FORCE

Learning outcomes

By the end of this theme, students will be able to:

- define a force and explain its different effects
- describe the different types of forces
- explain how a force is measured
- define the force of friction and explain the factors that affect it
- describe the effects of friction
- describe static, sliding and rolling friction
- list the advantages and disadvantages of friction
- explain how friction can be increased or reduced

Warm-up

Encourage students to complete the *Get going* section given at the beginning of the chapter.

GUIDELINES TO TEACH

Introduction

Ask students:

Have you been ever hit by a cricket ball or a flung stone? *How does it feel*? *Can you say why it hurts*?

If your lunch box is tightly closed, what would you do?

- Have a discussion on the above questions and make students say the word **force—** when the lunch box is tight they have to exert more force to open it or take it to someone stronger who can open it for them.
- After the casual introduction of the term, give its scientific definition.
- List out some situations where a force in the form of a push or pull is exerted.

Effects of forces

Ask students:

What does a force do?

- Invite answers from students and refine their answers.
- List out the effects of force, as given in the coursebook.
- For each effect, ask students to come up with examples. Discuss the examples given in the coursebook.
- With student participation, bring out the idea that a force can change the state of rest or state of motion of a body.

- Now modify the definition of force as—a push or pull that can change the state of rest or state of motion of a body.

Ask students:

Can you name something a force cannot change?

- Point out that a force cannot change the mass of an object.

Unit of force

- Introduce the SI unit of force as newton (N).
- Weight of an object is also a force—the force of pull by the Earth on it, or gravitational force.
- Point out that when we refer to weight of an object the unit kilogram-force is also used.
- Explain that 1 kgf is the weight of an object of mass 1 kg. 1 kgf is very close to 10 N.
- Tell students that the device to measure the weight of an object is a spring balance.
- Refer to the figure of the spring balance, given in the coursebook, and describe the working of a spring balance as given in 'Spotlight'.

Types of forces

Ask students:

Why does a mango fall down from a tree?

- Tell them that objects fall down because the Earth exerts a force on them which pulls them down. This force is known as *gravitation*.
- Point out that the Earth does not touch the objects to pull them down.

Ask students:

Can you pull or push an object without touching it?

- Tell students that there are two types of forces—*contact forces* and *non-contact forces*.
- Explain that contact forces can be applied only through physical touch or contact while non-contact forces do not need physical touch.
- Ask students to come up with examples. List out and explain the two examples, as given in the coursebook.

Contact forces

Ask students:

What happens to a ball if you roll it on the floor?

- Guide students to come up with the answer—it will come to rest finally after rolling through some distance.

- Explain how the force of friction acts against the direction of motion and finally bringing the object to rest.

Ask students:

Is it easy for you to walk if there is water spilled on the floor? What if instead of water oil is spilled?

- Explain more about frictional forces.
- Point out that even for walking without slipping, friction is necessary. When there is water, friction is reduced and hence we tend to fall. In case of oil, friction is very much reduced which makes it impossible for us to walk over it.

Non-contact forces

Ask students:

Gravitational force is one non-contact force. Can you name any other non-contact forces? Have you noticed a magnet attracting a piece of iron?

- Introduce magnetic and electrostatic forces as non-contact forces.
  - **Gravitational force**: Define force of gravitation. Explain why rain drops, ball thrown up, water from waterfall all fall down. Define weight and explain why it would vary from planet to planet. Share the fact from 'Know more'.
  - **Magnetic force**: Describe a magnet and how it affects certain other objects near it. Introduce the concept of poles of a magnet and demonstrate the attraction or repulsion between the two poles with laboratory magnets as shown in the figure, given in the coursebook.
  - **Electrostatic force**: Ask students to rub their hands on the armrest of a plastic chair and then bring their elbow close to the rubbed area. Bring their attention to the experience of a pull on the fine hair on their hand. Introduce electric charge and the two types which attract each other as in the case of magnets. Like charges repel. Tell students that this attractive or repulsive force is called *electrostatic force*. Explain that the chair acquires one type of electric charge due to rubbing and this charge attracts the opposite charge in our hair, hence, we get a pulling sensation. Point out that they can find the same kind of attraction using a plastic comb and small bits of paper also. Caution students that in order to give an electric charge to the comb, it needs to be rubbed against dry hair.

Measurement of force

Tell students: Since the force can be a push or a pull (opposite actions), we need to specify the direction in which the force acts along with magnitude. Together they inform us how much of force acts and in which direction.

