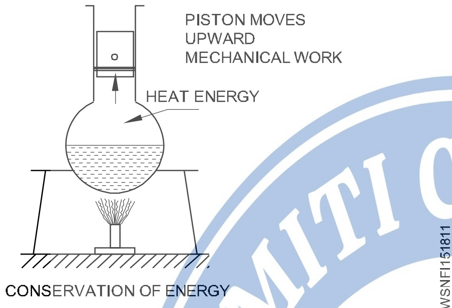
Heat & Temperature and Pressure - Concept of heat and temperature, effects of heat, difference between heat and temperature, boiling point & melting point of different metals and non-metals

Heat

It is a form of energy. Heat energy can be transformed into other forms of energies. Heat flows from a hotter body to a colder body. (Fig 1)

Fig 1



Units of heat

Calorie: It is the quantity of heat required to raise the temperature of 1 gram of water through 1°C.

BTHU: It is the quantity of heat required to raise 1 lb of water through 1°F. (British thermal unit).

C.H.U; It is the quantity of heat required to raise 1 lb of water through 1°C.

Joule : S.I. Unit (1 Calorie = 4.186 joule)

Effects of heat

- Change in temperature
- Change in size
- Change in state
- Change in structure
- Change in Physical properties

Specific heat

The quantity of heat required to raise the temperature of one gm of a substance through 1^0C is called specific heat. It is denoted by the letter 's'.

Specific heat of water	= 1
Aluminium	= 0.22
Copper	= 0.1
Iron	= 0.12

Thermal capacity:

It is the amount of heat required to raise the temperature of a substance through 1^0C is called the thermal capacity of the substance.

Thermal capacity = ms calories.

Calorific value: The amount of heat released by the complete combustion of unit quantity of the fuel (Mass or volume) is known as calorific value of fuels.

Water equivalent

It is the mass of water which will absorb the same amount of heat as the given substance for the same temperature rise. Water equivalent = Mass of the substance x specific heat of the substance.

Therefore water equivalent = ms

Types of heat

1 Sensible heat and

2 Latent heat

1 Sensible heat

Sensible heat is the heat absorbed or given off by a substance without changing its physical state. It is sensible and can be absorbed by the variation of temperature in the thermometers.

2 Latent heat

The heat gained or given by the substance during a change of state (from solid to liquid to gas) is called latent heat or hidden heat. The heat absorbed or given off does not cause any temperature change in the substance.

Types, 1. Latent heat of fusion of solid

2. Latent heat of vaporisation of solid.

1 Latent heat of fusion of solid

The amount of heat required per unit mass of a substance at melting point to convert it from the solid to the liquid state is called latent heat of fusion of solid. Its unit is cal/gram.

Latent heat of fusion of ice

The amount of heat required to convert per unit mass of the ice into water at 0^0C temperature is called latent heat of fusion of ice.

Latent heat of fusion of ice(L) = 80 cal/gram

2 Latent heat of vaporisation of liquid

The amount of heat required to vaporise a unit mass of liquid at its boiling point is called latent heat of vaporisation.

Latent heat of vaporisation of water or latent heat of steam

The amount of heat required to convert into steam of a unit mass of water at its boiling point (100^0C) is called latent heat of vaporisation of water or latent heat of steam.

Latent heat of steam(L) = 540 cal/gram

Temperature

It is the degree of hotness or coldness of a body. The temperature is measured by thermometers.

Difference between heat and temperature

Heat	Temperature
1 It is a form of energy.	This tells the state of heat.
2 Its unit is calorie.	Its unit is degree.
3 Heat is measured by calorimeter.	Temperature is measured by thermometer.
4 By adding quantity of heat of two substances their total heat can be calculated.	By adding two temperatures we cannot find the temperature of the mixture.
5 By heating a substance the quantity of heat is increased regardless of increase in temperature.	Two substances may read the same temperature though they might be having different amount of heat in them.

Boiling point

Any substance starts turning into a gas shows the temperature at which it boils this is known as the boiling point. The boiling point of water is 100^0C.

