JECRC Foundation

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTER

Class – B.Tech Civil (III SEM)
Subject –Fluid Mechanics
Unit – 1
Presented by – Ashish Boraida (Assistant Professor)

VISION AND MISSION OF INSTITUTE

<u>VISION OF INSTITUTE</u>

To became a renowned centre of outcome based learning and work towards academic professional ,cultural and social enrichment of the lives of indivisuals and communities

<u>MISSION OF INSTITUTE</u>

Focus on evaluation of learining ,outcomes and motivate students to research apptitude by project based learning.

- Identify based on informed perception of indian ,regional and global needs ,the area of focus and provide plateform to gain knowledge and solutions.
-
- Offer oppurtunites for interaction between academic and industry .
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders may emerge.

VISION AND MISSION OF DEPARTMENT

Vision

To become a role model in the field of Civil Engineering for the sustainable development of the society.

Mission

1)To provide outcome base education.

2)To create a learning environment conducive for achieving academic excellence.

3)To prepare civil engineers for the society with high ethical values.

Introduction, Objective and Outcome of Fluid Mechanics

Objective:

,
The primary purpose of the study of Fluid mechanics is to develop the capacity to understand important basic terms used in fluid mechanics, understand hydrostatics and buoyancy with practice of solving problems. Student could be able to understand Kinematics of flow and fluid dynamics, Bernoulli’s equation and laminar flow with practice of solving problems in practical life for the benefit of society and mankind.

Outcomes

- Student will be able to understand basics of fluid mechanics, types of fluids.
- Student will be able to understand fluid statics and buoyancy.
- Student will be to understand Kinematics of flow and fluid dynamics and solving relevant problems.
- Student will be to understand Bernoulli’s equation and laminar flow with practice of solving problems.

CONTENTS

Pressure

- Other pressure units commonly used in practice, especially in Europe, are bar and standard atmosphere

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa} = 100 \text{ kPa}$$

$$1 \text{ atm} = 101{,}325 \text{ Pa} = 101.325 \text{ kPa} = 1.01325 \text{ bars}$$

- The actual pressure at a given position is called the **absolute pressure,** and it is measured relative to absolute vacuum (i.e., absolute zero pressure).
- Most pressure-measuring devices, however, are calibrated to read zero in the atmosphere , and so they indicate the difference between the absolute pressure and the local atmospheric pressure. This difference is called the **gage pressure.**

Pressure

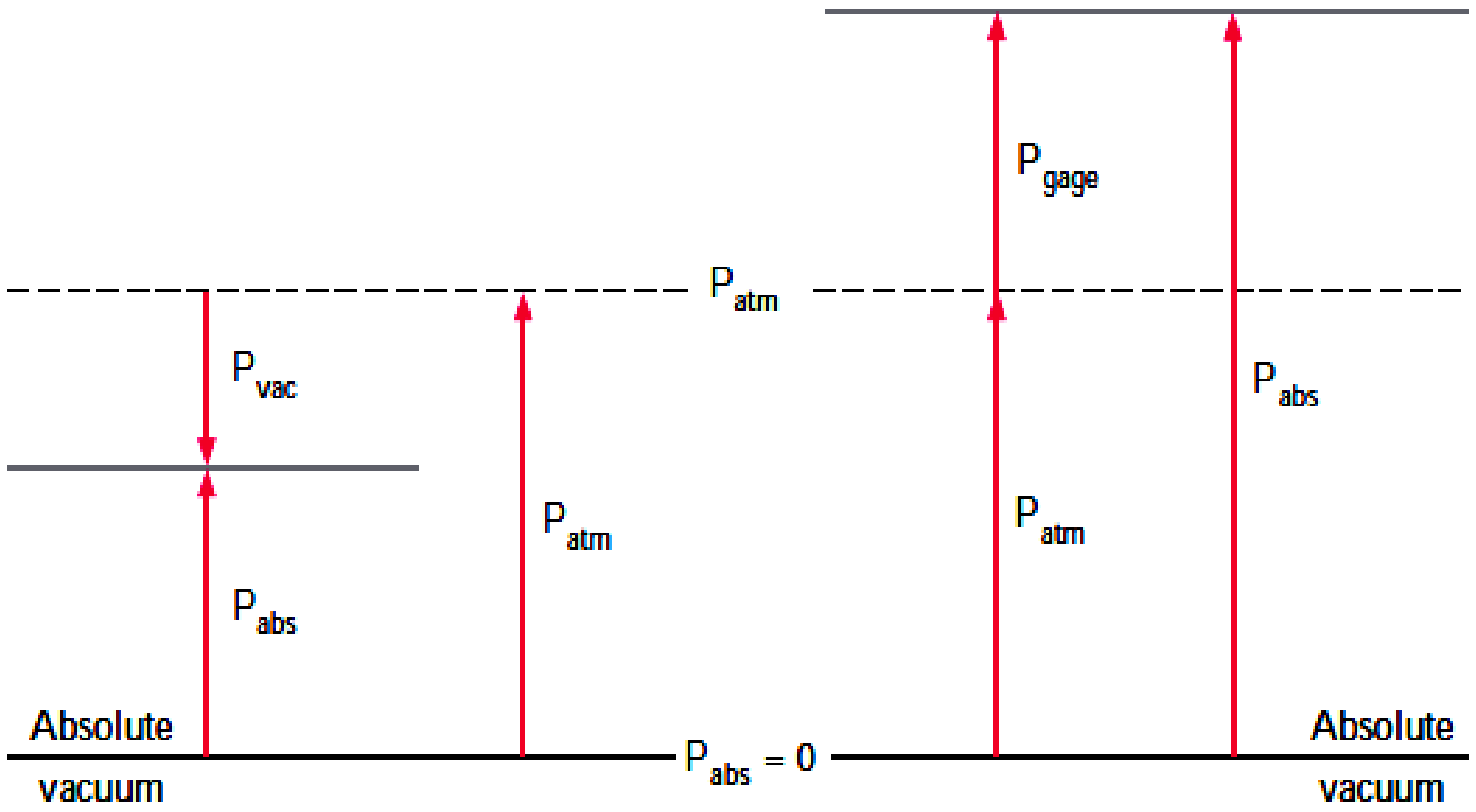
- Pressures below atmospheric pressure are called **vacuum pressures** and are measured by vacuum gages that indicate the difference between the atmospheric pressure and the absolute pressure.
- Absolute, gage, and vacuum pressures are all positive quantities and are related to each other by

$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{vac} = P_{atm} - P_{abs}$$

- In thermodynamic relations and tables, absolute pressure is almost always used. Throughout this course, the pressure P will denote absolute pressure unless specified otherwise.

Pressure

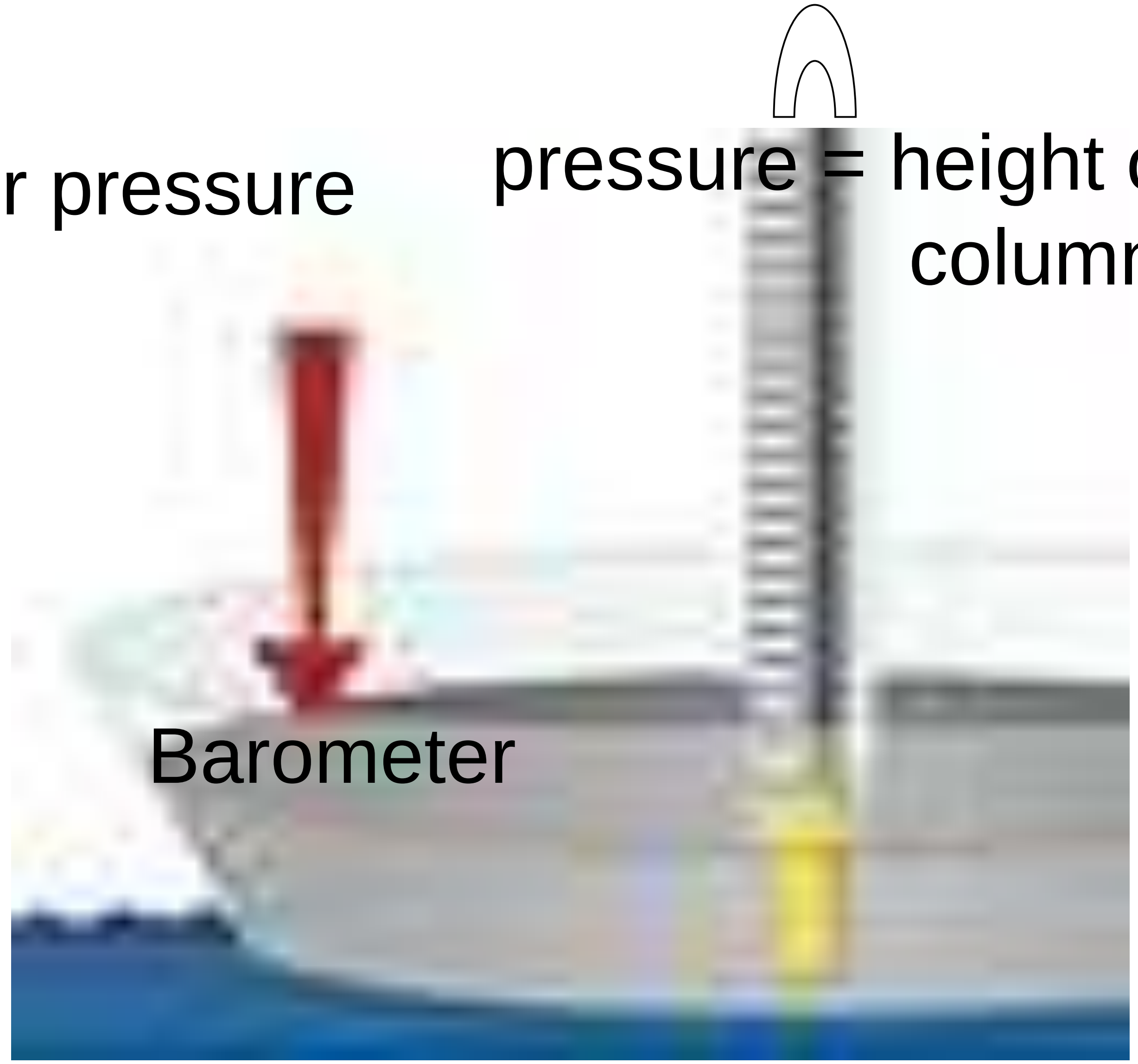


P gage
P atm
P vac
P abs
P atm
P atm
P abs
P abs
Absolute
vacuum
P abs = 0
Absolute
vacuum

