UNIT 2

FORCE AND PRESSURE

Learning Objectives

QKB4NM

After the completion of this lesson, students will be able to:

- understand the concept of force and its effects.
- differentiate thrust and pressure.
- understand the characteristics of atmospheric and liquid pressure.
- apply pascal's law in day to day life.
- understand the applications of surface tension and viscosity.
- analyse friction in rest and motion.
- know about the ways of increasing and decreasing friction.
- solve numerical problems related to force and pressure.

Introduction

We see many objects in our daily life. Some of them are moving and some of them are at rest. A ball at rest, moves when it is kicked. Similarly when we push or pull objects which are at rest, they begin to move. This push or pull is called force. A force acting in a particular area, produces pressure. For example when we fasten a nail on the wall, pressure is exerted. Not only solids, gases and liquids also exert pressure. Pressure exerted by liquids and gases finds application in different fields. Hydraulic lift and hydraulic break are working due to liquid pressure. In this lesson you will study about force and pressure. You will also study about surface tension viscosity and friction.

2.1 Force

We do so many activities in our daily life like, opening a door, kicking a football, striking a carrom coin etc., To do these activities an external agency is needed. This external agency is called force. Force can either set an object at rest into motion or bring a moving object to rest. It can even change the shape and size of certain objects.

Force is defined as an external agency which changes or tends to change the state of rest or the state of uniform motion of a body or the direction of a moving body or the shape of a body. Force is a vector quantity, which has magnitude and direction. It is measured by a unit called 'newton' (N).

2.1.1 Effects of Force

Observe the strokes a batsman in cricket game. If he wants to hit the cricket ball to the boundary, the striking force on the ball must be greater. So, the greater the force you apply on a body, greater will be its effect on it.

Activity 1

Fix a matrix of sharp pins on a wooden board in rows and columns. Take a big blown up balloon. Place it gently over the pins and place a small book on the top of the balloon. Will the balloon burst? Will the pins prick the balloon?

If you prick a blown up balloon with a single pin it will burst. But, this did not happen even though many more pins were pricking the balloon. A single pin produces a large pressure over a small area. But, when large number of pins prick a body, each pin exerts very little pressure on the balloon, as the applied force gets distributed over a large surface of the body. So, the balloon will not burst.

Thus, we can conclude that the effect of a force depends on the magnitude of the force and the area over which it acts. The force acting perpendicularly on any given surface area of a body is known as thrust. It is measured by the unit newton.

2.2 Pressure

The effect of force can be measured using a physical quantity called pressure. It can be defined as the amount of force or thrust acting perpendicularly on a surface of area of one square meter of a body.

$$\text{Pressure} = \frac{\text{Thrust (or) Force}}{\text{Area}} \quad \text{ie., } P = \frac{F}{A}$$

The SI unit of pressure is pascal (named after the French scientist Blaise Pascal).

1 pascal = 1 Nm^{-2}

Pressure exerted by a force depends on the magnitude of the force and the area of contact.

Problem 1

The average weight of an elephant is 4000 N. The surface area of the sole of its foot is 0.1m^2. Calculate the pressure exerted by one foot of an elephant.

Solution

Average weight of the elephant = 4000 N

Weight of one leg = Force exerted by one leg
= 4000/4 = 1000 N

Area of the sole of one foot = 0.1 m^2

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{1000}{0.1} = 10000 \ \frac{N}{m^2} = 10^4 \ Nm^{-2}$$

Pressure exerted by one leg of the elephant is 10,000 newton on one square metre.

The effect of pressure can be increased by increasing the thrust or by decreasing the surface area of the body. The axe, nail, knife, injection needle, bullet etc., are having sharp fine edges so as to exert a larger pressure on a smaller area of the body in order to produce maximum effect.

Examples

1. More number of wheels are provided for a heavy goods-carrier for decreasing the pressure thereby increasing the area of contact on the road.
2. Broader straps are provided on a back-pack for giving less pressure on the shoulders by providing a larger area of contact with the shoulder.

Figure 2.1 Bags with broader straps

DO YOU KNOW?

It is very difficult for us to walk on sand. But, camels can walk easily on it because they have large padded feet, which increase the area of contact with the sandy ground. This reduces the pressure and enables them to walk easily on the sand.

