UNIT 3

FORCE AND NEWTON'S LAWS OF MOTION

Unit outcomes: **After completing this unit you should be able to:**

- ✓ **develop a qualitative understanding of Newton's laws of motion and force in static situations.**
- ✓ **develop introductory skill of manipulating numerical problems related to Newton's law of motion and force.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

Introduction

In unit two of this book you learned important concepts that describe motion. The concepts such as speed, velocity and acceleration are used for describing various types of motion around you.

Activity 3.1

Discuss with your friends or parents.

- The concepts: speed, velocity and acceleration.
- The difference between uniform and accelerated motions.
- Do you think that force and motion have a relation? Explain.

The motion of bodies (relative to a chosen reference system) is either uniform or accelerated or slowed down, or change in directions. In the last three cases, the velocities of moving bodies are changing. That is, acceleration is produced. Clearly it is very important to be able to study acceleration. However, to understand acceleration in its full sense you must know how it emerges or is produced.

3.1. Force

Activity 3.2

Discuss the followings with your friends.

i. What is a force?
ii. Mention some examples of forces from your daily activities.
iii. explain the following phrases
   - Social force,
   - Political force,
iv. Explain the following actions.
   - A push you exert on a wall,
   - A pull exerted to drag a box on a table.
v. Do you think that forces in iii) and iv) are the same? Explain

The term force is used in different situations in the English language. Force is a technical term in physics. The term force in physics is different from the term force in political and social.

Force is a very important physical quantity. It is used to describe interactions between two bodies in nature. For example, when you kick a ball, tear a piece of paper, hold your exercise book and walk on the floor you apply forces. Hence, in physics the term 'force' is used to describe a 'push' or a 'pull' exerted on a body.

A force is a push or a pull exerted on a body by another body.

Types of forces

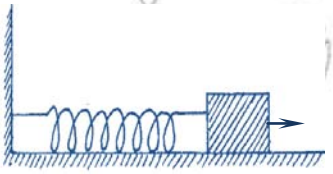
Activity 3.3

i. Throw a ball vertically upward and observe its motion. What will happen to the ball? Will it continue to move upward forever? Why?
ii. Take a magnet and pieces of iron fillings. Move the magnet over the iron filings without a physical contact between the magnet and the iron fillings. Describe your observation for your teacher.
iii. Move your desk from its current position. Can you do it without a physical contact? Why?
iv. Explain the types of forces that exist in the above 3 activities.

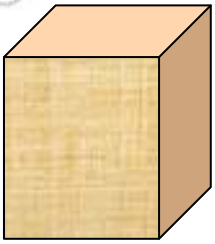
You know that a force is a push or a pull. But do all bodies push or pull other bodies by making a physical contact only? From your Activity 3.3, you might have noticed that bodies could be in contact to each other or they could be without contact or at a distance from each other. Therefore, forces are classified into two broad categories known as: (i) **Contact forces** and (ii) **Non-contact forces**

i. **Contact forces** are forces exerted when two objects are in touch or contact.
For example;
- A force exerted by a stretched or compressed spring.
- An upward force exerted by a table on a box resting on it.

a) Pushing a table



b) Stretching a spring

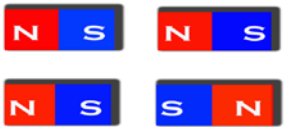


c) A box resting on a floor

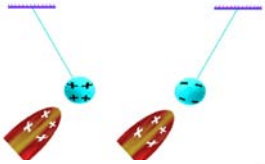
Fig.3.1. Examples of contact forces

ii. **Non-contact forces** are forces exerted without body contact. They are forces acting at a distance. Gravitational force, magnetic force and electrical forces are examples of non – contact forces.

A falling ball



Attraction or repulsion of two magnets



Electrostatic forces

Fig. 3.2 Different types of non contact forces

Challenging Questions

1. Discuss examples of contact forces in Fig 3.1
2. Discuss the differences between gravitational force, magnetic force and electric forces. (Fig 3.2)

Effects of a force

When a force is exerted on a body, the body may change its shape or size.

Activity 3.4

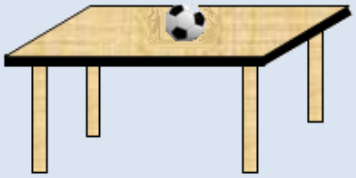
Observe the activities shown in Fig 3.3

a. Explain the effects of forces in each activity.
b. Can you summarize the effects of force?

a) When the person kicks the ball the ball moves in the direction of the force

b) When the engine applies a force the car moves.

c) When a spring is stretched the size and the shape change.



d) When a ball roles over the table and falls off the table forces are exerted.

Fig.3.3 Different effects of forces

The change in shape or size of a body is known as deformation. There are two types of deformation;
I. Permanent
II. Temporary.

