3.1 Inertia and qualitative concept of force- Newton's first law

We have already known about rest, motion, displacement, velocity, acceleration etc. We can see different types of objects around us. Some of them are in rest and some of them are in motion. Among the bodies in rest, there are chair, table, houses, log of wood etc. Can a body in rest move itself? Tonight your reading table is in a certain place. Will it be in the same place in the next morning? What do we observe from these practical experiences? It is observed that the bodies at rest are still at rest. These bodies can't move by themselves. Suppose that one of your friends is riding a bi-cycle on a plane road. At any moment he stopped paddling the cycle. Will the cycle stop at once? We find that the cycle will stop slowly after crossing a small distance. Would the cycle move continuously if there is no air resistance and friction?

From this evidence we can understand that everybody has the tendency to remain in the same state as it is. If the body is at rest it continues to be at rest. On the other hand if the body is in motion it continues to be in motion. This tendency or property of a body to maintain its own state is called inertia. Thus the tendency of a body to maintain its own state for ever in which the body is at present or the property of a body to preserve that state is defined as inertia.

The inertia of a body depends on its mass. That is, mass is the measure of its inertia. The more the mass, the more the inertia of a body. In other words, it is difficult to move, increase or decrease velocity or change the direction of velocity of a body whose inertia is large.

Do yourself

- Keep a pen and a book on a table. Now strike the pen with finger. What do you observe? The pen moved a small distance on the table.
- Now repeat this procedure for the book. The book won't move. Now push the book with your hand. The book will be displaced from its original position.

Between the pen and the book, it needs more effort to move the book as the mass i.e. the inertia of the book is greater.

Example of inertia

If a bus at rest suddenly starts moving the passengers lean backwards. The reason behind this is inertia. When the bus is at rest, the bodies of the passengers are also at rest. When the bus starts moving, the part of the passenger's body attached to the bus also moves with it. But the upper part of the body tends to remain stationary due to inertia of rest. Thus the upper part of the body lags behind with respect to the lower part. As a result the passenger inclines backwards. On the other hand, when a sudden brake is applied in a moving bus the passengers lean forwards. When a bus is in motion, the passenger of the bus is also in the same speed of the bus. When the bus stops suddenly, the lower part of

the body also becomes stationary with the bus. But the upper part of the passenger's body moves forward due to inertia of motion.

During car driving the drivers wear seat belt for safety. What is the reason? The reason behind this is inertia. If he doesn't use seat belt, he would lean forward due to inertia of motion for applying fast brake. For this reason he would hit the steering and other bodies in front of him, for this a serious accident may happen. Not only have the drivers, the passengers also had to wear the seat belt if there is an arrangement of seat belt in the car.

We have a general concept about force from our daily life experiences. When we pull or push a body, then we say a force is applied upon the body. This applied force can create or tends to create motion in a stationary body. If the body is in motion, then the applied force can cease the motion of the body or tries to increase its velocity. In both cases to apply force, it needs direct contact between the force applier and the body. These types of force are known as contact force. If the two bodies are not in direct contact, still they can apply force on each other. Such a well-known force is the force of gravitation, whose practical example is the weight of a body. When a body falls from your hand, then it quickly touches the ground. What is the reason? It happens due to the weight or attraction of the earth on the body. We define this force as the force of gravitation. In this way we feel the existence of different type of forces in different events of nature.

For example- the magnetic force between two poles of a magnet, the electrical force between two charged bodies, nuclear force within the nucleus.

Now we will see how we can get concept about inertia and force from Newton's first law of motion. Newton's first law of motion is-

'Every object will continue in its state of rest or of uniform motion in a straight line unless an external force is applied to it.'

Newton's first law expresses the property of inertia of matter.

From Newton's first law of motion we observe that a body cannot change its state on its own. If the body is at rest, it tends to remain at rest forever and if it is in motion it tends to keep on motion with uniform speed for all time. This property of a body is termed as inertia. Thus from the Newton's first law of motion we get the concept of inertia.

Again from Newton's first law we see that to change the state of a body something external must be applied. That is, the external cause which changes or tends to change the state of an object is called force. Thus from Newton's first law we get qualitative definition of force. According to Newton's first law, a force is that which acting on a body at rest produces or tends to produce motion or acting on a moving body changes or tends to change its state of motion.

