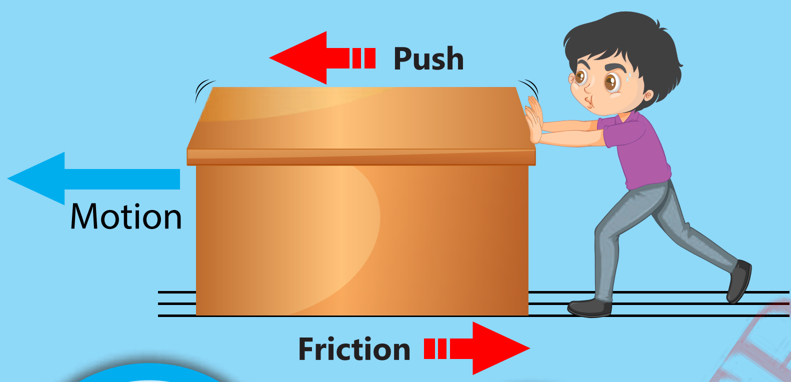

What makes the things at rest move?

What makes the moving objects stop motion?

What is gravitational acceleration?

08 Force and Motion

Students' Learning Outcomes

After studying this chapter, students will be able to:

- Describe the effect of force on changing the speed and direction of motion with time.
- Define and state the SI unit of force.
- Formulate the relationship between speed, distance and time.
- State SI (System International) unit of speed.
- Calculate average speed.
- Interpret a distance-time graph.
- Give examples of contact forces and non-contact forces.
- Demonstrate that forces always work in action and reaction pairs (equal in magnitude, opposite in direction).

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VOCABULARY

Force	Distance	Speed	Gravity	Displacement	N (newton)
Push, pull, friction, gravity, etc.	Measure of how far apart objects or points are	Measure of how fast or slow an object moves per unit time	The Earth's pull on objects	Shortest distance between two points	Standard quantity or unit used for measuring force

Recall what you have learnt

We have learnt:

- The act of push and pull
- Gravity
- Friction

Figure 8.1 given below will help you recall what you have learnt about force.

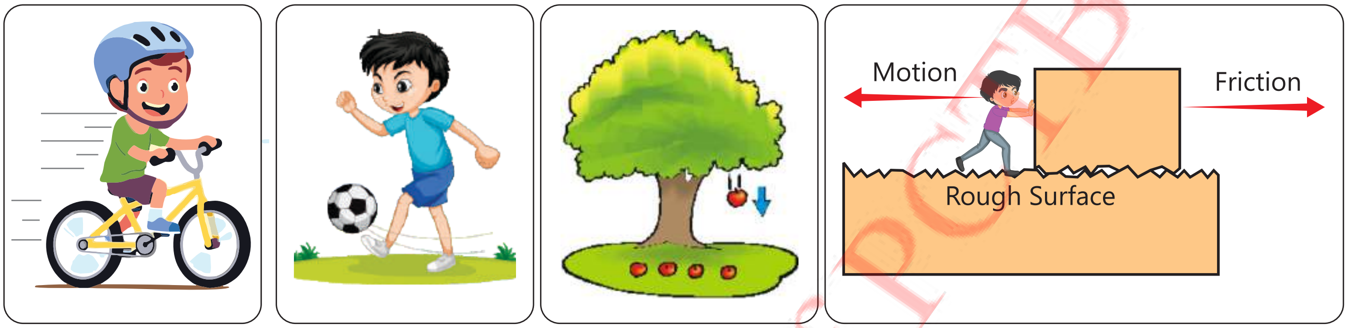

Figure 8.1 Examples of force

Activity 8.1 Assessment

Write **C** against the correct and **I** against the incorrect statement in the middle column. Also correct the incorrect statement and write it in the next column.

Correct/Incorrect	C/I	Correct statement
Kicking a football is application force on it		
Whatever is thrown upward, return to the ground is due to the Earth's push on the objects. .		
Force makes the thing at rest move.		
Friction stops or tends to stop the moving objects.		
Machines make the work easier.		

In this chapter we will learn about:

- Force
- Unit of force
- Relationship between speed, distance and time
- Contact forces and non-contact forces

8.1 FORCE

Push and pull makes the things move. Gravity is the Earth's pull on the objects. Moving objects cannot stop if there is no friction. Push and pull, gravity and friction are the examples of the force.

