FORCES AND PRESSURE

FORCE

- Opening up a pen, opening a door, kicking a football, striking a carrom coin, making of chapattis etc., all these actions need a force.
- Force is an 'action of push or pull', which makes the bodies to move or brings the moving bodies to rest.
- It even changes the shape and size of certain bodies.

Definition of force

- Force is that which changes or tends to change: i) the state of rest or ii) the state of uniform motion of a body or iii) the direction of a moving body or iv) the shape of a body.
- Pushes and pulls are forms of forces.
- Force is a vector quantity, which has magnitude and direction.
- It is measured with a unit called "newton (N)".

Factors on which a force depends

- If he wants to hit the cricket ball to the boundary, the striking force on the ball must be greater.
- Fix a matrix of sharp pins on a wooden board in rows and columns.
- Take a big blown up ballo on.
- Next, place it gently over the pins.
- Place a small book on the top of the balloon.
- Will the balloon burst? Will the pins prick the balloon?
- Inference: It is a wonderful sight to see that the balloon will not burst. How is this possible?
- Reason: If you prick the 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 a large number of pins prick a body, each pin exerts very little pressure on the balloon, as the applied force gets distributed over a larger surface of the body.
- So, the balloon will not burst.
- We conclude that the effect of a force depends on the magnitude of the force and the area over which it acts.

Thrust

- It is a force acting perpendicularly on any given surface area of a body.
- It is measured by the unit newton.
- 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 one square meter of a body.
- Unit of pressure is pascal (Pa) or N m^{-2}.

  Pressure = $\frac{\text{Thrust (or) Force}}{\text{Area}}$,P= $\frac{F}{A}$ The SI

- Unit of pressure is pascal (named after the French scientist Blaise Pascal). 1 pascal = 1 N m^{-2}

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

- Calculate the pressure exerted by the foot of an elephant using the following data.
- Average weight of an elephant is 4000 N.
- Surface area of the sole of its foot is 0.1m^2

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

Pressure= $\frac{\text{Force}}{\text{Area}} = \frac{1000}{0.1}$

$= 10000 \frac{N}{m^2} = 10^4 \text{ N m}^2$

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

Increasing pressure:

- The effect of pressure can be increased by increasing the thrust or by decreasing the area of the surface of the body experiencing the thrust.

Examples:

- The axe, nail, knife, injection needle, bullet etc., all these are having sharp fine edges so as to exert a larger pressure on a smaller area of the body; in order to get the maximum effect from them.
- It is very difficult 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.

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 a lower pressure on the shoulders by providing a larger area of contact with the shoulder.
- 3. It is difficult to drive an automobile, which has flattened tyres.

PRESSURE EXERTED BY AIR – ATMOSPHERICPRESSURE

- 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.

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

1 atmospheric pressure = 1 atm = pressure exerted by the mercury column of height 76 cm in the barometer = 1.01×10^5 N m^{-2}

In the SI system 1 atm = 1,00,000 pascal (approximately).

SI unit of atmospheric pressure is N m^{-2} or pascal.

- Take a conical flask.
- Take a well boiled egg, after removing its shell.
- Place the egg on the mouth of the flask.
- It will not enter the flask.
- Next, take a piece of paper.
- Burn it and drop it inside the flask.
- Inference: The egg placed at the mouth of the flask gets compressed and it falls into the flask, due to the atmospheric pressure.
- Reason: 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.
- Eventually, the egg falls down to the bottom of the flask.

FORCES IN LIQUIDS

Buoyant force of a liquid

- An upward force is exerted by water on a floating or a partly submerged body.
- This upward force is called buoyant force.
- The phenomenon is known as “buoyancy”.
- Liquids and gases together are called fluids.
- This upward force decides whether an object will sink or float.
- A body floats if the buoyant force > its weight; A body sinks if its weight > buoyant force.
- Pressure exerted by liquids
- Liquids do not have a definite shape.
- The force acting on unit area of the surface, on which the liquid is placed, is called the static pressure of the liquid.
- Liquids exert a pressure not only on the base of their container/vessel, but also on its side walls.
- The pressure exerted by a liquid depends upon the depth of the point of observation considered in it.
- An instrument used to measure the difference in the liquid pressure is called a “manometer”.
- You can measure the pressure of fluids enclosed in a definite container using the manometer.
- a) Pressure exerted by a liquid on the base of a container depends upon the height of the liquid column:
- Take a glass tube that is open at both ends.
- Fix a rubber balloon at the lower end of the tube.
- Put some water into the tube and observe the balloon.
- Now, pour some more water into the balloon and again observe the balloon.
- Inference: The balloon starts bulging outwards.
- The bulge increases with an increase in the height of the water column.
- Reason: The pressure exerted by a liquid at the bottom of a container depends on the height of the liquid column in it.
- b) Liquids exert the same pressure in all directions at a given depth:
- c) Liquid pressure varies with the depth:

- 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.
- Inference: The water comes out from all the holes with the same force and falls on the g round/t able, at the same distance from the bottle.
- Reason: This activity confirms that liquids exert the same pressure in all directions, at a given depth in their container.
- 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.
- Inference: The water comes out from all the holes with a different force and falls on the table at points that are at variable distances from the bottle.
- Water from the lowest hole comes out with the greatest force and falls at a point that is at the maximum distance from the bottle.
- Water from the topmost hole comes out with the least force and falls at the point that is at the minimum distance from the bottle.
- Reason: This activity confirms that the pressure in a liquid varies with the depth of the point of observation in it.
- Take a rubber ball.
- Fill it with water.
- Then, make tiny holes on it with a pin at different points on its surface.
- Press anywhere on the ball. What do you observe?
- Inference: There are identical streams of water flowing in all directions from the holes.
- Reason: This is due to the phenomenon 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:

- The pressure applied at any point of a liquid at rest, in a closed system, will be distributed equally through all regions of the liquid.

Application of Pascal's law:

- In an automobile service station, the vehicles are lifted upward using the hydraulic lift.
- The automobile brake system
- The hydraulic press is used to make the compressed bundles of cotton or cloth so as to occupy less space.
- Fill two identical syringes with water.
- Connect them with a plastic tube.
- Press gently on one end of a piston. What do you observe?
- Inference: If one piston is pressed downward, then the other piston will move up slightly, depending on the pressure given on the first piston.
- Reason: This activity confirms that the pressure exerted on a liquid at rest is transmitted equally to other portions of the liquid.
- Why are rain drops spherical in nature?
- A liquid flowing out of a very small opening of a tube or tap comes out in the form of fine drops and not as a continuous stream. Why?
- Trees are greenish.
- They are greenish at the tip too.
- How does the water rise upward in a tree or plant against the force of gravity?
- All the above questions have an answer, i.e., "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.
- Thus, the amount of force acting per unit length, on the surface of a liquid is called surface tension.
- It has the unit N m^{-1}.

Application of 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"
- For a given volume, the surface area of a sphere is the minimum.
- This is the reason for the liquid drops to acquire a spherical shape.

- Water strider insect slides on the water surface
- easily due to the surface tension of water.
- During a heavy storm, sailors pour soap powder or oil into the sea near their ship to decrease the surface tension of sea water.
- This process reduces the impact of the violent water current against the all of ship.

VISCOUS FORCE OR VISCOSITY

- When a liquid is flowing, there is a frictional force between the successive layers of the liquid.
- This force 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.
- Viscosity force is measured by the unit called poise in CGS and kg m^{-1} s^{-1} or N s m^{-2} in SI.
- Contact force and non-contact force.
- One of the contact forces, i.e., friction.
- It is easy to hold a tumbler due to the friction between the surfaces of your palm and the tumbler.
- But, when oil is applied to your palm, the contact force between your fingers and the tumbler is reduced.
- So, the friction is reduced. Hence, it is difficult to hold it with an oily hand.

Origin of friction

- Frictional force or friction arises when two or more bodies in contact move or tend to move, relative to each other.
- Effects of friction:

Friction can produce the following effects:

- a) Friction opposes motion.
- b) Friction causes wear and tear of the surfaces in contact.
- c) Friction produces heat.

Types of friction:

- Static friction: The friction experienced by the bodies, which are at rest is called static friction.
- Kinetic friction: Friction existing during the motion of bodies is called kinetic friction.
- Further, kinetic friction can be classified into two: sliding friction and rolling friction.
- Sliding friction: When a body slides over the surface of another body.
- Rolling friction: When a body rolls over another surface.
- Rolling friction is less than sliding friction.
- That is why wheels are provided in vehicles, trolleys, suitcases etc.

Factors affecting friction

a) Nature of a surface:

- A rough surface like the cotton cloth, offers more frictional force.
- So, the marble moves slowly and covers a minimum distance.
- The smooth surface of glass, offers lesser friction.
- So, the glass marble travels a greater distance over it.
- The above activity reveals the 'effect of the force of friction', which increases as the roughness of the surface increases.
- b) Weight of the body
- c) Area of contact

Advantages of friction

- Friction is a necessity in most of our day to day activities.
- We can hold any object in our hand due to friction.
- We can walk on the road because of friction.
- The footwear and the ground help us to walk without slipping.
- Writing easily with a pen on paper is 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 in the wall because of friction.
- It is called as "necessary evil".

Disadvantages of friction

- Friction wears out the surfaces rubbing with each other
- This leads to wastage of energy.
- Physical damage to the machines.

Increasing and decreasing friction

a) Area of contact:

- Friction can be increased by increasing the area of the surfaces in contact.
- E.g.: Sumo players, Kabbadi players rub their hand with mud, to get a better grip. Football shoes are having soles with many projections, for providing a stronger grip with the ground.

b) Using lubricants:

- A substance, which reduces the frictional force, is called a lubricant. E.g.: grease, coconut oil, graphite, castor oil, etc.

c) Using ball bearing:

- Since, the rolling friction is smaller than sliding friction, sliding is replaced by rolling with the usage of ball bearings.