Pressure at a point

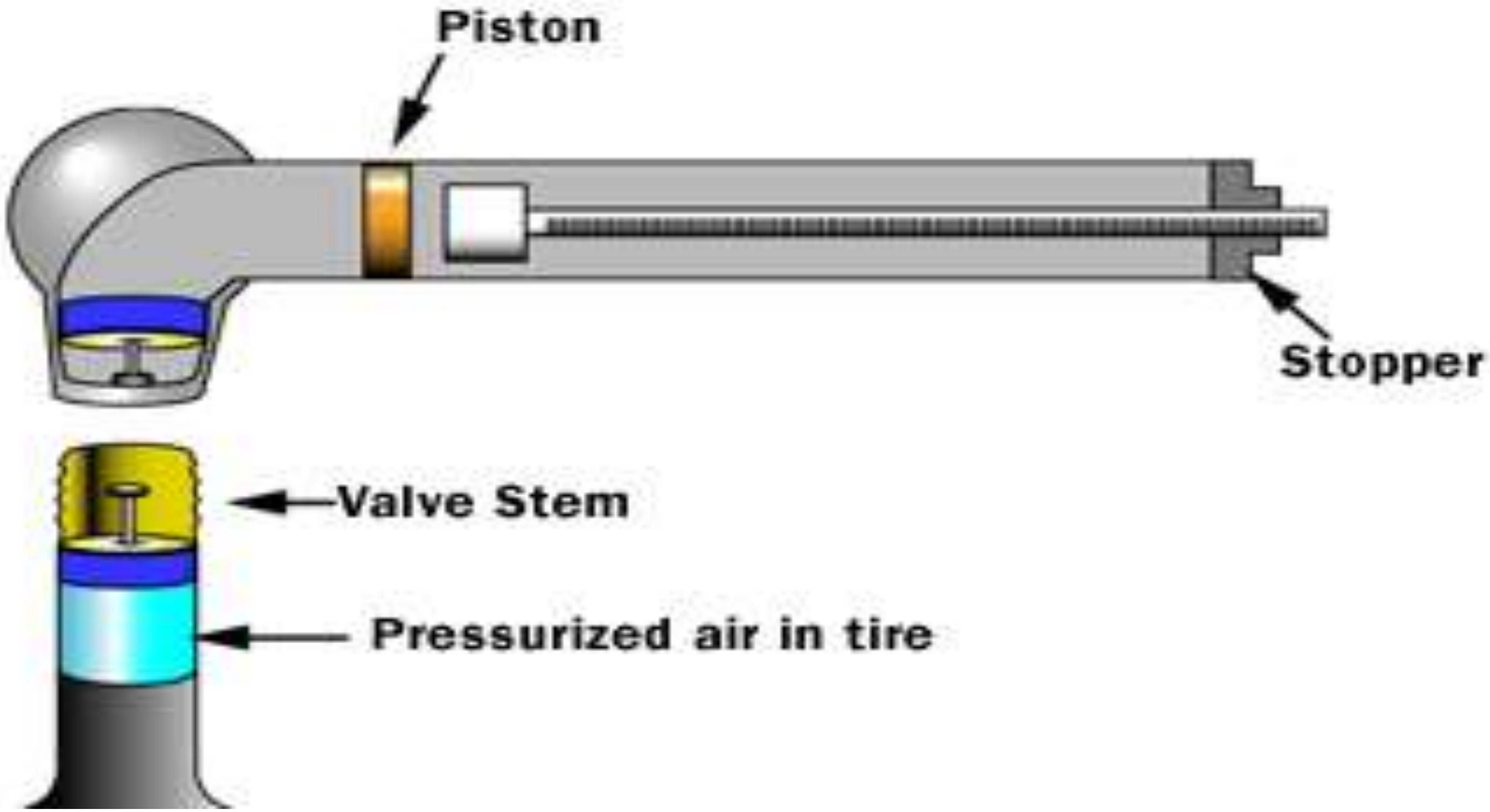
- Pressure is the compressive force per unit area, and it gives the impression of being a vector. However, pressure at any point in a fluid is the same in all directions. That is, it has magnitude but not a specific direction, and thus it is a scalar quantity.
- This can be demonstrated by considering a small wedge-shaped fluid element that was obtained by removing a small triangular wedge of fluid from some arbitrary location within a fluid mass.
- Since we are considering the situation in which there are no shearing stresses, the only external forces acting on the wedge are due to the pressure and the weight.

PRESSURE OF A FLUID

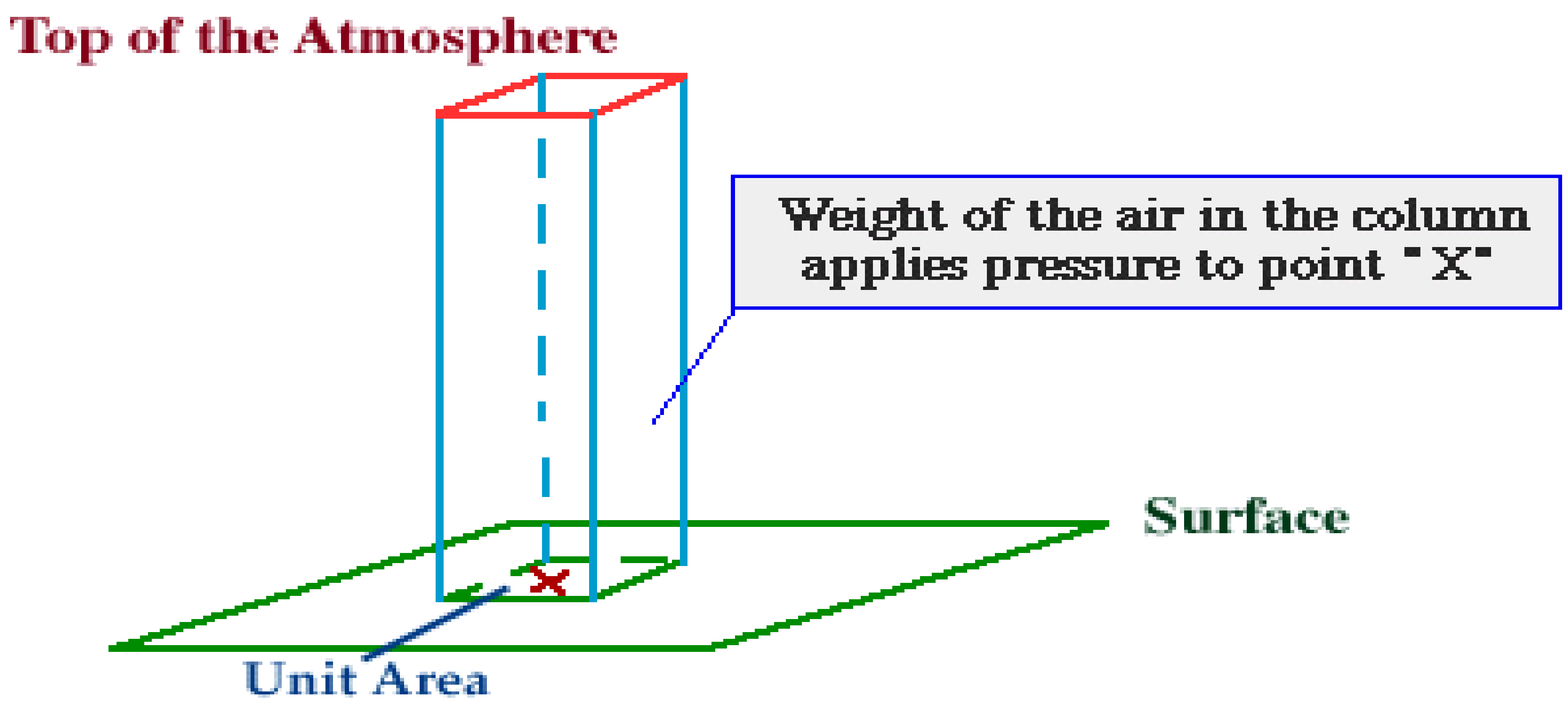


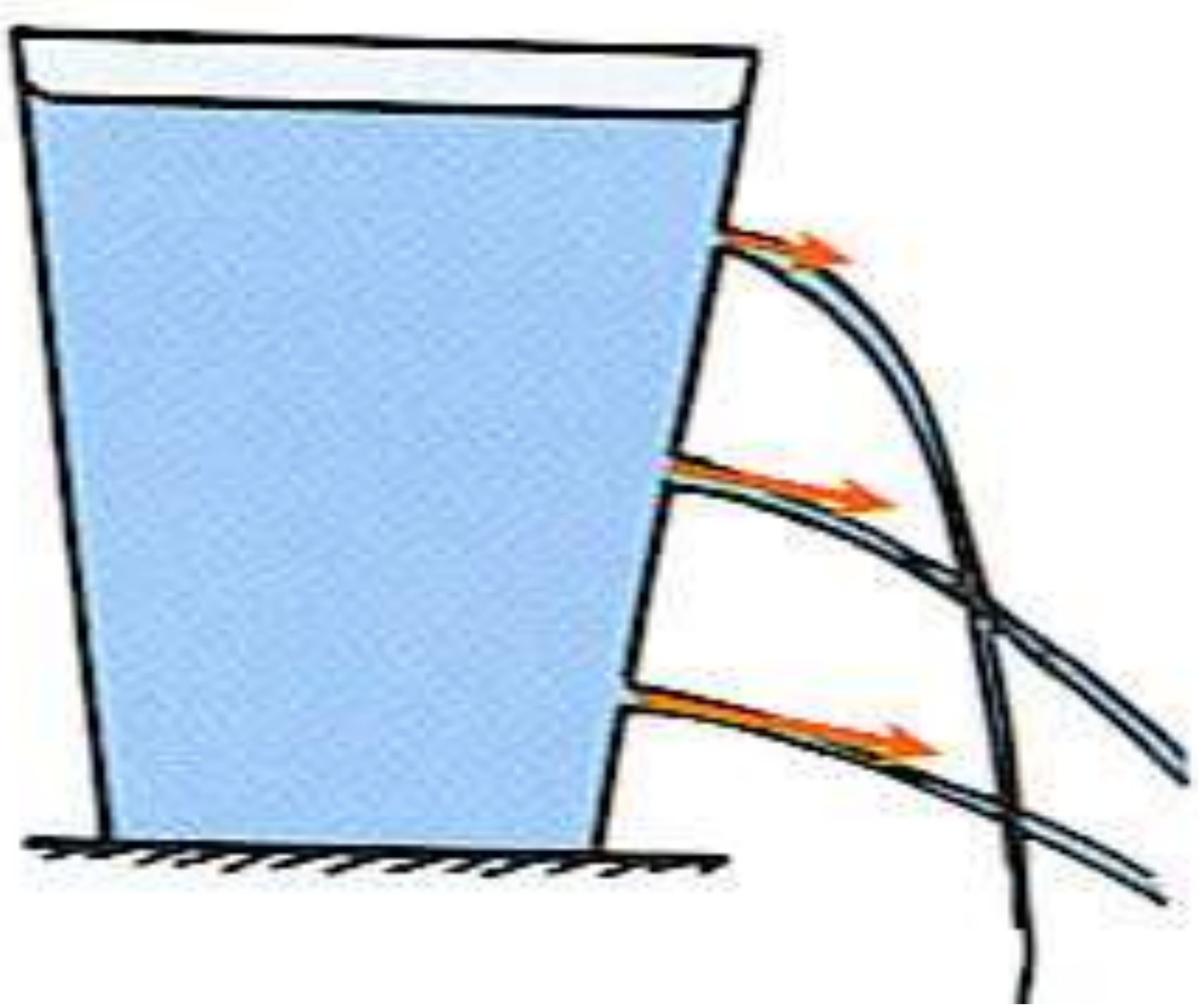
Gauge pressure – pressure above the atmospheric pressure.

absolute (total) pressure =
gauge pressure + atmospheric press.