It is not simple to describe a force as you can describe some material objects such as a chalk, pen, orange etc. You can only say what a force can do. For example when a body at rest is acted upon by a force it will begin to move. If a body is already moving a force may change its velocity. That is, a force produces motion or changes motion of a body.

Force produces an acceleration of a body.

A force has the following main effects, when it is exerted on an object:

i. It changes the shape and size of the objects.
ii. It changes the magnitude or direction of motion of the objects. i.e. when a force is exerted on a body:
   a. a stationary body starts to move
   b. a moving body increases its speed,
   c. a moving body decreases its speed and gradually stops moving
   d. a moving body changes it direction.

Measuring a Force

Activity 3.5

Do the following tasks with your friends.

i. Describe methods of measuring a force.
ii. What is the instrument used to measure a force?
iii. Mention the SI unit of force.

A force is measured using an instrument called a **spring balance** (Fig 3.4 a). As you can observe from Fig 3.4 there is a stretch (increase in length) of the spring when it is pulled. We can use this increase in length of a spring to measure the magnitude of the force stretching the spring.

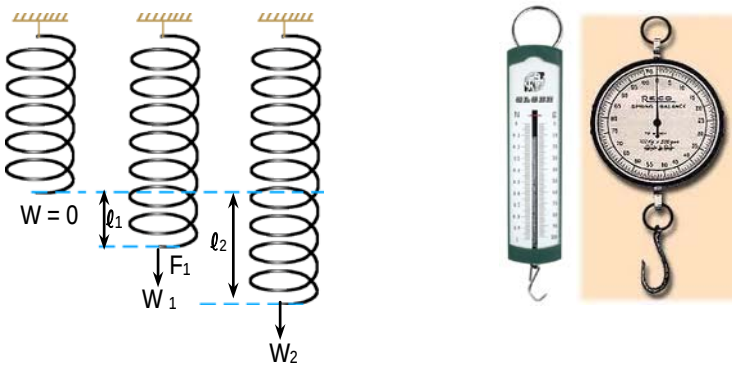


Fig 3.4 Spring balance

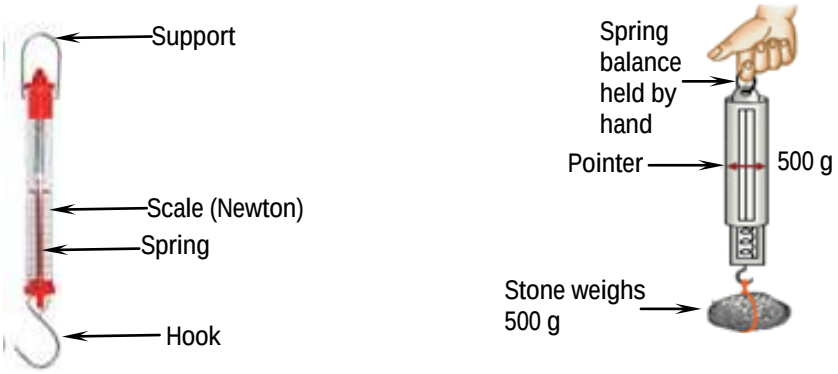
Each time an extra weight is added you find that there is the same extension because each object is identical.

They are attracted to the earth with the same force, so what we have found is that equal force produced equal extensions of the spring. **Newton meter** is the scientific instrument used to measure a force. The SI unit of force is **newton** symbolized by N**.** The unit newton is named, after the great scientist **Sir Isaac Newton**.

Fig 3.5 (a) illustrate the structure of a Newton meter. It is made up of a spring attached to a hook and a scale leveled in newton.

Fig 3.5 (b) measures the weight of stone in gram. When the spring balance is held by the hand it shows a certain weight for the piece of stone. Here the weight is 500 grams. To know the weight of the stone in newton you have to multiply by 10 m/s^2.

Describing a Force: A force is a vector quantity. (A vector quantity is a quantity which has both magnitude and direction.) To fully describe the force acting upon an object, you must describe both its magnitude and direction. For example, "10 N of force" is not a complete description of the force acting on an object. '10 N downwards' is a complete description of the force acting upon an object.



a) Newton meter *b) Spring balance*

Fig 3.5 Force measuring instruments

Check points 3.1

1. What is a force in physics?
2. Name two types of force and give example for each type.
3. Describe some effects of a force.
4. Write the unit of force both in word and symbol.
5. Read the weight of a body from the spring balance.

3.2. Newton's Laws of Motion

In unit two of this book you learned about the motion of bodies in a straight line. In the first section of this unit, you learned the major effects of a force. Combining these two backgrounds, it is now necessary to study the relationship between force and motion.

Galileo Galilee (1564-1642 AD) and Sir Isaac Newton (1642-1727 AD) tried to explain the causes of motion of bodies in a certain direction or why bodies stop their motion. These ideas were put together by Sir Isaac Newton in the form of laws of motion called Newton's laws of motion.

