2.7 FLUID MECHANICS

What is a fluid ?

A fluid is a substance that can flow. Only liquids and gases can flow freely. Liquids and gases are together called fluids [From Latin word – meaning "to flow"]

A liquid has no shape and size of its own. A container is needed to take a liquid. Liquids assume the shape of the container. Gases also require container. Gases expand enormously and can occupy any volume. Hence, they do not have a definite shape nor definite volume.

Note :

1) Fluid mechanics is the branch of physics, which deals with the properties of fluids under the action of several forces.
2) Fluid mechanics is classified into two branches
   i) Fluid dynamics ii) Fluid statics

Fluid dynamics : It deals with the motion of fluids under the action of forces.

Fluid statics : It deals with the fluids at rest under the action of forces.

3) Fluid mechanics assumes that, every fluid obeys the following laws of.

A) conservation of mass
B) conservation of energy
C) conservation of momentum

4)Fluids are composed of molecules that collide with one another and solid objects.

Fluid thrust : Consider a liquid in a container. The liquid is at rest. The force exerted by the liquid is always normal to the surface in contact with the liquid. . The total normal force exerted by a liquid at rest on a surface in contact with it is called fluid thrust. SI unit fluid thrust is newton (N) and is a vector quantity.

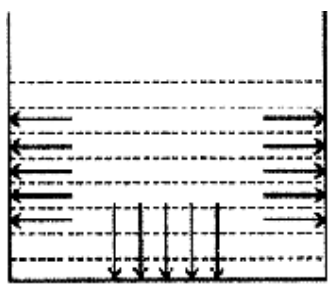


Fig (1)

Pressure in fluids : A solid exerts pressure on a surface due to its weight. Similarly fluids have weight and they also exert pressure on the base and walls of the container in which they are enclosed.

Definition of pressure : Pressure at any point in a fluid is the fluid thrust per unit area around that point.

$$\text{Pressure} = \frac{Thrust}{area}$$

Note :

1) Pressure is a scalar quantity.
2) The SI unit of pressure is Nm^{-2} (pascal).
3) $1Pa = 1\ Nm^{-2}$
4) $1\ atm = 1.013 \times 10^5\ Pa$

Pressure exerted by a liquid : Liquids exert pressure on the walls of the container. Pressure exerted by the liquid at the bottom of the container depends on the height of its column.

Example : It is common experience that fountains of water comes out of the pipe if it has leaking joints or holes in it. It is due to the pressure exerted by water on the walls of the pipes.

Activity 1 : A liquid exerts pressure. To Show it, consider a vessel containing a liquid. Make a small hole near the bottom. Now the liquid will flow out of it. If the flow of liquid is stopped by pressing a finger against the hole, the finger will experience an outward force due to the liquid contained in the vessel. Therefore it is reasonable to conclude that the liquid exerts pressure on the walls and base of the containing vessel.

Pressure exerted by a gas : Gases too exert pressure on the walls of the container.

Example : Air in the bicycle tube comes out when it has a puncture. We cannot inflate the balloon which has holes, because air exerts pressure in all directions.

Atmosphere and atmospheric pressure :

Earth is surrounded by a gaseous envelope, extending up to a few thousand kilometers. This gaseous envelope is made up of 78% nitrogen, 21% oxygen and small amount of carbon dioxide, water vapor etc, and is called 'atmosphere of earth'. The density of the atmosphere goes on decreasing as one goes above the surface of earth. The pressure exerted by the atmosphere is called 'atmospheric pressure'. Obviously it is maximum at the surface of the earth, and decreases as we move higher. The pressure due to air is about 1.013×10^5Pa at sea level.

Note (1) : The pressure 'P' exerted by a column of height h of a fluid of density 'ρ' at a place, where the acceleration due to gravity is 'g' is given by

$$P = \rho g h$$

2) The blood pressure in case of human is greater at the feet than at the brain, because the height of the blood column is quite large at the feet than at the brain.

Archimedes's principle :

Statement : When a body is immersed completely or partially in a liquid, the apparent loss of weight of the body is equal to the weight of the liquid displaced by it.

Activity 2 : Immerse a heavy stone in water. Try to lift the stone immersed in water. You will feel it lighter as long as it is in water. Once the stone comes up to the air, you feel it to be heavier. This is because any body inside a liquid loses some weight.

Think and list some more activities.

Buoyancy : The resultant up thrust on a body immersed completely or partially in a liquid is called buoyancy.

