SECTION 6

FORCE

VIGOUR BEHIND LIFE

Forces acting on substances and mechanisms

INTRODUCTION

Hello learners! You will recall from your science lessons in Junior High School that a force is a push or pull that can change the state of motion or the shape of an object.

In this section, you will identify and explain more concepts associated with forces like velocity, acceleration, and speed. We will also discuss other forces like friction, tension, and gravitational forces.

At the end of this section, you will be able to:

Identify and explain concepts associated with forces

KEY IDEA

Force is a vector quantity, which means it has both magnitude (size) and direction. It is measured in Newtons (N). Forces are a fundamental concept in physics that describes interactions between objects and can cause changes in their motion or shape.

IDENTIFICATION AND EXPLANATION OF CONCEPTS ASSOCIATED WITH FORCES

Forces play a vital role in our everyday lives in situations such as kicking a soccer ball, running and weeding the school farm, and many other less easily identifiable scenarios.

Frictional Forces

1. Frictional forces can be described as forces that arise when two objects physically touch each other.
2. Friction resists relative motion between two surfaces in contact.

Frictional force can be beneficial. For example, the friction between your shoe and the ground stops the shoe from moving ('slipping') so you don't fall over! However, it can be inconvenient when resisting the motion of a moving car that the driver is trying to accelerate.

Let's undertake the following activities to discover how forces shape the world around us!

Activity 6. 1: What are frictional forces?

1. With your legs in your shoe, try dragging your feet on a cemented or tiled floor in the classroom. Try the same exercise on the bare floor outside. Share your observations with your partner. Have you wondered why vehicle tyres have many markings and rough surfaces? Can you link your observations to this design feature?
2. Now look at the image in **Figure 6.1** and compare the actions of the people in each photo, who are gliding on different surfaces.

A

B

Fig. 6.1: Gliding on two different surfaces

3. In Figure 6.1, A is gliding on a polished surface (a slide) while B is gliding with the feet on bare ground.
   - **a.** Which of them will move faster?
   - **b.** Which of them will move slower?
   - **c.** Which of them will easily be able to stop themselves and change direction?
4. Point out reasons in the image that support your response.

In groups, perform the following experiment and share your observations.

Activity 6.2: Exploring the effects of different surfaces and the frictional forces they generate.

Aim: To investigate the effects of friction on the distance an object can slide along a surface

Materials:

- Wooden block / a book / a toy car
- Smooth surface (e.g., a glass table, a plastic tray)
- Rough surface (e.g., sandpaper, a carpet, floor)
- Ruler or measuring tape
- Weighing scale (optional)

Procedure:

1. Start by placing the smooth surface (e.g., glass table) on a flat, stable table or floor.
2. Take the wooden block (or the object with a flat surface) and place it on a smooth surface.
3. Gently push the block with a constant force and measure the distance it travels before coming to a stop.
4. Mark the block's motion's starting and ending points.
5. Record the distance in a table.
6. Repeat the above steps, ensuring the pushing force is the same, for the rough surface (e.g., A-4 size sandpaper) and record the distance the block travels before stopping.
7. Analyse the results, including an analysis of the challenges involved with ensuring a constant pushing force and suggestions about how to improve the consistency of this.
8. Compare the distance the block travelled on the smooth surface with the distance it travelled on the rough surface. See **Annex 6.1**

Activity 6.3: Advantages and disadvantages of frictional forces in everyday life.

Discuss with your friends more benefits and detriments of friction and write them down.

Gravitational Force

Observe the image in **Figure 6.2** and consider the forces acting on the ball as it moves through the sky.