Newton's First Law of Motion

Activity 3.6

Discuss the following questions with your friends.

i. Place any object (text book, or pen, or eraser) on a floor.
ii. What happens to the state of motion of the object, when you don't exert a force on it?
iii. Exert a force (push or pull) on the objects. What happens to their states of motion?

Based on the discussion of activity 3.6 you can generalize that unless you or someone else exerts a force on the object, an object at rest will remain at rest. But when a force is applied it starts to move.

Similarly, a body moving with a constant velocity along a straight line will not increase or decrease its speed unless an external force is applied on it. These conditions led Newton to state the important law called Newton's first law of motion.

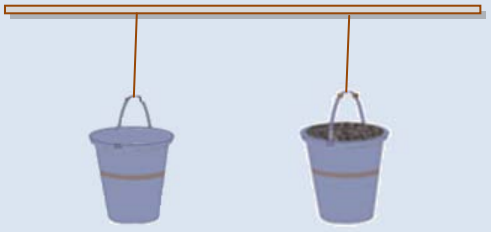
> Newton's first law of motion states that: "an object continues in its state of rest or of uniform motion in a straight line unless it is forced to change that state by the application of an external force."

This means, in the absence of an external force, a body at rest will remain at rest and a body in motion will continue its motion in a straight line with uniform velocity. This law is also called the **Law of Inertia**.

This law points out that force is something that changes the state of a body. In other words we can say that if the state of a body changes, a force is acting on it. A force may be defined as a push or a pull which produces or tends to produce motion, stop or tend to stop motion.

Activity 3-7

i. Discuss with your friends and report to your teacher. (Fig 3.6)
   a. pull both cans with the same force. Which can is easy to move? Why?
   b. If both cans are moving towards you, which is easier to stop its motion?
   c. What do you call the property of a body to resist change in its motion?



a) Empty can b) Can full of Sand

Fig 3.6 Bodies having different masses

ii. What is the use of seatbelt/safety belt in a car? Ask a driver or a traffic police and discuss your findings with your group members.

iii. When you are standing in a moving bus, you fall or tend to fall forward when it suddenly stops. How can you explain this effect? What are the forces acting on you?

iv. Explain the term 'inertia' using practical examples.

From your Activity 3.7 you noticed that an object at rest would insist to be at rest. A moving object would like to continue its uniform motion in a straight line. This is the property of all objects and it is known as **inertia**.

Inertia is the property of a body to retain its state of rest or state of uniform motion in a straight line in the absence of an external force.

Activity 3.8

i. Place your pen on the surface of a floor. Push the pen and observe its motion. Similarly apply the same amount of force on a table; standing on a floor. What effects do you notice in both activities?
ii. Is the speed of the table the same as that of the pen?
iii. Do you think that for the same applied force the change in velocity is the same? Explain your answer.

From the above two activities you noticed that mass and inertia are the same. To move a large mass, a large force is required for motion to begin; and if the mass is small, a small force is required. We use the term mass instead of inertia in this book.

Generally large masses have greater inertia and smaller masses have less inertia.

Activity 3-9

Do the following activity to understand the effects of inertia. (Fig 3.7)

i. Pile of four or five smooth wooden blocks on the top of a table.
ii. Give a sharp kick with a hammer on the bottom block.
iii. What did you observe?
iv. Why do the blocks of wood drop vertically down when the bottom block is kicked with the hammer?

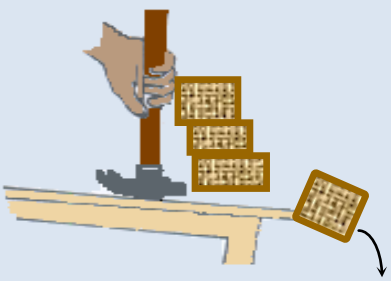


Fig.3. 7 A pile of wooden blocks

When the bottom block is given a sharp kick it causes out of the stack while the top three blocks drop vertically down as shown in Fig. 3.7. Do the rest in the same manner as the first. You will observe that when the kicked block moves away the remaining will be dropped vertically down.

Activity 3.10

i. Apply a force to move a heavy box placed on a smooth floor, it will resist to stay at rest or don't move. This means you didn't bring a change in motion even though you applied a force.

ii. Why do you think the body does not move when you apply a force?

The above activities show that mass and inertia are the same. To move a large mass, a large force is required, and to move a small mass, a small force is required. In this book we use the term mass instead of inertia.

Newton's second law of motion

Newton's first law describes the qualitative property of a force. It describes how force changes the state of rest or uniform motion of a mass of body. In other words, it states that every change in the magnitude or direction of a body's velocity is caused by applying an external force.

In Newton's second law you will learn how to measure the magnitude of a force required to bring a given body to rest or set in motion.

Activity 3-11

- Consider two boxes 'A' and 'B' as in Fig 3.8. Let the mass of 'A' is 20 kg and that of 'B' is 40 kg. Both are at rest.
- Suppose you push separately the two boxes with the same force of 10 N. which box change its motion easily? Explain it.