- Point out that more than one force can also act on a single object.
- The total effect of all the forces together is called the *resultant force*.

Ask students:

If you want to pull your study table to a different place and if the table doesn't move when you pull it, what will you do? Won't you call another person to help you? What will happen if both of you pull it in opposite directions?

- Tell students about the resultant of two forces in the same direction and in opposite directions, as given in the coursebook.
- Ask students what will be the resultant if the opposite forces were of same magnitude.
- Ask students to find the resultant of 8 N and 5 N if they acted (i) in the same direction and (ii) in the opposite directions.
- Use **Stop and check** for a quick recap. 

Force of friction

Ask students:

Can you name a few situations where frictional force is present?

- Highlight the fact that friction is a contact force and acts in the opposite direction of motion.

Ask students:

Do we have to apply the same force to pull an object through different surfaces? *Which is easy, pulling an object through a mud road or a smooth tar road*? *Do we apply the same force to pull all objects through the same floor*?

- Point out that since friction is a contact force, the nature of surfaces in contact affects the magnitude of frictional force. Also the effort needed to pull a heavier object is more than the lighter object.

Ask students:

From the above statement, can you figure out the two factors affecting the magnitude of frictional force?

- List out the two factors—nature of the surfaces and the weight of the object, as given in the coursebook.
  - **Nature of the surface**: Draw students' attention to the figure, given in the coursebook, and explain how a smooth surface will look under a magnifying glass. Explain the origin of friction in terms of these irregularities. With the help of the activity, given in the coursebook, draw the conclusion on why rough surfaces offer greater friction.
  - **Weight of the moving object**: Point out that for greater weight of the object, these irregularities press against each other with greater force and hence force of friction will be larger.
- Share the information from 'Know more'

Effects of friction

Ask students:

Can you imagine what the world would be like if there were no friction? *Would you be able to walk on the floor*? *What would happen to a ball that slips out of your hand*?

- Impress upon the students that life would become impossible if there were no friction.
- List out the three effects, given in the coursebook, and explain each in detail.
- Using the case of a rolling ball coming to rest, establish the fact that friction opposes motion.
- Ask students to rub the palm of their hand and observe the heat produced.
- Explain how ancient people generated fire by rubbing stones together,
- Remind them of how a matchstick catches fire.

Ask students:

Do you know why we have to change the ball bearing in a machine (for example, in a bicycle) periodically?

- Tell them about friction producing wear and tear.

Types of friction

- List out the three types of friction on the board.
  - **Static friction**: Define static friction and explain with the help of the example, given in the coursebook. Ask students to try it with one of their textbooks.
  - **Sliding friction**: Define sliding friction. Draw the attention of students to the fact that once the book starts moving, only a smaller force is needed to keep it moving. So sliding friction is smaller than static friction.
  - **Rolling friction**: Ask students the advantage of wheels on travel bags. What if there were no wheels? Define rolling friction and point out that rolling friction has the smallest value for a given object moving through the same surface.
- Write down their relative strengths.
- Demonstrate the activity, given in the coursebook, to show the relative strength of static friction if a spring balance is available. Or else show the video available in the link -- https://study.com/academy/lesson/static-friction-definition-formula-examples.html

Advantages of friction

- Point out that friction is present everywhere. We cannot make it go away.

Ask students:

Is it a good force or a bad one for human life? Have you heard of vehicles skidding on a wet or oily road?

- List out and explain all the advantages of friction, as given in the coursebook.

Methods to increase friction

Ask students:

Can you guess some ways to increase friction from the discussion so far? *Why are there grooves on the sole of your shoes? What happens if there were no grooves*?

- Point out the reason for treads on the surface of tyres, grooves on the sole of shoes, spikes on athletic shoes and so on.

Disadvantages of friction

Tell students: If there were no friction, we wouldn't have to change the ball bearings of the bicycle!

- Discuss about the loss of energy in the form of heat and wear and tear of machines caused by friction.

Methods to reduce friction

- Tell students that since we cannot remove friction, the only way is to minimise its undesirable effects. How can this be achieved?
- Call their attention to the fact that smooth surfaces offer less friction and hence polishing surfaces is an effective way to reduce friction.
- Tell them about lubricants and how they reduce friction, and why machines need lubrication.
- List out the types of lubricants and their respective applications.
- With the help of the figure, given in the coursebook, describe how ball bearings reduce friction. The trick is to replace sliding friction with rolling friction!
- Share the 'SciTech' information on Cold welding.

Tell students:

When a fish swims through water, it also experiences the force of friction. Do you know how they avoid spending too much energy on swimming?

