RADIANT 2026

Physics

Pressure in Fluid and Atmospheric Pressure

Lecture - 02

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Topics *to be covered*

1. Thrust and Pressure
2. Units of Pressure
3. Pressure in Fluids

4) Pascal's Law & its application


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Fluid

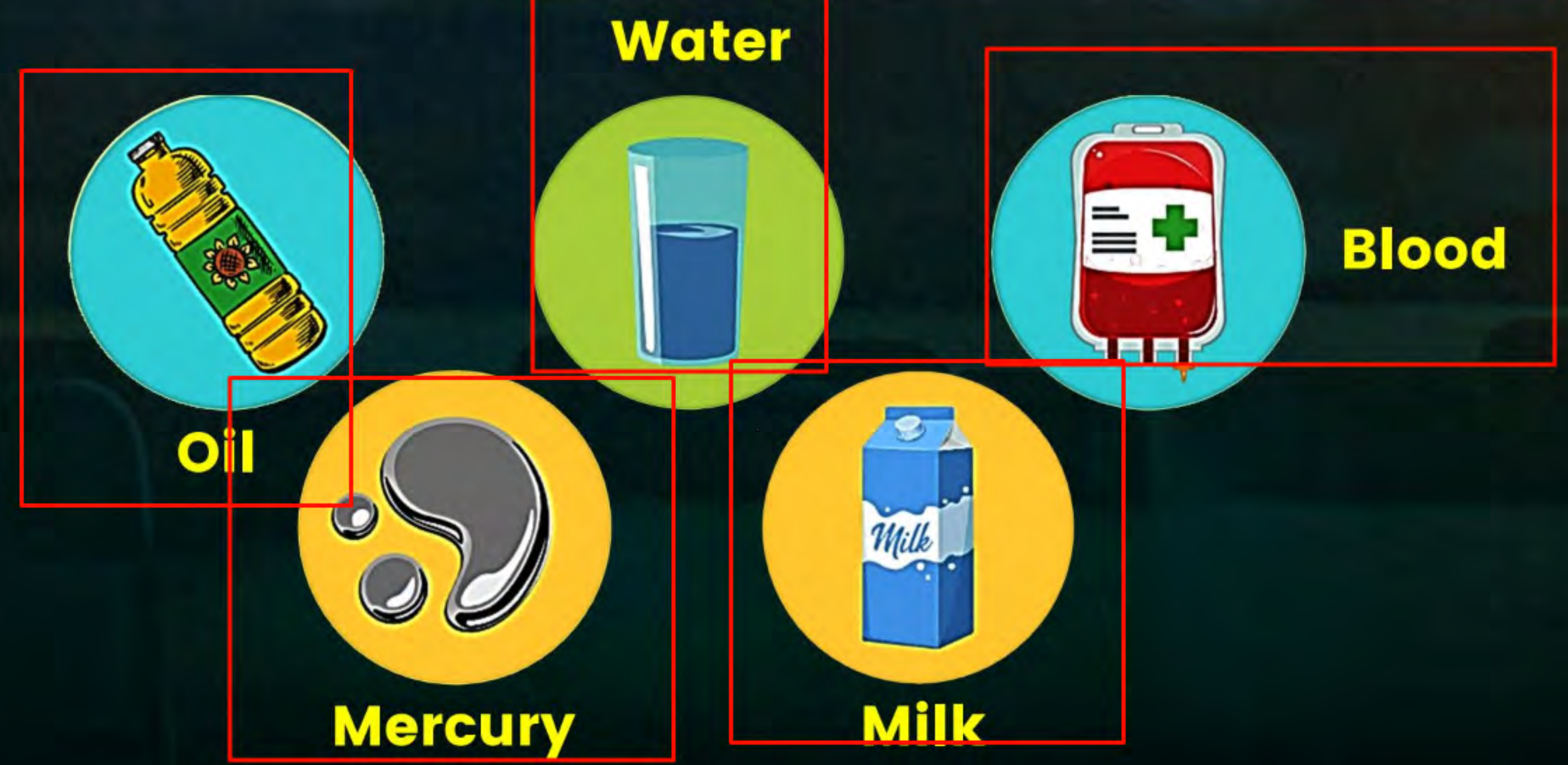
air
पानी
oil

→ liquid or gas

Pressure in Fluids

Examples of Liquids

A liquid is a state of matter with a definite volume, but no fixed shape.

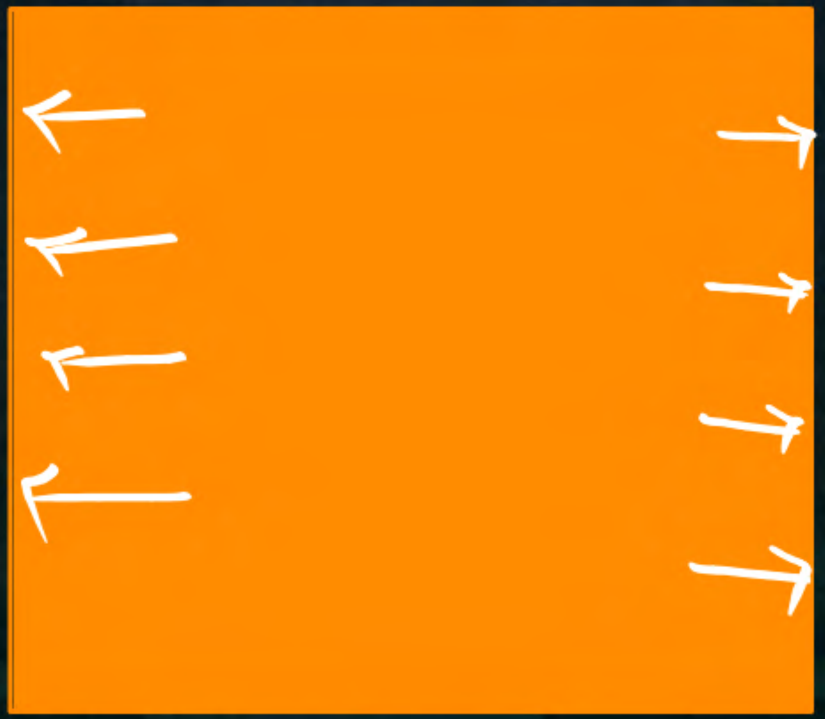


Pressure in Fluids

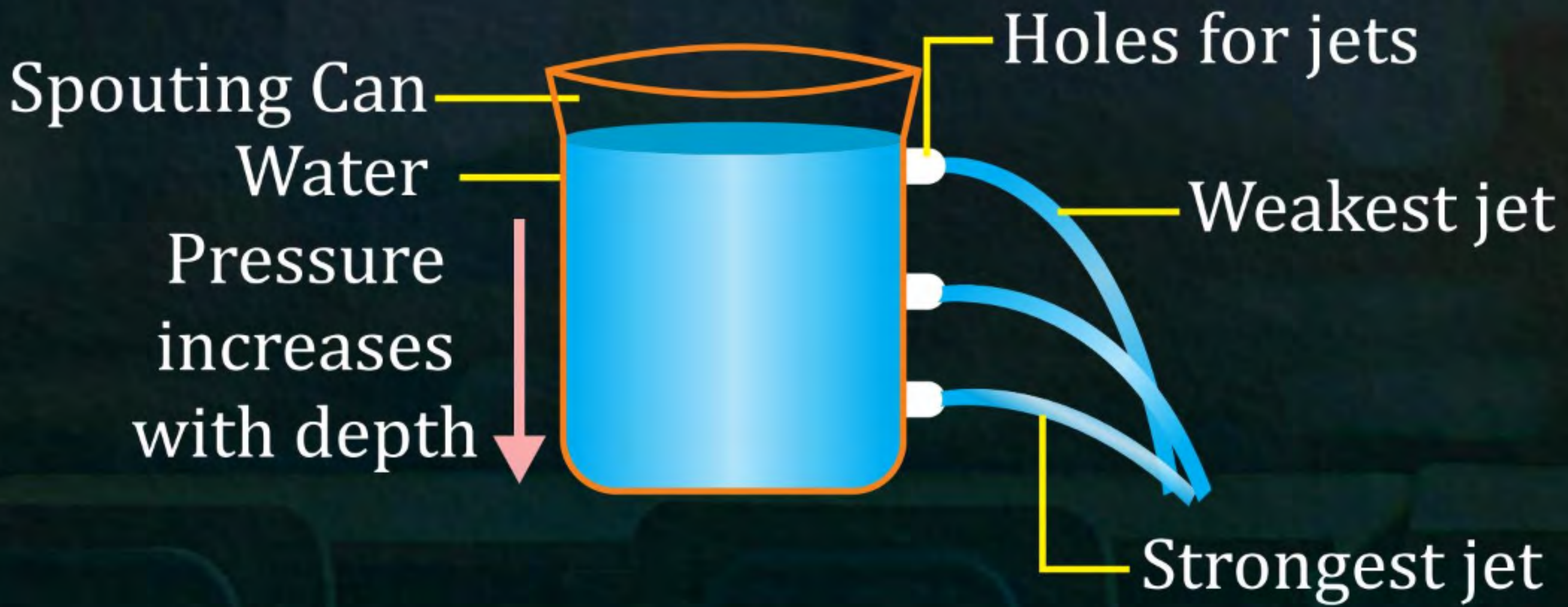
- A substance which can flow is called a fluid.
- All liquids and gases are, thus, fluids.