Melting point

The temperature at which any solid melts into liquid or liquid freezing to solid is called the melting point of substance. ` The melting point of ice is 0^0C.

List of melting point and boiling point of metals and Non -metals

Metals and Non-metals	Melting point °C	Boiling point °C
Aluminium	660.25	2519
Argon	-189.19	-185.85
Arsenic	817	614
Barium	729	1897
Beryllium	1287	2469
Bromine	-7.1	58.8
Cadmium	321.18	767
Calcium	839	1484
Carbon (diamond)	3550	4827
Carbon (graphite)	3675	4027
Chlorine	-100.84	-34.04
Cobalt	1495	2927
Copper	1084.6	2562
Gold	1064.58	2856
Helium	-	-268.93
Hydrogen	-259.98	-252.87
Iodine	113.5	184.3
Iridium	2443	4428
Iron	1535	2861
Lead	327.6	1749
Lithium	180.7	1342
Magnesium	650	1090

Metals and Non-metals	Melting point °C	Boiling point °C
Manganese	1246	2061
Mercury	-38.72	357
Molybdenum	2617	4639
Nickel	1453	2913
Nitrogen	-209.86	-195.79
Oxygen	-226.65	-182.95
Phosphorus (white)	44.1	280
Plutonium	640	3228
Potassium	63.35	759
Radium	700	1737
Silicon	1410	3265
Silver	961	2162
Sodium	98	883
Sulfur	115.36	444.6
Tin	232.06	2602
Titanium	1660	3287
Tungsten (wolfram)	3422	5555
Uranium	1132	4131
Zinc	419.73	907

Heat & Temperature and Pressure - Concept of pressure - Units of pressure atmospheric pressure, absolute pressure, gauge pressure and gauges used for measuring pressure

Concept of pressure

Continuous physics force exerted on or against an object by something in contact with it.

Definition

Pressure is an expression of force exerted on a surface per unit area, i.e., the force applied is perpendicular to the surface of object per unit area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Newton}}{\text{sq.meter}} = P = \frac{F}{A} \text{N/m}^2$$

As the amount of gas increases assuming the volume of chamber and the temperature remain constant the pressure increases.

Unit: Standard unit and also the S.I. unit of pressure is Pascal (Pa) and Metric unit of pressure is Bar.

1 Pascal is defined as a force of one newton per square metre

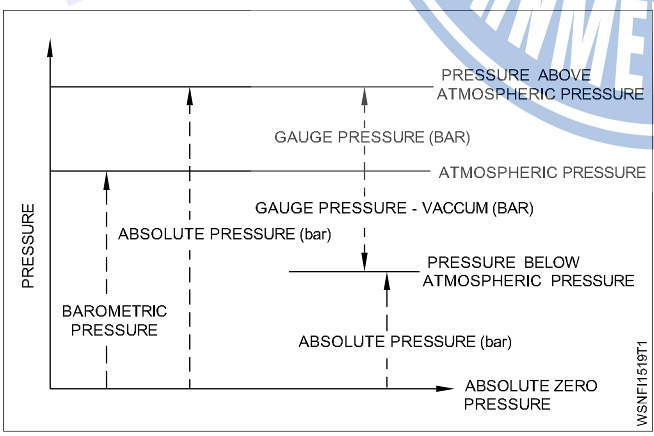
i.e., 1 Pascal = 1 N/m^2

1 Bar = 10^5 N/m^2

Pressure units in different systems

British unit FPS	Pounds per square inch	lb/in^2
Metric units CGS	Gram per square centimetre	g/cm^2
MKS	Kilogram per square metre	kg/m^2
International unit SI	Newtons per square metre	N/m^2

Types of Pressure



1 Absolute pressure

2 Atmosphere pressure

3 Gauge pressure

Measuring Instruments

I Manometers

a Simple manometer

i Piezometer

ii 'U' tube manometer

iii single column manometer

b Differential manometer

i 'U' tube differential manometer

ii Inverted 'U' tube manometer

II Mechanical Gauges

a Diaphragm pressure gauge

b Bourdon's tube pressure gauge

c Dead weight pressure gauge

d Bellows pressure gauge

Example

A liquid gives force of 100 N over an area of $2m^2$. What is the pressure?

