m dash in a time of 10.75 s. In this example, measure ments convey information about the year of the race, its length, the finishing order, and the time. Information about who competed and in what event are not measurements but help describe the event completely.

Estimation

What happens when you want to know the size of an object but you can't measure it? Perhaps it is too large to measure or you don't have a ruler handy. Estimation can help you make a rough measurement of an object. When you estimate, you can use your knowledge of the size of something familiar to estimate the size of a new object. Estimation is a skill based on previous experience and is useful when you are in a hurry and exact numbers are not required. Estimation is a valuable skill that improves with experience, practice, and understanding.

How practical is the skill of estimation? In many instances, estimation is used on a daily basis. A caterer prepares for each night's crowd based on an estimation of how many will order each entree. A chef makes her prizewinning chili. She doesn't measure the cumin; she adds "just that much."
Firefighters estimate how much hose to pull off the truck when they arrive at a burning building.

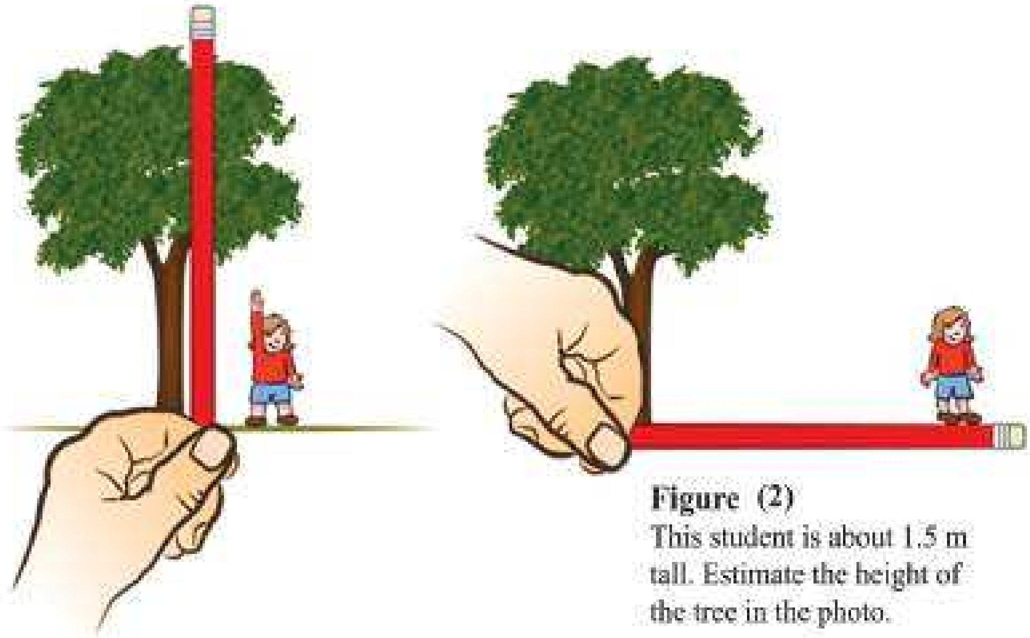


Figure (2)
This student is about 1.5 m tall. Estimate the height of the tree in the photo.

Using Estimation You can use comparisons to estimate measurements. For example, the tree in Figure (2) is too tall to measure easily, but because you know the height of the student next to the tree, you can estimate the height of the tree. When you estimate, you often use the word about. For example, doorknobs are about 1 m above the floor, a sack of flour has a mass of about 2 kg, and you can walk about 5 km in an hour.

Estimation also is used to check that an answer is reasonable. Suppose you calculate your friend's running speed as 47 m/s. You are familiar with how long a second is and how long a meter is. Think about it. Can your friend really run a 50m/s ? Estimation tells you that 47 m/s is unrealistically fast and you need to check your work.

Precision and Accuracy

One way to evaluate measurements is to determine whether they are precise. Precision is a description of how close measurements are to each other. Suppose you measure the distance between your home and your school five times with an odometer. Each time, you determine the distance to be 2.7 km. Suppose a friend repeated the measurements and measured 2.7 km on two days, 2.8 km on two days, and 2.6 km on the fifth day. Because your measurements were closer to each other than your friend's measurements, yours were more precise. The term precision also is used when discussing the number of decimal places a measuring device can measure. A clock with a second hand is considered more precise than one with only an hour hand.

Degrees of Precision The timing for Olympic events has become more precise over the years. Events that were measured in tenths of a second 100 years ago are measured to the hundredth of a second today. Today's measuring devices are more precise. **Figure below** shows an example of measurements of time with varying degrees of precision.

Accuracy When you compare a measurement to the real, actual, or accepted value, you are describing accuracy. A watch with a second hand is more precise than one with only an hour hand, but if it is not properly set, the readings could be off by an hour or more. Therefore, the watch is not accurate. On the other hand, measurements of 1.03m, 1.04m and 1.06m compared to an actual value

Figure illustrates the difference of 1.05 m is accurate, but not precise. between precision and accuracy.

A Before the invention of clocks, as they are known today, a sundial was used. As the Sun passes through the sky, a shadow moves around the dial.

C Digital clocks are now as common as analog ones.

B For centuries, analog clocks- the kind with a face- were the standard.

SI Units

The International System

Can you imagine how confusing it would be if people in every country used different measuring systems? Sharing data and ideas would be complicated. To avoid confusion, scientists established the International System of Units, or SI, in 1960 as the accepted system for measurement. It was designed to provide a worldwide standard of physical measurement for science, industry, and commerce. SI units are shown in **Table below.**

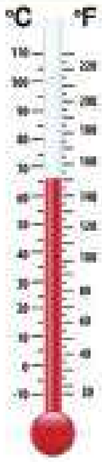
The SI units are related by multiples of ten. Any SI unit can be converted to a smaller or larger SI unit by multiplying by a power of 10. For example, to rewrite a kilogram measurement in grams, you multiply by 1,000. The new unit is renamed by changing the prefix, as shown in Table below. For example, one millionth of a meter is one micro-meter. One thousand grams is one kilogram.

Table1: SI Base Units

Quantity	Unit	Symbol
length	meter	m
mass	kilogram	kg
temperature	kelvin	K
time	second	s
electric current	ampere	A
amount of substance	mole	mol
intensity of light	candela	cd

Table2: SI Prefixes

Prefix	Multiplier
giga-	1,000,000,000
mega-	1,000,000
kilo-	1,000
hecto-	100
deka-	10
[unit]	1
deci-	0.1
centi-	0.01
milli-	0.001
micro-	0.000 001
nano-	0.000 000 001



CHAPTER QUESTIONS

Q.1 choose the correct answer from the following:

1. What is the SI unit for the length?

a. inch.
b. foot.
c. meter.
d. kilometer.

2. A room is measured to be 3.6 m by 5.8 m. What is the area of the room?

a. 20.88 m^2.
b. 2×10^1 m^2.
c. 20×10^2 m^2.
d. 21 m^2.

3. The earth mass 5.94×10^{24} kg, what its mass in (mg)?

a. 0.594 mg.
b. 5.94×10^{24} mg.
c. 5.94×10^{30} mg.
d. 0.594×10^{27} mg.

Q.2 Answer the following:

1. convert the following to SI units:

a. 9.12 µs. b. 3.42 km.
c. 44 cm/ms. d. 80 km / hour.

2. Convert the following to SI units:

a. 1.0 hour. b. 1.0 day. c. 1.0 year. d. 24 min.

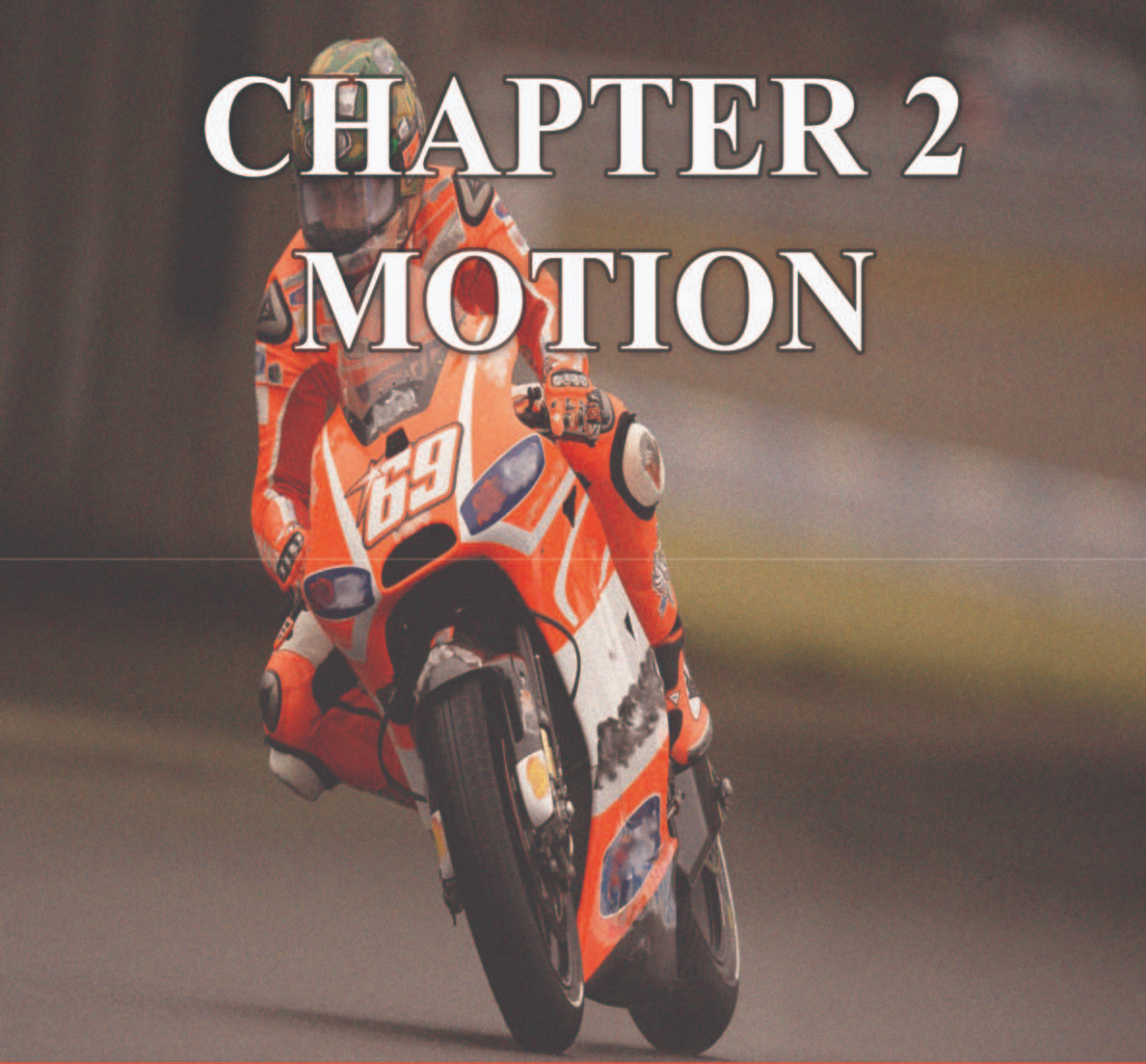
3. List the following distances from the shortest to the longest:

1 mm, 1Mm,1nm, 1 km,1 cm, 1 µm.

Q.3 A bacterium with 2 µm long, 1µm diameter and its mass 1×10^{-12} g, Answer the following in SI units:

a. What is its length?
b. Diameter?
c. Mass?

CHAPTER 2
MOTION



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Describe position.
2. Compare between distance and displacement.
3. Distinguish between speed and velocity.
4. Distinguish between uniform and non-uniform motion.
5. Define the physical meaning of acceleration.
6. List the kind of motion.
7. Describe the Nature of the wave.
8. List type of wave.
9. Understand the properties of the wave.

MOTION

From an electron to galaxies, everything in the universe is in a continuous state of motion. For example electrons turn around the nucleus of atoms, planets revolve around the sun. The sun rotates together with the Milky way galaxy.

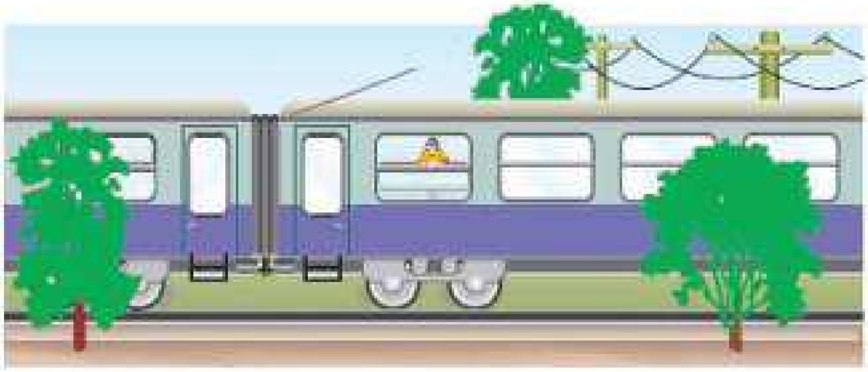
On the earth, all living things move to survive: Plant's leaves turn towards the Sun, Animals move to find food.

Day and night occur because of the motion of the Earth around its axis. Everything on the earth is in motion together with it.

So we can say that we live in a world full of motion. In this chapter we will learn the meaning of motion, speed and other term related with it.

2.1 WHAT IS MOTION?

Suppose that you are in a train. How can you decide if the train is moving, or waiting at the station? Can you say that the train is moving by just looking at the passengers inside the train?



To make a decision about the train's motion, you must look outside the window. If the buildings, trees and electric lines appear to move past, you know that they are not moving, you and the train are moving. An object is in motion if its place changes with respect to a fixed point which we call the reference point. The reference point can be any stationary point such as that on a tree, a building, a bridge, an electric pylon etc.

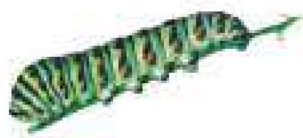


Figure 2.1 Living things move to survive.

a) What is position?

Read the sentences below and look at the picture in **Figure 2.2. Figure 2.3**

- There is a dog on the hill.
- There is a dog on the hill near the tree.
- There is a dog on the hill 50 metres away from the tree.
- There is a dog on the hill 50 metres away from the tree, due east.

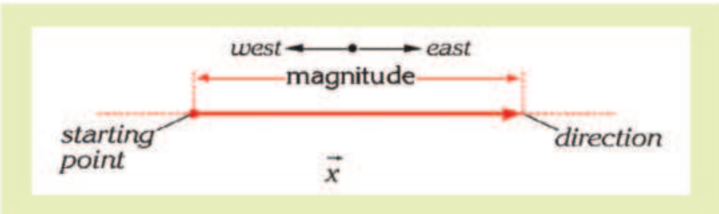
Which sentence describes the location of the dog the best?

The distance of an object to a reference point in a stated direction gives the position of the object. **Position** is a vector quantity which has both direction and magnitude. Therefore the last sentence gives the necessary information about the location of the dog.

There is a dog away from the tree, but where?

Figure 2.2

The position is shown as a vector in the drawing below.



The arrow on the letter x shows that it is vector. When we talk about magnitude, we don't use arrows. We can show the position of the dog with a vector as shown in the figure 2.3

The dog is 50 m away from the tree due east.

Figure 2.3

b) What is displacement?

The change in position of an object is called displacement. Displacement is also a vector quantity. We can find the displacement of an object by subtracting the initial position from the final position:

Displacement = Final position – Initial position

$\Delta x = x_{final} - x_{initial}$ Here, "Δ" means change.

If the dog moves away from the tree due east and its final position is now 87 m, what will its displacement be? The dog's initial position was 50 m it's, final position is 87 m due east;

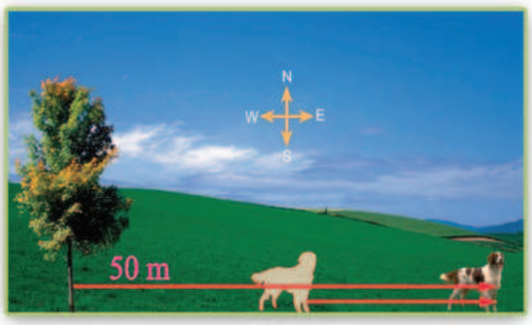


Figure 2.4

$$x_{final} = 87 \text{ m}; x_{initial} = 50 \text{ m}$$

$$\Delta x = x_{final} - x_{initial}$$

$$\Delta x = 87 - 50 = 37 \text{ m}$$

The dog's displacement is 37 m due east. This is shown in the figure 2.4

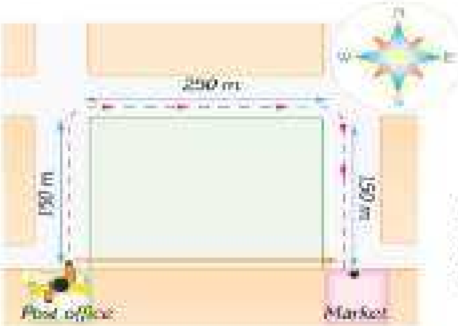


Figure 2.5

To make clear the concept, let's think about the following example:

A postman walks around a building, as shown in the figure 2.5 to deliver the mail.
What is the distance travelled by the postman and what is his displacement?

As any object move from one position to another can be define as the length of the path from inital position to the final position called the distance (d) which is scaler quantity

The postman travels 150 m to the north, 250 m to the east and 150 m to the south. In total he travels

$$d = 150 + 250 + 150 = 550 \text{ m}$$

But his displacement is different: It is the change in his initial and final positions. His final position is 250 m due east.
If we take the initial position to be 0, the displacement of the postman is:

$$\Delta x = x_{final} - x_{initial}$$

$$\Delta x = 250 - 0 = 250 \text{ m}$$

Figure 2.6

A boy with a dog crosses a street. The width of the street is 25 m. The boy goes on a straight path, but the dog follows a curved path. At the end their displacements will be the same, but the distances travelled by the boy and dog will not be the same!

Δx = 25 meter

Example 2.1

A girl walks 5 m due right. Then she returns and walks 7 m due left. What is the distance taken and the displacement during this motion?

Solution

The girl moves 5 m due right and 7 m due left.
The distance (d) taken by the girl is:
$d = d_1 + d_2 = 5 + 7 = 12$ m
Let's take displacement to the right to be positive and that towards the left to be negative. Δx shows the change in position.

Calculation

First, it is better to sketch a diagram as shown below.
$\Delta \bar{x} = \bar{x}_1 + \bar{x}_2$ $\qquad \Delta \bar{x} = 5 + (-7)$ $\qquad \Delta \bar{x} = -2$ m

Although the girl walks totaly 12 m, her displacement is –2m.

Exercise 2.1

A ball is released from a height of 5 m, bounces from the floor and is caught at a height of 2 m from the floor. Find the distance covered by the ball and its displacement.

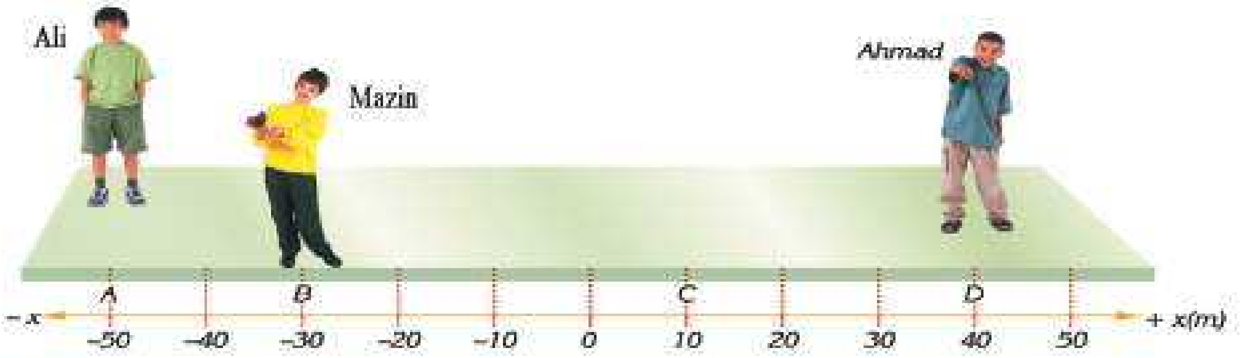
Ans : Distance covered, d = 7 m; displacement, Δx=3m with respect to the ground

Example 2.2

Look at the figure below.

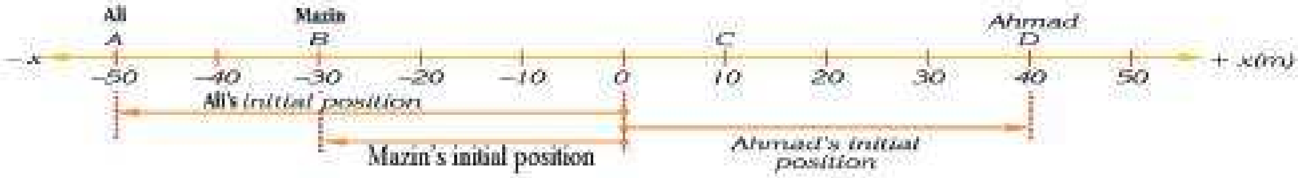
a) State the positions of the students and draw their position vectors.

b) After a while they all move to point C, what will their final positions be? What will their final displacements be?

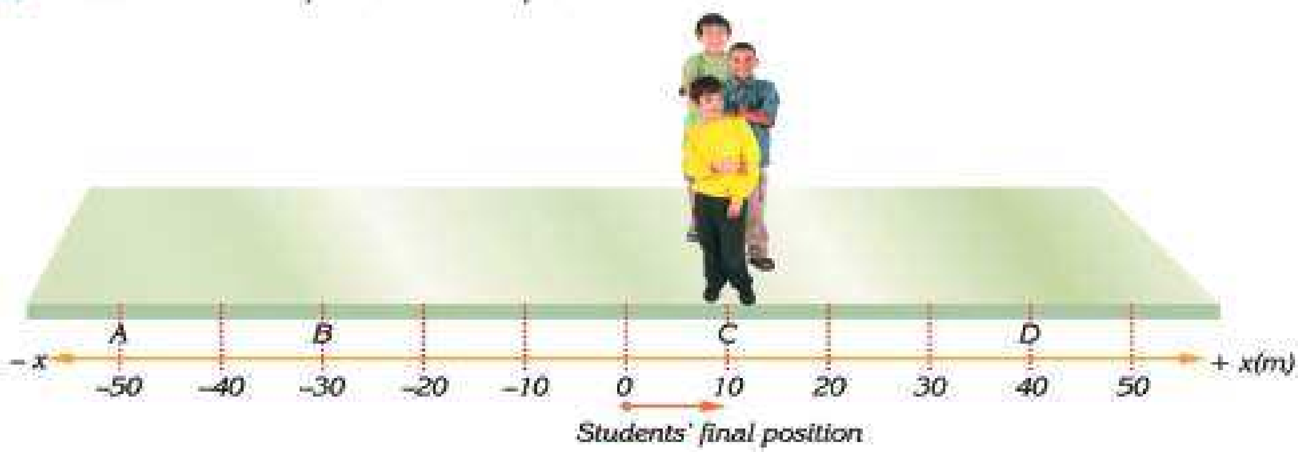


Solution

a) **Ali's** initial position is – 50 m, that of Mazin is – 30 m, and that of Ahmad is + 40 m. Their position vectors are as follows:



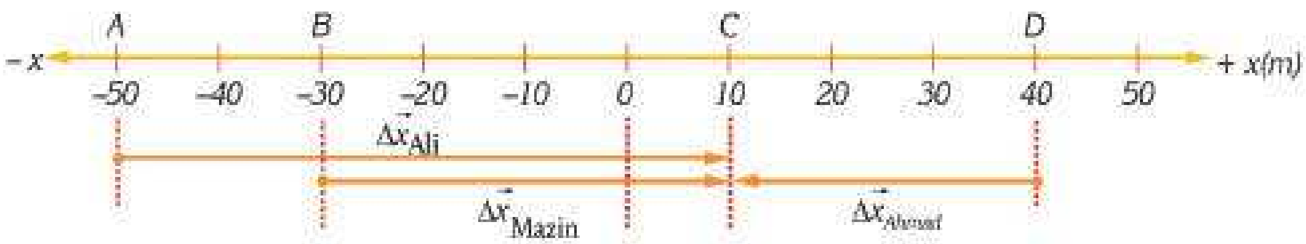
b) The students meet at the point C. Their final position is +10 m.



Ali moves from point A to point C, his displacement is; $\Delta x_{Ali} = x_f - x_i = +10 - (-50) = +60$ m

Mazin moves from point B to point C, his displacement is; $\Delta x_{Mazin} = x_f - x_i = +10 - (-30) = +40$ m

Ahmad moves from point D to point C, his displacement is; $\Delta x_{Ahmad} = x_f - x_i = +10 - (+40) = -30$ m



c) What is Speed?

We usually classify motion as either fast or slow. When we travel, we prefer safe and fast vehicles to travel long distances in a short time. For example a car is a fast vehicle but a plane is faster than a car. The measure of how fast an object moves is called speed. All moving things cover different distances during their motion depending on their speeds. For example a car can cover 90 km in one hour but an aeroplane can fly 900 km in the same duration. Study the figure (2.7), which two quantities should we know to calculate the speed of an object?

Figure 2.7

We can define speed as the distance travelled in unit time. If we know the distance travelled and the time taken during the motion, we can find the speed. The speed is calculated by dividing the distance travelled by the time taken. We can state it as in an equation;

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}} \quad \text{in symbols} \quad s = \frac{d}{t}$$

If the baby takes 20 cm in 1 s, his speed is 20 cm/s.

Figure 2.8

where s represents speed, d represents distance and t represents time. In scientific measurements the distance is measured in metres(m) and the time in seconds(s), so the unit of speed is metres per second(m/s). For example a baby crawling on the ground a distance of 20 cm in 1 second, has a speed of 20 cm/s see the **Figure 2. 8**

If we measure the distance in kilometers (km) and the time in hours (h) then the unit of speed is kilometres per hour (km/h). For example a man riding a bicycle a distance of 12 km in 1 hour has a speed of 12 km/h (12 km per hour. Here the slash (/) is read as "per").

If the man rides at a constant speed of 12 km/h, he travels 24 kilometres per two hours.

$$s_{bicycle} = 12 \text{ km/h} = \frac{12 \text{ km}}{1 \text{ h}}$$

12 km — distance travelled in a unit of time

1 h — unit of time

1) Average speed

Study the diagram in figure (2.9) what can you say about the speed of car during the motion? Is it the same everywhere? see figure (2.10), figure (2.11).

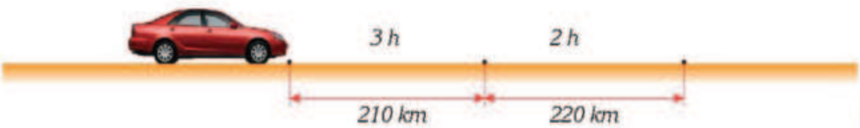
Figure 2.9

A car on a highway cannot go with the same speed every time. On flat roads it can go very fast but slows down when climbing uphill. A car rarely moves at a constant speed. Due to this reason, we usually prefer to use the **average speed** of objects. Average speed is calculated by dividing the total distance travelled by the total time taken. We can state it as an equation;

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} \quad \text{in symbols} \quad s_{average} = \frac{d_{total}}{\Delta t_{total}}$$

Figure 2.10 In marathons competitors run with varying speeds, therefore we talk about their average speeds.

Lets' say a car moves 210 km during the first 3 hours and 220 km during the next 2 hours. The average speed of the car is calculated as follows:



$$d_{total} = 210 \text{ km} + 220 \text{ km} = 430 \text{ km}$$

$$t_{total} = 3 \text{ h} + 2 \text{ h} = 5 \text{ h}$$

Average speed = Total distance / Total time = 430 km / 5 h= 86 km/h

The car's average speed is 86 km per hour. It takes 86 km in one hour on average.

Figure 2.11 Racing cars on the track cannot move with the same speed every instant.

Example 2.3

A ship moves with a speed of 5 m/s for half an hour. Calculate the distance covered by the ship in metres and in kilometres.

Solution

What is asked in the question?

The distance covered by the ship, d=?

What is the information given?

Speed, $s = 5$ m/s; time, $t = 30$ min.

$t = 30 \times 60 = 1800\,s$

What is the equation needed to solve the problem?

$d = s \cdot t$

distance = speed × time

Calculation

$d = s \cdot t$

$d = 5 \times 1800$

$d = 9000$ m

$d = 9$ km

Exercise 2.2

An athlete runs 3 km at a speed of 5 m/s. Calculate the time taken by the ath lete in min.

Ans : 10 min

Example 2.4

In a race, a runner covers a distance of 1200 m with an average speed of 4 m/s. How long does it take to run this distance? then calculate the time in min.

Solution

What is asked in the question?
The time to run the distance, t=?
What is the information given?
Distance, d=1200 m, s_{av} = 4 m/s
What is the equation needed to solve the problem?

$$t = \frac{d}{s} \quad \text{time = distance / speed}$$

Calculation

t = d / s
t = 1200 / 4
t = 300 s
The runner completes 1200 m in 300 s seconds.

$$t = \frac{300\ s}{60\ \frac{s}{m}} = 5\ min$$

Exercise 2.3

A train travels 4 hours and covers 380 km during it's motion. Calculate its speed.

Ans : 95 km/h

Example 2.5

A boy covers a distance of 3000 m in 10 min with a bicycle. What is the average speed that the boy rides his bicycle with in m/s and km/h?

Solution

What is asked in the question?
The speed of the bicycle in m/s, km/h; v=?
What is the information given?
Distance, d=3000 m; time, t=10 min.
What is the equation needed to solve the problem?

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

Calculation

First, convert given time into seconds and then hours.

t= 10 min= 10 · 60
t=600 s

$$s = \frac{d}{t} = \frac{3000\ m}{600\ s} = 5\ m/s$$

$$t = 10\ min = 10 \cdot \frac{1}{60} h \quad = \frac{1}{6} h$$

$$d = 3000\ m = 3\ km$$

$$s = \frac{3\ km}{\frac{1}{6} h} = 18\ km/h$$

Exercise 2.4

A man walks 300 m in five minutes, then walks 450 m in 20 minutes. What is the average speed of the man in m/s?

Ans : 0.5 m/s

2) What is instantaneous speed?

Together with average speed, it is also important to know the instantaneous speed. This is the speed of an object at a given instant of time. The speedometers of cars, motorcycles, aeroplanes etc. show instantaneous speed. Thus, when you read the speed on any speedometer, it is the instantaneous speed of the vehicle. see figure (2.12).

Figure 2.12 Speedometers show instantaneous speed.

d. What is velocity?

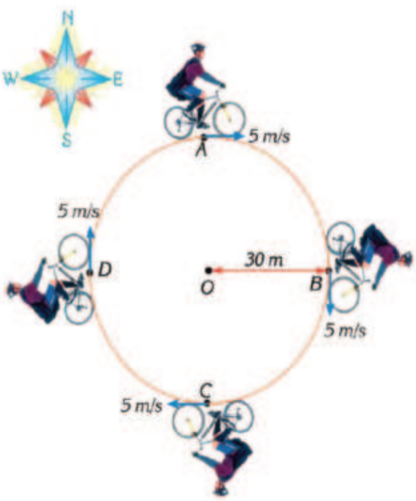
From weather forecasts on TV you may hear of storms travelling at up to speeds of 20 km/h. Do you have to make a plan to protect yourself from it's hazardous effects? What additional information about the storm should you know about that makes it dangerous?

Figure 2.13 The cars have the same speed but their velocities are different. What are their velocities?

The speed of objects don't detail everything about their motion. It is also important to know the objects' direction of motion together with it's speed. If you know the direction of a storm, you can decide better whether you must take it's dangers into consideration or not. It may not even be directed towards your neighbourhood.

When we talk about direction and speed of motion, we use the term velocity. The speed of an object may be the same in different locations but its direction can change, this causes its velocity to change. In short, velocity is the speed in a given direction, look at the **Figure 2.13**. We represent the magnitude of velocity with the letter v, when we represent both direction and magnitude as velocity we add an arrow over the letter, v. When we write down the speed, we don't use an arrow: For example v=8 m/s. Study the figure **2.14** and state the velocities of the bodies.

Figure 2.14



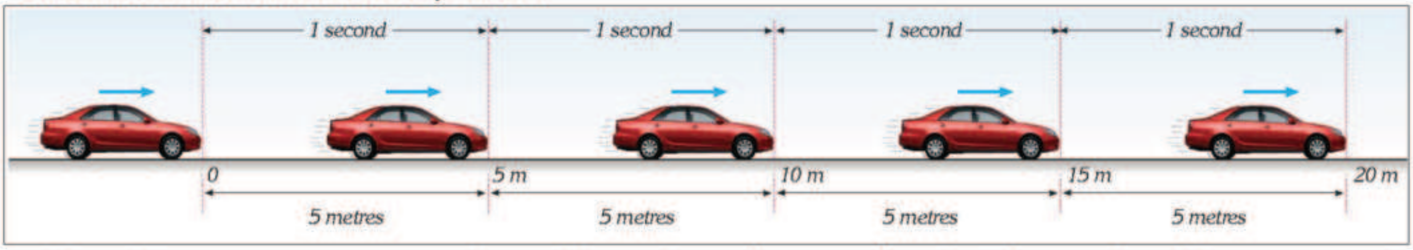
Look at the figure on the left, a cyclist riding around a circle has the same speed at every instant but its direction always changes. What are the velocities of the rider at the points A, B, C, D?

In some jobs, the velocity of objects is very important. For example aeroplane pilots require to keep precise control over the velocity of their aircraft when they fly. They work together with the control tower teams to avoid collisions with other aircraft. Another example is on the seas: ship captains must know both the wind direction and speed to navigate correctly.

e. Motion

1) What is uniform motion?

Look at the figure below. What can you say about the motion of the car? Does it take the same distance every second?



If an object moves at constant speed, we call its motion **uniform motion**. An object moving with constant speed travels equal distances in equal times.

The car shown in the figure travels equal distances in the same time intervals, so it performs uniform motion.

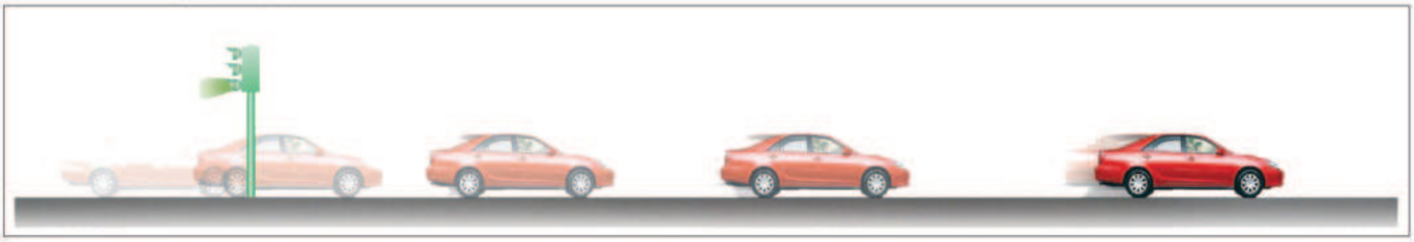
2) What is non uniform motion?

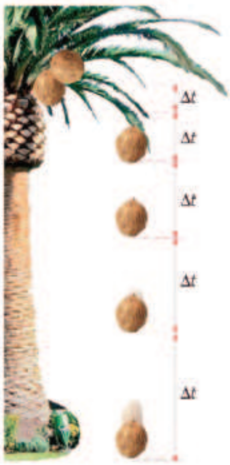
If an object speeds up or slows down, we say that the object performs non uniform motion.

a. Speeding up

If an object covers more distance than before in each second this motion is called speeding up. Study the motion of the car in Figure below. At the beginning, the car stops at the red light.

When the green light is on, the car begins it's motion from rest and travels a greater distance during each second, that is "it speeds up".



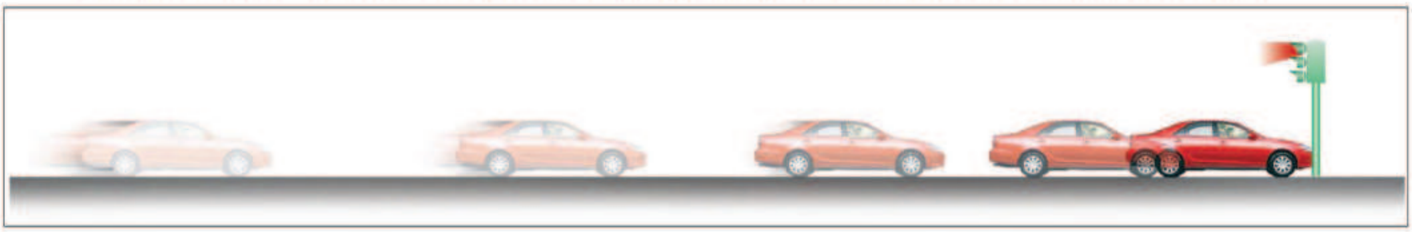


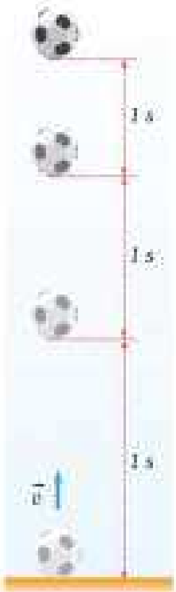
Acoconut falling from a palm cocounut a ball rolling down a slope and water flowing from a height speed up.

b. Slowing down

If an object travels less distance than before in each second, this motion is called slowing down.

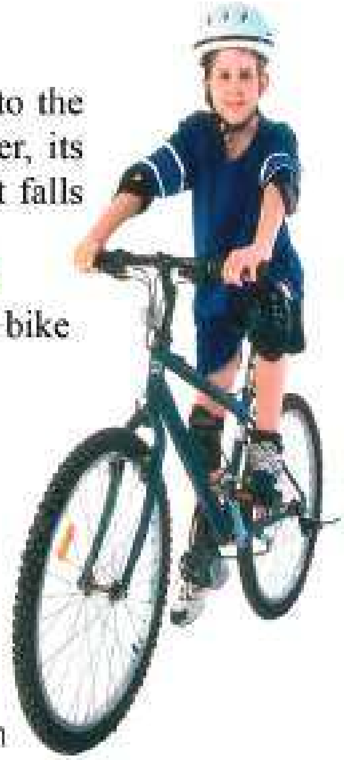
Look at the picture below, the car decreases its speed as it gets closer to the red light, and then stops.





A ball thrown up vertically slows down. Due to the gravity of the earth, as the ball goes up higher, its speed continuously decreases and stops, then it falls down

When we put on the brakes, we slow down the bike



Kinds of motion

If you look around, you will see that the objects surrounding you perform different kinds of motion. We can study motion in two ways:

a. According to the speed of objects

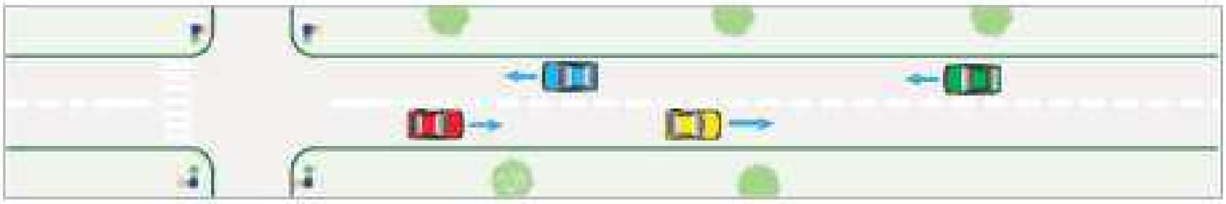
As we stated before, objects perform uniform or non-uniform motions

b. According to the path of objects

We can classify the motion of objects according to the path that the objects follow. Linear, circular, vibrational, elliptic and projectile motions are some examples of paths objects may follow

1- Linear motion (Translational motion)

Linear motion is motion in a straight line as shown on the left. A car travel- ling on a straight road, a train on a straight railroad or a plane flying along a straight path in air perform linear motion. Water droplets falling from a tap, a ball rolling along a straight line are other examples of linear motion



Examples of linear motion.