Floatation : When a body is immersed in a liquid, two forces acts on it.

a) The weight W of the body, which acts in the downward direction.

b) The buoyant force W', which acts in the upward direction.

There are three possibilities.

Case (I) : If W > W' , In this case the weight of the body (downward force) is more than the upward force (up thrust). Hence the body sinks completely in the liquid. See in fig (2)

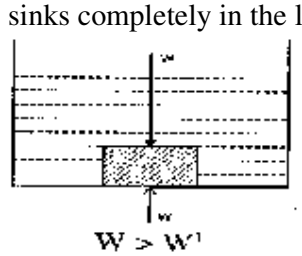
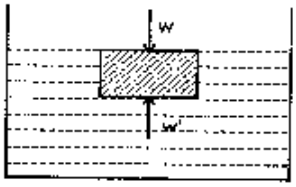


Fig (2)

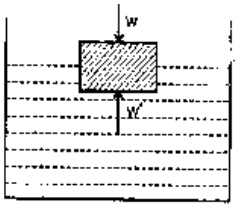
Case (II) : If W = W' In this case the downward force is equal to the upward force. Hence the body will be at any point inside the liquid. See in fig (3)



W = W'

Fig (3)

Case (III) : If W < W' in this case the downward force is less than the upward force. Hence the body experiences a net upward thrust and it rises to the surface. This is the condition for flotation. See in fig (4)



W < W'

fig (4)

<u>Laws of floatation</u> : When a body floats freely in a liquid,

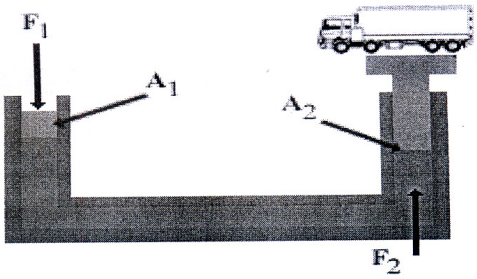
1) The weight of the body is equal to the weight of the liquid displaced.
2) The centre of gravity of the body and the centre of buoyancy lie in the same vertical line.

<u>Pascal's law</u> : The pressure due to a liquid is independent of the container. This fact was made use by the French mathematician, Blaise Pascal for the first time to state it in the form of a principle which is now known as Pascal's principle or Pascal's law.

It state that in an enclosed fluid, if an increased pressure is produced in any part of the fluid, then this change of pressure is transmitted undiminished to all the other parts of the fluid.

<u>Application of Pascal's law</u> :

1) In hydraulic lift used to lift heavy objects, such as a car at a service station.
2) Hydraulic lift multiplies the force applied. When a small force applied over a piston of small cross-section area due to transmission of pressure equally in all directions, a large force appears over a piston of large cross-sectional area, which is then utilized to support and lift heavy weights. As in fig (5)
3) In the working of a hydraulic brakes.
4) In the crushing of oil seeds and extraction of oil from them.



Schematic diagram illustrating the principle behind the hydraulic lift

Fig (5)

Questions :

1. What is a fluid?
2. Define fluid thrust.
3. Mention SI unit of fluid thrust.
4. Define pressure of a fluid.
5. Is pressure a scalar or a vector?
6. State Archimedes principle.
7. What is Buoyancy?
8. Write the condition for floatation of a body.
9. State Pascal's law.
10. Write any two applications of Pascal's law.

Answers
2.7 – Fluid Mechanics

1) Fluid is a substance that can flow. Gases and liquids are together called fluids.
2) The total normal force exerted by a fluid at rest on a surface in contact with it is called fluid thrust.
3) SI unit of fluid thrust is newton(N).
4) Pressure of a fluid at any point is defined as the fluid thrust per unit area around that point.
5) Pressure is a scalar quantity.
6) When a body is immersed completely or partially in a liquid ,it loses some weight, the apparent loss of weight of the body is equal to the weight of the liquid displaced by it.
7) The resultant up thrust on a body immersed completely or partially in a liquid is called buoyancy.
8) If the weight of the body is less than the buoyant force, the body experiences a net upward thrust and it rises to the surface of the liquid. This is the condition for floatation.
9) It states that in an enclosed fluid if an increased pressure is produced in any part of the fluid, then this change of pressure is transmitted undiminished to all the other parts of the fluid.
10) 1.In hydraulic lift used to lift the heavy objects .
    2.In the working of a hydraulic brakes.