3.2 Nature of force

Contact force:

We are familiar with different types of force in our daily lives. Nature of them is of different types. Some of them are produced due to direct contact between two bodies. In addition, there are some forces which do not need direct contact between two bodies. The force which needs direct contact between two bodies to be created is defined as contact force. When we push or pull a body with hand our hand exerts a force on the body at that time. This push or pull force is contact force. Since this force is the consequence of the direct contact between the hand and the body. The examples of contact forces are- frictional force, pulling force and the force created during collision.

When a body tends to move or move over another body, then a resistive frictional force is produced against the motion between the contact surfaces of two bodies. Here the frictional force is produced due to direct contact between the surfaces of the two bodies. We apply pulling force on a box when we pull it over the floor. At that time frictional force is produced opposite to the motion of the box.

Non-Contact force:

The force which acts without direct contact between two bodies is called non-contact force. The attractive gravitational force between two bodies, the attractive or repulsive electric force between two charged bodies, the attractive or repulsive force between two poles of two magnets, the force of attraction acting between a magnet and a magnetic material are the examples of non-contact force or distant force.

Do yourself: Release a pen or pencil or any object from your hand.

The body will fall down. Something is pulling the body downward certainly. Who is pulling? Here, the earth is pulling the body towards it, though there is no direct connection between the body and the earth i.e. the earth is not in contact with the body. Here the earth is applying force of gravitation on the body. The force of gravitation is a non-contact force. Any two body of the universe exert force of gravitation on each other. When the earth exerts force of gravitation on another body, then this force is called gravity.

Though we observe different kinds of force in nature, fundamental force are of four types. Rest of them is some forms of these fundamental forces. The forces which are root or independent i.e. the forces which are not produced from some other forces or not any forms of some other forces are called fundamental forces. Instead, other forces are some forms of these fundamental forces.

The four fundamental forces which exist in nature are:

1. Force of gravitation
2. Electromagnetic force
3. Weak nuclear force
4. Strong nuclear force

Force of Gravitation:

In this universe every body attracts each other by a force towards them. The mutual attraction between any two bodies of the universe is called gravitation. This attraction occurs due to mass of the bodies. The force of gravitation is comparatively weak among the fundamental forces. Weight of us is the consequence of gravitation. The planets of the solar system are revolving round the Sun due to force of gravitation. The range of gravitation extends to infinity.

Electromagnetic force:

The electromagnetic force is defined as the force exerted by two charged particles or bodies on each other due to their charges. This force may be of both types- attractive or repulsive. When the charged particles are at rest, only electric force works between them. The magnetic force is created simultaneously in addition to the electric force between the particles when the charged particles are mobile. The force of attraction or repulsion between two magnetic poles is also electromagnetic force. The electric force acting between two charged fundamental particles is more powerful than the force of gravitation between them. Nevertheless, electric force is of medium type considering strength. Frictional force, spring force etc. are produced due to electric forces between the charged particles.

Weak nuclear force

The short range and small magnitude force that exists between the fundamental particles within the nucleus is called weak nuclear force. Due to this force the nucleus becomes unstable and beta decay occurs. Most of the radioactive disintegration occurs due to weak nuclear force. The range of this force is less than 10^{-16} m.

Strong nuclear force

It is known that there are two particles namely proton and neutron within the nucleus of an atom. These particles are called nucleon. The strong force that exists between two nucleons within the nucleus of an atom is called strong nuclear force. This force bounds the nucleons together. The strong nuclear force is responsible for the stability of the nucleus. This force is very short range and attractive. The range of this force is 10^{-15} m which is the radius of the nucleus. This force is the strongest among the fundamental forces.

3.3 Balanced and unbalanced forces

When two or more forces acting on an object produce zero resultant force, i.e. the object has no acceleration; we say that the forces are balanced. The forces that produce this balanced condition are called balanced forces.

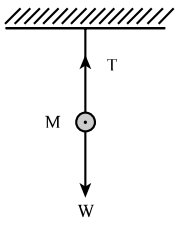

Fig. 3.1

It is seen in figure 3.1 that an object is suspended with a thread. The force of attraction of earth on the object i.e. the weight of the object *W* is acting vertically downward. The tension of the thread *T* is acting vertically upward. Here the two forces are equal in magnitude but opposite in direction thus canceling each other's action and producing a balanced condition.