2- Circular And Rotational Motion

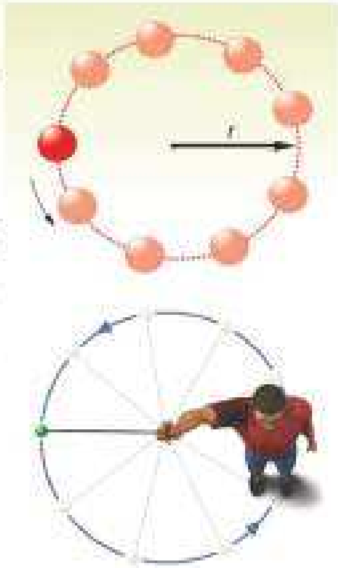


Figure 2.15 Circular motion

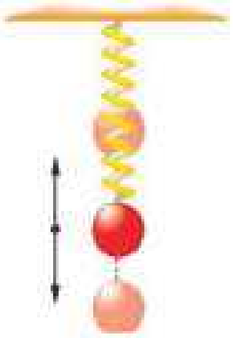
Circular Motion: This is the motion of an object around a central point, as shown in the figure 2.15 on the right , a Person rides on the rotating ferris wheel are said to be in circular motion, a car moves around a circular track, when a ball is whirled in a circle are some examples of circular motion.

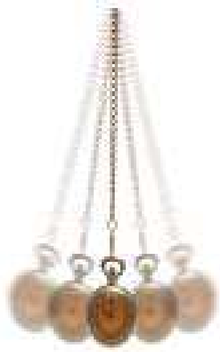
Rotational Motion: The motion of a wheel around its axle, the rotation of earth and other planets around their axis, the rotation of the blades of wind mills and air fans, the motion of records, cd's, mixers, drums of washing machines, car or motor tyres are some examples of rotational motion. Look at the pictures below. State the name of the objects that perform rotational motion.

Figure 2.16 Rotational motion

3-Periodical motion

Periodical motion is the movement of an object back and forth about a central point. A child swinging back and forth, a spring moving up and down, a guitar string moving back and forth perform Periodical motion. Study the figures below.



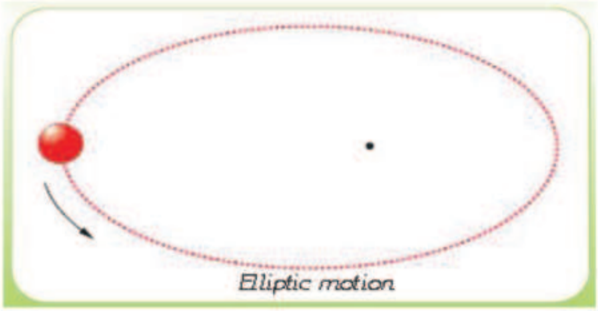


4- Projectile motion

In many games, a ball is thrown upwards into the air, it follows a different path to a straight line or a circular path, as shown in the figures. We call this type of motion projectile motion. State some other examples of projectile motion.

5-Elliptic Motion

The earth and other planets move around the sun in elliptic paths Although it looks like a circle,an ellipse has some differences compared to a circle. study the figures on the right and below .



f) What is Acceleration?

If an object changes its velocity, the object accelerates. Acceleration is defined as the change in velocity of an object in a unit of time. We usually experience acceleration when a car starts motion from rest.

The greater the change in velocity, the greater the acceleration. Velocity is a vector quantity, so is the acceleration. Therefore a change in direction of motion also causes acceleration even though the object moves at constant speed.

When a moving object slows down, its velocity decreases, this has a special name; **deceleration**. We experience deceleration when a moving car slows down. Look at the figures below, which figure shows acceleration, deceleration.

Nature of wave

Wave Energy

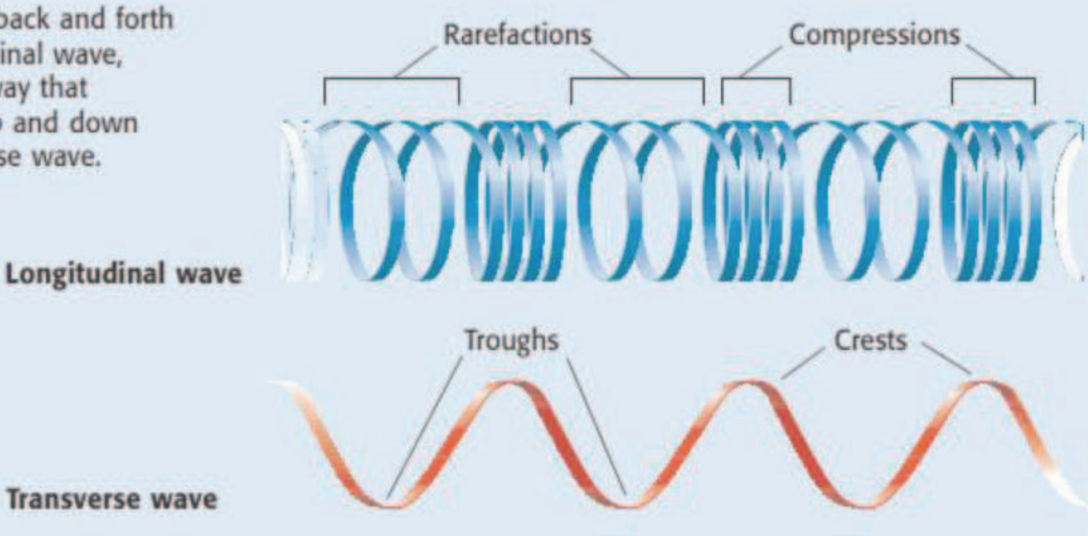
Energy can be carried away from its source by a wave. You can observe an example of a wave if you drop a rock in a pond. Waves from the rock's splash carry energy away from the splash. However, the material through which the wave travels does not move with the energy. Can you move a leaf on a pond if you are standing on the shore? You can make the leaf bob up and down by making waves that carry enough energy through the water. But you would not make the leaf move in the same direction as the wave

Wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

Types of Waves

All waves transfer energy by repeated vibrations. However, waves can differ in many ways. Waves can be classified based on the direction in which the particles of the medium vibrate compared with the direction in which the waves move. The two main types of waves are **transverse waves** (transverse wave is a wave in which the particles of the medium move perpendicularly to the direction the wave moves) and longitudinal waves (longitudinal wave is a wave in which the particles of the medium move parallel to the direction of wave motion)

Pushing a spring back and forth creates a longitudinal wave, much the same way that shaking a rope up and down creates a transverse wave.

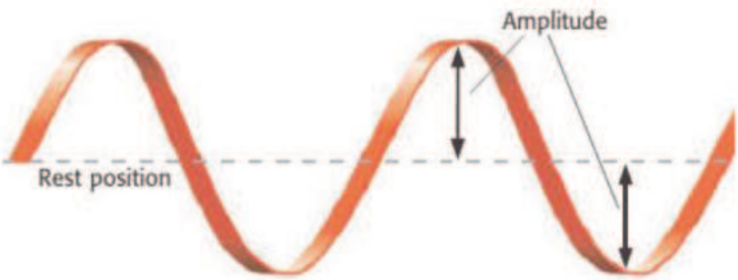


Properties of Waves

Amplitude

The amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position

A wave with a large amplitude carries more energy than a wave with a small amplitude does

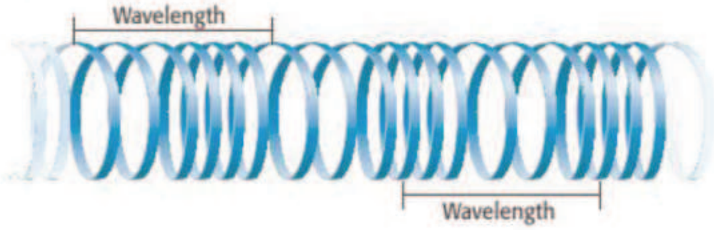


Wavelength

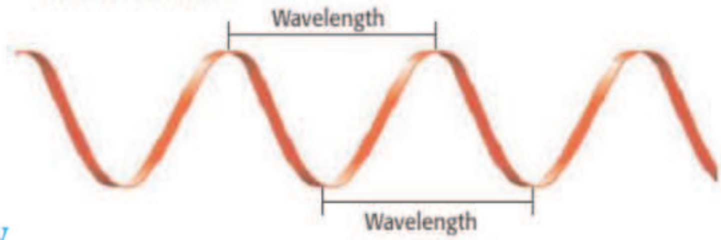
The wavelength the distance from any point on a wave to an identical point on the next wave.

A wave with a shorter wavelength carries more energy than a wave with a longer wavelength does.

Longitudinal wave



Transverse wave



Frequency

The number of waves produced in a given amount of time is the frequency of the wave. If the amplitudes are equal, high-frequency waves carry more energy than low-frequency waves.

Wave Speed

Wave speed is the speed at which a wave travels. Wave speed can be calculated using wavelength.

$$v = \lambda f$$

Fill in the boxes correctly.

1. Change in position.
2. The distance of an object from a reference point in a stated direction.
3. The distance travelled by an object in a unit of time.
4. A type of motion around a central point:....... motion.
5. The name of speed in a given direction.
6. The name of the speed of an object at a given instant of time:....... speed.
7. A type of motion where the object moves with a steady speed.
8. A type of motion where the object covers more and more distance in each second.

CHAPTER QUESTIONS

Q.1 Use the words below in your own sentences:
displecement , linear, speed , velocity , speeding up, instantneous , circular

Fill in the blanks with appropriate words

1. The change in position of an object is called .... is also a vector quantity.
2. .... is the distance travelled in unit time.
3. The speedometer of a car indicates the .... speed of the car.
4. .... is the speed in a given direction.
5. If an object covers more distances than before in each second this motion is called ....
6. water droplets falling from a tap performs .... motion.
7. Earth follows an .... path around the sun.

Q.2 Solve the following problems

1- What is the position of the athlete.
a) Relative to point 0.
b) Relative to point C.
c) Relative to point F.

2- A car moves 200 m in 10 s. What is the speed of the car?

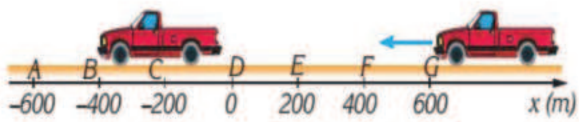
3- A horse runs with a constant speed of 8 m/s. What is the distance covered by this horse after 1 h.

4- A body moves from a point A to a point B with a velocity of 5 m/s and returns to point A with a speed of 3 m/s. What is the average velocity?

5- Two students meet in school at 8:00 a.m. One of them came to the school by bus, the other one by train. The first student left home at 7:30 a.m. his home was 18 km away from school. The second student left home at 7:00 a.m. and he was 40 km from school. Which student has a greater average speed? Which transportation vehicle is faster?

Q.3 Answer the test questions

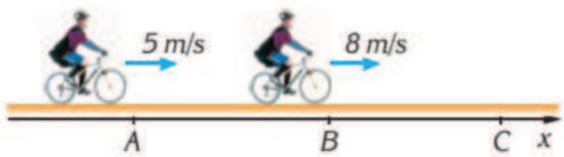
1.



The car moves from point G to point B. What will the final position of the car be?

A) –400 m B) 600 m C) 800 m D) 1000 m

2.



A cyclist rides his bike from point A to point B with a speed of 5 m/s in 2 min. Then rides from point B to point C at a speed of 8 m/s in 40 s. What will the displacement of this cyclist be in metres?

A) 840 B) 600 C) 920 D) 280

3. A car travels a distance with a speed of 20 m/s in 3 min. Then another car covers this same distance with a speed of 5 m/s. What will the time taken by the second car be in minutes?

A) 10 B) 11 C) 12 D) 13

4. A car moves with a constant speed a distance of 12.6 km in 15 min. What is the car's speed in metres per second?

A) 11 B) 12 C) 13 D) 14

5. An airplane flown at a speed of 800 km/h in 3 h. What is the distance flown by the plane in kilometres?

A) 1400 B) 2400 C) 3400 D) 1600

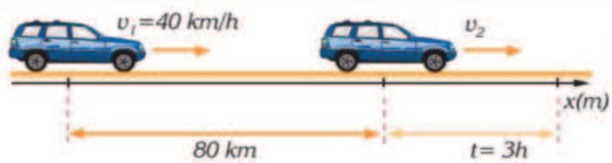
6. Which of the following is not correct?

A) Displacement is a scalar quantity.
B) Displacement is the change in position.
C) Displacement is the distance between two points in a certain direction.
D) Displacement has both magnitude and direction.

7. Which of the statements below is not correct?
A) Velocity is a vector quantity.
B) We represent the magnitude of velocity with the letter v.
C) Speed has both magnitude and direction.
D) The unit of speed is metres per second " m/s".

8. Emre kicks a goal at an average speed of 10 m/s. It is a good kick that travels a long distance of 30m. How long does the ball take to reach the goal line?
A) 5 s B) 4 s C) 3 s D) 2 s

9.



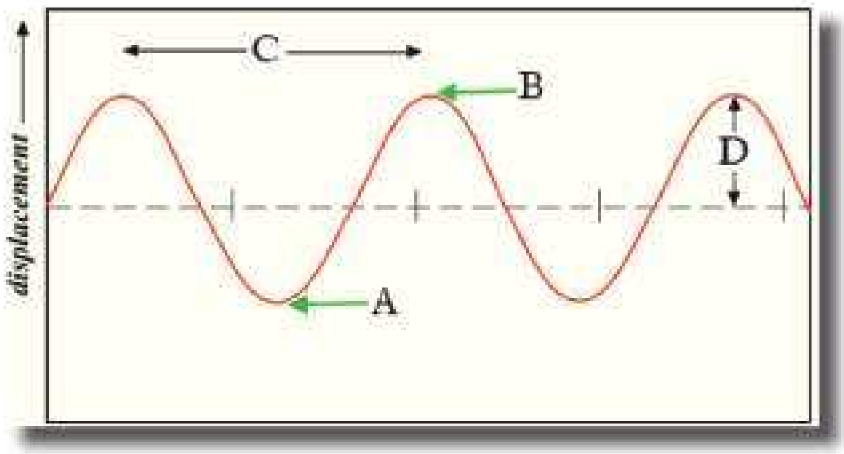
A car travels 80 km at an avarage speed of 40 km/h. It travels the remaining distance in 3h. What is its dis placement if the average speed of the car is 30 km/h.?

A) 100 km B) 120 km C) 150 km D) 180 km

10. what kind of wave dose this graph represent.

a. Transverse waves

b. Longitudinal wave.



11. Which letter on the above graph is used for wave length.

a. A
b. B
c. C
d. D

12. Which letter on the above graph is used for trough.

a. A
b. B
c. C
d. D

13. Which letter on the above graph is used for crest.

a. A
b. B
c. C
d. D

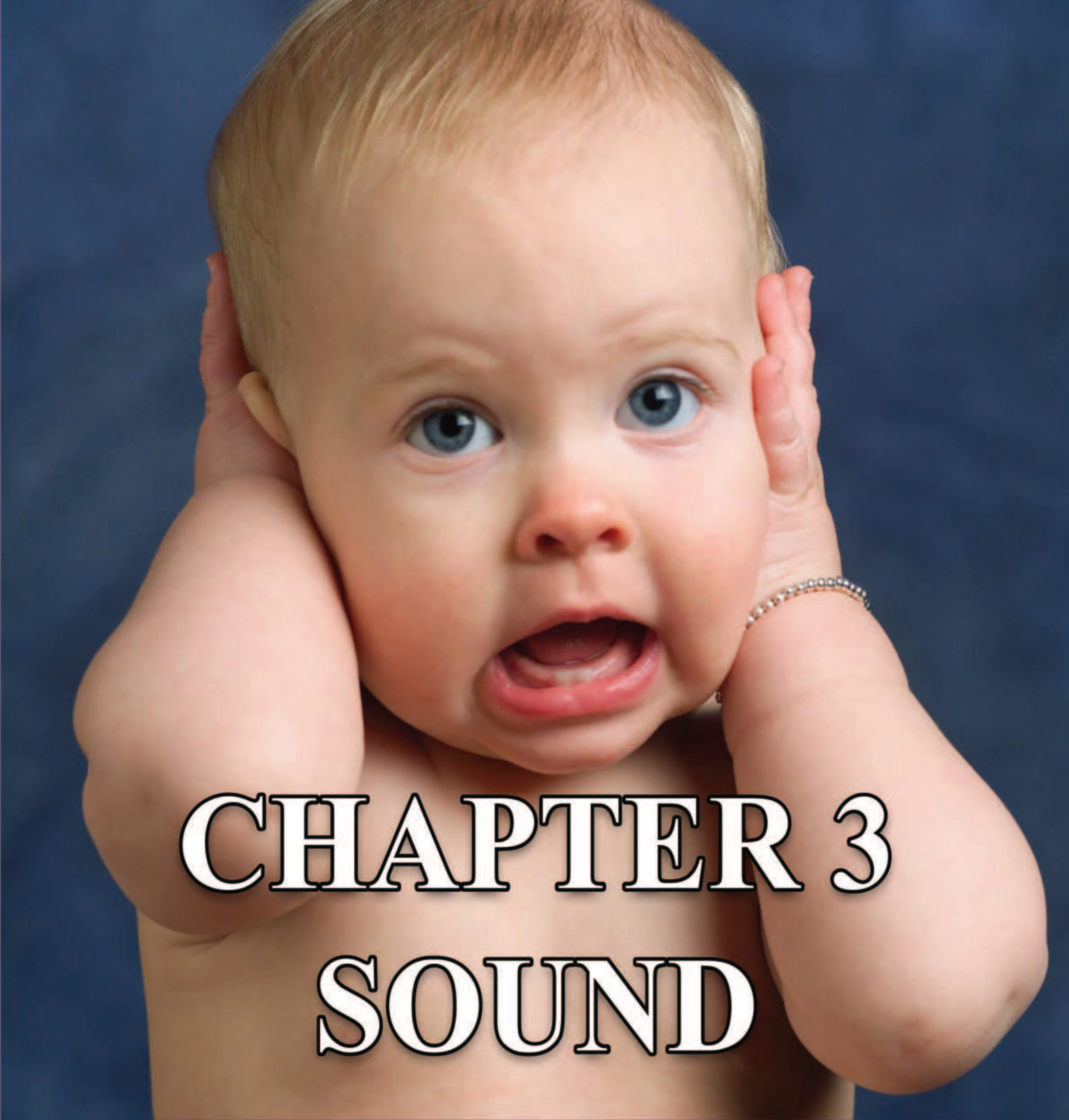
8. Compare between longitudinal wave and transverse wave.

9. List the wave properties and explain one of them.

10. List kind of motion according to :

a. Speed of the objects.

b. Path of objects.



CHAPTER 3
SOUND

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Define the sound wave.
2. Know the relation between the sound and vibration.
3. Distinguish how the human ear work.
4. Listed the properties of sound.
5. Give some examples of interaction of sound wave (Reflection, absorption, …)
6. Describe the Sound Quality.

What Is Sound?

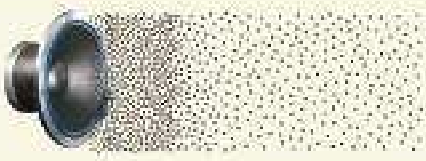
You are in a restaurant, and without warning, you hear a loud crash. A waiter dropped a tray of dishes. What a mess! But why did dropping the dishes make such a loud sound?

In this section, you'll find out what causes sound and what characteristics all sounds have in common. You'll also learn how your ears detect sound and how you can protect your hearing.

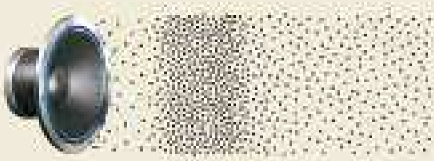
Sound and Vibrations

As different as they are, all sounds have some things in common. One characteristic of sound is that it is created by vibrations. A vibration is the complete back-and-forth motion of an object. Figure 1 shows one way sound is made by vibrations.

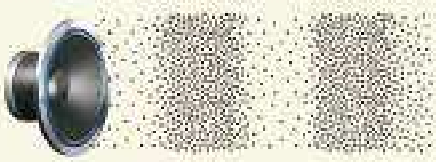
***Figure 1:* Sounds from Stereo Speaker.**



A Electrical signals make the speaker vibrate. As the speaker cone moves forward, it pushes the air particles in front of it closer together, creating a region of higher density and pressure called a *compression*.



B As the speaker cone moves backward, air particles close to the cone become less crowded, creating a region of lower density and pressure called a *rarefaction*.



C For each vibration, a compression and a rarefaction are formed. As the compressions and rarefactions travel away from the speaker, sound is transmitted through the air.

Sound Waves

Longitudinal waves are made of compressions and rarefactions.

A **sound wave** is a longitudinal wave caused by vibrations and carried through a substance. The particles of the substance, such as air particles, vibrate back and forth along the path that the sound wave travels. Sound is transmitted through the vibrations and collisions of the particles. Because the particles vibrate back and forth along the paths that sound travels, sound travels as longitudinal waves.

sound wave a longitudinal wave that is caused by vibrations and that travels through a material medium

Sound waves travel in all directions away from their source, as shown in Figure 2. However, air or other matter does not travel with the sound waves. The particles of air only vibrate back and forth.

Figure 2 You can't actually see sound waves, but they can be represented by spheres that spread out in all directions.

Figure 3 Tubing is connected to a pump that is removing air from the jar. As the air is removed, the ringing alarm clock sounds quieter and quieter.

Properties of Sound

Imagine that you are swimming in a neighborhood pool. You can hear the high, loud laughter of small children and the soft splashing of the waves at the edge of the pool.

Why are some sounds loud, soft, high, or low? The differences between sounds depend on the properties of the sound waves.

The Speed of Sound

Suppose you are standing at one end of a pool and two people from the opposite end of the pool yell at the same time. You would hear their voices at the same time. The reason is that the speed of sound depends on the medium in which the sound is traveling and the temperature of the medium. So, you would hear them at the same time even if one person yelled louder!

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

How the speed of Sound can change

Table1 shows how the speed of sound varies in different media. Sound travels quickly through air, but it travels even faster in liquids and even faster in solids Temperature also affects the speed of sound. In general, the cooler the medium is, the slower the speed of sound. Particles of cool materials move more slowly and transmit energy more slowly than particles do in warmer materials

The speed of sound in air is increase as increase the temprutre from 0°C about 0.6m/s for each degree celsius as increase the air particles movment, So it can be calculated by the following formula

$$S = 331 + 0.6 \times T$$

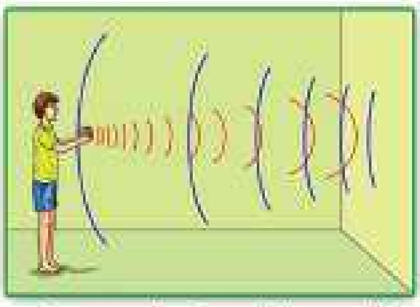
Table 1 Speed of Sound in Different Media

Medium	Speed (m/s)
Air (0°C)	331
Air (20°C)	343
Air (100°C)	366
Water (20°C)	1,482
Steel (20°C)	5,200

Reflection of Sound Waves

Reflection is the bouncing back of a wave after it strikes a barrier. You're probably already familiar with a reflected sound wave, otherwise known as an echo. The strength of a reflected sound wave depends on the reflecting surface. Sound waves reflect best off smooth, hard surfaces. Look at **Figure 4**. A shout in an empty gymnasium can produce an echo, but a shout in an auditorium usually does not.

The diffrence is that the walls of a gymnasium are hit a flat, hard surface, they will be reflected back.



Sound waves easily reflect off the smooth, hard walls of a gymnasium. For this reason, you hear an echo.

In well-designed auditoriums, echoes are reduced by soft materials that absorb sound waves and by irregular shapes that scatter sound waves.

Figure 4 : Sound Reflection and Absorption.

Echo happens when sound waves reflects from a surface to your ears , generally part of the sound reflects when it waves hit a large barrier ,Echo is the repetition of a sound caused by reflection of sound waves from a wall, mountain, or other obstruction surface .

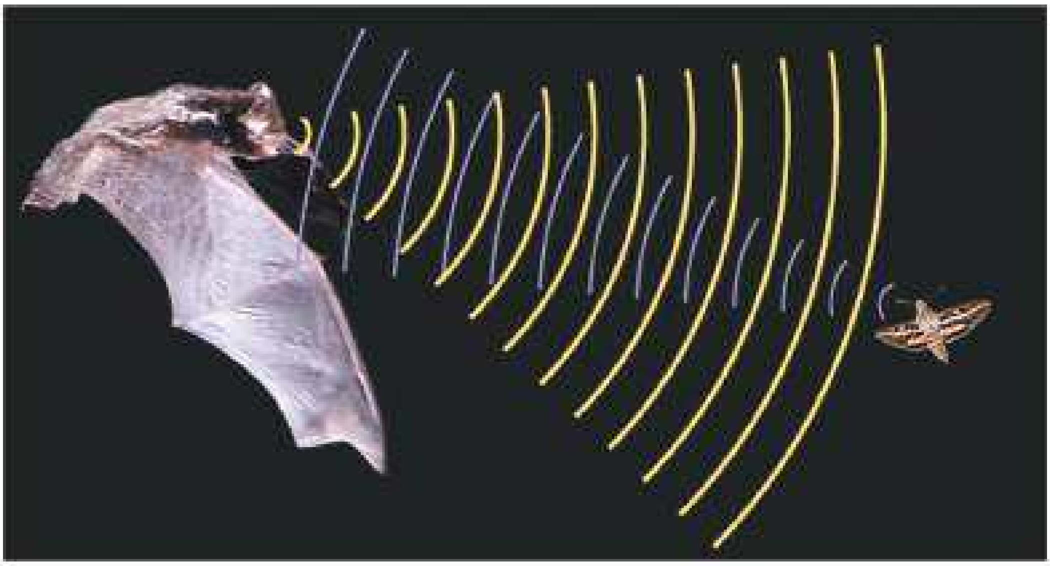


Figure 5 Bats use echolocation to navigate around barriers and to find insects to eat.

Echo occurs in two conditions :

1. The distance between the sound source and the reflecting surface must not be less than 17 meters

2. The time period between hearing the original sound and its echo should not be less than 0.1s

Echo can be used to measure the distance or the depth by creating a sound as a gunshot then calculating the time between the hearing of the real sound and its echo. We can find the distance between the source of sound and reflective surface from knowing the speed of the sound and we can also calculate the distance that the sound passes to reach the reflective surface by applying the following relationships

$$\text{distance} = \text{the speed of the sound} \times \frac{1}{2}\ \text{time}$$

$$d = s \times \frac{1}{2}\ t$$

t:The time represents the time that the sound takes back and forth

Echolocation

Beluga whales use echoes to find food. The use of reflected sound waves to find objects is called **echolocation.** Other animals such as dolphins, bats, and some kinds of birds also use echolocation to hunt food and to find objects in their paths. Figure 5 shows how echolocation works. Animals that use echolocation can tell how far away something is based on how long it takes sound waves to echo back to their ears.

echolocation the process of using reflected sound waves to find objects; used by animals such as bats

Echolocation Technology People use echoes to locate objects underwater by using sonar (which stands for sound navigation and ranging). Sonar is a type of electronic echolocation. Figure 6 shows how sonar works. Ultrasonic waves are used because their short wavelengths give more details about the objects they reflect off. Sonar can also help navigators on ships avoid icebergs and can help oceanographers map the ocean floor.

Figure 6 A fish finder sends ultrasonic waves down into the water. The time it takes for the echo to return helps determine the location of the fish.

Ultrasonography

Ultrasonography is medical procedure that uses echoes to"see" inside a patient's body without doing surgery. A special device makes ultrasonic waves with a frequency that can be from 1 million to 10 million hertz, which reflect off the patient's internal organs.

These echoes are then changed into images that can be seen on a television screen, as shown in Figure 7. Ultra sonography is used to examine kidneys, gallbladders, and other organs. It is also used to check the development of an unborn baby in a mother's body. Ultrasonic waves are less harmful to human tissue than X rays .

Figure 7 Images created by ultrasonography are fuzzy, but they are a safe way to see inside a patient's body.

Resonance

If you have a tuning fork, shown in Figure 8, that vibrates at one of the resonant frequencies of a guitar string, you can make the string make a sound without touching it. Strike the tuning fork, and hold it close to the string. The string will start to vibrate and produce a sound.

Using the vibrations of the tuning fork to make the string vibrate is an example of resonance. Resonance happens when an object vibrating at or near a resonant frequency of a second object causes the second object to vibrate.

Figure 8 When struck, a tuning fork can make another object vibrate if they both have the same resonant frequency.

Sound Quality

Have you ever been told that the music you really Iike is just a Iot of noise? If you have, you know that people can disagree about the difference between noise and music.

You might think of noise as sounds you don't like and music as sounds that are pleasant to hear. But the difference between music and noise does not depend on whether you like the sound. The difference has to do with sound quality.

What is Sound Quality?

Imagine that the same note is played on a piano and on a violin. Could you tell the instruments apart without looking? The notes played have the same frequency. But you could probably tell them apart because the instruments make different sounds. The notes sound different because a single note on an instrument actually comes from several different pitches: the fundamental and several overtones. The result of the combination of these pitches is shown in Figure 9. The result of several pitches mixing together through interference is sound quality. Each instrument has a unique sound quality. Figure 9 also shows how the sound quality differs when two instruments play the same note.

Figure 9

Noise a sound that consists of a random mix of frequencies

Music or Noise?

Most of the sounds we hear are noises. The sound of a truck roaring down the highway, the slam of a door, and the jingle of keys falling to the floor are all noises. Noise can be described as any sound, especially a nonmusical sound, that is a random mix of frequencies (or pitches). Figure 10 shows on an oscilloscope the difference between a musical sound and noise.

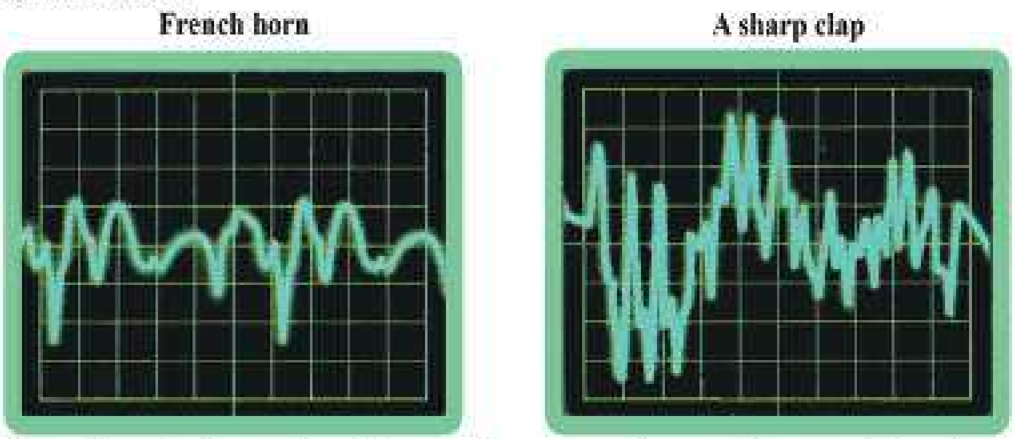


Figure 10 a note from a French horn produces a sound wave with a repeating pattern, but noise from a clap produces complex sound waves with no regular pattern.

CHAPTER QUESTIONS

Q.1. Where can sound not travel?

Q.2. Fill the empty box in the following table.

Speed of Sound in Air	
Temperature (°C)	Speed (m/s)
0	331
20	
25	
100	

Q.3. ***choose the correct answer from the following:***

1- During a laboratory experiment about the nature of sound, Sara walked into a large, dark room and yelled Hello! She heard a strong echo of the word almost immediately. Which of the following is a valid conclusion Sara could draw from her observations?

A. The room has smooth, hard walls and few things in it.

B. The room is full of pillows and other soft objects.

C. The room has no walls.

D. The room is very cold.

2- Sound travels fastest through

A.vacuum. C.air.

B.sea water. D.glass.

Q.4. A man standing in front of a wall a way from him 360 m he sent a sound and heared it's echo after 2 sec, find the speed of sound ?

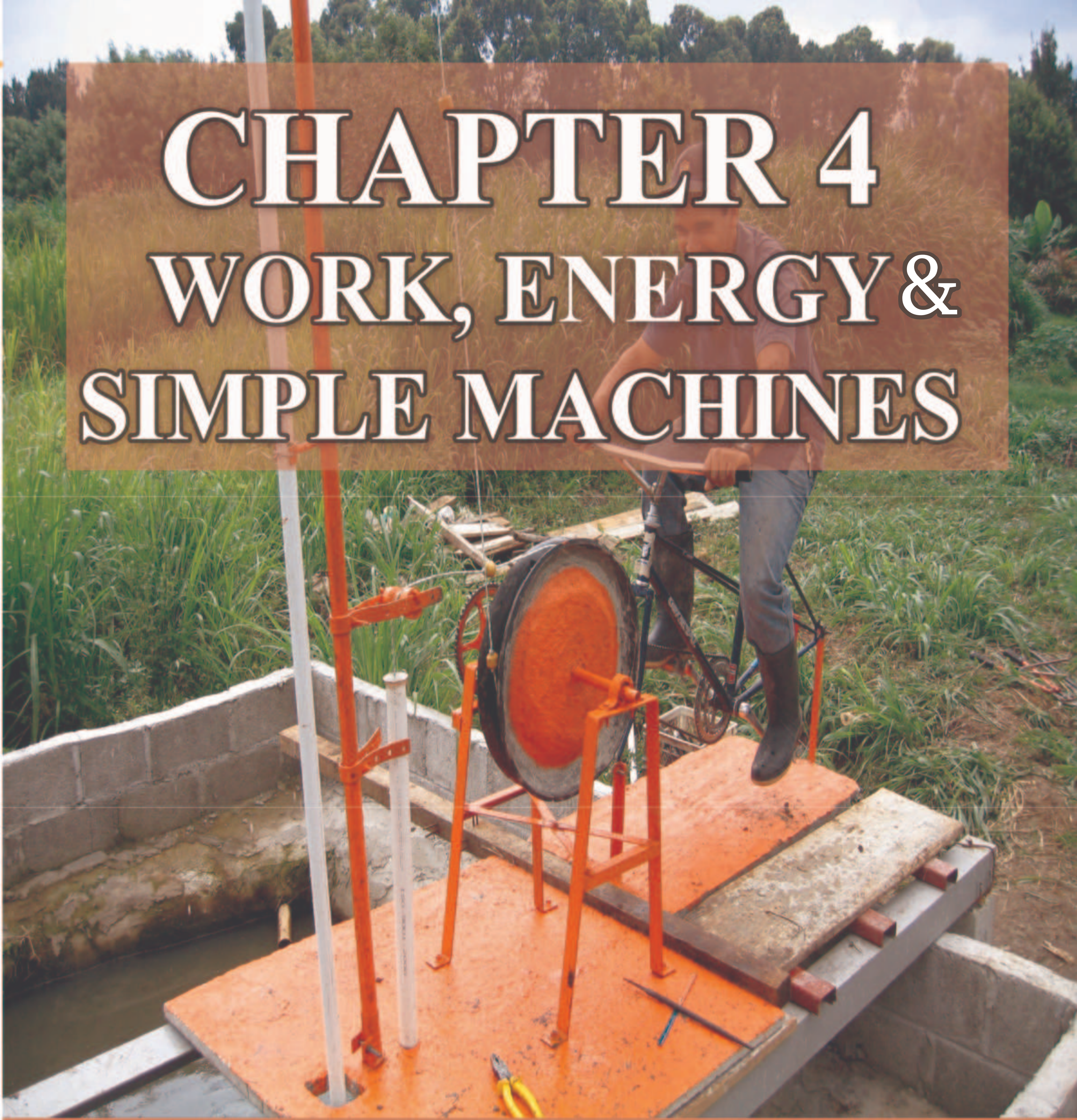
Q.5. A man standing in front of a mountain sends a sound and hear it's echo after 2 sec ,calculate the distance between the man and the mountain ? (consider the speed of the sound is 340 m / s).

Q.6. Under what conditions does resonance occur?

Q.7. Why do ultrasonic waves produce images of objects inside the body effectively ?

Q.8. Explain why the speed of sound in air depends on the temperature ?

CHAPTER 4
WORK, ENERGY & SIMPLE MACHINES



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Define the Work and its unit.
2. Define the energy and its unit.
3. Describe how to exchange energy.
4. Give some examples of conservation of energy.

Figure 4.1 Which of the above people are doing work? Explain your ideas.

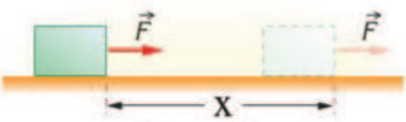


Figure 4.2

WORK

The word "work" in everyday life describes any activity which requires muscular or mental effect. But in physics, the concept "work" has a special meaning. In the scientific sense, it involves motion, and is done when a force changes the position or speed of an object.

Look at figure on the left. **Work** is defined as the product of the force applied upon an object and the **displacement** that the object is moved in the displacement of the force. Work can be expressed as a formula;

Work = Force × displacement in symbols, $W = FX$

where F is in newtons, and X is in metres.

From the equation, it can be seen that in the case of zero displacement there will be no work done. Therefore holding up a pair of binoculars, or reading a book are not examples of work, because no motion occurs.

Look at the figure below. When a force of 1 newton acts on an object over a displacement of 1 metre, however, the work done is equal to 1 Newton . metre (1 N.m).

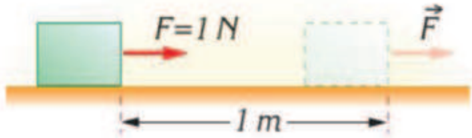


Figure 4.3

Note that, work has the units of force (N) and displacement (m). Therefore its unit is (newton . metre), but this unit has a special name: Joule (J).

$$1\ N \times 1\ m = 1\ N{\cdot}m = 1\ J$$

A larger unit of work is the kilojoule.

1 kJ = 1000 J.

A common unit of energy is called the calorie.

1 calorie (cal) is equal to 4.18 joules (J).

1 cal = 4.18 J

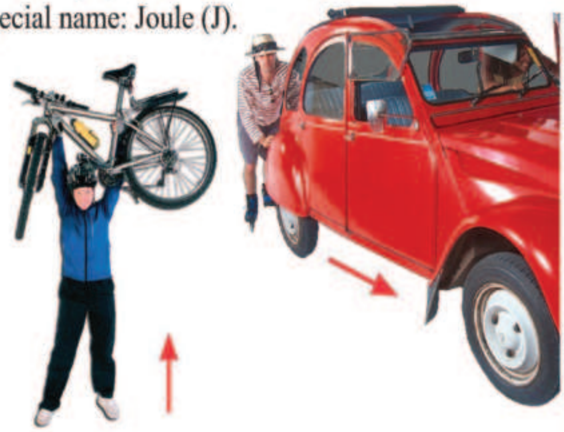


Figure 4.4 Pulling a lawnmower, lifting a bicycle and pushing a car are all work.

