FRICTION

We have learnt about the various types of forces in the chapter 'Force'. We also have learnt about the 'force of friction' which plays an important role in daily life. Let us learn in detail about this force in this chapter.

Force of friction and its Types

Activity -1

Identifying forces acting on a body and effect of frictional force

Fig-1: Pushing the book

Gently push a book on a horizontal floor as shown in fig.1.

What do you observe?

You may observe that the book acquires a certain speed in the direction of push. However, the speed of the book gradually decreases and after some time it stops.

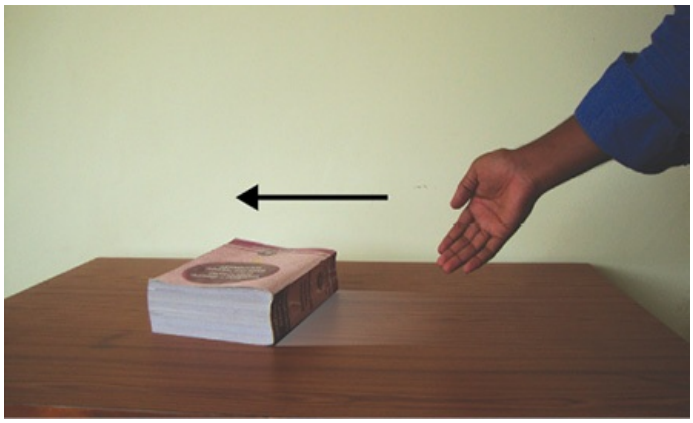


Fig-2 : The book acquires a speed

↳ Why does the book stop after covering some distance?

↳ Is the book moving with uniform speed?

↳ Why does the speed of the book change gradually?

You know that the book is in non-uniform motion with respect to the floor. In the "Force" chapter we studied that non-uniform motion of a body takes place only when a net force acts on it.

↳ How many forces act on the book when it is pushed on the floor?

Let us examine the forces acting on the book. Two forces act on the book in the vertical direction as shown in fig-3.

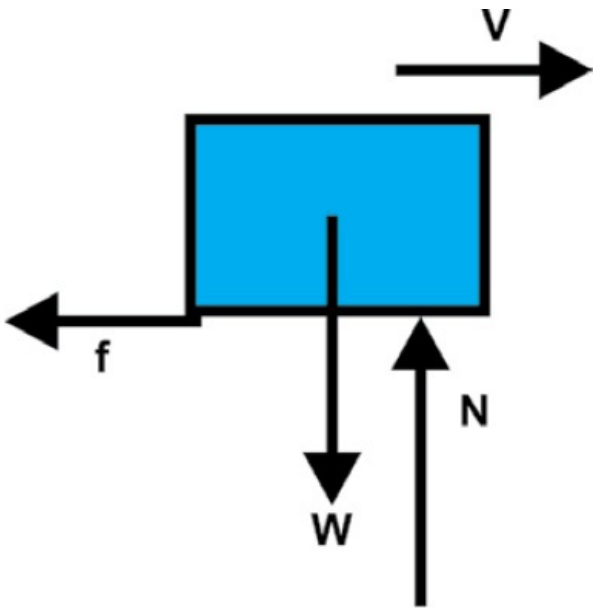


Fig-3: Forces acting on the book

They are

(i) Weight of the book (W) or gravitational force acting vertically down.

(ii) Normal force (N) or reaction force applied by the floor vertically up.

As there is no change in motion of the book along the vertical direction, the net force acting on the book in the vertical direction is zero.

That is, $W - N = 0 \Rightarrow W = N$

In the horizontal direction, the speed of the book is changing continuously. Its speed is decreasing gradually in the horizontal direction i.e., the book has acceleration opposite to the direction of motion (which we call deceleration).

↳ What are the forces acting on the book in the horizontal direction?

↳ What is the net force acting in the horizontal direction?

When the speed of the body moving in a straight line changes continuously, we say that the body has acquired an acceleration.

By close observation of this activity, we can understand that the floor applies a force on the book against its motion. Similarly the book also applies the same amount of force on the floor in the opposite direction. Here it is clear that the floor is at rest. Hence the net force acts in the direction of the force applied by the floor on the book.

The force applied by the floor on the book is called **“frictional force” or friction.**

Lab Activity

Aim: Understanding the nature of friction and the concept of static friction.

Material required: Toy Trolley, small wooden block, inextensible string, weight hanger, weights, pulley and table.