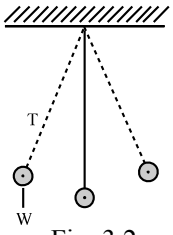

Fig. 3.2

Only the attractive force of the earth i.e. the force of gravity will act on the object if the thread is cut. Then the object will fall down with acceleration due to gravity. Here, the force of gravity or weight of the object is the unbalanced force. If the body is displaced slightly along one side, the tension of the thread *T* and the weight *W* will not be in a straight line. Then a resultant force will act on the body without creating balanced condition. Due to this, the body will oscillate. This is an example of unbalanced force.

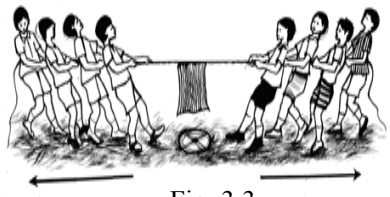
Fig. 3.3

Another example of balanced and unbalanced forces can be seen in the game of tug-of-war competition. In this game, a handkerchief is tied to the center of the rope. In this competition equal numbers of competitors pull on the rope in two sides and try to move the handkerchief to their side. If the handkerchief does not move then it is understood that either the team are applying equal amount of force and the rope or the handkerchief is in balanced condition. Here, forces applied by the two teams are balanced forces.

If one team applies more force than the other, then the resultant force will act along them thus creating unbalanced force and the handkerchief will move to their side. Then this team will be declared as the winning team in the competition.

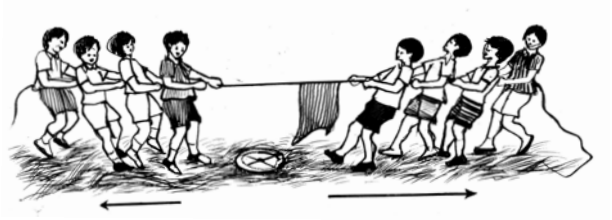

Fig. 3.4: Tug-of-war (unbalanced force)

3.4 Momentum

The physical quantity which is produced by the combination of mass and velocity of a moving body is the momentum. Momentum depends on the mass and velocity of the body. Think about a loaded truck and a private car. You have to stop both the cars within the same distance. Which car needs hard brake to stop? The answer is truck. Though the truck and the car are moving with the same speed, the truck possesses that physical quantity which is more is its momentum.

Momentum is a measure of how difficult it is to stop something that is moving. Momentum is related to the force. This relation is obtained quantitatively in Newton's second law of motion.

Momentum is the product of the mass and velocity of a moving body.

Let, the mass of a body = m

Velocity = v

$\therefore$ Momentum = mv (3.1)

Momentum is a vector quantity. Its direction is in the direction of velocity. It is observed from equation (3.1) that the momentum of a body will be large if the body has a large mass and moving faster.

Unit: the unit of momentum is, unit of mass × unit of velocity, i.e. $kg \times ms^{-1}$ or $kg\ ms^{-1}$.

If a body of 1 kg moves with a velocity of $1ms^{-1}$, its momentum will be $1kg\ ms^{-1}$.

Dimension: The dimension of momentum: $[p] = MLT^{-1}$.

3.5 Effect of force on motion

A force can cause a stationary object to start moving.

What happens when a stationary football is kicked by a player? It is seen that the ball moves off in the direction it is kicked from its stationary state. In this case the ball accelerates from rest. Here acceleration is positive, and in the same direction as the force exerted by the kick.

A force can cause a moving object to increase its velocity.

What would be the velocity when a cricket ball is hit by the batsman in the same direction as the ball moves? It is observed that the ball moves faster after the hit. In this case the acceleration is positive and its velocity increases. The velocity of a moving marble increases if it is stroked in same direction as it moves.

A force can cause a moving object to decrease speed.

Think you are riding a bicycle in the village road. After a while you observed that the road is slanting downwards. Now what will you do? Will you continue the pedaling as

before or give a brake? You have to apply brake to cross this sloping road safely. Due to this, the cycle decelerates.

A force can cause a moving object to change its velocity or direction of motion.

A batsman hits the cricket ball coming from opposite direction during a game of cricket. Due to the hit, the magnitude and direction of the velocity of the ball change. The ball moves in a different direction due to this hit by the bat. In this case too, the ball has acceleration.

