PHYSICS CLUB

STEM ASYUT

Grade 10

PHYSICS
LO.08

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Concepts

•1. Fluids
•2. Pressure
•3. Manometer
•4. Pressure gauge
•5. Units of pressure
•6. Effect of atmospheric pressure on boiling point of water
•7. Change in atmospheric pressure with altitude
•8. Pressure difference and force
•9. Archimedes Principle
10. pascal principle

In this file, **LO.8** will be explained by collecting important explanations from different sources (**Halliday, Hult, El-Moasser,etc..**). The ideas will be presented in **points** to provide a **complete understanding and explanation** of the LO.

Additionally, **key information** will be **highlighted**.

Fluids

Fluids vs. Solids

- **Solids**: Keep their shape when a force is applied. They resist change in shape.
- **Fluids**: Can flow and take the shape of their container because they can't resist forces that push or pull along their surface (called shear forces).

Pitch is a Fluid Too

- **Pitch**: It seems like a solid because it doesn't flow easily, but over time, it does conform to the shape of its container. This is because it can eventually flow, even though very slowly.
- **Why is pitch a fluid?**: It may flow slowly, but since it can flow at all, it is still classified as a fluid.

Liquids and Gases Are Both Fluids

- Both **liquids** (like water) and **gases** (like steam) can flow and cannot resist shear forces, just like other fluids.
- **Liquids**: Take the shape of their container but have a fixed volume. They are nearly incompressible.
- **Gases**: Spread out to fill any container and can be compressed easily.

Crystalline Solids vs. Fluids

- **Crystalline Solids**: In materials like **ice**, atoms are arranged in a fixed, orderly pattern called a **crystalline lattice**. This gives solids their rigid structure.
- **Fluids (Liquids & Gases)**: In both liquids and gases, the atoms don't have a regular structure. In liquids, atoms are close together but move around. In gases, atoms are far apart and move freely.

Pitch is a unique substance that behaves like a fluid, but very slowly.

The late John Mainstone, who never quite got to see it drop. (Image courtesy of the University of Queensland).

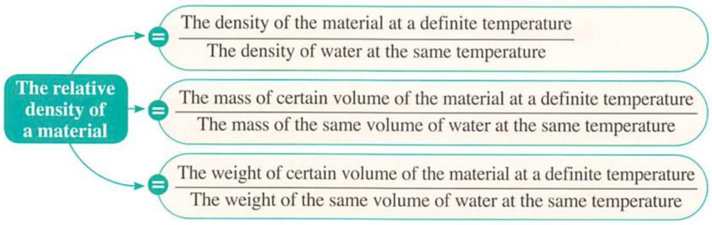
Density

1. **Density**:
   - **Definition**: Density is the mass per unit volume of a substance, often represented by the Greek letter "ρ" (rho).

   - **Formula**: Density(ρ)=

$$\frac{\text{mass}}{\text{volume}}$$

   - **Units**: The SI unit of mass density is kilograms per cubic meter (kg/m^3).
   - **Fluid Density**: The density of fluids varies with temperature and pressure. Solids and liquids are generally incompressible, while gases are compressible.
   - **Relative density**:



The density of a material can be determined by knowing its relative density using the following relation:

$$\rho_{material} = \rho_{relative} \times \rho_{water} = \rho_{relative} \times 1000\ kg/m^3$$

Where: $\rho_{water} = 1000\ kg/m^3$, unless something else is mentioned

   - **Density of a mixture**:

Enrichment information

To determine the density of the mixture when the volume changes during mixing:

$$\rho_{mixture} = \frac{\rho_1 (V_{ol})_1 + \rho_2 (V_{ol})_2}{R \times [(V_{ol})_1 + (V_{ol})_2]}$$

Where: R is the ratio between the volume of a mixture and the sum of the volumes of its components.