Force = 100 N

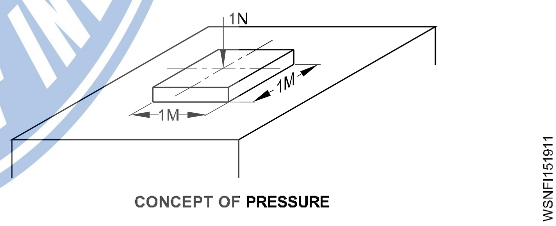
Area = 2 m^2

Pressure = ?

$$P = \frac{F}{A} = \frac{100}{2}$$

$= 50$ N/m^2

Fig 1



Unit of pressure N/m^2, 1 N/m^2 = 1 pascal.

This unit is too small (Pressure of a fly on a area of 1 cm^2). Hence 'bar' is introduced as the unit of pressure. 1 bar = 10^5 pascal.

$$10^5 P_a = 10^5 \frac{N}{m^2} = 10 \frac{N}{cm^2} = 1 \text{ bar}$$

1 bar = 1000 mbar. [SI unit of Pressure is Pascal (Pa) and Metric unit of Pressure is bar]

Properties of Pressure

1 Liquid pressure increase with depth.

2 Liquid pressure depends upon the density of the liquid

3 The pressure is same in all directions about a point in liquid at rest

4 Upward pressure at a point in a liquid is equal to downward pressure

Pascal's Law

A French scientist, Pascal stated that the pressure applied at any point in liquid, at rest is transmitted equally in all directions. This is known as Pascal' law.

Applications of Pascal's law

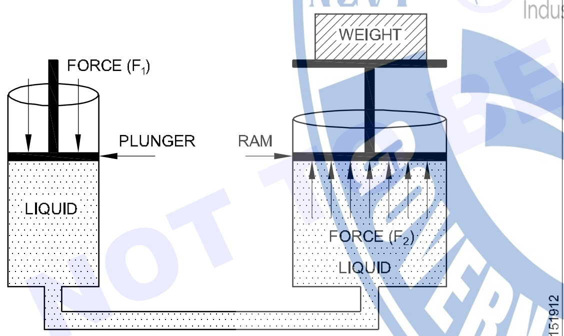
Pascal's law is applied in many devices like the siphon, hydraulic press, hydraulic lift, brahma press, air compressor, rotary pump and hydraulic brake. These hydraulic machines are based on the principle of transmission of pressure in liquids.

Principle of Hydraulic press

Two cylinders having different cross sectional area are connected to each other by a horizontal connecting tube. The apparatus is filled with a liquid. The two cylinders are fitted with air tight piston .

By giving a small input force on a plunger of a small cross sectional area cylinder a large output force are produced on the ram of large cross sectional area cylinder. According to Pascal's law, small input pressure exerted on plunger is transmitted by the liquid to the ram without any loss. Therefore a small force can be used to lift a much large force or weight. (Fig 2)

Fig 2



PRINCIPLE OF HYDRAULIC PRESS

$$\frac{\text{Force on plunger(F)}}{\text{Plunger area(a)}} = \frac{\text{Weight on the ram(W)}}{\text{Ram area(A)}}$$

$$\frac{F}{a} = \frac{W}{A}$$

$$\text{Weight on the ram (W)} = \frac{FxA}{a}$$

Properties of Air

- Actually speaking, air is a mixture of gases. Air is invisible, colourless, odourless, and tasteless.
- Composition: The main constituents of air by volume are 78% nitrogen, 21% oxygen, and 1% other gases such as argon and carbon dioxide.
- The gaseous layer of air around the earth is known as atmosphere

Pressure Relationship

- **Atmospheric pressure :** The air surrounding the earth exerts a pressure on the earth's surface. The pressure prevailing directly on the earth's surface is known as atmospheric pressure.
- The atmospheric pressure is also referred to as reference pressure. Normally it considers the sea level as its reference point.
- The atmospheric pressure may be calculated from the fundamental principle of barometer which states that the barometer reads the pressure due to the height of mercury (Hg) in the tube and its weight.