2.3 Pressure exerted by Air

You all know very well that air fills the space around us. This envelope of air is called as atmosphere. It extends upto many kilometres above the surface of the Earth. All objects on the surface of the Earth experience the thrust or force due to this atmosphere.

The amount of force or weight of the atmospheric air that acts downward on unit surface area of the surface of the Earth is known as **atmospheric pressure**. It can be measured using the device called **barometer**. The barometer was invented by **Torricelli**.

Atmospheric pressure decreases with altitude from the surface of the Earth. It can be measured by the height of the mercury column in a barometer. The height of the mercury column denotes the atmospheric pressure at that place at a given time in 'millimetre of mercury'. Even if you tilt the tube at various angles, you will see that the level of mercury will not vary. At sea level, the height of the mercury column is around 76 cm or 760 mm. The pressure exerted by this mercury column is considered as the pressure of magnitude 'one atmosphere' (1 atm).

One atmospheric pressure (1 atm) is defined as the pressure exerted by the mercury column of height 76 cm in the barometer. It is equal to $1.01 \times 10^5 Nm^{-2}$.

In the SI system 1 atm = 1,00,000 pascal (approximately). SI unit of atmospheric pressure is Nm^{-2} or pascal.

More to know

Cooking in a place located at a higher altitude is difficult. Why? At a higher altitude, due to lack of atmospheric pressure the boiling point of a substance reduces. So, water boils even at 80°C. The thermal energy that is produced at this temperature is not sufficient enough for baking or cooking. So, cooking is difficult at higher altitude.

Activity 2

Take a conical flask and a well boiled egg, after removing its shell. Place the egg on the mouth of the flask. It will not enter the flask. Now take a piece of paper. Burn it and drop it inside the flask. Wait for a few seconds to burn fully. Now, keep the egg on the mouth of the flask. Wait for a few minutes. What do you observe?

When the paper is burning in the flask, the oxygen present in the air inside the conical flask is used up for its combustion. This reduces the pressure of the air in the flask. The air in the atmosphere tends to occupy the low pressure region in the flask. So, it rushes through the mouth of the flask, thus pushing the egg into the flask.

2.4 Force and Pressure in Liquids

You would have noticed that an upward force is exerted by water on a floating or a partly submerged body. This upward force is called **buoyant force**. This phenomenon is known as **buoyancy**. This force is not only exerted by liquids, but also by gases.

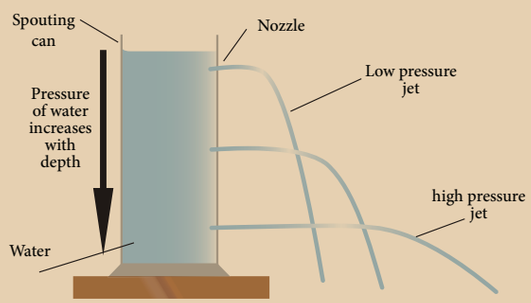
This upward force decides whether an object will sink or float. If the weight of the object is less than the upward force, then the object will float. If not, it will sink.

2.4.1 Pressure exerted by Liquids

Liquids exert a pressure not only on the base of the container/vessel in which they are kept, but also on the side walls. The pressure exerted by a liquid depends on the depth of the point of observation considered in it.

Activity 3

Take a plastic bottle. Punch three holes on its side in the same direction, but at different heights. Now pour some water into it and let it flow through the holes. Observe the flow of water. Water from the lowest hole comes out with the greatest force and the water from the topmost hole comes out with the least force.



This activity confirms that the pressure in a liquid varies with the depth of the point of observation in it.

Activity 4

Take a glass tube that is open at both ends. Fix a rubber balloon at the lower end of the tube. Pour some water into the tube and observe the balloon. Now, pour some more water into the balloon and again observe the balloon. The balloon starts bulging outwards.

This shows that the pressure exerted by a liquid at the bottom of a container depends on the height of the liquid column in it.

Activity 5

Take a plastic bottle. Punch three holes on its sides at the same height from its base. Now, pour some water into it and let it flow through the holes. Observe the flow of the water. Water comes out from all the holes with the same force and falls on the ground/ table, at the same distance from the bottle.

Thus, we can conclude that liquids exert the same pressure in all directions, at a given depth.