8.1.1 Effects of Force

Force can **(Figure 8.2)**:

- make the things at rest move.
- stop the moving objects.

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- change the speed of a moving object.
- change the direction of a moving object.
- change the shape of an object.

Force makes the objects move

Force stops the moving object

Force changes the speed

Force changes the shape of object

Force changes the direction of motion

Figure 8.2 Effects of force

8.1.2 Change in speed

Consider you are moving by a bicycle at certain speed. If your friend pushes the bicycle from behind, the speed of your bicycle will increase and it will move faster. If he pulls your moving bicycle from behind, the speed of bicycle will decrease and you will move slower.

If a force is applied on a moving object in the direction of motion, its speed increases. If the force is applied in the direction opposite to the direction of motion of the object, its speed decreases.

8.1.3 Change in direction

In a cricket match, when the bowler throws ball towards batsman, he hits the ball. In this way, the direction of motion of the ball is changed. The force exerted by the batsman on the moving ball changes its direction of motion.

Do you know?

1. The quantity of matter in an object is called its mass (m)
2. The Earth pulls the things towards itself. The Earth's pull on the objects is called gravity.
3. How fast things move towards the Earth is termed as acceleration due to gravity (g). The value of 'g 'is taken as 10 N/kg.
4. The quantities of mass, force, length, time, etc., that can be measured are called physical quantities.
5. The standard quantity used to measure that quantity is called its unit.
6. According to International System of Units, called Standard International (SI):
   - The standard quantity of mass used to measure it is kilogram (kg). Hence, SI unit of mass is kilogram (kg). Gram (g), milligram (mg), etc. are smaller units of mass.

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- The standard quantity of length or distance used to measure it is kilometre (km). Hence, SI unit of length or distance is kilometre (km). Metre (m), millimetre (mm), etc. are smaller units of length or distance.
- The standard quantity of time used to measure it is second (s). Hence, SI unit of time is second (s). Minute (min), Hour (hr), etc., are the bigger units of time.

8.2 UNIT OF FORCE

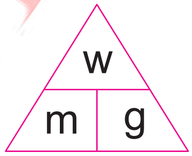
Force is a physical quantity. The Standard International (SI) unit of force is newton. The symbol used for newton is 'N'.

Weight is a force. In fact, it is the gravitational force acting on an object. The symbol used for weight is 'w'. If 'm' is mass is of an object and 'g' is the acceleration due to gravity having value (10 N / kg), then we can express weight as:

$$w = mg \quad .... \quad (1)$$

The weight (force) acting on an object of mass 1 kg can be calculated using equation (1) as:

$$w = mg$$
$$w = 1\ (kg) \times 10\ N/kg$$
$$w\ (force) = 10\ N$$



Thus, the weight (force) of 1 kg mass on the Earth is 10 N.
It means weight (force) of 1000 g mass = 10 N.
The weight (force) of 100 g mass = 1 N

The standard one newton force is the force (weight) that the Earth acts on an object of mass 100 g.

Problem 8.1: Calculate the weight (force) of an object having mass 5 kg on the Earth's surface.

Solution:

m (mass) = 5 kg
g = 10 N/kg
w = mg
w = 5 kg × 10 N/ kg
w = 50 N

Mini Exercise

Calculate the weight of an object of mass 10 kg on the surface of the Earth.

Test yourself!

What will be the weight of an object of mass 10 kg on the moon, where value of g is 1.6 N/kg.

Think Tank

Suppose the spherical shape of the Earth as shown in the Figure. Person 'A' is standing on the ground in Pakistan.

(i) Which country is opposite to Pakistan on the Earth's surface?

(ii) Why doesn't the person 'B' standing on the ground in Brazil fall away into the space from the Earth?

(iii) What is the direction of the Earth's gravitational force or gravity?

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Informative

An English scientist, Sir Isaac Newton (1642 – 1727) was the first who understood the gravitational force.

Brain teaser

Suppose a metallic block consists of ten billion particles. If we take it on the moon, how many particles does it consist of at the moon?

The position where the same force of gravity acts on two objects of different masses, the object with bigger mass has the greater weight.