Fig. 6.2: Ball throwing

The gravitational force is the force of attraction between any two objects with mass. It is this same force that is responsible for keeping planets in orbit around stars and objects anchored to the Earth's surface as shown in **Figure 6.3.**

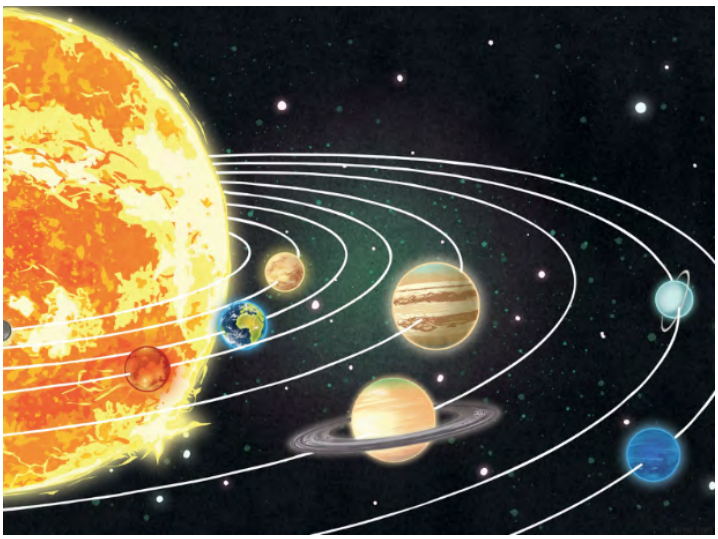

Fig. 6.3: Gravitational force holding the planets in their respective orbits

Now do the following activity to investigate more on gravitational force.

Activity 6.4: Investigating Gravitational Force

Aim: To understand the concept of gravitational force and explore its relationship with mass.

Materials:

- Two objects of different masses (e.g., a small ball and a heavier object like a book)
- Spring scale (Newton meter)

Procedure:

1. Ensure that the spring scale is calibrated by allowing it to hang from your hand and zeroing it.
2. Using a string, attach a lighter object, such as a little ball, to the spring scale.
3. Take note of the mass (in grams or kilograms) shown on the spring scale for this object.
4. Repeat with a heavier object, such as a book.
5. To calculate the gravitational force on an item, use the formula $F = mg$, where F represents the gravitational force, m represents the object's mass in kilograms, and g represents the acceleration due to gravity (9.8 m/s^2).
6. Drop both objects from the same height above the ground (for example, 1 metre) and note the time it takes for each of the objects to hit the ground.
7. Discuss with your peers whether this is the result that you expected. See Annex 1 for a possible conclusion.

Velocity

Velocity is a vector quantity that represents the rate of change of an object's position with respect to time. It has both magnitude (speed) and direction. Speed is a scalar quantity. Scalar quantities have magnitude only.

The word equation for velocity is:

$$\text{Velocity} = \frac{\text{displacement}}{\text{time taken}}$$

Displacement is the distance travelled in a particular direction.

Velocity is measured in units such as metres per second (m/s) or kilometres per hour (km/h).

Positive velocity indicates motion in the forward direction, while negative velocity indicates motion in the reverse direction.

Activity 6.5: Exploring velocity

In a small group, complete the following activity.

Aim: Investigate the concept of velocity and how it relates to everyday life.

Materials: Stopwatch, measuring tape, toy cars, markers, chart paper, plank of wood/ramp.

Procedure

1. Using a measuring tape, mark out a one-metre length on your plank of wood or ramp.
2. Lift one end of the ramp by placing it onto a stable object, such as a book.
3. Set your stopwatch and the toy car in motion at the top of the one-metre distance. Stop the stopwatch when your toy car has travelled one metre.
4. Calculate the velocity of the toy car.
5. Repeat the experiment, but this time with the ramp lifted to a greater height (by using more books!).
6. Record all of your results in a table.
7. Describe how distance and time affect velocity.

In the next discussion, observe the images in **Figures 6.4** and **6.5.**

Fig. 6.4: 100m race

Fig. 6.5: 3,000m race

In observing the images in Figures 6.4 and 6.5, identify:

a. Which of the races will you say covers long distances and which one has a short distance coverage?

b. Which one will require a shorter time to finish?

c. Which one will require a longer time to finish?

d. Which race is likely to involve greater accelerations?

e. Discuss your responses with the friend next to you.

Now go through the discussions below on distance and speed and compare them to your responses.

Distance

Distance is a scalar quantity representing the total path length an object covers during its motion. It measures the total amount of ground covered, regardless of the direction taken. Distance is always positive or zero, as it only considers the magnitude of motion. It is measured in units such as metres (m), kilometres (km), miles (mi), etc.