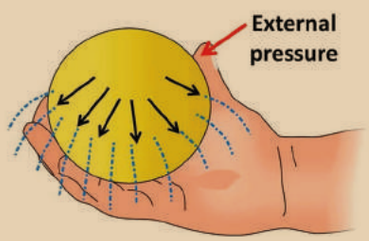
Why dams are made stronger and broader at the bottom than at the top?

Why do scuba divers wear a special suit while they go into deep sea levels?

2.4.2 Pascal's Law

Activity 6

Take a rubber ball and fill it with water. Make tiny holes on its surface with a pin at different points. Press anywhere on the ball. What do you observe?



You can see identical streams of water flowing in all directions from the holes. This is due to the fact that the pressure, which is applied on the liquid, is equally transmitted in all direction. This concept was first given by the French scientist Blasie Pascal.

Pascal's law states that the pressure applied at any point of a liquid at rest, in a closed system, will be distributed equally through all directions of the liquid.

Applications of Pascal's Law

The applications of Pascal's law are:

- In automobile service stations, the vehicles are lifted upward using the hydraulic lift which works as per Pascal's law.
- Automobile brake system works according to Pascal's law.
- The hydraulic press is used to compress the bundles of cotton or cloth so as to occupy less space.

2.5 Surface Tension

Activity 7

Take some water in a beaker and spread a tissue paper on the surface of the water. Gently place the paper clip on the tissue paper. Observe what happens to the paper pin after some time.

After a few moments the tissue paper will submerge and the paper clip will make a small depression on the surface of the water. It will instantly begin to float on the surface, even though it is denser than water.

How is it possible? This is because the water molecules on the surface which tend to contract themselves like the molecules of an elastic membrane. A force exists on them, which tends to minimize the surface area of water. The paper clip is balanced by the molecules on the water surface that is now behaving like a stretched elastic membrane. So, it does not submerge.

Have you ever wondered why rain drops are spherical in nature? How does the water rise upward in a tree or plant against the force of gravity? These are all due to surface tension.

Surface tension is the property of a liquid. The molecules of a liquid experience a force, which contracts the extent of their surface area as much as possible, so as to have the minimum value. The amount of force acting per unit length, on the surface of a liquid is defined as surface tension. Its unit is Nm^{-1}.

2.5.1 Applications of surface tension

Surface tension is the reason for many events we see in our daily life.

- In plants, water molecules rise up due to surface tension. Xylem tissues are very narrow vessels present in plants. Water molecules are absorbed by the roots and these vessels help the water to rise upward due to 'capillarity action', which is caused by the surface tension of water.
- During heavy storm, ships are damaged due surface tension of water. By pouring oil or soap powder into the sea, sailors reduce its impact.
- Water strider insect slides on the water surface easily due to the surface tension of water.

Figure 2.2 Water strider

2.6 Viscous Force or Viscosity

Activity 8

Take a small quantity of different kinds of liquid like coconut oil, honey, water and ghee etc., Place one drop of each liquid on a separate glass plate. Now gently raise one end of the glass plate, so as to allow the liquid to slide down the smooth surface of the plate. Observe the speed of each liquid.

Each liquid moves with a different speed. Water flows faster than other liquids. Coconut oil flows with a moderate speed. Ghee flows very slowly. Between the layers of the liquid, which is in motion, there is a frictional force parallel to the layers of the liquid. This frictional force opposes the motion of the liquid layers while they are in motion.

The frictional force acting between the successive layers of the liquid which acts in order to oppose the relative motion of the layer

is known as viscous force. Such a property of a liquid is called viscosity. Viscous force is measured by the unit called poise in CGS system and $kgm^{-1}s^{-1}$ or Nsm^{-2} in SI system.

2.7 Friction

We walk on roads without falling. But, we tend to fall when we walk on wet surfaces. Why? We walk on the roads safely because of the friction between the feet and the road. But, the friction is less when we walk on wet surface and so we tend to fall.

Frictional force or friction arises when two or more bodies in contact move or tend to move, relative to each other. It acts always in the opposite direction of the moving body. This force is produced due to the geometrical dissimilarities of the surface of the bodies, which are in relative motion. Friction can produce the following effects.

- Friction opposes motion.
- It causes wear and tear of the surfaces in contact.
- It produces heat.

2.7.1 Types of Friction

Friction can be classified into two basic types: static friction and kinetic friction.