∴ Atmospheric pressure = $\rho g h$

Where (rho) ρ = Density of mercury (Hg) = 13600 kg/m^3

g = Acceleration due to gravity = 9.81 m/s^2, and

h = height of mercury (Hg) column = 760 mm of Hg at normal sea level.

Substituting the above values in equation, we get

Atmospheric pressure = 13600 x 9.81 x 0.76

= 1,01,396 N/m^2

= 1.013 bar

But for easy and simple calculation, we take the atmospheric pressure as 1 bar.

1 **Absolute pressure:** absolute pressure is defined as the pressure which is measured with reference in absolute vacuum pressure.

2 **Gauge pressure:** It is defined as the pressure which is measured with the help of a pressure measuring instrument in which the atmospheric pressure is taken an datum. The atmospheric pressure on the scale is marked a zero.

3 **Vacuum pressure:** It is defined as the pressure below the atmospheric pressure.

Mathematically:

i) Absolute pressure = Atmospheric pressure + Gauge pressure

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

ii) Absolute pressure = Atmospheric pressure – Vacuum pressure

$P_{ab} = P_{atm} - P_{vacc}$

iii) Vacuum pressure = Atmospheric pressure – Absolute pressure

1 Atmospheric pressure = 76 cm of mercury = 33.91 ft of water

= 76 x 13.6 gm/cm^2

= 76 x 13.6 x 10^{-3} kg/cm^2

= 76 x 13.6 x 10^{-3} x 9.8 N/cm^2

= 10.13 N/cm^2

= 1.013 bar

= 1013 mbar [1 bar = 1000 mbar]

1 Pascal = 1 N/m^2

1 bar = 10^5 Pascal = 10^5 N/m^2 = 10 N/cm^2

1 bar = 0.986923 atmosphere

1 millibar = 0.01 N/cm^2 = 10^{-2} N/cm^2

1 atmospheric Pressure (FPS) = 14.7 $Pound/inch^2$ (psi)

1 atmospheric Pressure (Metric) = 1.0336 Kg/cm^2

1 atmospheric Pressure (Metric) = 1.014 x 10^6 $dyne/cm^2$

Effects of altitude on atmospheric pressure

Atmospheric pressure changes according to altitude a tabulation is shown here with variations.

For every 11 meter above sea level drop in air pressure is 1.3 m bar.

For every 1000 ft above sea level drop in air pressure is 1" Hg (mercury)

S. No.	Place	Unit of Pressure	Mercury column	Inch units
1	Sea level	1013 m bar	750 mm	14.7 psi
2	520 metres above sea level	951.5 m bar	700 mm	13.7 psi

Pressure gauges

They are instruments or devices used to measure the pressure of liquid steam or gas contained in a vessel. There are also known as mark meters.

Types of manometers

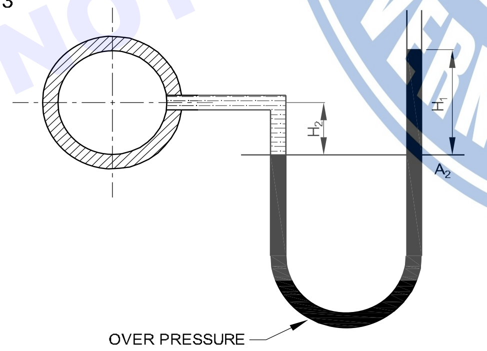
- Open tube
- Closed tube
- Differential type
- Inverted type

Mechanical pressure gauges

- Bourdon's pressure gauge
- Diaphragm pressure gauges
- Dead weight pressure gauges

Open tube manometer (Fig 3)