- Point out the fact that liquids and gases also offer friction as objects move through them.

Ask students:

Why does a meteor catches fire as it falls through the atmosphere of the Earth? (As it falls with great speed, it rubs with the air molecules generating a lot of heat. When the heat is too much, it catches fire.)

- Introduce the term *streamlining*.
- With the help of the figures, given in the coursebook, list out the objects that are streamlined.
- Share the information, given in 'Career watch'.

Give the following instructions to students / Write on the board.

Activity: Make an oral presentation on *A world without friction/Friction a necessary evi*l.

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Stop and check

1. True 2. True 3. False 4. True

Checkpoint

A. Choose the correct option.

1. b, mass 2. b, muscular force 3. b, is the Earth's force of attraction 4. b, 1.5 N
5. d, static friction 6. d, rounded in front and narrow at the back

B. Fill in the blanks

1. repel, attract 2. electrostatic force 3. rolling friction 4. treads 5. lubricant

C. Say if the statements are true or false.

1. True 2. False 3. True 4. False 5. False 6. False

D. Give reasons

1. By kicking the football, we apply a force on it. The effect of a force on a body is to change its state of rest or change the direction of motion. Since the ball was already in motion, the kick changes the direction.
2. Gravity is the force by which the Earth pulls objects towards its centre. In the absence of any other stronger force in the opposite direction, objects will fall down till they reach the surface of the Earth.
3. When the comb is rubbed against dry hair, it loses some electric charge. Hence it acquires an electric charge. Since this electric charge attracts opposite charges in the paper, the paper bits get attracted by the comb.
4. When there is more than one force acting on a body, the motion of the body depends on the net or resultant force. For forces acting in opposite direction, the resultant force is the difference between the two. When we apply two equal and opposite forces, the resultant is zero, hence the body does not move.
5. If we try to drag travel bags without wheels, we have to apply a larger force because we have to overcome the force of sliding friction. On the other hand, when the bags have wheels, we have to overcome the rolling friction only. So travel bags are fitted with wheels to make us carry these bags more easily.
6. Vehicles stop when we apply the brakes because of friction between the brake pads and the wheels of the vehicle. If there is no friction between brake pads and the wheels due to wear and tear, brakes may not work. Hence they are to be regularly checked and faulty one replaced.

E. Define the terms.

1. Muscular force is the force applied on an object by the muscles of the body, for example when we push, pull or lift objects. It is a contact force.
2. Forces that act between objects that are not in contact are called non-contact forces. Examples are force of gravity, electrostatic force and magnetic force.
3. Magnetic force is the force of attraction or repulsion that acts between the poles of two magnets. Like poles repel each other while unlike poles attract. It is a non-contact force.

4. Frictional force is a contact force that acts between two surfaces in contact. It opposes the relative motion between the objects.
5. Static friction is the maximum value of frictional force between two surfaces of objects in contact. It is experienced just before the object starts to move when we apply a force on it.
6. The frictional force experienced by objects moving through a fluid medium (liquid or gas) is known as drag. Drag is the force opposing the motion of a raindrop through the atmospheric air.

F. Short-answer questions

1. A force can be defined as a push or pull that changes or tends to change the state of rest or of motion of an object, or its shape. A force does not change the mass of an object.
2. Muscular force and friction are examples of contact forces while electrostatic and gravitational forces are examples of non-contact forces.
3. A force of repulsion is felt when two positively charged objects are brought close to each other as like charges repel.
4. The SI unit of force is newton (N). Weight is usually expressed in units of kilogram force—kgf. It is the force with which the Earth attracts a body of mass 1 kg.
5. The resultant of the forces are—
   (i) The sum of the two forces—when two forces act in the same direction.
   (ii) The difference of the two—when two forces act in opposite directions.
   (iii) Zero—when two opposite forces are equal in magnitude.
6. Frictional force is experienced due to irregularities, that is, the surfaces getting stuck against each other. Heavier objects would feel a larger friction because they press down against these irregularities with larger gravitational force.
7. Frictional force generates heat. When the match stick is struck against the rough surface on the matchbox, it generates heat. This heat ignites the chemical in the match stick producing fire.
8. Friction gives rise to wear and tear of machine parts that move against each other. This requires us to periodically replace such parts. Since friction makes bodies slow down and come to rest, we need to provide energy to keep them moving. For example, a vehicle moving on the road needs to be provided with energy constantly. Otherwise it will come to rest. (This is why we need to constantly pedal the bicycle.)
9. Streamlining is constructing objects in the shape of a tear drop with a rounded front side and a tapering back side. This shape can minimise drag thereby keeping the effects of friction to minimum. Birds and fish have streamlined shapes that help them to move easily through air and water, respectively.

