MECHANICAL SCIENCE—2007

Time : 3 Hours *Full Marks : 70*

Group–A

[Multiple Choice Type Questions]

1. **Choose the correct alternatives for the following:** 10×1=10

(i) Which of the following quantities is not a property of a system?
(a) Pressure (b) Temperature (c) Heat (d) Specific volume

(ii) During throttling process
(a) Internal energy does not change (b) Pressure does not change (c) Entropy does not change (d) Enthalpy does not change (e) Volume does not change

(iii) Thermal power plant works on
(a) Carnot cycle (b) Joule cycle (c) Rankine cycle (d) Otto cycle

(iv) Work done in a free expansion process is
(a) Positive (b) Negative (c) Zero (d) Maximum

(v) The more effective way of increasing efficiency of Carnot engine is to
(a) Increase higher temperature (b) Decrease higher temperature (c) Increase lower temperature (d) Decrease lower temperature.

(vi) A refrigerator and a heat pump operate between the same temperature limits. If C.O.P. of the refrigerator is 4, the C.O.P. of the pump would be
(a) 3 (b) 4 (c) 5 (d) Cannot be predicted (e) None of these

(vii) A pitot tube is used for measuring
(a) State of flow (b) Density of fluid (c) Velocity of fluid (d) None of these

(viii) Stream line, path line and streak line are identical when
(a) The flow is uniform (b) The flow is steady (c) The flow velocities do not change steadily with time (d) The flow is neither steady nor uniform.

(ix) Bernoulli's equation deals with the law of conservation of
(a) Mass (b) Momentum (c) Energy (d) Work

(x) Which fluid does not experience shear stress during flow?
(a) Pseudoplastic (b) Dilatant (c) Inviscid (d) Newtonian

Ans. (i)(c) ; (ii)(d) ; (iii)(c) ; (iv)(c) ; (v)(d) ; (vi)(c) ; (vii)(c) ; (viii)(b) ; (ix)(c) ; (x)(c).

Group–B

[Short Answer Type Questions]

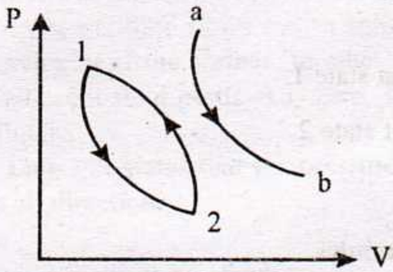
Answer *any three* questions. 3 × 5 = 15

2. (a) **What is the basic difference between a process and a cycle?** 2

(b) **Show that work done in isothermal process from state 1 to state 2 is given by :**
$W_{1-2} = p_1 V_1 (\ln p_1 - \ln p_2)$ 3

Ans. (a) Process : A thermodynamic process is a procedure by which a system is taken from one state to another. Hence if a process is executed, then at least one property of the system must change.

Cycle : A thermodynamic cycle is defined as a series of state changes such that the final state is identical with the initial state.



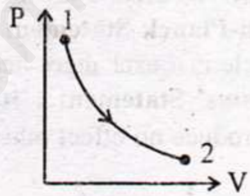
$a - b \Rightarrow$ a process

$1 - 2 - 1 \Rightarrow$ a cycle

Ans. (b) For an isothermal process 1–2,

$pV = k = \text{constant}. \quad \therefore p_1V_1 = p_2v_2 = k$

$\therefore \dfrac{V_2}{V_1} = \dfrac{p_1}{p_2} \quad \therefore$ Work done by the system $= W_{1-2}$



$$W_{1-2} = \int_{V_1}^{V_2} p\,dv = \int_{V_1}^{V_2} \frac{K}{V}\,dv$$

$$= K[\ln V]_{V_1}^{V_2} = P_1V_1 \ln\left(\frac{V_2}{V_1}\right) = P_1V_1 \ln\left(\frac{P_1}{P_2}\right) \quad \therefore W_{1-2} = p_1V_1 (\ln p_1 - \ln p_2)$$

3. What is steady flow process? Write the steady flow energy equation for a single stream entering and a single leaving a control volume and explain the various terms in it. 2 + 3

Ans. Steady Flow Process : When a fluid flows through a certain control volume, its thermodynamic properties vary along the space coordinates as well as with time. If the rates of flow of mass and energy across the control surface are constant, then the flow process is called a STEADY FLOW PROCESS ; that is, at the steady state of the system, any thermodynamic property has a fixed value at a particular location and does not alter with time.

