Tutorial 1

A pump discharges a liquid into a drum at the rate of 0.032 m3/s. The drum, 1.50 m in diameter and 4.20 m in length, can hold 3000 kg of the liquid. Find the density of the liquid and the mass flow rate of the liquid handled by the pump.

$$\text{Volume of drum} = \frac{\pi d^2}{4} \times h$$

$$= \frac{\pi \times 1.50^2}{4} \times 4.2 \text{ m}^3$$

$$= 7.422 \text{ m}^3$$

$$\text{density} = \frac{\text{mass}}{\text{Volume}} = \frac{3000}{7.422} \text{ kg/m}^3 = 404.203 \text{ kg/m}^3$$

$$\text{mass flow rate} = \text{Vloume flow rate} \times \text{density}$$

$$= 0.032 \times 404.203 \text{ kg/s}$$

$$= 12.9345 \text{ kg/s}$$

Convert the following readings of pressure to kPa, assuming that the barometer reads 760 mmHg:

(a) 90 cmHg gauge
(b) 40 cmHg vacuum
(c) 1.2 m H_2O gauge
(d) 3.1 bar

$$760 \text{ mm Hg} = 0.760 \times 13600 \times 9.81 \text{ Pa}$$

$$= 10139.16 \text{ Pa}$$

90 cm Hg gauge

$$= 0.90 \times 13600 \times 9.81 \times 10^{-3} + 101.4 \text{ kPa}$$
$$= 221.4744 \text{ kPa}$$

40 cm Hg vacuum

$$= (76 - 40) \text{ cm (absolute)}$$
$$= 0.36 \times 43.600 \times 9.81 \text{ kPa}$$
$$= 48.03 \text{ kPa}$$

1.2 m H_2O gauge

$$= 1.2 \times 1000 \times 9.81 \times 10^{-3} + 101.4 \text{ kPa}$$
$$= 113.172 \text{ kPa}$$

3.1 bar = 3.1 × 100 kPa = 310 kPa

A 30 m high vertical column of a fluid of density 1878 kg/m^3 exists in a place where g = 9.65 m/s^2. What is the pressure at the base of the column.

(**Ans.** 544 kPa)

$$p = z\rho g$$
$$= 30 \times 1878 \times 9.65 \text{ Pa}$$
$$= 543.681 \text{ kPa}$$

(a)A pump forces 1 m^3/min of water horizontally from an open well to a closed tank where the pressure is 0.9 MPa. Compute the work the pump must do upon the water in an hour just to force the water into the tank against the pressure. Sketch the system upon which the work is done before and after the process.

(**Ans.** 5400 kJ/h)

(b)If the work done as above upon the water had been used solely to raise the same amount of water vertically against gravity without change of pressure, how many meters would the water have been elevated?

(**Ans.** 91.74 m)

(c)If the work done in (a) upon the water had been used solely to accelerate the water from zero velocity without change of pressure or elevation, what velocity would the water have reached? If the work had been used to accelerate the water from an initial velocity of 10 m/s, what would the final velocity have been?

(**Ans.** 42.4 m/s; 43.6 m/s)

Flow rate $1 m^3/hr$.
Pressure of inlet water = 1 atm = 0.101325 MPa
Pressure of outlet water = 0.9 MPa

$$\text{Power} = \Delta p \dot{v}$$
$$= (0.9 - 0.101325) \times 10^3 \text{kPa} \times \frac{1}{60} \text{ m}^3/\text{s}$$
$$= 13.31 \text{ kJ/s}$$

(b) So that pressure will be 0.9 MPa

$$\therefore \quad h\rho g = 0.9 \text{ MPa}$$

$$\text{or} \quad h = \frac{0.9 \times 10^6}{1000 \times 9.81} \text{ m} = 91.743 \text{ m}$$

(c)
$$\frac{1}{2}\dot{m}\left(V_2^2 - V_1^2\right) = \Delta p \dot{v} \qquad \text{where } \dot{m} = \dot{v}\rho$$

$$\text{or} \quad \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) = \Delta p$$

$$\text{or} \quad V_2^2 - V_1^2 = 2\frac{\Delta p}{\rho}$$

$$\text{or} \quad V_2^2 = V_1^2 + 2\frac{\Delta p}{\rho}$$

$$= 10^2 + \frac{2 \times (0.9 - 0.101325) \times 10^6}{1000}$$

$$V_2 = 41.2 \text{ m/s.}$$

The piston of an oil engine, of area 0.0045 m^2, moves downwards 75 mm, drawing in 0.00028 m^3 of fresh air from the atmosphere. The pressure in the cylinder is uniform during the process at 80 kPa, while the atmospheric pressure is 101.325 kPa, the difference being due to the flow resistance in the induction pipe and the inlet valve. Estimate the displacement work done by the air finally in the cylinder.

(Ans. 27 J)

Volume of piston stroke

$= 0.0045 \times 0.075 \text{m}^3$

$= 0.0003375 \text{m}^3$

$\therefore \quad \Delta V = 0.0003375 \text{ m}^3$

as pressure is constant

$= 80 \text{ kPa}$

So work done $= p\Delta V$

$= 80 \times 0.0003375 \text{ kJ}$

$= 0.027 \text{ kJ} = 27 \text{ J}$