Pressure in Fluids

$$P = \frac{F}{A}$$

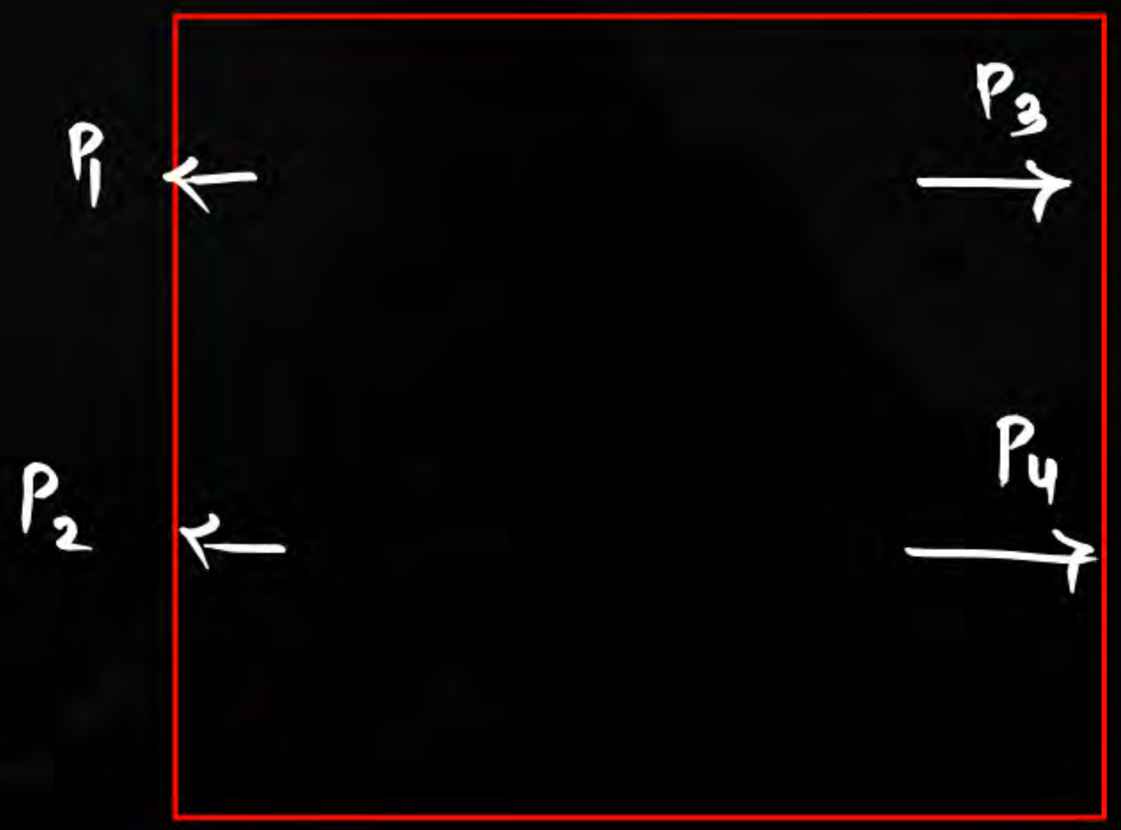


Pressure in Fluids



Pressure in Fluids

- A substance which can flow is called a fluid.
- All liquids and gases are, thus, fluids.
- A fluid contained in a vessel exerts pressure at all points and in all directions.



$$P_1 = P_2 = P_3 = P_4$$

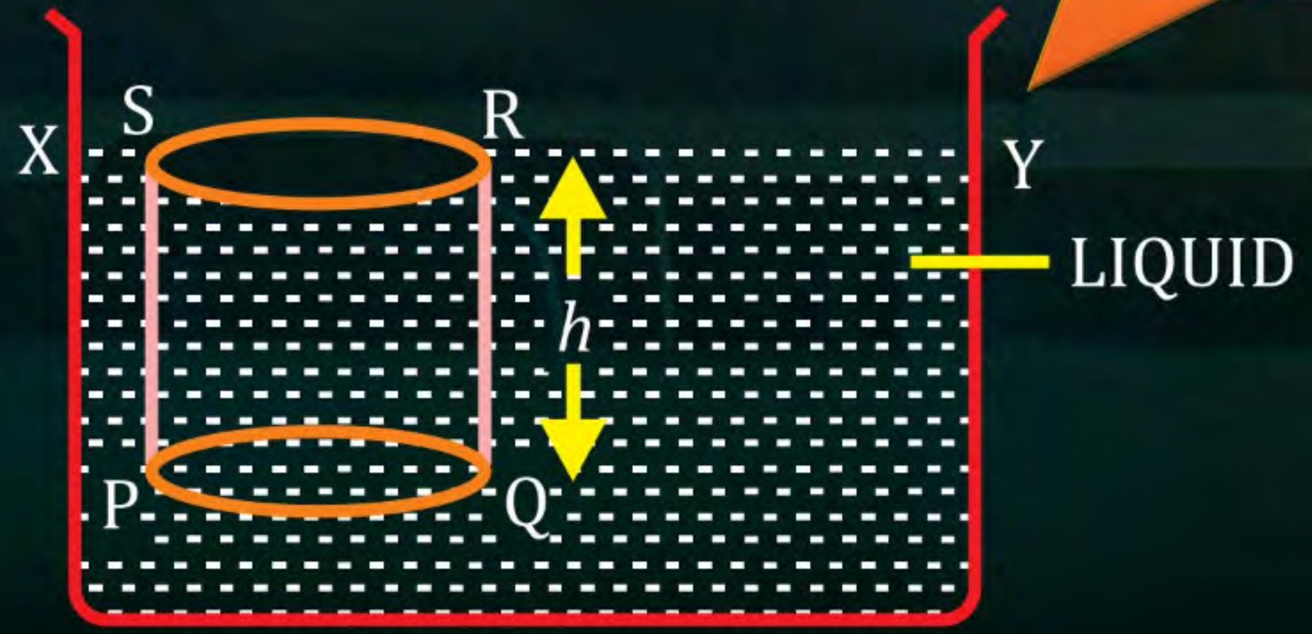
Pressure Exerted by a Liquid Column (P = $h\rho g$)

The pressure exerted by a liquid of density ρ at a depth h is P = hρg where g is the acceleration due gravity i.e.,

Proof

Consider a vessel containing a liquid of density ρ. Let the liquid be stationary. In order to calculate circular surface PQ of area A at depth *h*.

Pressure P = hρg
= depth × density of liquid × acceleration due to gravity



below the free surface XY of the liquid (Fig). The pressure on surface PQ will be due to the weight of the liquid coloumn above the surface PQ (i.e., the liquid contained in cylinder PQRS of height h with PQ as its base and top face RS lying on the free surface XY of the liquid).