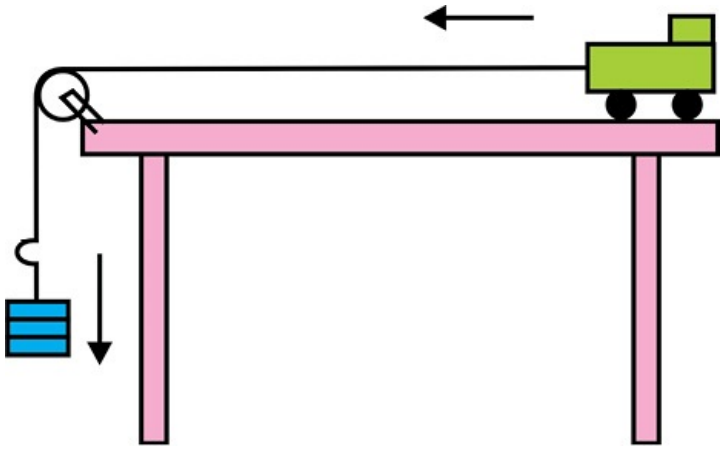


Fig-4:The trolley accelerating towards left

Procedure: Take a small toy trolley and keep a small wooden block on it as shown in fig-4. Tie an inextensible string to the trolley and pass it over a pulley. And other end of the string is fixed to weight hanger. Take a small weight and keep it on weight hanger and observe the changes in motions of block and trolley.

- What happens to the position of the block kept on the trolley?
- Does it fall or move along with the trolley?
- What changes occur in the motion of trolley and block?

You will notice that the trolley with the block on it moves towards left with an acceleration. The block is at rest with respect to the surface of the trolley, but it is in motion with respect to the surface of the table.

Now keep on increasing the weight on the hanger. Observe the motions of both trolley and block.

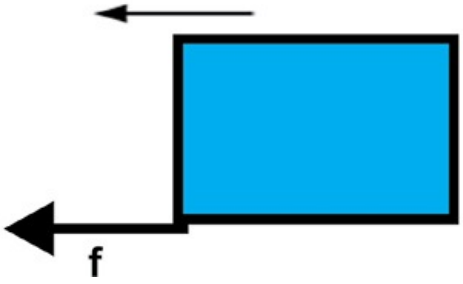


Fig-5: The direction of friction on the block.

The surface of the trolley tries to keep the block at rest here with respect to its surface.

Thus, the force of friction by the surface of the trolley acts on the block in the direction of motion. At the same time the block also applies a force on the trolley in opposite direction and tries to move towards the right.

We can increase the trolley's acceleration by increasing the weight on the hanger. If we increase the

acceleration of trolley gradually, at certain limiting acceleration or limiting weight, the block comes into motion in the reverse direction. This means that now there exists relative motion between the surface of the trolley and the block.

- What happens when the experiment is repeated by using rock and iron blocks of the same mass and different masses?
- Does the limiting weight change? If so, why?

Apply some grease to the bottom of the wooden block and keep it on the trolley's surface and do the same experiment.

- What happens to the limiting weight?
- What should we do to increase the limiting weight?

From the above activities we may define friction as follows,

The force which opposes the relative motion of two surfaces of bodies in contact, is called 'frictional force'.

In activity-1, the book moves with respect to the floor. So, this friction is called sliding friction.

Sliding friction is the friction which comes into play when the surface of one object moves relative to the surface of another object.

In lab activity, the block is at rest relative to the surface of the trolley up to a certain limiting acceleration. The friction exists at this stage is a static friction.

*So, **static friction** is the friction which comes into play when surfaces of the objects are at rest relative to each other.*

In the above activity we observe that there exists two types of frictional force at a time. One is sliding friction between surface of the table and trolley, and the other is the static friction that exists between the surface of trolley and wooden block kept on it.

Activity-2

Observing the variation of friction

Push a heavy box which is kept on a floor with a small force to move horizontally as shown in fig-6. The box does not move because there is a frictional force which is equal and opposite to the applied force on the box.

Fig-6: Pushing a heavy box with small force

Now gradually increase the applied force, the box still does not move, because the frictional force also increases accordingly and thus balances the increased applied force.