Static friction

The friction experienced by the bodies, which are at rest is called static friction. Eg. All the objects are rigidly placed to be at rest on the earth.

Kinetic friction

Friction existing during the motion of bodies is called kinetic friction. Kinetic friction can be further classified into sliding friction and rolling friction.

When a body slides over the surface of another body, the friction acting between the surfaces in contact is called sliding friction. When a body rolls over another surface, the friction acting between the surfaces in contact is called rolling friction. Rolling friction is less than sliding friction. That is why wheels are provided in vehicles, trolleys, suitcases etc.

2.7.2 Factors affecting Friction

Some of the factors which affect friction are given below.

a. Nature of a surface

Moving an object on a rough surface will be difficult, but we can eassily move it on a smooth surface. It is because, friction varies between the surfaces.

b. Weight of the body

It is easy to pedal your cycle without any load on its carrier. With a load placed on its carrier, it is difficult to move it because the weight on the carrier increases the friction between the surface of the tyre and the road.

c. Area of contact

For a given weight, the friction is directly related to the area of contact between the two surfaces. If the area of contact is greater, then, the friction will be greater too.

A road roller has a broad base, so it offers more friction on the road. But, a cycle has the least friction, since the area of contact of the tyre with the surface of the road is less.

2.7.3 Advantages of Friction

Friction is necesary for our day to day activities. It is desirable in most of the situations of our daily life.

- We can hold objects in our hand due to friction.
- We can walk on the road because of friction. The friction between footwear and the ground help us to walk without slipping.
- Writing on the paper with a pen is easy due to friction.
- Automobiles can move safely due to friction between the tyres and the road. Brakes can be applied due to frictional resistance on brake shoes.
- We are able to light a matchstick, sew clothes, tie a knot or fix a nail on the wall because of friction.

Though friction makes our life easy, it has some negative effects also. So, it is called as 'necessary evil'.

2.7.4 Disadvantages of Friction

- Friction wears out the surfaces rubbing with each other, like screws and gears in machines or soles of shoes.
- An excess amount of effort has to be given to overcome the friction while operating a machine. This leads to wastage of energy.
- Friction produces heat, which causes physical damage to the machines.

2.7.5 Increasing and decreasing Friction

a. Area of contact

Friction can be increased by increasing the area of the surfaces in contact. For example, brake shoes in a cycle have to be adjusted so that they are as close as possible to the rim of the wheel, in order to increase the friction.

b. Using lubricants

A substance which reduces the frictional force is called a lubricant. Eg. Grease, coconut oil, graphite, castor oil, etc. The lubricants fill up the gaps in the irregular surfaces between the bodies in contact. This provides a smooth layer thus preventing a direct contact between their rough surfaces.

c. Using ball bearing

Since rolling friction is smaller than sliding friction, sliding is replaced by rolling with the usage of ball bearings. For the same reason, lead shots are used in the bearing of a cycle hub.

Points to Remember

- Force acting on a body tends to change its state of rest or of motion or its shape. The SI unit of force is newton.
- Force acts only when two or more objects interact with one other.
- The effect of force can be measured using the physical quantity called pressure.
- Liquids, gases and air also exert pressure.
- All objects on the surface of the Earth experience a constant thrust or force due to the atmosphere.
- Atmospheric pressure can be measured by a device called barometer.
- Friction is the force that opposes the motion of an object.
- Friction is caused by irregularities on the surfaces, which are in contact.
- Friction depends on the nature of the surfaces and mass of the bodies in contact.
- Friction is classified into two types: static friction and kinetic friction. Kinetic friction can be further classified as rolling friction and sliding friction.
- Surface tension is the tendency of liquid surfaces to shrink to have minimum surface area as mush as possible.
- When liquids are flowing there is a frictional force between the layers of the liquid, which oppose their relative motion. This force is called viscous force and the phenomenon is known as viscosity.
- Viscosity is measured by the unit called poise in CGS system and $kgm^{-1}s^{-1}$ and Nsm^{-2} in SI.

A-Z GLOSSARY

Buoyant force	An upward force exerted by liquid on a floating body.
Force	Ation of push or pull.
Friction	Force produced due to the geometrical dissimilarities of the surface of the bodies which are in relative motion.
Pressure	Force acting on unit area.
Surface tension	Force which contracts the surface area of the liquids.
Thrust	Force acting perpendicularly on any given surface area.