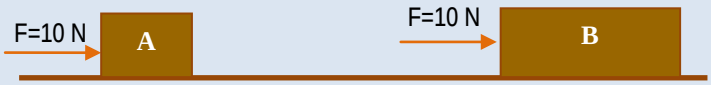


Fig.3.8 Different masses acted by the same force

Activity 3.11 helps you to know that, when the same force is applied on two bodies of different masses, the smaller mass accelerates more than the larger mass.

Mathematically you can state as follows. Acceleration is inversely proportional to the mass of a body for a given applied force. i.e. $\mathbf{a} \propto \frac{1}{m}$ where 'm' is the mass of the body and 'a' is the acceleration. $\propto$ is proportionality symbol.

Activity 3-12

i. Consider two bodies of equal masses and different forces are applied to make them move. (Fig 3.9)

- Which one of the masses do you think will accelerate more?
- What do you conclude about force and acceleration?

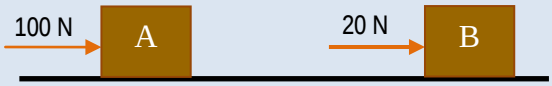


Fig. 3.9 Equal masses acted by different forces

Activity 3.12 helps you to observe that as the force increases the acceleration increases for a given constant mass.

Acceleration is directly proportional to the force applied. i.e. $\mathbf{a} \propto \mathbf{F}$. This means that the greater force you apply to an object the greater the acceleration is.

Combining Activities 3.11 and 3.12 together we get the following important law known as Newton's second law of motion.

Newton's second law of motion states that: "the acceleration of a body is directly proportional to the force '(F)' acting on the body and inversely proportional to the mass '(m)'of the body."

Mathematically expressed as:

$$\text{Acceleration (a)} = \frac{\text{force (F)}}{\text{mass (m)}}$$

Force = mass × acceleration

$F = ma$

The SI unit of force is newton, represented by 'N'. 1 N = 1 kg m/s^2

1 newton is the force needed to give an acceleration of 1m/s^2 to a mass of 1kg.

This law is valid for objects ranging from the size of atoms to size beyond the distances of galaxies and everything in between. This is why Newton's second law of motion is called the 'universal' law. It describes the way objects in the universe move.

Activity 3-13

i. Can you mention any other physics laws you know that applies universally?
ii. Discuss them with your friends.

Example 3.1

1. How large a force is required to set a 10 kg toy car in motion with an acceleration of 2 m/s^2.

Given	Required
m = 10 kg	F = ?
a= $2m/s^2$	

Solution

According to Newton's 2nd law of motion

F = ma

= 10 kg × $2m/s^2$

= 20 kg m/s^2

= 20 N

2. A force of 30 N is applied on a box of unknown mass to set it with an acceleration of $5m/s^2$. What is the mass of the box?

Given	Required
F= 30N	m = ?
a = $5m/s^2$	

Solution

From F = ma, we get

$m = \frac{F}{a} = \frac{30N}{5 {}^{m}/_{s^2}} = 6$ kg

∴ m = 6 kg

- Verify that N/ (m/s^2) = kg

3. A girl pulls a box on a horizontal floor by applying a horizontal force of 100N. The mass of the box is 20 kg. What is the acceleration of the box?

Given	Required	Solution
F = 100 N m = 20 kg	a = ?	from F = ma, we have: $a = \frac{F}{m} = \frac{100N}{20kg} = 5\ N/kg$ $\therefore a = 5m/s^2$

- Can you verify that N/kg = m/s^2?

4) How much external force is required to accelerate a 1500 kg car at the rate of $6m/s^2$?

Given	Required	Solution
m = 1500kg a = 6 m/s^2	F = ?	F = ma = 1500 kg × 6 m/s^2 F = 9000 N

Fig. 3.10. A man measuring his weight on a balance.

Activity 3.14

i. What is mass?
ii. What is weight?
iii. Explain the difference between mass and weight.

Mass and weight

You learnt in unit one that the mass of a body depend on the quantity of matter it contains and being measured using a beam balance everywhere.

Mass is the amount of matter in a substance. The mass of a body characterizes its inertia and it is a scalar quantity which is measured in kilogram (kg). Thus the mass of a given body is the same everywhere. Whereas weight is the pulling force of the earth towards its center and it is a vector quantity.

If you throw a stone vertically upward, it will fall back to the earth. The same thing will happen every time you throw an object in any direction. The pulling of objects by the earth towards its center is called the force of **gravity**.

The pull of gravity acting on a body towards the centre of the earth is called the weight of a body. Thus the weight of a body is a force.

What is the Difference between Mass and Weight?

Fig. 3.11 a and b shows two types of scales commonly used in the science classroom. These are **spring scale** and a **beam balance** scale.

a) Spring scale

b) Beam balance scale

Fig 3.11 Two types of scales for measuring mass

For example on earth the spring scale reads 100g with a mass attached to the hook (Fig 3.11 (a)). When a beam balance scales is used, you balance the scale on the right by a 100 g mass of substance.