8.2.1 Newton – The Unit of Force

The SI unit of force is **Newton (N)**. It is named after the English Scientist Sir Isaac Newton. On the Earth, a body of mass 100g has a weight of about 1 N. For example, a medium sized apple has a mass about 100g. The gravitational pull on this apple is 1 N approximately, i.e., its weight is 1 N.

The Earth's gravitational field strength (g) is 10 N/kg. This means that for each kg of mass, an object will experience 10 N of force.

The gravitational acceleration (g) is a constant and equal to 9.8 meter per second square (ms^{-2}).

Problem 8.2: Calculate the weight of a wooden block of mass 45 kg. The value of g = $10ms^{-2}$.

Solution:

Mass of the block (m)	=	45 kg
Gravity acting on it (g)	=	$10ms^{-2}$
Weight (W)	=	?
W	=	mg
W	=	$45\,kg \times 10ms^{-2} = 450\,N$ (Ans.)

8.2.2 Measuring Force

Force is measured by using an instrument called **force meter**. The force meter is a spring balance **(Figure 8.3)**, which is of two types; extension spring balance and compression spring balance. In an extension spring balance, when a pulling force acts on its extension, it stretches and the pointer moves along the scale, showing the value of force. In the compression spring balance, its spring compresses when a pushing force acts on it.

Figure 8.3 Spring balance

8.3 RELATIONSHIP BETWEEN SPEED, DISTANCE AND TIME

8.3.1 Force and Motion

Force is needed to make a body move. When we apply some force on an object, it moves and covers some distance in the direction of applied force.

Speed of a moving object tells us how fast or slow it moves. If you drive your vehicle at greater

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speed, you will move fast and cover more distance in a given time. If you drive the vehicle at slower speed, you will move slow and cover less distance in the given time. Speed is defined as the distance travelled per unit time.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \quad \ldots\ldots\ldots\ldots (2)$$

This equation (2) reveals that speed is a measure of the distance, an object travels, per unit time.

If distance covered is denoted by **S**, speed by **v** and time by **t**, the equation (2) may symbolically be written as:

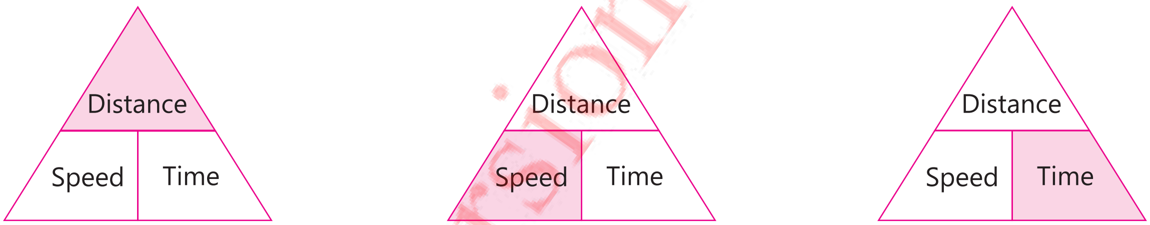
$$v = \frac{S}{t}$$

The unit for measuring speed can be derived by dividing the unit of distance kilometer (km) or metre (m) by the unit of time hours (hr) or second (s). The unit of speed is therefore kilometre per hour (km/hr or km hr^{-1}) or metre per second (m/s or m s^{-1}).

Problem 8.3: A boy runs 240 m in 80 second. Calculate its speed.

Solution: $v = \frac{S}{t} = \frac{240\text{ m}}{80\text{ s}} = 3\text{ ms}^{-1}$

Speed, distance and time are related as under:



Distance = Speed × Time

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

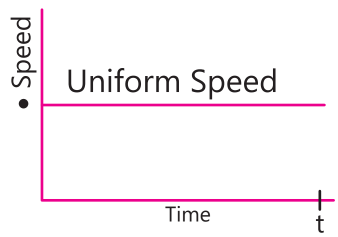
$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$

8.3.2 Types of Speed

- Uniform speed
- Variable speed
- Average speed

Uniform speed

If an object travels the same distance in the same intervals of time, its speed is called **uniform speed**.



Example: If a vehicle covers 70 km in first hour, 70 km in second hour and 70 km in third hour, its speed is uniform, i.e., 70 km/hr.