Fig 3



OPEN TUBE MANOMETER (OVER PRESSURE)

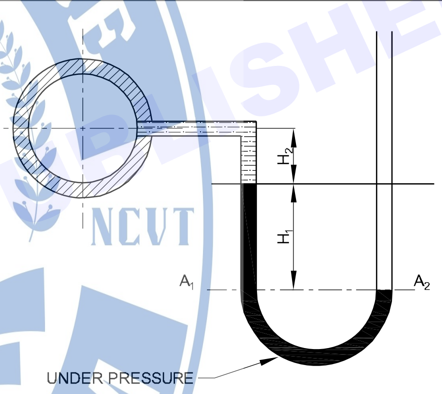
It is more suitable to measure pressure in vessels which is having little variation to atmospheric pressure. It is a 'u' shaped tube containing mercury having its one end connected to the vessel container in which the liquid is there whose pressure is to be determined. The other end is open. The manometer will show a difference in both the limbs of the tube when the pressure inside the vessel is more or less than the air pressure outside.

For a barometer reading with reference to an atmospheric pressure of 1 bar we have

$P_a = 1 + P_o$ (shown in Fig 3)

$P_a = 1 - P_u$ (shown in Fig 4)

Fig 4

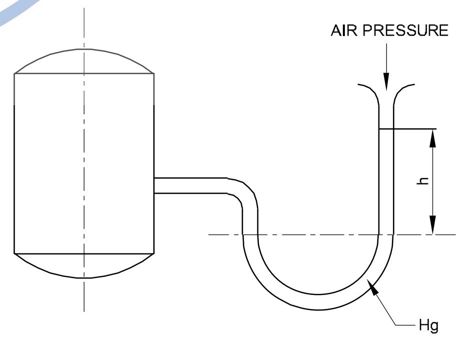


OPEN TUBE MANOMETER (UNDER PRESSURE)

Example (Fig 5)

A manometer is connected to an air pressure tank and it indicates an over pressure of 615 mm pressure head. The external air pressure is 1015 mbar. Calculate the absolute pressure in bar and in Pascal (Fig 5).

Fig 5



OPEN TUBE MANOMETER

Absolute Pressure = External Air Pressure + Over Pressure

P_a = 1015 mbar + 100 mbar x 615 mm/750 mm

= 1835 mbar

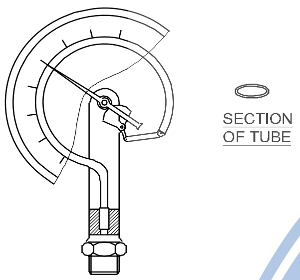
P_a = 1.835 bar = 1.835 x 10^5 Pascal

If the barometer reading is in mm, it is always necessary to convert into m bar.

Pressure and Vacuum gauges

Bourdon tube pressure gauges (Fig 6)

Fig 6



THE BOURDON PRESSURE GAUGE

In I.C. Engines, Bourdon tube pressure gauges are widely employed for measurement of pressure, temperature and vacuum. In these gauges, a Bourdon tube which is a tempered, one is used and it attempts to straighten out under pressure and temperature and contact under vacuum.

The working is briefly described here refer to figure. A phosphor bronze tube or elliptical cross section is used and bent to an arc of a circle. The free end of the tube is sealed under internal pressure (or temperature), it attempts to straighten out. During this process, it operates sector, pinion and needle which indicates pressure or temperature over a calibrated dial. The entire unit is mounted on a casing and covered with glass and frame and around it.

Vacuum gauges

These are also of Bourdon tube type gauges where the tube attempts to contract under vacuum thus recording vacuum of the engine in mm Hg (millimeters of mercury)

A reading of 760 mm Hg is prefect vacuum (zero absolute pressure)

A zero of say 300 mm Hg means to say that 300 mm of vacuum is equivalent to (760-300) 460 milliHg absolute pressure.

