# JSR IAS ACADEMY

## GENERAL SCIENCE

## PHYSICS

# Force, Pressure and Energy, Everyday application of the basic principles of Mechanics - II

**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 = Thrust (or) Force/Area , P = 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 0.1m2 .

**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 $m^2$.

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

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

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.
- More number of wheels are provided for a heavy goods-carrier for decreasing the pressure; thereby increasing the area of contact on the road.
- 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.
- It is difficult to drive an automobile, which has flattened tyres.

**PRESSURE EXERTED BY AIR - ATMOSPHERIC PRESSURE**

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.

Atmospheric pressure 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.

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 80° 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.

- 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).
- 1 atmospheric pressure = 1 atm = pressure exerted by the mercury column of height 76 cm in the barometer = $1.01 \times 10^5$ N $m^{-2}$.
- In the SI system 1 atm = 1,00,000 pascal (approximately).
- SI unit of atmospheric pressure is $Nm^{-2}$ or pascal.
- To realise the effect of atmospheric pressure:

**FORCES IN LIQUIDS**

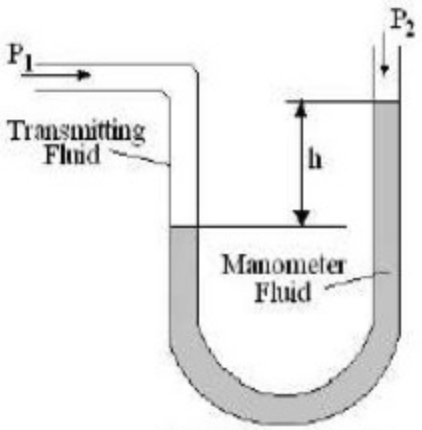
**Buoyant force of a liquid**

- 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".

- ❖ This force is not only exerted by liquids, but also by gases.
- ❖ Liquids and gases together are called fluids.
- ❖ 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.
- ✓ 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.




U-tube Manometer

Figure 2.2 Manometer

An instrument used to measure the difference in the liquid pressure is called a "manometer".

- ➢ Pressure exerted by a liquid on the base of a container depends upon the height of the liquid column:
- ➢ Liquids exert the same pressure in all directions at a given depth:
- ➢ Liquid pressure varies with the depth:

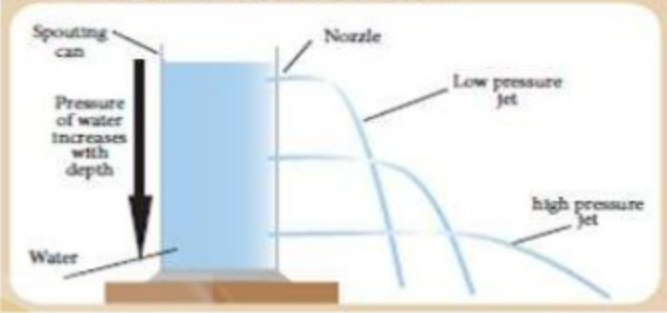
**Pascal's law:**

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:**

- ❖ Some of the following examples highlight their working according to Pascal's law.
- ❖ In an automobile service station, the vehicles are lifted upward using the hydraulic lift, which works as per Pascal's law.
- ❖ The automobile brake system works according to Pascal's law.
- ❖ The hydraulic press is used to make the compressed bundles of cotton or cloth so as to occupy less space.

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




**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 $m^{-1}$

- 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"**.

**Application of surface tension:**

- ❖ 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" (you will study this topic in

the forth-coming classes), which is caused by the surface tension of water.

- 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**

- 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.

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

**Inference:** Each liquid moves with a different speed. Water flows faster than other liquids. Coconut oil flows with a moderate speed. Ghee flows very slowly.

**Reason:** Between the layers of each liquid, 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.

**FRICTION**

- 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.

**Effects of friction:**

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. (E.g.: all the objects rigidly placed to be at rest on the Earth, a knot in a thread.)

**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, the friction acting between the surfaces in contact is called sliding friction.

**Rolling 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.

**Factors affecting friction**

**a)Nature of a surface:**

**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.

**Advantages of friction**

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.

**Disadvantages of friction**

Though it is giving a negative effect, in most of our day to day life friction helps us to make our life easy. So, it is called as "necessary evil".

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

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.

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. You can see lead shots in the bearing of a cycle hub.

| System | Length | Mass | Time |
|---|---|---|---|
| CGS | centimetre | gram | second |
| FPS | foot* | pound | second |
| MKS | metre | kilogram | second |

| Fundamental quantities | Unit | Symbol |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Temperature | kelvin | K |
| Electric current | ampere | A |
| Luminous intensity | candela | cd |
| Amount of substance | mole | mol |

| S.No | Physical quantity | Expression | Unit |
|---|---|---|---|
| 1 | Area | length × breadth | $m^2$ |
| 2 | Volume | area × height | $m^3$ |
| 3 | Density | mass / volume | $kgm^{-3}$ |
| 4 | Velocity | displacement / time | $ms^{-1}$ |
| 5 | Momentum | mass × velocity | $kgms^{-1}$ |
| 6 | Acceleration | velocity / time | $ms^{-2}$ |
| 7 | Force | mass × acceleration | $kgms^{-2}$ or N |
| 8 | Pressure | force / area | $Nm^{-2}$ or Pa |
| 9 | Energy (work) | force × distance | Nm or J |
| 10 | Surface tension | force / length | $Nm^{-1}$ |

| Larger units | In metre |
|---|---|
| Kilometre (km) | $10^3$ m |
| Astronomical unit (AU) | $1.496 \times 10^{11}$ m |
| Light year (ly) | $9.46 \times 10^{15}$ m |
| Parsec (pc) | $3.08 \times 10^{16}$ m |

| Smaller units | In metre |
|---|---|
| Fermi (f) * | $10^{-15}$ m |
| Angstrom (Å)* | $10^{-10}$ m |
| Nanometre (nm) | $10^{-9}$ m |
| Micron (micrometre μ m) | $10^{-6}$ m |
| Millimetre (mm) | $10^{-3}$ m |
| Centimetre (cm) | $10^{-2}$ m |

Mass of 1 m*l* of water = 1g

Mass of 1*l* of water = 1kg

Mass of the other liquids vary with th density.

| Power of 10 | Prefix | Symbol |
|---|---|---|
| $10^{15}$ | peta | P |
| $10^{12}$ | tera | T |
| $10^{9}$ | giga | G |
| $10^{6}$ | mega | M |
| $10^{3}$ | kilo | k |
| $10^{2}$ | hecto | h |
| $10^{1}$ | deca | da |
| $10^{-1}$ | deci | d |
| $10^{-2}$ | centi | c |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | μ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |
| $10^{-15}$ | femto | f |