Example 1

An object is pulled 4 m on a horizontal surface by applying a force of 50 N. Calculate the work done on the object.

Solution

Calculating Work

What is asked in the question?

The work done on the object, W = ?

What is the information given?

displacement travelled, x = 4 m; force applied F = 50 N

What is the equation needed?

Work= Force . displacement

Calculation

W = F x

Enter the numbers into the equation.

W = 50 N×4 m

W = 200 N.m

Result : The work done is 200 J.

Exercise 1

A boy pushes a box 10 m on a frictionless surface by applying 200 N. Find the work done on the box. **Ans :** 2000 J

ENERGY

a) What is Energy?

If an object has energy it can do work, so we can define energy as the ability to do work. We do work by using energy, so we can say that work and energy should have the same units. Both work and energy are measured in joules (J).

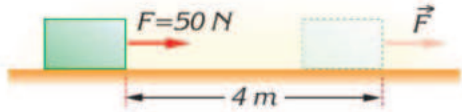


Figure 4.5

For instance, in Figure 4.5 the work done on the object is,

$$W = 50\ N \times 4\ m = 200\ J.$$

How much energy is spent? Since the energy spent is equal to the work done, the answer is: 200 J

Look at table below and state how much energy we spent in the listed activities.

Energy of 1 joule is equal to the energy used in lifting an apple from a table to your mouth.

b) Types of Energy

Energy exists in a variety of different forms; such as potential energy, heat energy, electrical energy, chemical energy, nuclear, sound energy etc. Here, the two main kinds of energy will be discussed: Potential energy and Kinetic energy.

Potential Energy

The hammer in the figure below is pivoted at point O. When we release it, it strikes the nail and drives it into the wood. By repeating this action, the nail completely enters the wood. To strike the nail, the hammer needs energy. Where does this energy come from? Besides the gravitational force, nothing affects the hammer, so the hammer gets its energy from its position. The higher the hammer is lifted, the more energy it gains and the farther the nail enters into the wood.

Table 4.1

Work done	Value
Opening a door	5 J
Throwing a brick	75 J
Climbing the stairs	1500 J

Some typical work values in daily activities.

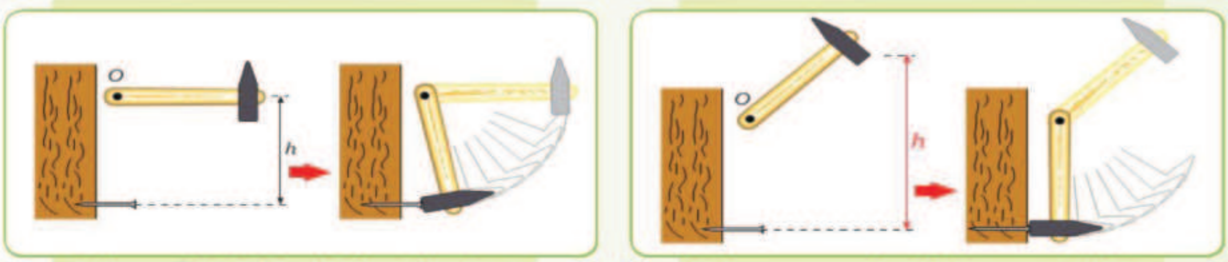


Figure 4.6 The higher the hammer is lifted, the more potential energy it stores.

Examine the illustration on the right. At the beginning two men try to lift a load from the ground. But one of them releases the rope. Now the load lifts the other man by doing work on him.

By raising an object from the ground to a height h, we change its position, so we do work against the force of gravity (Figure right). The work done on the object is stored as a type of energy. This energy is called potential energy. That is, potential energy is the energy an object attains due to its position.

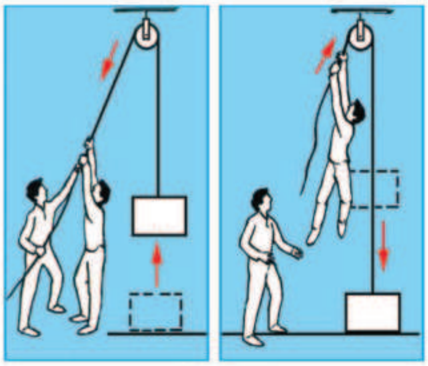


Figure 4.7

Figure 4.8 We store potential energy in the box by lifting it up.

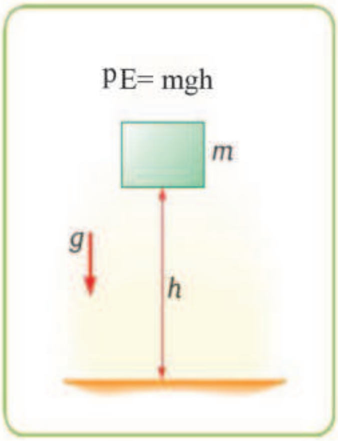


Figure 4.9

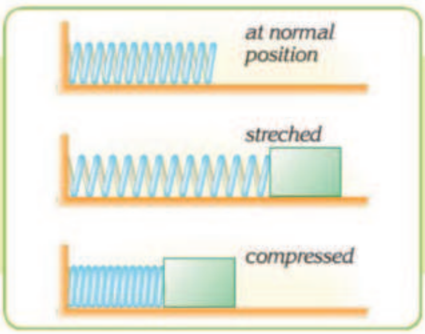
The potential energy of an object having mass m and height h is given as;

Potential energy = mass x gravitational field strength x height

in symbols;

$$PE = mgh$$

here m is in kg, g is 10 N/kg and h is in m (Figure 4.9).
Another example of potential energy is compressed or stretched springs. We use energy to compress, twist and stretch a spring, so our energy is transmitted and stored in the spring as potential energy.



A spring stores potential energy when stretched or compressed.

While travelling vertically upwards, the man gains potential energy.

Kinetic Energy

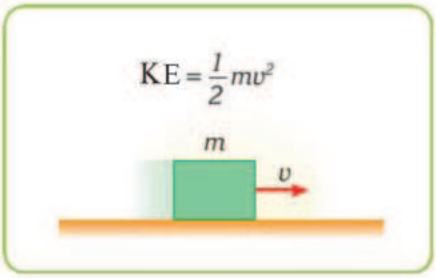


Figure 4.10

The energy of an object due to its motion is called kinetic energy. Put simply, kinetic energy is the energy of motion.(Figure **4.10)**.

Kinetic energy (KE) of a moving object at a speed v and mass m is given as;

$$KE = \frac{1}{2} m v^2$$

here m is in kg and v is in m/s. The faster a body moves, the more energy it has. Moving objects do work, because they have energy. For example, moving air (wind) turns windmills, falling water turns electric generators, a spinning propeller moves boats and turning wheels move vehicles etc.

Kinetic energy depends on speed and mass.

c) Changes of Energy

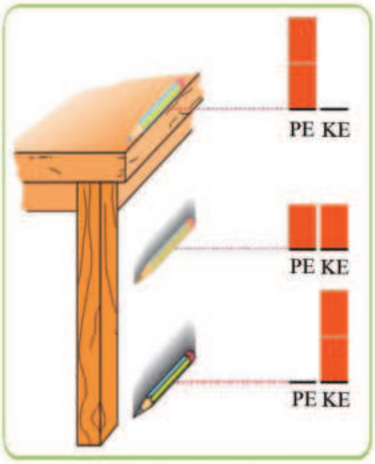


Figure 4.11 Changes of energy shown in bar graphics.

The total energy of an object does not change; while its potential energy decreases its kinetic energy increases, or while the kinetic energy of the object decreases its potential energy increases. Now let us study this in the example shown in Figure 4.11. A pencil falling off a desk loses potential energy but gains kinetic energy. Just before it strikes the floor, it has only kinetic energy, because all its potential energy has changed into kinetic energy.

Skiers go up hills to ski very fast. Since, the higher they go, the greater the potential energy they gain. A brick on a wall has a potential energy; when it falls down it gains speed, and so potential energy changes into kinetic energy (Figure 4.12).

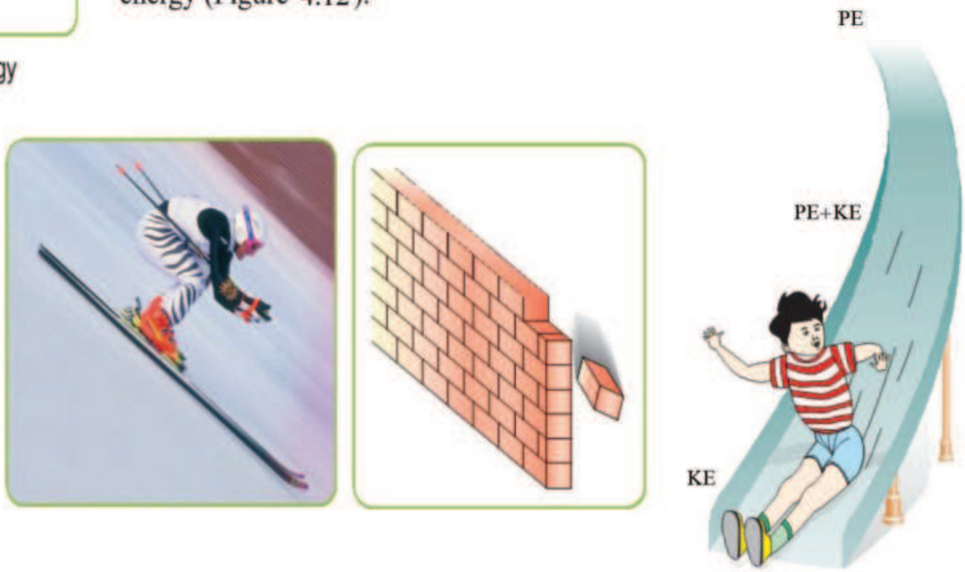
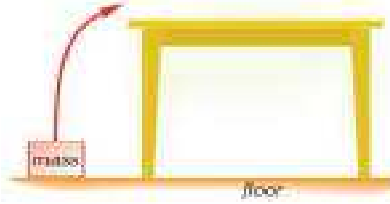


Figure 4.12 Examples of potential energy changing into kinetic energy.

Example 2

A man lifts up a 4.5 kg box on to a table which is 120 cm high. How much potential energy does the box gain? (g= 10 N/kg)



Solution

Calculating potential energy

What is asked in the question?

Potential energy gained, PE= ?

What is the information given?

Mass, m=4.5 kg; height, h=120 cm.

What is the equation needed?

PE= mgh

Calculation

First we should state the height in terms of m. Then write down the equation and enter the numbers into it.

h = 120 cm = 1.2 m,

PE = mgh

$$= 4.5\ \cancel{kg} \times 10 \frac{N}{\cancel{kg}} \times 1.2\ m$$

PE= 54 N·m

Result: The box gained an energy of 54 Joules.

Exercise 2

A man with his bag weight 700 N. If this man travels 15 m vertically upwards walking on the upstairs, how much energy does he spend?

Ans : 10500 Joule

Example 3

A cyclist has a mass of 43 kg and his bicycle weight 7 kg. If the cyclist moves with a speed of 4 m/s in the forest, what will his kinetic energy

Solution

Calculating kinetic energy

What is asked in the question?

Kinetic energy, KE = ?

What is the information given?

Mass of cyclist, m_c=43 kg, of bicycle m_b=7 kg; speed, v= 4 m/s.

What is the equation needed?

$$KE = \frac{1}{2} m v^2$$

Calculation

First we should find the total mass (m_t),

$m_t = m_c + m_b$

m_t = 43 + 7= 50 kg

Then enter the data given into the formula;

$$KE = \frac{1}{2} m\ v^2 = \frac{1}{2} 50 \times 4^2 = 400\ J$$

Exercise 3

A bird of 1.6 kg flies at a speed of 5 m/s. Calculate its kinetic energy.

Ans : 20 Joules

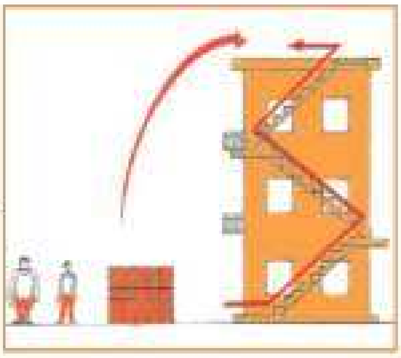
d) Conservation of Energy

Energy can be changed from one form into another. The total energy in nature never changes. This is known as the law of conservation of energy. If the total amount of energy never changes, where does the kinetic energy of a moving car get lost when it stops? Study the figure below.

An electric motor converts electrical energy into kinetic energy, but some of it turns into heat and sound because of friction. When a lamp glows, it turns electrical energy into light and mostly heat energy, so there is no energy loss, but just the conversion of energy into another form.

POWER

In daily life we hear about powerful cars, nuclear power or the power of motors. People usually talk about the power of men, animals and machines.



So what is the meaning of power?

"Power" has a special meaning in physics, like "work" and "energy". The following example may be useful in understanding the word "power". Let us suppose that we are constructing a building as shown in the figure on the right. There are two workers to carry up 200 bricks, which weigh 600 kg, to the third floor of an apartment, which is 9 m vertically above the ground. One of the workers can carry up the bricks in one hour, but the other can carry them up in two hours. If we ask which of them is the more powerful, what will the answer be? Of course the answer will be the first one, because he does the same work in a shorter time than the other.

In scientific terminology, *power* is defined as the amount of work done (or energy spent) in a unit of time. The unit of power is watt It can be stated as;

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \quad \text{or} \quad \text{Power} = \frac{\text{Energy spent}}{\text{Time taken}}$$

in symbols, $$P = \frac{W}{t} \quad \text{or} \quad P = \frac{E}{t}$$

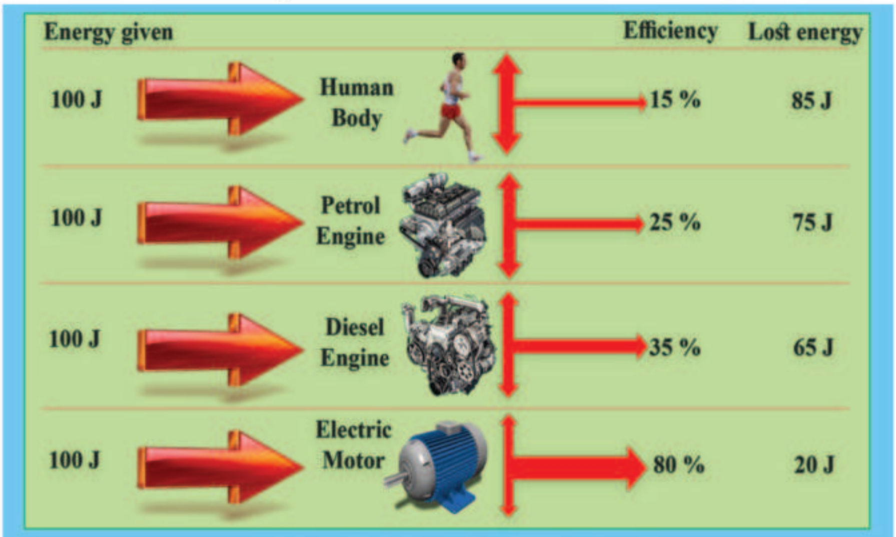
Efficiency is a measure of how well a machine works

The simple machines(real machines), however, are not frictionless. They dissipate energy when the parts of a machine move and contact other objects, some of the input energy is dissipated as sound or heat.

The efficiency of a machine is the ratio of useful work output to work input .

It is defined by the following equation

$$\text{Mechanical efficiency} = \frac{\text{output work}}{\text{input work}} \times 100\%$$



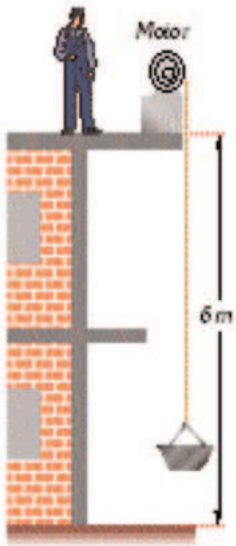
Some Examples of Efficiency

Example 4

The machine in the figure raises a 120 kg load vertically upwards to 6 m in 10 seconds.

a) Calculate the work done by the machine.

b) Calculate the power of the machine.



Solution

Work, energy and power

What is asked in the question?

Work, W = ?; power, P = ?

What is the information given?

Height , h = 6 m; mass of the load, m =120 kg , time t= 10 s and energy input = 9000 J.

What are the equations needed?

work = force × displacement

weight = mass × g

$$\textbf{Power} = \frac{\textbf{Work}}{\textbf{Time}},$$

Calculation

a) First of all we should find the work done by the machine.

The pulling force of the machine is equal to the weight of the load.

weight = 120 kg × 10 N/kg = 1200 N,

Work = weight of the load × height

W = 1200 N × 6 m = 7200 Nm = 7200 J.

b) Power of the the machine, P = W / t ,

P = 7200 J / 10 s = 720 watt

Exercise 4

A motor pumps 1000 kg water 10 m vertically upwards in 1 minute. Calculate its power. Ans : 1667 Watts

Many times in a day we do work which is beyond our limits of muscular force. In many cases, we move the objects by using simple tools. Door handles, keys, screwdrivers, can openers and mixers are a few examples of the simple tools

SIMPLE MACHINES

The "machine" is a symbol of modern life. A washing machine, sewing machine, vacuum cleaner, drier, car engine and a computer are all machines but rather complex ones. A simple machine may be much simpler than any of these. Simple tools with one or two parts are called simple machines. Complex machines are just a combination of simple ones.

Simple machines *are devices that work with one movement and a change in size or direction of the forces. Although simple machines provide the advantage of using less force and thus making the work easier, they do not reduce the amount of work.*

Simple machines *make work easier by providing a large force over a small distance derived from a small force over a large distance or by changing the direction of the applied force. There are always two forces related with a simple machine; the force which we apply to the machine is known as force (F) and the force which we have to overcome is known as resistance force (R) or load force (L).*

There are six kinds of simple machines; the lever, the pulley, the wheel and axle, the inclined plane, the screw and the wedge.

Tools are some examples of simple machines.

a) Levers

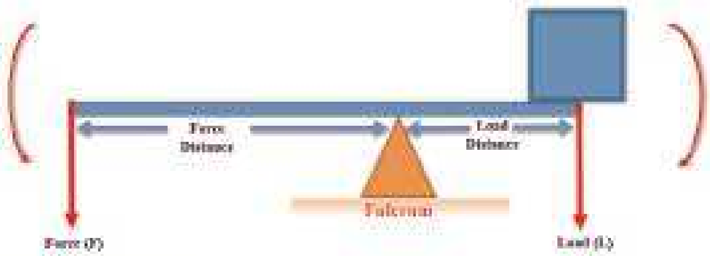
One of the simplest machines is the lever. A lever is simply a rigid bar which is free to move around a fixed point, known as the fulcrum or pivot.

We determine the class of the lever by noting the relative positions of the load, fulcrum and force.

1. First Class Lever

A first class lever is used to lift heavy loads with small forces. It has a fulcrum between the force and the load as in the figure on the right. Ifthe system is in equilibrium there are two equal turning effects but in opposite directions.

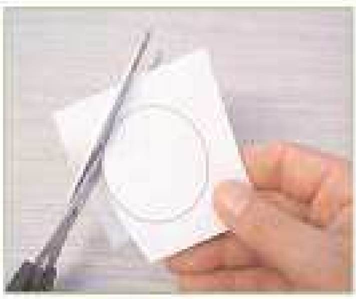
According to the law of levers we can write;



Force x Force distance = Load x Load distance

$$F \times d_F = L \times d_L$$

Scissors, see-saws, can openers, equal-arm balances and crowbars are some examples of first class levers. Study the figures below.

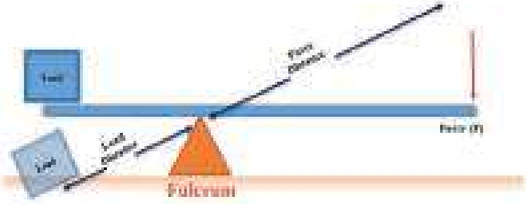


Scissors

Crowbar

Can opener

Some examples of first class levers



The force applied to the lever can be calculated from the law of conservation of energy too. look at the figure on the left and the equation shown below.

$$W_{\textit{done on the load}} = W_{\textit{done by the force}}$$

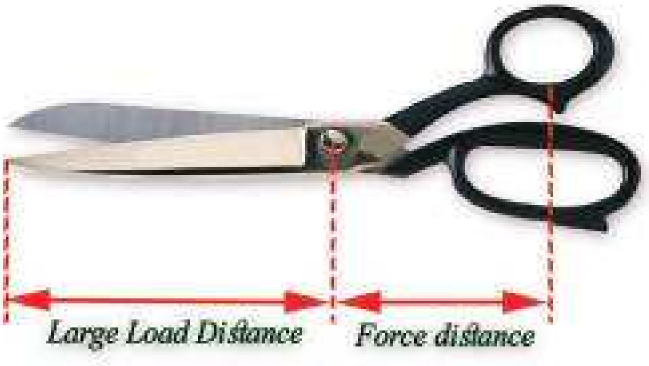
$$h_{load} \times F_2 = h_{force} \times F_1$$

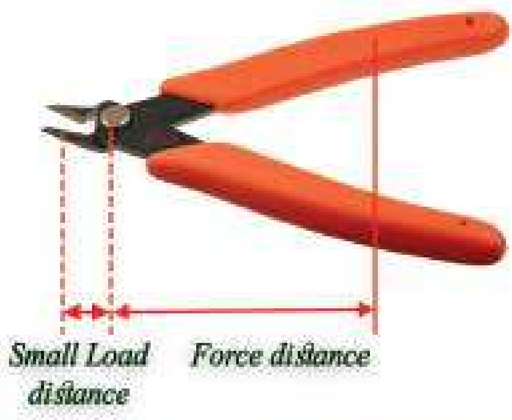
Mechanical Advantage of simple machines

As seen before, simple machines provide the advantage of using a small force to do work. The relationship between the load and the force acting on the simple machine is called the mechanical advantage In ideal conditions it is equal to the ratio of load to force. As a formula, it is stated as;

$$\text{Mechanical Advantage} = \frac{Load}{Force} \quad \text{in symbols,} \quad M.A. = \frac{L}{F}$$

If the mechanical advantage is 2, this result tells us that by using this lever a load can be lifted with a force half of the load. In other words, a force can lift a load two times greater. However, we cannot get the same result in daily life, because there are always energy losses in the moving parts of machines. Simple machines are manufactured for different purposes; for example a tailor needs scissors to cut cloth to long lengths with little force. However an electrician needs cutters to cut through hard materials in short distances with a greater force. Both scissors and cutters are levers.





Example 5

Calculate the force required to balance a load of 700 N using a lever 3 m long, The fulcrum is 1 m away from the load.

Solution

What is asked in the problem?

The force, F = ?

What is the information given?

Load, L = 700 N, length of the lever 3 m and the load distance, d_L = 1 m.

What is the relationship between load, load distance, force and force distance?

$$F \times d_F = L \times d_L$$

Calculation

First, we have to find force distance.

Force distance = length of the stick - load distance

Force distance = 3 m - 1 m = 2 m

Then, use the numbers in the formula to get the result.

$$700\ N \times 1\ m = F \times 2\ m$$

$$F = \frac{700N \times 1m}{2\ m} = 350\ N$$

Result: The force to balance the load is 350 N.

Exercise (5)

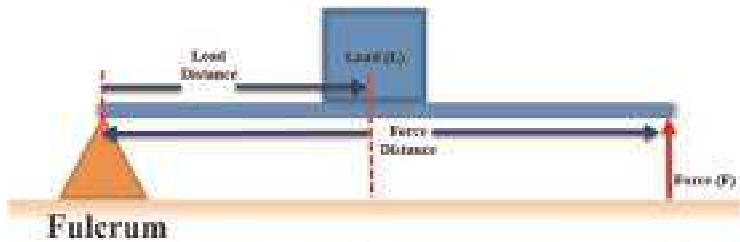
A lever 120 cm long is used to move a 80 kg load, the distance from the load to the fulcrum is 30 cm, find the force needed to lift the load.

Ans = 267N

2) Second Class Lever

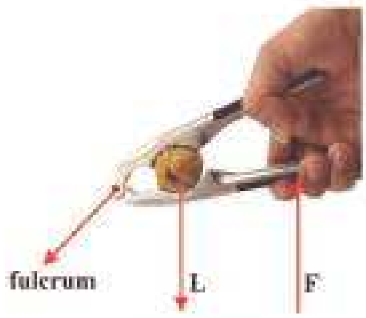
As shown in the Figure below a second class lever has the load between force and the fulcrum. From the law of the levers we can write;

$$F \times d_F = L \times d_L$$



A wheelbarrow, nutcracker and bottle opener are some examples second-class levers. Study the figures below.

Bottle Opener



Nutcracker

Wheelbarrow

Tools are some examples of simple machines.

Example 6

A man carries a 60 kg load using a wheelbarrow. What is the force the man applies for the values given in the figure. Find the mechanical advantage of the wheelbarrow?

Solution:

What is asked in the problem?

The force and mechanical advantage, F = ? M.A.= ? What is given in the problem?

Load, L= 60 kg; load distance, d_L = 40 cm and force distance, d_F =120 cm

What is the relationship between L, d_L, and d_F ?

$$W = m \times g, \quad L \times d_L = F \times d_F \text{ and } M.A = \frac{L}{F}$$

Calculation:

First we should find the load in newton,

$$W = 60 \text{ kg} \times 10 \text{ N/kg}$$
$$= 600 \text{ N}$$

Then enter the data given in the formula;

$$600 \text{ N} \times 40 \text{ cm} = F \times 120 \text{ cm}$$

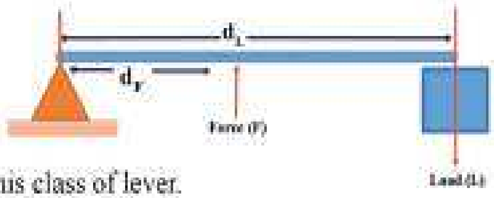
$$F = \frac{600\text{N} \times 40 \text{ cm}}{120 \text{ cm}} = \mathbf{200N} \qquad \mathbf{M.A.} = \frac{600\text{N}}{200\text{N}} = 3$$

Result : The force is 200N,and the mechanical advantage is 3.

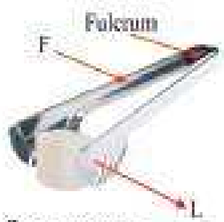
3) Third Class Lever

A third class lever has the force between the load and fulcrum, as shown in the Figure 4.22. A third class lever also obeys the law of the lever;

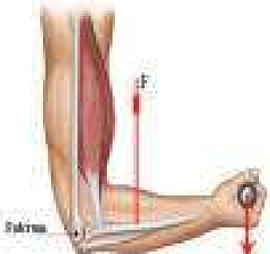
$$F \times d_F = L \times d_L$$



Sugar tongs, tweezers and forearm are good examples of this class of lever.

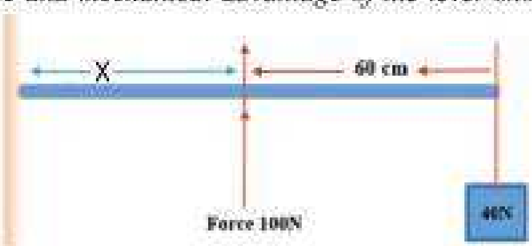


Sugar tongs



forearm

Exercise 6: *What is the load distance and mechanical advantage of the lever shown in the figure? (The weight of the rod is ignored) .*



Ans 1 m ,0.4

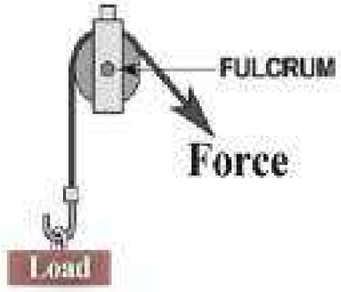
b) Pulleys

Pulleys have a wide range of uses in our lives. A winch uses a combination of pulleys to lift heavy loads. A pulley is a wheel which can rotate around an axle so that a rope can pass over it. Pulleys are used to change the direction or size of the applied force. For example, a pulley is very useful for pulling a flag to the top of a pole, otherwise we would have to climb up a pole to raise the flag (Figure right). There are two types of pulleys, fixed pulleys and movable pulleys.

Figure A fixed pulley is used to change the direction of an applied force

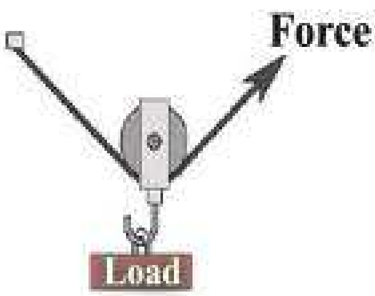
1. Fixed Pulley

A ***fixed pulley*** is used only to change the direction of applied force as shown in Figure below. If we neglect the friction in a fixed pulley, the force is equal to the load.



2. Movable Pulley

A ***movable pulley*** is a pulley which moves along a rope with the load attached to it (Figure below). A movable pulley is used to reduce the amount of force needed. Half of the load is necessary lift a given to load with a movable pulley, because each side of the rope supports the load in equal amounts. The mechanical advantage of a movable pulley is 2.



3. Block and Tackle

In many cases, to raise heavy loads a single pulley is not sufficient, a combination of pulleys might be necessary. A system of both fixed and movable pulleys is called a *block and tackle* see figure on the right. The pulleys are side by side, and are called *the block*, and the rope, going around the pulleys, is called *the tackle*. The number of movable pulleys increases the mechanical advantage of the system.

c) Wheel and Axle

A wheel and axle is also widely used in our daily lives. A doorknob, pencil sharpener and screwdriver are all examples of a wheel and axle. A *wheel and axle* is made up of a wheel and axle tightly attached to each other so that they turn together. If two wheels of different diameters are attached together, a wheel and axle is formed. Bicycles, cars, trains and almost all machines working with wheels use the wheel and axle principle. The illustrations on the right show how a wheel and axle works.

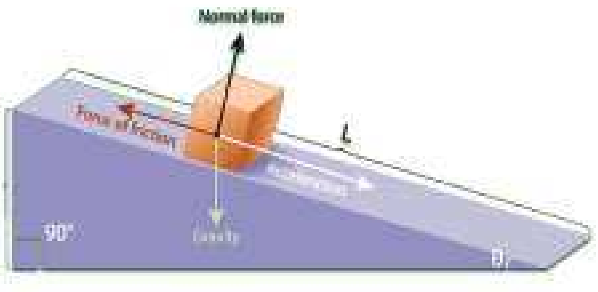
$$\textbf{M.A} = \frac{\textbf{Radius of wheel}}{\textbf{Radius of Axel}}$$

Bike sprocket gear is an example of a wheel and axle.

d) Inclined Plane

Another simple machine used to carry heavy loads is the inclined plane. An inclined plane is a smooth surface with one end higher than the other (See Figure below). It is an easy job to raise a heavy load using an inclined plane or ramp. Although the load is moved through a greater distance, less force is applied to raise the load. Due to the simplicity of the system, the inclined plane is known as the simplest of all the machines. Sloping roads and ramps are examples of inclined planes. **For a inclined plane the force calculated using the following formula :**

$$\textbf{M.A} = \frac{\text{Length of inclined plane}}{\text{height of inclined plane}}$$



e) Screw

Like a load moving up or down on an inclined plane under the effect of a force, a screw goes in or out of a bolt when a turning force is applied to it (Figure on the left).

In fact, a *screw* is a combination of both an inclined plane and a cylinder. A screw is a long slope turning around a pole, like a spiral staircase. To demonstrate how a screw works, cut a piece of paper in right triangular form and roll it around a cylinder as in Figure on the left.

f) Wedge

The wedge is another type machine consisting of an inclined plane having either one or two sloping sides (Figure on the right).

In a wedge, the sloping surface is pushed through the material which is held still.

Wedges are used to cut materials or raise heavy objects off the ground. A knife, nail, axe, chisel, needle, razor blade, saw, scissors and other cutting tools are examples of wedges.

$$\text{Mechanical Advantage} = \frac{\text{length of wedge}}{\text{width of wedge}}$$

g) Wheels and Gears

A wheel is kind of lever which can rotate around a fixed point continuously. The most important advantage of wheels is that they offer little friction. Car engines, lifting machines, pulley blocks, turbines, almost all kinds of machines and even clocks use wheels. Wheels have different uses in machines. Some of them are connected by belts while others have teeth around their perimeters. A gear is a wheel which has teeth to increase friction and prevent slipping. The wheels or gears are used to change the direction and/or speed of rotation.

CHAPTER QUESTIONS

Q.1 Use the words below in your own sentences

work, energy, potential energy, kinetic energy, power, **joule** , efficiency

Fill in the blanks with appropriate words

1. The work done when a force of 1 N acts over a displacement of 1 m is (N.m) or ....

2. .... can be defined as the ability to do work.

3. There are two main kinds of energy; .... and ....

4. .... energy is the energy of an object due to its position.

5. The energy of an object due to its motion is called .... energy.

6. When a pencil falls from a height its .... energy changes into .... energy.

7. .... is the work done in a unit time

8. The ratio of the output work to the input work is called ....

Q.2 Answer the following questions

1. Does a man do work when he carries a 75 N bag horizontally for 5 m? Why / why not?

2. Can an object have energy at rest? Why?

3. Give an example of an event where all of the potential energy is converted into kinetic energy or all of the kinetic energy is converted into potential energy.

4. Can an object do work at rest? Why?

5. State the various types of energy.

6. What is gravitational potential energy?

7. State the conservation of energy theorem.

8. Can work be performed without any force? Why / Why not?

9. What is the relationship between work and power?

10. Explain the energy changes occuring during the fall of a brick.

11. Search,how can we increase the efficiency of a machine?

Q.3 Solve the following problems

(Where necessary, take g = 10 N/kg.)

1. A boy of mass 50 kg climbs a wall 2 m high and then jumps to the ground.

a) How much work is done in climbing the wall?

b) What kind of energy and how much of it does he have just before he lands on the ground?

c) What happens to this energy after he lands?

2.
a) How much work is done when lifting a 2 kg mass to a height of 1 m?

b) What will be the total work done if this mass is lowered back to its original position?

3. A 10 kg object has a speed of 12 m/s.

a) Find E_K of the object.

b) If its speed is halved, what percentage of its energy is reduced?

4. A crane can lift a 450 kg mass through a vertical height of 16 m in 20 s. What is the power output of the motor driving the crane? If the motor has an efficiency of 60%, what power input is required?

(Where necessary, take g = 10 N/kg.)

Q.4 *Choose the correct answer for the following:*

1. In which action(s) below is there work performed?

I. Pushing a wall without moving it.
II. Taking a book from a table to a shelf higher up.
III. Pushing a pram.

A) I Only B) II Only
C) III Only D) II And III

2. Which of the events below is an action where no work is performed?

A) Loading some stones onto a lorry.
B) Walking on an inclined path.
C) Throwing a stone upwards.
D) Carrying a bag horizontally.

3. A man carrying a load of 6 kg runs upstairs. If the work that the man does on the load is 300 J, find the height of the stairs.

A) 3 m B) 5 m C) 6 m D) 10 m

4. A toy car is pulled with a force of 10 N for 5 m. If the friction force between the car and the surface is 5 N, what is the net work done on the car?

A) 50 J B) 100 J C) 200 J D) 25 J

5. A 15 kg object falls by 5m vertically. Find the decrease in potential energy of the object.

A) 75J B) 150J C) 750J D) 1500J

Q.5 *Use the words below in your own sentences* :

Simple machines, mechanical advantage, fixed pulley, inclined plane, wheel and axle

Fill in the blanks with appropriate words

1. The ratio of the load to the force is................
2. .... they do not reduce the amount of work
3. In a.......... the force is equal to the load if we neglect the firction
4. A doorknob is an example of .... and ....
5. .... is a surface with one end higher than the other.

Q.6 *Answer the following questions*

1. In simple machines does the work input equal the work output?
2. Some simple machines have mechanical advantages less than 1 and some others greater than 1. Why is this so? Explain using examples.
3. Draw a pulley system (block-and-tackle) consisting of 3 pulleys and a rope.
4. What do we use a fixed pulley for?
5. Classify the following objects into three groups as 1st class lever, 2nd class lever and 3rd class lever: door handle, tweezers, equal-arm balance, see-saw, scissors, wheel and barrow, pliers.

Q.7 *Solve the following problems*

1. If you use a bar 30 cm long with the fulcrum at one end, what force must you exert at a point 5 cm away from the fulcrum to lift a 15 N load at the other end of the bar?

2. What is the mechanical advantage of a wheelbarrow if the load distance (bucket) is 1 m from the fulcrum and force distance (handle) is 2 m from the fulcrum?

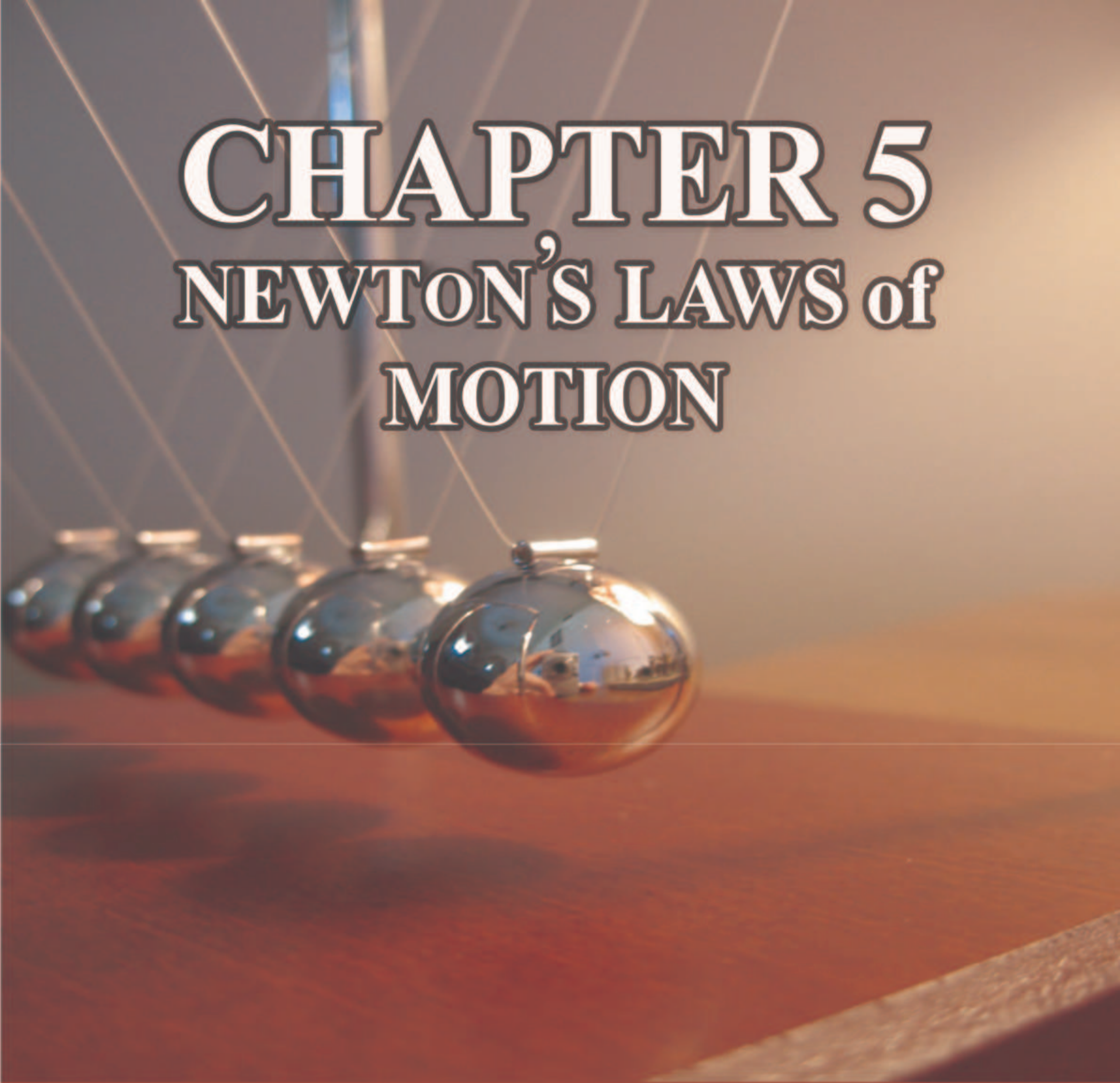
3. A nut is located 4 cm from the hinge of a nutcracker. If you exert a force of 10 N at a point 8 cm from the hinge, what resistance force does the nut exert?