From this experience we conclude that static friction is a self adjusting force

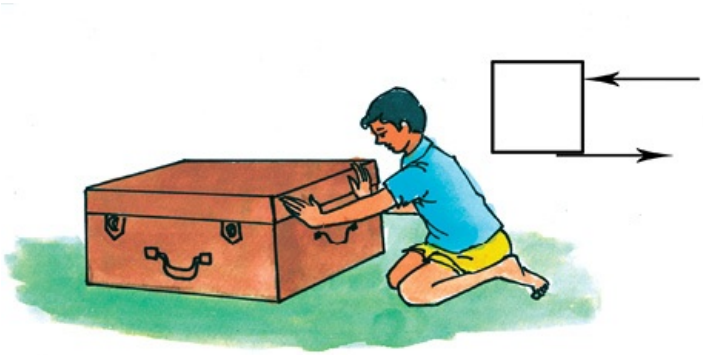


Fig-7 : Pushing a heavy box with increasing force.

But there is a limit to this static friction. As you keep on increasing the applied force, at some point the box starts moving. That is, when the applied force is more than the limit of the static friction, the body starts to move as shown in fig-8.

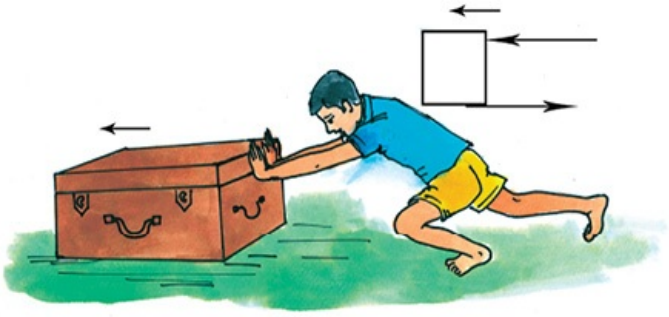


Fig-8: The heavy box starts moving

Think and Discuss

- Does friction oppose motion or relative motion of surfaces in contact? Disscuss.
- What observations and experiments can you cite to show the existence of friction?
- When do we speak of sliding friction?

Factors affecting friciton

Activity-3

Effect of roughness on frictional force

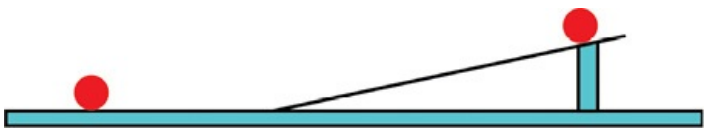


Fig-9: Motion of a Ball on an inclined plane.

Set up an inclined plane on the horizontal floor. Use a wooden board as inclined plane. Put a mark at any point "A" on the inclined plane. Now let a pencil cell or ball move down from this point. Note the distance covered by the pencil cell from the bottom of the inclined plane to point where it comes to a stop.

Now, spread a cloth over the floor. Make sure that there are no wrinkles in the cloth. Try again with pencil cell. Now note down the distance.

- What are your observations from these experiments?

- In which case is the distance covered maximum?
- In which case is the distance covered minimum?
- Why is the distance covered by the pencil cell different on different surfaces? Discuss the result.

If you do the above activity by replacing the cloth with white marble surface or glass surface, can you predict the distance covered by the pencil cell?

You can conclude that smoothness / roughness of the surfaces of both the floor and the pencil cell could affect the distance travelled by it.

Though many surfaces look like perfect planes, there exists many ups and downs (irregularities of surface) on them.

See Fig-10.

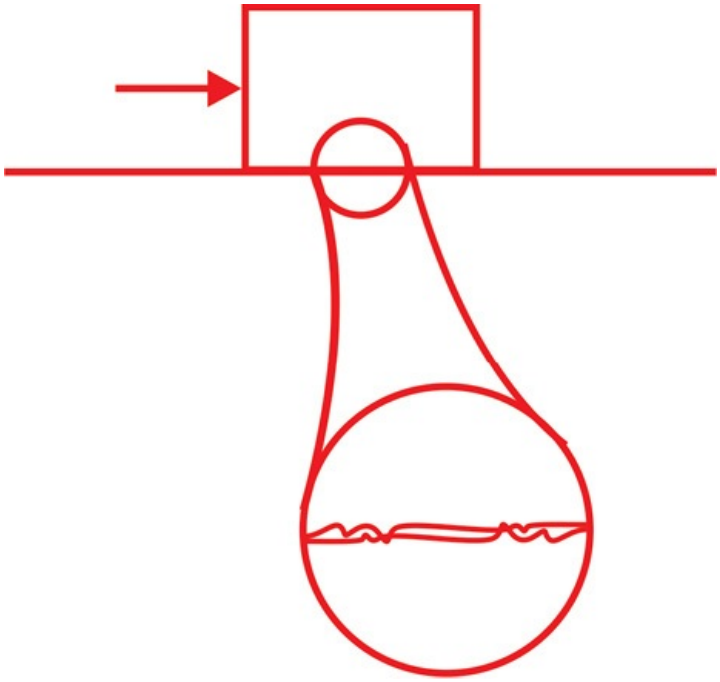


Fig-10: Irregularities of two surfaces in contact

Friction is caused by the irregularities on the two surfaces which are in contact. Irregularities on the two surfaces lock into one another, when we attempt to move on any surface. We have to apply a force to overcome interlocking. On rough surfaces, there exist a large number of irregularities (ups and downs). Hence, the force of friction is greater if a rough surface is involved.