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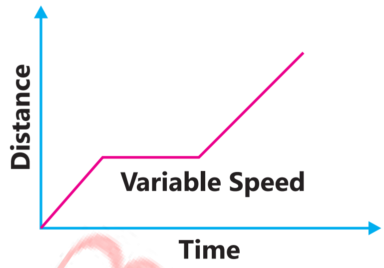
Variable speed

If a car travels different distances in the same intervals of time, its speed is called **variable speed**.

Example: If a car travels 55 km in first hour, 64 km in second hour and 75 km in third hour, the car will have variable speed.



Average speed

The speed of an object may vary during the total time it has moved. The **average speed** can be calculated by dividing the total distance an object covers by the total time it takes to cover that distance.

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

Problem 8.4

A person travels by car at a speed of 60 km/hr for 2 hours and then slows down to 40 km/hr for the next 2 hours. Calculate the average speed?

Solution: Suppose S_1 is the first distance and S_2 is the second distance travelled.

We know:

$$S = v \times t$$

$$S_1 = 60\ \text{km hr}^{-1} \times 2\ \text{hr} = 120\ \text{km}$$

$$S_2 = 40\ \text{km hr}^{-1} \times 2\ \text{hr} = 80\ \text{km}$$

Total distance $= S = S_1 + S_2$

$S = 120\ \text{km} + 80\ \text{km}$

$S = 200\ \text{km}$

Total time $= t = t_1 + t_2$

$t = 2\ \text{hr} + 2\ \text{hr}$

$t = 4\ \text{hr}$

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

$$= \frac{200\ \text{km}}{4\ \text{hr}} = 50\ \text{km hr}^{-1}$$

Problem 8.5

A student covers 80 m in 8 s and 120 m in 12 s. Calculate his average speed?

Solution: Total distance covered $= S_1 + S_2$

$= 80\ \text{m} + 120\ \text{m}$

$= 200\ \text{m}$

Total time taken $= t_1 + t_2 = 8\ \text{s} + 12\ \text{s} = 20\ \text{s}$

Average speed $= \dfrac{\text{Total distance covered}}{\text{Total time taken}}$

$$= \frac{200\ \text{m}}{20\ \text{s}} = 10\ \text{m s}^{-1}$$

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Problem 8.6

A motor car covers 100 m in 5 seconds. If the speed is uniform, find its value.

Solution

Distance (S) = 100 m

Time (t) = 5 s

Speed (v) = ?

We know:

$$v = \frac{S}{t}$$

$$v = \frac{100\ \text{m}}{5\ \text{s}}$$

$$= 20\ \text{m s}^{-1}$$

Problem 8.7

A boy runs for 20 seconds with a uniform speed of 5m/s. Find the distance he covers?

Solution

Speed (v) = $5\ \text{m s}^{-1}$

Time (t) = 20 s

Distance (S) =?

We know:

$$S = v \times t$$

$$S = 5\ \text{m s}^{-1} \times 20\ \text{s} = 100\ \text{m}$$

$$S = 100\ \text{m}$$

Problem 8.8

A train took 12 minutes to travel 10 km from station **A** to **B** and 24 minutes to travel 20 km from station **B** to **C**. Calculate the average speed of train in km/hr.

Solution

Total distance = 10 km + 20 km = 30 km

Total time = 12 min + 24 min = 36 min

Time in hours = $\frac{36}{60}$ = 0.6 hr

Average speed = ?

We know:

$$v = \frac{S}{t}$$

$$v = \frac{30\ \text{km}}{0.6\ \text{hr}} = 50\ \text{km hr}^{-1}$$

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Problem 8.9

The distance of the Earth from the Sun is 149,000,000 km. The speed of light is 300,000 km/s. What is the time taken for light to travel from the Sun to the Earth?

Solution

Distance (S) = 149,000,000 km

Speed (v) = 300,000 km s^{-1}

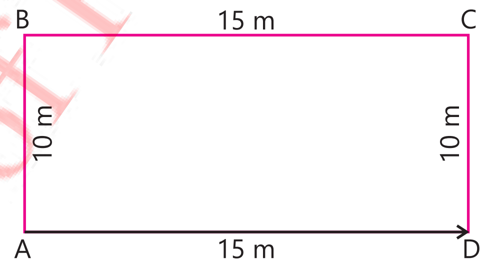
Time (t) = ?