Piston
Stopper
Valve Stem
Pressurized air in tire

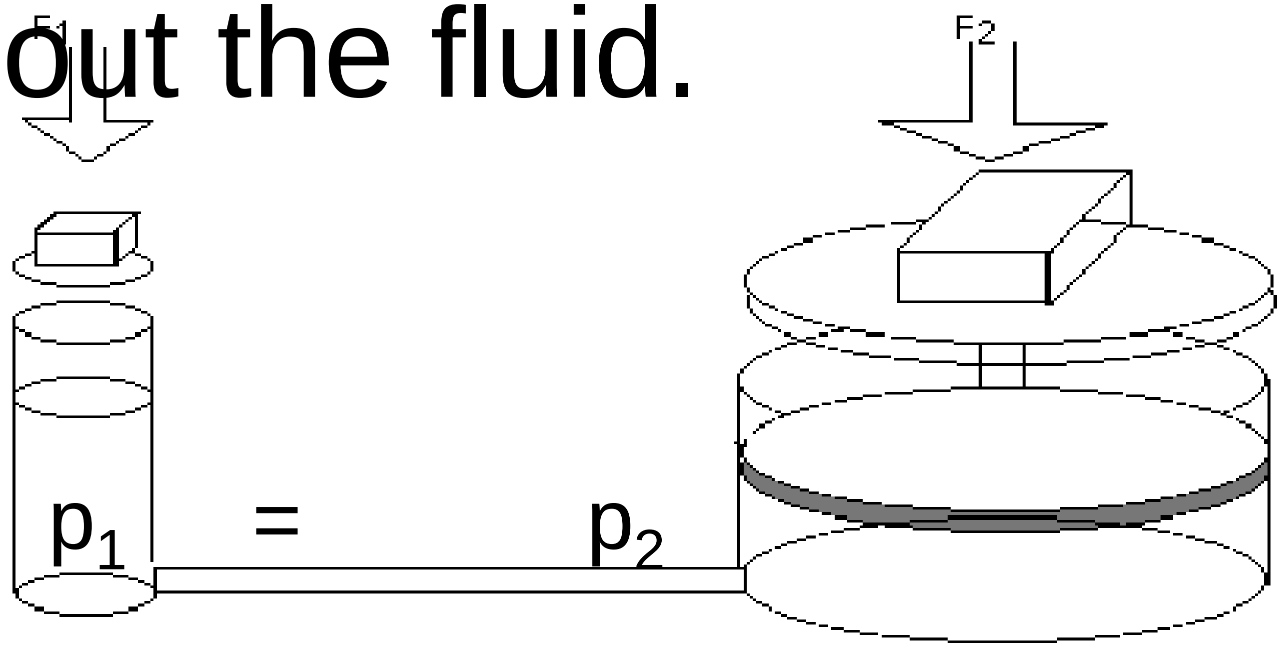
Pressure is produced by the weight of the fluid above the surface.





Pressure of fluid depends on depth.

Pascal’s Principle – The pressure in an enclosed fluid is constant throughout the fluid.



$$p_1 = p_2$$

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

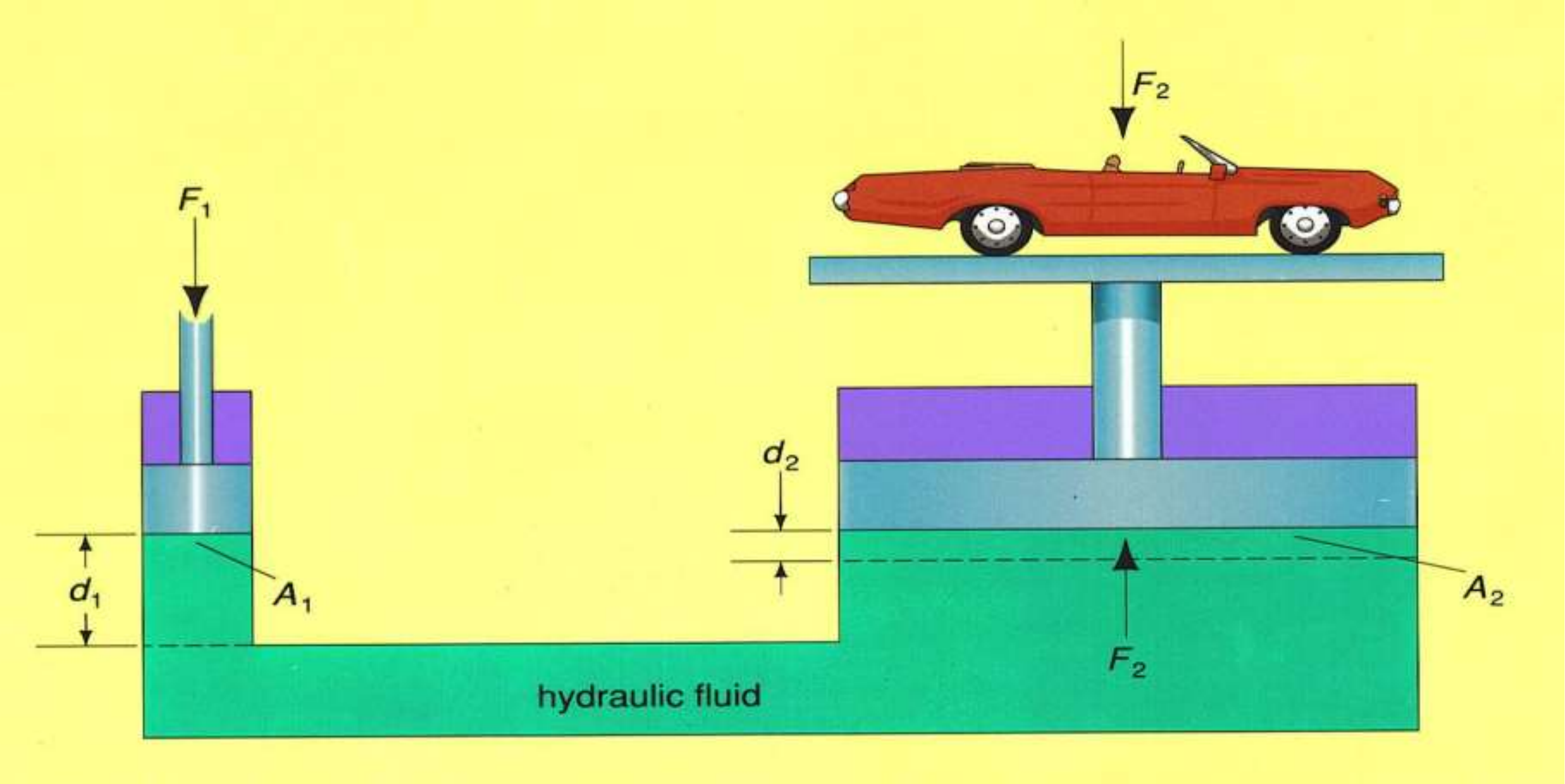
If piston on left moves 10 cm, what distance does piston on right move?