4. What is the mechanical advantage of a single fixed pulley? How much rope must you pull over a fixed pulley to lift a 10 N load vertically by 2 m? How much work must you do?

5. A combination of pulleys lifts a 480 N load. The force moves 4 meters to lift the load 1 meter. What force is required?

6. An inclined plane 4 m long has one end on the ground and the other end on a platform 3 m high. A man wishes to push a 900 N object up this plane. Calculate the force that the man must apply.

CHAPTER 5
NEWTON'S LAWS of MOTION



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Define newton's Laws.
2. Write the mathematical equation for the 2nd newton's low.
3. Define the weights unit.
4. Describe the gravitational force.
5. Understand physical meaning of inertia.
6. Distinguish between mass and weight.
7. Understand free falling object.

THE FIRST LAW OF MOTION

Assume that an object is at rest in space, where no force acts upon it, as shown in Figure right. Unless a net force (unbalanced force) acts on it, it remains at rest. If the object initially moves with a constant velocity, it continues to move with the same constant velocity unless it experiences a net force.

From this simple experiment, the first law of motion can be inferred, it was stated by Newton more than 3 centuries ago as follows:

If the net force acting on an object is zero

→ If it is at rest, it will stay at rest.

→ If it is moving, it keeps on moving at a constant velocity (a constant speed in a straight line)

Figure 1 An object at rest in space where no force of gravity acts. Unless a net force acts on it, it remains at rest. If the object initially were moving with a constant velocity, it would continue to move with the same constant velocity until it experiences a net force.

a. Inertia

Inertia is the tendency of an object to resist any change in its state of motion.

If an object is at rest, it tends to remain at rest. If the object is in motion with a constant velocity, it tends to continue to move with the same velocity, (the same magnitude and direction)

The first law is often called the law of inertia because it states that in the absence of a net force, a body will preserve its state of motion.

The following situations can be discussed in order to understand the law of inertia. If you are in a car which is at rest.

→ As the car starts moving with an acceleration in a straight line, as shown in Figure 2 , you can feel the car seat exerting a force on your back which acts to push you forward. Since your body resists the change in its resting state, you experience and feel this force. This force overcomes your inertia and puts you in motion with the same velocity as the car.

Figure 2 As the car begins accelerating, the body resists the acceleration and tends to remain at rest due to inertia.

→ Let's assume that your car is taking a turn to the right, as shown in Figure 3 Your body resists the change in the direction of its velocity due to your inertia and tries to keep moving on the straight line. And you feel as though you are being pushed to the left.

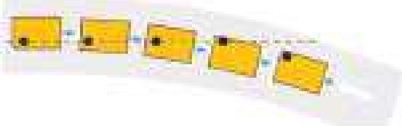


Figure 3 As the car takes a turn to he right, a body inside it resists the change in the direction of its velocity due to its inertia and tries to keep moving on the straight line

→ Finally if the car breaks suddenly, as shown in Figure 4 , since your body tends to move with the velocity that your car had before breaking, because of your inertia it reacts to this change in its velocity by moving forward.

Here are some other examples of inertia;

→ When a hard surface is struck with the back of a hammer, it stops suddenly and the hammer head feels tightened.

→ When a table cloth, on which there are some plates, is pulled rapidly from under the plates, the plates remain on the table.

→ When a sheet of kitchen paper is pulled slowly, more and more paper rolls off. However, when a sheet is pulled quickly, it is torn off the roll since the pulling force doesn't have enough time to overcome inertia

Figure 4 As the car slows down, a body inside tends to move with the velocity that the car had before breaking, due to its inertia.

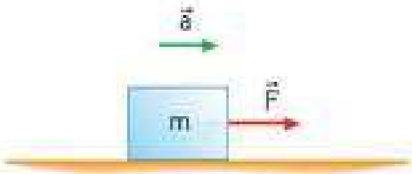


Figure 5 Force F causes the object of mass m to accelerate at a value of a.

THE SECOND LAW OF MOTION

The first law of motion describes what happens when the net force acting on an object is zero. In that case, the object either remains at rest or moves in a straight line with a constant speed. The second law of motion explains what happens when the net force acting on an object is not zero.

As stated in the simple experiment of the previous section, a net force acting on an object causes it to accelerate. Now assume that an object of mass m is pulled along a frictionless horizontal surface, exerting a horizontal force, F, on it as shown in Figure left . In this case, the net force acting on the object is F and the object gains an acceleration (a) If the force is increased to 2F, the acceleration increases to 2a. If the applied force is tripled, the acceleration triples and so on.

From such experiments it can be concluded that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

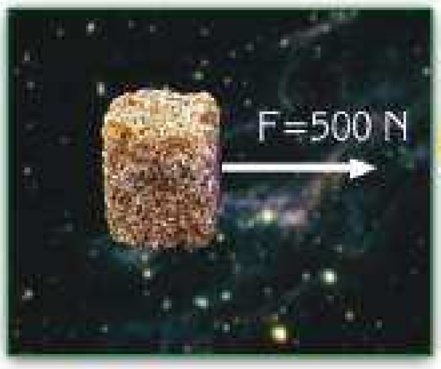
From all these experiments, the second law of motion is stated as follows

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. This law was discovered and formulated by Newton as

$$\vec{F}_{net} = m a$$

Note that net force and acceleration always have the same direction.
The unit of force, Newton, was derived from the equation of the second law of motion in terms of the fundamental units of mass, length, and time

$$1 \text{ N} = 1 \text{ kg} \cdot 1 \text{ m/s}^2$$



where 1 Newton can be defined as the force which produces an acceleration of 1 m/s^2, when applied on a 1-kg mass.

Example

A force of 500 N acts on a load of 250 kg which is at rest in space, as shown in the figure. Find

a) the acceleration of the load.

Solution

a) The force of 500 N is the net force acting on the object.
From the equation of the second law of motion we can find its acceleration.

$F = m.a$

$500 \text{ N} = (250 \text{ kg})a$

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

THE THIRD LAW OF MOTION

Newton realized that a single isolated force could not exist. Forces always occur in pairs. Thus, Newton stated the third law of motion as follows

When one object exerts a force on a second object, the second object exerts an equal but opposite force on the first.

The force that the first object exerts on the second is called an action force and the force that the second object exerts on the first is called a reaction force.

Figure 6 The Earth pulls on an apple, the apple pulls on the Earth

This law is sometimes expressed as

To every action there is an equal and opposite reaction.

These forces have the following properties

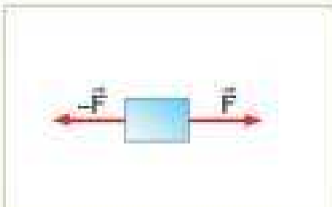


Figure 7 Two equal and opposite forces acting on the same object cancel each other.

→ Action-reaction pairs are equal in magnitude, but opposite in direction, and Due to the force $\overline{F}$, the apple accelerates towards the Earth. Also the Earth accelerates toward the apple due to the reaction force, $\vec{F}$. However, since the Earth has a huge mass, its acceleration is negligibly small.

→ Action-reaction pairs act on different objects. If two forces which are equal in magnitude and opposite in direction act on the same object as in Figure 7 the forces cancel each other. However, although action and reaction forces are equal in magnitude and opposite in direction, they do not cancel each other out, because they act on different objects. For example, when a force, F is exerted on a grocery cart by a shopper, as in Figure 8 the cart reacts on the shopper with a force of F. Since F acts on the cart and F acts on the shopper, the cart moves.

→ Action-reaction pairs are of the same type; either two contact forces or two field forces.

→ Action-reaction pairs act for the same time interval.

Figure 8 A shopper exerts a force on the grocery cart, and the grocery cart exerts an equal but opposite force on the shopper. Therefore these forces do not cancel each other out, since they act on different objects.

Here are some simple experiments of the third law of motion

1. Assume that you and a friend are standing on ice skates facing each other, as shown in Figure 9. If you push your friend away from you, you will observe that as he moves away from you, you will also move backwards because of his equal and opposite reaction force upon you.

2. You can only walk due to the reaction force of the ground on your shoes when you yourself exert an action force on the ground, as shown in Figure 10.

3. The tyres of a car push on the ground, thus, the ground pushes on the tyres, as shown in Figure 12, and the car moves.

4. Rockets also use the action and reaction principle. As a rocket pushes (action force) out a huge mass of exhaust gas downwards, as in Figure 11, the gas pushes (reaction force) on the rocket and the rocket moves upward.

Figure 9 Pushing a friend forwards means pushing yourself backwards

Figure 10 A pedestrian pushes the ground backwards; the ground then pushes the pedestrian forwards.

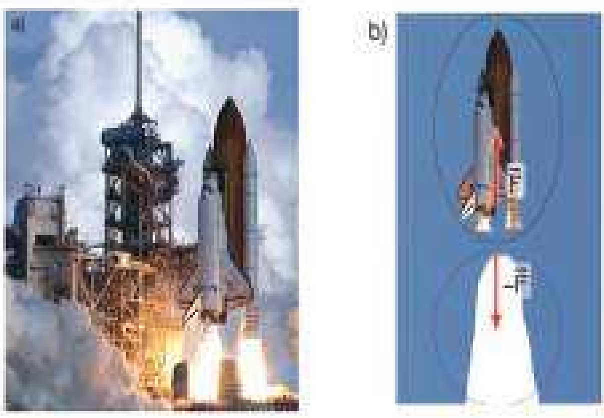


Figure 11 The rocket exerts an action force on the gas and the gas exerts an equal and opposite force upon the rocket. Thus, the rocket moves forwards

Figure 12 The tyres of a car push the ground backwards; the ground then pushes the tyres forwards.

Gravitational Force and Weight

An object released from a height falls to the ground. This indicates that there is a force acting on the object directed towards the centre of the earth. This downward force is called the gravitational force. It is not a force that exists only between the earth and objects. It exists between all objects. In other words, gravitational force is the force of attraction between any two objects (Figure 13).

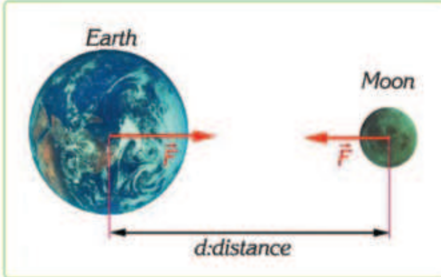


Figure 13 The gravitational force of the earth keeps the moon orbiting about earth.

Gravitational force depends on;
a) The masses of the objects,
b) The distance between them.

The greater the masses the greater the gravitational force. The larger the distance between the objects the smaller the gravitational force. It is the gravitational force of the earth that holds the moon in orbit, and the sun's gravitational force that keeps the planets in their orbits.

The force of attraction between an apple and a human body is too weak to feel less than one ten-millionth of a Newton (1/10 000 000 N). However, larger masses such as the sun, earth and moon have greater attractional forces. The pull on a 1 kg mass is about 10 N on the earth, 1.7 N on the moon and 280 N on the sun.

Weight

Weight is the gravitational force exerted on an object by the earth. Weight is measured in Newtons, because it is a kind of force. On the earth the force exerted on a 1 kg body is 9.8 N, but for simplicity in calculations, it is taken as 10 N/kg.

As shown in the figure above, a 1kg mass has a weight of 10 N, a 2 kg mass has a weight of 20 N, and so on, we calculate weight as follows:

Weight = mass × g in symbols, $W = m \times g$

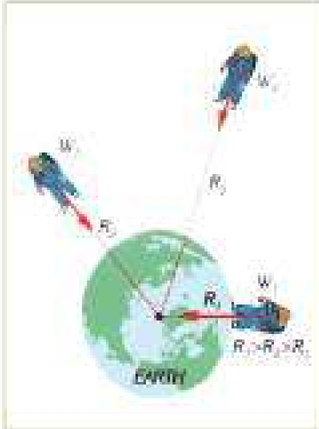
where g is the gravitational field strength. Near the earth's surface gravitational field strength is 10 N/kg. For example, if an object has a 20 kg mass, using the formula its weight is,

$$W = 20\ \text{kg} \times 10\ \text{N/kg} = 200\ \text{N}.$$

How does weight change?

Since the attractional force depends on the distance between the objects, the weight of an object on the earth depends on its distance from the earth's centre.

By increasing this distance, the gravitational pull of the earth (that is the weight of the object) reduces (Figure left). Near the earth, an object of mass 1 kg has a weight of about 10 N (Figure 14 A), whereas 22 000 km away from the centre, the weight of the object reduces to 1 N, see figure 14 B.



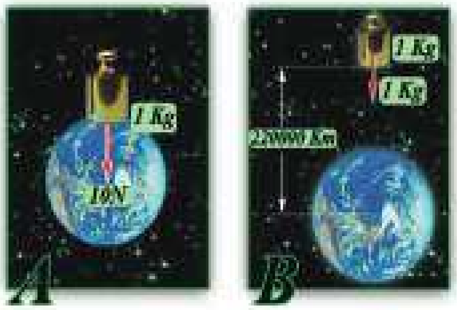


Figure 14 The weight of an object depends on it's distance from a given planet.

Figure 15 Changing weight of a body over the surface of the earth.

Earth is not a perfect sphere. It is compressed at the poles. The poles are slightly closer to the centre of the earth than the equator. Therefore the weight of an object slightly changes from one place to another on earth. A 1 kg mass weighs most at the poles (9.83 N) and least at the equator (9.78 N).

A body having a weight of 600 N at the equator would have a weight of 603 N at the poles (Figure 15)

The weight of an object also changes from one planet to another because all planets have different gravitational field strengths (g). If an object could be sent into deep space and away from all gravitational forces, it would become weightless. (Figure below)

The weight of an object on the moon is less than on earth, because the moon is smaller than earth. A mass of 1 kg weighing 10 N on earth weighs 1.7 N on the surface of the moon. For example a man weighing 400 N on earth weighs 67 N on the moon (Table below)

Table

Planet	Gravitational Field Strength		Mass	Weight
Mercury	3.78 N/kg	×	40 kg	= 151 N
Venus	8.94 N/kg	×	40 kg	= 358 N
Earth	10 N/kg	×	40 kg	= 400 N
Moon	1.7 N/kg	×	40 kg	= 67 N
Mars	3.79 N/kg	×	40 kg	= 152 N
Jupiter	25.4 N/kg	×	40 kg	= 1016 N
Saturn	10.7 N/kg	×	40 kg	= 428 N
Uranus	9.2 N/kg	×	40 kg	= 368 N
Neptune	12 N/kg	×	40 kg	= 480 N
Pluto	0.3 N/kg	×	40 kg	= 12 N

Comparing weight and mass

Weight is the pulling force applied on an object, and varies from one place to another. It is measured in newtons, but mass is measured in kg and is the same everywhere. However, the kilogram is used, wrongly, as a unit for both mass and weight, because of the way balances and sets of scales are marked. For instance the box of sugar in the figure does not "weigh" 1 kg. It has a weight of about 10 N on earth, and a mass of 1 kg.

FREELY FALLING OBJECTS

A common example of one-dimensional motion with constant acceleration is that of an object falling freely towards the Earth. If air resistance is neglected as well as any small variations in gravity with altitude, all objects, regardless of their mass and size, fall with the same acceleration towards the centre of the Earth. This constant "acceleration of free-fall" is denoted by g, which has the value 9.8 m/s^2. The motion of an object in a vertical line (rising as well as falling) with a constant acceleration of g in the absence of air resistance is called free-fall. Compare the motion of a rock and feather in the presence and absence of air resistance in Figure 16

Figure 16

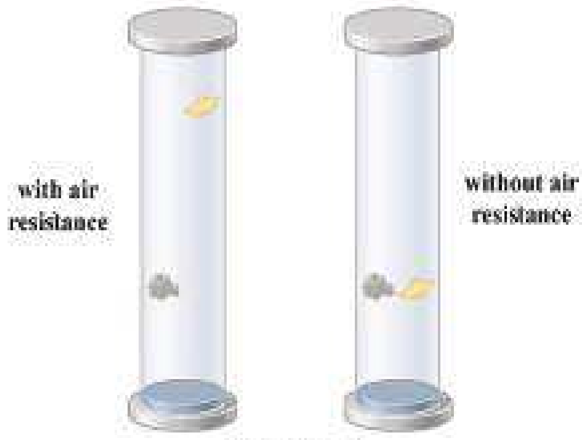


Figure 17

The positions of the rock and the feather are shown at a given instant as they fall freely in the absence and the presence of air.

There is more resistance acting on the feather, so the stone falls earlier in the first tube. However, they fall at the same rate in the absence of air resistance in the second tube.

CHAPTER QUESTIONS

1. Explain the first law of motion and inertia

2. If a body is stationary, can we say that there is no force acting on it?

3. If no net force acts on a body, is it possible for it to move?

4. Explain the second law of motion

5. Express the unit Newton in terms of base SI units.

6. If there is only one force acting on a body, can it be at rest?

7. If the acceleration of a body is zero, can we say that no force acts on it?

8. Is the motion of bodies always in the same direction as that of the net force?

9. Can the direction of the net force acting on an object be opposite to that of its acceleration?

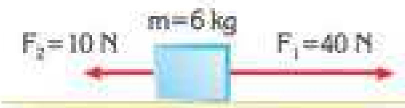
10. To which law of motion is the operation of car seat belts related?

11. Which forces act on an apple when it
a) remains on a tree?
b) falls from a tree?
c) remains on the ground?

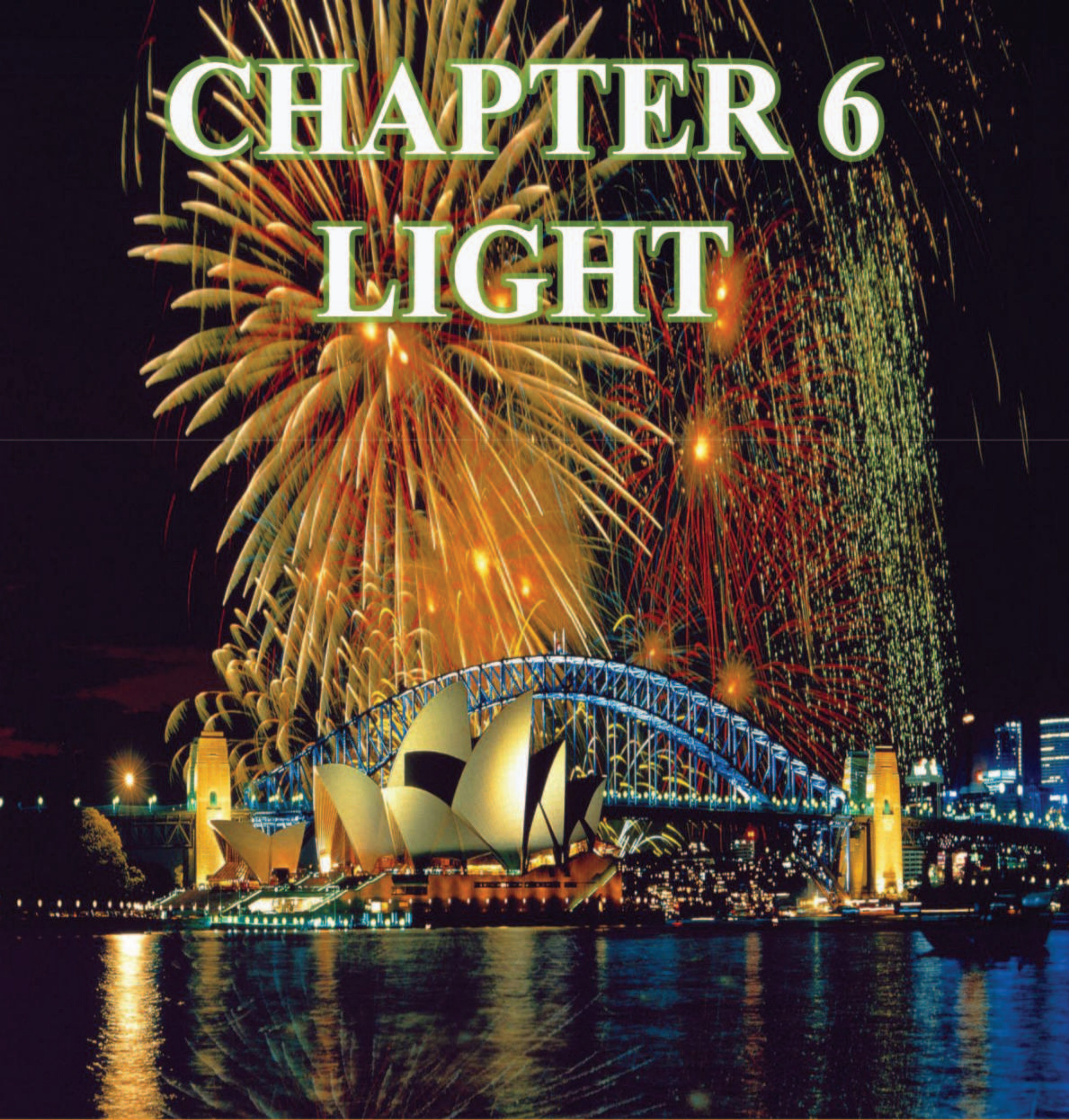
12. According to the third law of motion, when you push somebody, he does not have a right to complain about you. Why?

13. Find the acceleration of an object experiencing a force F=120 N, as shown in the figure. (The surface is frictionless).

14. Find the acceleration of an object on a smooth surface, as shown in the figure.acting on him.



CHAPTER 6
LIGHT



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Express the Light.
2. Compare between Luminous and illuminous objects.
3. Describe how the Light pass through the matter (transparent, opaque, translucent).
4. Understand what shadow is?

Light

LIGHT

Light is a kind of energy, it is essential in order to see things. In the dark we cannot see. Look at the pictures in figures 6.1-6.2

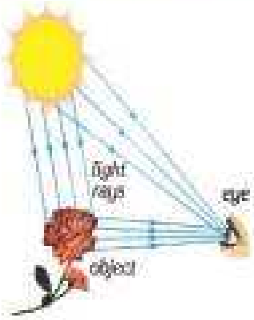


Figure 6.1

Figure 6.2 Light makes things visible.

a. How do we see?

To be able to see an object, light from the object should enter the eye either directly from the source or indirectly by reflection as shown in figure right.

Luminous and illuminous objects

An object which produces its own light is called a luminous source. Sun, stars, glow-worms etc. are self luminous natural sources. Lamps, candles, and torches are artificial light sources.

Objects such as the moon and mirrors are not light sources, because they just reflect the light falling upon them.

Does light pass through all matter?

Light cannot pass through all materials. Glass, air and water are some substances which allow light to pass through them. These substances are called transparent. Wood, iron and concrete don't allow light to pass through them, so they are called opaque. Materials which only allow some light to pass through them are called translucent. Waxy paper and frosted glass are examples of translucent materials as shown in figure 6.3.

Figure 6.3

How does light travel?

Light travels in straight lines. We use arrows to indicate the direction of light. We call these lines rays of light (Figure 6.4).

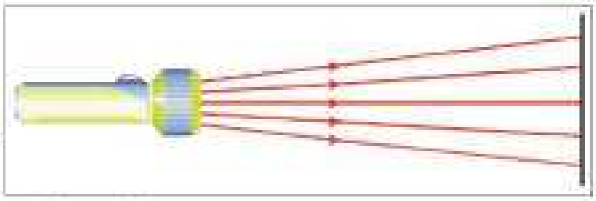


Figure 6.4 Light rays travel in straight lines.

b. What is shadow?

If an opaque object is placed in front of a light source, some light rays are blocked by the object, while others continue to travel. As a result, a dark region forms behind the object. This dark region is called a shadow.

Usually a shadow has a completely dark region in the centre, which we call the umbra and a partial shadow around it, which we call the penumbra. The penumbra is the region extending from the very dark to the bright area. Figure 6.5 shows the regions of the umbra and penumbra.

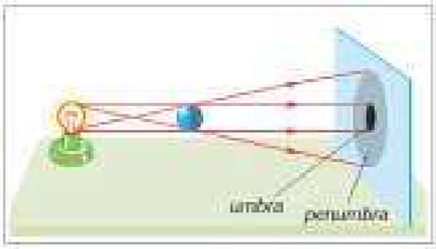


Figure 6.5 Formation of umbra and penumbra

Dark shadow (Umbra)

The light bulb is a large light source. It cannot form shadows with sharp edges. A dark shadow with sharp edges can be for med with a point light source. A point light source can be made when a piece of card with a pin hole in the middle is placed in front of a lamp. See the Figure 6.6.

In some hot countries houses are built close to each other so that each one is under the shadow of another.

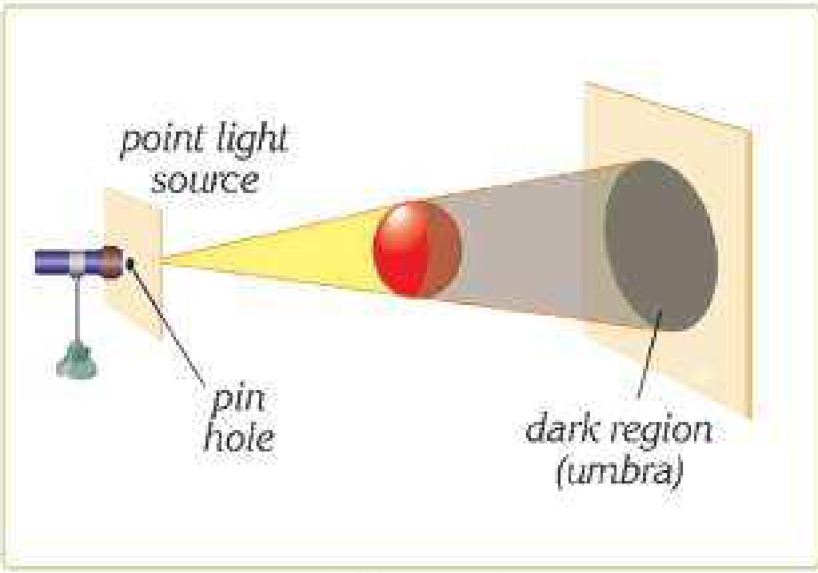
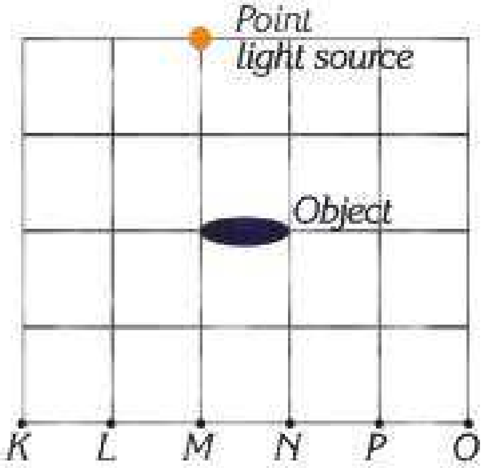


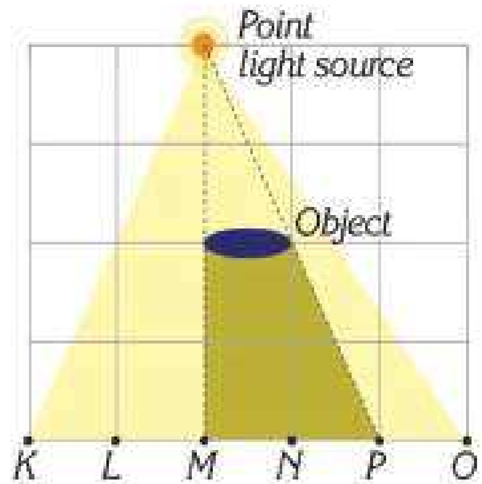
Figure 6.6

Example 6.1 **An opaque object is placed in front of a point light source as shown in the figure. Locate the region where a shadow forms when the source is on.**



Solution

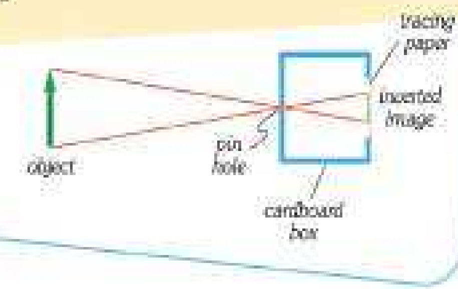
Light travels in straight lines and cannot pass through opaque objects. Thus a shadow forms behind it. Look at the drawing below, the region between the points M and P are dark, other regions are bright.



Pinhole camera

A pinhole camera is an instrument that we can use to observe light travelling in straight lines. It is a small closed box with a pinhole in the front and a screen at the back. The figure below shows how the pinhole camera works. To locate the image on the screen, two rays from the object are enough. In fact, many rays coming from the object pass through the pinhole.

The picture formed on the screen is called the *real image* since it is formed by rays travelling from the object. The image is inverted. That is, it is turned upside-down and left-to-right.



c. Does the Moon block sunlight ?

The Moon revolves around the Earth, and similarly the Earth revolves around the Sun. Occasionally the Earth and the moon enter each others dark regions.

Solar eclipse

When the Moon enters the region between the Sun and the Earth, the Moon blocks sunlight! As a result a shadow forms on Earth. This is called a solar eclipse. See the figure 6.7.

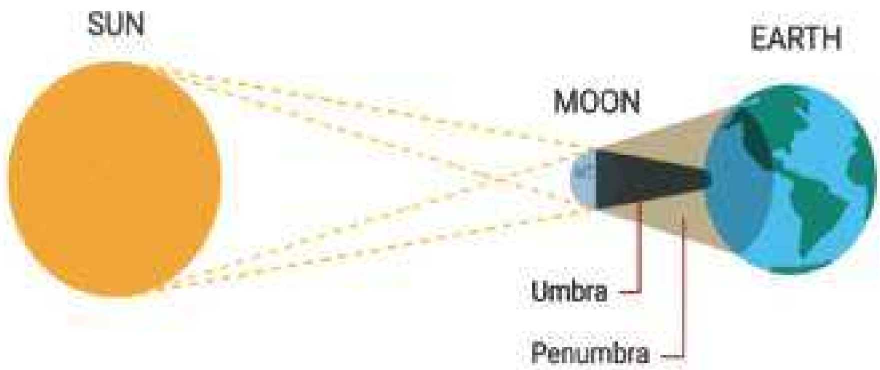


Figure 6.7 Illustration of solar eclipses

During a solar eclipse, observers in the dark region see only the flames around the outer edge of the Sun. This is called a total eclipse. A total eclipse of the Sun occurs only rarely. The observers in the penumbra can see some parts of the Sun. This is called a partial eclipse.

Lunar eclipse

This occurs when the Earth enters the region between the Moon and the Sun, During a lunar eclipse we cannot see the Moon, because it is in the shadow of the earth. Unlike a solar eclipse a lunar eclipse occurs frequently.

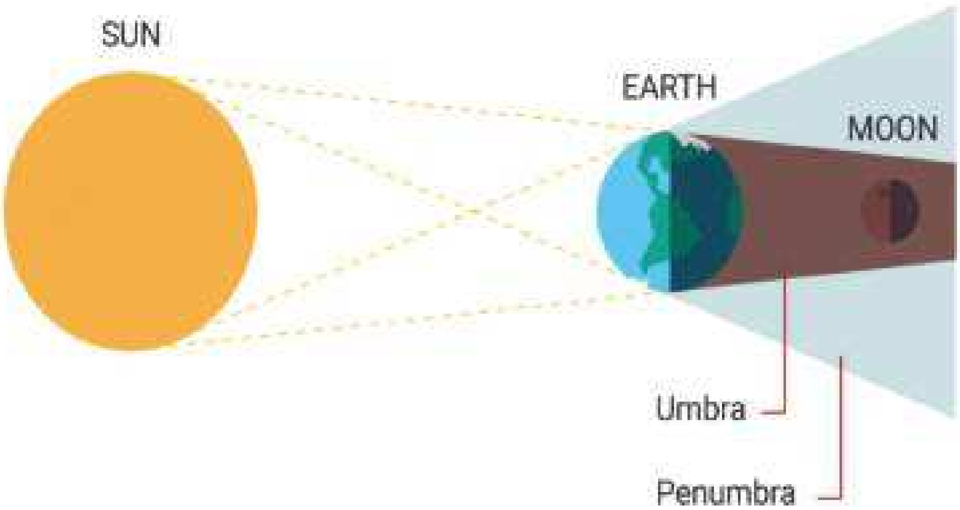


Figure 6.8 Illustration of lunar eclipses

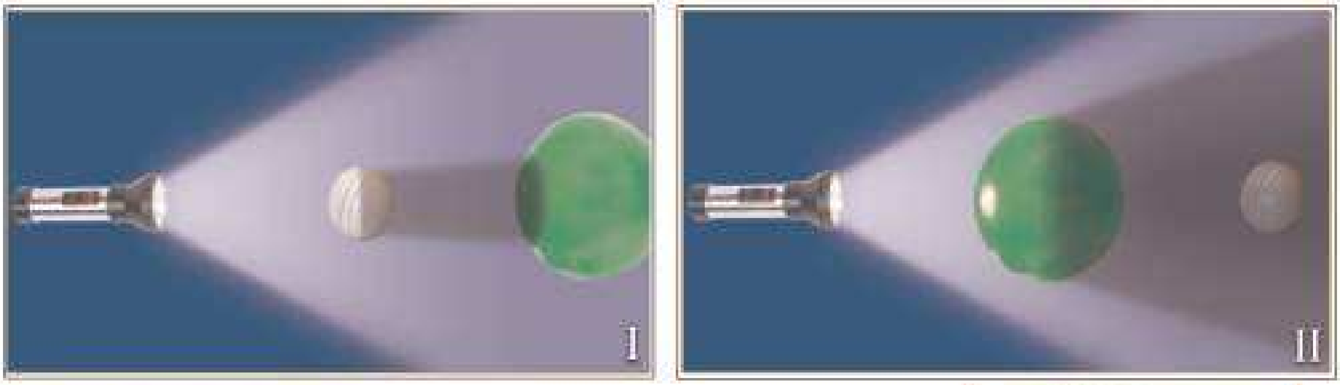
Activity: How are eclipses formed?

Materials: A light source (i.e. a torch), a big ball and a small ball.

Procedure: Assume that the light source represents the Sun, the big ball represents the Earth and the small ball represents the Moon.

Place them as shown in figure I. Turn on the light. Which ball is in the shadow?

Now, arrange them as shown in figure II. Where does shadow form on the Earth?



Where do we need shadows?

In some cases we need shadows. For example on hot sunny days, we prefer to sit under a tree or a large umbrella and use hats with brims. Car drivers use sun visors to keep sunlight out of their eyes. These examples are show in figures 6.8.

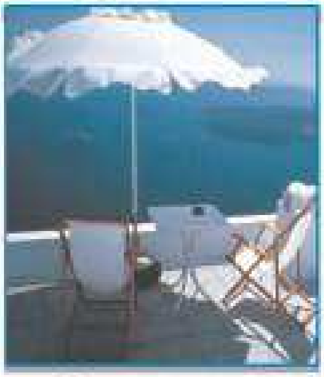


Figure 6.8 Umbrella forms shadow

Sunglasses also form partial shadows on our eyes and protect them from excessive sunlight.

Why does a candle not illuminate the region below it?

A candle illuminates the space around it, but not below it. This is because light travels in straight lines. The upper end of the candle stops light reaching the bottom. As a result, a shadow forms in this region.

d. The speed of light

Light travels at a speed of 300 000 km/s. That is, it covers 300000000 m in one second. The speed of light depends upon the medium the light is travelling in. The speed of light is about 225000 km/s in water and about 200000 km/s in glass.see figure **6.9**

What is a light year? A light year is the distance travelled by light in one year. The distance between stars is so great that it is not practical to express it in metres. Instead we use the light year as a unit of distance. Let's find a light year in kilometers.

Figure 6.9 Light from the Sun takes more than 8 minutes to travel to Earth.

1 year = 365 days; 1 day = 24 hours; 1 hour = 60 min; 1 min = 60 s.

1 year = $365 \cdot 24 \cdot 60 \cdot 60$ s = 31 536 000 second.

Distance is given with the formula; distance (d) = speed× time

Light travels 300 000 km in one second. So in one year it travels;

d= 300 000 km/s× 31 536 000 s = 9 460 800 000 000 km.

Example 6.2

The distance between the Earth and the Sun is 150 000 000 km. Calculate the time it takes sunlight to reach the Earth.

Solution

$$time = \frac{distance}{speed} = \frac{150\,000\,000 \text{ km}}{300000 \text{ km/s}} = 500 \text{ s}$$

t = 500 seconds

1 min=60 seconds so

500 sec=8 min 20 sec.

Exercise 6.1

The distance between the Earth and the Moon is about 384 000 km. Calculate the time it takes for light to travel from the Moon to Earth.

Ans: 1.28 s

CHAPTER QUESTIONS

Use the words below in your own sentences

self luminous, transparent, opaque, translucent, umbra, solar eclipse, lunar eclipse, speed of light

Fill in the blanks with appropriate words

1. Light is a kind of ....

2. Light travels in .... lines.

3. Glass is a .... material.

4. .... is the region from the very dark to the partially bright area.

5. Sometimes the Moon enters the shadow of the ....

6. Light travels .... km in one second.

Answer the questions

1. Name three luminous objects.

2. Does light pass through every type of matter? Explain.

3. Which places around you form shadows on a clear sunny day?

4. Which kind of shadow usually occurs on sunny days? On cloudy days?

5. How does a sun clock work?

6. Keep your hand over white paper under a lamp. You will see that a shadow forms on the paper. Now move your hand towards the lamp, and then away from the lamp. How does the size of the shadow change?

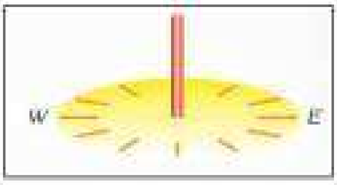
7. Explain how solar and lunar eclipses occur using diagrams. Show all the parts of the shadow, umbra and penumbra.