Steady Flow Energy Equation for a single stream entering and leaving a control volume :

$$\dot{Q} - \dot{W} + \dot{m}\left(h_1 + \frac{\overline{V}_1^{\,2}}{2} + gz_1\right) = \dot{m}\left(h_2 + \frac{\overline{V}_2^{\,2}}{2} + gz_2\right)$$

Where, $\dot{Q} = \dfrac{\delta Q}{\delta t}$ = rate of heat transfer into the system.

$\dot{W} = \dfrac{\delta W}{\delta t}$ = rate of work transfer from the system i.e. power developed by the system.

$\dot{m}$ = rate of mass flow into the system at state 1 and also that coming out of the system at state 2.

h_1 = specific enthalpy at state 1.

h_2 = specific enthalpy at state 2.

$\overline{V}_1$ = velocity of the fluid at inlet i.e. at state 1.

$\overline{V}_2$ = velocity of the fluid at exit i.e. at state 2.

z_1 = elevation at state 1.

z_2 = elevation at state 2.

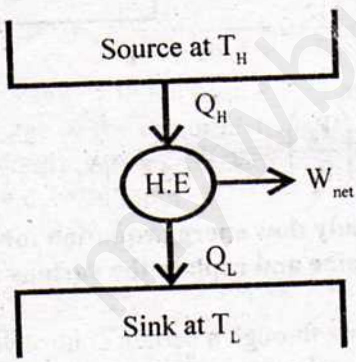
4. (a) State second law of thermodynamics. 3

(b) What is a perpetual motion machine of 2nd kind? 2

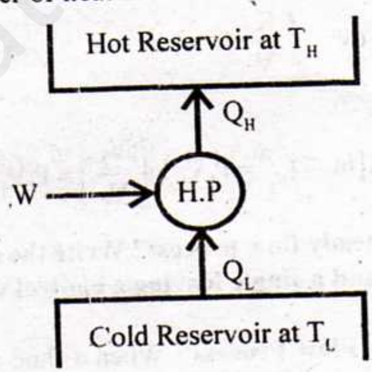
Ans. 4. (a) The second law of thermodynamics has two statements stated as under :

(i) **Kelvin-Planck Statement :** It is impossible for a heat engine to produce network n a complete cycle if it exchanges heat only with bodies at a single fixed temperature.

(ii) **Clausius' Statement :** It is impossible to construct a device, which, operating in a cycle, will produce no effect other than the transfer of heat from a cooler to a hotter body.



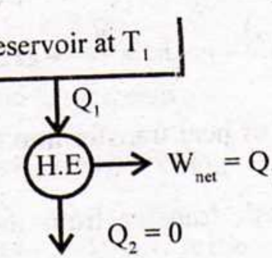
(i) Kelvin-Planck statement



(ii) Clausive' statement

Ans. (b) A perpetual motion machine of 2nd kind or PMM2 is a fictitious heat engine that will produce network in a complete cycle by exchanging heat with only one reservoir, thus violating the Kelvin Planck statement.

A PMM2



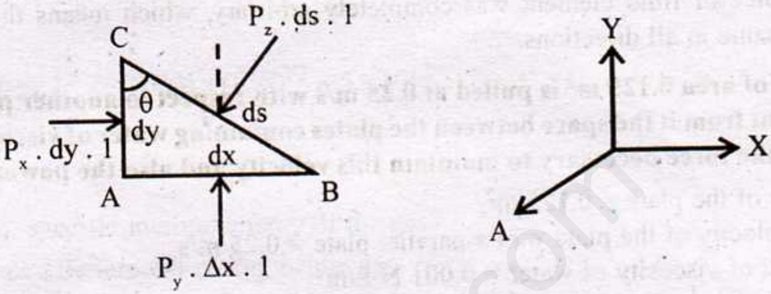
5. (a) Explain the no-slip condition of viscous fluids. 2

(b) State and prove Pascal's law of hydrostatics. 3

Ans. 5.(a). When a viscous fluid flows over a solid surface, the fluid elements adjacent to the surface attain the velocity of the surface. In other words, the relative velocity between the solid surface and the adjacent fluid particles is zero. This phenomenon is known as "no-slip" condition of viscous fluids.