$$\text{work}_1 = \text{work}_2$$

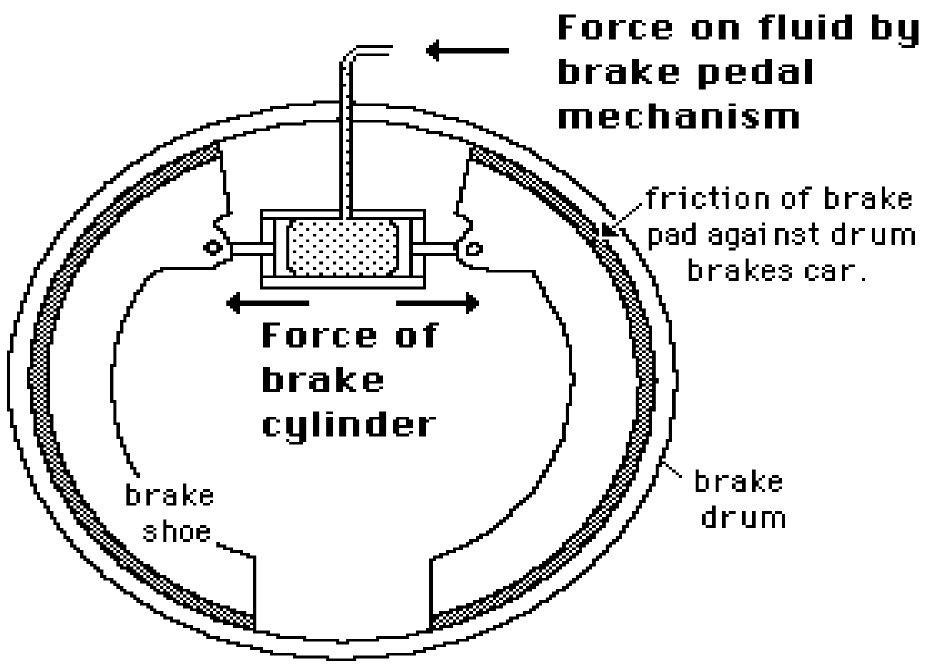
$$F_1\, d_1 = F_2\, d_2$$

$$(1)\,(10) = (50)\, d_2$$

0.2 cm



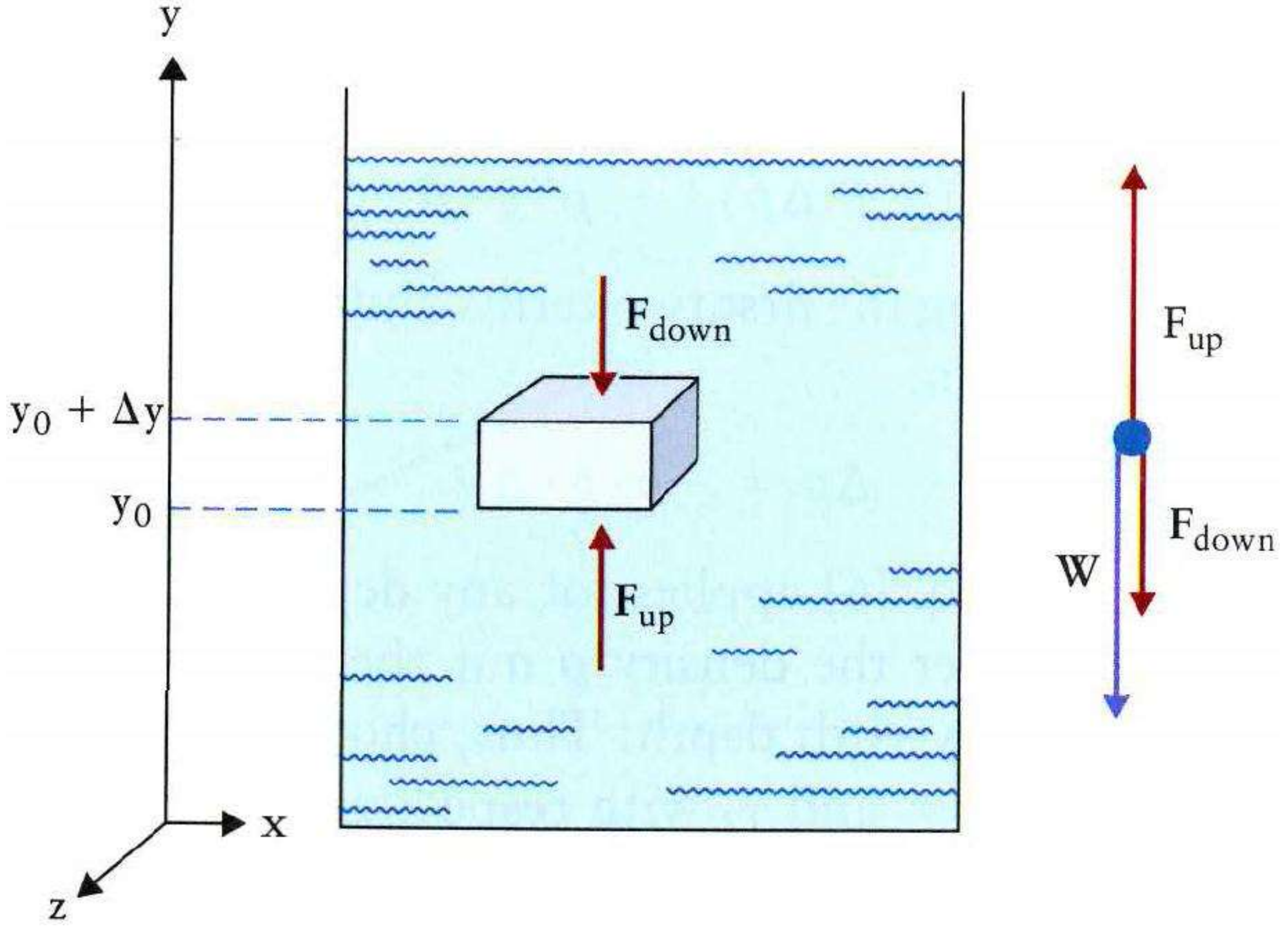
Hydraulic lift



Area of brake cylinder > area of brake line

force of brake cylinder > force of brake pedal

Pascal's Law for liquids

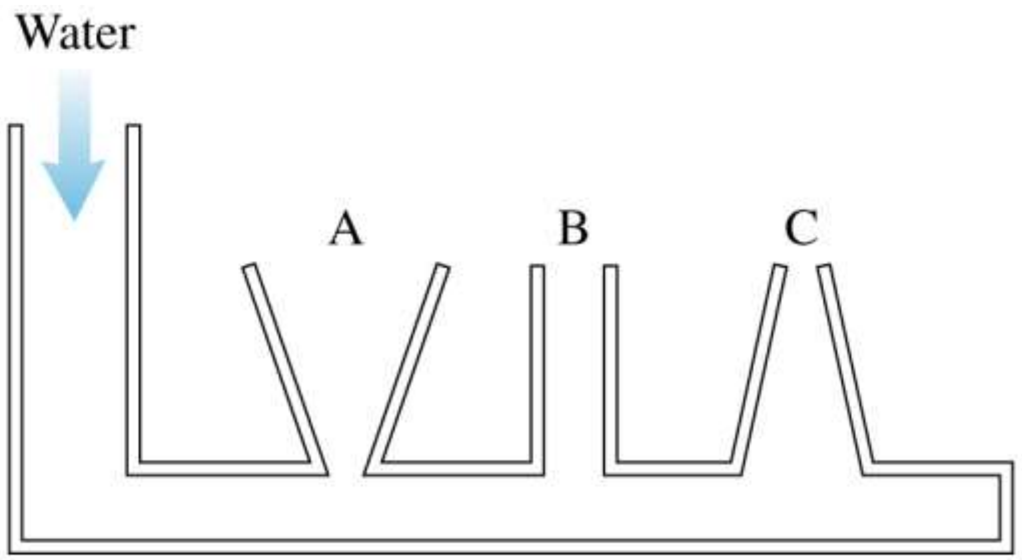


Pascal’s Law for liquids

- Consider a small element of fluid in a beaker.
- Pressure acts inward on all surfaces of the small element.
- Gravity pulls it downward.
- To balance the force of gravity, the upward pressure on the bottom surface must be greater than the downward pressure on the top surface: “buoyancy”

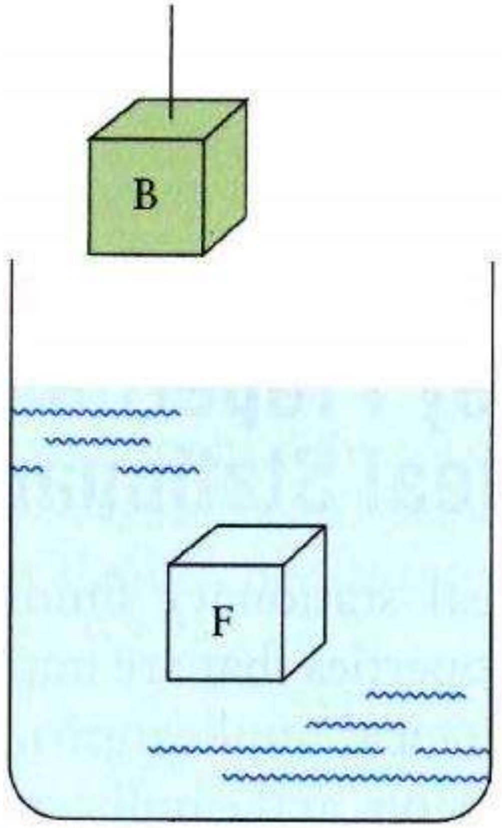
- This is the equation for the pressure of an incompressible fluid in hydrodynamic equilibrium in a gravitational field.
- Pressure increases with depth! Scuba divers know this!

Water is slowly poured into the container until the water level has risen into tubes A, B, and C. The water doesn’t overflow from any of the tubes. How do the water depths in the three columns compare to each other?



Buoyancy: Archimedes Principle

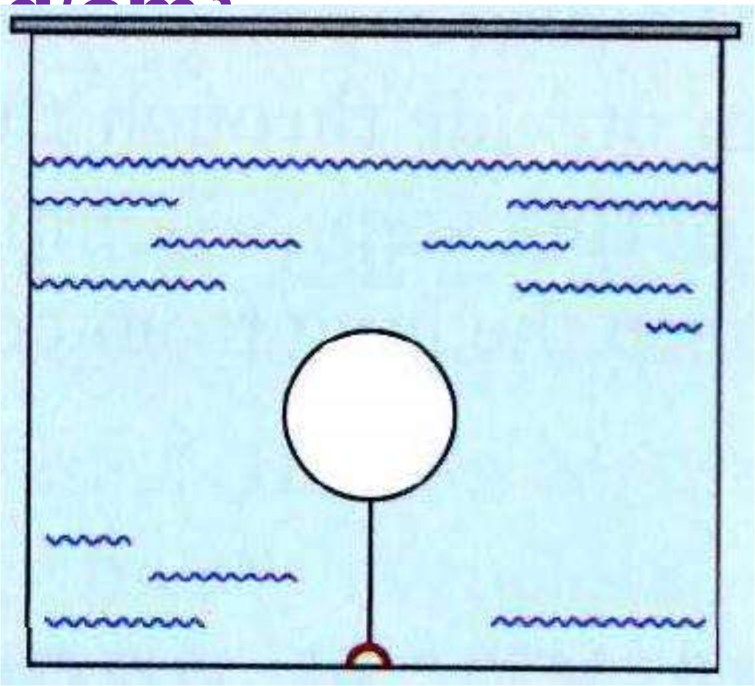
- **Let's do a "thought experiment" (Gedanken).**
- **Imagine a beaker with a fluid and a block, B, hanging near it.**
- **There is a fluid element F with the same shape and volume as the block B.**
- **The fluid element F is in mechanical equilibrium:**



- **where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of fluid F.**

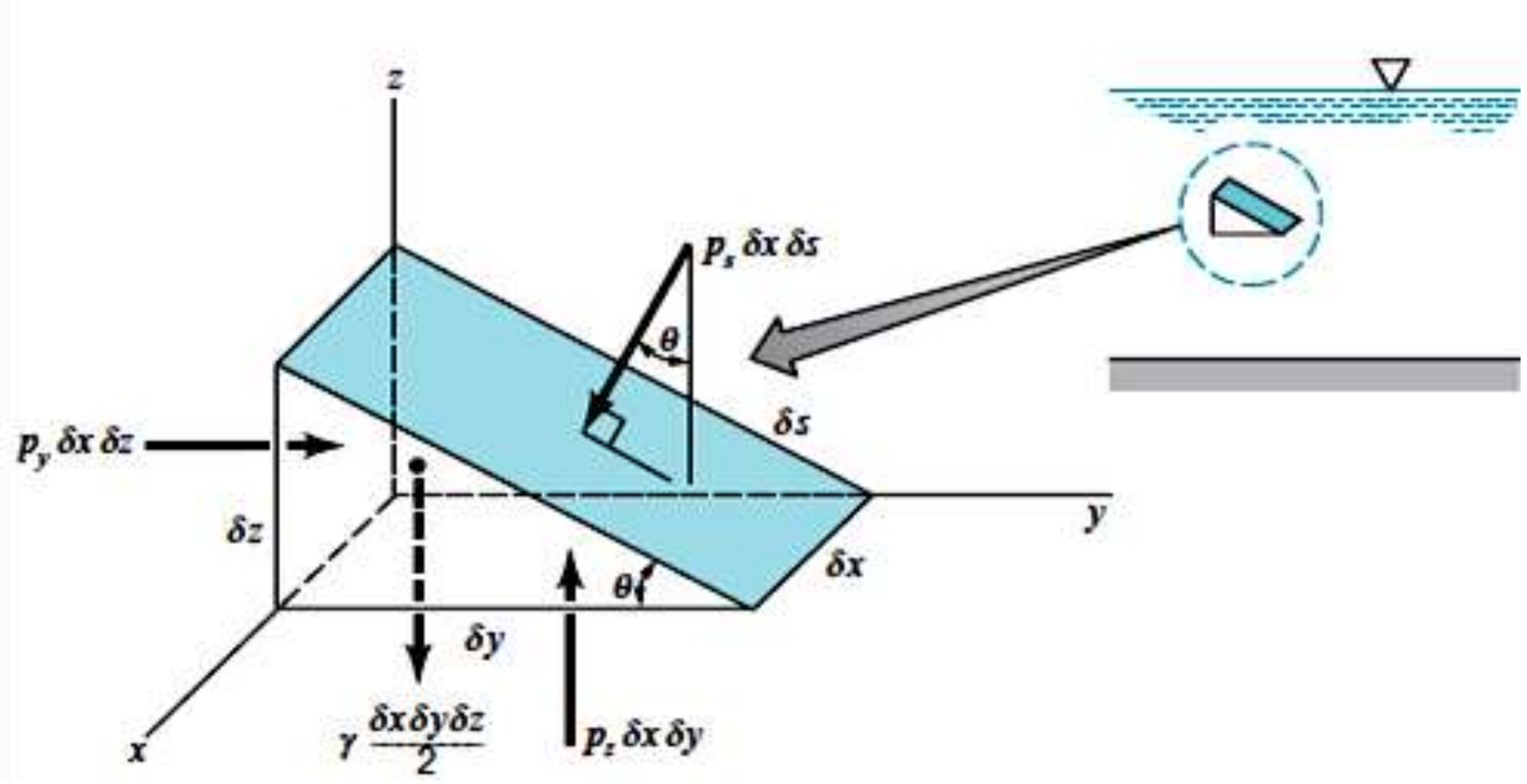
Example

- **A wooden sphere with a diameter of d = 10 cm and density ρ = 0.9 g/cm^3 is held under water by a string. What is the tension in the string?**
- **Note that the density of water in these units is 1.00 g/cm^3.**



Pressure at a point

- For simplicity the forces in the x direction are not shown, and the z axis is taken as the vertical axis so the weight acts in the negative z direction.



