

KSU

Phys 109

Chapter 13 — Fluids:

Mr. Abdullah Mohamed

@Chem31Phys

خاص بالمشتركين فقط

1. What is a Fluid?

A fluid is any substance that can flow. fluids classified into:

Type	Main idea	Compressibility
Liquid	Has fixed volume, no fixed shape	Nearly incompressible
Gas	No fixed shape, expands to fill container	Compressible
Plasma	Ionized gas at high temperature	Compressible

A liquid takes the shape of its container but keeps nearly the same volume. A gas spreads out and can be compressed because its molecules are far apart.

2. Density is the mass per unit volume:

$$\rho = \frac{m}{V}$$

ρ is density (kg/m^3)

m is mass (Kg)

V is volume (m^3)

3. Pressure is force per unit area:

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

Where: P is pressure ($\text{pa} = \text{N/m}^2$)

F is Force (N)

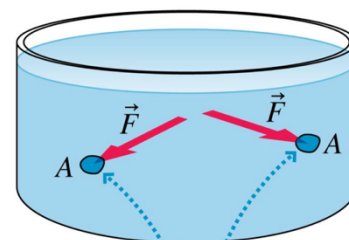
A is Area (m^2)

Important pressure conversions

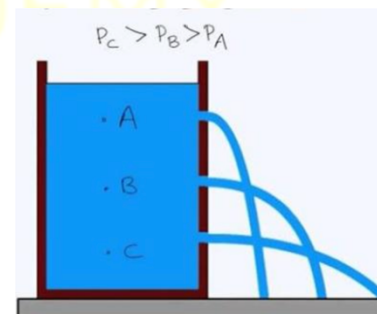
$$1 \text{ atm} = 101.3 \text{ kPa} = 1.013 \times 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

Fluids exert pressure on the walls of their container. The deeper you go in a liquid, the greater the pressure. This is why water comes out faster from a lower hole in a tank than from an upper hole.



The fluid pushes with force \vec{F} against area A .



4. Pressure in Liquids — Hydrostatic Pressure

For a liquid at rest:

$$P = P_o + \rho g d$$

Where: P = absolute pressure at depth d

P_o = pressure at the surface
 $g = 9.8m/s^2$

ρ density of the liquid
 d = depth below surface

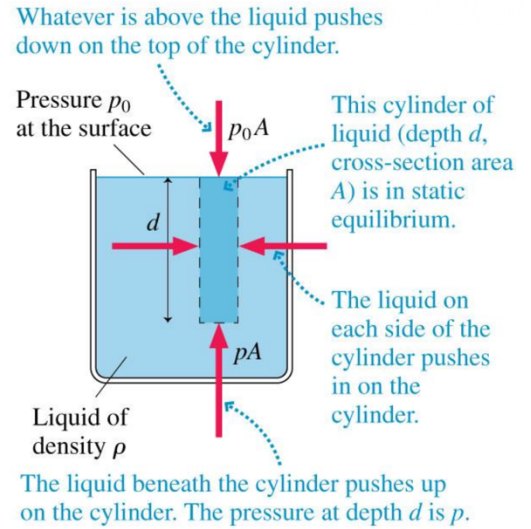
Key meaning

Pressure increases with:

1. Greater depth
2. Greater density
3. Greater gravitational acceleration

So: $P \propto \rho d$

A point deeper in water has higher pressure than a point near the surface.



5. Gauge Pressure vs Absolute Pressure

Absolute pressure Pressure measured relative to vacuum. $P_{absolute}$

Gauge pressure Pressure measured relative to atmospheric pressure.

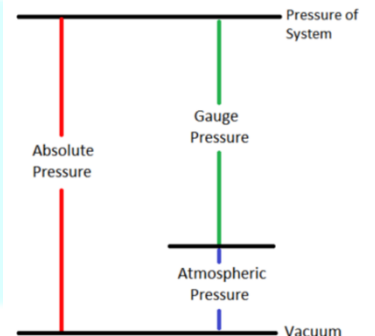
$$P_{gauge} = P_{absolute} - P_{atm}$$

For liquids: $P_{gauge} = \rho g d$

Very important exam point

A pressure gauge usually reads gauge pressure, not absolute pressure.