8. Explain using a diagram, how a pinhole camera works

Solve the problems

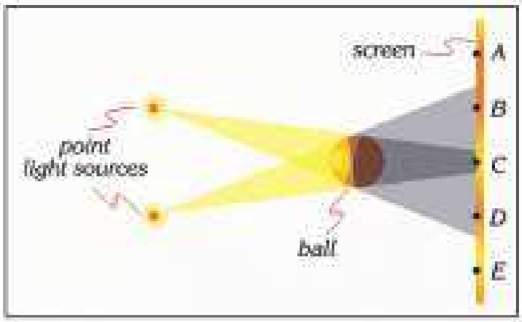
1. Calculate, how many kilometers light travels in space:
a. in a day
b. in a week
c. in a month

2. A rod fixed in the ground as shown in the figure can be used as a sun clock.
When is the shadow of the stick,

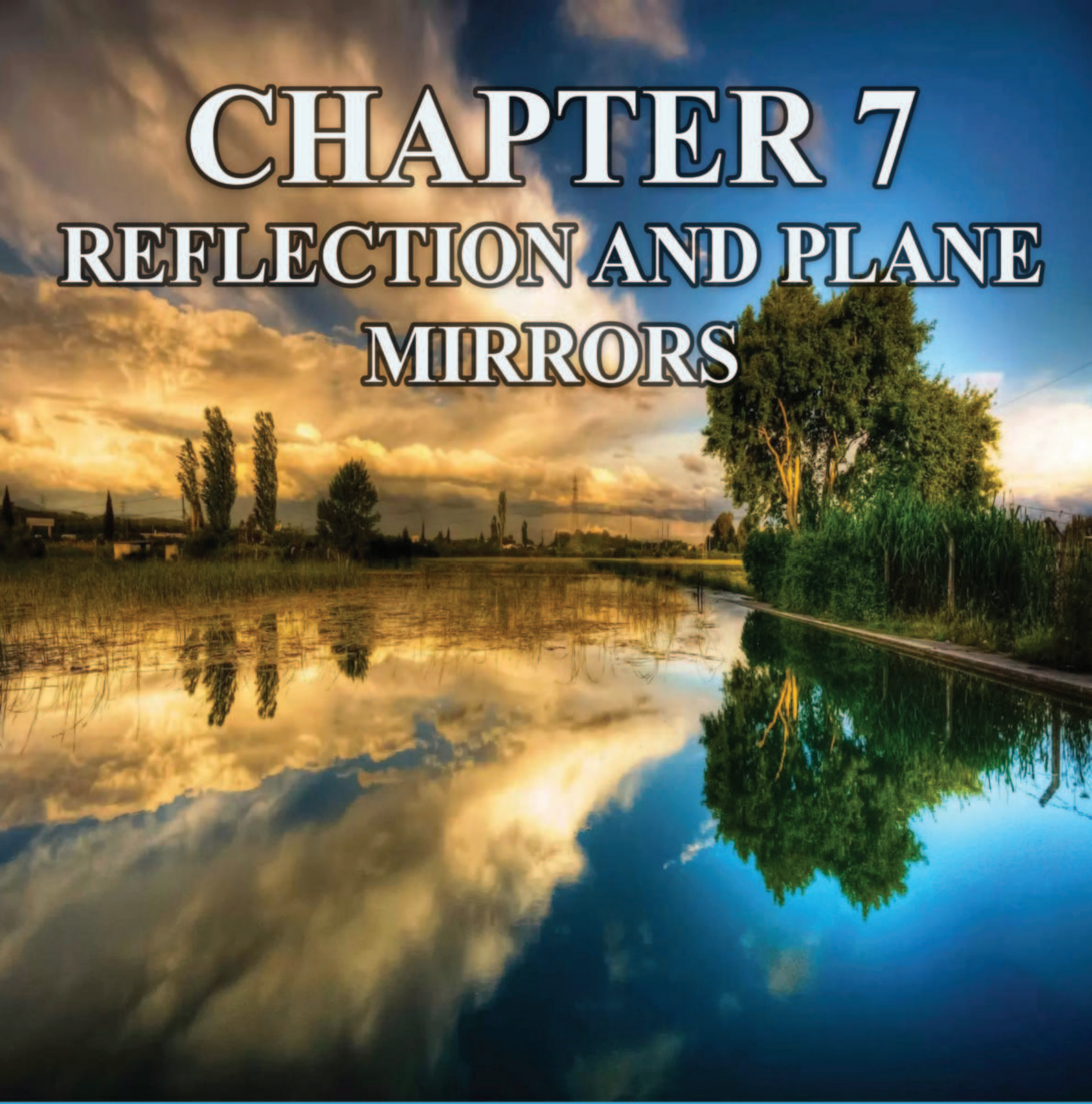


a. longest?
b.smallest?
When is the shadow directed towards the west?

3. In the figure below, which points on the screen are
a. illuminated?
b. in the umbra?
c. in the penumbra?



CHAPTER 7
REFLECTION AND PLANE MIRRORS

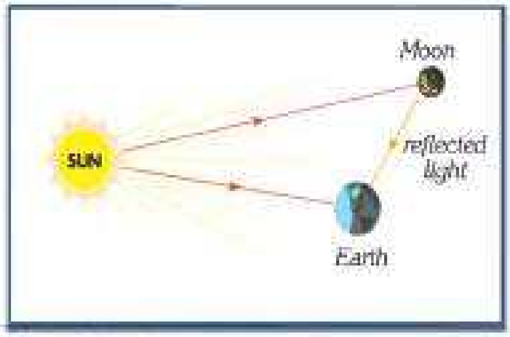


PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Know the physical meaning of Reflection.
2. Define the Laws of Reflection.
3. Listed the type of Reflection.
4. Describe how we see images.
5. Represent the reflection graphically.
6. Give some uses of plane Mirrors.

7 REFLECTION AND PLANE MIRRORS



a. What is a reflection?

We see objects because they produce or reflect light falling on them. During the day we see the Sun and at night we see the stars because they produce light. We also see the environment in the daytime and the Moon at night, because both of them reflect light coming from the Sun.

If light does not enter our eyes from an object, we are not able to see it. This explains why we can see stars but we cannot see space. We will nowfind out how light reaches our eyes from objects.

When light rays strike a mirror, they are reflected as shown in the figure 7.1 . The line perpendicular to the point where the light strikes the boundary is called the normal and it is represented by N. The angle between 'N' and the mirror is 90°.

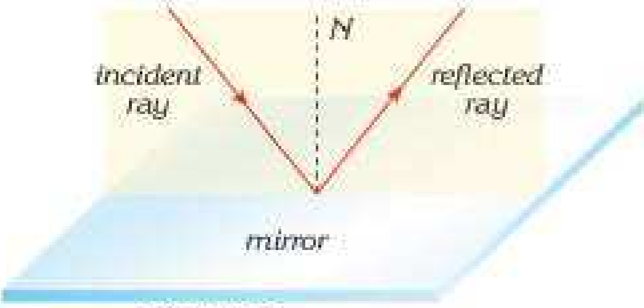


Figure 7.1

The angle between 'N' and the incident light is called the angle of incidence. The angle between 'N' and the reflected light is the called the angle of reflection. See Figure 7.2.

Figure 7.2

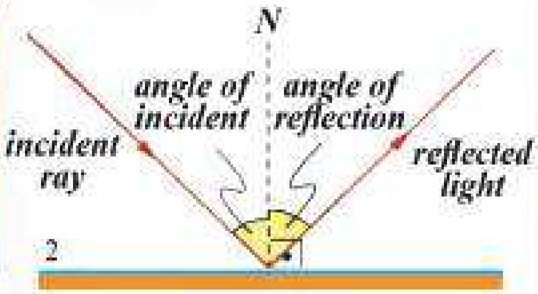


Figure 7.3

Laws of reflection

There are two rules for reflection of light:

1. The angle of incidence is equal to the angle of reflection.

2. The incident ray, the reflected ray and the normal are all in the same plane.

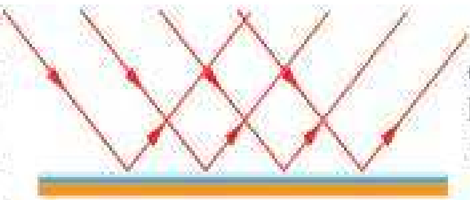
b. Types of reflection

Many objects reflect light in all directions. But objects which have smooth surfaces reflect almost all light in one direction. For example mirrors and polished metal surfaces reflect light in a regular way as figure 7.3.

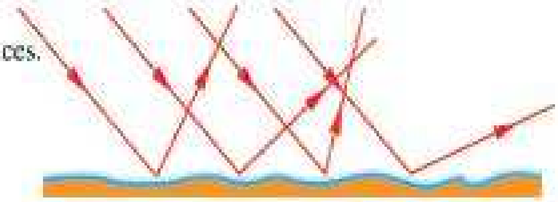
This kind of reflection is called regular reflection.

Many surfaces are not shiny, but rough. Rough surfaces reflect light in all directions as shown in the figure to the right. This kind of reflection is called diffuse reflection. see figure 7.4.

This page of the book, leaves, walls etc. are examples of rough surfaces.



on a smooth surface **Figure** 7.3 Regular reflection



on a rough surface **Figure** 7.4 Diffuse reflection

c. Plane mirror and image formation

A plane mirror is a flat, smooth and shiny surface. It reflects light in a regular way. It is made of a flat piece of glass with one side coated in silver.

Plane mirrors form the image of objects in front of them. When we look into a plane mirror, we see our images. Give examples of what we use plane mirrors for.

Figure 7.6

How does an image form?

To describe the image formation of a point in a plane mirror, we need to construct at least two light rays coming from it.

The figure 7.5 illustrates the image formation of the point X. The rays coming from the point X are reflected by the mirror obeying the laws of reflection. If we take the extension of the reflected rays, they cross behind the mirror. At the point where the lines cross, the image of the point X forms.

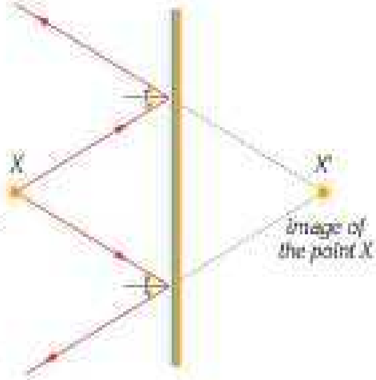


Figure 7.5

How do we see images?

In the figure at the side there are two light rays coming from the candle. The rays are reflected by the mirror and then enter the eye. According to the eye, the light rays seem to come from behind the mirror, therefore the eye sees the candle inside the mirror, this is shown in figures **7.7-7.8**. Actually, the candle is not there, it is just an image. This type of image is called a virtual image. Virtual images cannot be formed on a screen.

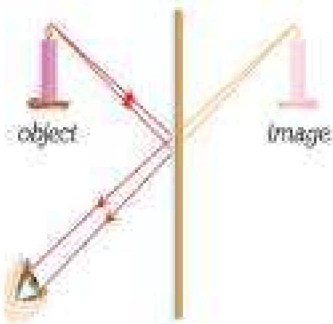


Figure 7.8

Figure 7.7

An object placed in front of a plane mirror has the followin properties:

1. The image is the same size as the object ($h_{object} = h_{image}$).
2. The distance between the image and the mirror is equal to the distance between the object and the mirror ($x_{object} = x_{image}$).
3. The image is virtual.
4. The image is behind the mirror.
5. The image is laterally inverted, that is, the left side of the object is at the right side of the image.

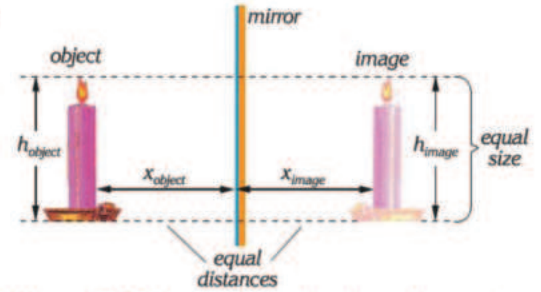


Figure 7.9 Image formation in a plane mirror.

Figure 7.10 Reflection in nature

Figure 7.11

Why is the word "AMBULANCE" written as "AMBULANCE" on vehicles?

Ambulances carry ill or wounded people to hospitals, so they must travel at high speeds.If an ambulance is at the back of a car in the traffic, the driver of the car can read the reversed writing correctly from the driving mirror as and give way to it. see figure (7.11).

"AMBULANCE"

Tricks with candles

You can play some funny tricks with the experiment above. Burning finger While the candle is burning, put your finger on the unlit candle behind the mirror. Does your finger seem to be in the flame?

Burning candle under water

Place a beaker full of water behind the mirror so that the image of the burning candle forms in water. Does it appear as if the candle is burning in water?

Example 7.1

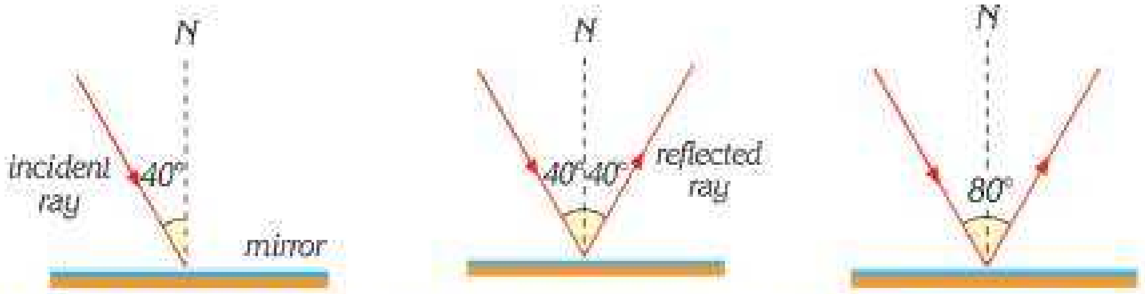
a. Draw a diagram showing the incident ray
b. What is the angle of reflection?
c. What is the angle between the incident and reflected ray?

Solution

a. The light strikes the mirror as in the figure below.

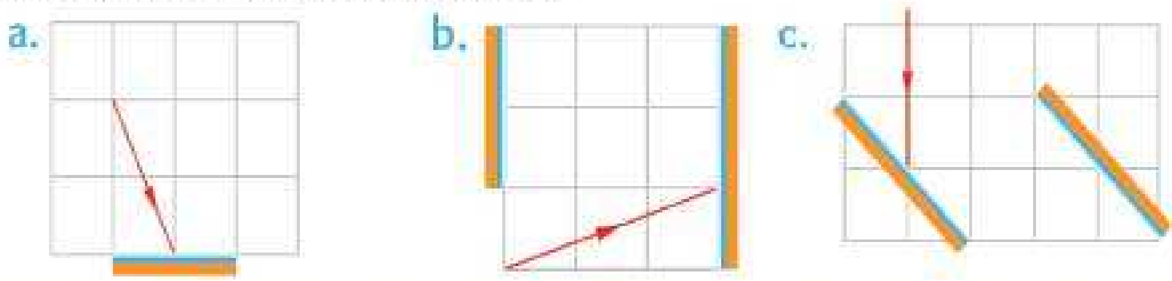
b. The reflected ray makes the same angle as the incident ray.

c. The angle between the rays is $40° + 40° = 80°$.



Exercise 7.1

Draw the rays reflected from the mirrors in the figures.

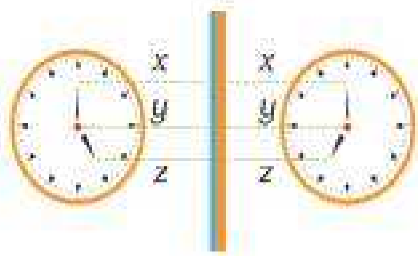


Example 7.2

What time is it if you look at the clock in the mirror?

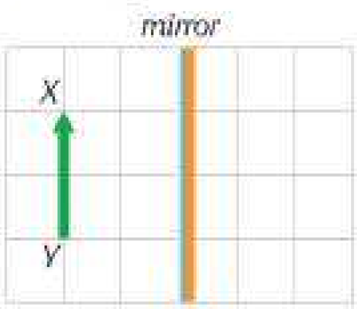
Solution

The image size is equal to the object size andthe images' distance to the mirror equals the distance of the object to the mirror. Since the image is symmetrical with the object, the mirror acting as the line of symmetry,there-fore we read the time as 7 o'clock



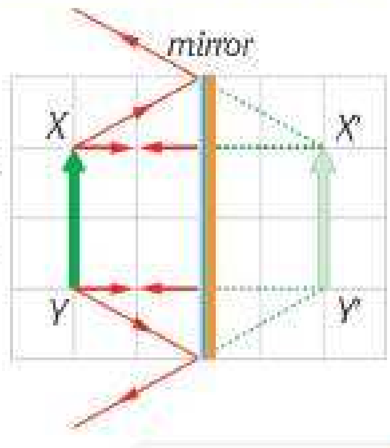
Example 7.3

Find the image of the arrow i



Solution

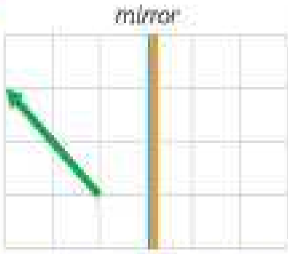
We need at least two rays from a point to draw its image. Using the rules of reflection we draw the image. It is the same size and the same distance to the mirror as the object.



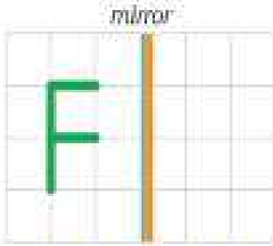
Exercise 7.2

Draw the image of the figures below in the plane mirrors.

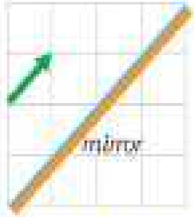
a.



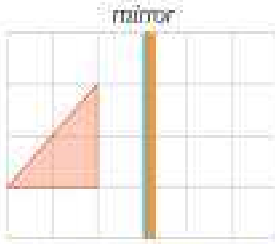
b.



c.



d.



Example 7.4

A girl is standing 75 cm from the front of a flat mirror.

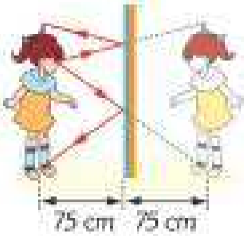
a. How far is her image beyond the mirror? What is the distance between the girl and her image?

b. If the girl moves 1 m away from the mirror, what will be the final distance between the girl and her image?

c. Does the size of the girl's image change while she is walking?

Solution

a. The distance between the girl and the mirror is the same as the distance between the image and the mirror. So the image is 75 cm beyond the mirror. The distance between the girl and her image is;
75 + 75 = 150 cm



b. When the girl moves 1 m away from the mirror, the image also moves 1 m beyond the mirror.
The final distance between the girl and her image is:
2 ×175 = 350 cm.

c. No, there will be no change in the size of the image, only its position changes.

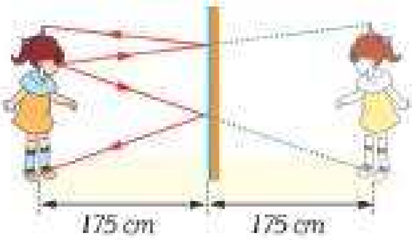


Figure 7.12

d. Image formed by two plane mirrors

If two plane mirrors are placed side by side so that they make an angle to each other, a lot of images form in the mirrors, because of the reflection between them.

The number of images depends upon the angle between the mirrors. The number of images (n) in the mirrors is given by;

$$n = \frac{360}{\theta} - 1$$

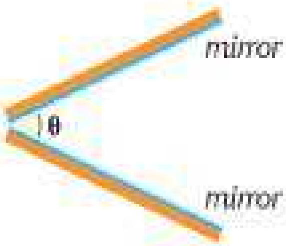


Figure 7.13 An infinite number of images form between parallel mirrors.

here "θ" is the angle between the mirrors.
For example, if the angle is 90° as in figure **7.12.** then the number of images is:

$$n = (360/90) - 1 = 3$$

The angle between two parallel mirrors is zero, here, an infinite number of images will be formed, as shown in figure 3.26. n = (360/0) – 1 = infinite. see figure 7.13.

CHAPTER QUESTIONS

Use the words below in your own sentences

kaleidoscope, virtual, sun, space, plane mirror, image, reflection, periscope, reflection

Fill in the blanks with appropriate words

1. The angle between the normal and the incident ray is called ....

2. The incident ray, the reflected ray and the normal are all in the ....

3. Rough surfaces reflect light in all directions. This reflection is called ....

4. .... number of images form between parallel mirrors.

Answer the questions

1. The figures show "the image of clocks" in a mirror. For each case find the right time.

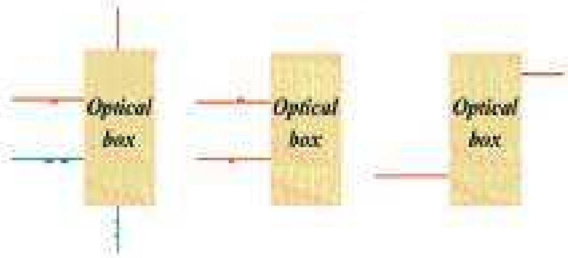
a)

b)

2. Write down the properties of an image formed in a plane mirror.

3. Why can't the image formed in a plane mirror be projected onto a screen? Explain.

4. The figures below shows rays of light entering and leaving the optical boxes. Each box contains two plane mirrors. Show how they are placed.



5. To see the ball from the openings K, L and M, indicate where the plane mirrors should be located in the tubes?

Answer the test questions

1. Which of the properties below is not correct for the image in a plane mirror?

A. virtual
B. the same size as the object
C. can be projected onto a screen
D. inverted

2. A boy stands 10 m in front of a plane mirror, then he moves 3 m towards the mirror. How many metres does his image move towards him?

A) 20 B) 14 C) 7 D) 6

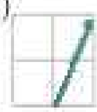
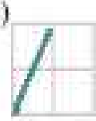
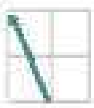
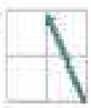
3. Which letter shows the angle of incidence in the figure?

A) a B) b C) c D) d

4. Which of the following is the angle of reflection for the light ray given in the figure?

A) 70° B) 60° C) 35° D) 30°

5. Which of the figures below is the image of the arrow in a plane mirror?

A)  B)  C)  D) 

6. The image of a clock-face in a mirror is as shown in the figure. Which of the following is the right time?

A) 06:55 B) 13:20 C) 08:05 D) 8:20

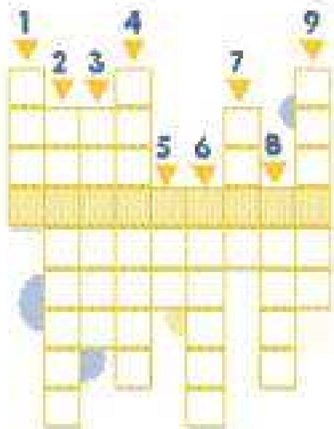
Which of the following is the image of the number in the mirror?

A) 0821 B) 1580

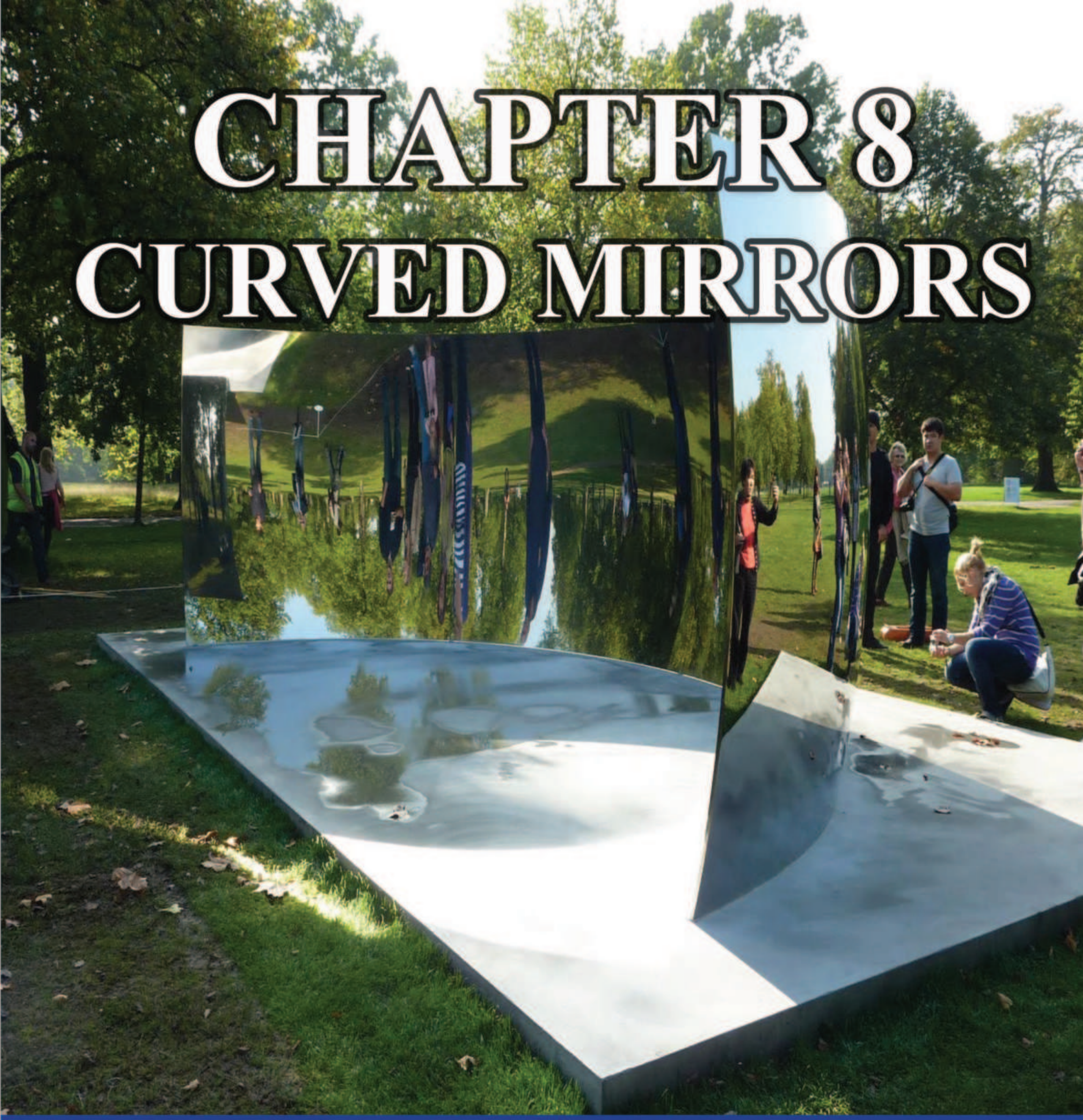
C) 1280 D) 0851

Fill in the boxes correctly. The coloured region will give you the name of the apparatus used in submarines to observe objects on the surface of the sea.

1. An electrical device producing light
2. The name of a projector which has a plane mirror at the top.
3. A piece of glass which shows images.
4. The light falling upon a surface: .... light.
5. The light and heat source of the Earth.
6. An artificial light source made of wax.
7. The giant sunlight reflector in the sky seen at night.
8. Flat mirror: .... mirror.
9. A surface upon which the images fall.



CHAPTER 8
CURVED MIRRORS



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Describe curve mirrors.
2. Graph the images formed by a concave mirror.
3. Graph the images formed by a convex mirror.
4. Give some examples of the use of curved mirrors.

8.1 CURVED MIRRORS

Not all mirrors are plane mirrors. Some mirrors have a curved shape. A curved mirror can either curve outwards or inwards.

a. What are concave and convex mirrors?

The reflecting surface of a concave mirror curves inwards like the bowl of a metal spoon. The reflecting surface of a convex mirror curves outwards like the back surface of a metal spoon as in figure **8.1.**

Figure 8.1

Centre of a curved mirror

Small curved mirrors form part of the surface of a sphere. The centre of curvature of a curved mirror is the centre of the sphere. The distance between the centre of curvature and the mirror is the radius of curvature (R). The principal axis is the line passing through the centre of curvature and the mirror. The point where the principal axis passes through the mirror is called the pole (P) see Figure **8.2.**

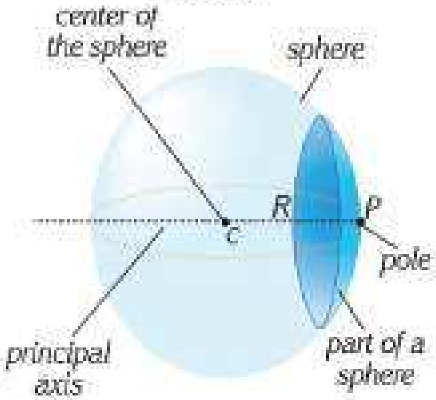


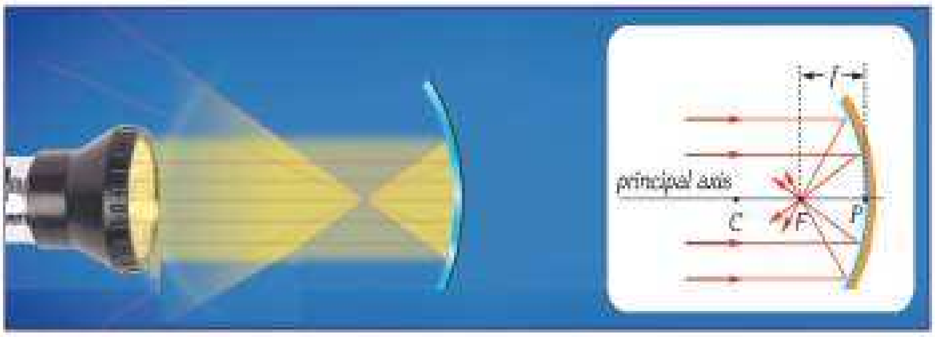
Figure 8.2

What is the focal point?

The light rays parallel to the principal axis get closer to each other after reflection from a concave mirror. The reflected rays meet at a point on the principal axis. This point is called the focus and is represented by F. The distance between the focus and the mirror is called the focal length (f). The focus is midway between the pole and the centre.

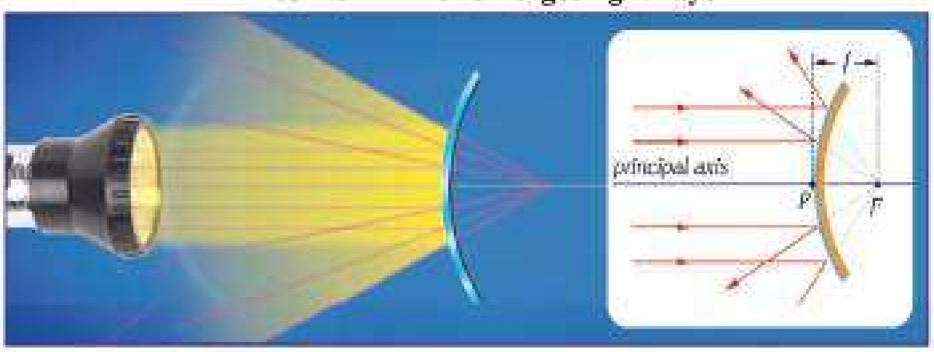
$$\text{focal length (f)} = \frac{1}{2}\text{ radius of curvature (R)}$$

Aconcave mirror converges light rays



The light rays parallel to the principal axis of a convex mirror travel in different directions after reflection from the mirror. If we take the extensions of these reflected rays, they appear to come from a point behind the mirror. This is the focal point of the convex mirror.

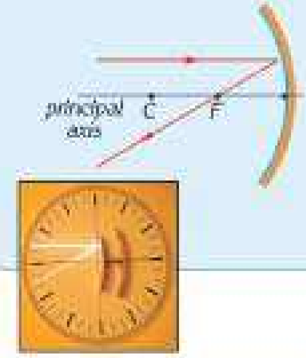
Aconvex mirror diverges light rays



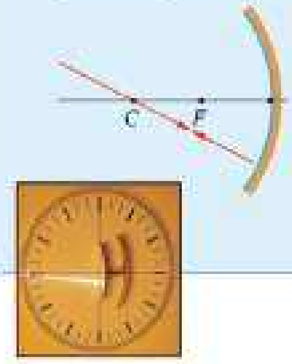
b. Special rays of light for concave mirrors

The light rays reflected from concave mirrors follow different paths depending upon their points of reflection. However there are some paths that we can predict without any measurement. We will call rays of light which follow these paths "special rays of light". Using special rays, we can find the position and the size of the image formed by the curved mirrors. The special light rays for concave mirrors are as follows:

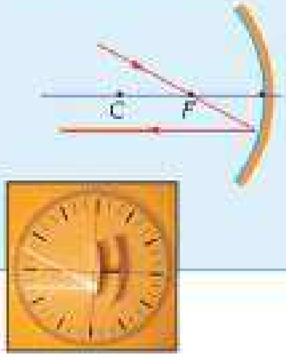
1 A light ray travelling parallel to the principal axis is reflected back through F.



2 A light ray passing through the centre(C) is reflected back again through the point C.



3 A light ray passing through F is reflected back parallel to the principal axis.



4 The angle of incidence of the light striking the pole is equal to the angle of reflection

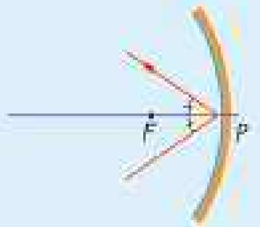
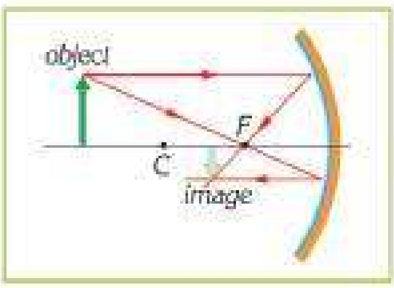


Image formation by a concave mirror

As mentioned earlier we need at least two light rays are needed to draw the image of a point in front of a mirror. In order to draw the image, we should find the point where all the reflected rays cross. Now we will look at the images of an object formed by a concave mirror at different positions.

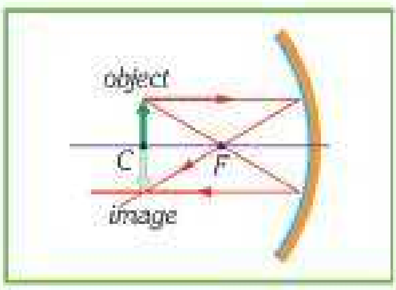
Case 1: If the object is beyond the centre, the image is;

a. between the centre and the focus
b. smaller than the object (diminished)
c. real
d. inverted

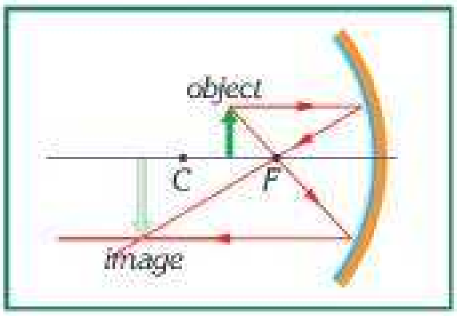


Case 2: If the object is at the centre, the image is;

a. at the centre
b. the same size as the object
c. real
d. inverted

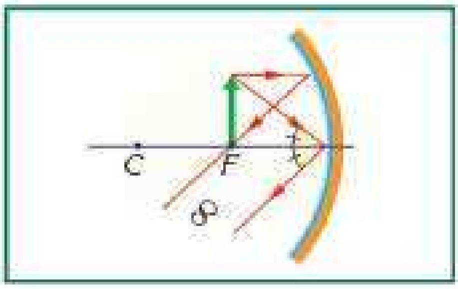


Case 3: If the object is between the focus and centre of the mirror, the image is;
a. beyond the centre
b. larger than the object (magnified)
c. real
d. inverted



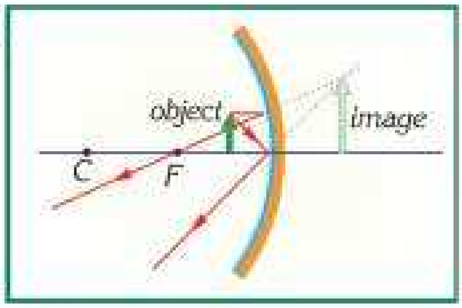
Case 4: If the object is at the focus,

its image is said to be formed at infinity. Because the reflected rays travel parallel to each other, they never cross. (No image)

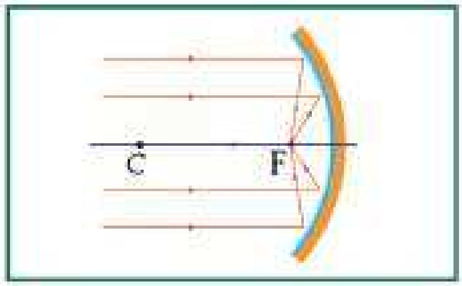


Case 5: If the object is between the focus and the mirror, the image is;

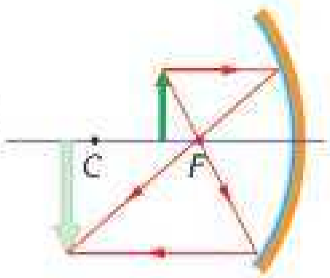
a. behind the mirror
b. larger than the object (magnified)
c. virtual
d. upright (erect)



Case 6: Another type of image is the reverse of case 4.
if the object is at infinity (far away from the mirror)
- its image forms at the focus of the mirror.
- the image is real.

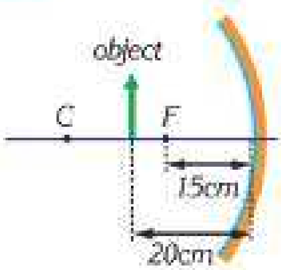


Example 8.1
An object is 20 cm away from a concave mirror. It's focal length is 15 cm.
a. Draw the diagram showing the position of the object in front of a mirror.
b. At what position does the image form?
c. What properties does the image have?



Solution

a.



b. The curvature of the mirror is, $R = 2 \cdot f \rightarrow R = 2 \cdot 15 = 30$ cm
Since the object is 20 cm away from the mirror, it is between C and F. Therefore, the image is formed beyond C.

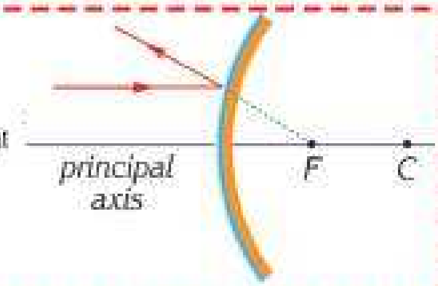
c. When we draw two special light rays and their reflection we obtain the image. It is real, magnified and inverted.

c. Special rays of light for convex mirrors

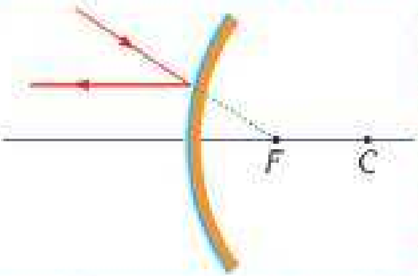
The focal point of a convex mirror is behind the mirror and it diverges the light rays falling upon it. Therefore the extensions of the reflected light rays meet behind the mirror.

There are also special rays for convex mirror as there are for concave mirrors.

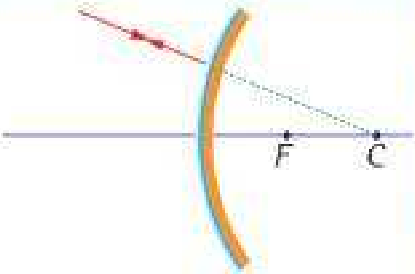
1. A light ray travelling parallel to the principal axis is reflected back so that itsextension passes through F.



2. A light ray arriving at the mirror is reflected back, parallel to the principal axis. However, its extension passes through F.