We know:

$$t = \frac{S}{v}$$

$$t = \frac{149000000 \text{ km}}{300000 \text{ km s}^{-1}} = 496.7 \text{ s} = 8 \text{ min } 16.7 \text{ s}$$

8.3.3 Distance and Displacement



Suppose a man travels 10 m from point **A** to **B**, 15 m from **B** to **C** and finally 10 m from point **C** to **D**. In this way he covers a distance of 35 m.

Distance = AB + BC + CD

Distance = 10 m + 15 m + 10 m = 35 m

Displacement is defined as the shortest distance between two points.

In above example, 35 m is the distance a man travels from initial point **A** to final point **D** via **B** and **C**; but it is not the shortest distance between initial and final points (**A** and **D**).

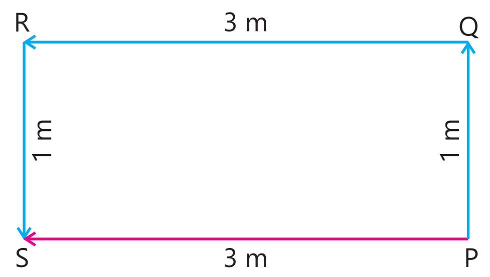
The shortest distance from point **A** to **D** is 15 m which is represented by the line **AD**.

Thus, the distance = 35 m

and displacement = 15 m

Problem 8.10

An object moves from point **P** to **S** along a rectangular path **PQRS** as shown in the Figure. Find:



(i) Total distance covered.

(ii) Displacement from **P** to **S**.

Solution:

(i) Total distance = PQ + QR + RS

= 1 m + 3 m + 1 m = 5 m

(ii) To find the displacement we join P to S by a straight line, hence

Displacement = PS

= 3 m

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8.3.4 Distance, Time Graph

The relationship between two variable quantities (e.g., distance and time) can be shown with the help of a graph.

Activity 8.2

Teacher Guide

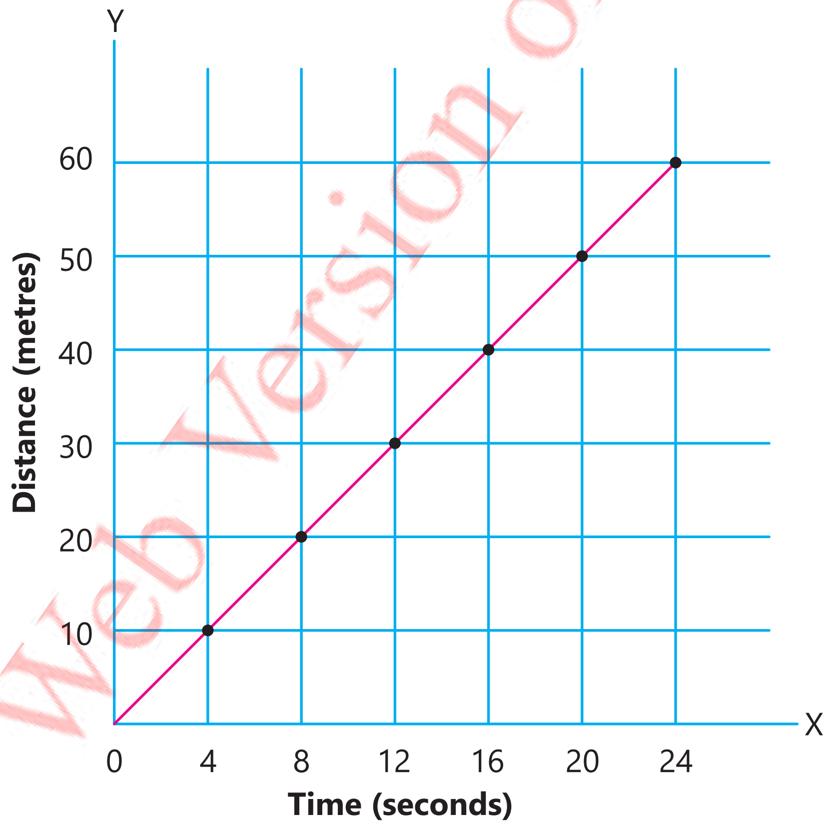
Facilitate students:

- Understand and show the relationship between distance and time with the help of a graph as under:

Suppose a person travels continuously and covers the distance 10 m in 4 s, 20 m in 8 s, 30 m in 12 s, 40 m in 16 s, 50 m in 20 s and 60 m in 24 s.