So: $P_{absolute} = P_{gauge} + P_{atm}$

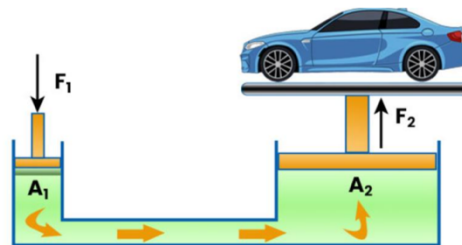


6. Pascal's Principle

If pressure at one point in an incompressible fluid is changed, the pressure at every other point in the fluid changes by the same amount.

This principle explains:

1. Hydraulic lift
2. Hydraulic press
3. Hydraulic brakes
4. Hydraulic aircraft systems



Hydraulic lift equation

Because pressure is transmitted equally:

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

If (A_2) is much larger than (A_1), a small force can lift a heavy object.

Exam shortcut

Hydraulic lift = Pascal's law.

7. Pressure at the Same Horizontal Level

In a connected liquid of the same kind, at rest:

$$P_1 = P_2$$

if both points are on the same horizontal line.

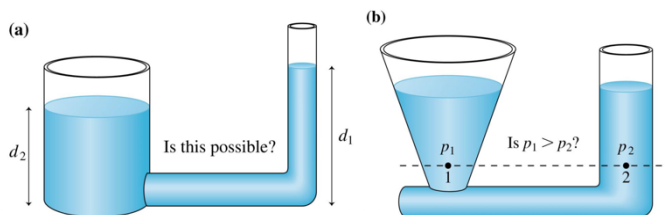
This rule is extremely important for U-tube and manometer problems.

Key rule

Same liquid + same horizontal level + static equilibrium:

same pressure

It does not matter if the container has different shapes.



8. Hydrostatics Problem-Solving Method

For any hydrostatic problem:

1. Draw the container or tube.
2. Mark open surfaces, closed surfaces, pistons, and gases.
3. Identify the known pressure at the surface: $P_o = P_{atm}$ if open to air.
4. Use: $P_1 = P_o + \rho g d$
5. when moving downward in liquid.
6. Pressure increases downward.
7. Pressure decreases upward.
8. Use horizontal lines: same liquid at same height means same pressure.
9. Convert gauge pressure to absolute pressure when required.

9. Manometers A manometer measures gas pressure.

The tube is filled with liquid, often mercury. If one side is open to the atmosphere and the other side is connected to gas, then:

$$P_{gas} = P_{atm} + \rho g d$$

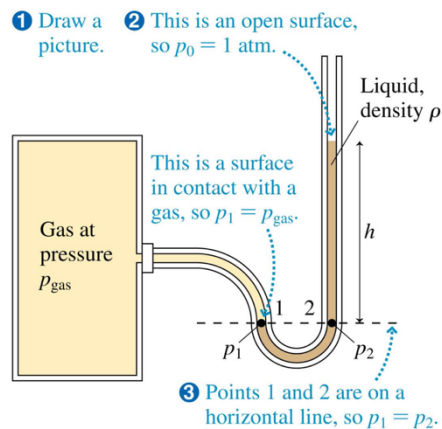
if the gas pressure is higher than atmospheric pressure.

Important idea

The height difference (h) tells you the pressure difference.

$$\Delta P = \rho g d$$

Manometer questions are usually solved by comparing pressures at the same horizontal level.

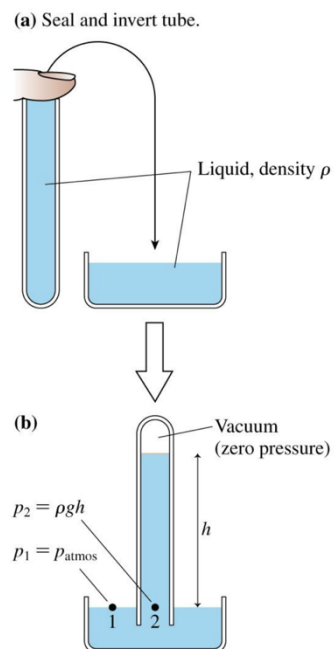


10. Barometers *A barometer measures atmospheric pressure.*

For a liquid column: $P_{atm} = \rho g d$

For mercury: $1 \text{ atm} = 760 \text{ mmHg}$

That means atmospheric pressure can support a mercury column of height 760 mm.