$P = h\rho g$

The thrust exerted on the surface PQ

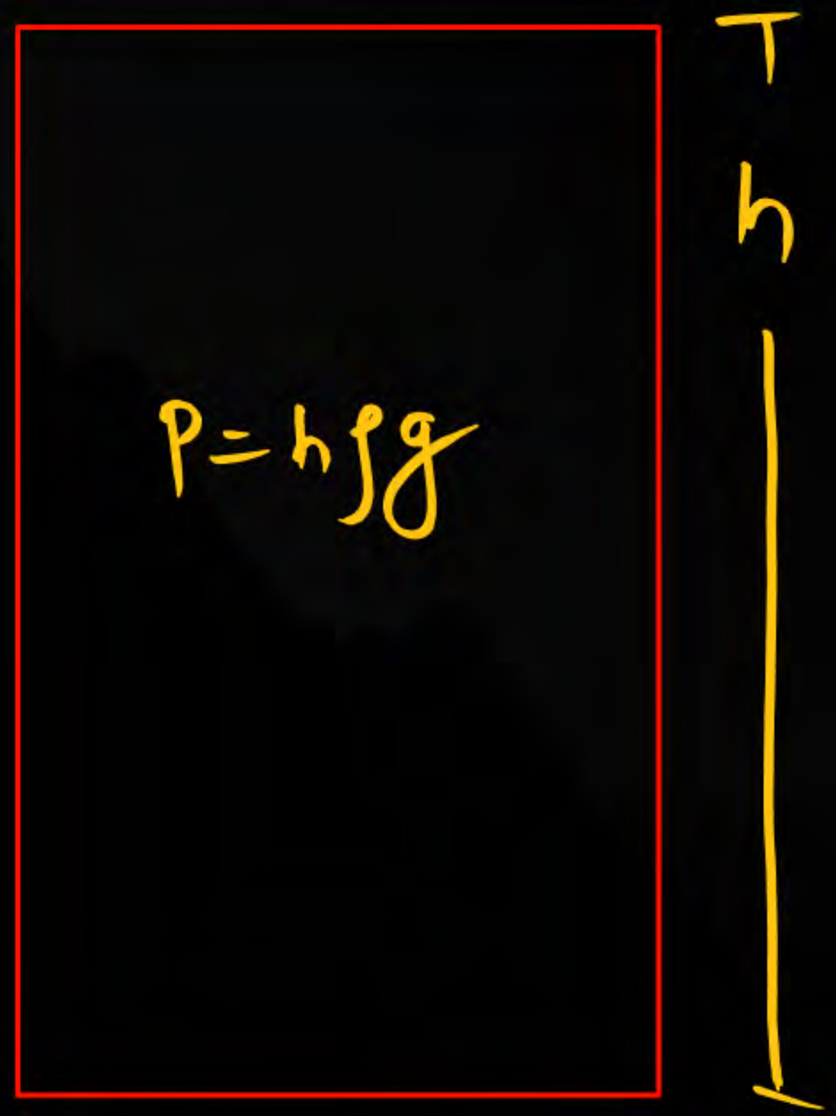
$=$ Weight of the liquid column PQRS

$=$ Volume of liquid column PQRS $\times$ density $\times\ g$

$=$ (Area of base PQ $\times$ height) $\times$ density $\times\ g = (\mathrm{A} \times h) \times \rho \times \mathrm{g} = \mathrm{Ah\rho g}$

This thrust is exerted on the surface PQ of area$A$. Therefore, pressure

$$\mathrm{P} = \frac{\text{Thrust on surface}}{\text{Area of surface}} = \frac{\mathrm{A}h\rho g}{\mathrm{A}} = h\rho g$$


h
$P = h\rho g$

Note:

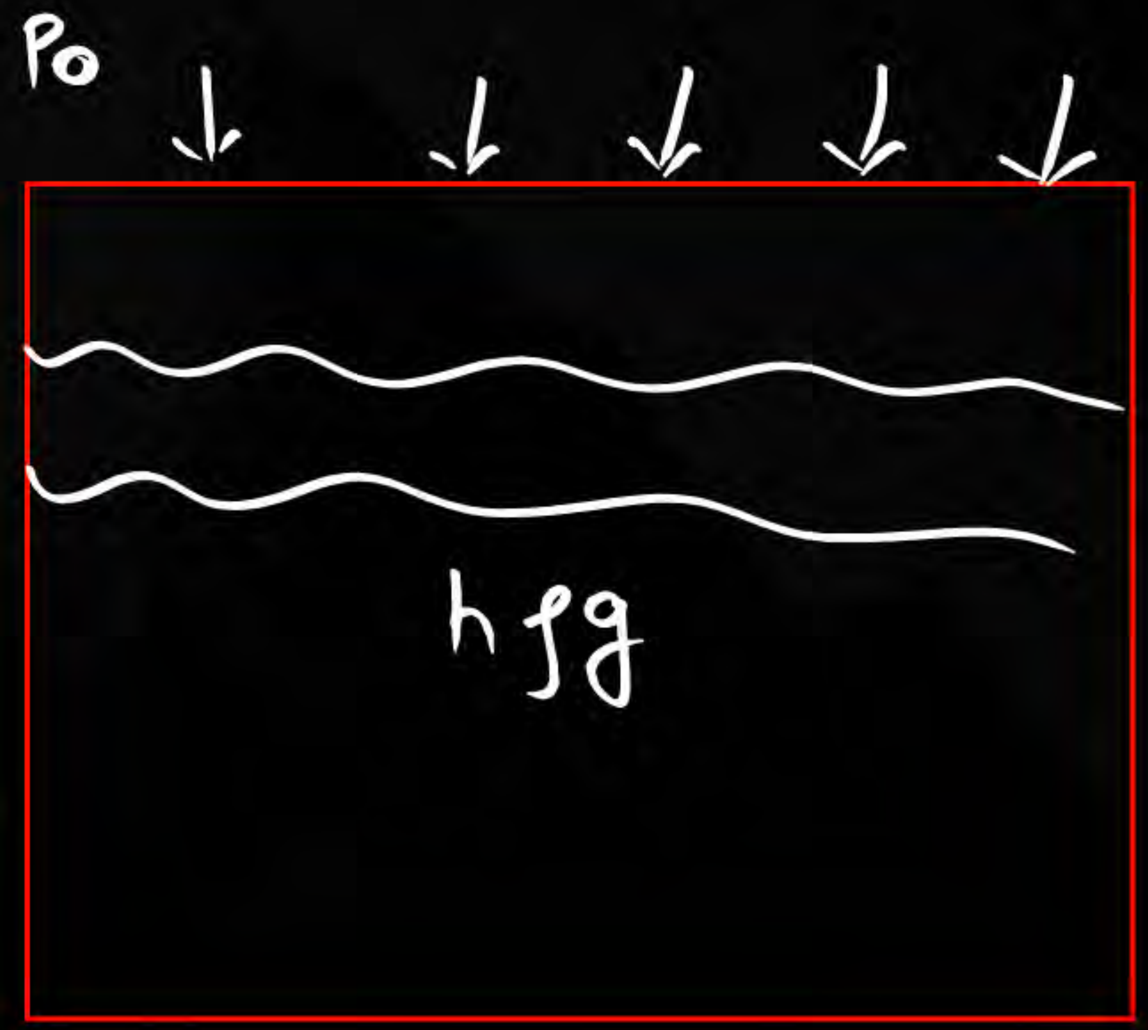
Since there is atmospheric pressure above the free surface of liquid, so to find the total pressure at a depth inside a liquid, it must also be taken into consideration. If the atmospheric pressure acting on the free surface of liquid is P_0, then.

Total pressure in a liquid at a depth h

= Atmospheric pressure + pressure due to liquid column

$= P_0 + h\rho g$

$$P = P_0 + h\rho g$$



Factors affecting the pressure at a points in a liquid

From eqn., it is clear that the pressure at a point inside the liquid depends directly on the following three factors:

(i) depth of the point below the free surface (h),

(ii) density of liquid (ρ), and

(iii) acceleration due to gravity (g).

$P = h\rho g$

$P \propto h$

$P \propto \rho$

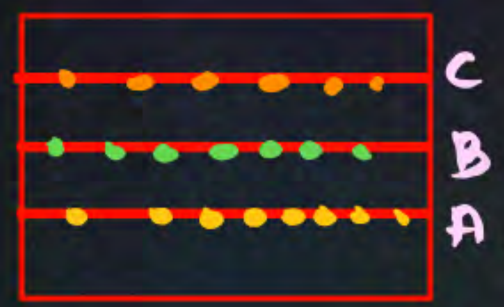
$P \propto g$

At a particular place on the earth surface, the acceleration due to gravity g is constant, therefore, the pressure at a point in a liquid is **(i)** directly proportional to the depth h of the point below the free surface of the liquid, and **(ii)** directly proportional to the density ρ of the liquid.

However

The pressure inside a liquid does not depend on (i) the shape and size of the vessel in which the liquid is contained, and (ii) the area of surface on which it acts.

Law of Liquid Pressure



Following are the **five laws** of liquids pressure:

(i) Inside the liquid, pressure increases with the increase in depth from its free surface