2
4

Pressure at a point

- From Newton's second law, a force balance in the y- and z directions gives

$$\sum F_y = p_y \delta x \delta z - p_s \delta x \delta s \sin\theta = 0 \qquad \text{(a)}$$

$$\sum F_z = p_z \delta x \delta y - p_s \delta x \delta s \cos\theta - \gamma \frac{\delta x \delta y \delta z}{2} = 0 \qquad \text{(b)}$$

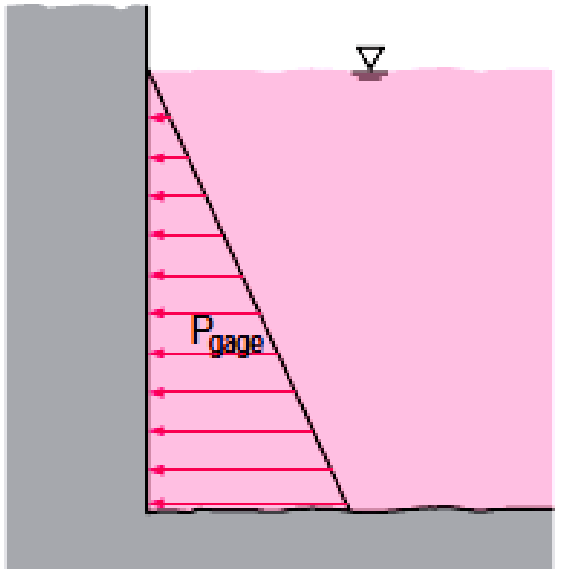
- where p_s, p_y and p_z are the average pressures on the faces, γ and ρ are the fluid specific weight and density
- From the geometry

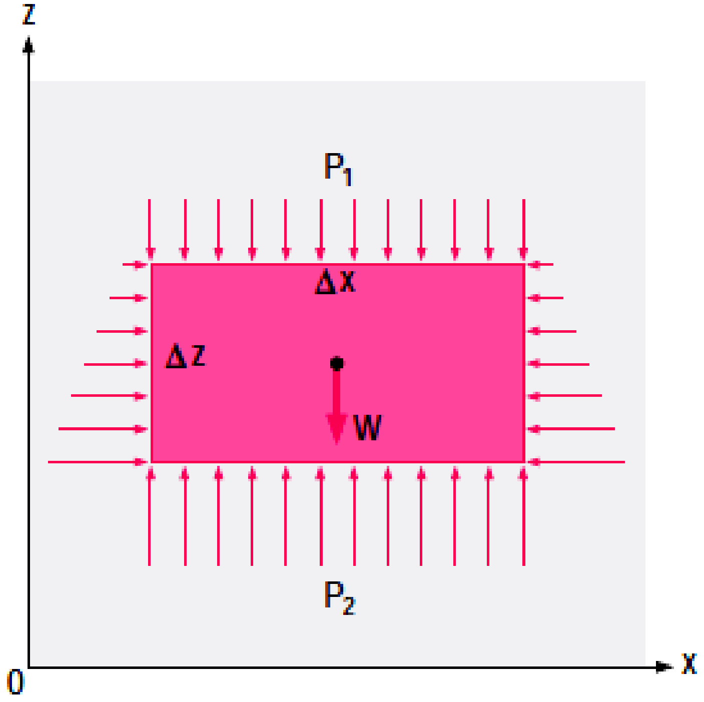
$$\delta y = \delta s \cos\theta \qquad \delta z = \delta s \sin\theta$$

- The last term in Eq. b drops out as δx ,δy and $\delta z \to 0$ and the wedge becomes infinitesimal, and thus the fluid element shrinks to a point.

Variation of pressure with depth

- Pressure in a fluid increases with depth because more fluid rests on deeper layers, and the effect of this “extra weight” on a deeper layer is balanced by an increase in pressure.
- To obtain a relation for the variation of pressure with depth, consider a rectangular fluid element of height Δz, length Δx, and unit depth (into the page) in equilibrium.
- Assuming the density of the fluid ρ to be constant, a force balance in the vertical z-direction gives

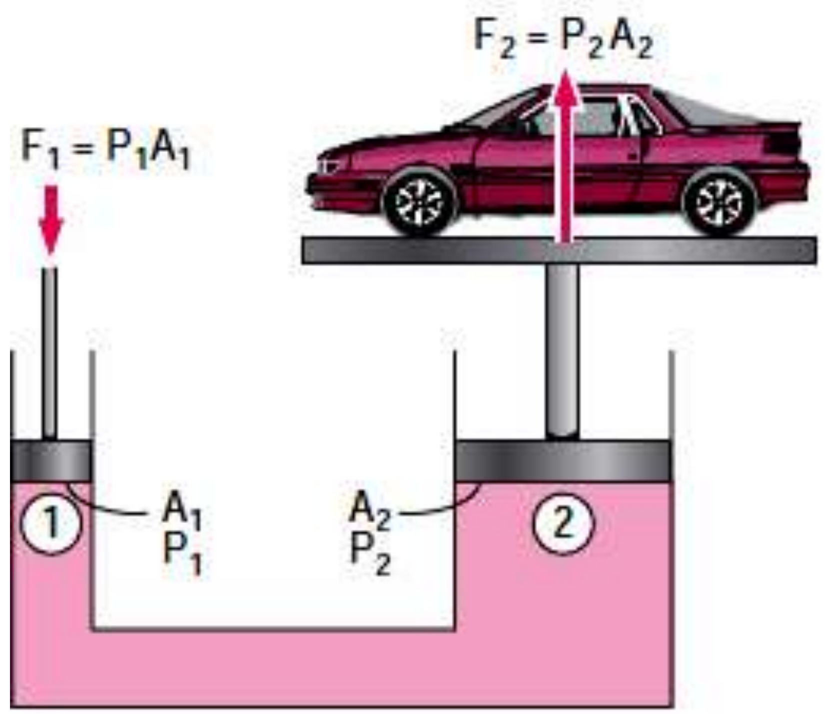




Variation of pressure with depth

Application of Pascal's law

- Two hydraulic cylinders of different areas could be connected, and the larger could be used to exert a proportionally greater force than that applied to the smaller.
- Noting that $P_1 = P_2$ since both pistons are at the same level.

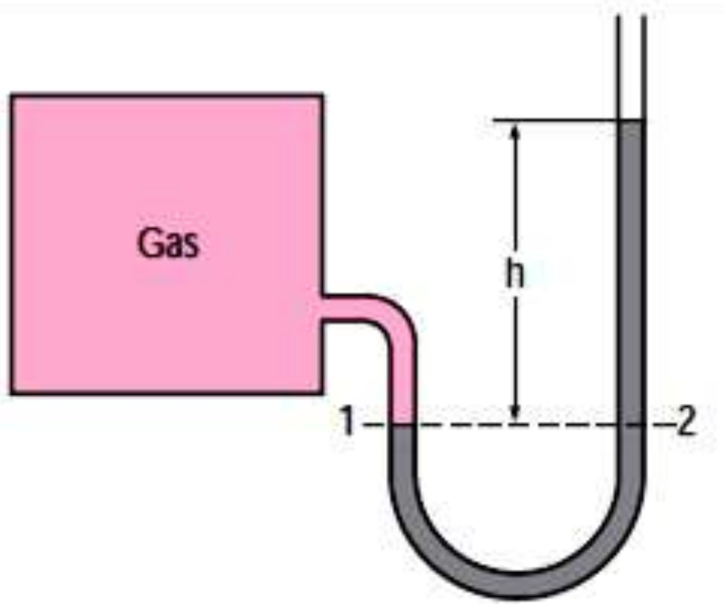


The area ratio A_2/A_1 is called the ideal mechanical advantage of the hydraulic lift.

$$P_1 = P_2 \quad \rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \rightarrow \quad \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

U-tube Manometer

- Consider the manometer that is used to measure the pressure in the tank.
- Since the gravitational effects of gases are negligible, the pressure anywhere in the tank and at position 1 has the same value.
- Furthermore, since pressure in a fluid does not vary in the horizontal direction within a fluid, the pressure at point 2 is the same as the pressure at point 1, $P_2 = P_1$.



The differential fluid column of height h is in static equilibrium, and it is open to the atmosphere. Then the pressure at point 2 is determined directly by

$$P_2 = P_{atm} + \rho g h$$

Differential Manometer

- Manometers are particularly well-suited to measure pressure drops across a horizontal flow section between two specified points due to the presence of a device such as a valve or heat exchanger or any resistance to flow.
- This is done by connecting the two legs of the manometer to these two points, as shown in the Fig.
- The working fluid can be either a gas or a liquid whose density is ρ_1. The density of the manometer fluid is ρ_2, and the differential fluid height is *h*.