Ans. (b) Pascal's Law : It states that the pressure or intensity of pressure at a point in a static fluid is equal in all directions.

It can be proved as :



Consider an arbitrary liquid element of wedge shape in a fluid mass at rest. Let the width of the element is unity and p_x, p_y and p_z are the pressures or intensity of pressure acting on the face AC, AB and BC respectively. Let $\angle ACB = \theta$. Then forces acting on the element are :

(i) Pressure forces normal to the surfaces.

(ii) Weight of element in the vertical direction.

Force on the face AC = $p_x \times d_y \times 1$

Force on face AB = $p_y \times \Delta x \times 1$

Force on face BC = $p_z \times ds \times 1$

Weight of element $= \dfrac{AC \times AB}{2} \times 1 \times w,$

where w = weight density of fluid

Resolving the forces in x-direction, we have

$$p_x \times dy \times 1 - p_x(ds \times 1)\sin(90^o - \theta) = 0$$

or, $p_x \times dy \times 1 - p_z\, ds \times 1 \cos\theta = 0$

But from fig. $ds\cos\theta = AB = dy$

$\therefore p_x \times dy \times 1 - p_z \times dy \times 1 = 0$

or, $p_x = p_z$

Similarly, resolving the forces in y-direction, we get :

$$p_y \times dx \times 1 - p_z \times ds \times 1 \cos(90^\circ - \theta) - \frac{dx \times dy}{2} \times 1 \times w = 0$$

$$\text{or, } p_y \times dx - p_z(ds)\sin\theta - \frac{dx \cdot dy}{2} \times w = 0$$

But ds $\sin\theta$ = dx and also the element is very small and hence weight is negligible.

$\therefore\ p_y dx - p_z \times dx = 0$ or, $p_y = p_z$

Hence we have, $p_x = p_y = p_z$

Since the choice of fluid element was completely arbitrary, which means the pressure at any point is the same in all directions.

6. A hot plate of area 0.125 m^2 is pulled at 0.25 m/s with respect to another parallel plate 1 mm distant from it the space between the plates containing water of viscosity 0.001 N-s/m^2. Find the force necessary to maintain this velocity and also the power required. 5

Ans. A = area of the plate = 0.125 m^2.
v = relative velocity of the plate w.r.t a parallel plate = 0.25 m/s
μ = coefficient of viscosity of water = 0.001 N-S/m^2.
From Newton's Law of viscosity,

$$\tau = \mu.\frac{du}{dy}$$

τ = shear stress

du = change in velocity = 0.25 m/s
dy = change in distance = 1×10^{-3}m

Force necessary to maintain this velocity = F

$$F = A.\tau = A\mu\frac{du}{dy} = 0 \cdot 125 \times 0 \cdot 001 \times \frac{0 \cdot 25}{1 \times 10^{-3}}\ \text{N}$$

$$\Rightarrow F = 0 \cdot 03125\text{N}$$

Power required = F × v = 0.03125 × 0.25 = 7.8125×10^{-3} Joules.

And force necessary to maintain the velocity = 0.03125N

and Power required = 7.8125×10^{-3} Joules.

Group–C

[Long Answer Type Questions]

Answer *any three* questions. $3 \times 15 = 45$

7. (a) A mass of 8 kg gas expands within a flexible container so that p-v relationship is of the form pv$^{1.2}$ = constant. The initial pressure is 1000 kPa and the initial volume is 1m^3. The final pressure is 5 kPa. If specific internal energy of the gas decreases by 40 kJ/kg, find the heat transfer in magnitude and direction. 7

(b) A heat pump working on the Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C. The heat pump is driven by a reversible heat engine which takes in heat from a reservoir at 840°C and rejects heat to a reservoir at 60°C. The reversible heat engine also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from the 5°C reservoir, determine (a) the rate of heat supply from the 840°C source and (b) the rate of heat rejection to the 60°C sink. 8

Ans. (a) m = mass of gas = 8 kg ; $pV^{1.2}$ = constant

$p_1 = 1000$ kPa ; $V_1 = 1 m^3$

$p_2 = 5$ kPa .