Activity-4

Effect of area of contact on frictional force

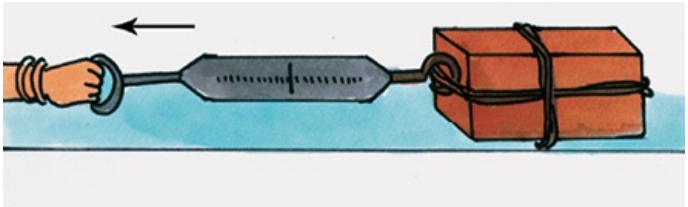


Fig -11: Pulling a brick with spring balance

Tie a string around a brick and pull the brick by using a spring balance as shown in fig-11. We use spring balance as a device to measure the applied force.

In a spring balance the spring is stretched by the applied force. The change in the length of the spring is proportional to the applied force. So the scale of the spring balance directly gives the applied force in Newtons and in some spring balances the force is given in kilogram-weight also.

Pull it to move the brick. Note down the reading of spring balance when the brick just begins to move.

⇝ How many forces act on the brick in the horizontal direction?

Two forces act on the brick in the horizontal direction as shown in fig-12 .

Fig-12: Horizontal forces on the brick

One is force of friction (f) and the other is the force applied (F) by you. The applied force is equal to the maximum limit of the frictional force at the instant when the brick just begins to move. But they act in opposit direction. You can note down its value by observing the reading of the spring balance. In this way we can measure the maximum frictional force offered by the surface.

Now turn the brick upright as shown in fig-13 so that the contact area with the floor becomes small. Repeat the same experiment and measure the friction using the spring balance.

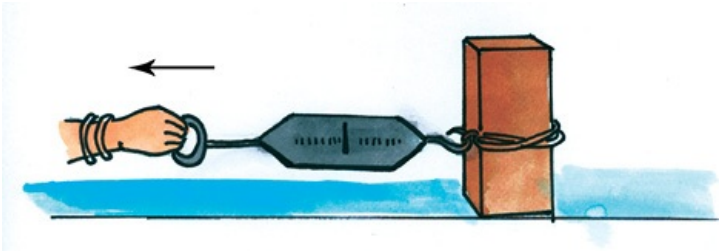


Fig-13: Pulling same brick with another orientation

⇝ How does the frictional force vary with the change in the area of contact?

The frictional force appears to be the same in both cases irrespective of area of contact of the surfaces. So, the frictional force is independent of the area of contact.

Activity-5

Effect of normal force on friction

As in the activity-4, keep a brick on the horizontal floor and pull it with the spring balance attached to it and measure the frictional force.

Now put another brick over the brick tied to the spring balance or press it vertically with your hand and then measure the force of friction as described above.

⇝ Is there any difference between frictional forces in two cases? If yes, why?

From the above activity you can understand that when we add a brick to the existing brick or apply a force by pressing it vertically, the normal force increases and hence, we find there is an increase in the frictional force.

So, Friction is proportional to the Normal force i.e.,

Friction $\propto$ Normal Force

where $\propto$ the symbol is representing “proportional to”.

Think and Discuss

- Does friction act on a table resting on the floor?
- If normal force is doubled, what happens to friction? Discuss.
- Your friend says, "Friction depends on the area of contact". How do you correct your friend through some experiments?
- "Friction is independent of weight, but depends on normal force between surfaces of contact where friction exists". Do you agree with this statement? Discuss.

Is friction necessary?

Try to walk on muddy or slippery surface. Why do you find it difficult to walk on slippery surfaces?

We cannot walk or run without friction. Let us see the things that will not happen in the world if friction were not present. We will not have any cars, bicycles or scooters. All of them move only because of friction.

Even if somebody pushes a car, we will not be able to stop it by applying brakes. Carpenters will not be able to smoothen surfaces. You will not be able to hold any appliances such as hammer, soap etc.