Distance (m)	0	10	20	30	40	50	60
Time (s)	0	4	8	12	16	20	24

If the distances covered are shown vertically on Y-axis and the time intervals taken for covering the said distances are shown horizontally on X-axis, The distance-time relation can be represented with the help of a graph as under:



This graphs shows that:

1. The person took 4 seconds to go from each marker post to the next and so its speed was constant.
2. The distance travelled is 2.5 metre every second (= 10m/4s) and so its speed is 2.5 m/s.

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8.4 CONTACT AND NON-CONTACT FORCES

Forces can broadly be categorized as:

- Contact forces
- Non-contact forces

8.4.1 Contact Forces

Contact forces are those forces that act only when objects are in physical contact with other objects and bring about necessary changes.

Examples of contact forces

1. Push and pull

For pushing a box ahead and pulling a rope in opposite directions, we need to make physical contact with them **(Figure 8.4)**.

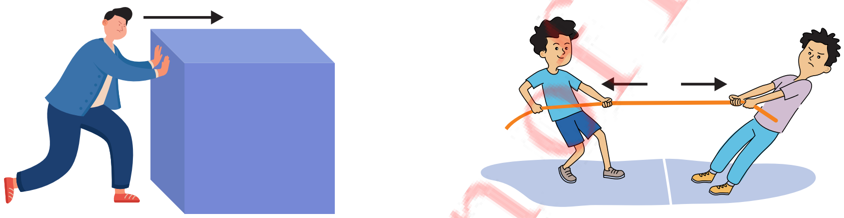

Figure 8.4 **Push and pull (contact forces)**

For pushing and pulling the objects, the **muscular force** of animals and humans is applied. Muscular force is also an example of contact force **(Figure 8.5)**.

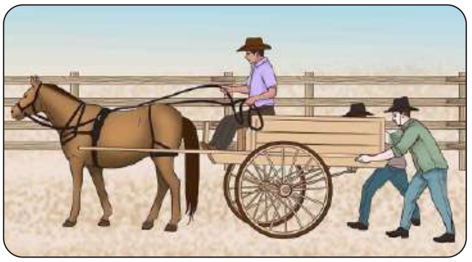

Figure 8.5 **Pushing and pulling a cart**

2. Frictional force

When a boy stops paddling, the bicycle facing the **frictional force** between its tyres and the ground stops to move **(Figure 8.6)**. The frictional force is produced due to a contact between tyres of bicyle and the ground. The frictional force is therefore a contact force.

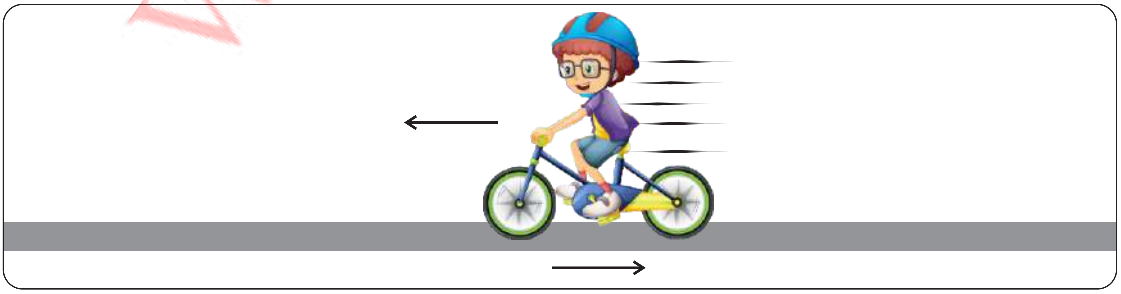

Figure 8.6 **Frictional force stops the moving bicycle**

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3. Mechanical force

Force is required for lifting heavy objects. Such a force is provided by the machines like cranes. The force exerted by a machine is called **mechanical force**. Machines do not produce force by themselves. They need energy from other sources to produce force. For lifting a heavy object, the object and the carne come in contact with each other. Therefore, the mechanical force that makes the crane lift the object is also a contact force **(Figure 8.7)**.