Pressure

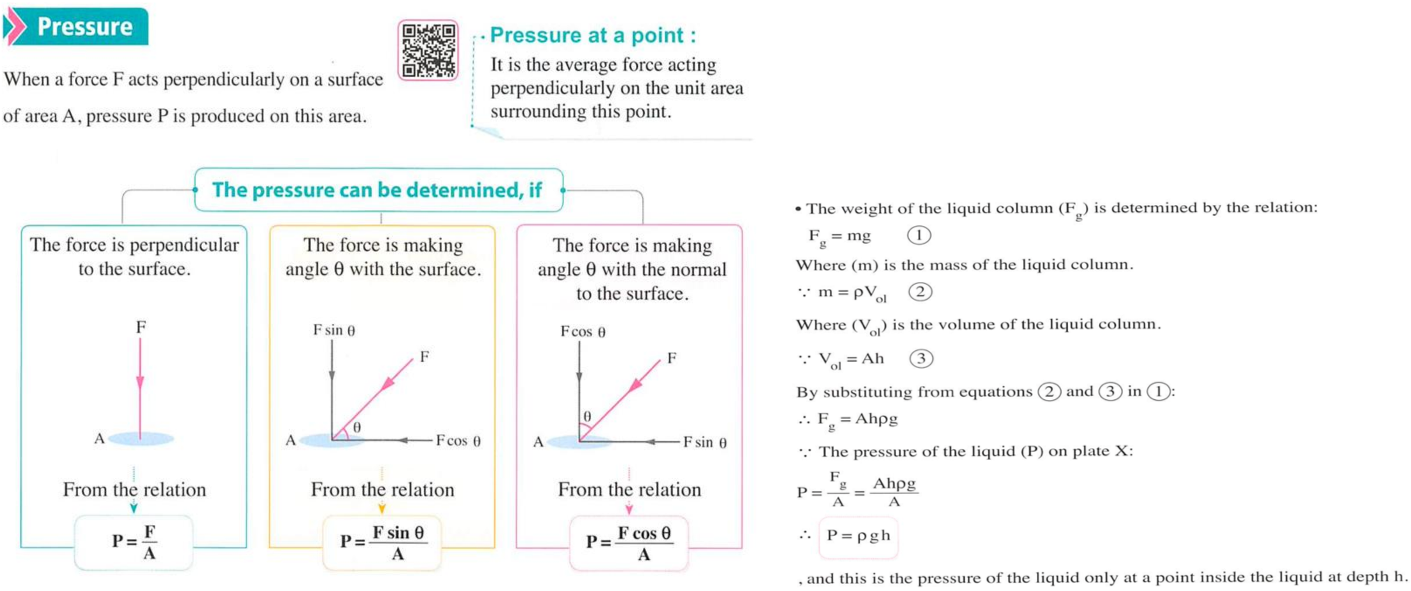
Pressure and Its Effects:

- **Pressure** is the force applied over an area. The formula for pressure is:

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

Where:

- P is the pressure,
- F is the force applied,
- A is the area over which the force is applied.



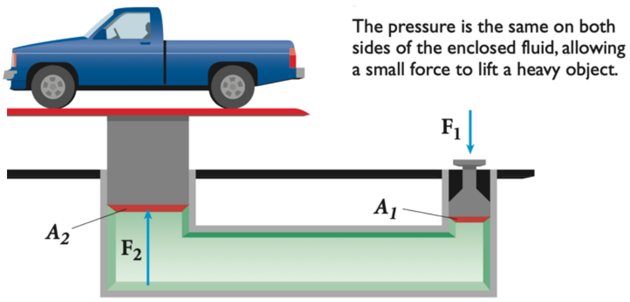
- **Atmospheric Pressure**:
  - The average air pressure at sea level is about 1.01×10^5 Pa or 1 atm.
  - Tire pressure is approximately 3×10^5Pa (3 atm).
- **Pressure Transmission in Fluids**:
  - According to **Pascal's Principle**, any pressure applied to a fluid in a closed container is transmitted equally to every part of the fluid and to the container walls.