- Vacuum gauges are often used by service mechanics to find out the mechanical condition of the engine and whether valves, ignition timing and carburetor setting are correct and carry out fine adjustments to obtain the best performance of the engine.
- **Vacuum in Diesel Engine governors:** This is measured by water column methods in fuel injection test bench
- **Vacuum in manifolds of an engine:** This can be measured by using vacuum gauge

- **Over-pressure:** The gas pressure of the tyre is bigger than the pressure of the atmosphere. In the tyre we have over pressure.
- **Under-pressure :** The gas pressure in the cylinder during the suction process is smaller. There is under pressure in the cylinder.
- **Absolute pressure:** The absolute pressure = air pressure + over-pressure. The pressure in vacuum is 0 bar.

The manometer indicates the over-pressure. The absolute pressure on the earth is normally 1 bar. The measured pressure plus 1 bar is the absolute pressure in normal conditions.

The unit for gas pressure is bar.

P_a = absolute pressure

P_o = over pressure

P_u = under pressure

Air pressure in technical calculations is assumed to be 1 bar.

Rules and examples

Absolute pressure = over-pressure + air pressure

$P_a = P_o + 1$ bar

Over-pressure = absolute pressure - air pressure

$P_o = P_a - 1$ bar

Under-pressure = air pressure - absolute pressure

$P_u = 1$ bar $- P_a$

Absolute pressure = air pressure - under-pressure

$P_a = 1$ bar $- P_u$

Examples

- What pressure is 2 bar over-pressure?

  P_a = 2 bar + 1 bar = 3 bar

- What over-pressure is 4 bar?

  P_o = 4 bar - 1 bar = 3 bar over-pressure

- How many bar under pressure is 0.7 bar?

  P_u = 1 bar - 0.7 bar = 0.3 bar under-pressure.

- How many bar is 0.3 bar under-pressure?

  0.7 bar.

Properties of gases

1 Charles's law

First law or law of volume

At constant pressure the volume (V) of a given mass of gas is directly proportional to its absolute temperature(T)

$$V \propto T \; ; \; \frac{V}{T} = K \text{ (K - Constant)}$$

Second law or law of pressure

At constant volume the pressure (P) of a given mass of gas is directly proportional to its absolute temperature (T).

$$P \propto T ; \frac{P}{T} = K \text{ (K - Constant)}$$

2 Boyle's law or Gas law

At constant temperature the volume (V) of a given mass of gas is inversely proportional to its pressure. (P)

$$V \propto \frac{1}{P} ; PV = K \text{ (K - Constant)}$$

3 Perfect gas equation

Since boyle's law and charles's law can not be applied independently due to changes in pressure, volume and temperature a combined law called "gas equation" has been formulated. Gas equation is relating to pressure, volume and temperature of perfect gas which obeys both the boyle's law and charles's law. A gas which obeys boyle's and charles's law is called ideal gas.

As per boyle's law

$$V \propto \frac{1}{P} \qquad PV = K \text{ (Constant) } P_1V_1 = P_2V_2 = K$$

As per charle's law

$$V \propto T \qquad \frac{V}{T} = K \text{ (Constant) } \frac{V_1}{T_1} = \frac{V_2}{T_2} = K$$

Combining the above two laws,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = R \text{ [R = gas constant]}$$

$$\frac{PV}{T} = R$$

$$PV = RT$$

P = Pressure (KN/m^2)
V = Volume (m^3)
m = Mass (Kg)
R = gas constant (Kgf.m/kg/k)
T = absolute temperature (K)

If mass of the gas is m, then

$$PV = mRT$$

Gas constant R = 29.27 kgf.m / kg/ k

= 287 joule/Kg/k

True gas and its properties

1 It has mass and volume. So, it has weight.

2 It can be compressed or expanded into a container.

3 It is invisible.

4 General Gas Law

Boyle's, Charles', and Gay-Lussac's laws can be combined to obtain the general gas law is given by,

$$\frac{PV}{T} = \text{Constant (or)}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} = \text{.............} \frac{P_nV_n}{T_n}$$

In the perfect gas law, the P and T represents absolute pressure and absolute temperature (in °K) respectively.