If we were to take both scales to the moon, what would the spring scale read? How much mass would be needed to balance the 100g mass on the balance beam? Can you explain your answer?

In science or physics you need to recognize between '**weight**' and **'mass'**. They are two different physical quantities in physics.

Activity 3.15

i. Have you noticed that people are using the terms 'mass' and weight interchangeably? Comment on it.

ii. What is the reading you get from a balance when you stand on it? Is it your weight or your mass?

According to Newton's second law, force equals to the product of mass and acceleration, that is F= ma. Similarly the force of gravity of the earth equal to the product of mass and acceleration due to gravity 'g', thus;

Weight (W) = mass (m) × gravitational acceleration (g) ⇒ W = mg
Where 'm' stands for mass and 'g' is acceleration due to gravity.

Example: 3.2

1. The mass of one quintal of 'teff' is 100 kg. What is its weight? Take g = 10m/s^2.

Given	Required	Solution
m= 100 kg g = 10 m/s^2	W = ?	From W = mg, we have = 100 kg × 10m/s^2 = 1000 N

2. How much does a 100 kg body weight on the surface of the moon whose acceleration due to gravity is equal to 1.63 m/s^2?

Given	Required	Solution
m = 100 kg g = 1.63m/s^2	W = ?	Using the definition of weight, we get, W = mg = 100 kg × 1.63 m/s^2 = 163 N

Newton's Third Law (Law of Action and Reaction)

Activity 3.16

a) Kick a ball with your bare foot, what do you feel?
b) Hold your physics book by placing it on your palm. Do you feel that a force is exerted by the book on your palm? What about the reverse? Is there a force exerted by the palm on the book?
c) Push the wall of your classroom; do you feel that the wall is pushing against you?
d) Place a box on a table and let it stay at rest. What are the forces acting between the box and the table?

a) A book resting on a palm b) A rocket moving upward c) A girl pushing a box on a floor d) Two persons pushing each other

Fig. 3.12 Action and Reaction forces

From Activity 3.16 you noticed that, it is not possible to exert a force on a body without the body exerting a force in the opposite direction. These forces are called the **action** and **reaction** forces.

Newton's third law states that "To every action there is always an equal and opposite reaction". That is, whenever one body exerts a certain force on a second body, the second body also exerts an equal and opposite force on the first. This law is also called the law of Action and Reaction.

Action and reaction forces always act on two different bodies and always exist in pairs. In Fig 3.12 the force exerted by the palm on the book is F_{wp}. It is applied to the book and is directed upwards. In return the weight will act on the palm with the force $F_{pw.}$ This force is applied to the palm and is directed down ward. In this and in all other action and reaction cases it can be summarized mathematically as:

$\overrightarrow{F_A} = -\overrightarrow{F_R}$ where $\overrightarrow{F_A}$ is the action force and $\overrightarrow{F_R}$ **is the reaction force.**

The negative (-) sign indicates the reaction force is opposite in direction to the action force.

Challenging Questions

1. When you push a wall with your hand you exert a force on the wall. Explain the forces between the wall and your hand
2. What are the forces exerted by the bodies indicated in Fig 3.12 (a, b, c and d)?
3. Indicate the action and reaction forces in the following actions.
   a) A student carrying his school bag.
   b) A horse pulling a cart.
   c) A bullet shot from a gun.

Check point 3.2

1. Define the term inertia.
2. What is the relationship between mass and inertia?
3. State a) Newton's first law of motion.
   b) Newton's second law of motion.
   c) Newton's third law of motion.
4. What are the relationships between force, mass and acceleration?
5. What is the difference between mass and weight?

3.3. Frictional Force

In the previous sections you learnt about a force. You apply a force when you kick a ball and when you hold your physics book. A force is applied when a body accelerates.

Activity 3.17 *Discuss with your friends on the following questions.*

i. Have you ever walked on a muddy road or on a smooth polished floor?
ii. Is it more difficult to walk on these surfaces than on a rough road (surface)? Why?
iii. What makes easier to walk on a rough road?
iv. What type of force is a friction force?