3. A light ray arriving at the mirror so that its extension passes through C, is reflected back over itself.



4. A ray of light arriving at the pole, is reflected back so that its angle of reflection equals its angle of incidence.

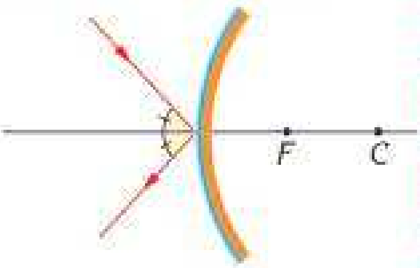
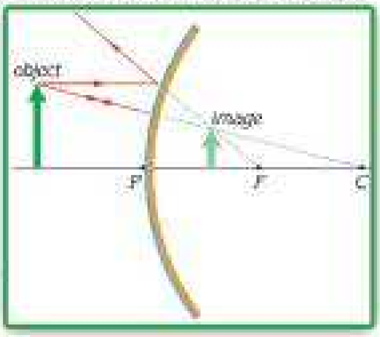


Image formation by a convex mirror

Using the special rays, the image of an object in front of a convex mirror can be easily drawn. It is formed by the extensions of the reflected rays from the mirror.

There is only one type of image for convex mirrors. The image of the object in front of a convex mirror is;

a. behind the mirror (between F and P)
b. smaller than the object (diminished)
c. virtual
d. upright

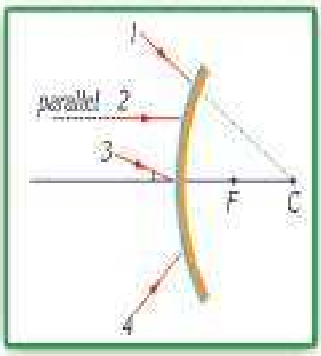


The image always forms between the focus and the the mirror independent of the distance of the object from the mirror.

Figure 8.3 The shiny and curvy back surface of a tanker acting as a convex mirror

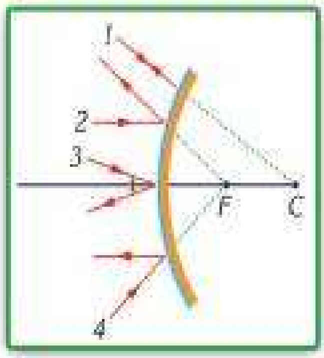
Example 8.1

Four light rays are directed towards a convex mirror as shown in the figure. Draw their paths after reflection from the mirror.



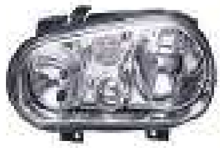
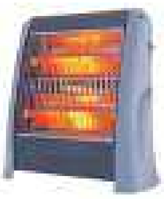
Solution

Using the rules for special light rays we can draw the reflected rays as follows.



Uses of concave mirrors.

Concave mirrors have the property of being able to collect light rays faling upon them, to reflect rays produced at its focus to great distances and produce upright and magnified images. Therfore they have many important uses in everyday life.


Uses of convex mirrors.

Convex mirrors have a wide field of view and produce upright images. Therfore they have important uses.



Sometimes, convex mirrors are placed at corners of narrow streets so that other cars on the road are visible.

CHAPTER QUESTIONS

Use the words below in your own sentences

concave mirror, convex mirror, real image, virtual image, field of view, focus, focal length, centre, pole of the mirror, rear mirror, torches

Fill in the blanks with appropriate words

1. The outside of a metal spoon is a good example of a .... mirror.

2. The angle of incidence of the light on striking the pole is .... to the angle of reflection.

3. If an object is between the centre and the focus of a concave mirror, the image forms beyond the ....

4. The ray of light whose extension passes through the focus of a convex mirror is reflected back .... to the principal axis.

5. The image of an object in front of a convex mirror forms .... the mirror.

6. Plane and convex mirrors give .... images but concave mirrors can give both .... and .... images.

Answer the questions

1. What is a curved mirror?

2. State the differences between flat, concave and convex mirrors.

3. How can you find the focus of a concave mirror?

Explain using a sketch.

4. Draw the special rays for a concave mirror.

5. A bottle stands 1.5 m in front of a concave mirror which has a 50 cm focal length.

a. Write down the properties of the image.

b. Where should it be placed in order to obtain a magnified image?

6. What does "real image" mean. How can you obtain a "real image"? Explain.

7. Where is the light bulb located in a car headlight?

8. Draw images of the objects in the figures below.

9. Draw the special rays for a convex mirror.

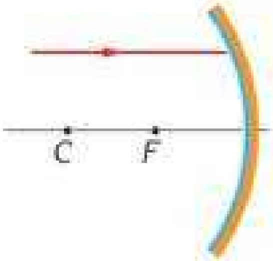
10. A boy stands in front of a convex mirror and looks at his image. List the properties of the image.

11. Give examples of appliances or devices where concave and convex mirrors are used.

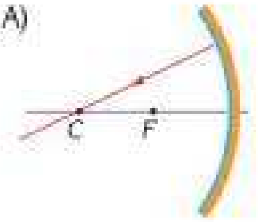
12. Why does the image of the ball at the back seem smaller than the others although they have the same size.

Answer the test questions

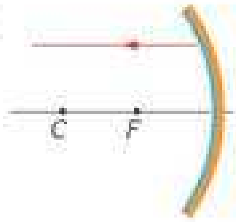
1. What is the path of the ray reflected from the mirror?



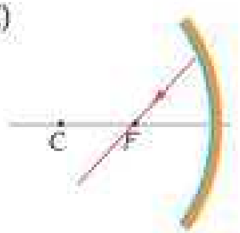
A)



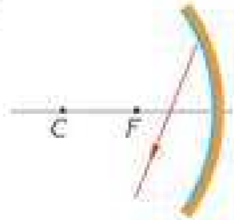
B)



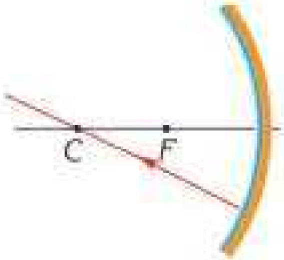
C)



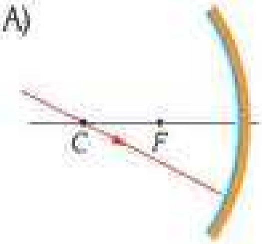
D)



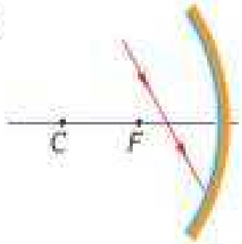
2. If the figure to the right shows the reflected ray from the mirror. Which one of the figures below shows the incident ray?



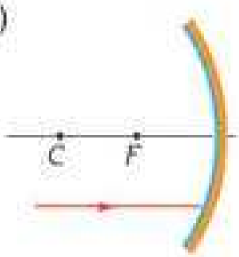
A)



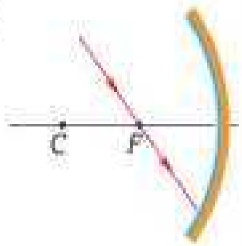
B)



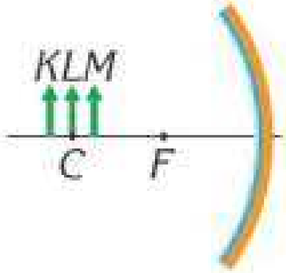
C)



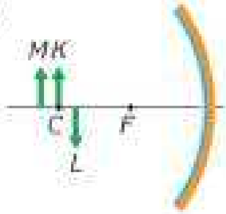
D)



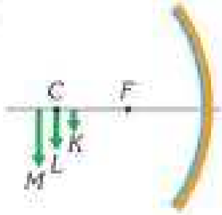
3. The objects named K, L and M are placed in front of a concave mirror as shown in the figure. Which one of the figures below correctly shows the images of the objects?



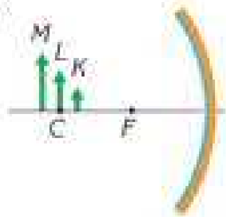
A)



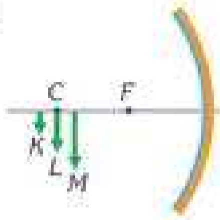
B)



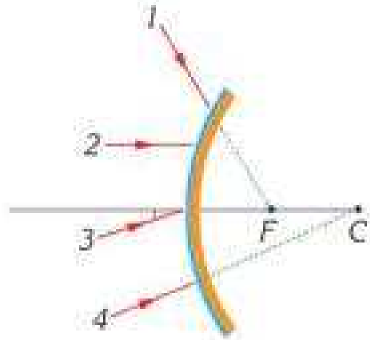
C)



D)



4. Which one of the rays given in the figure follows a path parallel to the principal axis after reflection?

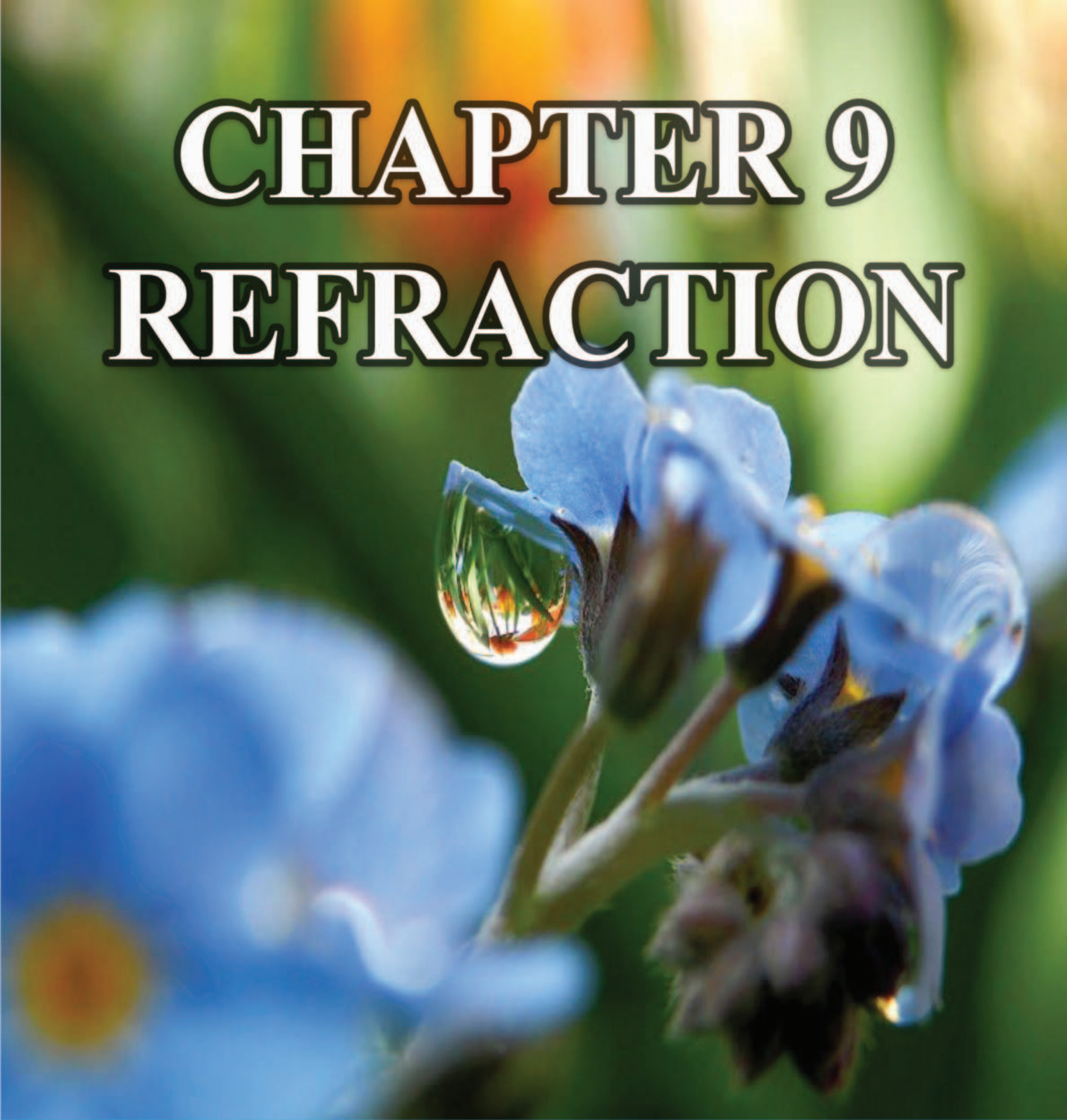


A. 1 B. 2 C. 3 D. 4

5. Which one of the statements below is a property of an image formed by a convex mirror?

A) in front of the mirror
B) virtual
C) inverted
D) between centre and focus

CHAPTER 9
REFRACTION



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Know the physical meaning of Refraction of light.
2. Define the Laws of Refraction.
3. Describe the total internal reflection.
4. Give some examples of the total internal reflection.
5. Give some application for the prisms.
6. List the color of the rainbow.

9.1 REFRACTION OF LIGHT

a. What is the refraction of light?

Refraction of light is defined as the bending of light. When light passes from one medium into another, it changes direction. This is called the refraction of light.

Why does light bend?

Light travels with different speeds in different mediums. Its speed is 3×10^5 km/s in air, 225 000 km/s in water and 200 000 km/s in glass. Therefore when it passes from air into water it slows down. This and some other effects cause the light to change its path. This is similar to a car changing direction as it enters an icy or a muddy road. Because the car starts to skid, it cannot go in the same direction as before, see the figure 9.1.

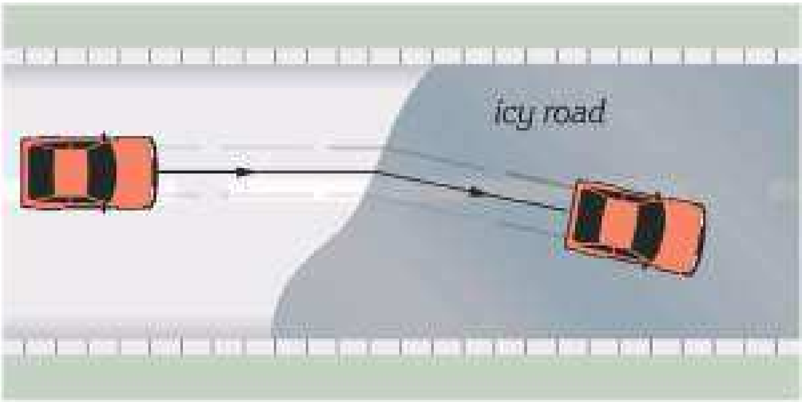


Figure 9.1

There are so many examples of the refraction of light. One of them is a spoon in a glass of water. The spoon in the glass seems broken because the light rays from the part of the spoon above the water directly come to our eyes and the light rays from the part of the spoon immersed in water reach our eyes after bending. This is a good example of the refraction of light.

b. What are the laws of refraction?

1. The incident light, the refracted light and the normal are all in the same plane.
2. Light passing from an optically less dense medium into a denser medium bends towards the normal.
3. Light passing from an optically denser medium into a less dense medium bends away from the normal.

The angle of incidence is the angle between the incident ray and the normal. The angle of refraction is the angle between the refracted ray and the normal. This is illustrated in Figure 9.2.

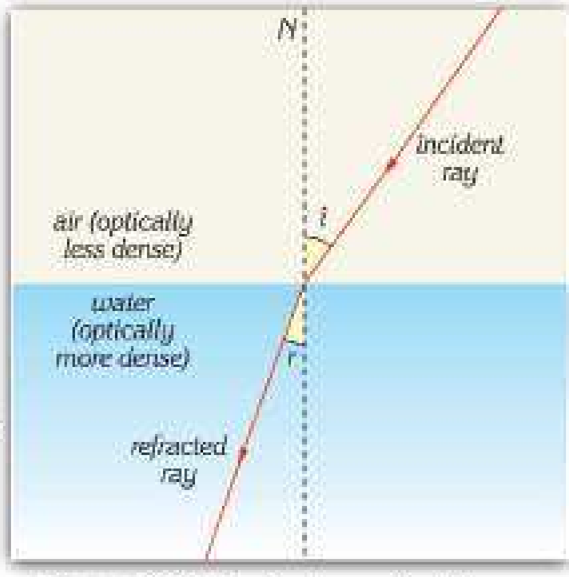


Figure 9.2 The incident ray, refracted ray and the normal all lie in the same plane.

Figure **9,3** shows the refraction of a light ray passing from air into glass. Notice that the angle of refraction is smaller than the angle of incidence.

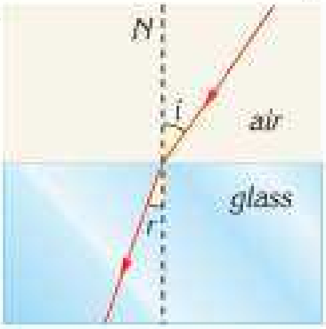


Figure 9.3 Light bends towards the normal as it passes from air into glass.

Light travels faster in air than in water, so water is optically denser than air. Light bends away from the normal as it enters air from water as shown in figure **9.4** .

Figure 9.4 Light bends away from the normal as it passes from water into air.

There is only one case where light does not bend when it travels from one medium into another. If a light ray is exactly perpendicular to the surface, it does not bend. In other words, if a light ray enters from one medium into another along the normal, it does not change its direction as shown below.

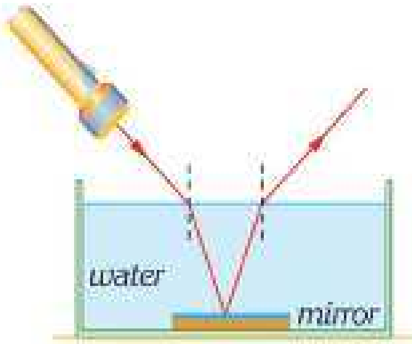


Figure 9.5 Light bends towards the normal when it enters water and bends away from the normal when it leaves the water.

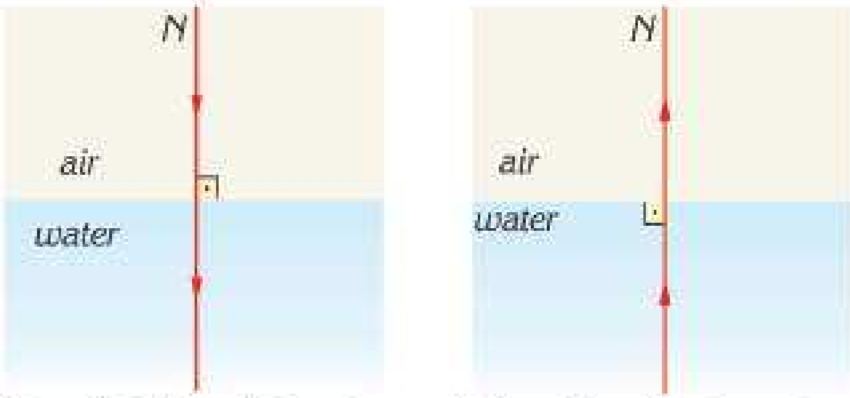
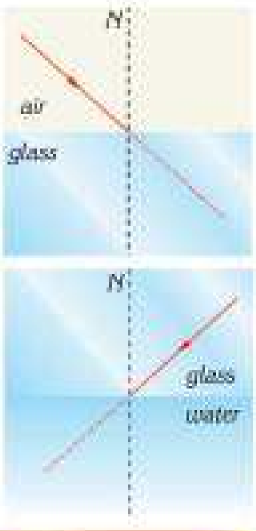


Figure 9.6 When a light ray is perpendicular to the surface, it passes into the other medium without bending

Example 9.1

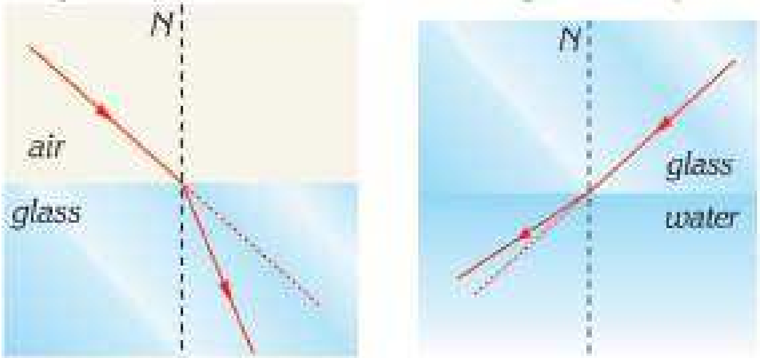
Which path do the light rays follow? Sketch them on the figures.



Glass is optically denser than water.

Solution

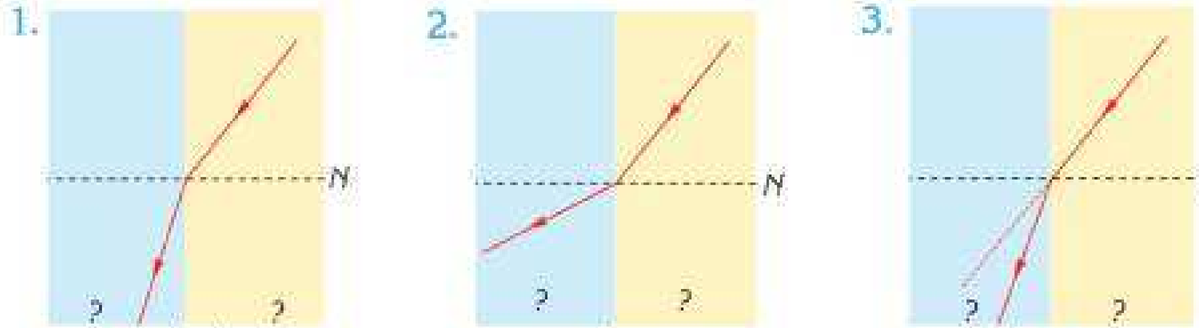
Using the laws of refraction, we can draw the path of the rays.



Notice that light bends towards the normal when it passes from glass into water. Why?

Exercise 9.1

Following the path of the light rays, name the mediums in the figures.



air, glass   air, water   glass, water

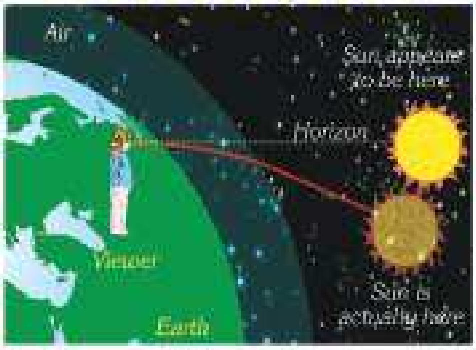


Figure 9.7

c. Misconceptions caused by the refraction of light

The bending of light sometimes misleads us. The following activities give examples and explanations for them.

Are stars really in the positions in which we observe them?

The atmosphere's optical density changes as it gets higher. Therefore light rays coming from the stars gradually refract while they travel in air, as shown in the figure to the right. Therefore, stars appear at different positions than they actually are.

d. What is total internal reflection?

We know that, when light passes from an optically denser medium into an optically less dense medium, it bends away from the normal. But for a certain angle of incidence, light cannot pass into the optically less dense medium instead it travels along the surface after it is refracted. When the angle of refraction is 90°, the angle of incidence is called the critical angle. It is represented by $\theta_{critical}$, (θ_c) in figure 9.8 .

If light is incident at an angle greater than the critical angle, light cannot pass into the other medium and is reflected back. This is called total internal reflection. Follow the figures (9.9 – 9.10) below.

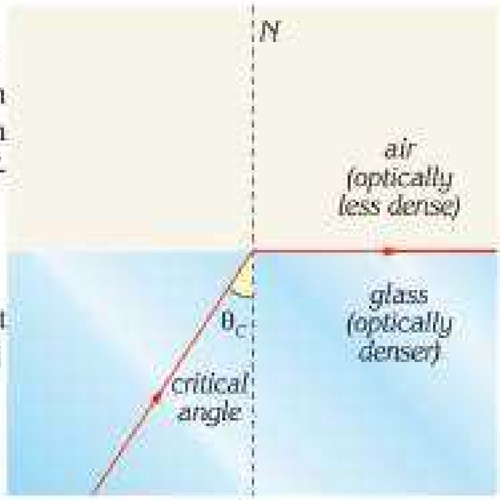


Figure 9.8 Critical angle

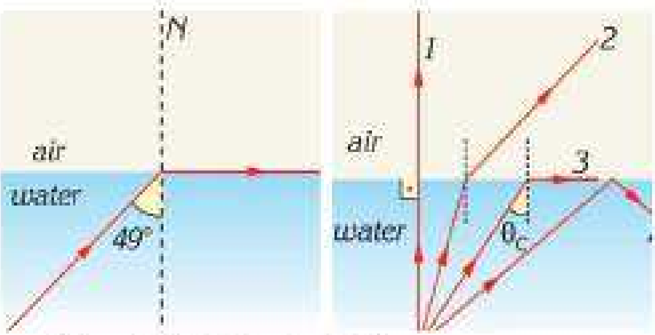


Figure 9.9 Critical angle for water and total internal reflection

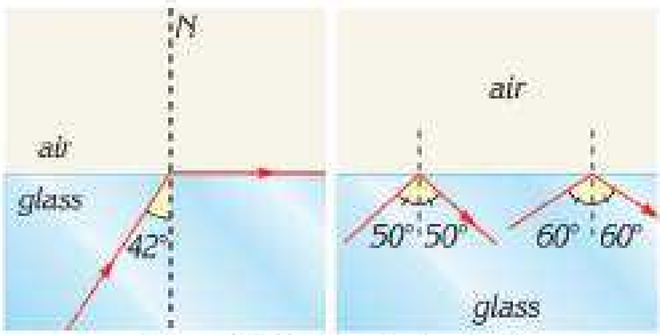
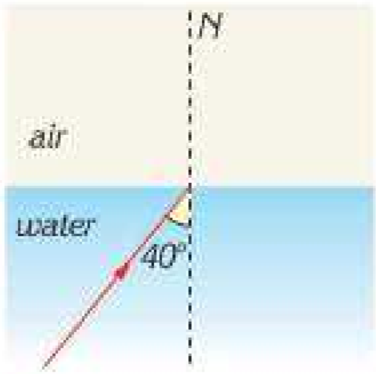


Figure 9.10 Critical angle for glass and total internal reflection

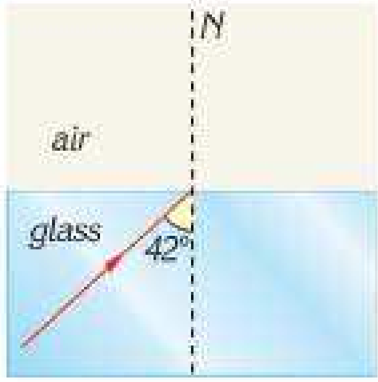
Example 9.2

For each figure given below, draw the path of the ray.

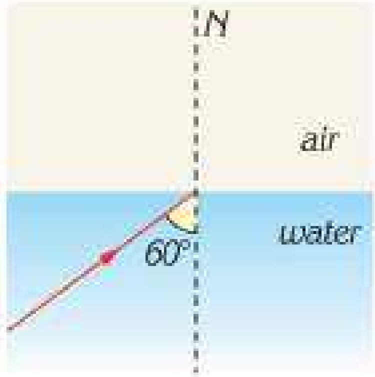
a.



b.



c.



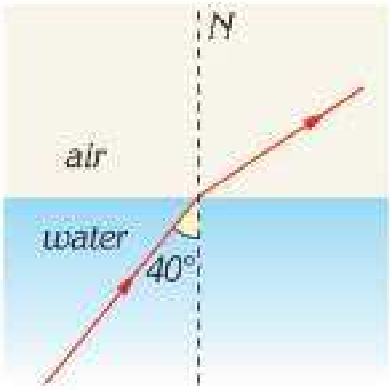
Solution

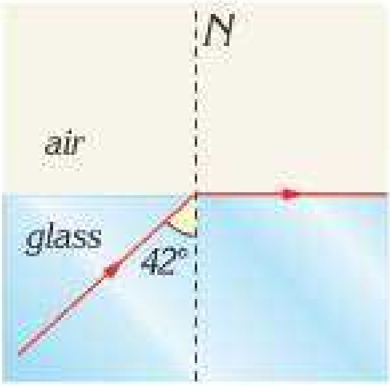
We know that the critical angle for water is 49° and for glass 42°.

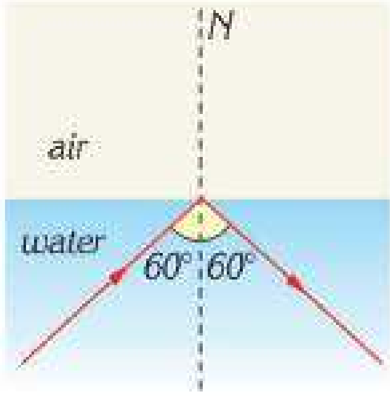
a. 40°<49° (θ_c=49° for water) Because the angle of incidence is smaller than the critical angle. The light ray bends away from the normal when it enters air.

b. The light strikes the surface at an angle equal to the critical angle for glass, 42°. So, it travels parallel to the surface after it is refracted.

c. The light ray strikes the surface at an angle greater than the critical angle for water. i=60° > 49°. So, it is reflected back into the water.

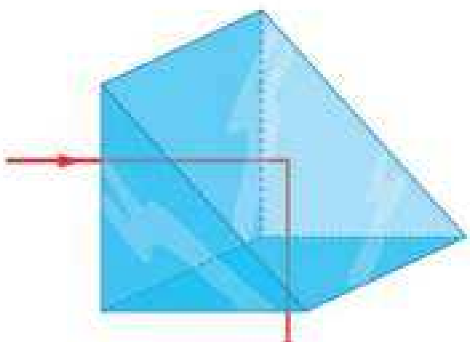






e. Totally reflecting prisms

The light ray entering the glass prism cannot pass into air from the long side of the prism as seen in figure 9.11. This is because the light ray strikes this surface at an angle of incidence of 45° which is greater than the critical angle for glass (42°). Thus, total reflection occurs inside the glass hence the name total internal reflection. Now the direction of light is changed by 90°.



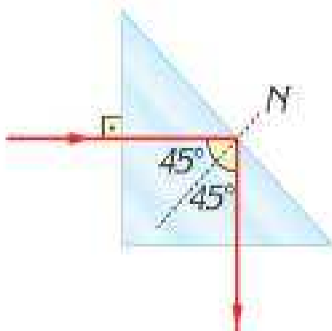
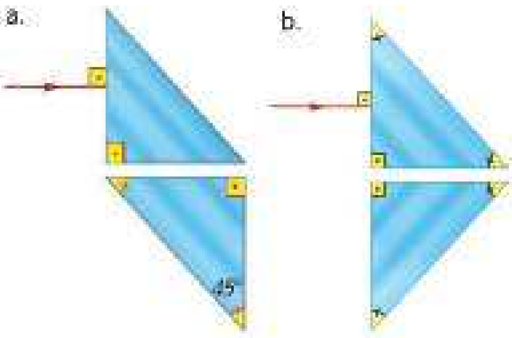


Figure 9.11 Total internal reflection inside the glass prism

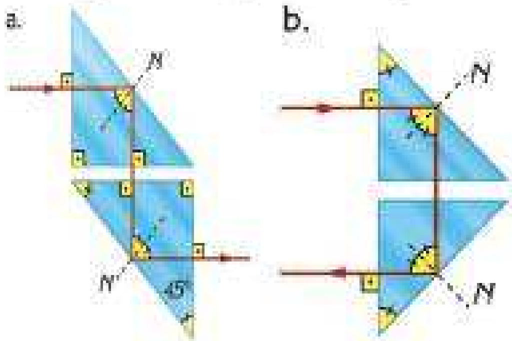
Example 9. 3

Draw the path of light rays inside the glass prisms. Prisms are placed in parallel.



Solution

We know that if the angle of incidence of the ray is greater than 42° for glass, it cannot pass into air, and total internal reflection occurs inside the prism. The rays follow the paths shown.



f. Total internal reflection in daily life

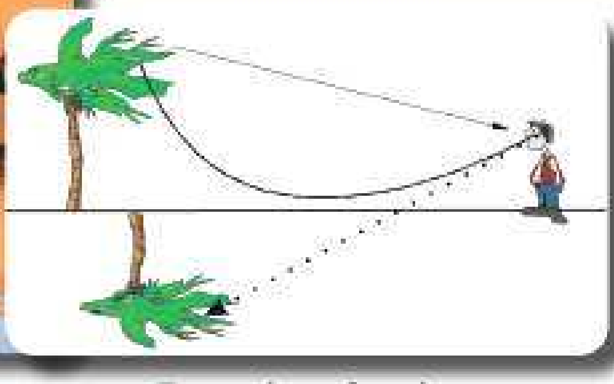
Observing mirage on the road

On very hot days, the layer of air above the road becomes very hot, but higher layers are cooler. The hot air is optically less dense than cool air. Therefore a ray of light from the sky is reflected as it travels downwards. When it reaches the layer of hot air on the ground, its angle of incidence becomes greater than the critical angle of the hot air. Total internal reflection occurs near to the surface of the road. As result, the image of the blue sky appears as a pond of water on the road. this is called (mirage) is shown in figure below.

Did you Know?

Stands of polar bears fur are able to carry light. They are like optical fibers. They carry ultraviolet sun light to its skin.

A mirage

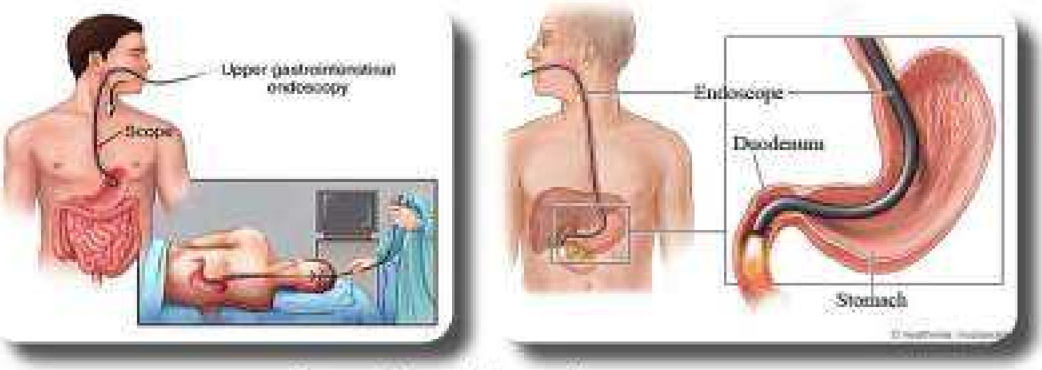


Formation of a mirage

Can light be carried?

An optical fiber is a long thin class tube. Its used to carry light for vary-long distances. When a light ray enters one end of the fiber, it travels through the tube without escaping, as shown in figure on the right. Due to the internal reflection that occurs inside the glass. Light rays can turn corners. There are many deferent uses of optical fibers. in communication technology they are used to carry telephone signals very long distances, a signal wire can carry hundreds of deferents massages at once.

In medical operation, called an endoscopy, doctors use optical fibers (endoscope) to see inside the body, i.e. inside the lungs and stomach.



Operation with endoscope

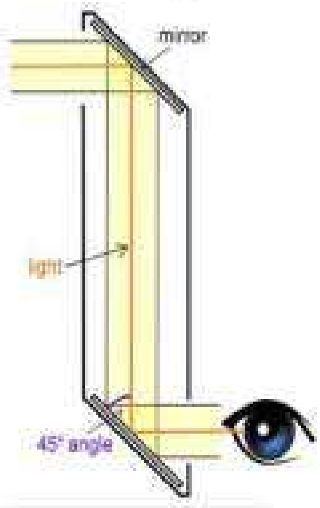
We also observe total internal reflection of light in-streams of fountain water which carry light from colored lamps placed under these fountain light enters the water stream at the beginning and then travels p through the stream undergoing total internal reflection.

Internal reflection of light in streams of fountain

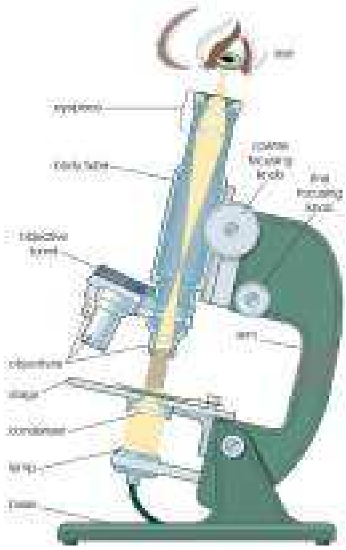
g. Where do we use prisms?

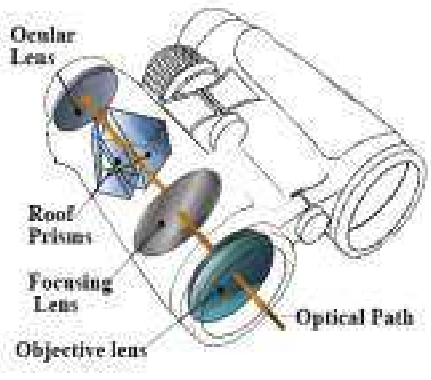
There are many uses in optical instruments, such as periscope, microscopes, binoculars and bicycle reflectors.

In some devices such as periscopes totally reflecting prisms are used instead of plane mirrors. Because they give better reflection than ordinary mirrors.



A bicycle reflector includes many small prisms. When light from a car headlight falls upon this reflector, it s totally reflected inside the prisms so that the car driver sees the bicycle clearly. a car rear reflectors also include small prisms. They reflect light in the same way as a bicycles reflectors do. Prisms inside binoculars turn the image the right way up after some total internal reflections.

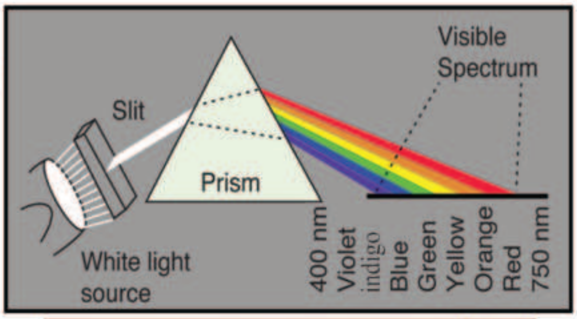




f. Colours of the rainbow

White light is a mixture of colours. We are familiar with this due to a natural phenomenon called a rainbow, a wonderful display of colours in the sky.

Sometimes you may see the colours of the rainbow on walls formed by diamonds in chandeliers.



How can we get colours from white light?

When white light falls upon an equilateral glass prism, different colours can be seen leaving the prism on a screen. This is called the spectrum of white light, and is shown in Figure 9.12.

The colours are arranged from red to violet in the order: red, orange, yellow, green, blue, indigo and violet. It is easy to remember the order of the colours since their first letters form the word, 'ROYGBIV' which contains the first letter of each colour in order. Violet light is refracted the most and red the least.

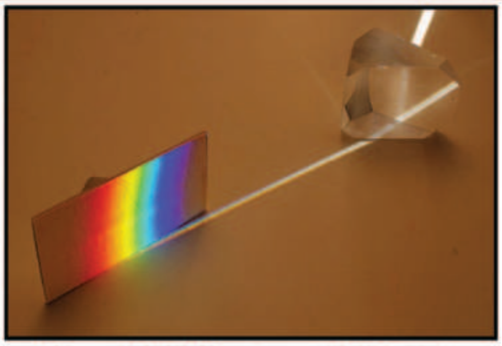


Figure 9.12 Spectrum of white light

Can we obtain white light from its spectrum?

If we place a glass prism upside down behind the first prism as shown in Figure 9.13, the second prism recombines the colours and produces white light.

Another method of recombining the spectrum is to spin a disccontaining the seven colours on it. When the disc is spun quickly enough, the colour appears to be white.