11. Fluids in Motion

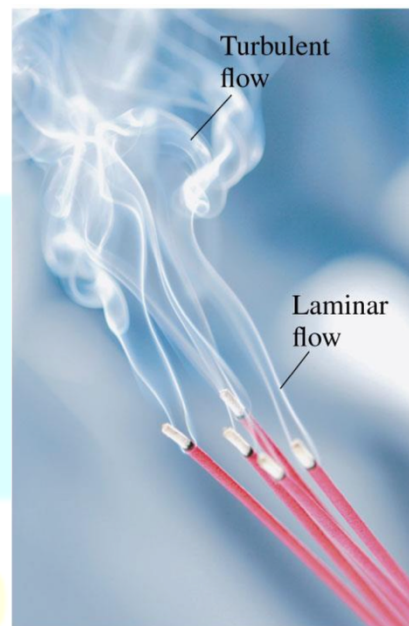
For fluid dynamics, (the ideal fluid model)

An ideal fluid is:

1. *Incompressible*
2. *Nonviscous, meaning frictionless*
3. *Steady flow*
4. *Usually treated as laminar flow*

Laminar vs. turbulent flow

<i>Flow type</i>	<i>Description</i>
<i>Laminar flow</i>	<i>Smooth, orderly flow</i>
<i>Turbulent flow</i>	<i>Irregular, fluctuating flow</i>



The equations mainly apply to ideal, steady, laminar flow.

12. Equation of Continuity

For an incompressible fluid:

$$A_1 v_1 = A_2 v_2$$

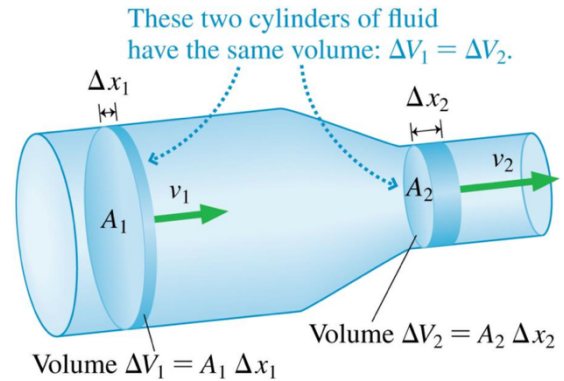
Where:

A = cross-sectional area

v = fluid speed

Meaning

The volume of fluid entering one part of a pipe per second **equals** the volume leaving another part per second.



So:

$$Q = Av$$

Where:

Q = volume flow rate Unit: m^3/s

Very important exam rule

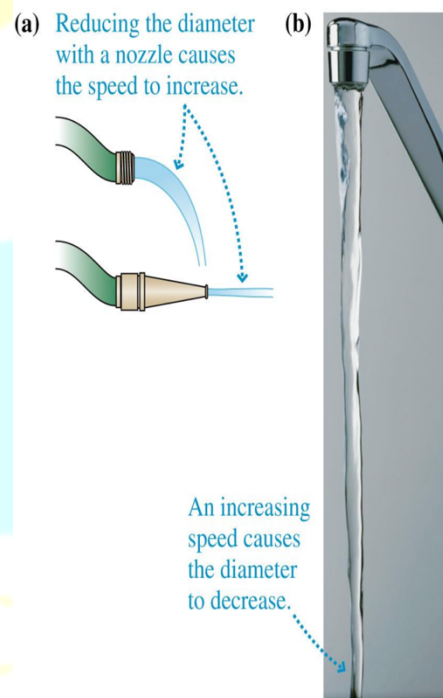
If the pipe becomes narrower:

$$A \downarrow \Rightarrow v \uparrow$$

If the pipe becomes wider:

$$A \uparrow \Rightarrow v \downarrow$$

So water moves faster in the narrow part of a pipe.



13. Volume Flow Rate

$$Q = Av$$

Also: $Q = \frac{\Delta V}{\Delta t}$

Where: $\Delta V = \text{volume}$ $\Delta t = \text{time}$

Then: $v = \frac{Q}{A}$

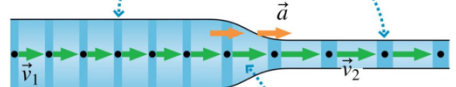
If speed must increase by factor 4, area must decrease by factor 4. Since area depends on diameter squared:

$$A \propto d^2$$

So diameter must decrease by factor 2.