Effect of forces on shape

There are many examples around us where the shape of a body changes by the application of force. The shape of an empty plastic bottle changes when it is pressed. Again when a rubber band is stretched by pulling it, it becomes narrow and its shape changes.

Sometimes, the changes of shape of the bodies are temporary in nature. Sometimes, the shape of the object is permanently changed due to the application of force. Such changes occur in the crushed metallic can or a car after a collision.

A temporary change of shape may provide a useful way of absorbing and storing energy. Compressing the spring by rotation of the key the potential energy is stored in a toy car. When the car is released the potential energy is transformed into kinetic energy. A permanent change of shape may mean the failure of a structure- as a bridge collapse due to excess load.

3.6 Relation between force and acceleration- Newton's second law

Newton's first law gives qualitative definition of force. Newton's second law gives the equation for the measurement of force. From Newton's second law we know the relationship between the force acting on a body and the acceleration produced due to this force. The law is as follows:

The rate of change of momentum of a body is proportional to the applied force acting on it and takes place in the direction in which the force acts.

Let a body of mass m is moving with an initial velocity u. Now a constant force F acts on the body for a time t in the direction of its velocity. Let the velocity of the body changed from u to v due to the application of the force.

Therefore,

$\therefore$ the initial momentum of the body = mu

$\therefore$ the final momentum of the body = mv

The change of momentum in time t = $mv - mu$

So, the rate of change of momentum $= \frac{mv - mu}{t}$

$= ma$ [Since, acceleration, $a = \frac{v-u}{t}$]

According to Newton's second law of motion, the rate of change of momentum is proportional to the applied force.

i.e., $ma \propto F$

$= kF$ (3.2)

Here, k is a constant of proportionality. To define the unit of force Newton consider k=1. The unit of force is Newton (N). One newton (N) is defined as the force that will produce an acceleration of $1 ms^{-2}$ when it acts on a mass of 1 kg.

Thus if mass m is in kg, acceleration a is in ms^{-2}, and force F is in N, then equation (3.2) becomes,

$$ma = 1.F$$

$$\text{or } F = ma \quad (3.3)$$

$$\text{or Force} = \text{mass} \times \text{acceleration}$$

The dimension of force: $[F] = MLT^{-2}$

Mathematical Example 3.1: What is the force to be applied to a mass of 50 kg to produce an acceleration of 4 ms^{-2} ?

We know,

$F = ma$
$= 50\ kg \times 4\ ms^{-2}$
$= 200\ kg\ ms^{-2}$
$= 200\ N$

Here,
mass of the body, m = 50 kg
acceleration, a = 4 ms^{-2}
force, F = ?

Ans: 200 N

Mathematical Example 3.2: A boy pushes a box of mass 20 kg with a force of 50 N. What will be the acceleration of the box?

We know
$F = ma$
$a = \frac{F}{m}$
$= \frac{50N}{20kg}$
$= 2.5\ ms^{-2}$
Ans: $2.5\ ms^{-2}$

Here,
mass of the box, m = 20 kg
applied force, F = 50 N
acceleration of the box, a = ?

3.7 Action and reaction force- Newton's third law

Whenever a force acts on one body, at that time an equal and opposite force acts on some other body. This matter is generally stated as-

To every action there is an equal and opposite reaction.

This statement is known as Newton's third law of motion.

Therefore, according to Newton's third law, the values of the action and reaction forces are same but their directions are opposite to each other. In figure 3.5 if the object P exerts a force F_1 on the object Q, then according to this law, the object Q will also exert an equal and opposite force F_2 on the object P. The force exerted by the object P on object Q is called action force and the force exerted by Q on P is called reaction force.

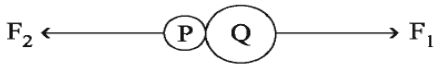

Figure 3.5

Therefore, according to Newton's third law, $F_1 = - F_2$

It is noticeable that the action and reaction force act on different bodies. The reaction force will exist as long as the there is action.

Example:

Walking on road

In our daily life we walk or run on the ground [Figure 3.6]. When we walk on the ground, we exert a backward force on the ground by the leg behind obliquely. This is the action force. According to the third law a reaction force is produced opposite to this. We are able to walk on the road due to this reaction force.