G. Long-answer questions

1. Example for each:
   (i) A ball rolled on the floor experiences a frictional force opposing its motion. Therefore, it slows down and finally comes to rest.
   (ii) A batsman hits the cricket ball moving in some direction with a bat. Thus, he exerts a force on the ball. As a result of this force, the direction of motion of the ball changes and it moves in another direction.

(iii) A student who is trying to hold his books together using an elastic band exerts a force at the two ends of the elastic band. This force increases the length of the elastic band. When the force is removed, it comes back to the original length.

2. The two main types of forces are contact forces and non-contact forces. In contact forces, the force is exerted by physical contact while in non-contact forces physical contact is not necessary to exert the force. Example of contact forces are frictional forces and muscular forces while examples of non-contact forces are gravitational force and magnetic force.
3. Gravity is the force of attraction exerted by the Earth on other objects. The Earth pulls all objects to its surface by force of gravity. The weight of an object varies from place to place depending on the strength of gravity at that place.
4. Friction opposes relative motion between two surfaces in contact. It produces heat and wear and tear. When the rough surfaces of two stones are rubbed together, it generates heat. When there is sufficient heat a fire is generated. In ancient times when there were no match sticks, people started a fire by rubbing rough surfaces.
5. The two factors affecting frictional forces are the nature of the surfaces in contact and the weight of the moving object. Smoother surfaces reduce frictional forces while rough surfaces increase it. Lighter bodies experience smaller friction. Frictional force increases with weight.
6. When a small force is applied on a body resting on a surface, it does not move. If the force is gradually increased, the body remains stationary till the force reaches a particular value which is equal to the frictional force. With any further increase in the applied force, the body will start to slide through the surface. The maximum frictional force just before the body starts sliding is known as the static friction. Once the body starts sliding, a smaller force is sufficient to keep it moving. This shows that the frictional force has decreased. The new frictional force between the surfaces while the body is sliding is known as the sliding friction. Static friction is greater than sliding friction for an object of the same mass.
7. Friction is advantageous in many ways.
   (i) Friction between our feet and the ground helps us to walk and run without falling.
   (ii) We are able to grasp and hold objects because of friction between our fingers and the object.
   (iii) Friction between paper and pencil tip enables us to write on paper.
   (iv) Moving vehicles slow down and stop on application of brakes because of friction between brake pads and the wheels.
   (v) We are able to light a match because of the friction between the match stick and matchbox.
8. The friction between the road and tyres of a vehicle can be increased by having treads on the surface of the tyres. This prevents skidding. Soles of footwear are grooved to increase friction and prevent slipping. Sand and gravel are strewn over snow to increase friction and avoid accidents during snowy weather in cold countries.
9. Since rough surfaces have more irregularities and offer more friction, friction between surfaces can be reduced by polishing the surfaces to reduce irregularities. Use of lubricants also reduces friction. They fill the gaps between irregularities and make the surfaces more even. By using ball bearings between moving surfaces, we can change sliding friction to rolling friction and thereby reduce friction.

Think and Answer

1. True. When a force acting on an object is not sufficient in strength to move the object, there is no visible effect of the force. Example is a person pushing a wall. When more than one force act on a body in such a way that the net (resultant) force on the body is zero, there will not be any visible effect of the forces. Example is tug of war when both teams apply equal and opposite force on the rope, the rope will not move. When a force squeezes a rigid body trying to deform it, there is no visible deformation. Example is a boy trying to squeeze a cricket ball.
2. Since friction produces heat, the lubricant will get heated up. If the boiling point of the lubricant is low, it will easily evaporate and vanish exposing the machine parts to wear and tear due to friction. The intermolecular force in oil is stronger than that of water. So, molecules of oil hold together when sliding over each other while water molecules disperse easily. Therefore, oil will make a better lubricant for an engine.
3. Machines like car engines are complex machines with many moving parts. When these parts rub against each other, they generate a lot of heat due to friction. If the engine is not cooled down properly, the temperature can rise rapidly leading to fire. So for security reasons and the efficient and prolonged life of the engine it should have a cooling arrangement.

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A. Answer the following questions.

1. Why do your hands feel warm when you catch a fast moving object like a cricket ball?

   Ans: When we catch a fast moving object, it suddenly comes to rest. This requires a large frictional force offered by our hand. Since friction produces heat, our hands feel warm.