The two surfaces used in Activity 3.17 will slip you away since there is no sufficient friction force to prevent you from slipping. The force of friction is important for walking.

a) Motion of a bicycle on a straight road

b) A walking person

Fig 3.13 Fiction force on a bicycle and walking man

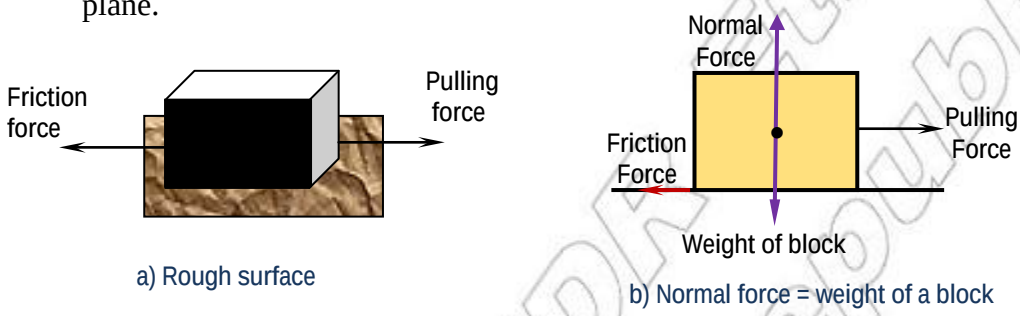
When an object moves over the surface of another object, it experiences a resistance or opposing force against the relative motion of the objects. This opposition or resistance to the motion of objects is called friction.

Friction force is the force that opposes the relative motion of two bodies in contact. If we try to push a block of wood across a table, there are two opposing forces that act on the block of wood. The force related to the push, and a force that is related to the friction. These two forces act in the opposite direction.

As frictional forces are decreased (for example, by placing oil on the table) the object moves further and further before stopping. This demonstrates Galileo's law of inertia which states: "an object in a state of motion possesses an inertia that causes it to remain in that state of motion unless an external force acts on it". Friction force always arises when one body tries to slide on another. The frictional force depends on;

i) The roughness of the surfaces in contact.

ii) The normal force (the force perpendicular to the surface). The normal force is the same as the weight of a body when it lies along a horizontal plane.



a) Rough surface

b) Normal force = weight of a block

Fig 3.14 Factors affecting frictional force

Activity 3.18

Prepare two boxes which have different masses. Try to push each box separately across a rough floor. Which one is difficult to push?

From activity 3-18 you learnt that heavier (bigger) objects are more difficult to move on a rough surface. i.e. because as the weight increases, the friction force also increases. That is because there is an increase in the force that presses the two sliding surfaces together. This force is the normal force reacting the floor on the block.

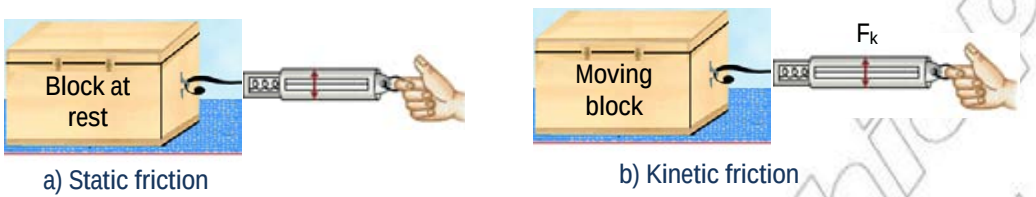
Activity 3.19

What causes friction?

Types of frictional force

There are two types of friction;

i. Static friction ii. Kinetic friction.



a) Static friction b) Kinetic friction

Fig 3.15 Types of friction

Activity 3.20

i. Try to pull a heavy box across a floor; explain the force you needed, to start the motion and the force required during the motion to continue it moving.
   a) First pull it slowly and notice the force just needed to start it moving. (Fig 3.15 a)
   b) Then continue to pull it. (Fig 3.15 b)

ii. Which one has greater value? Starting force or force that keeps it moving?

From the Activity 3.20 you notice that the force required in setting the box into motion is larger than the force required to continue the motion of the box.

The friction force that opposes motion just before the box starts its motion is called the **static friction**. The force that is being constantly over come during the motion of the box is called the **kinetic friction**. Activity 3.20 shows that static friction is greater than kinetic friction.

Static frictional force is the maximum frictional force which enables to start the relative motion of two objects.

Kinetic frictional force is the force which arises when one body slides or moves over the other. The term "kinetic" means 'moving'.

Once the object begins to move, the force required is not so great. This shows that kinetic friction on a body is smaller than the static friction.

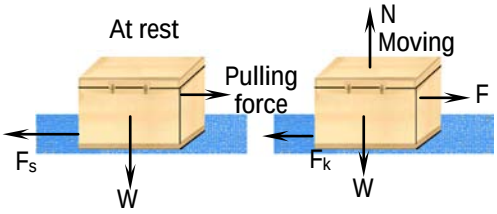


Fig 3.16 Relationship between Fs and F_k

If F_s = static friction and

F_k = kinetic friction

Static friction is greater than kinetic friction, $F_s > F_k$

Factors affecting frictional force between two contacting surfaces

Activity 3-21

i. Try to slide your physics text on your mathematic textbook.
ii. Observe what force you apply to start the motion of the physics book.
iii. Next try to slide the physics textbook on your table. What do you notice?
iv. Are the forces you require to push the physics textbooks in the two situations the same?
   a. What is a normal force?
   b. How is friction affected by a normal force?