Speed

Speed describes how fast an object is moving. Speed is a scalar quantity representing the rate of change of distance with respect to time. It only considers the magnitude of motion and does not consider the direction. The formula for calculating speed is:

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Speed is measured in units like metres per second (m/s), kilometres per hour (km/h), or miles per hour (mph). Unlike velocity, speed does not involve direction and can only be positive or zero.

Acceleration

Let us discuss acceleration and compare it to velocity

a. When something is accelerating, its velocity is changing.

b. Acceleration = change in velocity/ time taken

$$a = \frac{(v - u)}{t}$$

Where u is the initial velocity, v is the final velocity, and t is the time taken (in seconds).

Acceleration (a) is measured in metres per second square (m/s^2)

A negative acceleration means deceleration. A uniform acceleration means a constant (steady) acceleration.

Resultant force and acceleration

According to Newton's First Law, an object's velocity will remain unchanged unless it is acted on by a resultant (net) force.

According to Newton's Second Law, the resultant force on an object is related to its acceleration in the following way:

Resultant force = Mass × acceleration

$$F = ma$$

where force is measured in Newtons, mass in kilograms and acceleration in metres per second squared.

Activity 6.6

Examples

1. A runner covers a distance of 200 metres in 20 seconds. Calculate the average velocity of the runner.
2. A car covers a distance of 300 kilometres in 5 hours. Calculate the average speed of the car in kilometres per hour.
3. A car with a mass of 1500 kg accelerates from 0 to 20 m/s in 10 seconds. What is the net force acting on the car?
4. A car travels 200 kilometres in 2 hours. Calculate the speed of the car.
5. A car accelerates from 0 m/s to 20 m/s in 5 seconds. Calculate the acceleration of the car.

Activity 7: Experiment about acceleration (gravity) - Investigate the concept of acceleration using simple materials.

Materials: Toy car or small object that can roll e.g. iron ball, car tyre etc., smooth flat surface (such as a tabletop or floor), measuring tape or ruler, stopwatch or timer, notebook and pen.

Procedure:

1. Set up the smooth, flat surface for the experiment. Ensure there is enough distance for the toy car to accelerate down the ramp and then come to a stop.
2. Set the toy car at one end of the surface and indicate its starting point.
3. Mark uniform distances along the surface with a measuring tape or ruler (e.g. 10cm intervals).
4. Start the stopwatch when you release the toy car/rolling item from its starting place.
5. Measure the time it takes for the toy car/rolling item to reach each marked spot on the surface. You may find it easiest to do this by filming the car in slow motion using your phone, with the stopwatch in the shot.
6. To calculate the average speed of the toy car/rolling item between intervals, use the formula speed = distance/time.
7. Analyse speed data to determine if the toy car is accelerating, decelerating, or at a constant pace.
8. To compute acceleration, apply the formula: acceleration = (final velocity - initial velocity) / time.
9. Repeat the experiment and make adjustments to see how surface smoothness and incline affect acceleration.
10. Document your observations, measurements, and conclusions in the notebook.

Cohesive and Adhesive Forces

During your basic school education, you learn that cohesive forces are the attractive forces between molecules of the same substance that make them stick together. For example, the forces between individual water molecules are cohesive. Adhesive forces are the attractions between different substances that help them stick together; an example is water adhering or sticking to a glass surface.

Now do the activities below to determine the differences and share your findings with the class.

Activity 6.8: Understanding Cohesive and Adhesive Forces

This activity can be done in your science group.

Aim: To differentiate between cohesive and adhesive forces through a series of interactive experiments.

Experiment 1: Cohesive Forces

Materials: Small containers (e.g. cut-out plastic bottle) or cups, water, salt, spoon, small objects (e.g., paper clips, coins), droppers/pipettes, and paper towels.

1. Pick 2 containers and label them A and B.
2. Fill the 2 small containers with water.
3. Stir a pinch of salt into container A until dissolved.
4. Using a pipette, drop water from each container onto a clean, flat surface and compare the behaviour of plain water in B and saltwater droplets in A.
5. Explain how saltwater's cohesive forces hold droplets together compared to ordinary water.