$\because p_1V_1^{1\cdot2} = p_2V_2^{1\cdot2} \Rightarrow (1000)\times(1/8)^{1\cdot2} = 5\times V_2^{1\cdot2}$

$\Rightarrow V_2 = 10.33 m^3/kg$

$\therefore V_2 = 82.7 m^3$

Let u_2 = final specific internal energy of the gas.

u_1 = initial specific internal energy of the gas

$\therefore u_2 - u_1 = -40$ kJ/kg

$$\delta W = \frac{p_1V_1 - p_2V_2}{1\cdot2-1} = \frac{1000\times1-5\times82\cdot7}{0\cdot2} = 2932.5 \text{ kJ}$$

From first law of thermodynamics,

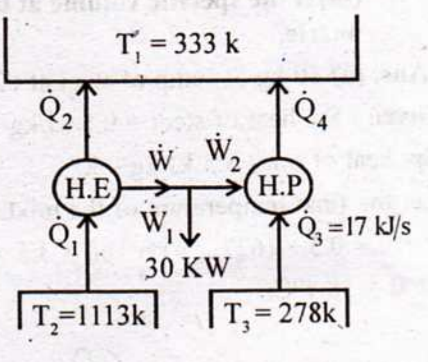
$\delta Q = du + \delta W = -40\times8 + 2932.5 = 2612.5$ kJ

Heat is transferred to the system as indicated by the positive sign.

Ans. 2612.5 kJ of heat energy is transferred to the system.

Ans. (b) Given $\dot{Q}_3 = 17$ kJ/s ; $\dot{W}_1 = 30$ kW

(a) $\dot{Q}_1 = ?$ (b) $\dot{Q}_2 + \dot{Q}_4 = ?$



$$(COP)_{H.P} = \frac{1}{1-\frac{T_3}{T_1}}$$

(as it works on carnot cycle)

$$= \frac{1}{1-\frac{278}{333}} = 6.05$$

$\therefore$ We know, $(COP)_{H.P} = \dfrac{\dot{Q}_4}{\dot{Q}_4 - \dot{Q}_3} = \dfrac{1}{1-\frac{17}{\dot{Q}_4}} = 6\cdot05$

$$\Rightarrow 0\cdot165 = 1 - \frac{17}{\dot{Q}_4} \Rightarrow \frac{17}{\dot{Q}_4} = 0\cdot834 \Rightarrow \dot{Q}_4 = 20\cdot366 \text{ kJ/s}$$

$\therefore\ \dot{W}_2 = \dot{Q}_4 - \dot{Q}_3 = 20\cdot36 - 17 = 3\cdot36$ kJ/s

$\therefore\ \dot{W}_1 = \dot{W}_2 + 30 = 3\cdot36 + 30 = 33\cdot36$ kJ/s

$\therefore\ \eta$ = efficiency of the reversible heat engine

$$= \frac{\dot{W}}{\dot{Q}_1} = \frac{\dot{Q}_1 - \dot{Q}_2}{\dot{Q}_1} = 1 - \frac{T_2}{T_1} = 1 - \frac{333}{1113} = 0\cdot7008$$

$\therefore\ \dot{Q}_1 = \frac{\dot{W}}{\eta} = \frac{33\cdot36}{0\cdot7008}$ = 47.6 kJ/s = rate of heat supplied from the 840° source.

Rate of heat rejected to the 60°C sink $= \dot{Q}_2 + \dot{Q}_4$

$\dot{Q}_2 = \dot{Q}_1 - \dot{W} = 47\cdot6 - 33\cdot36 = 14\cdot24$ kJ/s

$\therefore\ \dot{Q}_2 + \dot{Q}_4 = 14\cdot24 + 20\cdot36 = 34\cdot6$ kJ/s

Ans. (a) the rate of heat supply from the 840°C source is 47.6 kw

Ans. (b) the rate of heat rejection to the 60° sink is 34.6 kW.