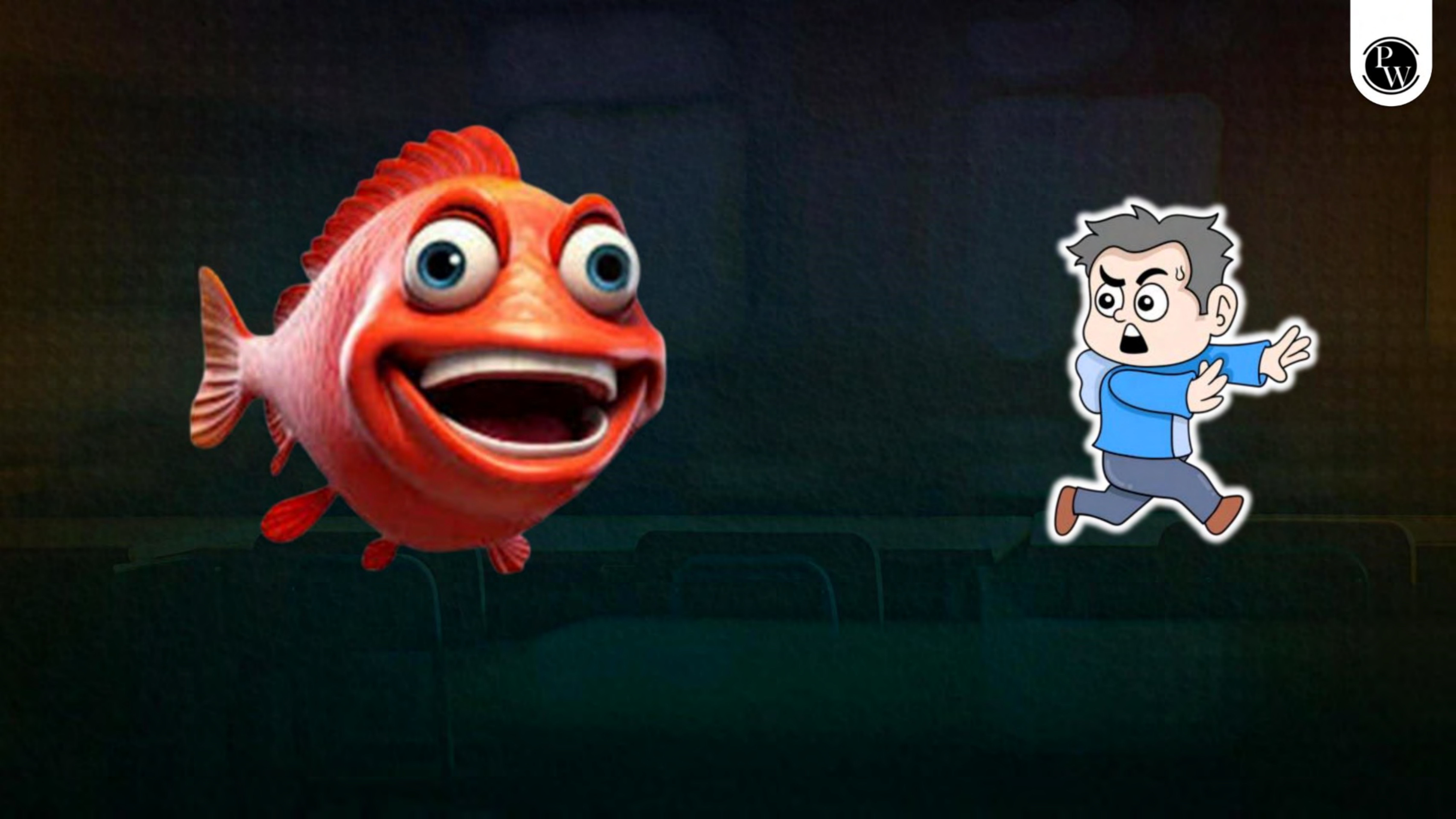
(ii) In a stationary liquid, pressure is same at all points on a horizontal plane.

(iii) Pressure is same in all direction about a point in liquid.

(iv) Pressure at same depth is different in different liquids. It increases with the increase in density of liquid.

(v) A liquid seeks its own level.

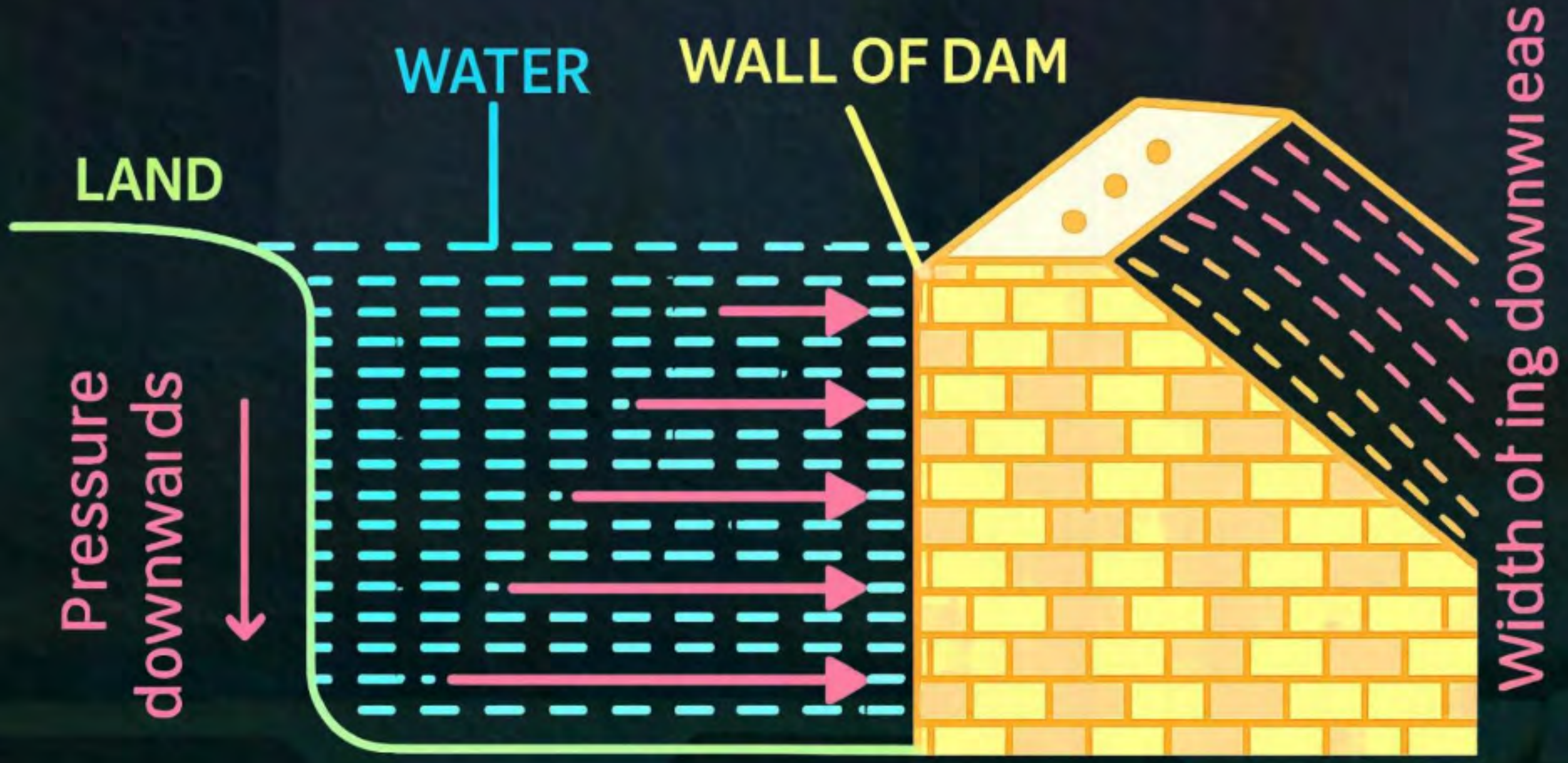
Altitude/Water Depth	Pressure
4000 m	Approx. 600 hpa
3000 m	Approx. 700 hpa
2000 m	Approx. 800 hpa
Altitude: 1000 m	Approx. 900 hpa
0 m	Approx. 1000 hpa
Depth: 1 m	Approx. 1100 hpa
2 m	Approx. 1200 hpa
3 m	Approx. 1300 hpa
4 m	Approx. 1400 hpa



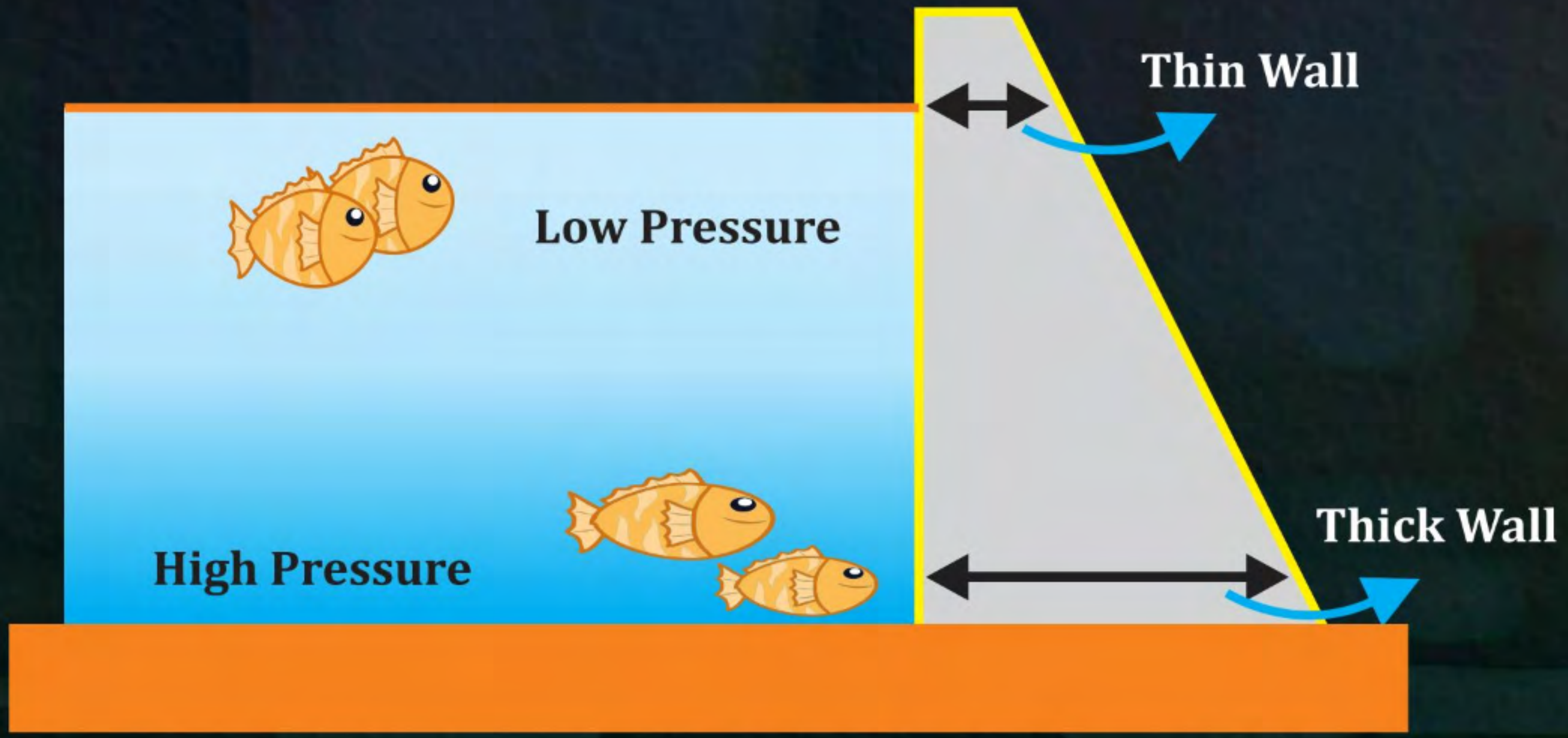
SOME CONSEQUENCES OF LIQUID PRESSURE P = $h\rho g$