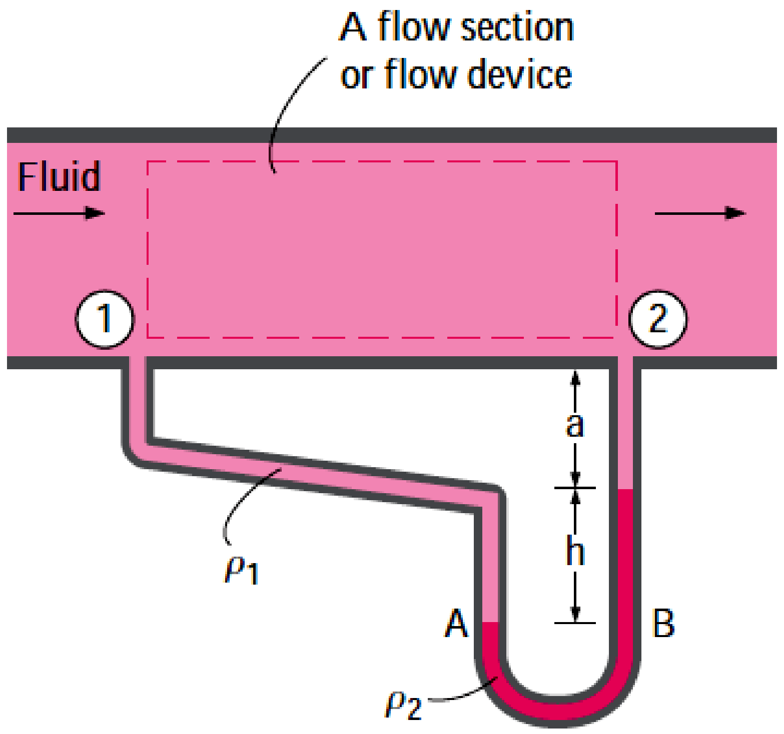
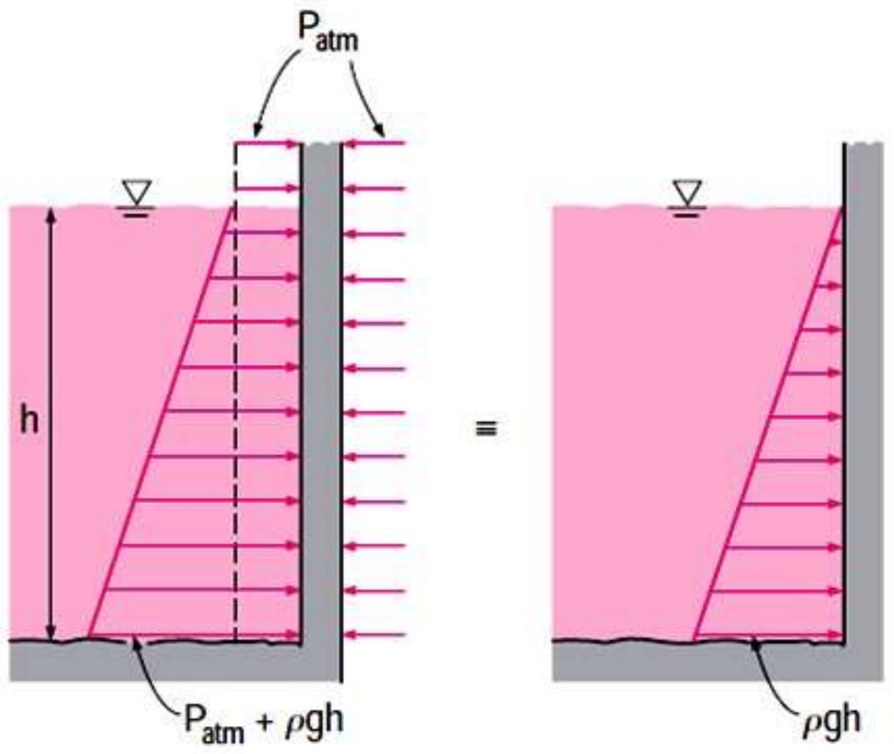


Fig. Measuring the pressure drop across a flow section or a flow device by a differential manometer.

Hydrostatic Forces on Submerged Plane surfaces

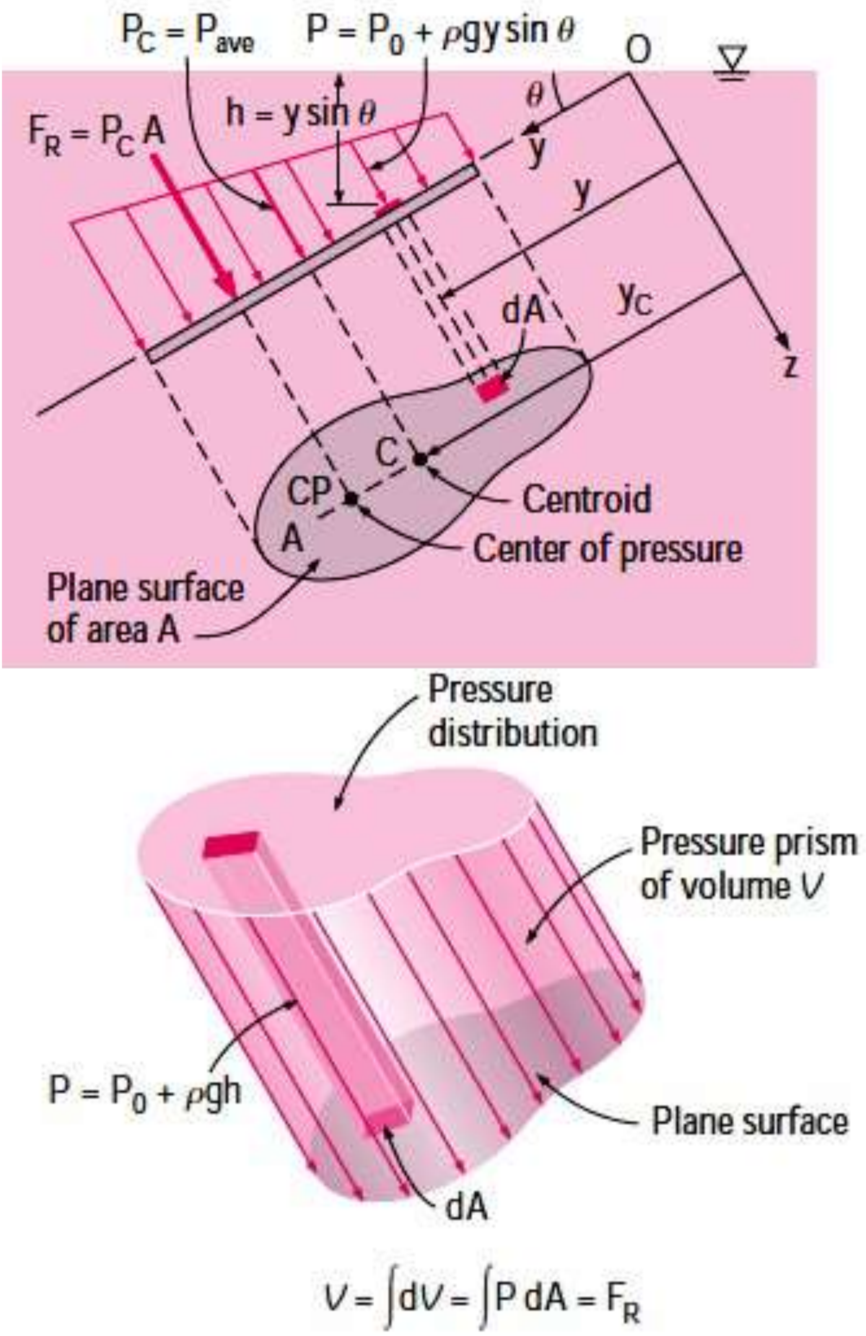
- In most cases, the other side of the plate is open to the atmosphere (such as the dry side of a gate), and thus atmospheric pressure acts on both sides of the plate, yielding a zero resultant.
- In such cases, it is convenient to subtract atmospheric pressure and work with the gage pressure only



(a) P_{atm} considered
(b) P_{atm} subtracted

Hydrostatic Forces on Submerged Plane surfaces

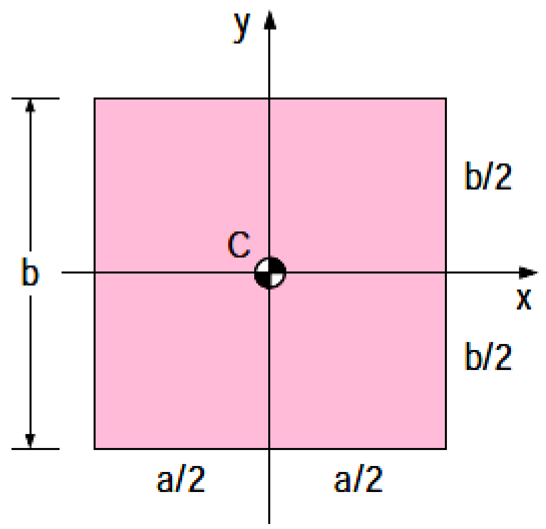
- Consider the top surface of a flat plate of arbitrary shape completely submerged in a liquid.
- The plane of this surface (normal to the page) intersects the horizontal free surface with an angle θ, and we take the line of intersection to be the *x-axis*.



Center of pressure

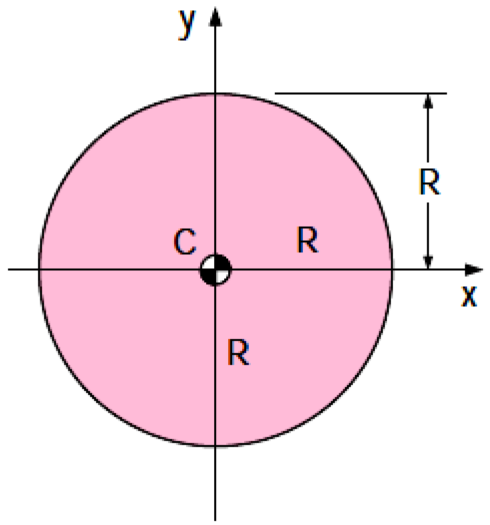
- The line of action of the resultant hydrostatic force, in general, does not pass through the centroid of the surface—it lies underneath where the pressure is higher.
- The point of intersection of the line of action of the resultant force and the surface is the **center of pressure.**
- The vertical location of the line of action is determined by equating the moment of the resultant force to the moment of the distributed pressure force about the *x-axis. It gives*
- or $$y_P F_R = \int_A yP\,dA = \int_A y(P_0 + \rho g y \sin\theta)\,dA = P_0 \int_A y\,dA + \rho g \sin\theta \int_A y^2\,dA$$