This force can be observed in experiments like dropping water onto a penny, where cohesion and surface tension allow multiple drops to accumulate before spilling over. Saltwater has lower cohesion than plain water, affecting the number of drops that can stay on the penny.

Experiment 2: Adhesive Forces

Materials:

- Capillary tubes (for example thin
- Plain-coloured straw for drinking fizzy drinks
- Borosilicate glass tubes)
- Tissue strip
- Water
- Food colouring (optional)

- Potassium permanganate crystal/powder (i.e. washing blue)
- Two tall glasses.

Precaution: Use a clean capillary tube to ensure proper adhesion.

Procedure:

1. Set out 2 tall glasses or cut-out plastic bottles
2. Label them A and B.
3. Fill A with water and B with water adding a few drops of food colouring or washing blue if desired.
4. Dip one end of the capillary tube into the water, making sure not to touch the sides of the glass.
5. Observe how the water rises up the capillary tube, seemingly defying gravity.
6. Measure the height of the water column in the capillary tube.
7. Do the same for the coloured water and observe.
8. Use tissue strips in both A and B and record your findings.

Compare your activity with the image in **Figure 6.6**

Fig. 6.6: Capillary action

From the above image, what other changes or additions would you like to make to your experiment?

Activity 6.9: Real-life applications of force

Having discussed some examples of forces, go through the following real-life applications and add on in the third column with more examples.

Table 6.1: Real-life applications of force

Type of force in action	Everyday activity	Add on (give more examples of everyday activities)
Friction	Gripping, writing	
Pushing/pulling	Opening doors	
Gravity	Orbiting planets, falling objects	
Capillarity	Drinking Fanta with a straw	

Activity 10: Sum it all up

Produce a summary sheet or poster on the topic of forces and motion. Include a glossary of key terms and highlight the differences between distance and displacement, speed and velocity, and acceleration.

Include examples from your everyday life, or from areas/hobbies that interest you, to illustrate your work.

ANNEX 6.1 – SOLUTIONS TO SOME ACTIVITIES

Activity 6.2

You will notice that the block travelled a shorter distance on the rough surface than on the smooth surface. In the experiment, the rough surface created more friction between the block and the surface, which caused it to slow down and stop sooner.

Activity 6.4

Objects of any mass accelerate at the same rate when free-falling on Earth. This means that all objects will hit the ground at the same time when released from the same height, as long as there are no other forces acting to increase or decrease their velocity (such as air resistance).

Activity 6.5

When the ramp is lifted to a greater height, the car takes a shorter amount of time to descend the one-metre distance. A smaller time gives a greater velocity (as time is the denominator in the velocity formula).

Activity 6.6

1. $\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$

$= \frac{200\ \text{m}}{20\ \text{s}}$

$\text{Velocity} = 10\ \text{m/s}$

The average velocity of the runner is 10 metres per second.

2. Given: Distance = 300 kilometres, Time = 5 hours

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

$= 300\ \text{kilometres} / 5\ \text{hours}$

$= 60\ \text{km/h}$

3. Calculate the acceleration:

$$a = \frac{(v - u)}{t}$$

$$a = \frac{(20 - 0)}{10}$$

$$= 2.0 \text{ m/s}^2$$

Use Newton's second law

$$F = ma$$

$$F = 1500 \text{ kg} \times 2 \text{ m/s}^2$$

$$= 3000 \text{ N}$$

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

$$\text{Speed} = \frac{(200 \text{ km})}{2 \text{ h}}$$

$$\text{Speed} = 100 \text{ km/h}$$

.: The speed of the car is 100 kilometres per hour.

5. $$\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Time taken}}$$

$$\text{Acceleration} = \frac{(20 \text{ m}}{\text{s - 0 m/s) / 5 s}}$$

$$\text{Acceleration} = 4 \text{ m/s}^2$$

The acceleration of the car is 4 meters per second squared.

Activity 6.8

From the activities, it may be observed that;

- Water molecules are attracted to the glass surface (adhesion) and to each other (cohesion).
- The narrow diameter of the capillary tube increases the relative surface area, allowing the water molecules to spread out and climb up the tube.
- The combination of adhesion and cohesion creates a "capillary force" that pulls the water up the tube.