(i) **In sea water, the pressure at a certain depth in sea water is more than that at the same depth in river water:** The reason is that the density of sea water is more than the density of river water.

(ii) **The wall of a dam is made thicker at the bottom:** Fig. 4.4 shows the side view of a dam. The thickness of its wall increases from top towards the bottom. The reason is that the pressure exerted by a liquid increases with its depth. Thus as depth increases, more and more pressure is exerted by water on the wall of dam. A thicker wall is required to withstand a greater pressure, therefore, the wall of the dam is made with thickness increasing towards the base. In Fig. 4.4, the increasing length of arrows in water shows the increasing pressure on the wall of dam towards the bottom.



Wall of a dam with its thickness increasing towards the bottom



Thin Wall
Low Pressure
Thick Wall
High Pressure

(iii) Water supply tank is placed high: To supply water in a town (or colony), tank to store water for supply is made at a sufficient height. The reason is that as greater is the height of tank, more will be the pressure of water in the taps of a house. Thus for a good supply of water, the height of the supply tank must always be a few metre higher than the level at which supply of water is to be made.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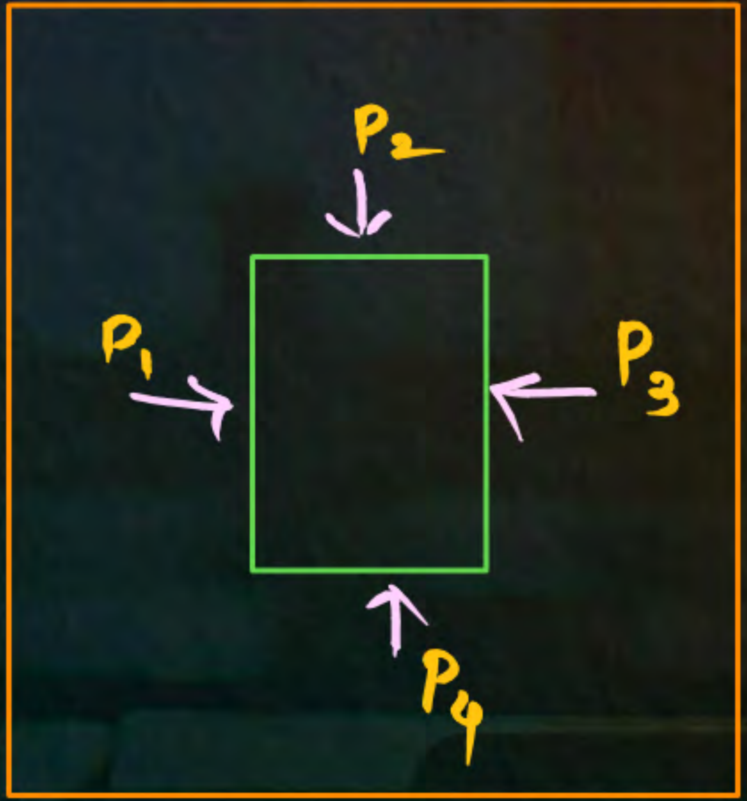
(iv) **Diver's Suit:** The sea divers need special protective suit to wear because in deep sea, the total pressure exerted on the diver's body is much more than his **blood pressure**. To withstand.

It, he needs to wear a special protective suit, made from glass reinforced plastic or cast aluminium. The pressure inside the suit is maintained at one atmosphere.

(iv) **Size of gas bubble inside the water:** It is noticed that as the gas bubble formed at the bottom of a lake, rises, it grows in size. The reason is that when the bubble is at the bottom of lake, total pressure exerted on it is the sum of the atmospheric pressure and the pressure due to water column. As the gas bubble rises, due to decrease in depth, the pressure due to water column decreases, so the total pressure exerted on the bubble decreases. According to **Boyle's law**, the volume of bubble increases due to the decrease in pressure, i.e., the bubble grows in size. When the bubble reaches the surface of liquid, total pressure exerted on it becomes just equal to the atmospheric pressure only which is minimum and so the size of bubble on surface becomes maximum.

TRANSMISSION OF PRESSUERE IN LIQUIDS; PASCAL'S LAW

$$P_1 = P_2 = P_3 = P_4$$



APPLICATION OF PASCAL'S LAW

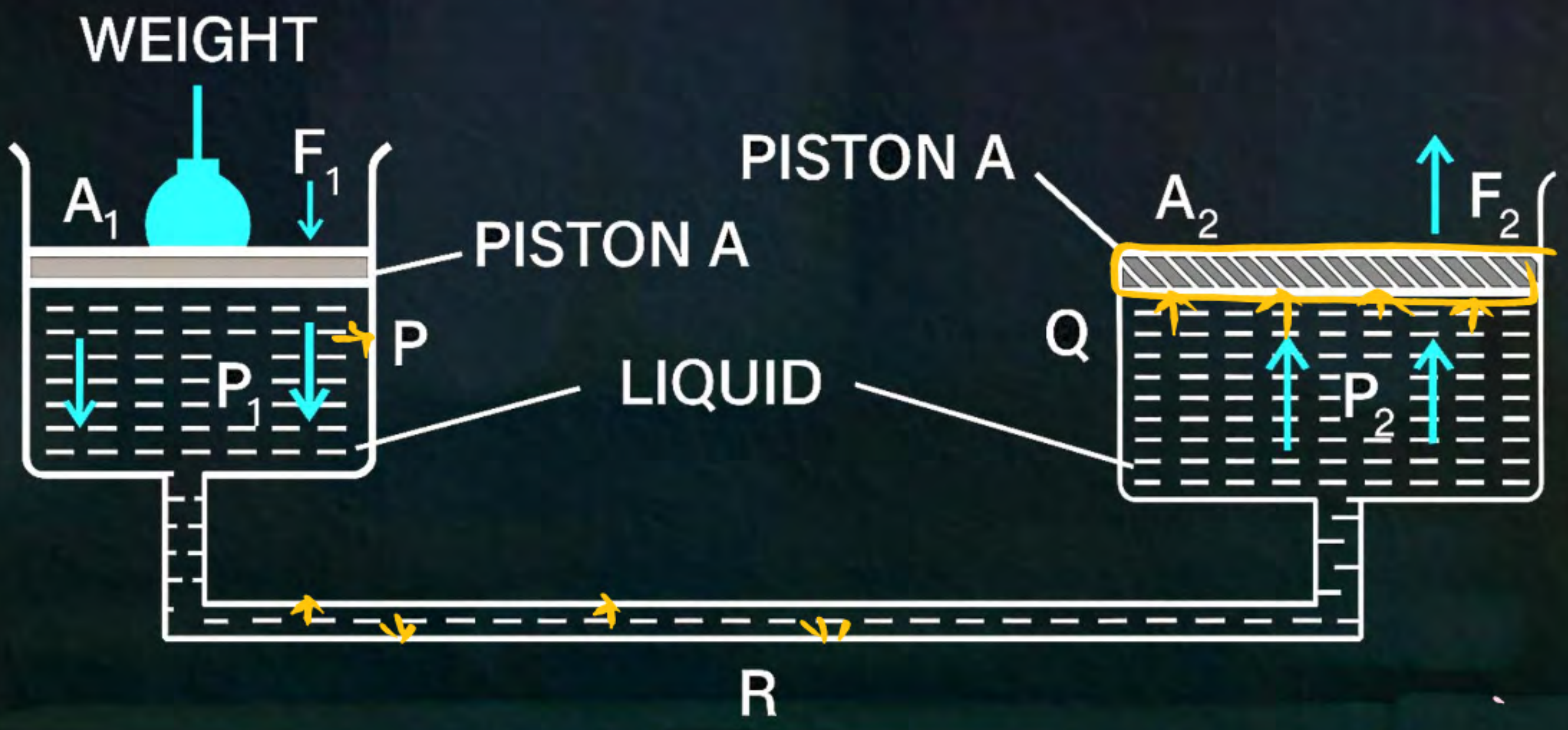
Hydraulic machines such as hydraulic press, hydraulic jack and hydraulic brakes are based on Pascal's law of transmission of pressure in liquids.