- **Hydraulic systems**
  - These lifts use Pascal's principle to amplify force:

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

Rearranging this equation to solve for F_2 produces the following:

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



Pressure Changes with Depth:

- **Water pressure increases with depth** because the weight of the water above exerts additional force.

Gauge Pressure and Absolute Pressure

1. **Gauge Pressure** is the pressure relative to atmospheric pressure, which is the pressure caused by the weight of the fluid above the object (e.g., the submarine). It can be expressed as:

$$P_{\text{gauge}} = \rho h g$$

where:

- ρ is the density of the fluid (water in this case),
- h is the depth,
- g is the acceleration due to gravity.

This formula calculates the **gauge pressure**, which tells you how much the pressure exceeds the atmospheric pressure at that depth.

2. **Absolute Pressure** is the total pressure acting on the object, including both the atmospheric pressure and the pressure due to the weight of the fluid. So, the total pressure at a given depth is:

$$P_{\text{total}} = P_{\text{gauge}} + P_0$$

where: $\cdot P_0$

is the atmospheric pressure at the surface of the fluid (usually about 101,325 Pa at sea level)

absolute pressure =
atmospheric pressure + **(density** · **free-fall acceleration** · **depth)**

Substituting the expression for P_{gauge} from earlier, we get:

$$P_{\text{total}} = \rho h g + P_0$$

- **Buoyancy**: The difference in pressure between the top and bottom of an immersed object creates a buoyant force. This is expressed by Archimedes' principle:

$$F_{\text{net}} = \rho g (h_2 - h_1) A$$

Where:

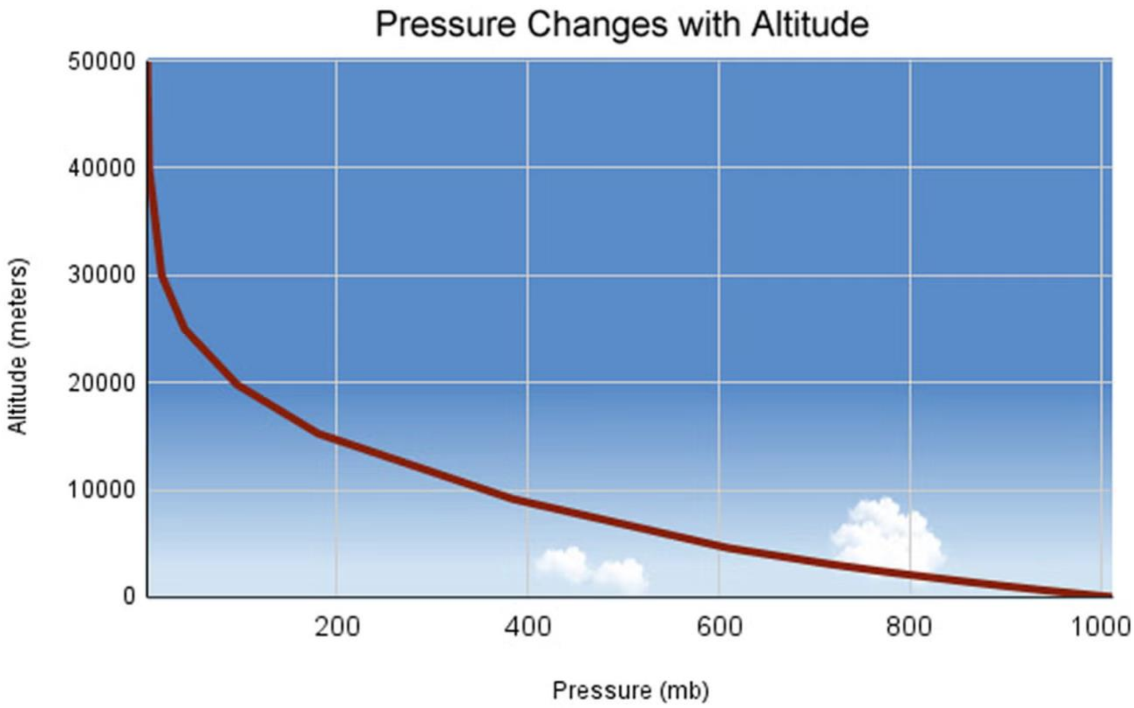
- ρ is the density of the fluid,
- g is the acceleration due to gravity,
- $h_2 - h_1$ is the difference in depth between the bottom (h_2) and top (h_1) of the object,
- A is the cross-sectional area of the object.