Figure 3.6

Firing by a gun

When a person fire with a gun, he feels a backward push at that time. What is the reason behind this? In this case, action and reaction force of bullet and gun exists for the same time. According to the Newton's second law of motion, the bullet and the gun acquire equal and opposite momentum. As a result the bullet moves forward with a particular momentum and the gun moves backward with a momentum of same magnitude but opposite in direction. Due to this, the person will feel a backward thrust. The backward velocity of the gun will be smaller in comparison to that of the bullet as the mass of the gun is large.

Collision

Among you, those who have played marble probably had seen how one marble hits another marble. In addition, you are familiar with different types of road accident through newspapers or television. These events are the practical examples of collision.

Therefore, when a moving object hits another body at rest or in motion, then it is said that a collision has taken place. During collision a force acts on each of the two bodies. If the force exerted by the first body on the second body is called action force, then the force exerted by the second body on the first one is called the reaction force. These two forces acting during collision are same in magnitude but opposite in direction. No other external force acts during the collision except the action and reaction force. From Newton's second law we get,

$$F = \frac{mv - mu}{t}$$

We can express the change of momentum from this equation as-

$$F \times t = mv - mu \qquad (3.4)$$

i.e. force × time = change of momentum.

The product of force and time is defined as impulse of force.

Therefore, impulse of force = change of momentum

Let two bodies A and B having masses m_1 and m_2 are moving with velocities u_1 and u_2 respectively along a straight line. If the velocity of A is greater than that of B, at any time the object A will collide with the object B [Figure 3.7]. The force exerted on B by A is the action F_1. The object B will also exert a force F_2 on A, this F_2 is the reaction force. According to Newton's third law of motion, $F_1 = -F_2$

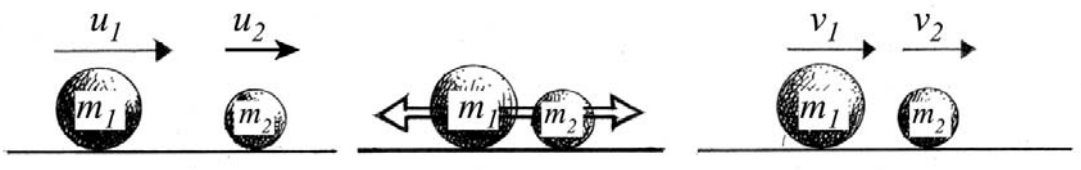

Figure: 3.7

During collision, the action and reaction force exists for the same time. Let the time duration of action and reaction be t. After the collision the two objects will continue to move along the same straight line with their changed velocities. Let v_1 and v_2 be the changed velocities of A and B respectively. If due to action and reaction, the accelerations of A and B are a_1 and a_2 respectively, then

$$F_1 = -F_2$$
$$\text{or, } m_1 a_1 = -m_2 a_2$$
$$\text{or, } m_1 \frac{v_1 - u_1}{t} = -m_2 \frac{v_2 - u_2}{t}$$
$$\text{or, } m_1 v_1 - m_1 u_1 = -m_2 v_2 + m_2 u_2$$
$$\text{or, } m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Therefore, the sum of the momentum of the objects A and B remains same before and after the collision. It is the law of conservation of momentum.

Mathematical Example 3.3: A force of 2000 N acts on a body of mass 20 kg for a time of 0.1 s. What is the change of momentum of the body?

Solution:

We know,

change of momentum = force × time

$mv - mu = Ft$

$= 2000 \text{ N} \times 0.1 \text{ s}$

$= 200 \text{ kg ms}^{-2} \text{ s}$

$= 200 \text{ kg ms}^{-1}$

Here,

applied force, $F = 2000$ N

time duration, $t = 0.1$ s

change of momentum, $mv - mu$ =?

Ans: change of momentum = 200 kg ms^{-1}

Mathematical Example 3.4: A bullet of mass 10 g was shot from a gun with a velocity of 500 ms^{-1}. If the mass of the gun is 2 kg, find the backward velocity of the gun.

Solution:

Let the direction of the bullet's velocity i.e. the forward direction be positive. From the conservation of momentum,

We get,

$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

ev $m_1 \times 0 \text{ ms}^{-1} + m_2 \text{ kg} \times 0 \text{ ms}^{-1} = 10^{-2} \text{ kg} \times 500 \text{ ms}^{-1} + 2 \text{ kg} \times v_2$

ev $v_2 = -\frac{5 \text{ kg ms}^{-1}}{2 \text{ kg}}$

$= -2.5 \text{ ms}^{-1}$

Here, the velocity of the gun is negative, i.e. the gun will move backward.