Principle of a hydraulic machine

The principle of each hydraulic machine is that a small force applied on a smaller piston is transmitted to produce a large force on the bigger piston.

Fig. shows two cylindrical vessels P and Q connected by a horizontal tube R. The vessels contain a liquid (or water) and they are provided with water-tight pistons A and B. The vessel P is of smaller diameter as compared to the vessel Q. Let area of cross section of the vessel P be A_1 and that of the vessel Q be A_2. When a weight is placed on the piston A, it exerts a force F_1 on the piston A. Therefore the pressure applied on the piston A is

$$P_1 = \frac{F_1}{A_1} \quad ....(i)$$



$A_2 > A_1$

$\frac{F_1}{A_1}$ $\frac{F_2}{A_2}$

Principle of a Hydraulic Machine

According to Pascal's law

The pressure exerted on piston A is transmitted through the liquid to the piston B. This exerts an upward pressure P_2 on the piston B which is equal to P_1. Thus

$$P_2 = P_1 \quad ....(ii)$$

If the upward force exerted on piston B is F_2, Then

Pressure on piston B is $P_2 = \frac{F_2}{A_2}$ From eqns. **(i)**, **(ii)** and (4.8), $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

or $\frac{F_2}{F_1} = \frac{A_2}{A_1}$ ....(iii)

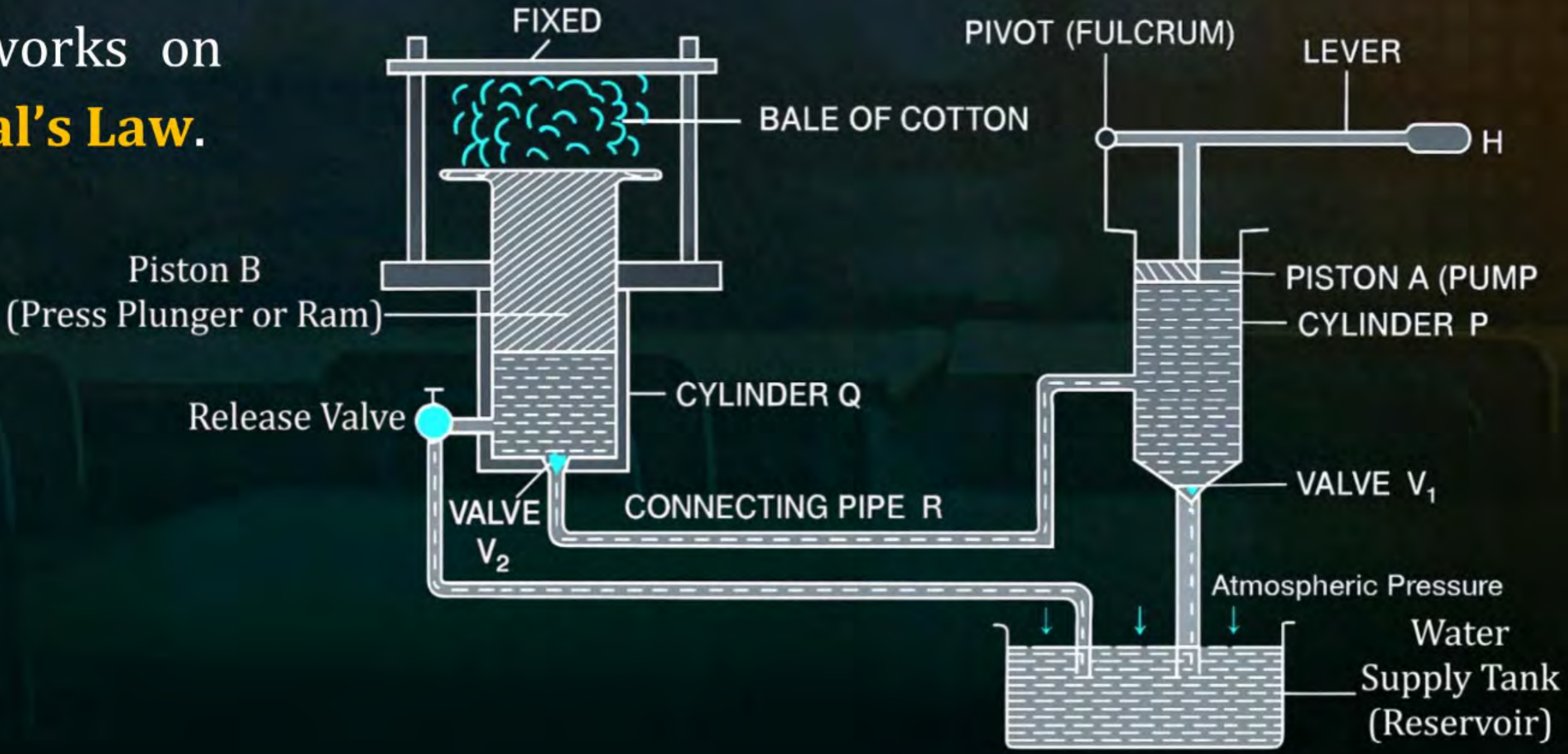
Since $A_2 > A_1$, therefore $F_2 > F_1$

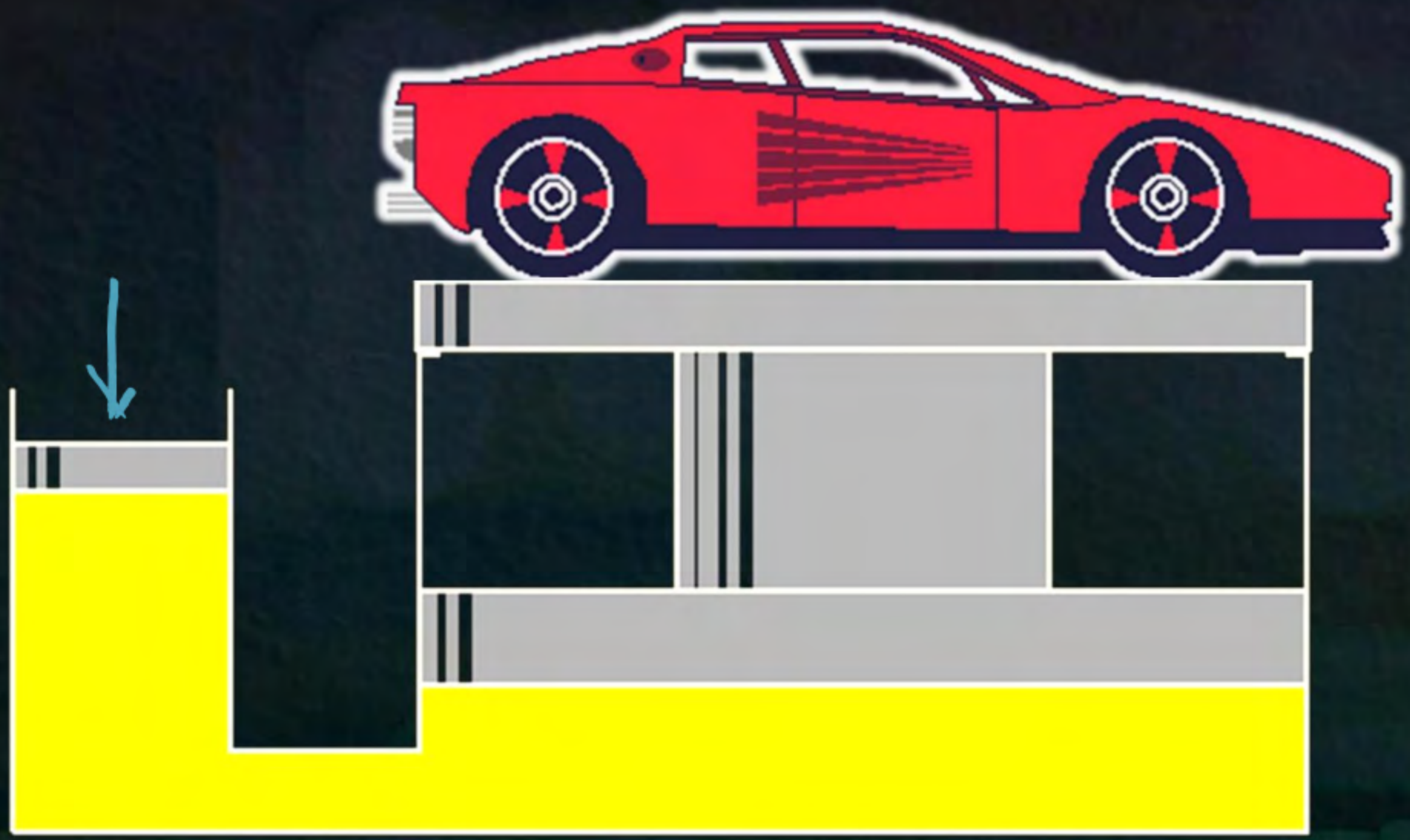
Thus a small force F_1 applied on the smaller piston A can be used to produce a large force F_2 on the bigger piston B. This is the principle of a hydraulic machine which acts as a force multiplier.