REVIEW QUESTION

Review Questions 6.1

1. During a soccer match, a player kicks the ball with a force of 50 N. If the ball has a mass of 0.5 kg.
   a. What will be its acceleration immediately after being kicked?
   b. What external forces should you consider, that could affect the ball's motion afterward?
2. You are stranded on a deserted road, and your car is stuck in the mud.
   a. What factors might be preventing the car from moving?
   b. How can you get the car moving?
3. In what ways does the gravitational force affect the motion of planets, moons, and the Sun, in our Solar System?
4. How do adhesive and cohesive forces interact with gravity and other forces to influence the behaviour of fluids in different scenarios, such as in a falling droplet or during liquid movement through a porous medium?

ANSWERS TO REVIEW QUESTION

Review Questions 6.1

1.

a. To determine the acceleration of the soccer ball immediately after being kicked, you can apply Newton's second law of motion, which states:

$F = m \cdot a$

Given:

- $F = 50\,N$
- $m = 0.5\,kg$

We can rearrange the equation to solve for acceleration (a):

$$a = F / m$$

Now, substituting the values into the equation:

$$a = \frac{50\ N}{0.5\ Kg}$$
$$= 100\,m/s^2$$

Thus, the acceleration of the soccer ball immediately after being kicked is **100 m/s²**.

b. After the soccer ball has been kicked, several external forces can affect its motion. These include:

- The force of gravity acts downward on the ball, pulling it toward the Earth. This force influences the ball's vertical motion and affects its trajectory.
- As the ball moves through the air, it experiences drag force, which opposes its motion. The amount of air resistance depends on the speed of the ball, its shape, and its surface texture.
- If the ball rolls or bounces on the ground, the surface it interacts with can exert a force that affects its motion. This may include frictional forces, which can slow it down or change its direction.

- Wind can exert a force on the ball and change its path. Depending on the wind's direction and speed, it can slow down, speed up, or alter the ball's trajectory.
- Any objects or players on the field can create forces if they come into contact with the ball or block its path, affecting its velocity and direction.

Considering these external forces is important for understanding the complete motion of the ball after it has been kicked.

2.

a. Factors Preventing Movement:

Frictional force, which is in turn affected by:

- Weight of the car. A heavier car experiences greater friction.
- Tire condition. If the tyres are bald or lack sufficient tread, they may not be able to generate enough friction to push against the mud effectively.

Mud consistency – The type and consistency of the mud can play a significant role. If the mud is particularly thick or sticky, it can create more resistance against the tyres.

b. To get the car moving, you can consider the following strategies:

- Increase friction – If possible, you can place materials such as gravel, sand, or wooden boards under the tyres to increase traction and reduce slippage.
- Reduce weight.
- Use a tow.
- Manual help. Additional push force can help overcome static friction.
- Tire pressure. If the tyres are overinflated, letting some air out may allow them to make better contact with the ground, improving traction.

By addressing these factors and employing these methods, you can increase your chances of getting the car unstuck from the mud.

3. Gravitational force is fundamental to the formation of planets, moons, stars, and other bodies as the matter that formed them accreted together due to gravity over some time.

The gravitational attraction between a planet and the Sun, or between a planet and its moons, results in orbital motion.

In summary, gravitational force is a fundamental force of nature that governs the motion of celestial bodies within our solar system and beyond. It is responsible for keeping planets in orbit, influencing tides, facilitating the formation of celestial bodies, maintaining the stability of the Solar System, and enabling interactions among various astronomical phenomena.

4. Adhesive and cohesive forces interact with gravity and other forces to profoundly influence the behaviour of fluids. In a falling droplet, surface tension due to cohesive forces can determine shape and stability. In porous media, the balance of these forces dictates how fluids move through soil or other materials. Understanding these interactions is essential in physics, biology, engineering, and environmental science, with applications ranging from designing fluid transport systems to understanding natural processes in ecosystems

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GLOSSARY

Celestial body: any natural object located in space. An object in space that has physical substance, distinguishes them from phenomena such as light or radiation.

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