It will not possible to write with pen or pencil if there is no friction. You would not be able to fix a nail on the wall. No building could be constructed if there were no friction.

All the above examples tells the importance of friction.

On the other hand friction is undesirable too in the machinery. For instance, friction is responsible for overheating and wearing out of moving parts. You need to apply oil or grease to your bicycle parts in order to make it move smoothly.

Make a list of few more examples of the situations where we need to reduce friction for efficient functioning of tools.

Activity-6

Friction produces heat

Fig-14: Rubbing the hands

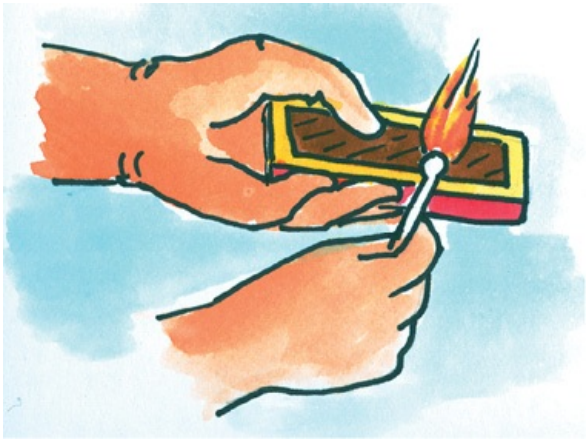


Fig-15: Striking a matchstick against the surface of matchbox

- Rub your palms against each other for a few minutes. How do you feel?
- Strike a match stick against the rough surface of match box. What happens?

In both the activities we observe because of the friction, temperature of the surfaces increases. Matchstick catches fire because of increase in temperature by friction.

Thus, we can conclude that friction can produce heat.

Give some more examples where friction produces heat.

You have probably heard that space craft returning to the earth has to be protected by a heat shield covering it. Find out why? What is the material used as the heat shield?

Think and Discuss

- What important role does friction play in the life of human being and animals?
- Why is friction important for transport?

Increasing and decreasing friction

Activity-7

How to reduce friction ?

Take a spoon and hold its head (broader portion) in the left hand and hold the mid portion of the spoon by the right hand and pull it towards the other end of the spoon.

- What do you notice?

Now dip your right hand fingers in water, do it again as said above.

- In which case it is easy to pull? Why?

Repeat the activity with other liquids such as coconut oil, grease etc and observe the difference.

Friction can be advantageous in some cases and disadvantageous in other cases. In the former case of activity 7 you will find that the friction is more, in the latter case, friction is reduced.

Let us try some examples.

Fig-16: Bottom of the shoe

⇝ Have you ever thought why the sole of your shoes is grooved as shown in fig-16?

It is done to provide the shoes better grip on the floor, so that you can move safely. Similarly, the tires of cars, trucks and bulldozers are threaded (fig-17). Why?

⇝ Why do you need to change the tyres when it's threading is worn out?

Fig-17: Pattern of tyre

Gymnasts apply some coarse substance on their hands to increase friction for better grip.

In some situations, however, friction is undesirable and we would like to minimize it.

Fig-18: The carom board

Play carom board without powder and then play with fine powder sprinkled on the board.

⇝ In which case is the movement of the striker and the coins easy? Why?

⇝ Why do we pour a few drops of oil on the hinges of a door?

⇢ Why do we use grease between the moving parts of motor vehicles?

In all the above cases, we want to reduce friction in order to increase efficiency.

When oil, grease or any other lubricants are applied between the moving parts of a machine, a thin layer is formed between the moving surfaces and hence they do not directly rub against each other. Interlocking of irregularities is avoided to a great extent by the application of lubricants. Hence movement becomes smooth.

The substances which reduce friction are called “Lubricants”

Activity -8

Effect of rollers on friction

Fig-19: Pulling suitcase with rollers

Pull a suitcase without rollers and pull a suit case which has rollers.

⇢ In which case is pulling easy? Why?

Fig-20: Pushing a book on pencils

Try to push a book lying on the table. Now place the book on two to three pencils or pens without caps. Push the book again.

⇢ What do you notice? Why?

⇢ In which case is it easy to pull the book? Why?

It is always easier to roll a body than to slide it over a surface. So it is convenient to pull the luggage fitted with rollers.

When one body rolls over the surface of another body, the friction offered is called **rolling friction.**

Activity-9

Understanding the principle of ball bearings

Fig-21: Rotating the lids

Take two lids and rotate them by putting one on the top of the other. What do you observe? Now place four to five marbles on one lid and place the other lid on the top of the marbles. Then try to rotate the top lid. What do you observe?