Note

is a PRESSURE DIFFERENCE and the force that causes can overcome gravity to pull it up and/or in.

Change of the atmospheric pressure with attiude

Atmospheric pressure decreases with increases in the altitude. As we know that the density of air becomes heavier near the surface of the earth (due to gravity) and begins to lighten as we go to higher altitudes and eventually leads to empty space



Effect of atmospheric pressure on boiling point

- The boiling point is reached when the vapor pressure of a liquid matches the atmospheric pressure . Raising the atmospheric pressure will raise the boiling point.
- lowering the atmospheric pressure will lower the boiling point of the liquid.
- This phenomena is due to the fact that the vapor pressure of water is temperature dependent. It is raised as temperature increases, and is lowered as temperature drops.

You can think of atmospheric pressure as pushing the liquid in a container back into the container (preventing it from transitioning to the gas phase). The greater the pressure, the more force is pushing the particles down into the container which means you'll need to heat the liquid even more in order to get it to boil.
Reducing the pressure means there is less force pushing liquid particles to stay in a container, so they are able to leave (transition into the gas phase) more easily.

For every pound of pressure exerted on the coolant in the system, the static boiling point of the coolant is raised by approximately 3° F

Effect of System Pressure on Boiling Point

Coolant	0 psi	4 psi	8 psi	12 psi	16 psi	20 psi	24 psi
Water	212F	225F	233F	242F	252F	260F	265F
33%	220F	230F	240F	253F	260F	268F	273F
44%	224F	234F	245F	257F	265F	272F	279F
60%	231F	241F	253F	264F	273F	280F	285F
50%	226F	236F	248F	259F	267F	275F	280F

Boiling Point of Coolant with Varying Percentages of Ethylene Glycol @t Atmospheric Pressure & @ 15 P.S.I.				
	Atmospheric		15 PSI (103 kPa)	
% E.G.	B.P. C	B.P. F	B.P. C	B.P. F
0	100C	212F	120C	248F
33	104C	219F	125C	257F
44	107C	224F	128C	262F
50	108C	227F	129C	265F
60	111C	232F	132C	270F

Effect of System Pressure on Boiling Point

Coolant	0 psi	3psi	5 psi	10 psi	12 psi	15 psi	20 psi
Water	212°F	221°F	227°F	242°F	248°F	257°F	272°F
PG Conc.	323°F	332°F	338°F	353°F	359°F	368°F	383°F
30%	216°F	225°F	231°F	246°F	252°F	261°F	276°F
40%	219°F	228°F	234°F	249°F	255°F	264°F	279°F
50%	222°F	231°F	237°F	252°F	258°F	267°F	282°F

If the atmospheric pressure is exactly 1 atm, the boiling point of water is 100.0 degrees Celsius. This is because the vapor pressure of water is 1 atm at this temperature.

• The boiling point decreases to 80.0 degrees at higher altitudes.

for every **6900 Pa** of pressure exerted on the coolant, the static boiling point is raised by **1.67°C**

Key Units of Pressure:

- **SI unit**: Pascal (Pa) = 1 N/m².

- **Common pressure units**:
  - 1 atm = 1.01×1051.01×105 Pa,
  - 1 atm = 760 torr,
  - 1 atm = 14.7 lb/in² (psi).

