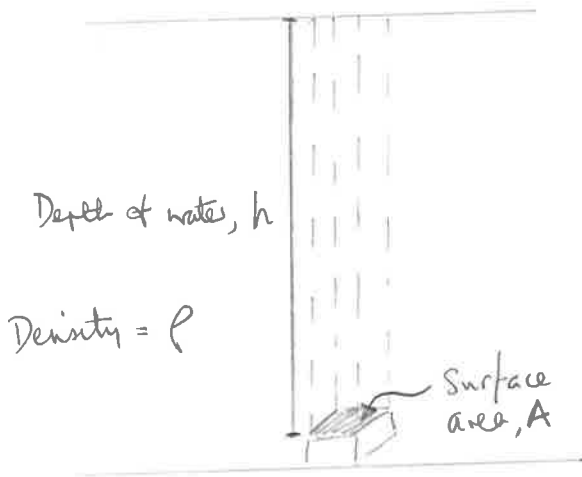


PRESSURE DUE TO A COLUMN OF LIQUID

Imagine a box that has a top of surface area A , which is at a depth h , below the surface of the water



- Volume of liquid above box $V = Ah$
- \therefore Mass of liquid = $m = \rho Ah$ ($m = \rho V$)
- The weight of the liquid = $W = \rho Ahg$ ($W = mg$)
- We know that pressure = $\frac{\text{Force}}{\text{Area}}$.
- In this case, the Force on the box is the weight of the water

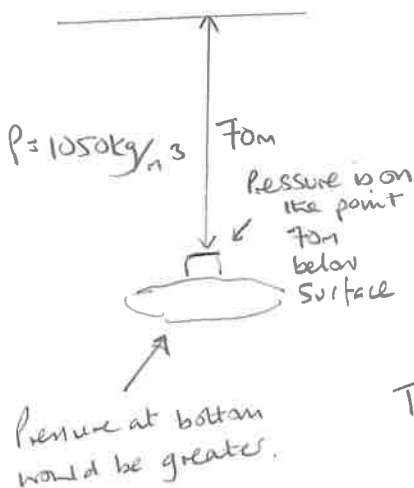
$$\therefore P = \frac{F}{A} = \frac{\rho Ahg}{A}$$

$$\therefore \text{Pressure due to the column of liquid} = \rho gh$$

$$= \text{density} \times g \times \text{depth of water}$$

$$\text{Units: } \underline{\underline{\frac{N}{m^2} \text{ or Pa}}}$$

e.g. A submarine is 70m below the surface. The density of the salt water is 1050 kg/m^3 . What is the pressure on the submarine due to the water



$$\therefore P = \rho gh$$

$$P = 1050 \times 10 \times 70$$

$$P = \underline{\underline{735,000 \text{ Pa}}}$$

What is the total pressure acting on the submarine?

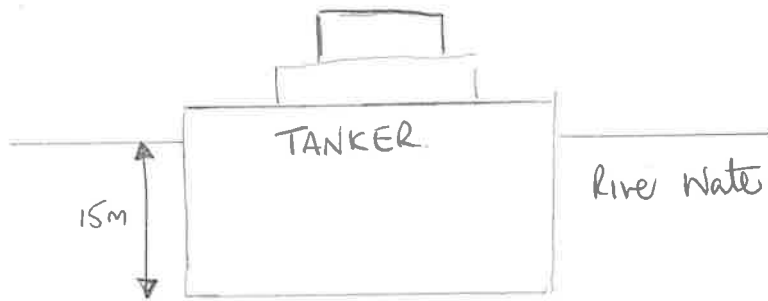
$$\text{Total Pressure} = \text{Pressure due to column of liquid} + \text{Atmospheric pressure}$$

$$\text{Total Pressure} = 735,000 + 100,000 \text{ Pa}$$

$$= \underline{\underline{835,000 \text{ Pa}}}$$

$$[\text{Atmospheric Pressure} \approx 100,000 \text{ Pa} \text{ or } 1 \text{ atm} \text{ or } 1 \text{ Bar}]$$

PRESSURE & BUOYANCY



The bottom of the tanker is 15m below the surface & has an area of 6000m^2 . Density of the water is 1000kg/m^3

Pressure due to water at a depth of 15m \Rightarrow

$$P = \rho g h$$

$$P = 1000 \times 10 \times 15$$

$$= \underline{150,000 \text{ Pa or } 150 \text{ kPa}}$$

The force due to the water pressure on the bottom of the tanker is:

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

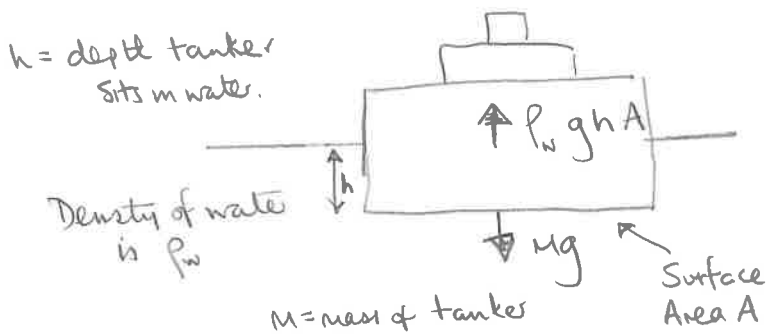
$$= 150,000 \times 6000$$

$$= \underline{9 \times 10^8 \text{ N}}$$

\leftarrow this is the force upwards due to the water.

\therefore The weight of the tanker must be $\underline{9 \times 10^8 \text{ N}}$ because the tanker is in equilibrium (not sinking or rising).

As tanker sails out to sea, the sea water has a greater density



Upward force increases as ρ (density) increases. The force now exceeds Mg , so tanker rises in the water until new equilibrium is achieved.

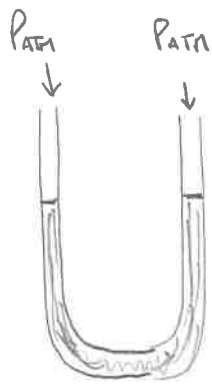
Eqn: $Mg = \rho_w g h A$

$$h = \frac{M}{\rho_w \cdot A} \quad \left[h \propto \frac{1}{\rho_w} \right]$$

$\rho_w g h A =$ the weight of the 'displaced water'

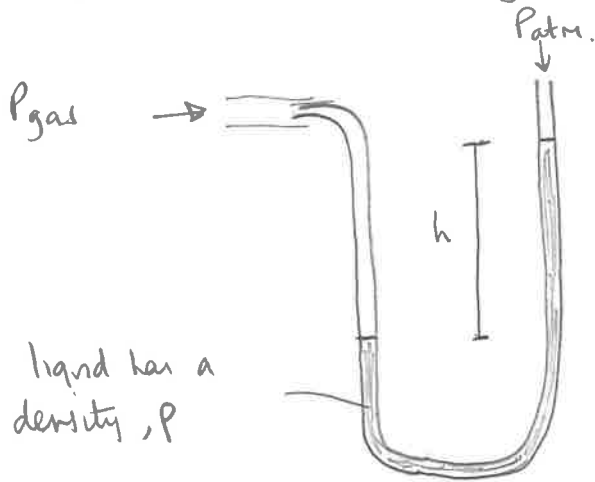
MANOMETERS

Take a u-shaped tube and put some water in it.



If both sides of the tube are open to the atmosphere, then water on both sides experiences atmospheric pressure ($\approx 100,000 \text{ Pa}$).

If the tube is connected to a gas supply on one side:



In this case, the gas pressure is greater than the atmospheric pressure. So the liquid on the left hand side goes down.

As the liquid is stationary, there is equilibrium which means:

Gas Pressure = Pressure Atmospheric + Pressure due to column of liquid of height, h

$$P_{\text{gas}} = P_{\text{atm}} + \rho g h$$

If this were water ($\rho = 1000 \text{ kg/m}^3$) and the displacement was 29 cm , the gas pressure would be:

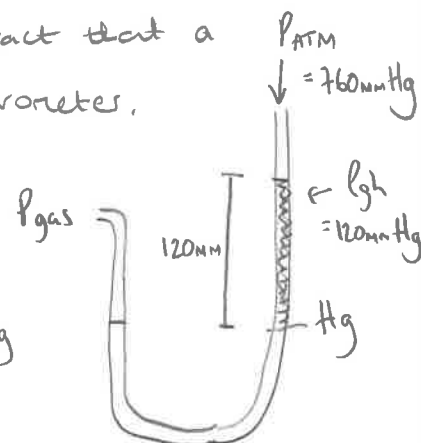
$$\begin{aligned} P_{\text{gas}} &= 100,000 \text{ Pa} + 1000 \times 10 \times 0.23 \text{ m} \\ &= \underline{\underline{102,300 \text{ Pa}}} \end{aligned}$$

In past IGCSE problems, the question has been tackled in terms of millimetres of mercury (mm Hg). This stems from the fact that a standard atmosphere is shown by 760 mm Hg on a barometer.

