Thermodynamics
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Lecture 05
Basic concepts and definitions – Part 4

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If $\delta\phi = f(T) \, dT + (RT/V) \, dV$ for an ideal gas

is ϕ a property?

If not, suggest what changes in the
function can make ϕ a property

We will now see how to measure pressure. We will see rigorous definition of temperature a little later on in the course, and at that point of time we will see how to measure temperature. Volume is relatively easy to measure.
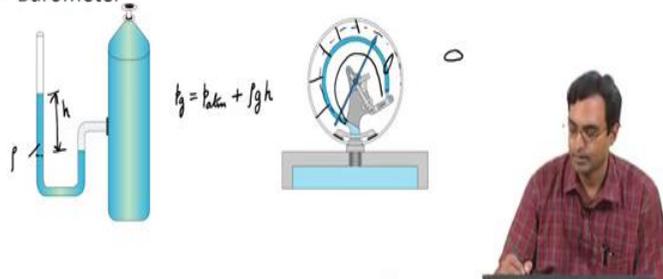
Figure 1

Pressure is defined as the normal force exerted by the fluid per unit area. We are mainly interested in fluids here, liquids and gases. We would look at it in that context.

The SI unit of pressure is Pa (pascal). 1 Pa is a force of 1 newton being exerted on an area of 1 meter squared. We will commonly use kilopascal and megapascal. 1 kilopascal equals 1000 Pa, while 1 megapascal is 10^6 Pa. Another commonly used unit is a bar, 1 barometer pressure. 1 bar equals 10^5 Pa. The value of 1 bar is close to the value of another unit of pressure which 1 atm (atmosphere). 1 atm is the pressure on the surface of earth at sea level.

1 atm equals 101325 Pa or 1.01325 bar. Many times 1 bar and 1 atm are taken approximately equal in calculations as their values are close to each other. However, it is not recommended as it introduces error in the calculations.

The pressure can be either the absolute pressure or the gauge pressure. The gauge pressure is the pressure with respect to the atmosphere. It is commonly measured using a manometer or a bourdon gauge.

A U-tube manometer connected to a cylinder at a pressure higher than the atmospheric pressure is shown in Fig. 1.

The U-tube contains some fluid (a liquid most of the times) which does not evaporate much and does not stick to walls of the tube. One end of the U-tube is connected to the cylinder, while the other end is open to atmosphere. If the pressure inside the cylinder is higher than the atmosphere, the level of the fluid inside the U-tube in the arm on the cylinder-side (right arm) goes down, while it goes up in the arm which is open to the atmosphere (left arm). Balancing pressures at the level of fluid in the right arm gives

Pressure of the gas in the cylinder = atmospheric pressure acting on the manometric fluid in the left arm + pressure due to height of the manometric fluid in the left arm above that in the right arm = $p_{atm} + \rho_{fluid}gh$.

If the pressure of the gas is measured with respect to the atmosphere, it is gauge pressure which in this case is $\rho_{fluid}gh$. If you add the atmospheric pressure to it, then you get the absolute pressure which in this case is $p_{atm} + \rho_{fluid}gh$.

Another device which is often used to measure the pressure is the bourdon gauge which is shown in Fig. 1. The blue-colored tube inside this gauge has an oval cross-section. When the gauge is attached to a system whose pressure is to be measured, the blue-colored tube bends/deforms which in turn rotates a gear mechanism which in turn rotates a needle. This needle rests on some value of pressure printed on the dial. A bourdon gauge gives you the gauge pressure.
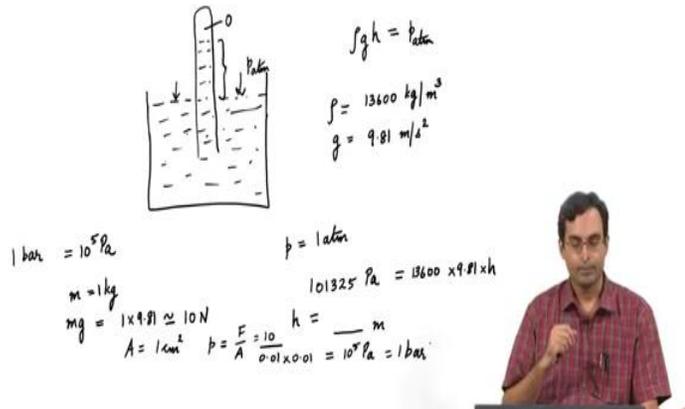
Figure 2.

We use barometer to measure the atmospheric pressure. Figure 2 shows the schematic of the barometer. The setup contains a long tube and a bath, both filled with mercury. Initially the tube is filled with mercury completely. Then it is inverted into the bath. The level of mercury in the tube falls until it reaches an equilibrium position. If we do a pressure balance at the level of mercury in the bath, we get

Pressure acting on the mercury in the bath (atmospheric pressure, p_{atm}) = pressure due to height of mercury column in the tube + pressure due gas above the mercury column in the tube (which is usually negligible as mercury has small vapor pressure) = $\rho_{mercury}gh = 13600\frac{kg}{m^3} \times 9.81\frac{m}{s^2} \times h$.

Since we know the value of p_{atm}, we can calculate the value of h. It comes out to be around 760 mm.

It is also useful to get a feel of these numbers.

Suppose you have a mass of 1 kg. Its weight, assuming g=10 m/s^2, is 10 N. When this weight is kept on a surface area of 1 cm by 1 cm, the pressure acting on that surface area is 1 bar.