If hose diameter is 16 mm, nozzle diameter becomes: 8mm

A fluid element coasts at steady speed through the constant-diameter segments of the tube.



As a fluid element flows through the tapered section, it speeds up. Because it is accelerating, there must be a force acting on it.

14. Bernoulli's Equation

Bernoulli's equation relates pressure, speed, and height for an ideal fluid:

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$$

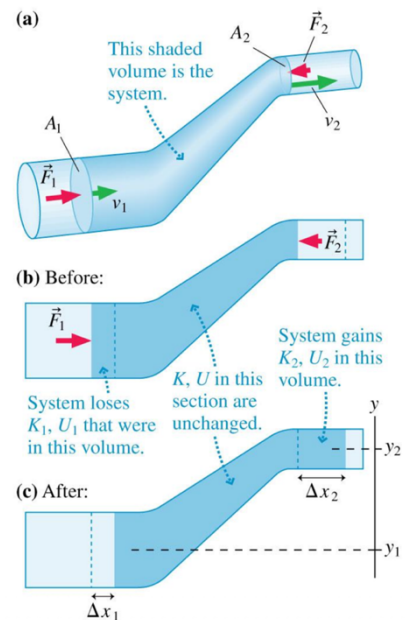
Meaning of each term

Term	Meaning
(P)	Pressure energy per unit volume
$\frac{1}{2} \rho v^2$	Kinetic energy per unit volume
$\rho g y$	Gravitational potential energy per unit volume

Exam interpretation

If speed increases, pressure usually decreases.

If height increases, pressure usually decreases.



If the pipe is horizontal: $y_1 = y_2$

So Bernoulli becomes:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

This is very common in exam questions.

15. Bernoulli + Continuity Together

Many exam questions require both equations:

First use continuity:

$$A_1 v_1 = A_2 v_2$$

Then use Bernoulli:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

Common exam logic

Narrow pipe:

$A \downarrow$

Therefore:

$v \uparrow$

Then from Bernoulli:

$P \downarrow$

So in the narrowest part of a horizontal pipe:

speed is maximum and pressure is minimum

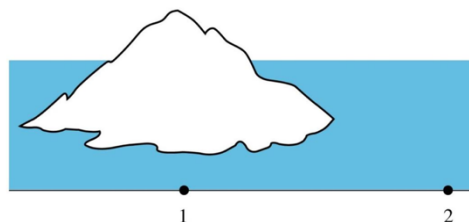
This directly answers one of the review questions.

1) What is the mass of air in a living room with dimensions $4.0\text{ m} \times 6.0\text{ m} \times 2.5\text{ m}$?
(the density of the air is 1.20 kg/m^3)

Table 13.1 gives air density at a temperature of 20°C , which is about room temperature.

- A) 72kg B) 60kg C) 24kg D) 21.5 kg

2) An iceberg floats in a shallow sea. What can you say about the pressures at points 1 and 2?

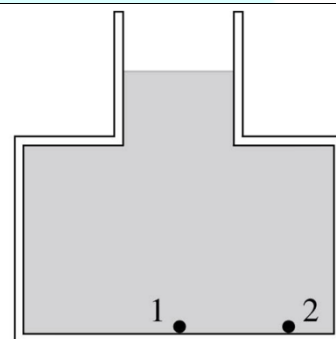


- A) $p_1 > p_2$ C) $p_1 = p_2$ D) $p_1 < p_2$

3) A garden hose has an inside diameter of 16 mm. The hose can fill a 10 L bucket in 20 s.
a. What is the speed of the water out of the end of the hose?
b. What diameter nozzle would cause the water to exit with a speed 4 times greater than the speed inside the hose?