\therefore If a mercury manometer is used:

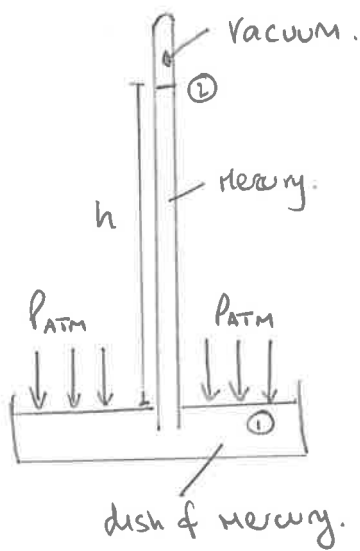
$$\text{Pressure Gas} = P_{\text{atm}} + \rho g h$$

$$P_{\text{gas}} = 760 \text{ mm Hg} + 120 \text{ mm Hg}$$



BAROMETERS.

Barometers are used to measure atmospheric pressure:



For a standard atmosphere, $h = 760 \text{ mm Hg}$

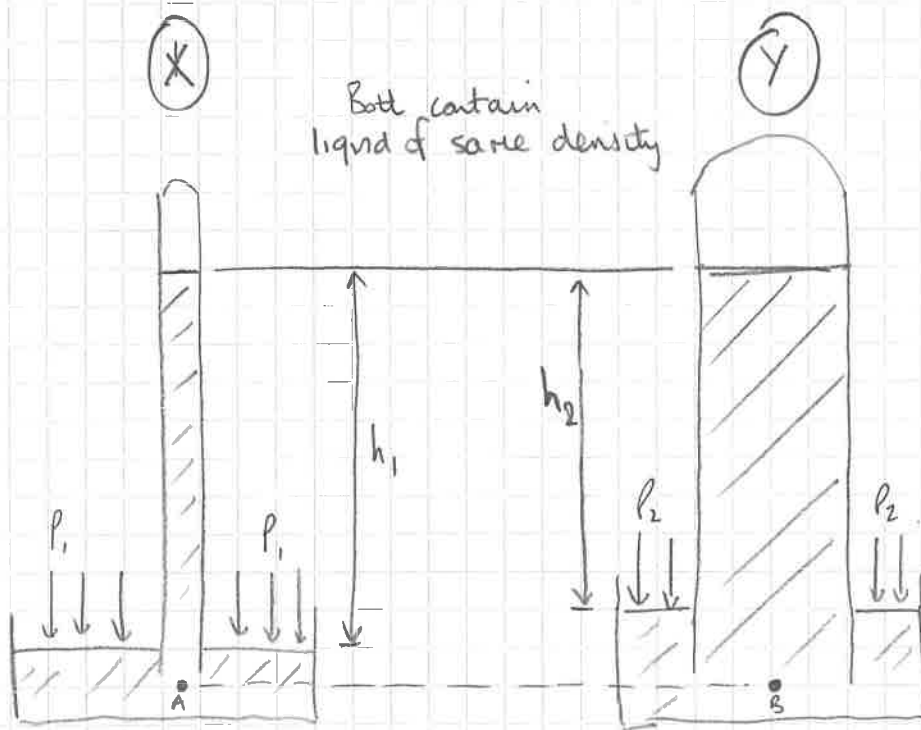
$$P_{atm} = \rho g h$$

$$P_{atm} = 13,593 \text{ kg/m}^3 \times 9.81 \text{ N/kg} \times 0.76 \text{ m}$$
$$= \underline{\underline{101300 \text{ Pa.}}}$$

[In aviation the standard pressure setting is 1013 millibars]

When P_{ATM} increases (A high pressure weather system) ① moves down and ② moves up \therefore h increases.

When P_{ATM} decreases (A low pressure weather system) ① moves up and ② moves down \therefore h decreases.



Question: Which pressure is greater P_1 or P_2 ?

P_1 is greater as $P = \rho gh$ and h_1 is greater than h_2 .

Question: Is the pressure greater at A or B.?

Pressure is the same at A & B as the height of the column of liquid above them is the same. [Remember: Area is cancelled when we derive $P = \rho gh$ from first principles; therefore, diameter of tube is not a factor.]