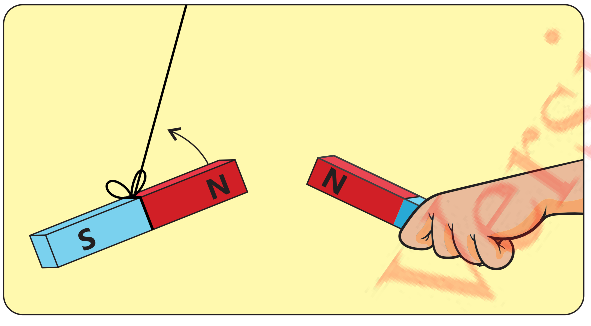
Figure 8.7 **Crane lifting heavy objects**

8.4.2 Non-Contact Forces

Some forces do not involve physical contact between the objects on which they act. They act through the space between them. Such forces are called **non-contact forces**.

Example of non-contact forces

Magnetic force **(Figure 8.8)**, electrostatic force **(Figure 8.9)** and gravitational force **(Figure 8.10)** are the examples of non contact forces.



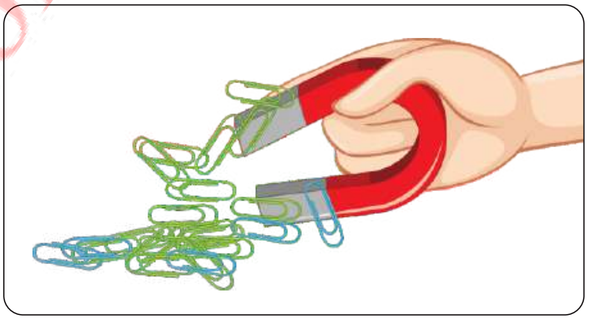


Figure 8.8 **Magnetic forces**

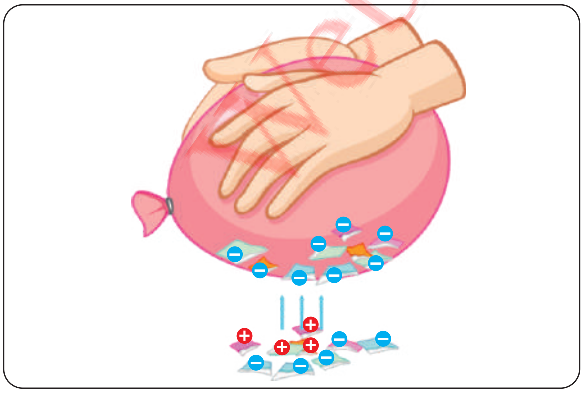


Figure 8.9 **Electrostatic force**

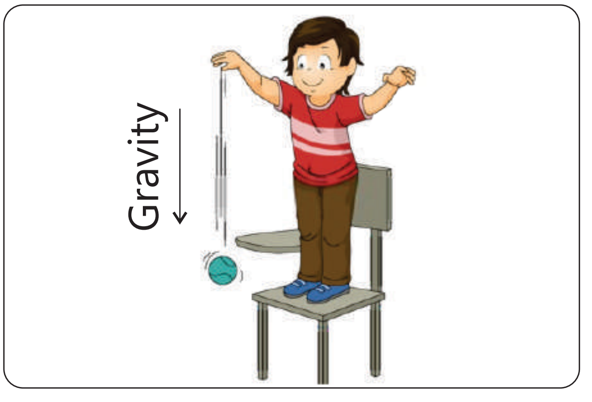


Figure 8.10 **Gravitational force**

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8.4.3 Action and Reaction Forces

A book placed on a table exerts a force (equal to weight of the book) on the table. This force is called **action**. In response to the action, an equal force is exerted in opposite direction by the table on the book. Such a responding force is called **reaction**. **(Figure 8.11)**.

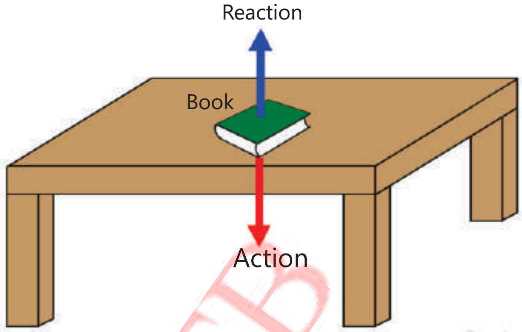

Figure 8.11 **Book placed on table**

The space shuttle engines push out hot gases as an action force and the hot gases exert a reaction force on the shuttle engine, which makes the shuttle lift up **(Figure 8.12)** .