1 1 kg of air at 5 kgf/cm² and 30°C is expanded to atmospheric pressure and 20°C. What will be the volume occupied?

Solution: Assuming atmospheric pressure is 1.033 kgf/cm² and gas constant

R = 29.27 kg m/kg/°K;

$P_1 = 5 \text{ kgf/cm}^2 = 5 \times 10^4 \text{ kg/m}^2$

$T_1 = 30°C = 30 + 273 = 303°$ Kelvin

Mass of air = m = 1 kg

Applying formula:

$$P_1V_1 = m.R.T_1$$

$$V_1 = \frac{m.R.T_1}{P_1}$$

$$= \frac{1 \times 29.27 \times 303}{5 \times 10^4}$$

= 0.1774 cubic metre

The following information is ready:

$P_1 = 5 \times 10^4 \text{ kg/metre}^2$

$V_1 = 0.1774$ cubic metre

$T_1 = 303°K$

$P_2 = 1.033 \text{ kgf/cm}^2 = 1.033 \times 10^4 \text{ kg/metre}^2$

$T_2 = 20°C = 20 + 273 = 293°K$

Let V_2 = Volume occupied = To Find

Applying formula:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{P_2T_1}$$

$$= \frac{(5 \times 10^4) \times 0.1774 \times 293}{(1.033 \times 10^4) \times 303}$$

= 0.8303 cubic metre

Volume occupied = 0.8303 cubic metre

2 Find the volume of a gas, if its absolute temperature doubled and the pressure is reduced to one half.

Solution: At initial stage:

Let initial pressure $= P_1$

Initial Volume $= V_1$

Initial temperature $= T_1$

At final stage:

P_2 = Final pressure

Since pressure is reduced to one half of initial pressure, we can say

$$P_2 = \frac{1}{2} P_1$$

T_2 = Final temperature

Since temperature is doubled, we can say

$$T_2 = 2T_1$$

V_2 = Volume of gas required = To Find

Applying formula

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2}$$

$$= \frac{P_1V_1 2T_1}{T_1 \frac{1}{2} P_1}$$

$$= 4V_1$$

$$V_2 = 4V_1$$

Final volume = 4 times of initial volume

3 Find the pressure at the depth of 40 metres below the surface of a lake in dynes per sq. cm., the atmospheric pressure being neglected.

Solution:

Depth of water level ρ = 40 m = 4000 cm

Density of water d = 1 gram/cc

Acceleration due to gravity g = 980 cm/sec^2

Pressure below the surface of lake is given by the formula

= ρ.d.g.

Pressure = ρ.d.g

= 4000 x I x 980

= 3920000 dynes per sq. cm.

4 At 5 atmospheric pressure 0.2 cu. metre air is filled in a container. If the same air is filled at constant temperature in a 1 cu. metre volume of container then calculate the air pressure in the container.

Solution: At constant temperature the gas follows Boyle's Law

$$P_1V_1 = P_2V_2$$

Here, P_1 = 5, V_1 = 0.2 cu. metre, V_2 = 1 cu. metre

$$P_1V_1 = P_2V_2$$

$$5 \times 0.2 = P_2 \times 1.0$$

$$P_2 = \frac{5 \times 0.2}{1.0} = 1$$

Air pressure in the container = 1 atmospheric.

5 The column of mercury in a barometer is 76 cm. If instead of mercury the kerosene oil is filled in the barometer, what would be the state of column when relative density of kerosene oil is 0.8?

Solution: Suppose the height of column of kerosene in the mercury tube is h_2, then the pressure of column of kerosene = pressure of column of mercury. Assuming relative density of mercury = 13.6

$$h_2d_2g = h_1d_1g$$

$$h_2 = \frac{h_1d_1g}{d_2g} = \frac{h_1d_1}{d_2}$$

$$= \frac{76 \times 13.6}{0.8}$$

= 1292 cm

= 12.92 metres

6 The volume of a gas at 770 mm pressure is 403 cc. Find the pressure when the volume is reduced to 341 cc.

As per Boyles Law

$$P_1V_1 = P_2V_2$$

$$770 \times 403 = P_1 \times 341$$

$$P_1 = \frac{770 \times 403}{341}$$

Pressure when volume is reduced **= 910 mm**

7 At 80 cm pressure the volume of a gas is 800 cu. cm. How much pressure be increased to bring the volume of gas at 200 cu. cm?