2. A box on a table is at rest. When a gradually increasing force is applied on it, it starts moving when the force reaches 5.8 N. What is the static friction between the box and the surface?

   Ans: 5.8 N

3. How does the use of ball bearings reduce friction?

   Ans: Ball bearings change sliding friction into rolling friction.

4. A body weighs 9 kgf on the Earth and 1.5 kgf on the Moon. What can be inferred about the strength of gravitational force on the Moon?

   Ans: Since the weight of an object is dependent on gravity, we can infer that gravitational force is much weaker in the Moon. Since $9/1.5 = 6$, we can conclude that the gravity of the Earth is six times stronger than the gravity of the Moon.

5. How can we reduce the friction between two surfaces?

   Ans: By making the surfaces smoother by polishing and by using lubricants.

6. Write 3.2 kgf in newton.

   Ans: 1 kgf = 10 newton. So, $3.2 \text{ kgf} = 3.2 \times 10 \text{ N} = 32 \text{ N}$.

7. Why does not the actual area of contact between two surfaces affect the frictional force?

   Ans: The frictional force does not change with area of contact. This is because it is the weight that affects the force of friction. When the area of contact is smaller, the weight is distributed through a smaller cross section, making the locking of irregularities between the surfaces stronger. When the area of contact is more, the weight is distributed through a larger area. As a result, the strength of locking decreases. These two factors balance each other. Hence the force of friction remains independent of the area of contact. This can be demonstrated with a spring balance and a brick.

8. How do lubricants reduce the friction between two surfaces?

   Ans: Lubricants occupy the vacant spaces on the rugged surface, thereby reducing the chance of the particles of the two bodies getting locked. Thus lubricants make the surfaces more even.

9. During rain, each raindrop is being pulled down by the force of gravity. Why do not the raindrops speed up and hit us like bullets?

   Ans: While the raindrops fall through the atmosphere, they rub against particles of air. This creates a frictional force opposing their motion. This reduces the speed of raindrops.

10. Why do vehicles skid more frequently on rainy days?

    Ans: On rainy days, the water on road mixed with dirt produce slush which behaves like a lubricant, reducing the friction between the road and the wheel. Any spilled oil from vehicles also spread out because of rainwater. This also reduces friction offered by the road.

11. Why are not the surfaces of roads made very smooth?

    Ans: Very smooth surfaces offer reduced friction. So it will be more difficult to control and stop the vehicles.

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1. Complete the sentences.

a. A force does not change the _____ of an object.

b. Pressing the brakes applies a force on the wheels in the _____ _____ and slows down the bicycle.

c. _____ force affects magnets and magnetic objects.

d. _____ force always acts in the direction opposite to the direction in which an object moves.

e. Electrically charged objects exert a force called _____ force.

f. Bullocks use _____ force to pull a cart.

g. A force is expressed in terms of its _____ and its _____.

h. The mass of an object is measured in _____.

i. Force is measured in _____.

j. A spring balance is used to measure _____.

2. Give one example for each of the given effects of force.

a. Force can change the shape of the object on which it acts.

_____

_____

b. Force can stop a moving object.

_____

_____

3. Explain how friction is useful or a nuisance in the following cases. What is the mechanism that has been adopted in each case?

a. The car tyres of racing cars

b. Holding a smooth glass tumbler with oily hands

c. The sides of a matchbox

d. The floor in a bowling alley

ANSWER KEY FOR THE WORKSHEET

FORCE

1. a. mass b. opposite direction c. magnetic d. frictional
e. electrostatic f. muscular g. magnitude, direction
h. grams/ kilograms i. newton j. weight

2. a. Answers vary b. Answers vary

3. a. Unlike the cars used for daily transportation, the race cars move very fast. The friction of the road should not come in their way. Hence, the tyres of the racing cars do not have treads and are smooth. This reduces friction between the tyres and the road, thus helping the cars move faster.

b. When the hands are greasy, the friction between the hand and the glass tumbler will be negligible. So either the hands must be washed to remove the greasiness or a rough glass like that made of clay should be used.

c. The matchstick has an inflammable material on its head. When we strike a matchstick, the temperature should rise to make the head hot enough to undergo spontaneous reaction. Hence, the side of the matchbox should be rough enough to cause a friction leading to rise in temperature.

d. The floor in a bowling alley—the bowling ball needs to roll smoothly so that the nine pins can be targeted. Hence, the floor should be really smooth. This is why it is a well-polished wooden floor.