TEXTBOOK EXERCISES

HHMB6Q

I. Choose the best answer.

1. If we apply force against the direction of motion of the body, then the body will
   a) stop moving
   b) move with an increased speed
   c) move with a decreased speed
   d) move in a different direction
2. Pressure exerted by a liquid is increased by
   a) the density of the liquid
   b) the height of the liquid column
   c) Both a and b
   d) None of the above
3. Unit of pressure is
   a) Pascal b) Nm^{-2}
   c) Poise d) Both a and b
4. The value of the atmospheric pressure at sea level is
   a) 76 cm of mercury column
   b) 760 cm of mercury column
   c) 176 cm of mercury column
   d) 7.6 cm of mercury column
5. Pascal's law is used in
   a) hydraulic lift
   b) brake system
   c) pressing heavy bundles
   d) All the above
6. Which of the following liquids has more viscosity?
   a) Grease b) Water
   c) Coconut oil d) Ghee
7. The unit of viscosity is
   a) Nm^2 b) poise c) $kgms^{-1}$ d) No unit

II. Fill in the blanks.

1. The pressure of a liquid column _____ with the depth of the column.
2. Hydraulic lift works under the principle of _____.
3. The property of _____ of a liquid surface enables the water droplets to move upward in plants.
4. A simple barometer was first constructed by _____.

III. State true or false. If false, correct the statement.

1. Force acting on a given area is called pressure.
2. A moving body comes to rest due to friction alone.
3. A body will sink if the weight of the body is greater than the buoyant force.
4. One atmosphere is equivalent to 1,00,000 newton force acting on one square metre.
5. Rolling friction is slightly greater than the sliding friction.
6. Friction is the only reason for the loss of energy.
7. Liquid pressure decreases with the decrease of depth.
8. Viscosity depends on the pressure of a liquid.

IV. Match the following.

a.

Static friction	Viscosity
Kinetic friction	Least friction
Rolling friction	Objects are in motion
Friction between the liquid layers	Objects are sliding
Sliding friction	Objects are at rest

b.

Barometer	reduce friction
Increasing area of contact	Atmospheric pressure
Decreasing area of contact	cause of friction
Lubricants	increases friction
Irregular surface	decreases friction

V. Complete the analogy.

1. Knot in a thread : _____ friction :: Ball bearing : _____ friction
2. Downward force : Weight :: Upward force offered by liquid : _____

VI. Numerical Problem.

1. A stone weighs 500 N. Calculate the pressure exerted by it, if it makes contact with a surface of area 25 cm^2.

VII. Consider the statements given below and choose the correct option.

1. **Assertion:** Sharp knives are used to cut the vegetables.
   Reason: Sharp edges exert more pressure.
2. **Assertion:** Broad straps are used in bags.
   Reason: Broad straps last for long.
3. **Assertion:** Water strider slides easily on the surface of water.
   Reason: Water strider experiences less buoyant force.
   a. Both assertion and reason are true and reason is the correct explanation of assertion.
   b. Both assertion and reason are true, but reason is not the correct explanation of assertion.
   c. Assertion is true, but reason is false.
   d. Both assertion and reason are false.

VIII. Answer very briefly.

1. Give two examples to verify that a force changes the shape of a body.
2. Give two examples to verify that a force tends to change the static condition of a body.
3. How do you feel when you touch a nail immediately after it is hammered into a wooden plank? Why?
4. How does the friction arise between the surfaces of two bodies in relative motion?
5. Name two instruments which help to measure the pressure of a fluid.
6. Define one atmosphere.
7. Why are heavy bags provided with broad straps?
8. How does surface tension help a plant?
9. Which has greater viscosity, oil or honey? Why?

IX. Answer briefly.

1. Define friction. Give two examples of the utility of friction in day to day life.
2. Mention any three ways of minimising friction.
3. State Pascal's law and mention its applications.
4. Why is a ball bearing used in a cycle hub?

X. Answer in detail.

1. Friction is a necessary evil - Explain.
2. Give the different types of friction and explain each with an example.
3. Describe an experiment to prove that friction depends on the nature of a surface.
4. Explain how friction can be minimised.
5. Describe an experiment to prove that the pressure in a liquid increases with depth.