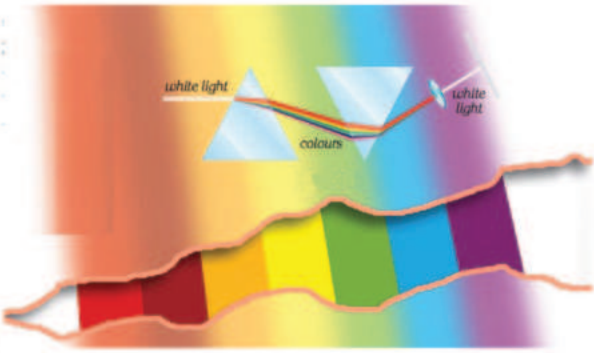


Figure 9.13

How does a rainbow form?

When it is raining and the sun is shining nearby, a coloured bow may form in the sky, this is called a rainbow. Each water droplet in the air acts as a small prism. The light is refracted as it enters the drop in the same way it is for a prism. Then it is reflected from the back of the drop, finally it is refracted again when it re-enters the air. Thus, the colours of the spectrum form in the sky. In order to observe the rainbow, the sun must be behind you.

Why do objects appear coloured?

The colour of objects we observe is just the colour of light they reflect. For example a leaf in sun light, looks green because it reflects only green light and absorbs the rest of the colours of the spectrum. Similarly a red flower looks red because it only reflects red light. objects of different colour are shown in figures 9.14-9.16.

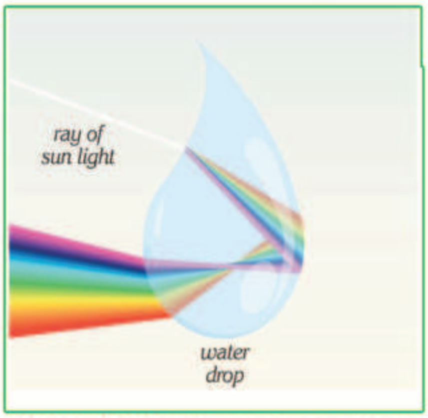


Figure 9.14 Each rain droplet acts as a tiny glass prism to produce a rainbow.

Figure 9.15 Objects seem to be the colour that they reflect

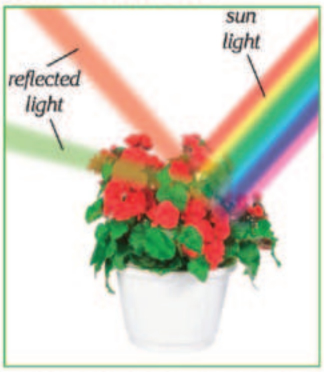


Figure 9.16 Leaves reflect only green colored light.

CHAPTER QUESTIONS

Use the words below in your own sentences

refraction, dense medium, total internal reflection, glass prism, binoculars, mirage, fibre optics, colour, rainbow, air, water

Fill in the blanks with appropriate words

1.When light enters one medium from another, it changes its . ...

2. Bending of light is called . ...of light.

3.Light travelling from an optically less dense medium into adenser medium bnds ....the normal.

4. Light travels . ...in air than in glass.

5.If the angle of refraction is 90°, the angle of incid nce is called the . ...angle.

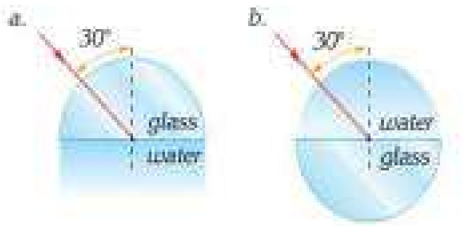
6

Answer the question

1. Why does light change its direction?

2.Explain, how light bends when it enters from one medium;
a) into an optically less dense medium?
b) into an optically denser medium?

3. Complete the path of each light ray given below.



4. Explain with a sketch;

a) why the bottom of a glass filled with water appears closer.

b) why a spoon in a cup of tea appears broken.

5.Does light travel from water into air for every angle of incidence? Explain why?

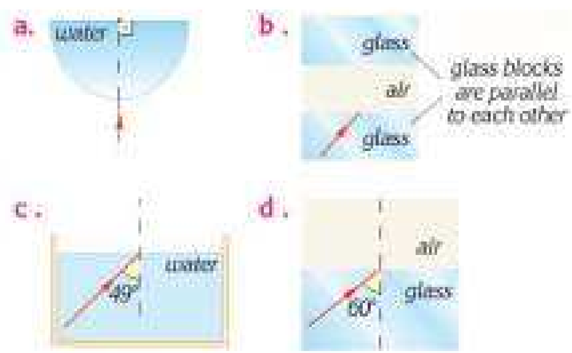
6. Explain;

a) how a reflecting prism works.

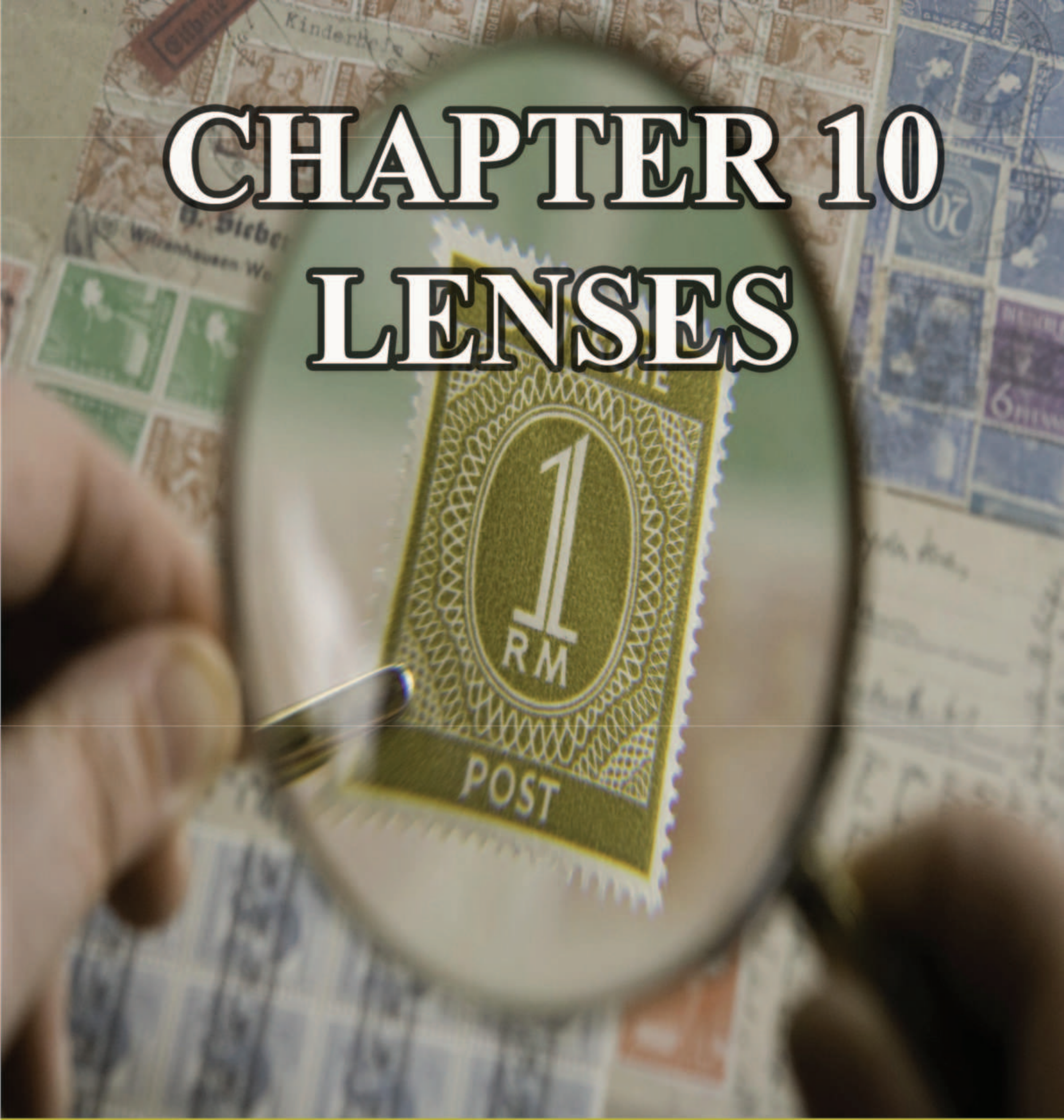
b) how a car's rear reflector works.

7. Can light be carried? Explain how.

8.Complete the paths of the rays shown in the figures.



CHAPTER 10
LENSES



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Describe Lenses (converging and diverging).
2. Graph the images formed by a converging lens.
3. Graph the images formed by a diverging lens.
4. Calculate the power of the lens.
4. Give some examples of the lens around us.

10.1 LENSES

a. Converging and diverging lenses

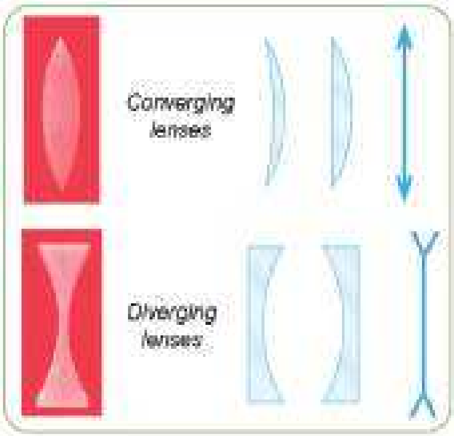


Figure 10.1 Examples of lenses and their representations

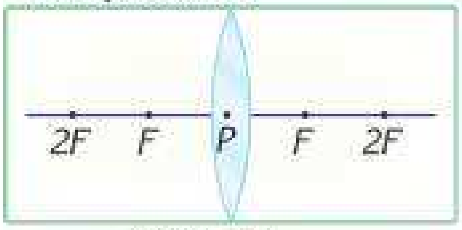


Figure 10.2

Glass can be given a curved shape to obtain magnified or diminished images. We call this specially shaped glass a lens. Lenses are used in many optical instruments. There are two types of lens: converging and diverging lenses.

A converging lens is thicker at the centre and thinner at the outside Figure 10.1. It collects parallel light rays at a point in front of it (converges them).

A diverging lens is thinner at the centre and thicker on the outside. It spreads light rays out (diverges them).

What is the principal focus?

The centre of the lens is called the optical centre and is represented by P (Figure 10.2. The line passing through the centre of the lens is called the principal axis. Rays travelling parallel to the principal axis of a converging lens collect at a point after passing through the lens. See figure 10.3 below. This point is called the principal focus and is represented by F. The distance from the centre of the lens to F is called the focal length. A lens has two focal points because light can enter the lens from both sides. Twice the focal length is represented as 2F.

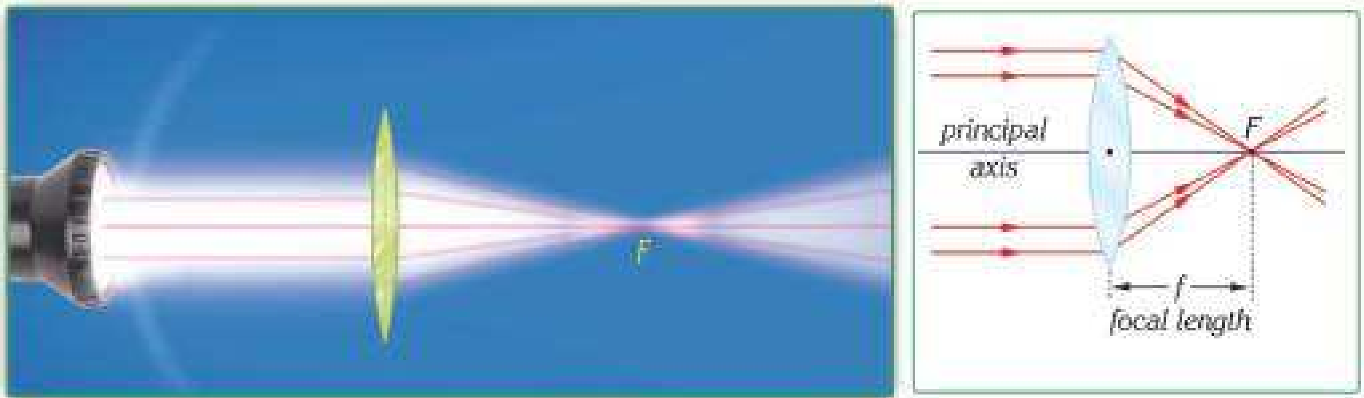
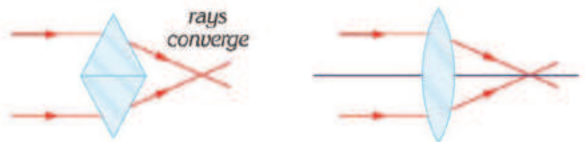


Figure 10.3 Converging lenses collect light rays after refraction.

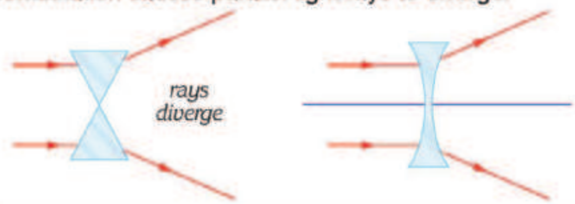
For a diverging lens, rays travelling parallel to the principal axis diverge after passing through the lens so that they appear to come from a point behind the lens. This is the principal focus of a diverging lens. See the figure 10.4 Diverging lenses also have two principal focuses on both sides the same as converging lenses.

Figure 10.4 Diverging lenses disperse light rays after refraction.

A converging lens is similar to the combination of two glass prisms placed base to base as shown below. This combination causes parallel light rays to converge.



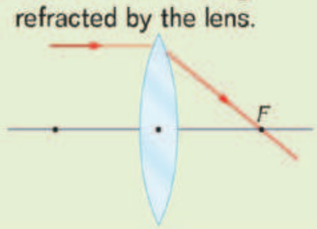
A diverging lens is similar to the combination of two glass prisms placed end to end as shown below. This combination causes parallel light rays to diverge.



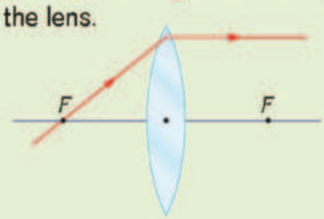
b. Special rays of light for converging lenses

There are some special rays for lenses, as there are for spherical mirrors:

1 A light ray parallel to the principal axis, passes through the focus after being refracted by the lens.



2 A light ray through the focus travels parallel to the principal axis after being refracted by the lens.



3 A light ray passing through the optical centre travels without changing its direction.

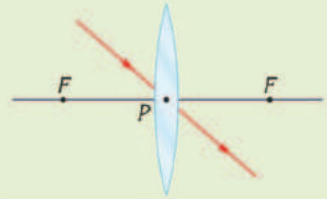
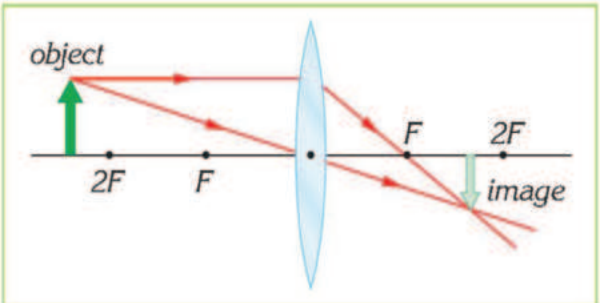


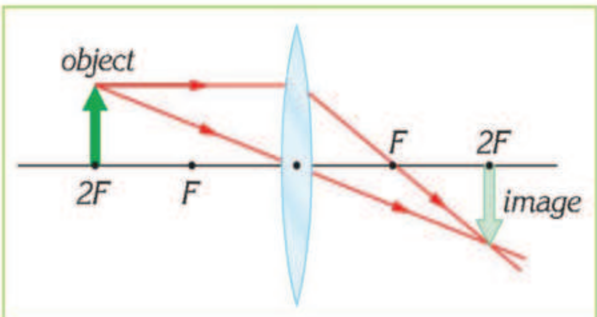
Image formation by a converging lens

Remember that to draw the image of an object in front of a converging lens, we need at least two rays of light coming from it and we should find where they cross. Also remember that a real image is an image which can be formed ona screen. Now, we will find out how images are formed by a converging lens for different locations of an object.

Case 1:If the object is beyond 2F from the lens, the image is;
a. between F and 2F on the other side of the lens
b. smaller than the object (diminished)
c. real
d. inverted

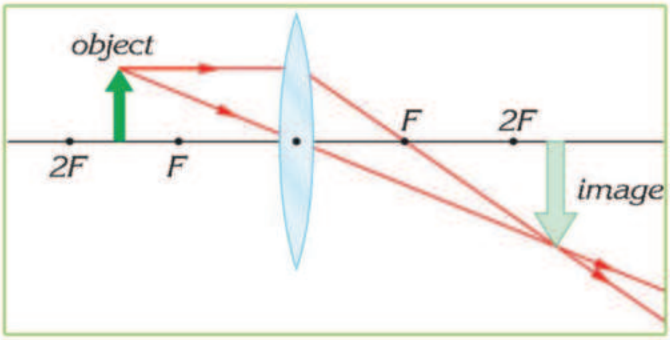


Case 2:If the object is at 2F, the image is;
a. at 2F on the other side of the lens
b. the same size as the object
c. real
d. inverted



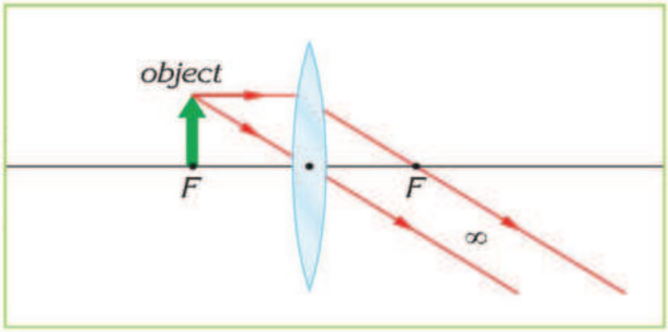
Case 3

If the object is between 2F and F, the image is;
a. beyond 2F on the other side of the lens
b. larger than the object (magnified)
c. real
d. inverted



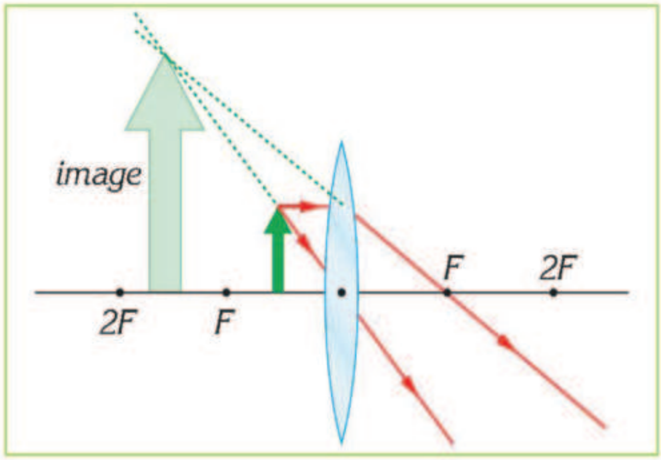
Case 4

If the object is at the focus then the image is said to be formed at infinity. Thus, if we place a light bulb at the focus of a converging lens we can obtain parallel light rays. Laboratory light sources include a converging lens and a bulb located at its focus as shown below.



Case 5

If the object is between the focus and the lens, the image is;
a. behind the object
b. larger than the object (magnified)
c. virtual
d. upright (erect)
Due to these properties converging lenses are known as magnifying lenses.
This is illustrated in Figure 10.5.



Case 6

There is one more case which is the reverse of case 4. If the object is far away (at infinity) from the lens, the rays are almost parallel. The image forms nearly at the principal focus, it is real and inverted. For this reason a real image of a car can be formed on a screen. **see figure (10.6).**

Figure 10.5

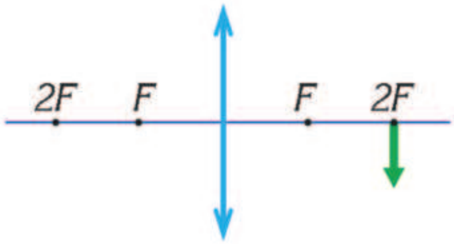
Figure 10.6

Example 10.1

The figure below shows an object which is placed at a distance of 2F from the converging lens.

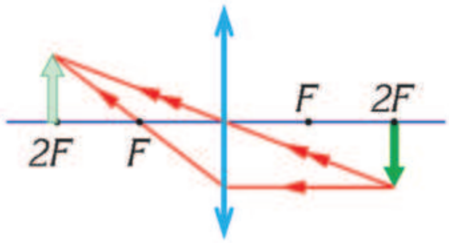
a. Where is the image formed?

b. List the image properties.



Solution

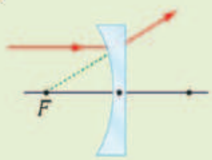
First we sketch a diagram. To draw an image we need two rays from the tip of the object: one parallel to the principal axis and one passing through the centre of the lens. The rays cross at 2F on the other side.



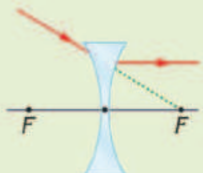
The image is real, upright and the same size as the object.

c. Special rays of light for a diverging lens

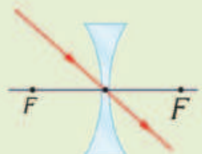
1 A light ray parallel to the principal axis is refracted so that it appears to come from the principal focus behind the lens.



2 A ray directed towards F on the other side of the lens bends, so that it becomes parallel to the principal focus.

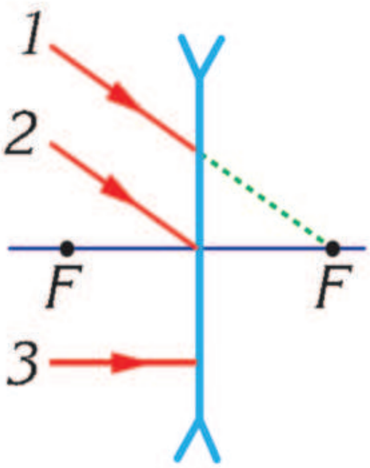


3 A light ray passing through the optical centre travels without changing its direction.



Example 10.2

Draw the correct reflected paths of the light rays incident upon the lens as shown in the figure.



Solution

Using the rules above, the paths of the rays can be drawn as shown below.

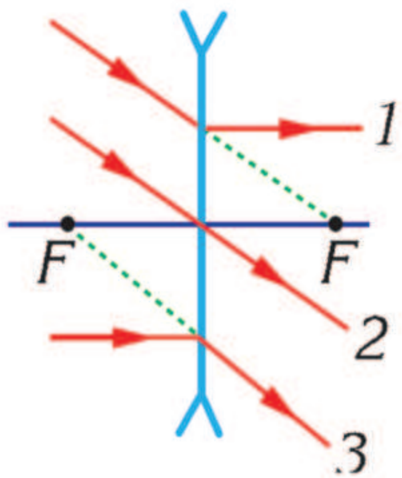
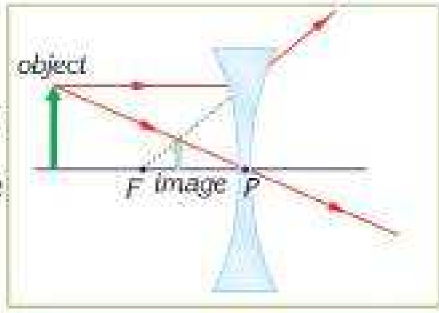


Image formation by a diverging lens



As you observed in the experiment above, the rays of light refracted by a diverging lens never cross. Diverging lenses spread rays out, in a similar way to convex mirrors.

To draw the image formed by a diverging lens, we take the extensions of the refracted rays. The extensions form an image between the focal length and the optical centre, P.

The image of an object in front of a diverging lens is always;

1. on the same side as the object
2. smaller than the object (diminished)
3. virtual
4. upright (erect)

Changing the distance of the object to the lens, changes the position of the image but the image always forms between the focus and the optical centre, virtual and upright. This is shown in figure on the right

d. The power of a lens

Opticians generally use the "power of a lens" instead of using "focal length". The reciprocal of the focal length (in metres) gives the power of a lens

$$\text{Power} = \frac{1}{\pm \text{ focal length (in meters)}}$$

(+) for converging lenses, (–) for diverging lenses. Its unit is the dioptre (D). The longer the focal length the smaller the power.

For example if the focal length of a lens is 40 cm, then the power;

$$\text{Power} = \frac{1}{0.4 \text{ m}} = 2.5 \text{ D.}$$

Example 10.3

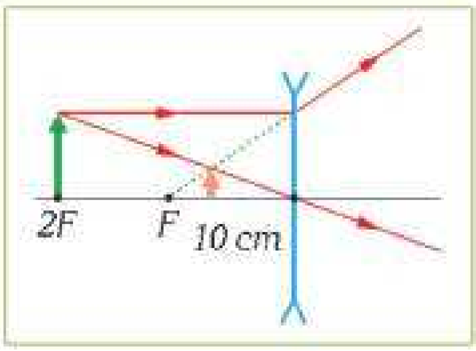
An object is 20 cm away from a diverging lens whose focal length is 10 cm.

a. Where does the image form?

b. What properties does it have?

c. What is the power of the lens?

Solution



Using the special rays, we sketch the diagram as in the figure.

a. The image forms between F and the lens.

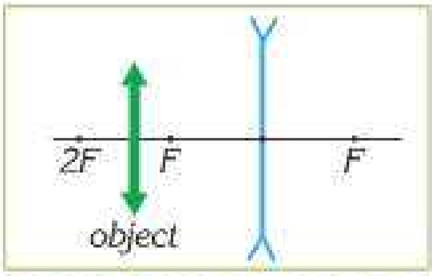
b. It is diminished, virtual and upright.

c. f = 10 cm = 0.1 m;

$$\text{Power} = \frac{1}{-0.1} = -10 \text{ D}$$

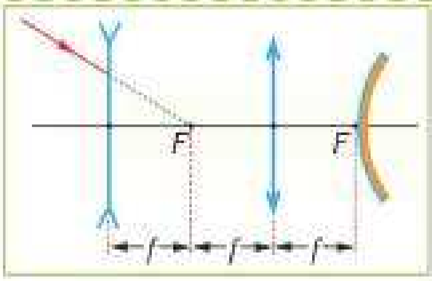
Exercise 10.1

Draw the image of the object near the concave lens.



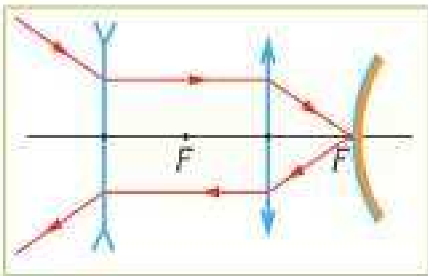
Example 10.4

Draw the path of the light ray in the figure. Both the converging and diverging lenses have the same focal lengths. The convex mirror is at the focus of the convex lens.



Solution

First, the ray is refracted after passing through the diverging lens and becomes parallel to the principal axis. Then it enters the converging lens and is refracted in such a direction that it goes through F. The ray is then reflected back by the concave mirror, following the same path back through the lenses as shown in the figure.



e. Examples of lenses around us

Objects behind a glass or a bottle full of water look larger than their actual sizes. This is because they act as converging lenses and produce magnified, virtual images as in figure 10.7.

A drop of water on a piece of glass can be used as a converging lens. Because it is thicker at the middle and thinner at the edge. It can be used to magnify small letters on a page as shown in figure 10.8.

Small pieces of glass can also act as converging lenses, thus if left on the grass after picnics they can focus sunlight onto the dried grass and start fires.

At the bottom of pools we observe light dancing in the form of water waves, as shown in figure 10.9. The crests (tops) of the waves act as converging lenses focussing light upon the sea bed. The troughs (bottoms) of the waves act as diverging lenses and spread light out.

Figure 10.7

Figure 10.9

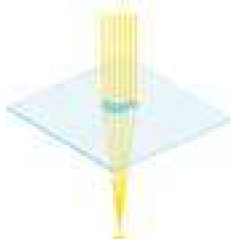


Figure 10.8

f. Uses of lenses

Lenses have very important uses in our life. The eye, cameras, telescopes, microscopes and many other optical instruments work with lenses.

The eye

The eye includes a converging lens as shown in figure 10.10 It produces an inverted real image of objects on the retina, the screen of the eye. Much more detailed information about this wonderful optical instrument will be given in the following pages.

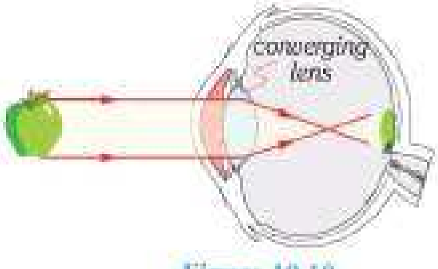


Figure 10.10

Spectacles

Some people need to use spectacles or contact lenses to correct their eye defects. Spectacles or glasses can include converging or diverging lenses depending on the users' needs.

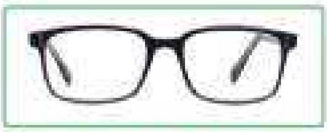


Figure 10.11

The lens camera

The figure 10.12 shows a simple camera, it is a very simple copy of our eyes. It consists of a box, a converging lens and polaroid film. Inside the box is completely dark. The film contains a chemical layer which is sensitive to light. The lens produces inverted, real and diminished images on the film. The film is the screen of the camera.

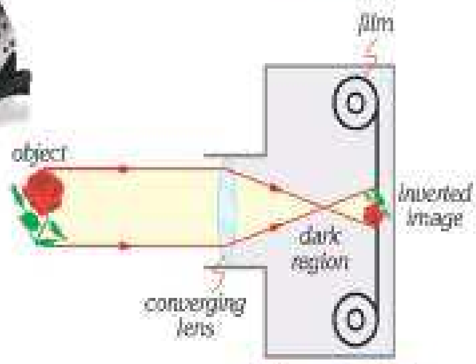


Figure 10.12

Telescopes

Telescopes are the instruments used to observe distant objects. (Figure10.13) A simple telescope includes two converging lenses. One is called the objective lens, and has a long focal length (thin lens). The other is called the eyepiece lens and has a short focal length (thick lens). The inside of a telescope is shown in figure 10.14.

The objective lens produces a real and inverted image of the object. The image is just inside the focal length of the eyepiece lens. Thus the eyepiece lens acts as a magnifying lens. The final image is a large and inverted image of the distant object. It is also a virtual image.

Figure 10.13

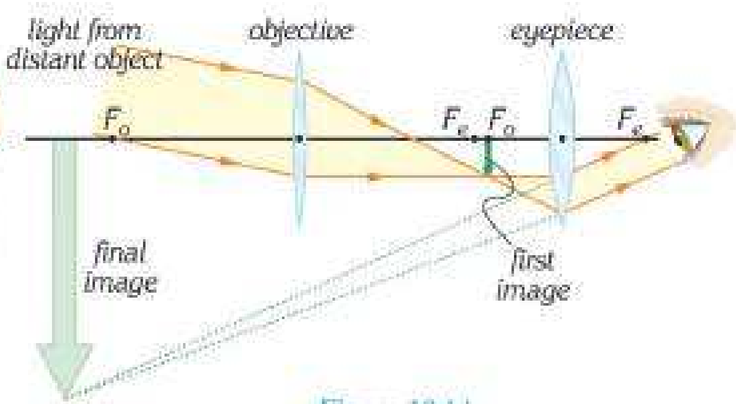


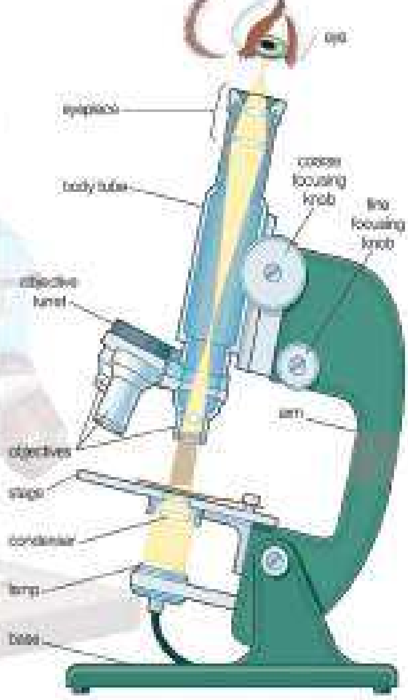
Figure 10.14

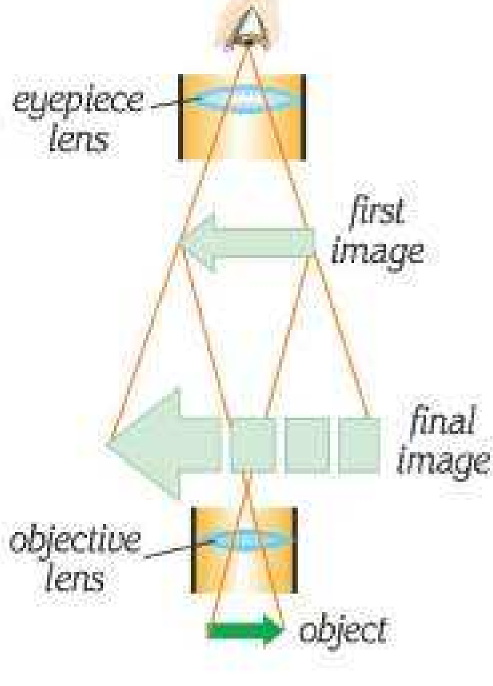
Prism binoculars

Prism binoculars include two small telescopes fixed side by side as shown in the figure. They have two converging lenses to observe distant objects.The prisms inside the binoculars turn the inverted image upright.

The microscope

A microscope includes two converging lenses to enlarge very small objects. One at the lower end (objective lens), one at the upper end (eyepiece lens).
The light reflected from the mirror passes through the object and enters the objective lens. This produces a real and magnified image between the focal point and the pole of the eyepiece lens as shown in the figure to the right. The eyepiece lens acts as a magnifier and produces a magnified image of the object. The image is inverted and virtual.





THE HUMAN EYE

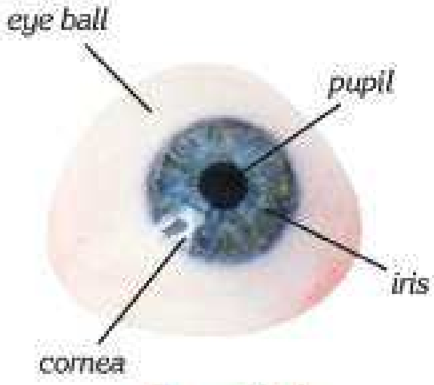


Figure 10.15

a. Parts of the eye

The eye has a spherical shape called the eyeball. There is a hole called the pupil in front of the eye. (Figure10.15).Joined onto the pupil is a converging lens. The inside of the eye ball is filled with a watery liquid. Light rays enter the eye through the pupil and the lens. The lens refracts the rays, forming an inverted image on the retina at the back of the eyeball.

The retina has about 130 million light-sensitive cells! These cells produce electrical signals when light falls upon them. The optic nerves carry these signals from the eye to the brain. The brain then converts the signals into an upright image. Although the image on the retina is inverted we don't see the world upsidedown! Figure10.16 shows thevarious parts of the eye.

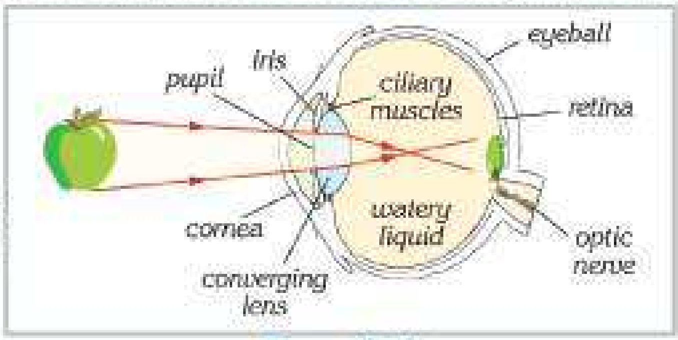


Figure 10.16

b. Night and day

Figure 10.17

The amount of light entering the eye is controlled by the iris, which is the coloured part of the eye. The hole in the middle of the iris is called the pupil. If there is too much light, the hole gets smaller and lets less light in. At night the pupil gets larger and lets much more light in. Figure 10.17 shows larger and smaller pupils in the light and dark, respectively.

c. Seeing nearby and at a distance: The focusing eye

The eye lens is flexible. The muscles (ciliary muscles) around the lens can change their shape and thickness, as shown in figure10.16 above. Changing the thickness of the eye lens changes its focal length. Thus, the eye can make focusing adjustments for near or distant objects. This is called accommodation of the eye.

For a person with normal vision, the eye can accommodate clearly for objects at infinity. That is, the far point for this eye is infinity. The nearest point the normal eye can focus clearly on objects is 25 cm. This is called the nearpoint.

d. Eye defects

1. Long-sightedness (Hyperopia)

Some people see distant objects clearly but can't see nearby objects with the same clarity. This is because their eyeballs are shorter than normal, or their eyelenses are too thin. These people are said to be long-sighted. Therefore light rays entering their eyes from a near object are focused behind the retina. A converging lens can correct this defect. It combine the rays so that the eye-lens forms an image exactly on the retina, as shown in figure 10.18.

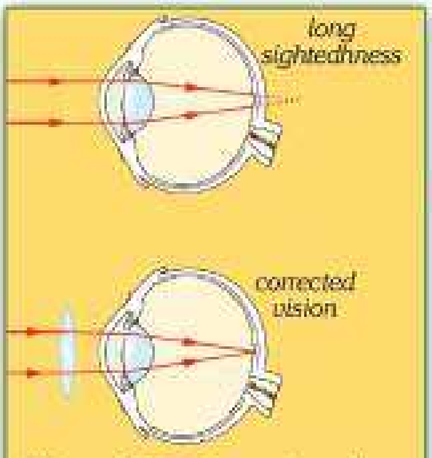


Figure 10.18 Correcting long sightedness with converging lens

2. Near-sightedness (Myopia)

Some people see nearby objects clearly but cannot see distant objects with the same clarity. These people are said to be near-sighted. Their eyeballs are longer than normal, or their eye-lenses are too thick. Therefore light rays from a distant object are focused in front of the retina. A diverging lens is used to correct this defect. It diverges the rays so that the eye-lens forms an image exactly on the retina, as shown in figure 10.19.

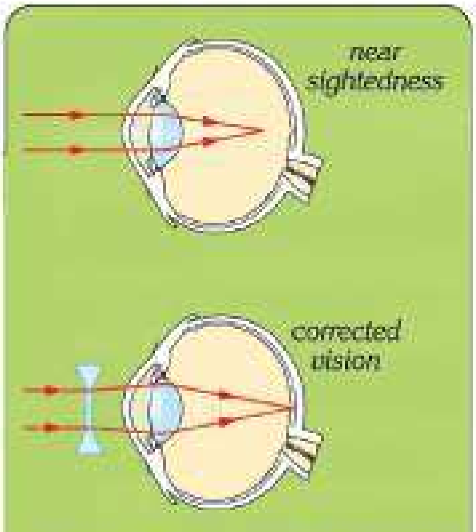


Figure 10.19 Correcting near sightedness with diverging lens

How to care FOR your eyes

Do not study under very strong or dim light.
Do not read books at too close or too far a distance away
Do not look at the Sun.
Light should come from your left when you study.
Do not watch television at a distance closer than 3 m.
Do not watch television for a long time.
Illuminate your room properly.
Have your eyes checked regularly.
Do not use others' glasses.
Prefer foods rich in vitamins.
Do not use alcohol, drugs and cigarettes. (They degrade the working of optical nerves and the brain).
Do not use dirty water to wash your face and eyes.
Sleep well.
Do not use poor quality sun glasses.