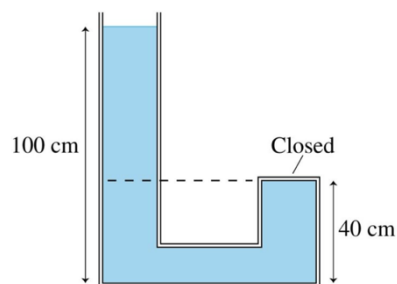
- A) 2.5 m/s B) 2.5 m/s C) 5 m/s D) 5 m/s
8mm 4mm 8mm 4mm

4) What can you say about the pressures at points 1 and 2?



- A) $p_1 > p_2$ B) $p_1 < p_2$ C) $p_1 = p_2$

5) Water fills the tube shown in the figure. What is the pressure at the top of the closed tube?

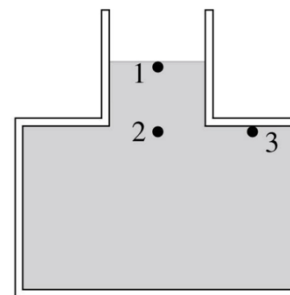


- A) 107.2kPa B) 7.2kPa C) 17.2kPa D) 67kPa E)

6) Is gauge pressure larger, smaller, or the same as absolute pressure?

- A) Greater B) Smaller C) The same D) E)

7) What can you say about the pressures at points 1, 2, and 3?

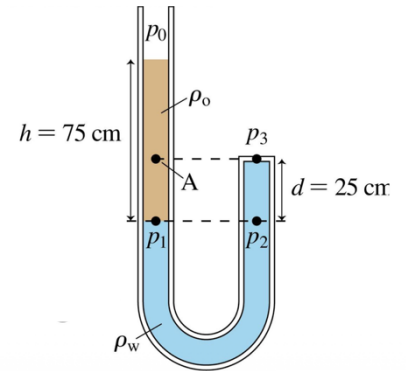


- A) $p_1 = p_2 = p_3$
 B) $p_1 = p_2 > p_3$
 C) $p_3 > p_1 = p_2$
 D) $p_3 > p_1 > p_2$
 E) $p_2 = p_3 > p_1$

8) Bernoulli's equation is a relationship between a fluid's

- A) Temperature and volume. B) Volume and pressure.
 C) Mass and density. D) Speed and pressure.

9) A U-shaped tube fills by Water in the side of the tube that includes the closed end, then fills by oil in the side of the tube open to the atmosphere. The oil is floating on the water. The two liquids do not mix. The height of the oil above the point where the two liquids touch is 75 cm, while the height of the closed end of the tube above this point is 25 cm. What is the gauge pressure at the closed end? Where $\rho_w = 1000 \text{ kg/m}^3$ and $\rho_o = 900 \text{ kg/m}^3$

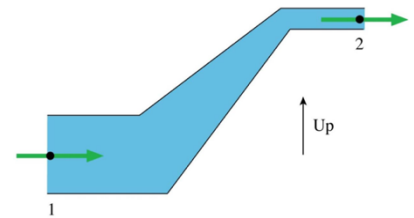


- A) 4.17 kPa B) 6.62 kPa C) 2.45 kPa D) 1.74 kPa

10) What is the SI unit of pressure?

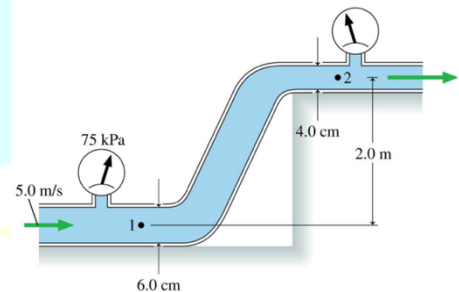
- A) The newton B) The erg C) The pascal D) The poise

11) Water flows from left to right through this pipe. What can you say about the speed of the water at points 1 and 2?



- A) $v_1 > v_2$ B) $v_1 = v_2$ C) $v_1 < v_2$

12) Water flows through the pipes shown in the figure. The water's speed through the lower pipe is 5.0 m/s, and a pressure gauge reads 75 kPa. What is the reading of the pressure gauge on the upper pipe?



- A) 4.60 kPa B) 19.6 kPa C) 75.0 kPa D) 50.7 kPa

13) On a sea-level standard day, a pressure gauge reads pressure of 1.3Mpa below the surface of the ocean (SG of seawater=1.025). How deep is the instrument?

- A) 140 m B) 4 m C) 133 m D) 129 m