Ans: backward velocity=2.5 ms^{-1}

Here,

mass of the bullet, $m_1 = 10$ g

$= 10 \times 10^{-3}$ kg

$= 10^{-2}$ kg

mass of the gun, $m_2 = 2$ kg

initial velocity of the bullet, $u_1 = 0$ ms^{-1}

initial velocity of the gun, $u_2 = 0$ ms^{-1}

final velocity of the bullet, $v_1 = 500$ ms^{-1}

final velocity of the gun, v_2 =?

3.8 Safe journey: force and motion

To control the speed of car is an important issue for a safe journey. We travel in a car to meet the necessity of our daily lives. We use different vehicles during the journey. Sometimes in bus or train or we use personal vehicles. The speed of a vehicle and force is inseparably related to each other during the journey in such vehicles. The speed of a car plays a vital role for a safe journey. The speed or velocity would not be such that which is not controllable. To travel in a distant destination, it is necessary to know about the road condition and environment.

The driver has to check the car well before start journey. As an example, whether the tyre or brake is perfectly right or not. He has to ensure whether the engine, used battery, front and rear lamps, wiper, and signal lights of two sides are right and properly working. In addition, he has to properly adjust the mirrors used in the car.

At first the driver and the passengers will wear the seat belt during driving time. It is observed that most of the road accidents occur due to very fast driving. So, the driver must be cautious to control the speed of the car. The kinetic energy becomes more due to increased speed. For example- if the velocity of the car is doubled, its kinetic energy is increased by four times in comparison to that of the earlier value. If the velocity is increased by three times, kinetic energy is increased by nine times. Then it becomes difficult to reduce or to control the velocity and the accident becomes terrible.

Drivers are advised to choose a vehicle which they are used to driving earlier. It is not wise to try to drive a new vehicle suddenly. It is observed that the youth try to drive a new car emotionally. It's not proper at all. Slow down the vehicle's speed when you meet other vehicles from opposite direction. To obey the traffic sign and traffic law is the citizen responsibility of the vehicle driver. The driver should concentrate on driving absolutely during driving.

3.9 Friction and force of friction

We are familiar with friction in various ways in our daily lives. From Newton's first law of motion we know that if no force acts on a body the body will continue in its state of rest or of uniform motion in a straight line. Does it actually happen in reality? Take a marble and roll it on the floor. When you roll the marble, you apply a force on it. As a result, the marble becomes mobile on the ground. According to Newton's law the marble should remain in uniform velocity. In practice, it is seen that the marble comes to rest after traversing a small distance. This happens due to the friction of the floor. When the marble is in motion on the floor, a frictional force is developed due to the mutual friction between the marble and the floor. This force acts in the direction opposite to the motion and hinders the motion. If the friction of the floor was absent, then the marble would continue its perpetual motion with uniform velocity.

When a body moves or tends to move over another body, then a resistance is developed between the two surfaces in contact, which is known as friction. This resistive force is called frictional force.

The frictional force always acts opposite to the motion and obstructs the motion.

Origin of friction

Whenever the surface of an object slides over the surface of another object, each object exerts a frictional force on the other. The question arises- why friction occur? Friction is the result of the surface irregularities of any two surfaces. Each object has a surface. Again, the surface may be smooth or rough. Apparently, the surface of an object seems to be smooth, but it is observed that there are high and low grooves on it when viewed by a microscope [Figure 3.8]. When an object moves on another object, then the grooves of the two surfaces in contact catch onto one another. As a result of which the motion of one surface over another surface gets obstacled.

As the grooves of a surface deepend and their number increases i.e. as the surface become rougher, the motion of one surface over another becomes more obstructed. Then the magnitude of frictional force also increases. The body becomes mobile if it can overcome the resistance of the surface in contact. The frictional force causes the object to slow down and stop thereby.

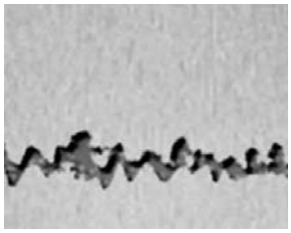

Figure: 3.8

Types of friction

Generally there are four types of friction.