The two major factors that affect friction are;

1. The nature of contacting surfaces.
2. The normal force between the surfaces.

A normal force is a force that presses two surfaces together. It is perpendicular to the pressed surfaces. For a flat surface the normal force is equal to the weight of the sliding body.

How does a normal force affect the force of static or kinetic friction?

From the Activity 3.18 you have observed that both static friction and kinetic friction increases as the weight of the sliding body increases. Further the static frictional force, is greater than the kinetic frictional force. Therefore, frictional force is proportional to the normal force. Mathematically;

$F_s \sim N$ and $F_k \sim N$

Or $F_s = \mu_s N$ and $F_k = \mu_k N$

Where, μ_s is coefficient of static friction and μ_k is coefficient of kinetic friction. μ is a Greek letter read as *miu*.

The values μ_s and μ_k are positive and less than one. Since $F_s > F_k$ then $\mu_s > \mu_k$.

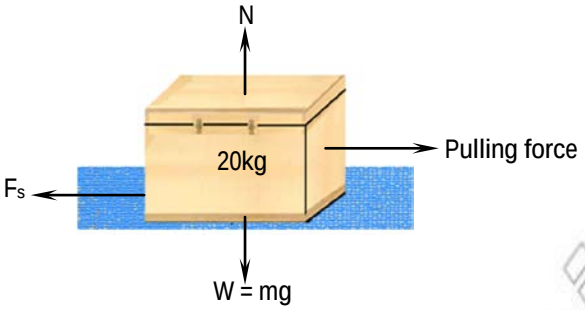


Fig 3.17 The normal force N is equal to mg

Example 3.3

The coefficient of static friction between a block of wood and the floor is 0.2. The mass of the block is 20 kg. What is the static friction between the block and the level floor? (Take g = 9.8 m/s^2)

Given	Required	Solution
$\mu_s = 0.2$ m = 20 kg	F_s = ?	$F = \mu_s N$ $N = w = mg$ $N = 20\ kg \times 9.8\ N/kg = 196\ N$ $F_s = 0.2 \times 196\ N$ $F_s = 39.20\ N$

2. The force of static friction between a body of mass 50 kg and a horizontal floor is measured to be 103N. What is the coefficient of static friction between the body and the table?

Given	Required	Solution
$F_s = 103\ N$ m= 50 kg	μ_s = ?	since N = mg = 50kg × 9.8 N/kg = 490 N $\mu_s = Fs/N$ Thus μ_s = 103N/ 490 N μ_s = **0.21**

Note: **Coefficient of friction /μ_s / is unit less.**

Effects of Friction

There are some common effects of friction. Friction-

- Increases the work necessary to operate a machinery; i.e it causes wastage of energy.
- Causes wearing out of a surface
- Generates heat, etc.
- Causes walking possible on roads

Are these effects of friction useful or harmful? Which ones are harmful and which ones are not?

Activity 3.22

i. Discuss some useful effects of friction from your daily experience (e.g. How fire is generated using friction).
ii. Mention also some harmful effects of friction.

Advantages of friction

Your discussion in Activity 3. 22 might have helped you to understand that there are some uses of friction. Among these uses or advantages of friction, the followings can be mentioned as examples.

i. **Walking**: The friction between your foot (shoes) and the ground enables you to walk. Where friction is very low like slippery mud surface, you will find it difficult to walk on it.
ii. **Tires**: The friction between the car tires and the road allows a car to move or to stop.
iii. **Brakes**: When the brakes of a car is applied, the brake shoes are pushed apart. This brings the brake lining and the drum into contact and the friction between them stops the car.

Disadvantage of Friction

Activity 3.23

Discuss with your friends or parents. Describing the disadvantages of friction. Example the making of fire in factories, vehicles, forests, etc.

If you rub the palms of your hands together, they will become warm. This is because of friction. The same thing applies to all machines which have moving parts.

Heat is developed in the moving parts when the machine works. This is because some of the energy supplied to drive the machine is changed into heat. This is a wastage of energy. It is not used for the desired purpose. Some parts of machines also wear out because of friction.

Challenging Question

Give some other advantages and disadvantage of friction.

Reducing Friction

In order to increase the efficiency of machines and reduce the wearing out of machine parts, friction has to be reduced.

Some of the most commonly used methods of reducing friction are the following.

A. **Removing of roughness of the surfaces** Smooth surfaces have less friction than rough surfaces.

B. **Lubricating**; If you introduce liquid film such as oil between the surfaces, friction will be reduced. The oil fills the valleys and separates the surfaces so that the hills and valleys do not hold each other.

C. **Rolling bodies**: The most effective and commonly used method of reducing friction is to use rolling bodies instead of sliding bodies. That is wheels, roller bearings and the ball bearings are used to reduce friction. Fig 3.18 illustrates the difference between sliding and rolling bodies.

a) A sliding body b) A rolling body

Fig 3.18 Rolling reduces friction

I think in this unit you have acquired the knowledge of force and you have also got some answers for your doubts which you always ask yourself why I fell

when something hits me. Why I tend to be pushed forward when the bus suddenly stops, etc.