8. (a) **A lump of steel of mass 10 kg at 627°C is dropped in 100 kg of oil at 30°C. The specific heats of steel and oil are 0.5 kJ/kg-K and 3.5 kJ/kg-K respectively. Calculate the entropy change of the steel, the oil and the universe.** 7

(b) **At the inlet to a certain nozzle, the enthalpy of the flowing fluid is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end the enthalpy is 2762 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it.**

(i) Find the velocity at exit from the nozzle.

(ii) If the inlet area is 0.1 m² and the specific volume at inlet is 0.187 m³/kg, find the mass flow rate.

(iii) If the specific volume at the nozzle exit is 0.498 m³/kg, find the exit area of the nozzle. 8

Ans. (a) 10 kg of lump of steel at 627°C is dropped in 100 kg of oil at 30°C.

Given : Sp. heat of steel = 0.5 kJ/kg–k

Sp. heat of oil = 3.5 kJ/kg – k

Let the final temperature of the mixture be θ.

$\therefore\ 10 \times 0.5 \times (627 - \theta) = 100 \times 3.5 \times (\theta - 30)$

$\Rightarrow \theta = 38.4$°C.

$$\text{Entropy change of steel} = \int \frac{\delta Q}{T} = 10 \times 0\cdot5 \times \int_{627}^{38\cdot4} \frac{dT}{T}$$

$$= 10 \times 0\cdot5 \ln \frac{38\cdot4}{627} = -13\cdot96 \text{ kJ/k}$$

Entropy change of oil $= 100 \times 3 \cdot 5 \times \int_{30}^{38\cdot 4} \frac{dT}{T} = 100 \times 3 \cdot 5 \times \ln \frac{38 \cdot 4}{30} = 86.4$ kJ/k

Entropy change of universe = Entropy change of steel + entropy change of oil

= – 13.96 + 86.4 = 72.44 kJ/k

Ans. Entropy change of steel = – 13.96 kJ/k

Entropy change of oil = 86.4 kJ/k

Entropy change of universe = 72.44 kJ/k.

Ans. (b). At inlet to the nozzle, h_1 = 3000 kJ/kg = enthalpy of the flowing fluid.

$\bar{v}_1$ = velocity of the fluid = 60 m/s.

At the discharge end,

h_2 = enthalpy = 2762 kJ/kg

Since, the nozzle is horizontal, $z_1 = z_2$

Heat loss is negligible.

(i) Hence, from the steady flow energy equation,

$$h_1 - h_2 + \frac{1}{2}\bar{v}_1^2 - \frac{1}{2}\bar{v}_2^2 = 0$$

$$\Rightarrow (3000 - 2762) \times 10^3 = \frac{1}{2}(\bar{v}_2^2 - 60^2)$$

$\Rightarrow \bar{v}_2 = 692 \cdot 53$ m/s = velocity at exit from the nozzle.

(ii) A_1 = inlet area = 0.1 m^2

v_1 = specific volume at inlet = 0.187 m^3/kg

Let $\dot{m}$ = mass flow rate.

We know, $\dot{m} = \frac{A_1\bar{v}_1}{v_1} = \frac{0 \cdot 1 \times 60}{0 \cdot 187} = 32.08$ kg/s.

(iii) v_2 = specific volume at exit = 0.498 m^3/kg.

Let A_2 = exit area of the nozzle.

$$\dot{m} = \frac{A_2 \bar{V}_2}{V_2} \Rightarrow A_2 = \frac{\dot{m}V_2}{\bar{V}_2} = \frac{32 \cdot 08 \times 0 \cdot 498}{692 \cdot 53} = 2.306 \times 10^{-2} \text{ m}^2$$

$= 0.023$ m^2

Ans. (i) Velocity at exit from the nozzle = 692.53 m/s

(ii) Mass flow rate = 32.08 kg/s

(iii) Exit area of the nozzle = 0.023 m^2.