$$y_P F_R = P_0 y_C A + \rho g \sin\theta\, I_{xx,\,O}$$



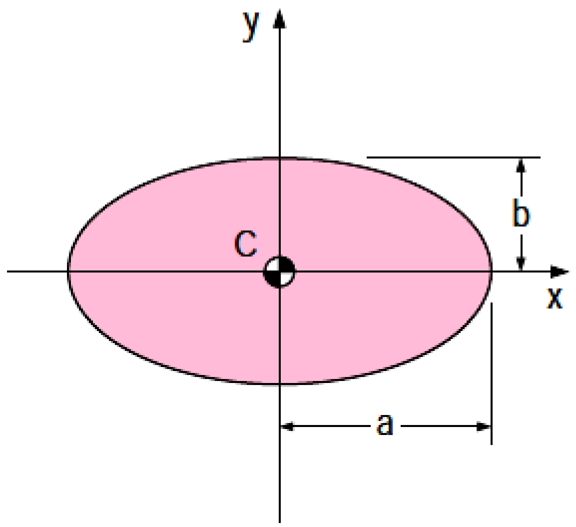
$A = ab, \; I_{xx,C} = ab^3/12$

(a) Rectangle



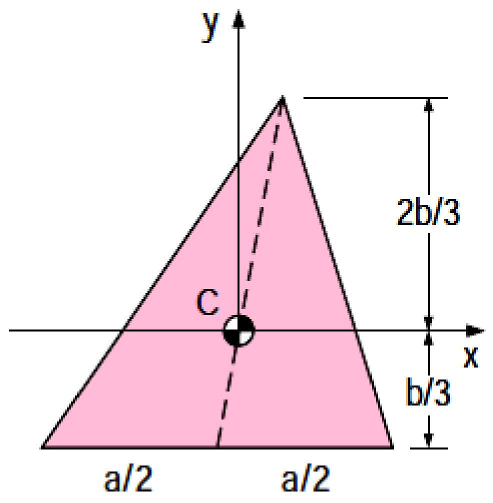
$A = \pi R^2, \; I_{xx,C} = \pi R^4/4$

(b) Circle



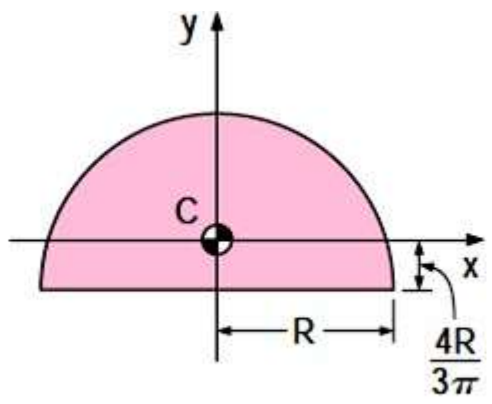
$A = \pi ab, \; I_{xx,C} = \pi ab^3/4$

(c) Ellipse



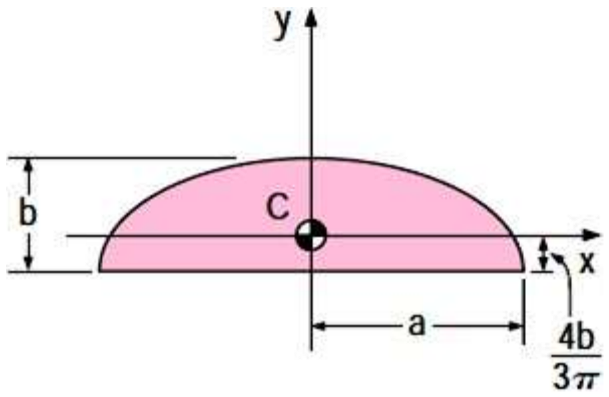
$A = ab/2, \; I_{xx,C} = ab^3/36$

(d) Triangle



$A = \pi R^2/2, \; I_{xx,C} = 0.109757R^4$

(e) Semicircle

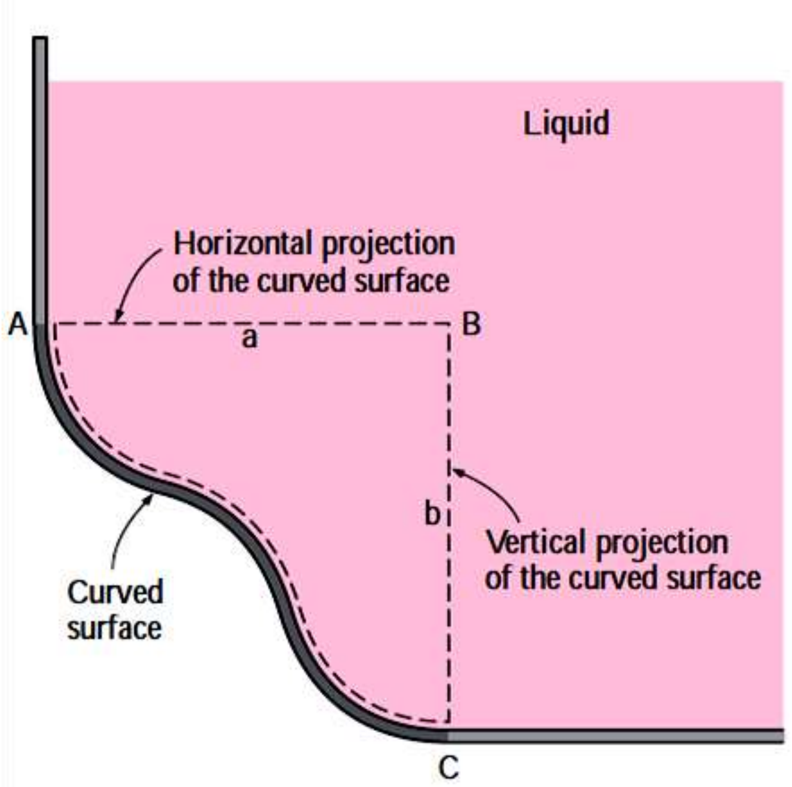


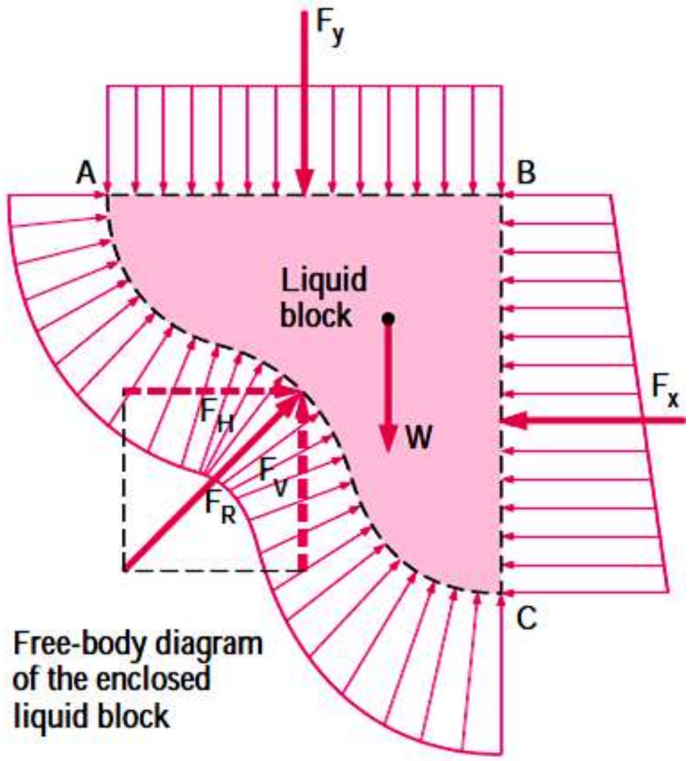
$A = \pi ab/2, \; I_{xx,C} = 0.109757ab^3$

(f) Semiellipse

Hydrostatic Forces on submerged curved surfaces

 The resultant force acting on the curved solid surface is then equal and opposite to the force acting on the curved liquid surface (Newton’s third law).





Hydrostatic Forces on submerged curved surfaces

- The weight of the enclosed liquid block of volume V is simply $W = \rho g V$, and it acts downward through the centroid of this volume.
- Noting that the fluid block is in static equilibrium, the force balances in the horizontal and vertical directions give

Horizontal force component on curved surface: $F_H = F_x$

Vertical force component on curved surface: $F_V = F_y + W$

- where the summation $F_y + W$ is a vector addition (i.e., add magnitudes if both act in the same direction and subtract if they act in opposite directions).
- The magnitude of the resultant hydrostatic force acting on the curved surface is $F_R = \sqrt{F_H^2 + F_V^2}$, tangent of the angle it makes with the horizontal is $\tan \alpha = F_V / F_H$

What Causes Buoyancy? : Pressure!

Recall: The pressure at depth *d* in a liquid is

where ρ is the liquid's density, and p_0 is the pressure at the surface of the liquid. Because the fluid is at rest, the pressure is called the **hydrostatic pressure**. The fact that *g* appears in the equation reminds us that there is a gravitational contribution to the pressure.

Fluid Mechanics

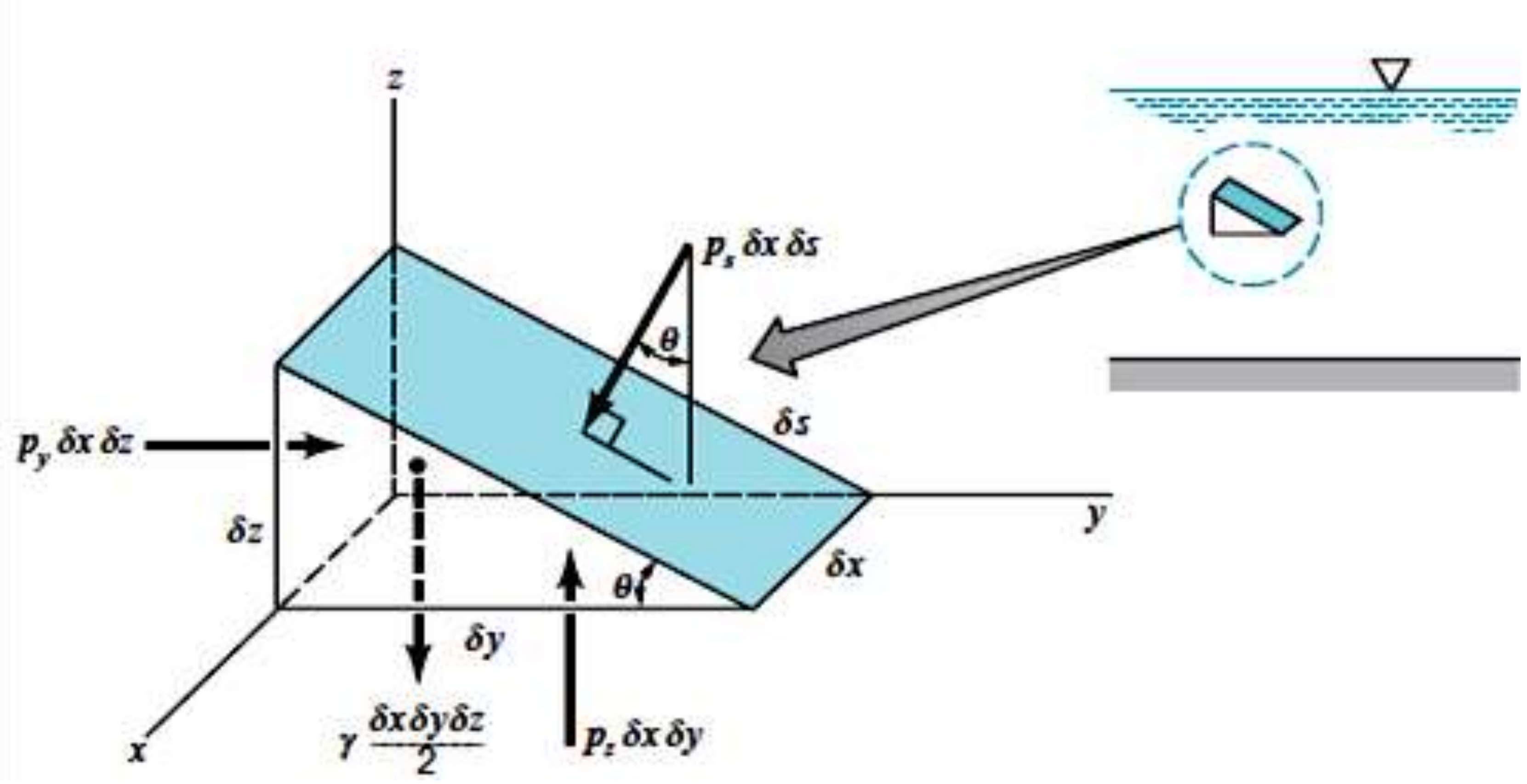
The branch of physical science that deals the study of fluids at rest or in motion.