Archimedes’s principle

Archimedes' Principle:

- **Principle**: Any object submerged (completely or partially) in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced by the object.
- **Formula**

Buoyant Force:

- **Definition**: Buoyant force is the upward force exerted by a fluid on an object submerged or floating in it.
- **Effect**: Buoyant force makes objects feel lighter underwater

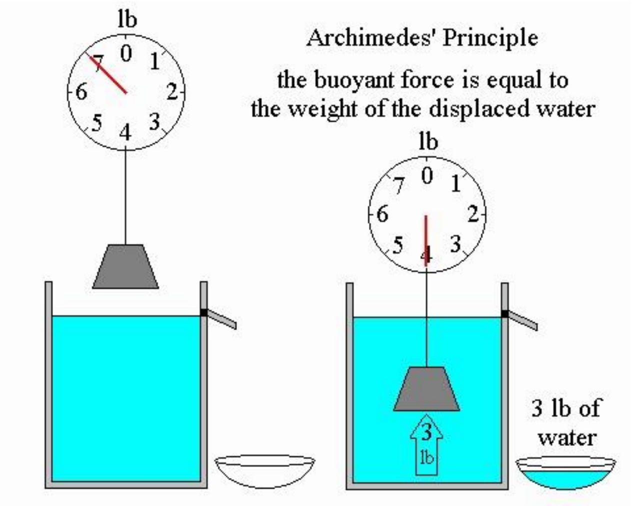
  than in air because it opposes gravity.

- **Apparent Weight**: The weight of an object submerged in a fluid is its apparent weight, which is its actual weight minus the buoyant force.

- This force occurs because **fluid pressure increases with depth**, creating a greater force on the bottom of the object than on the top.
- **Archimedes' Principle** states that the buoyant force is **equal to the weight of the fluid displaced by the object**:

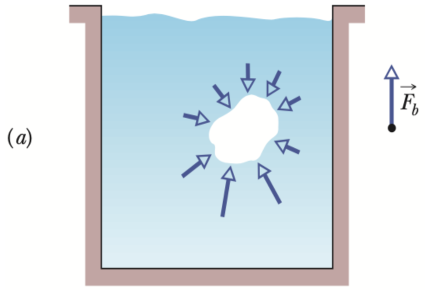
$F_b = m_f g$

where m_f is the mass of the displaced fluid, and g is gravitational acceleration.



Water-Filled Sack in Static Equilibrium (Fig. 14-10a)

- The **sack of water is submerged in the pool** and remains in place.
- The forces acting on the sack include:
  - **Gravitational force** (F_g) pulling it downward.
  - **Buoyant force** (F_b) pushing it upward.
- The **horizontal forces cancel out**, while the **vertical forces combine to create the buoyant force**.
- Since the **buoyant force exactly balances the gravitational force**, the sack is in **static equilibrium** (it neither rises nor sinks).

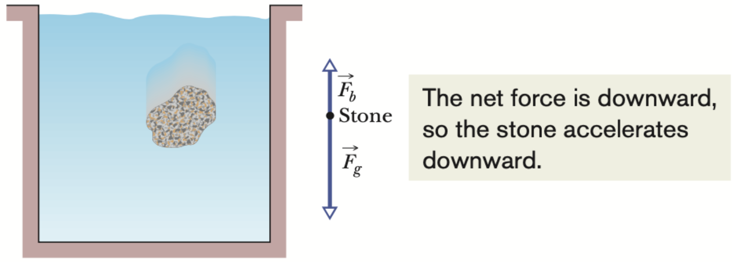


The buoyant force is due to the pressure of the surrounding water.

Stone in Water – Sinking Object (Fig. 14-10b)

- A **stone replaces the sack** and occupies the same volume, meaning it **displaces the same amount of water**.
- The stone **experiences the same buoyant force** as the sack since the displaced volume of water remains the same.
- However, the **stone is much denser than water**, so its **weight (F_g) is greater than the buoyant force (F_b)**.
- **Net force is downward**, causing the stone to **sink** to the bottom of the pool.