You might have asked yourself why do I fell when I step on a banana scrap. This is because of friction. As friction is necessary for motion it is also harmful for machines. You have a responsibility as a citizen to keep machines not to wear out due to friction, and do the necessary things to reduce friction.

Since this topic is very important and more applicable in all aspects of life you have to have an active participation in the class and outside in the community to give awareness how to reduce friction in machines.

Check point 3.3

1. What is a frictional force?
2. Name examples where frictional force plays an important role in our daily life.
3. State the factors on which a frictional force depend on.
4. What is the difference between static friction and kinetic friction?
5. Describe two methods of reducing friction.

Summary

In this unit you learnt that:

- force is a push or a pull that produces motion, stops or tends to stop motion.
- the relationship between a force and the motion produced is described by Newton's three laws of motion.

The Newton's laws of motion are:

1st law: A body at rest remains at rest, and a body in motion continue to move with a uniform speed in a straight line unless it is acted upon by an external force.

2nd law: The acceleration is directly proportional to the applied force and inversely proportional to the mass of the body, (F=ma).

3rd law: For every action there is an equal and opposite reaction.

- the unit of force is Newton, 1N is defined as a force that acts on a mass of 1 kg and produces an acceleration of 1 m/s^2.
- weight of a body is the gravitational force acting on the body. The weight of an object of mass 'm' is W= mg.
- frictional force is directly proportional to the normal force and is directed parallel to the surfaces of the moving bodies.

$$F_f = \mu F_N$$

- **the coefficient of friction 'μ' is defined as the ratio of the frictional force** to the normal force.

$$\mu = \frac{F_f}{F_N}$$

Review Questions and Problems

I. Fill in the blank spaces with the appropriate word(s).

1. The cause for the change in the state of rest or motion of an object is_____.
2. According to Newton's 2nd law of motion, force is the product of _____and _____.
3. Action and reaction forces are always _____ in magnitude and _____in direction.
4. The pull of gravity on a 1 kg body on the surface of the earth is _____Newton.
5. The gravitational force with which the earth attracts a body is called _____.

II. Short answer questions

1. Define a force.
2. Explain how the weight of a body changes as the body is taken farther away from the surface of the earth.
3. What are the units of g, F_N and μ?
4. Explain why the friction between two pieces of wood is reduced when they are smooth and polished.

III. Solve the following problems.

1. How much force is needed to accelerate a toy car of mass 8 kg at $2m/s^2$?
2. A trolley of mass 20 kg was originally at rest on a smooth horizontal surface. By how much will it accelerate if a pulling force of 22 N is applied on it horizontally?
3. What is the weight of a 60 kg boy on the surface of the Earth? Take $g = 10\ m/s^2$.
4. A 90 kg body is taken to a planet where the acceleration due to gravity is 2.5 times that of the earth. What is the weight of this body on the surface of this planet? Take $g = 10\ m/s^2$.

5. A car of mass 1500 kg starting from rest can reach a speed of 20 m/s within 10 seconds. Calculate the accelerating force of the car engine.
6. If the force acting on a body of mass 40 kg is doubled. By how much will the acceleration change?
7. A block of mass 5 kg is being pulled along a board horizontally with a constant velocity; the coefficient of friction between the two surfaces is 0.25.
   a) What is the normal reaction force between the board and the block?
   b) What is the frictional force that opposes the motion?

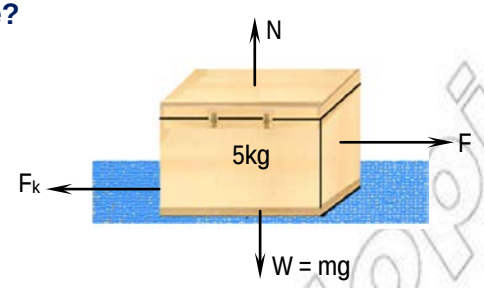


Fig 3.19

8. A 75 N horizontal force is sufficient to move a 150 N box on a level road at a uniform speed. What is the coefficient of friction between the box and the road?

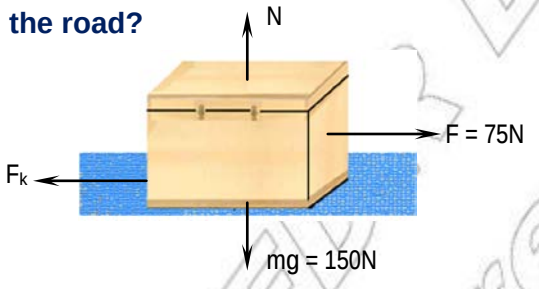


Fig 3.20

9. A space woman has a mass of 65kg on the earth surface. What is her weight on:
   a) the earth, where g = 10 m/s^2?
   b) the moon, where g = 1.6 m/s^2?