- It has traditionally been applied in such areas as the design of canal, and dam systems.

- The aerodynamics of automobiles and sub- and supersonic airplanes;
and the development of many different flow measurement devices such as gas pump meters

Pressure at a point

- For simplicity the forces in the x direction are not shown, and the z axis is taken as the vertical axis so the weight acts in the negative z direction.



3
8

Pressure at a point

- From Newton's second law, a force balance in the y- and z directions gives

$$\sum F_y = p_y \delta x \delta z - p_s \delta x \delta s \sin\theta = 0 \qquad \text{(a)}$$

$$\sum F_z = p_z \delta x \delta y - p_s \delta x \delta s \cos\theta - \gamma \frac{\delta x \delta y \delta z}{2} = 0 \qquad \text{(b)}$$

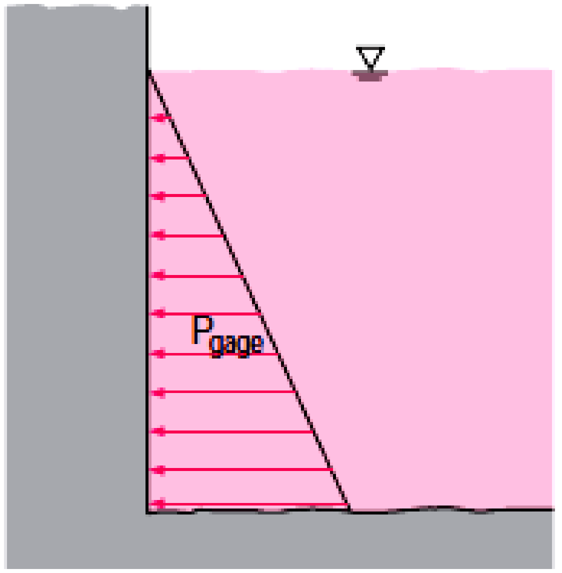
- where p_s, p_y and p_z are the average pressures on the faces, γ and ρ are the fluid specific weight and density
- From the geometry

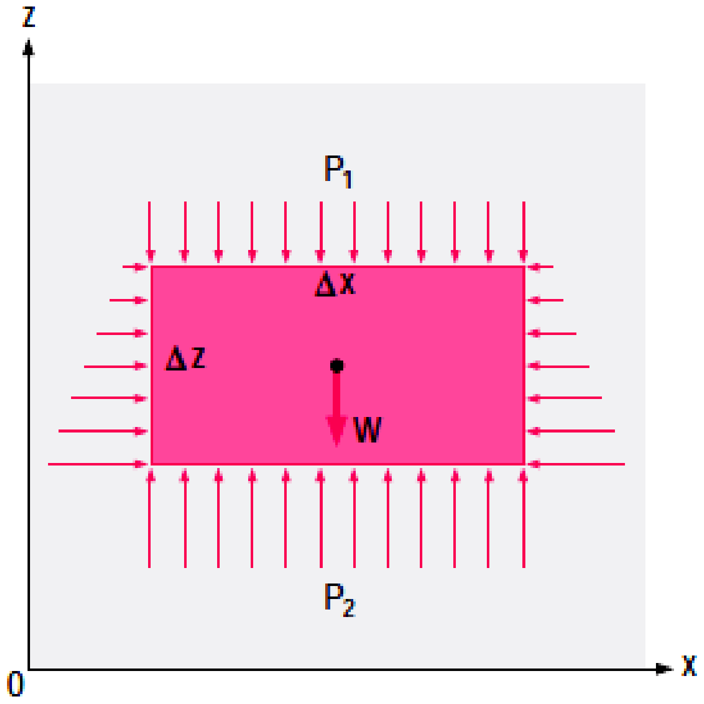
$$\delta y = \delta s \cos\theta \qquad \delta z = \delta s \sin\theta$$

- The last term in Eq. b drops out as δx ,δy and $\delta z \rightarrow 0$ and the wedge becomes infinitesimal, and thus the fluid element shrinks to a point.

Variation of pressure with depth

- Pressure in a fluid increases with depth because more fluid rests on deeper layers, and the effect of this “extra weight” on a deeper layer is balanced by an increase in pressure.
- To obtain a relation for the variation of pressure with depth, consider a rectangular fluid element of height Δz, length Δx, and unit depth (into the page) in equilibrium.
- Assuming the density of the fluid ρ to be constant, a force balance in the vertical z-direction gives

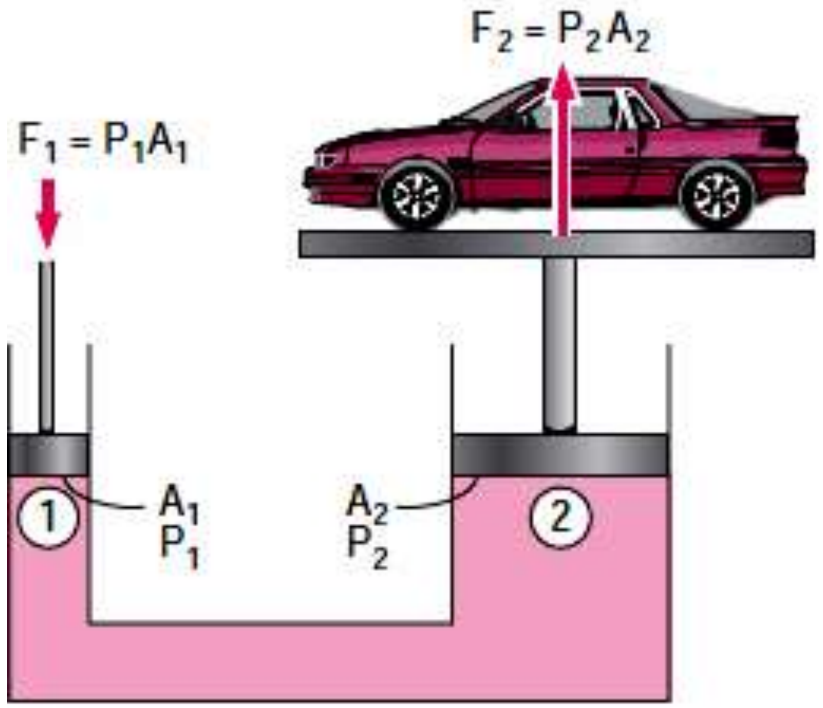




Variation of pressure with depth

Application of Pascal's law

- Two hydraulic cylinders of different areas could be connected, and the larger could be used to exert a proportionally greater force than that applied to the smaller.
- Noting that $P_1 = P_2$ since both pistons are at the same level.



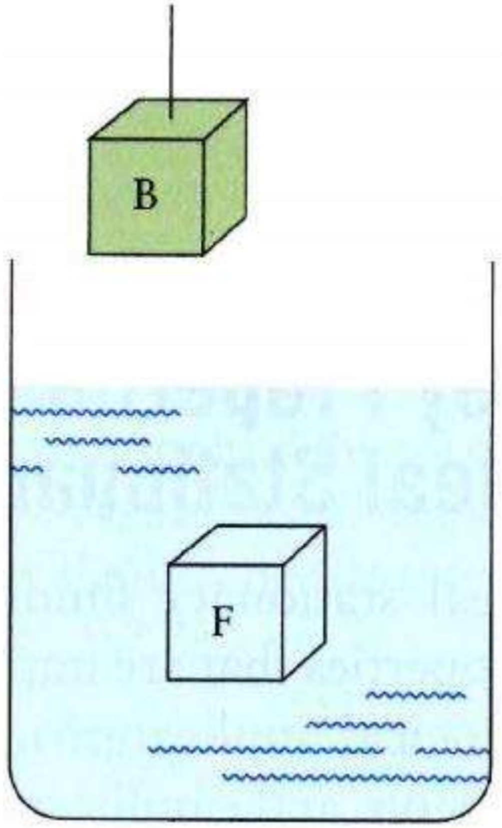
The area ratio A_2/A_1 is called the ideal mechanical advantage of the hydraulic lift.

$$P_1 = P_2 \quad \rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \rightarrow \quad \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

Buoyancy: Archimedes Principle

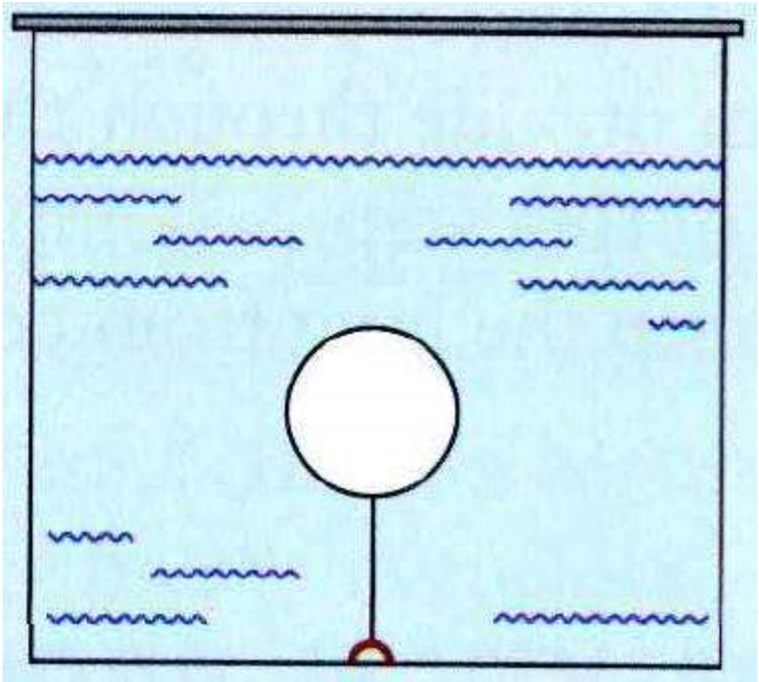
- **Let's do a "thought experiment" (Gedanken).**
- **Imagine a beaker with a fluid and a block, B, hanging near it.**
- **There is a fluid element F with the same shape and volume as the block B.**
- **The fluid element F is in mechanical equilibrium:**

- **where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of fluid F.**



Example

- **A wooden sphere with a diameter of d = 10 cm and density ρ = 0.9 g/cm^3 is held under water by a string. What is the tension in the string?**
- **Note that the density of water in these units is 1.00 g/cm^3.**



JECRC Foundation

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Thank you!

STAY HOME, STAY SAFE