BTU 1113 Physics

Chapter 6: Fluid Mechanics

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Chapter Description

- Aims
  - Understand about pressure and Pascal principle.
  - Measures mass, density and viscosity of substances and liquid.
  - Demonstrate Buoyant forces and Archimedes principles.

- Expected Outcomes
  - Students should be able to understand about pressure and Pascal principle.
  - Students should be able to measures mass, density and viscosity of substances and liquid.
  - Students should be able to demonstrate Buoyant forces and Archimedes principles.

- References

  - Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.
  - Jones, E., 2002. Contemporary College Physics. 3rd Ed, McGraw-Hill, Singapore.
  - Young, H. D. and Freedman, R. A., 2012. University Physics with Modern Physics. 13th edition, Pearson, San Francisco
  - Cengel, Y.A and Boles, M.A (2010),"Thermodynamics: An Engineering Approach. 7th edition. McGraw Hill, New York.

1st aim:
Understand about pressure and Pascal principle.

PRESSURE

- defined as force acting on per unit area of surface. It is the normal force exerted by a fluid per unit.

- SI Units used are as follows:

  N/m^2 or Pascal (Pa), bar, in Hg.

  $1 N/m^2$ = 1 Pascal

  1 bar = 105 N/m^2

  1 bar = 100 kPa

  1 atm = 1.013 bar

The 4 types of pressure commonly used are:-

(a) **gauge pressure**- pressure measured by the pressure gauge, P_g

(b) **atmospheric pressure**-pressure exerted by air on the earth's surface usually measured by a barometer. P_{atm}

(c) **absolute pressure**- the sum of gauge pressure and atmosperic pressure, P_{abs}

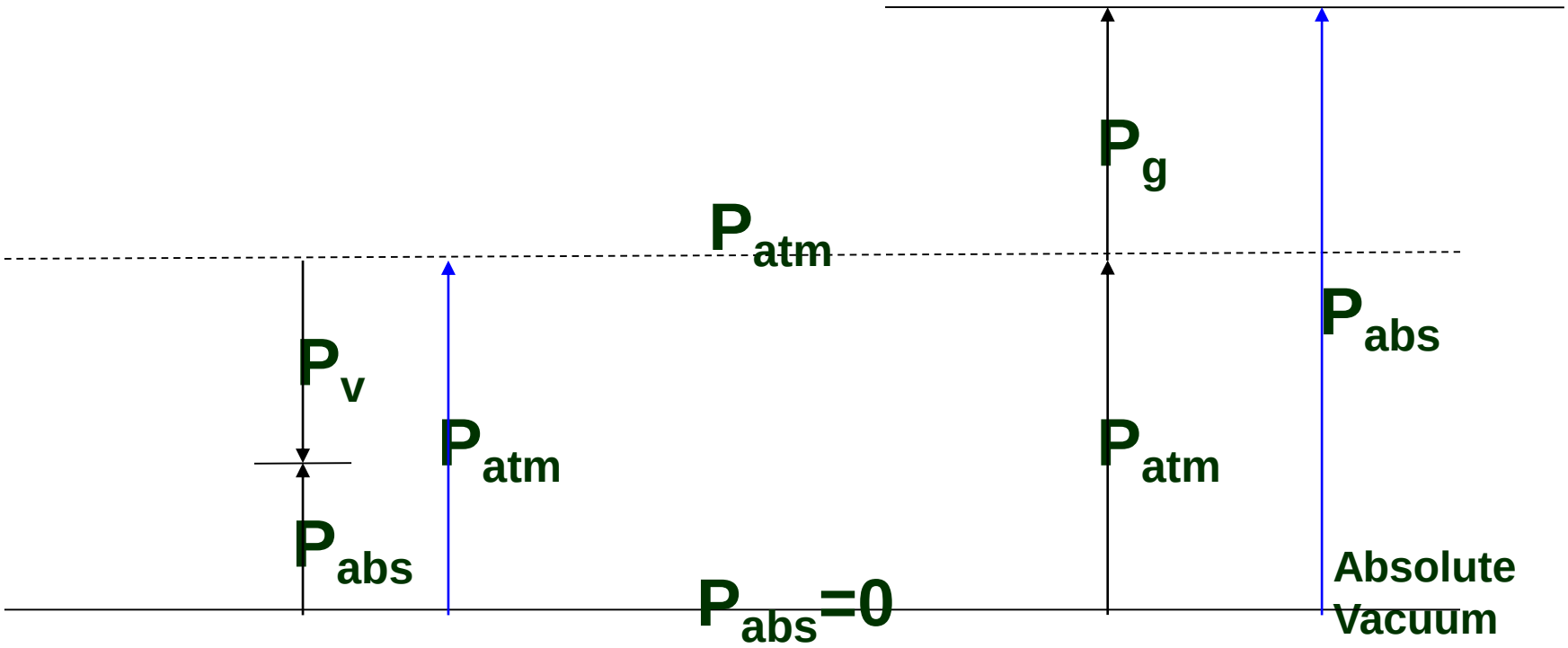
Mathematically:

$$P_{abs} = P_g + P_{atm}$$

(d) **vacuum pressure**- pressures below atmospheric pressure and are measured by vacuum gauges

$$P_v = P_{atm} - P_{abs}$$ where P_v = vacuum pressure

Relationship between these pressures are depicted in the Fig below :-



Pascal's law: The pressure applied to a confined fluid increases the pressure throughout by the same amount.

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

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

Lifting of a large weight by a small force by the application of Pascal's law.

Variation of Pressure with Depth

$$\Delta P = P_2 - P_1 = \rho g \, \Delta z = \gamma_s \, \Delta z$$

$$P = P_{\text{atm}} + \rho g h \quad \text{or} \quad P_{\text{gage}} = \rho g h$$

The pressure of a fluid at rest
increases with depth (as a result of added weight).

2nd aim:
Measures mass, density and viscosity of substances and liquid.

Mass - the amount of matter in a substance

-depends on the number and size of particles making up that substance

-the same wherever it is measured

SI unit for mass – the kilogram (kg)

Large masses (e.g. a car) - measured in tonnes
1 tonne
= 1 000 kg

Small masses (e.g. a watch) – measured in grams (g)
1 gram (g) = 0.001 kg

- The density of a substance is the amount of mass per unit volume of a substance.

- Device used to measure density in the standard test method is called pycnometers.

- SI unit for density is the kilogram per cubic meter (kg/m3).

- Another common unit for density is the gram per cubic centimetre (g/cm3).

Finding the density of a substance

Step 1: Measure the mass and the volume of the substance

Step 2: Divide the mass of the substance by its volume.

$$\textbf{Density} = \frac{\textbf{Mass}}{\textbf{Volume}}$$

Substances, e.g. a piece of metal or a volume of gas become less dense when they are hotter.

Why is this so?

They expand when they become hotter. With a bigger volume, their densities decrease, since density is mass per unit volume.

Floating and sinking

Some objects **float** and some others **sink.**

Objects such as pebbles or ball bearings sink in water because they have a higher density/are denser than water.

A piece of cork or wood will float on water because it has a lower density/is less dense than water.

What will happen to a solid when immersed in a liquid of the same density?

The solid will be freely suspended in the liquid.

Variation of Viscosity with Temperature

- As the temperature increased, most fluids viscosity decreases.

- Gases viscosity increases as the temperature increases.
  - The amount of change is generally smaller than that for liquids.

3rd aim:
Demonstrate Buoyant forces and Archimedes principles.

Archimedes' Principle

- **Archimedes' Principle**, law of physics that states that when an object is totally or partially immersed in a fluid, it experiences an upthrust equal to the weight of the fluid displaced.

  The principle is most frequently applied to the behaviour of objects in water, and helps to explain floating and sinking, and why objects seem lighter in water. It also applies to balloons in the air.

UPTHRUST AND BUOYANT FORCE

The key word in the principle is "upthrust" (or buoyant force), which refers to the force acting upward to reduce the actual weight of the object when it is under water.

for example, a metal block with a volume of 100 cm^3 is dipped in water, it displaces an equal volume of water, which has a weight of approximately 1 N. The block therefore seems to weigh about 1 N less.

Density and Buoyancy

From Archimedes's Principle :

Buoyant Force = Weight of fluid displaced

$= mg$ (note : $F = ma$)

$= \rho Vg$ (note : $\rho = \frac{m}{V}$)

Density and Buoyancy

Thus $F_B = \rho V g$

Where

F_B = Buoyant Force or Upthrust

ρ = Density of fluid

V = Volume of fluid displaced or the volume of the object that immersed in the fluid.

The Law of Floatation

A floating object displaces its own weight of fluid in which it floats.

APPLICATIONS

Hot air balloon

1. rises upwards

(Upthrust > Weight of hot air (helium gas) + weight of airship fabric + weight of gondola + weight of passengers.)(balloon expand)

2..descends

(Upthrust < Weight of hot air (helium gas) + weight of airship fabric + weight of gondola + weight of passengers.)(balloon shrinks)

3. stationary

(*Upthrust* = Weight of hot air (helium gas) + weight of airship fabric + weight of gondola + weight of passengers.)(balloon size uncanged)

Conclusion of The Chapter

This chapter explains Pascal law, Archimedes principle, Buoyant forces and relationship between mass, density and viscosity.

Reference

Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.