9. (a) **What is a pure substance?** 2

(b) **What is the "critical point"? State the values of critical pressure and critical temperature of water.** 3

(c) **Why is Carnot cycle not practicable for a steam power plant?** 3

(d) **In an ideal air-standard diesel cycle, the pressure and temperature at intake are 1.03 bar and 27°C respectively. The maximum pressure in the cycle is 47 bar and heat supplied during the cycle is 545 kJ/kg. Determine**

(i) The compression ratio

(ii) The temperature at the end of compression

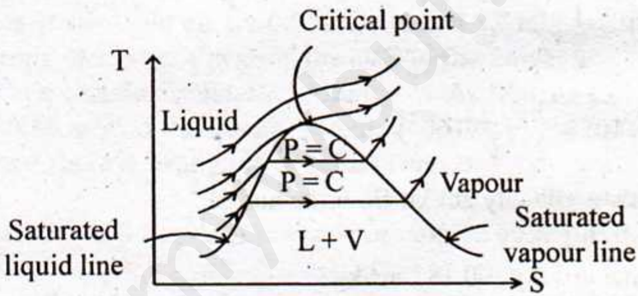
(iii) The temperature at the end of combustion

(iv) The air standard efficiency.

Assume $\gamma = 1.4$ and $C_P = 1.004$ kJ/kg-K for air. 7

Ans. (a) Pure substance : Pure substance in thermodynamics is defined as one that has invariable chemical composition in all phases. For example, water. Water resists in any one of the three phases : Solid, liquid & gas. Water, in all the phases ; ice, water, and steam has same chemical composition.

Ans. (b) In the pressure-volume diagram of water, saturated liquid line and the saturated vapour line meet smoothly at a point. This point is called critical point. similarly, we can



Vapour Dome for Water (STEAM)

represent the critical point on a T–S plane at which there is no transition zone from liquid to vapour. The temperature, pressure and volume of water at critical point are called critical temperature, critical pressure and critical volume.

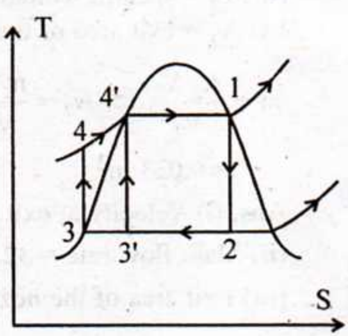
The critical pressure is equal to 221.2 bar.

Critical temperature is 374.15°C.

Ans. (c) Drawbacks of carnot cycle :

(i) In carnot cycle, steam is condensed upto point 3', so it is not completed. It is extremely difficult to stop the process at point 3'.

(ii) The working substance at point 3' is a mixture of water and steam. It is not a homogenous mixture and it is extremely difficult to compress a two-phase mixture isentropically.



(iii) Vapour has large specific volume. So size of compressor (pump) becomes large in Carnot cycle. More power is required ; so plant efficiency is low.

(iv) Carnot cycle has high specific steam consumption i.e. steam rate.

(v) Steam at exhaust from the turbine is of low quality i.e. high moisture content. The liquid water droplets cause pitting and erosion of turbine blades.

Ans. (d) $P_1 = 1.03 \text{ bar} = 1.03 \times 10^3 \text{ Pa}$

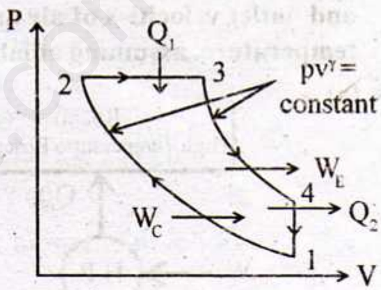
$T_1 = 27 + 273 = 300\text{K}$

$P_2 = P_3 = 47 \text{ bar} = 47 \times 10^3 \text{ Pa}$

$Q_1 = 545 \text{ kJ/kg}$

$\gamma = 1.4$; $C_p = 1.004$ kJ/kg–k for air.