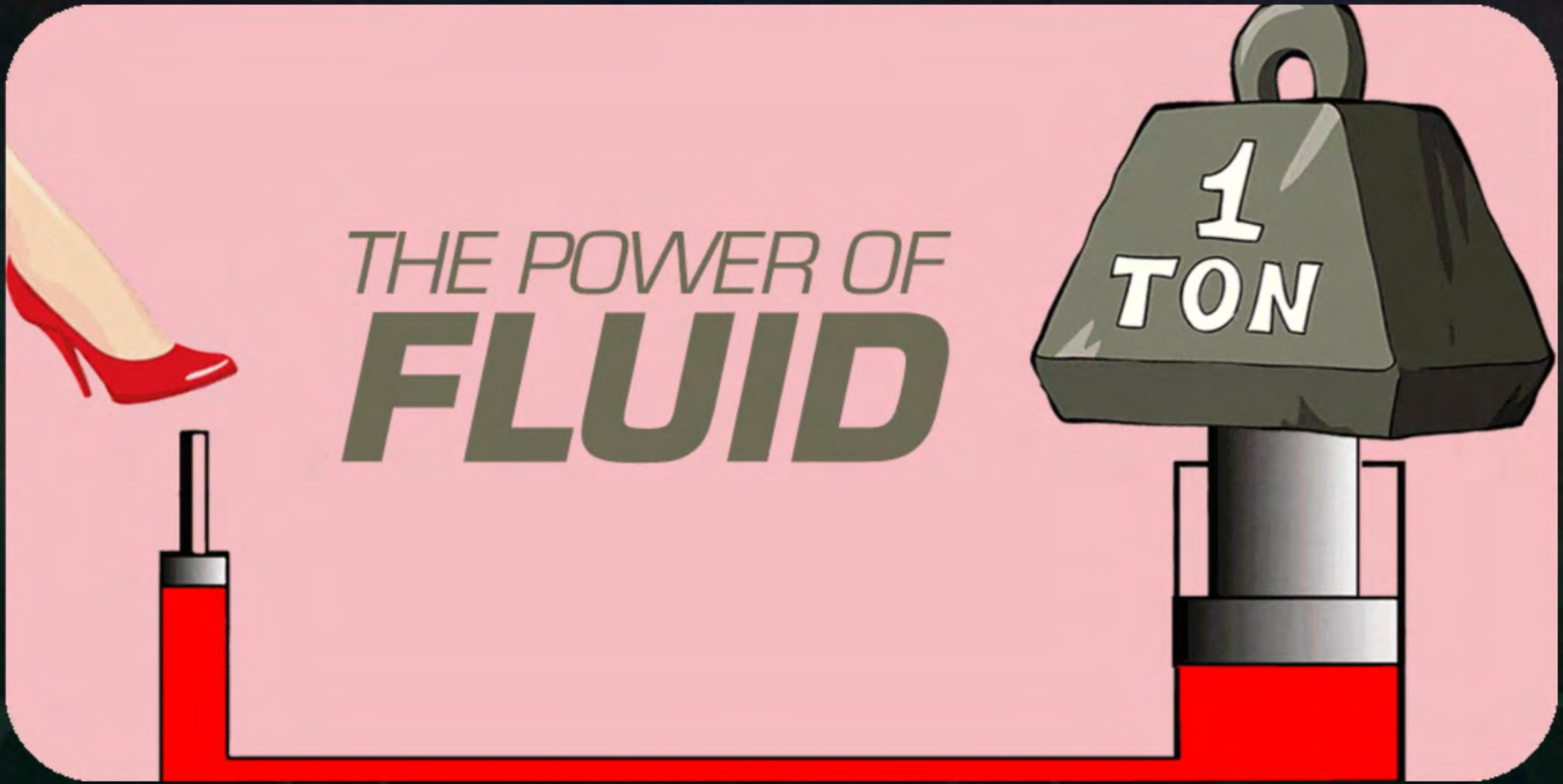
Examples of Hydraulic Machines

Hydraulic Press (or Bramah Press)

A hydraulic press works on the principle of **Pascal's Law**.



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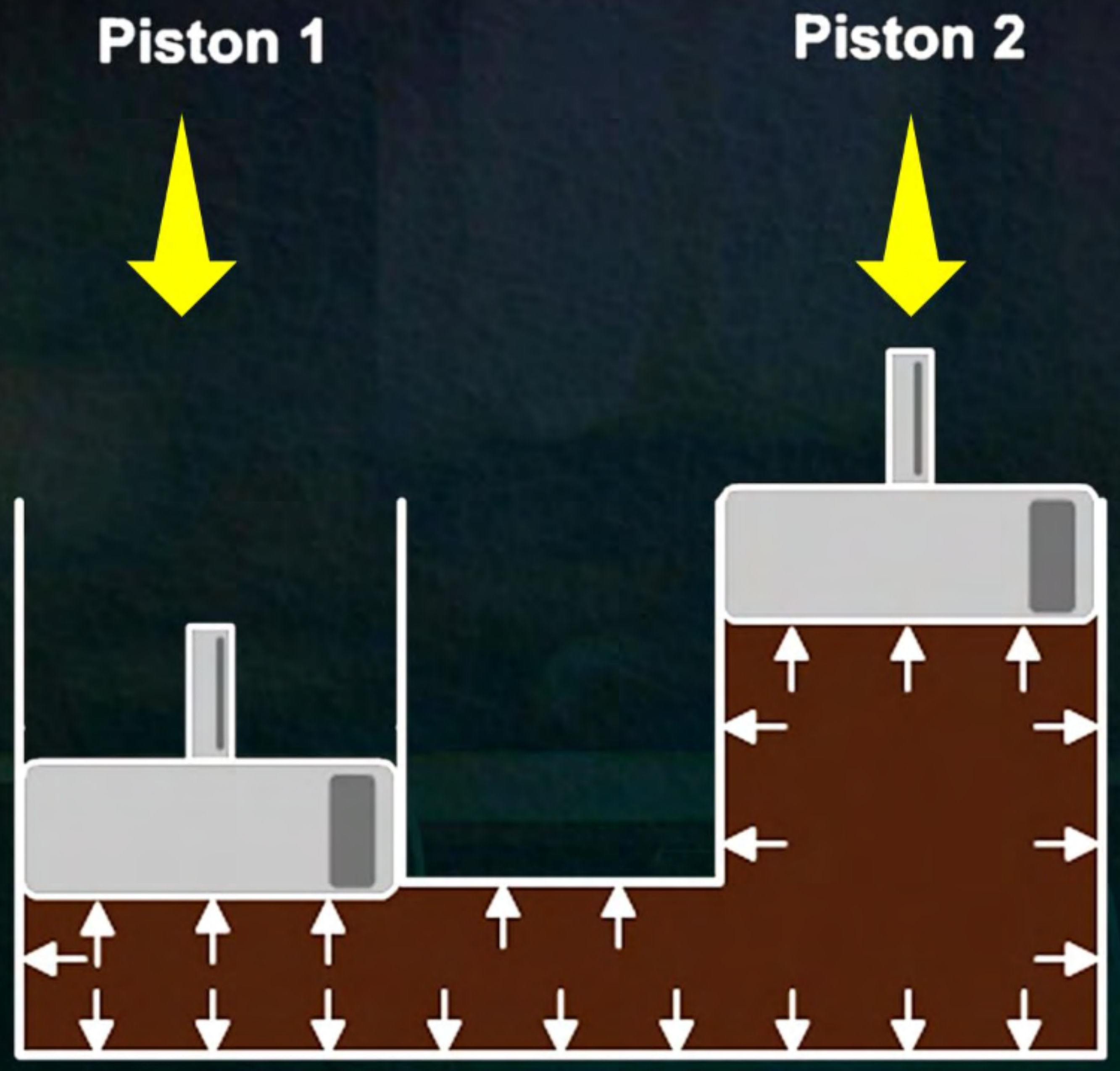
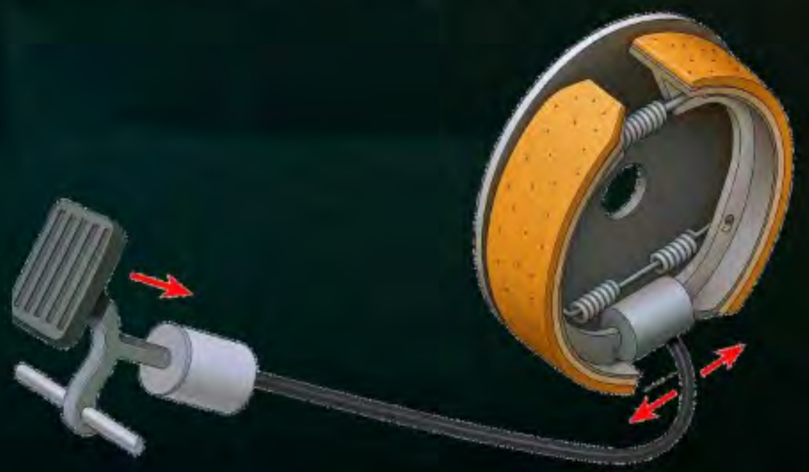
FLUID
1
TON