Pressure P_1 = 80 cm

Volume V_1 = 800 cu. cm

Volume V_2 = 200 cu. cm

As per Boyle's law

$$P_1V_1 = P_2V_2$$

$$80 \times 800 = P_2 \times 200$$

$$P_2 = \frac{80 \times 800}{200} = \frac{640}{2} = 320 \text{ cm}$$

Pressure to be increased = 320 - 80 = 240 cm

= 2.4 metres

8 A gas has a pressure of 2 kg/cm^2 and volume of 5m^3. What will be the volume of gas if the pressure is reduced to 1 kg/cm^2 keeping the temperature constant?

Gas pressure P_1 = 2 kg/cm^2

Volume V_1 = 5 m^3

Pressure P_2 = 1 kg/cm^2

As per Boyle's law

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1 \times V_1}{P_2} = \frac{2 \times 5}{1}$$

Volume of gas = 10m³

9 A gas at 1.5 kgf/cm² occupying 0.2 m³ is at 20°C. It is compressed to a pressure of 5 kgf/cm² such that its volume becomes 0.03m³. What will be final temperature of the gas?

Temperature T_1 = 20°C = 20 + 273 = 293° Kelvin

Volume of gas V_1 = 0.2 m³

Pressure of gas P_1 = 1.5 kgf/cm²

= 1.5 x 10⁴ kgf/m²

Volume V_2 = 0.03 m³

Pressure P_2 = 5 kgf/cm²

= 5 x 10⁴ kgf/m²

As per perfect gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$T_2 = P_2V_2 \times \frac{T_1}{P_1V_1}$$

$$= 5 \times 10^4 \times 0.03 \times \frac{293}{1.5\times10^4\times0.2}$$

$$= \frac{439500}{1.5\times10^4 \times 0.2}$$

$$= \frac{439500}{3000}$$

= 146.5

T_2 = 146.5 Kelvin

= 146.5 - 273

Final temperature of gas = -126.5° C

10 An automobile tyre contains 0.14 kg of air at 2 kg/cm² gauge pressure at 27°C. What is the volume of air in cubic cm?

In this sum gauge pressure is given. To solve it absolute pressure is necessary. Atmospheric pressure = 1.033 kg/cm²

Absolute pressure = Gauge pressure + Atmospheric pressure

= 2 + 1.033

= 3.033 kg/cm²

Pressure P = 3.033 kg/cm²

= 3.033 x 10⁴ kg/m²

Weight of air m = 0.14 kg

Temperature T = 27°C = 27+273

= 300° Kelvin

Gas constant R = 29.27 kgm kg/ Kelvin

(or) 287 Joule / kg/ Kelvin

As per perfect gas equation

PV = mRT

$$V = \frac{0.14 \times 29.27 \times 300}{3.033 \times 10^4}$$

$$= \frac{1229.34}{30330} = 0.0405 \text{ cu.m}$$

= 0.0405 x 10⁶

Volume of air = 40532 cu. cm

Assignment

1 At 10 atmospheric pressure 0.4 cu. metre air is filled in a container. If the same air is filled at constant temperature in a 2 cu. metre volume of container then calculate the air pressure in the container

2 The volume of a gas at 780 mm pressure is 413 cc. Find the pressure when the volume is reduced to 351cc.

3 A gas is transferred from one container of volume 100 cc. of a pressure of 1.5 kg/cm² into another container of capacity 200 cc. Find the pressure in the new container.

4 5 litre of air at 30°C and 1.1 atmospheric pressure is compressed to one litre and 10 atmospheric pressure. Calculate the temperature after compression.