Compression ratio $= \dfrac{V_1}{V_2} = r_k$



(i) $P_1 V_1{}^\gamma = P_2 V_2{}^\gamma$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma} = \left(\frac{1\cdot03}{47}\right)^{1/1\cdot4}$$

$$\therefore r_k = \frac{V_1}{V_2} = 15\cdot3$$

(ii) For Process 1 – 2, $P_1{}^{1-\gamma} \cdot T_1{}^\gamma = P_2{}^{1-\gamma} \cdot T_2{}^\gamma$

Temperature end of compression $= T_2 = T_1\left(\dfrac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}} = 893.708$ k $\quad\therefore t_2 = 620.708°\text{C}$

(iii) $Q_1 = C_p dT = C_p(T_3 - T_2)$

$545 \times 10^3 = 1.004 \times 10^3 (T_3 - 893.708)$

$T_3 = 1436.536\text{k} \Rightarrow t_3 = 1163.536°\text{C}$

(iv) Cut-off ratio $= r_c = \dfrac{V_3}{V_2}$

For process 2-3, p = c = a constant. $\quad\therefore \dfrac{T}{V} = C$

$$\frac{T_2}{V_2} = \frac{T_3}{V_3} \Rightarrow \frac{V_3}{V_2} = \frac{T_3}{T_2} \qquad \therefore r_c = \frac{T_3}{T_2} = \frac{1436\cdot536}{893\cdot708} = 1\cdot607$$

$$\eta = \text{efficiency} = 1 - \frac{1}{\gamma}\cdot\frac{1}{r_k{}^{\gamma-1}}\cdot\frac{r_c{}^\gamma - 1}{r_c - 1} = 1 - \frac{1}{1\cdot4}\cdot\frac{1}{(15\cdot3)^{1\cdot4-1}}\cdot\frac{(1\cdot6)^{1\cdot4} - 1}{1\cdot6 - 1} = 0.372 \text{ i.e. } 37.2\%$$

Ans. (i) The compression ratio = 15.3

(ii) The temperature at the end of compression = 620.708°C.

(iii) The temperature at the end of combustion = 1163.536°C.

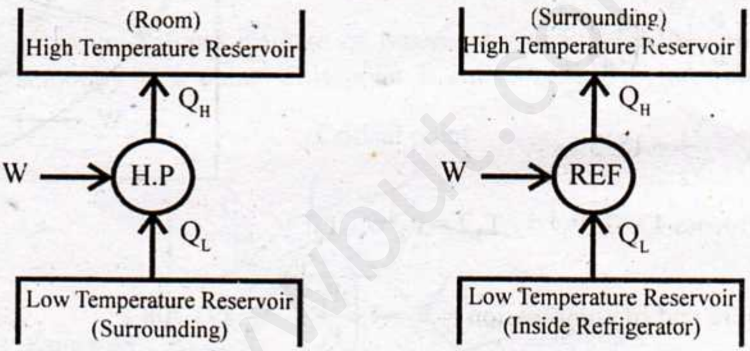
(iv) The air standard efficiency = 37.2%.

10. (a) How does a heat pump differ from a refrigerator? 3

(b) A household refrigerator is maintained at a temperature of 2°C. Every time the door is opened, warm material is phased inside, introducting an average of 420 kJ but making only a small change in the temperature of the refrigerator. The door is opened 20 times a day and the refrigerator operates at 15% of the ideal COP. The cost of work is Rs. 5.00 per kWh. What is the monthly bill for this refrigerator? The atmosphere is at 30°C. 6

(c) A blower handles 1 kg/s of air at 20°C and consumes a power of 15 kW. The inlet and outlet velocities of air are 100 m/s and 150 m/s respectively. Find the exit air temperature, assuming adiabatic conditions. Take C_p of air as 1.005 kJ/kg-K. 6

Ans. (a)



Heat Pump
Desired effect = Q_H

Refrigerator
Desired effect = Q_L

A refrigerator is a device which, operating in a cycle, maintains a body at a temperature lower than the temperature of the surroundings. On the other hand, a heat pump is a device which, operating in a cycle, maintains a body at a temperature higher than the temperature of the surrounding.

$$(COP)_{H.P} = \frac{Q_H}{W} \quad \text{and} \quad (COP)_{REF} = \frac{Q_L}{W}$$

$$\therefore (COP)_{H.P} - (COP)_{REF} = 1$$

Ans. (b) T_L = temperature inside the refrigerator = 2°C = (2 + 273)k = 275k

T_H = temperature of the surrounding i.e. atmosphere = 30°C = (30 + 273)k = 303k.