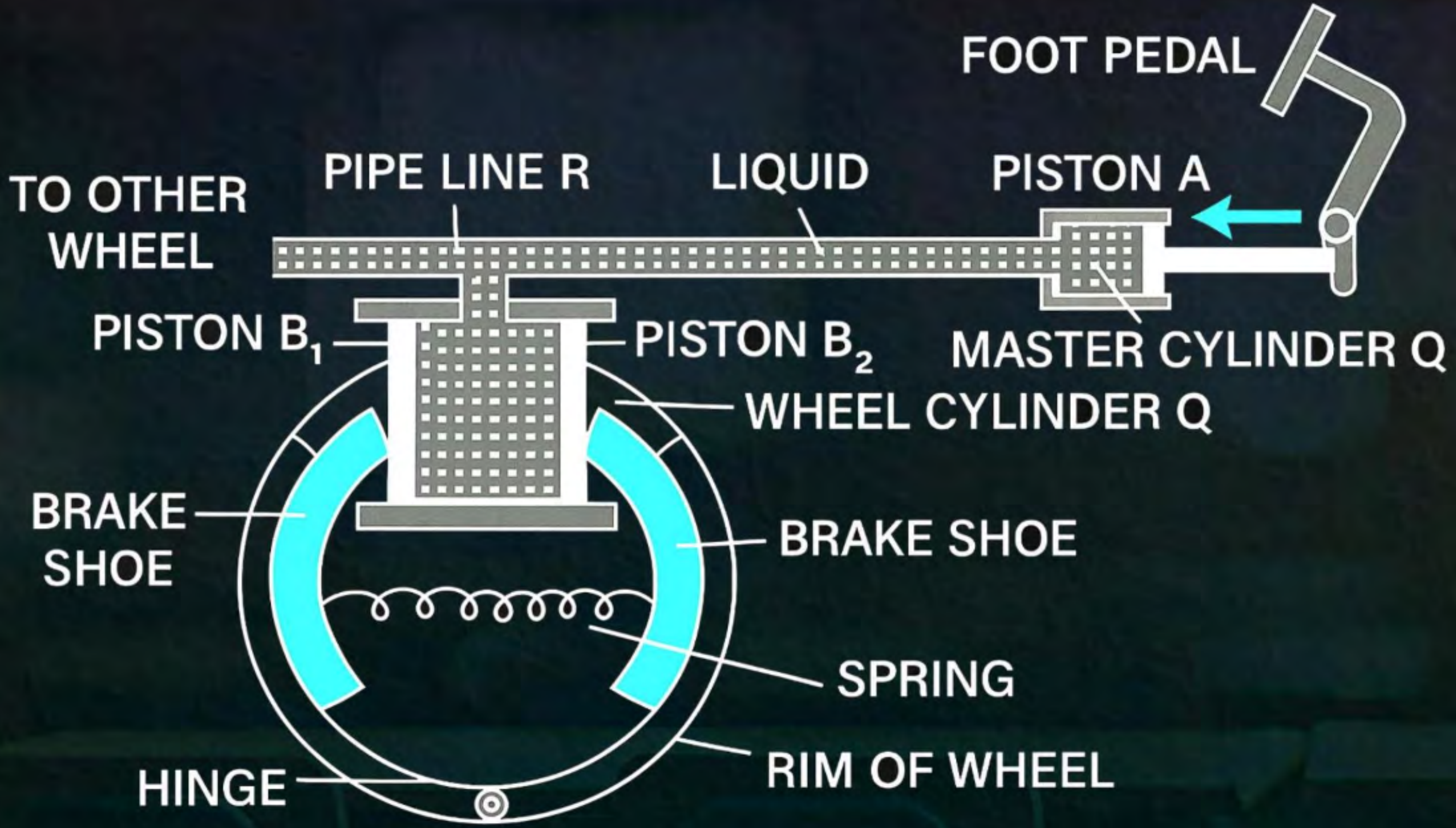


Pressure is indicated by the arrows in the fluid

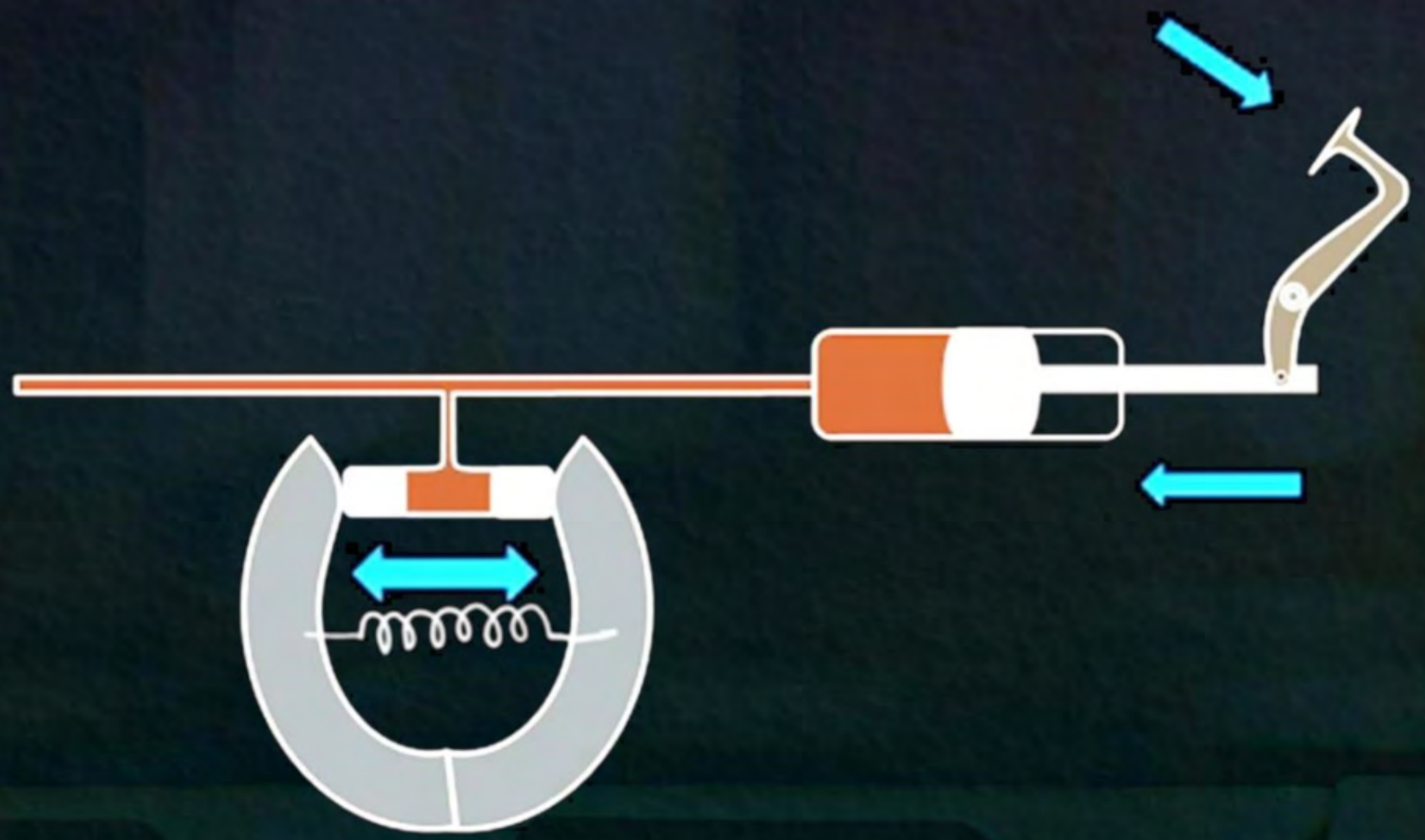
Hydraulic brakes

Construction : Fig. shows the hydraulic brake arrangement of a vehicle. It consists of a pipe line R containing a liquid (oil), one end of which is connected to the master cylinder P fitted with a piston A attached to the foot pedal. The other end of pipe R is connected to the brake arrangement of different wheels of the vehicle. Fig. shows only one wheel connected with the pipe line. For each wheel, there is a wheel cylinder Q having two pistons B_1 and B_2, attached to the brake shoes. The area of cross section of the wheel cylinder Q is greater than the area of cross section of the master cylinder P. The brake shoes press against the rim of wheel.





Hydraulic Brake




Thank You