1. Static friction
2. Sliding friction
3. Rolling friction
4. Fluid friction

Static friction

Static friction is the friction between two surfaces that aren't moving relatively to each other.

When a force is applied to an object, but it does not cause it to move, then static friction works. When a massive body on a floor is pulled by a force but it does not move, then the frictional force created is called force of static friction. The static frictional force is developed opposite to the applied force and acts until motion is produced.

When two bodies at rest are in contact with one another and one body is made to move on the other body, the friction produced between them until a relative motion is created is called static friction.

Sliding friction

Sliding friction is friction where an object slides, or rubs against, another surface.

We fall down and traverse a small distance when we move in a slippery road. When a hard brake is applied on a car moving fast, the car does not stop rather cross a small distance by sliding.

Rolling friction

Rolling friction is friction between a rolling object and the surface that it is rolling on.

The wheel's motion of a cycle, motion of marble is example of rolling friction. During travelling we use luggage carrier having wheels to carry goods. If there was no wheel in the luggage carrier then it was too difficult to pull it by sliding from one place to another. Due to the attachment of wheel it becomes easier to pull it i.e. the force of rolling friction is less than that of the static friction.

Fluid friction

When an object moves in a fluid i.e. a liquid or gas, the friction acts is called fluid friction.

We have to overcome a barrier in water while swimming in the pond. This barrier is the fluid friction. A parachute works by harnessing the air resistance. The air resistance is a type of frictional force which works against the force of gravity of the earth. As an open parachute has a large surface area, it helps provide enough air resistance. As a result, the sky-diver's falling speed is decreased mostly. So, the skydiver will then be able to descend slowly and safely.

3.10 Effects of friction on motion

Friction has enormous influence on the motion of an object. Friction is a kind of resistive force which slows down the motion of a body. Though friction creates many problems in our daily lives, it plays a vital role for movement and vehicle operaration. In this section we shall discuss about tyre's surface, smoothness of road and role of friction for controlling motion.

Figure: 3.9

Tyre's surface

Driving vehicles is possible because of the friction between the tyres and the road surface. The friction force between the tyres and the road depends on condition of the tyres and surface of the road. It also depends on the weight of the vehicle. The tyre's rubber surface is designed with treads i.e. grooves or teeth. The tyre surface is up and down due to these grooves. If the tyre is new, these grooves are distinct; as a result the force of friction between the tyre and the road is maximum. When the tyre becomes old,

their grooves are worn out and the surface becomes flat. As a result the frictional force between the tyre and the road decreased mostly. Say, what inconvenience may arise due to this.

Smoothness of road

The smoothness of road has a great impact on the motion of a body. When the road is smooth, movement of vehicles on the road becomes easier and the journey becomes comfortable. As the road becomes smoother, the resistive force of friction becomes lesser. The magnitude of the frictional force between the car's tyre and the road depends on the smoothness of the tyre as well as on the smoothness of the road. Many types of problems arise when amount of the frictional force is decreased largely. So, the road should not be too smooth. If the road is too smooth, it is not possible to stop the car within a certain distance in spite of applying brake. The friction is important for the motion of a car. If the road is too smooth, the necessary reaction force is not produced. The amount of the frictional force is largely reduced when the road is too smooth, as a result the car will not be able to move forward. So, the smoothness of the road will be such that it can supply the necessary frictional force.

Controlling motion and braking force

The speed of the vehicle has to increase or decrease according to the necessity at the time of vehicle movement. That is, we have to control the motion of a vehicle.

Brake is such an arrangement, which controls the speed of the car or rotation of the wheels according to the necessity by increasing the friction. With this it is possible to halt a vehicle in a certain place. When the driver applies the brakes, the shoe or pad made of asbestos press the metallic disc on the wheel. The friction between the pad and disc slows down the wheel's speed. As a result, the velocity of a car decreases.

3.11 Increasing and decreasing friction

Friction is inextricably related to our daily lives. Friction can be increased in necessity; again friction can be decreased too in necessity. How friction can be decrease and increase would be discussed in this section.

Reducing friction

Smoothing the surface

Friction makes many troubles to displace one body from one place to another. Let, you want to displace a massive box on the floor. If the friction of the contact surface is large enough, then it takes a lot of labor to displace it. By polishing or smoothing the surface it can be decreased.