Figure 8.12 **A space shuttle**

In both the above mentioned examples, action and reaction are two equal forces, but their directions are opposite. Newton explains this kind of force in a law which is known as the third law of motion This law is stated as:

"To every action, there is an equal and opposite reaction".

KEY POINTS

- Push, pull, gravity, friction, etc., are the examples of the force.
- Force is a physical quantity. The Standard International (SI) unit of force is newton. The symbol used for newton is 'N'.
- Force can change the direction of motion.
- Force is measured by using an instrument called force meter. The force meter is a spring balance, which is of two types; extension spring balance and compression spring balance.
- The shortest distance between two points is called displacement.
- Speed is defined as the distance travelled per unit time
- If an object travels the same distance in the same intervals of time, its speed is called uniform speed.
- If a force is applied on a moving object in the direction of motion, its speed increases.
- If the force is applied in the direction opposite to the direction of motion of the object, its speed decreases.
- If an object travels different distances in the same intervals of time, its speed is called variable speed.

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- The average speed can be calculated by dividing the total distance an object covers by the total time it takes to cover that distance.
- Contact forces are those forces that act only when objects are in physical contact with other objects and bring about necessary changes.
- Some forces do not involve physical contact between the objects on which they act. They act through the space between them. Such forces are called non-contact forces.

QUESTIONS

8.1 Encircle the correct option.

1. An example of contact force:

a. electrostatic force b. muscular force
c. magnetic force d. gravity

2. The force between two negatively charged particles is:

a. gravitational b. frictional c. repulsion d. attraction

3. Which statement is true?

a. for every action force, there is a smaller reaction force in the opposite direction
b. for every action force, there is a smaller reaction force in the same direction
c. for every action force, there is an equivalent reaction force in opposite direction
d. for every action force, there is an equivalent reaction force in the same direction

4. The Earth's pull on the objects is called:

a. gravity b. frictional force
c. electrostatic force d. magnetic force

5. A batsman hits the ball back towards the bowler, which effect of force is seen:

a. change of shape b. change of direction
c. change of state from motion to rest d. change of state form rest to motion

6. Which one of the following statements is correct?

a. 1 m = 1000 km b. m/s is the unit of displacement
c. N is the unit of force d. 1hr = 60 s

7. Which one of the following statements is not correct?

a. Displacement is the shortest distance between two points.
b. Displacement is the distance covered in one second.
c. Metre (m) is the unit of displacement.
d. Rate of change of distance with time is called speed.

8.2 Define the following:

1. Contact forces. 2. Non-contact forces. 3. Gravitational force
4. Displacement 5. Speed

8.3 Constructed Response Questions

1. A rocket has been fired upward to launch a satellite in its orbit. Name the two forces acting on the rocket immediately after leaving the launching pad.

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2. Briefly describe the effect of non-contact force on each of the following:

a. Falling of apple from the tree
b. A foot ball that is kicked
c. Iron pins are attracted towards a magnet
d. A porter carrying a load
e. Charged comb attracts small pieces of paper
f. Bringing like poles of two magnets near each other

3. The detail of a 12 hours journey of a car with an average speed of 60 km/hr is given below:

Duration	Distance covered
0 – 2 hours	X
2 – 6 hours	240 km
6 – 12 hours	240 km

What is the value of X?

8.4 Investigate:

1. The readings obtained during an experiment in which a toy train runs down a slope.

Time in seconds	0	2	4	6	8	10
Distance of train in metres	0	10	20	30	40	50

a. Use the data in the Table to plot a graph of distance on Y-axis against time on X-axis.

b. State what the graph tells you about the motion of the toy train:

(i) During the first second
(ii) From 2 to 4 seconds
(iii) From 8 to 10 seconds

8.5 Project:

1. Make a track 30 m long and 50 cm wide.
2. Walk fast along this track. Ask your friend to note the time taken by you for covering the distance 30 m.
3. Repeat the above activity at least three times. Record your findings in a Table as shown below:

S.No.	Duration	Average time taken
1.		___________ seconds
2.		
3.		

Distance travelled = 30 m

Average speed = Distance/time = _____________ m/s.

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