XI. Higher Order Thinking Questions.

1. Why is it not advisable to use a fountain pen while travelling in an aeroplane?
2. Is there any possibility of making a special device to measure the magnitude of friction directly?
3. Vidhya feels that mercury is costly. So, instead of mercury she wants to use water as a barometric liquid. Explain the difficulty of constructing a water barometer.

XII. Project Work.

Observe the devices, gadgets or things around you. List out the types of friction involved in each device. How would you minimise the friction? Record your observations and discuss your results with your classmates.

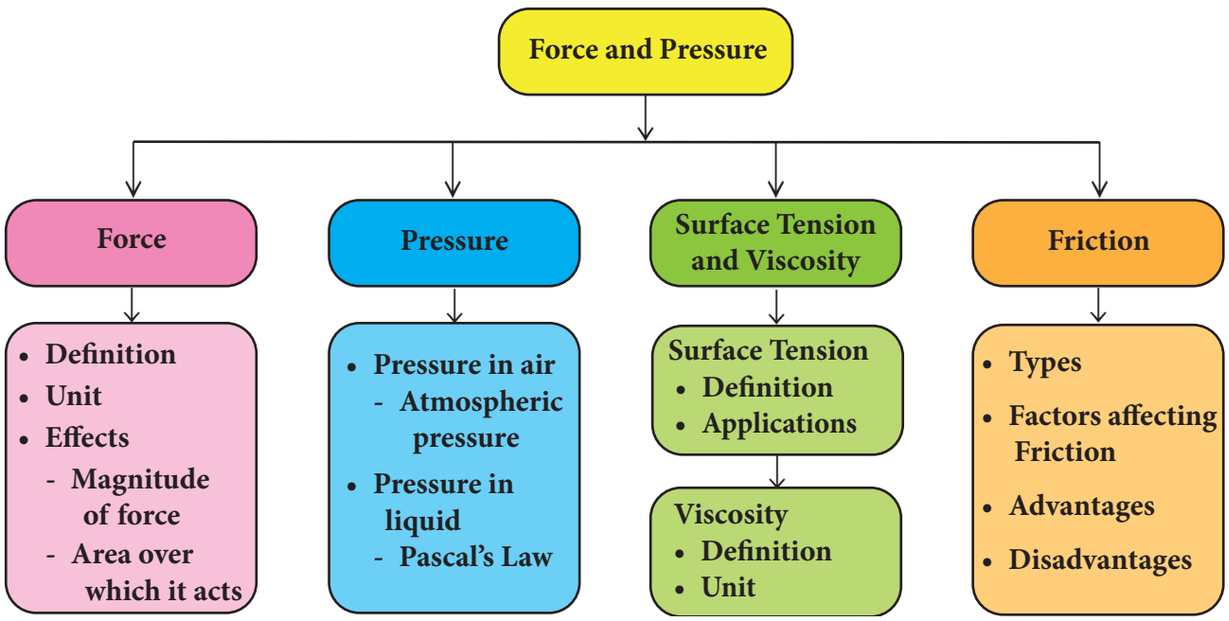
REFERENCE BOOKS

1. Fundamentals of Physics (English, Hardcover) David Halliday & Jearl Walker.
2. Principles of Physics, International Student Version (English, Paperback) Jearl Walker, David Halliday, Robert Resnick.
3. Concepts of Physics (Volume-1) 1st Edition (English, Paperback) H. C. Verma.
4. Fundamentals of Physics (English, Hardcover) David Halliday

INTERNET RESOURCES

1. https://www.youtube.com/watch?v=Oe6bDTL3YQg
2. https://www.youtube.com/watch?v=KndNN28OcEI
3. https://www.youtube.com/watch?v=-B5IBoZ08-I
4. https://www.stufftoblowyourmind.com/videos/51302-stuff-to-blow-your-kids-mind-atmospheric-pressure-video.htm

Concept Map



ICT CORNER

Force and Pressure

This activity helps to learn about the Fluid pressure & Pascal's Law

Steps

- Open the Browser and type the URL link given below (or) Scan the QR Code.
- Select the "Fluid Pressure and Pascal's Law" .You can view this page.
- You can view this page .Touch the play button.
- To get more idea about the Pascal's Law for fluid pressure through Experiment.

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Web link: https://www.youtube.com/watch?v=dx2P7i1GPaw (or) scan the QR Code