Using wheels

There are wheels in bus, truck and many types of machinery. The wheel is an ingenious invention. Its circular shape reduces friction to a minimum. Without wheel was it possible to use this machinery? Using wheel in a suitcase reduces the friction and it becomes easier to pull it. The value of the rolling friction in comparison to the sliding friction is reduced greatly due to the attachment of wheels.

Using lubricants

Oil, mobil and grease like materials are called lubricants or greasy materials in short. A layer of lubricant between the two surfaces can greatly reduce the friction. So, lubricants are used between the moving parts of an engine. In addition, we use oil in sewing machine, lock and hinges.

Using ball bearings

Another important invention similar to the wheel is the invention of ball bearing. It was possible to reduce the friction greatly between the surfaces by using ball bearing. Ball bearings are the small, smooth metal balls. Generally these are made of steel. Ball bearings are placed between the moving parts of a machine. They roll around so that the moving parts of the machine do not rub against each other directly. That is, the surfaces roll over one another instead of sliding and friction reduces. There are uses of ball bearing in car's wheel, cycle and electric fan [Figure 3.10].

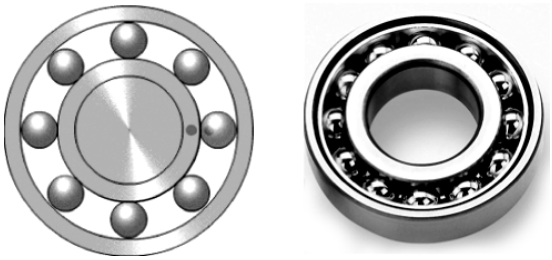

Figure 3.10

Increasing friction

Driving cars

Without friction in the road, the tyres of a car will just spin around at the same spot. Possibly you have seen how truck and bus is blocked in a slippery or muddy road in the rainy days. What is the reason behind this? This is due to the large decrease in friction. So friction is to be increased according to the necessity. The car tyres are so designed that they are able to grip the road properly and create necessary frictional force. Therefore the surface of the tyres are designed with treads i.e. grooves and teeth. In the rainy days, the water or mud enters the grooves and water and mud are thrown outside boldly. As a result, the tyres are able to grip the road surface well.

i.e. friction can be increased by making the surface rough.

Mountain climbing

Mountain climbers need to grip the rock or mountain surface with their hands and feet, in order to climb a mountain. They use chalk powder to grip the rock.

There are spikes under the boot of players so that they do not fall down while running.

3.12 Friction: a necessary evil

Though friction has many disadvantages it is considered as a necessary evil. What causes it? We cannot do anything without the force of friction. If there was no friction, the motion of a body would not cease at all and continue perpetually. Due to friction, a nail is fixed in a wall. It became possible to construct buildings and houses because of friction. Friction has made it possible to write on a paper with a pencil or a pen. We can walk as there is a friction between our shoes and the ground. We can change the direction of motion of a car owing to friction. Using a parachute it is possible to descend safely to the ground by harnessing the air resistance. In spite of having so many advantages we have to suffer a lot for friction. Because of excess friction the vehicles cannot move easily. Any device that has moving parts can wear out and tear due to friction. In any type of vehicles- may be car, boat or airplane, extra fuel has to be spent to overcome the excess friction. Fuel energy is being wasted because of friction.

The energy that is wasted for friction mainly appears as heat energy. Not only that energy is converted to heat due to friction, but also the parts of an engine may be overheated. As a result of friction, the soles of your shoes wear and tear out. So to make the life and works easier we need friction but excess friction is the cause of many losses too. Therefore to produce the necessary friction, we have to control it. Sometimes we need to increase or decrease friction by some processes. Therefore, we cannot discard friction totally; also friction is beneficial to us in many cases. For this reason friction is called a necessary evil.

Preparing report

Present a report to your teacher about the positive impact of friction in our life in the light of section 3.9 to 3.12.

Teacher will select the best report and tell the student to present in the class room.

Investigation 3.1: Measurement of force acting on a body

Objective: To measure force by simple experiment

Formula: We know, if a force *F* acts on a body of mass *m* and the resulting acceleration due to the force is *a,* then $F=ma$. The acceleration a of the body can be expressed by g in case of force due to gravity. That is, the force of gravity or weight of the body, $W = mg$. We shall measure weight of a body as an example of force.