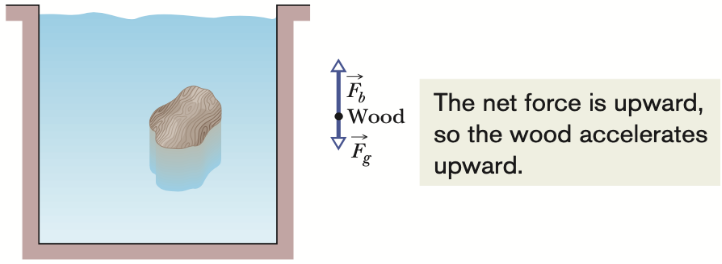
(b)



Wood in Water – Floating Object (Fig. 14-10c)

- A **block of lightweight wood replaces the sack or stone** in the same position.
- Like the stone, the wood **displaces the same volume of water** and experiences the same **buoyant force**.
- However, **wood is much less dense than water**, so its **weight (F_g) is smaller than the buoyant force (F_b)**.
- **Net force is upward**, meaning the wood **rises to the surface and floats**.

(c)



Floating vs. Sinking:

- For floating objects, the buoyant force equals the object's weight.
- **Condition for Floating**: If an object's density is less than the fluid's density, it will float. If it is denser, it will sink.
- **Net Force Formula** $F_{\text{net}} = \rho g(h_2 - h_1)A$

Where:

- ρ is the density of the fluid,
- g is the acceleration due to gravity,
- $h_2 - h_1$ is the difference in depth between the bottom (h_2) and top (h_1) of the object,
- A is the cross-sectional area of the object.

Manometer

Open-Tube Manometer

1. **Purpose**: Measures **gauge pressure** of a gas.
2. **Structure**:
   - A **U-tube** filled with liquid.
   - One end is connected to the gas container.
   - The other end is open to the **atmosphere**.
3. **How it Works**:
   - The **height difference (h)** in the liquid levels reflects the pressure difference between the gas and atmospheric pressure.
4. **Formula for Gauge Pressure**:
   - $p_g = p - p_0 = \rho g h$
     - p_g = gauge pressure of the gas
     - p_0 = atmospheric pressure
     - ρ = density of the liquid in the manometer
     - g = acceleration due to gravity
     - h = height difference between the liquid levels

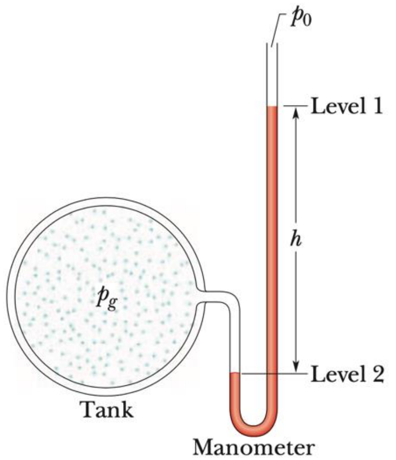


Fig. 14-6 An open-tube manometer, connected to measure the gauge pressure of the gas in the tank on the left. The right arm of the **U**-tube is open to the atmosphere.

5. **Gauge Pressure**:

   - **Positive gauge pressure**: Gas pressure **is greater** than atmospheric pressure (e.g., in an inflated tire).

Negative gauge pressure: Gas pressure **is less** than atmospheric pressure (e.g., sucking on a straw).

Barometer

1. Purpose

- **A mercury barometer** is a device used to **measure atmospheric pressure**.
    - It consists of a **long glass tube filled with mercury**, inverted into a dish of mercury.