This is the principle of ball bearings.

To reduce friction between rotating shafts of machine tools, we use “ball bearings”.

Think and Discuss

- Can we reduce friction to zero? Explain.
- What purposes are served by bearings in machines? Explain with daily life situations.

Fluid friction

Activity -10

Observing fluid friction

Fig-22: Stirring water

Take a glass of water and stir it with a spoon. You know that water whirls around an axis. Stop stirring and see what happens. You may notice that whirling speed of water gradually decreases and after some time, the water stops whirling and comes to a stable state.

- Which force is responsible for stopping the rotation of the water?

The frictional forces between the liquid layers and between the liquid surfaces that is in contact with glass surface are responsible for stopping the rotation of the water.

Similarly water and other liquids exert force of friction when objects move through them. You can observe fluid friction when you travel in a boat.

Not only liquids, gasses and air also offer friction to bodies like aeroplanes, jets when they move through air.

In science the common name for gases and liquids is 'fluids'. So, we can say that fluids exert force of friction on objects in motion through them.

The frictional force exerted by fluids is also called "drag".

Activity-11

Identifying factors influencing the fluid friction

Take a tub of water. Try to move your hand in water in the direction of stretched fingers (up and down).Now try to move your hand in the direction perpendicular to the plane of the hand (to and fro).

- In which orientation of your hand, do you experience more drag? Why?

Frictional force on an object in a fluid depends on its speed with respect to fluid, on the shape of the object and on the nature of the fluid.

Fig-23: Bird and Aeroplane

It is obvious that when objects move through fluids, they have to overcome friction acting on them. So efforts are made to minimize friction. Objects are given special shapes. Where do you think scientists get hints for these special shapes? From nature, of course.

Birds and fishes have to move about in fluids all the time. Their bodies must have evolved to shapes which would make them not to lose much energy in overcoming friction.

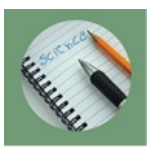
Do you find any similarity in the shape of an aeroplane and a bird? In fact all vehicles are designed to have shapes which reduce fluid friction.

Key words

Friction, Static Friction, Sliding friction, Lubricants,Ball bearings, Drag, Fluid Friction.

What we have learnt

- Friction opposes the relative motion between two surfaces in contact. It acts on both the surfaces.
- Static friction comes into play when we try to move an object at rest relative to another surface or object.
- Sliding friction comes into play when an object is sliding over another.
- Friction depends on the nature of surface and the normal force with which the body presses the other surface.
- Friction is independent of area of contact.
- Friction can be reduced by using lubricants and ball bearings in many machines.
- When bodies move through fluids, fluids exert a frictional force called drag.



Improve your learning

1. Do you agree with the statement, "friction is both good and an evil"? Explain with examples. (AS_1)
2. Explain why sportsmen use shoes with spikes? (AS_1)

3. Would it be easier or more difficult for you to walk on soapy water on the marble floor? Why? (AS_1)
4. What ways do you suggest to reduce friction? (AS_1)
5. What conditions are needed for static friction to come into play? (AS_1)
6. Give examples of practical application of static friction. (AS_1)
7. Give examples showing the existence of sliding friction. (AS_1)
8. Explain how can you measure frictional force? (AS_1)
9. Explain how does lubrication reduces friction? (AS_1)
10. What kinds of friction do you know? (AS_1)
11. Explain why sliding friction is less than static friction? (AS_1)
12. Give examples of how is friction responsible for energy wastages? Give suggestions to reduce energy wastages by friction. (AS_1)
13. Seetha is observing a moving bus with the luggage on its top. As the bus is moving slowly there is change in the state of luggage on its top. But when the bus speeds up and starts moving fast, she noticed that the luggage on the top of the bus fell to the back of the bus. This raised many doubts in her mind regarding the effect of frictional force acting on the luggage as well as on the tyres of the bus. Can you guess the questions raised in her mind? Write them. (AS_2)
14. Collect information either from internet or from books in library, about various new techniques being adopted by human beings to reduce energy losses due to friction. Prepare a note on that. (AS_4)
15. Draw a free body diagram (FBD) to show various forces acting on a body which is sliding on an inclined plane. (AS_5)
16. “Reducing friction to the lowest possible level in machine tools solves the problem of energy crisis and conserve biodiversity”. How do you support the statement? Explain? (AS_7)