3. Colourblindness

The cells on the retina are sensitive to colours, therefore objects appear coloured. However, a colour-blind person cannot recognise some colours. For a colour-blind person red and green colours look the same! Try to read number in the figure 10.20. This is the most common type of colour-blindness. Colour-blind people must not work where colours are important.

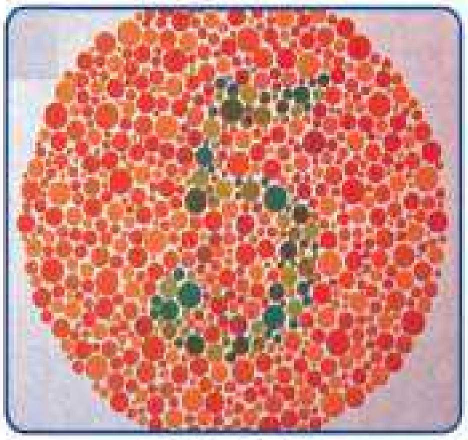


Figure 10.20

4. Astigmatism

This results from an irregularly shaped cornea or eye-lens. If the eye-lens or cornea is not perfectly spherical, the eye can form a correct image only in some directions, but not in others. A cylindrical lens can correct this defect.

5. Cataract

Some old people suffer from cataracts. This occurs when the eye becomes cloudy, rather than clear. A doctor can correct this in a simple operation.

CHAPTER QUESTIONS

Use the words below in your own sentences

lens, optical centre, converging lens, diverging lens, spectacles, telescope, lens camera, binoculars

Fill in the blanks with appropriate words

1. A converging lens is .... at the centre and thinner at the outside.

2. A .... lens causes light rays to spread out.

3. A light ray parallel to the principal axis of a converging lens passes through the .... after being refracted by the lens.

4. If an object is beyond a distance of 2F from a converging lens, its image is .... than the object.

5. A ray passing through the optical .... of a lens travels without changing its direction.

6. The image formed by a diverging lens is always ....

7. Microscopes include .... lenses.

8. Prism binoculars use both .... and ....

Answer the questions

1. What is a lens? Write down the different types of lenses and their differences.

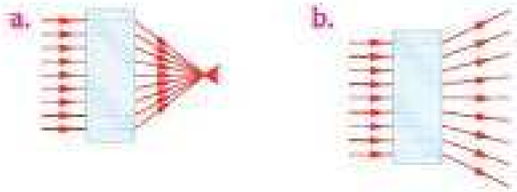
2. Draw the special rays for converging and diverging lenses.

3. An object is 50 cm beyond a convex lens which has a focal length of 20 cm.

a. Where does the image form?
b. List its properties.
c. Where should the object be placed in order to obtain a magnified image?

4. An object is placed in front of a diverging lens. Show how the image is formed by drawing a diagram.

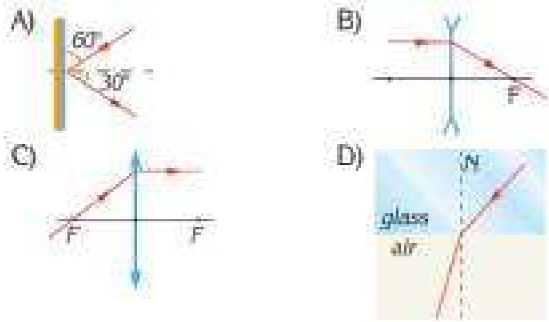
5. The boxes below include only one type of lens; either converging or diverging. Decide which box includes which lens.



Answer the test questions

1. Which of the following combination of prisms is similar to a diverging lens?

2. In which of the figures below is the path of the ray incorrect?



3. In which of the figures below is the path of the ray incorrect?

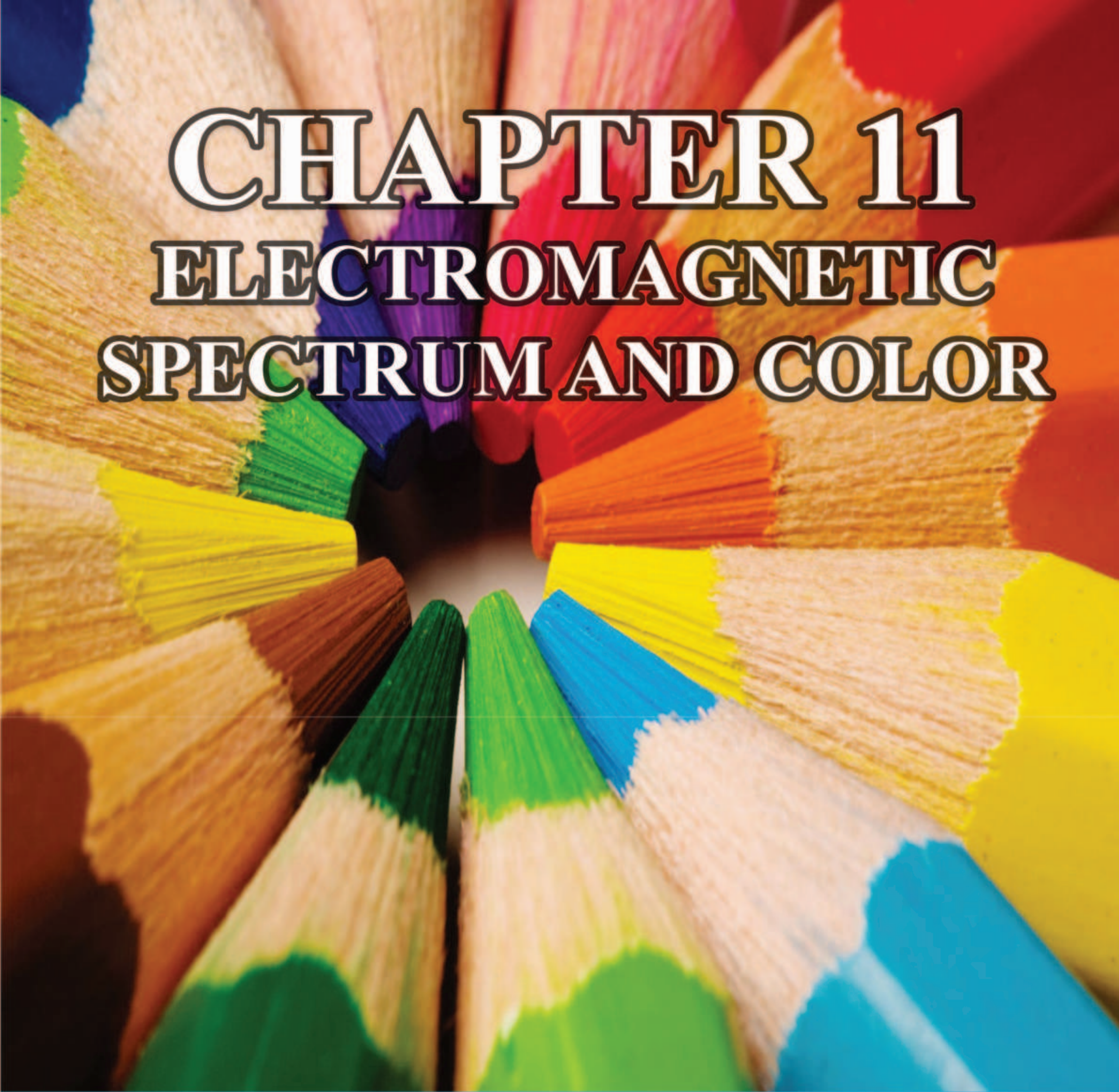
A) 4 B) 3 C) 2 D) 1

4. Which of the following produces a real image?

A) converging lens B) diverging lens

List the Eye defects and talk about one of them.

CHAPTER 11
ELECTROMAGNETIC SPECTRUM AND COLOR



PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. List the Electromagnetic Spectrum.
2. Describe Colors of Light.
3. Give some Characteristics of EM waves.

The Electromagnetic Spectrum and Color

When you look around, you can see things that reflect light to your eyes. But a bee might see the same things differently. Bees can see a kind of light—called ultraviolet light—that you can't see!

It might seem odd to call something you can't see light. The light you are most familiar with is called visible light. Ultraviolet light is similar to visible light. Both are kinds of electromagnetic (EM) waves. In this section, you will learn about many kinds of EM waves, including X rays, radio waves, and microwaves.

Characteristics of EM Waves

All EM waves travel at the same speed in a vacuum— 300,000 km/s. How is this possible? The speed of a wave is found by multiplying its wavelength by its frequency. So, EM waves having different wavelengths can travel at the same speed as long as their frequencies are also different. The entire range of EM waves is called the electromagnetic spectrum. The electromagnetic spectrum is shown in Figure 11.1.

The electromagnetic spectrum is divided into regions according to the length of the waves. There is no sharp division between one kind of wave and the next. Some kinds even have overlapping ranges.

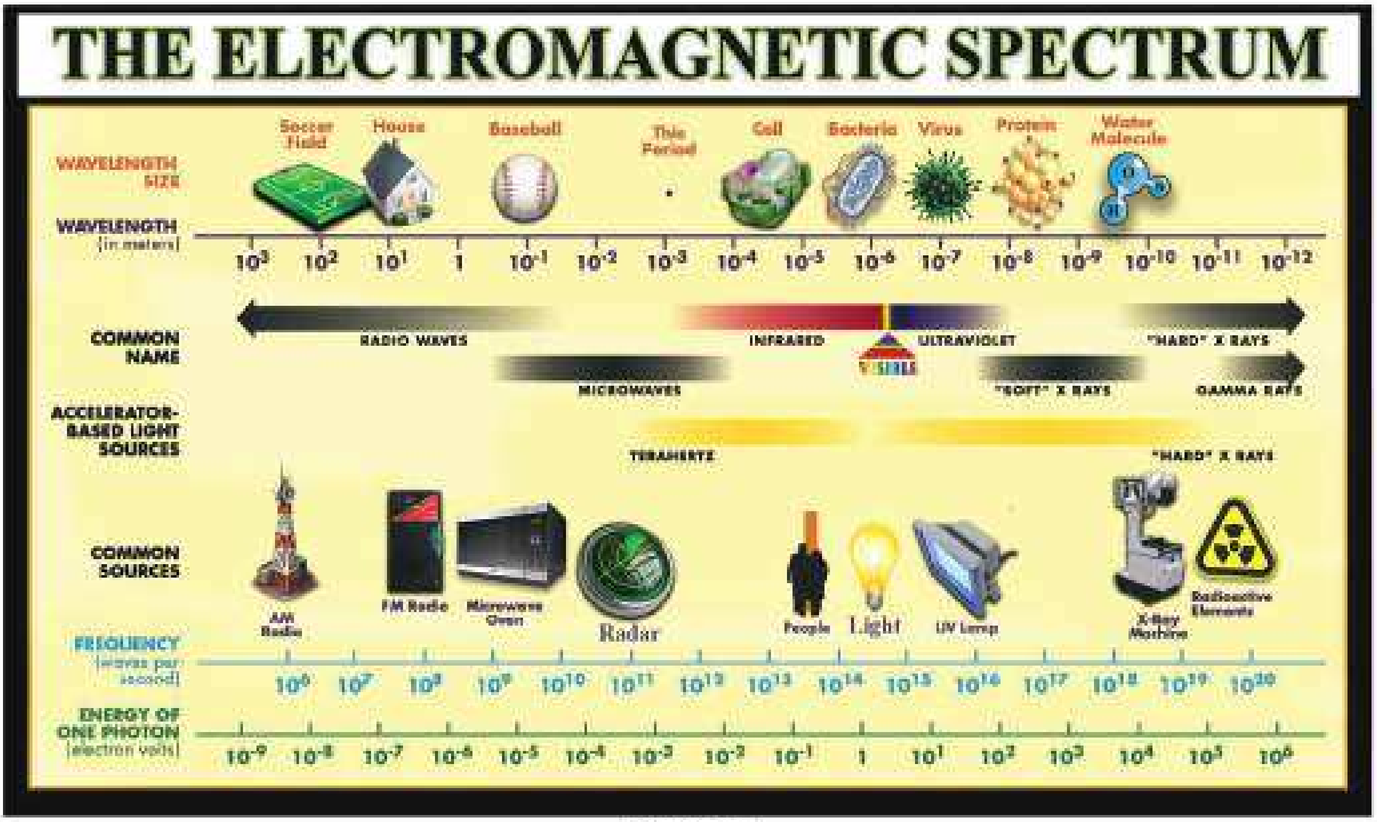


Figure 11.1

Radio Waves

Radio waves cover a wide range of waves in the EM spectrum. Radio waves have some of the longest wavelengths and the lowest frequencies of all EM waves. In fact, radio waves are any EM waves that have wavelengths longer than 30 cm. Radio waves are used for broadcasting radio signals. see figure (11.2).

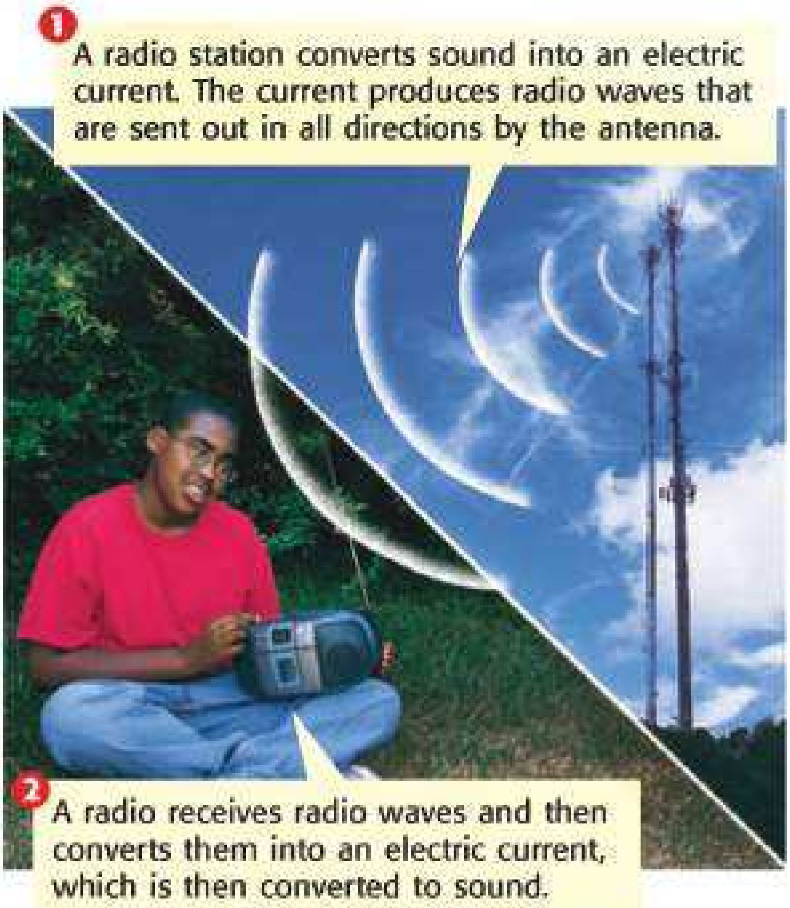
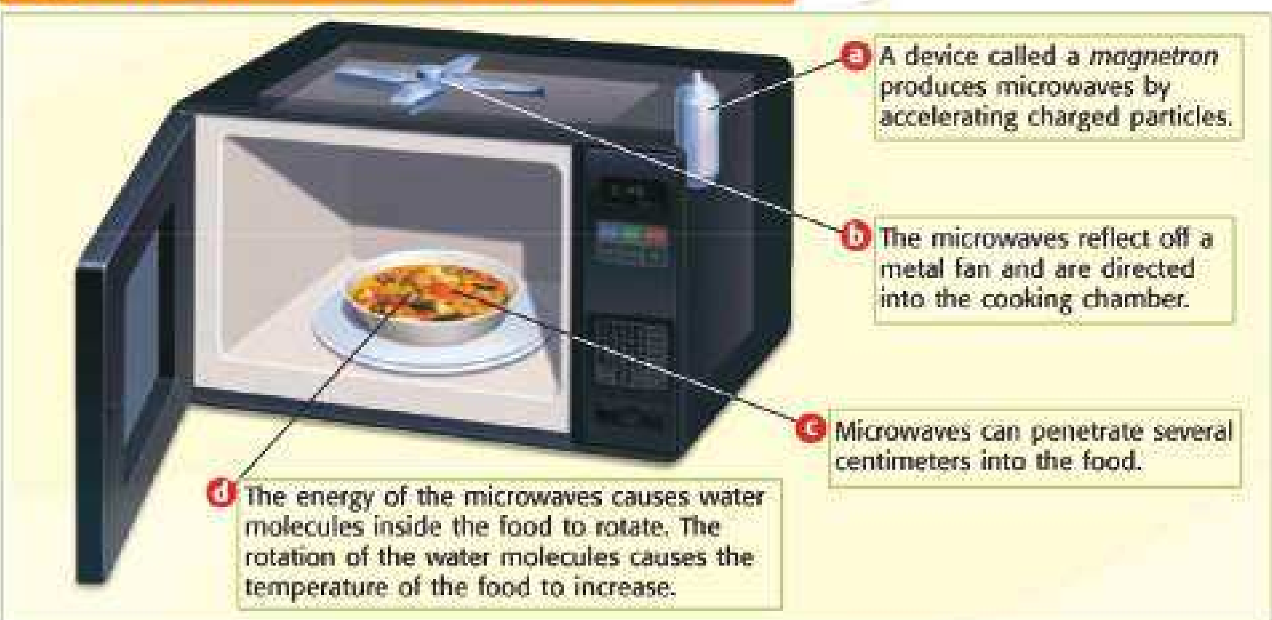


Figure 11.2 Radio waves cannot be heard, but they can carry energy that can be converted into sound.

Microwaves

Microwaves have shorter wavelengths and higher frequencies than radio waves do. Microwaves have wavelengths between 1 mm and 30 cm. You are probably familiar with microwaves— they are created in a microwave oven, such as the one shown in Figure 11.3.

Figure 11.3 How Microwave Oven Works



Radar

Microwaves are also used in radar. Radar (radio detection and ranging) is used to detect the speed and location of objects. The police officer in Figure 4 is using radar to check the speed of a car. The radar gun sends out microwaves that reflect off the car and return to the gun. The reflected waves are used to calculate the speed of the car. Radar is also used to watch the movement of airplanes and to help ships navigate at night.

Figure 11.4 Police officers use radar to detect cars going faster than the speed limit.

Infrared Waves

Infrared waves have shorter wavelengths and higher frequencies than microwaves do. The wavelengths of infrared waves vary between 700 nanometers and 1 mm. A nanometer (nm) is equal to 0.000000001 m.

On a sunny day, you may be warmed by infrared waves from the sun. Your skin absorbs infrared waves striking your body. The energy of the waves causes the particles in your skin to vibrate more, and you feel an increase in temperature. The sun is not the only source of infrared waves. Almost all things give off infrared waves, including buildings, trees, and you! The amount of infrared waves an object gives off depends on the object's temperature. Warmer objects give off more infrared waves than cooler objects do.

You can't see infrared waves, but some devices can detect infrared waves. For example, infrared binoculars change infrared waves into light you can see. Such binoculars can be used to watch animals at night. Figure 11.5 shows a photo taken with film that is sensitive to infrared waves.

Figure 11.5 In this photograph, brighter colors indicate higher temperatures.

Figure 11.6 Water droplets can separate white light into visible light of different wavelengths. As a result, you see all the colors of visible light in a rainbow.

Visible Light

Visible light is the very narrow range of wavelengths and frequencies in the electromagnetic spectrum that humans can see. Visible light waves have shorter wavelengths and higher frequencies than infrared waves do. Visible light waves have wavelengths between 400 nm and 700 nm.

Visible Light from the Sun

Some of the energy that reaches Earth from the sun is visible light. The visible light from the sun is white light. White light is visible light of all wavelengths combined. Light from lamps in your home as well as from the fluorescent bulbs in your school is also white light.

Colors of Light

Humans see the different wavelengths of visible light as different colors, as shown in Figure11.6. The longest wavelengths are seen as red light. The shortest wavelengths are seen as violet light.

The range of colors is called the visible spectrum. You can see the visible spectrum in Figure11.7.

→ When you list the colors, you might use the imaginary name ROY G. BiV to help you remember their order. The capital letters in Roy's name represent the first letter of each color of visible light: red, orange, yellow, green, blue, and violet. What about the i in Roy's last name?
You can think of i as standing for the color indigo. Indigo is a dark blue color.

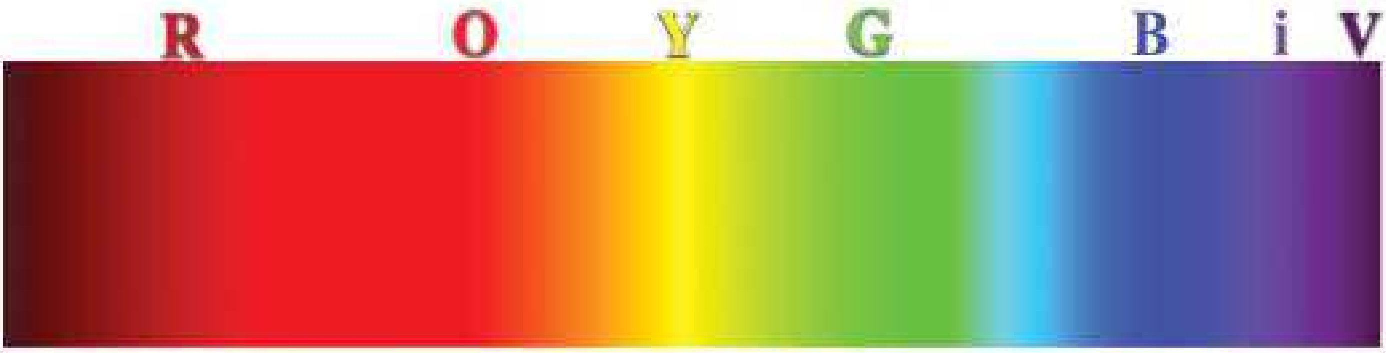


Figure 11.7 The visible spectrum contains all colors of light.

Ultraviolet Light

Ultraviolet light (UV light) is another type of electromagnetic wave produced by the sun. Ultraviolet waves have shorter wavelengths and higher frequencies than visible light does. The wavelengths of ultraviolet light waves vary between 60 nm and 400 nm. Ultraviolet light affects your body in both bad and good ways

Bad Effects

On the bad side, too much ultraviolet light can cause sunburn, as you can see in Figure 11.8 Too much ultraviolet light can also cause skin cancer, wrinkles, and damage to the eyes. Luckily, much of the ultraviolet light from the sun does not reach Earth's surface. But you should still protect yourself against the ultraviolet light that does reach you. To do so, you should use sunscreem with a high SPF (sun protection factor). You should also wear sunglasses that block out UV light to protect your eyes. Hats, long-sleeved shirts, and long pants can protect you, too. You need this protection even on overcast days because UV light can travel through clouds.

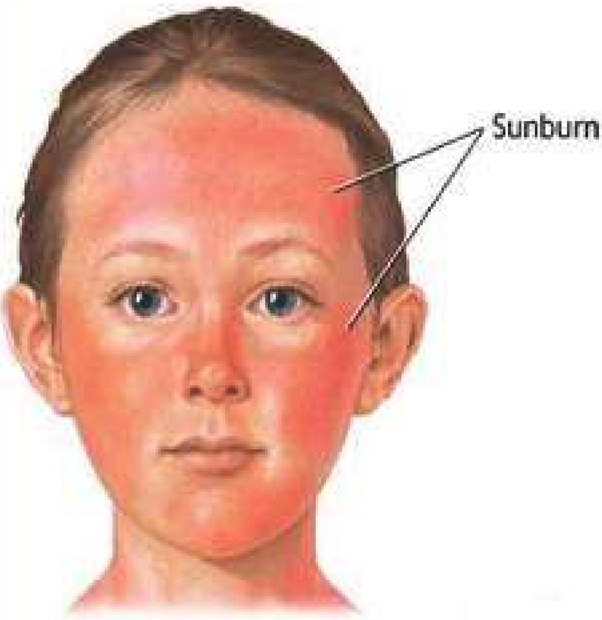


Figure 11.8

Good Effects

On the good side, ultraviolet waves produced by ultraviolet lamps are used to kill bacteria on food and surgical tools. In addition, small amounts of ultraviolet light are beneficial to your body. When exposed to ultraviolet light, skin cells produce vitamin D. This vitamin allows the intestines to absorb calcium. Without calcium, your teeth and bones would be very weak.

X Rays and Gamma Rays

X rays and gamma rays have some of the shortest wavelengths and highest frequencies of all EM waves.

X Rays

X rays have wavelengths between 0.001 nm and 60 nm. They can pass through many materials. This characteristic makes X rays useful in the medical field, as shown in Figure 11.9, But too much exposure to X rays can also damage or kill living cells. A patient getting an X ray may wear special aprons to protect parts of the body that do not need X-ray exposure. These aprons are lined with lead because X rays cannot pass through lead.

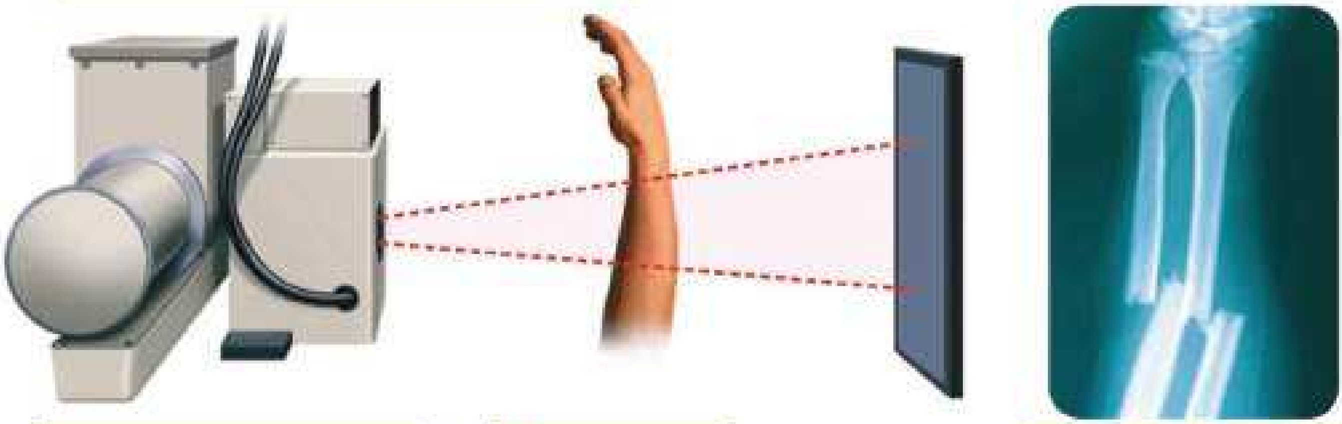
X-ray machines are also used as security devices in airports and other public buildings. The machines allow security officers to see inside bags and other containers without opening the containers.

Gamma Rays

Gamma rays are EM waves that have wavelengths shorter than 0.1 nm. They can penetrate most materials very easily. Gamma rays are used to treat some forms of cancer. Doctors focus the rays on tumors inside the body to kill the cancer cells. This treatment often has good effects, but it can have bad side effects because some healthy cells may also be killed.

Gamma rays are also used to kill harmful bacteria in foods, such as meat and fresh fruits. The gamma rays do not harm the treated food and do not stay in the food. So, food that has been treated with gamma rays is safe for you to eat.

Figure 11.9 How a Bone Is X-Rayed



1. X rays travel easily through skin and muscle but are absorbed by bones.

2. The X rays that are not absorbed strike the film.

3. Bright areas appear on the film where X rays are absorbed by the bones.

Light and Color

Why are strawberries red and bananas yellow? How can a soda bottle be green, yet you can still see through it?

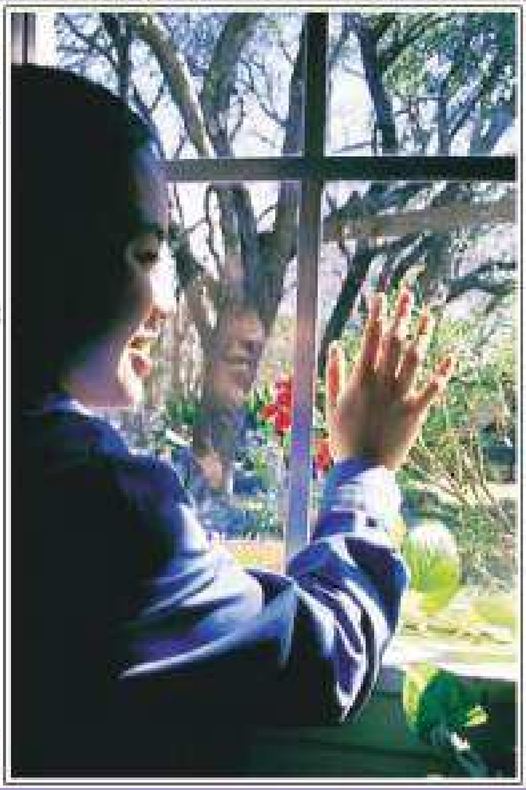
If white light is made of all the colors of light, how do things get their color from white light? Why aren't all things white in white light? Good questions! To answer these questions, you need to know how light interacts with matter.

Transmission, Reflection, and Absorption

You can see objects outside because light is transmitted through the glass.

You can see the glass and your reflection in it because light is reflected off the glass.

The glass feels warm when you touch it because some light is absorbed by the glass.



Light and Matter

When light strikes any form of matter, it can interact with the matter in three different ways.

the light can be reflected, absorbed, or transmitted.

Reflection happens when light bounces off an object. Reflected light allows you to see things. Absorption is the transfer of light energy to matter. Absorbed light can make things feel warmer. Transmossion is the passing of light through matter. You see the transmission of light all time. All of the light that reaches your eyes are transmitted through air. Light is transmitted, reflected and absrobed when it strikes the glass in the window.

Transparent, Translucent, and Opaque

Transparent plastic makes it easy to see what you are having for lunch.

Translucent wax paper makes it a little harder to see exactly what's for lunch.

Opaque aluminum foil makes it impossible to see your lunch without unwrapping it.

Colors of Objects

How is an object's color determined? Humans see different wavelengths of light as different colors.For example, humans see long wavelengths as red and short wavelengths as violet. And, some colors, like pink and brown, are seen when certain combinations of wavelengths are present.

The color that an object appears to be is determined by the wavelengths of light that reach your eyes. Light reaches your eyes after being reflected off an object or after being transmitted through an object. When your eyes receive the light, they send signals to your brain. Your brain interprets the signals as colors.

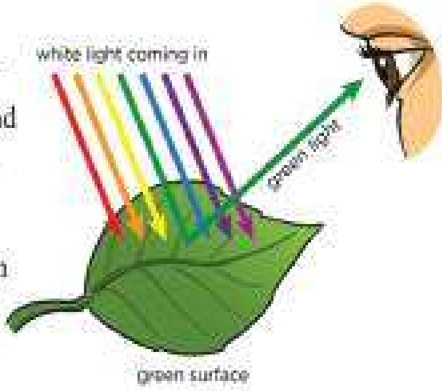


Figure 11.10 Opaque Objects and Color

When white light shines on a strawberry, only red light is reflected. Other colors of light are absorbed. Therefore, the strawberry looks red to you.

The white hair in this cow's hide reflects all the colors of light, but the black hair absorbs all the colors.

Colors of Opaque Objects

When white light strikes a colored opaque object, some colors of light are absorbed, and some are reflected. Only the light that is reflected reaches your eyes and is detected. So, the colors of light that are reflected by an opaque object determine the color you see. For example, if a sweater reflects blue light and absorbs all other colors, you will see that the sweater is blue. Another example is shown on the left in Figure 10.

What colors of light are reflected by the cow shown on the right in Figure 10? Remember that white light includes all colors of light. So, white objects—such as the white hair in the cow's hide —appear white because all the colors of light are reflected. On the other hand, black is the absence of color. When light strikes a black object, all the colors are absorbed.

Colors of Transparent and Translucent Objects

The color of transparent and translucent objects is determined differently than the color of opaque objects. Ordinary window glass is colorless in white light because it transmits all the colors that strike it. But some transparent objects are colored. When you look through colored transparent or translucent objects, you see the color of light that was transmitted through the material. The other colors were absorbed.

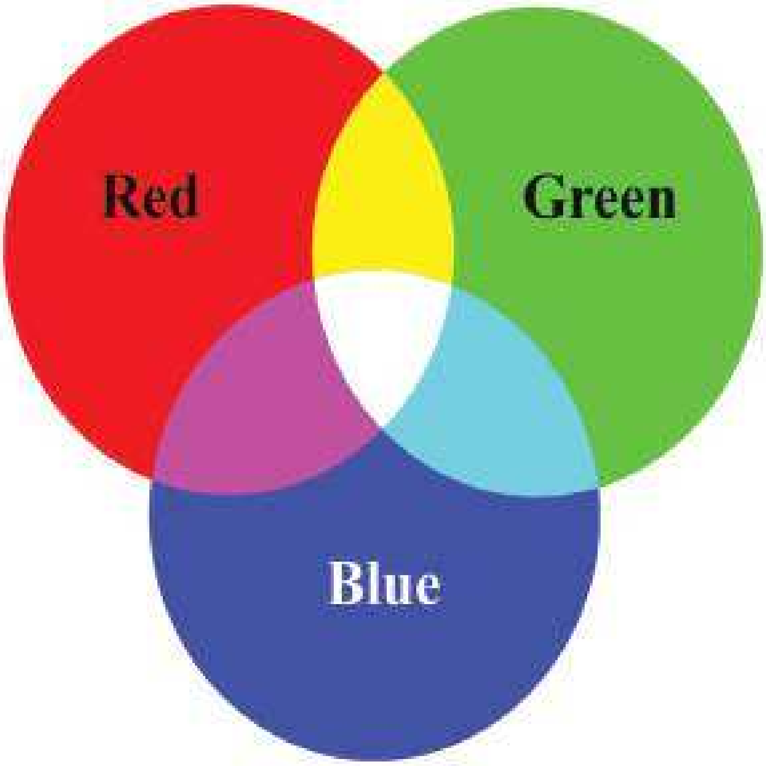


Figure 11.11 Primary colors of light —written in white-combine to produce white light. Secondary colors of light—written in black—are the result of two primary colors added together.

Mixing Colors of Light

In order to get white light, you must combine all colors of light, right? This method is one way of doing it. But you can also get light that appears white by adding just three colors of light together—red, blue, and green. The combination of these three colors is shown in Figure 11.11 In fact, these three colors can be combined in different ratios to produce many colors. Red, blue, and green are called the primary colors of light.

Color Addition

When colors of light combine, you see different colors. Combining colors of light is called color addition. When two primary colors of light are added together, you see a secondary color of light. The secondary colors of light are cyan (blue plus green), magenta (blue plus red), and yellow (red plus green). Figure 11.11 shows how secondary colors of light are formed.

Mixing Colors of Pigment

If you have ever tried mixing paints in art class, you know that you can't make white paint by mixing red, blue, and green paint. The difference between mixing paint and mixing light is due to the fact that paint contains pigments.

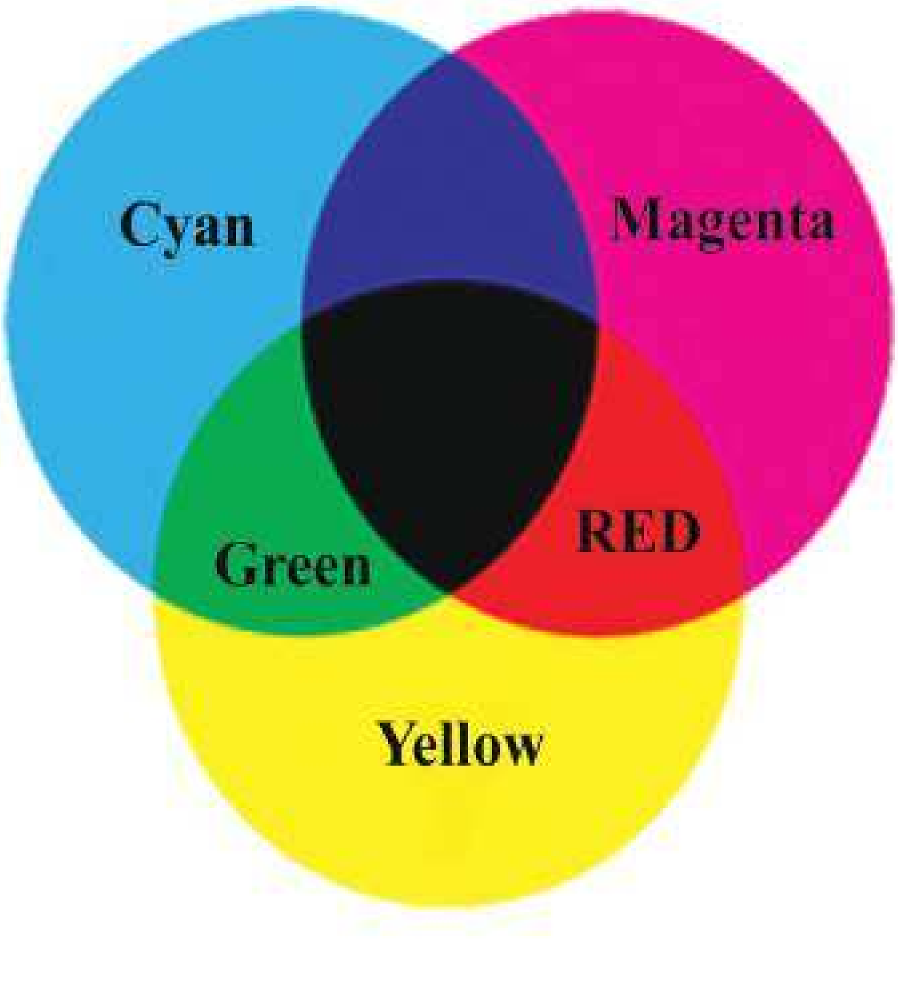
Pigments and Color

A pigment is a material that gives a substance its color by absorbing some colors of light and reflecting others. Almost everything contains pigments. Chlorophyll and melanin are two examples of pigments.
Chlorophyll gives plants a green color, and melanin gives your skin its color.

Color Subtraction

Each pigment absorbs at least one color of light. When you mix pigments together, more colors of light are absorbed or taken away. So, mixing pigments is called color subtraction. The primary pigments are yellow, cyan, and magenta. They can be combined to produce any other color. In fact, every color in this book was produced by using just the primary pigments and black ink. The black ink was used to provide contrast to the images. Figure **11.12** shows how the four pigments combine to produce many different colors.

Figure 11.12 Primary pigments– written in black– combine to produce black. Secondary pigments – written in white – are the result of the subtraction of two primary pigments.



CHAPTER QUESTIONS

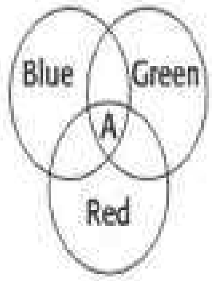
Q.1. What are the types of electromagnetic waves.

Q.2. What is electromagnetic spectrum.

Q.3. You can see yourself in the mirror, because of ____________

Q.4. What color of light is produced when red light is added to green light?

Q.5. *Use the diagram below to answer questions 1–2.*



1. While performing an experiment on the colors of light, Pablo mixed three colors of light to form the image above. What color would Pablo see at point A?

A. yellow

B. magenta

C. white

D. black

2. What color would Pablo find at point A if pigments were used instead of colors of light?

A. white

B. black

C. green

D. red