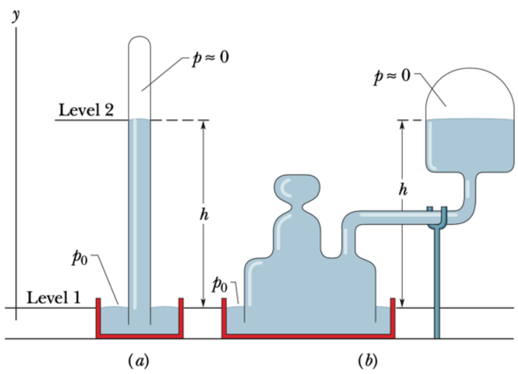
2. Working Principle

- The space above the mercury column contains **only mercury vapor**, whose pressure is negligible.
- The **height** (h) of the mercury column is directly related to **atmospheric pressure** (p_0).
- Using the hydrostatic pressure equation:

$p_0 = \rho g h$ (14-9)

where:

- p_0 = atmospheric pressure
- ρ = density of mercury
- g = acceleration due to gravity
- h = height of the mercury column



3. Key Observations

•The height **is independent of the tube's cross-sectional area**—only the **vertical height** matters.

•Figure 14-9b shows a differently shaped barometer that gives the **same pressure reading** as a standard one.

4. Factors Affecting Measurement

•**Gravity** (g): The height of the mercury column depends on **the local value of g.**

•**Temperature**: **The density of mercury** changes with temperature, affecting the measurement.

•**Standard Conditions**:

•At g=9.80665m/s^2**and 0°C**, the height in **millimetres** is numerically equal to the pressure in **torr**.

The pressure at a point in a fluid in static equilibrium depends on the depth of that point but not on any horizontal dimension of the fluid or its container.

Balancing of pressure in a U-tube

The U-tube in Fig. 14-4 contains two liquids in static equilibrium: Water of density ρ_w (= 998 kg/m^3) is in the right arm, and oil of unknown density ρ_x is in the left. Measurement gives l = 135 mm and d = 12.3 mm. What is the density of the oil?

KEY IDEAS

(1) The pressure p_{int} at the level of the oil–water interface in the left arm depends on the density ρ_x and height of the oil above the interface. (2) The water in the right arm *at the same level* must be at the same pressure p_{int}. The reason is that, because the water is in static equilibrium, pressures at points in the water at the same level must be the same even if the points are separated horizontally.

Calculations: In the right arm, the interface is a distance l below the free surface of the *water,* and we have, from Eq. 14-8,

$$p_{int} = p_0 + \rho_w g l \quad \text{(right arm).}$$

In the left arm, the interface is a distance $l + d$ below the free surface of the *oil,* and we have, again from Eq. 14-8,

$$p_{int} = p_0 + \rho_x g(l + d) \quad \text{(left arm).}$$

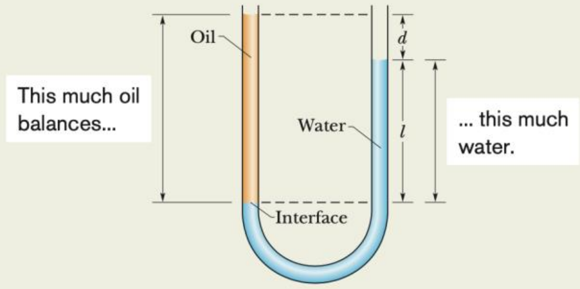


Fig. 14-4 The oil in the left arm stands higher than the water in the right arm because the oil is less dense than the water. Both fluid columns produce the same pressure p_{int} at the level of the interface.

Equating these two expressions and solving for the unknown density yield

$$\rho_x = \rho_w \frac{l}{l + d} = (998\ \text{kg/m}^3)\frac{135\ \text{mm}}{135\ \text{mm} + 12.3\ \text{mm}}$$

$$= 915\ \text{kg/m}^3. \quad \text{(Answer)}$$

Note that the answer does not depend on the atmospheric pressure p_0 or the free-fall acceleration g.

Using a barometer to estimate the height of mountain

https://www.youtube.com/watch?v=6lCOrkouX-U

Measuring Pressure With Barometers and Manometers

https://youtu.be/YI4RRZ3ZM7g?si=zQ3IpAzX7gRFQrqG