We know,

$$(COP)_{ideal} = \frac{T_L}{T_H - T_L} = \frac{275}{303 - 275} = 9 \cdot 821;$$

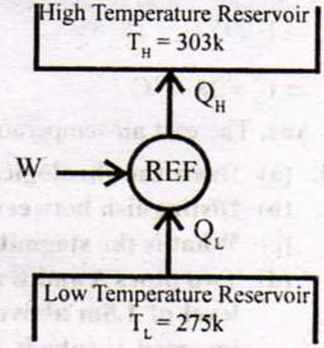
$(COP)_{ref} = 0.15 \times (COP)_{ideal} = 0.15 \times 9 \cdot 821 - 1.473$

In a day, the door of the refrigerator is opened 20 times.

$\therefore$ In a month, the door is opened (20×30) times.

Hence, for a month :

$$Q_L = (420 \times 20 \times 30)\text{ kJ} = 252000\text{ kJ}.$$



We know,

$$(COP)_{ref} = \frac{Q_L}{W}$$

$$\Rightarrow 1 \cdot 473 = \frac{252000}{W} \quad \Rightarrow W = \frac{252000}{1 \cdot 473}\text{ kJ}$$

Now, 1 kW = 1 kJ/s $\Rightarrow$ 1 kWs = 1 kJ.

$$\Rightarrow 3600\text{ kWs} = 3600\text{ kJ} = 1\text{ kWH} \quad \therefore W = \frac{252000}{1 \cdot 473 \times 3600}\text{ KWH} = 47 \cdot 52\text{ KWH}$$

By the problem, Cost of 1 KWH of work is Rs. 5.00

$\therefore$ Cost of 47.52 KWH of work is Rs. (5.00×47.52) = Rs. 237.60.

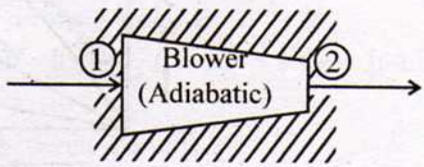
Ans. The monthly bill for this refrigerator is Rs. 237.60.

Ans. (c) Given : Mass flow rate into and out of the blower = $\dot{m}$ = 1 kg/s.

t_1 = temperature at inlet = 20°C

$\overline{V}_1$ = velocity at inlet = 100 m/s

$\overline{V}_2$ = velocity at outlet = 150 m/s.



$\dot{W}$ = power consumed = – 15 kw

C_P of air = 1.005 kJ/kg – k.

$\dot{Q}$ = 0 (assuming Adiabatic condition).

t_2 = exit air temperature = ?

From the S.F.E.E., we can write :

$$\dot{Q} - \dot{W} + \dot{m}\left(h_1 + gz_1 + \frac{\overline{V}_1^{\,2}}{2}\right) - \dot{m}\left(h_2 + gz_2 + \frac{\overline{V}_2^{\,2}}{2}\right)$$

where, h_1 and h_2 are specific enthalpies at inlet and exit respectively ; z_1 and z_2 are elevations at inlet and exit respectively.

$$15 + 1(h_1 - h_2) + \frac{1}{2}\left(\overline{V}_1^{\,2} - \overline{V}_2^{\,2}\right) = 0 \qquad [\because gz_1 = gz_2 = 0]$$

$$\Rightarrow 15 + 1 \times 1 \cdot 005(20 - t_2) + \frac{1}{2}(100^2 - 150^2) \times 10^{-3} = 0$$

$\Rightarrow 15 + 20 \cdot 1 - 1 \cdot 005 t_2 - 6 \cdot 25 = 0$

$\Rightarrow 1 \cdot 005\ t_2 = 28 \cdot 85$

$\Rightarrow t_2 = 28 \cdot 7^{\circ}C$

Ans. The exit air temperature is 28.7°C.

11. (a) Draw the rheological curve for a class of Newtonian and non-Newtonian fluids. 3

(b) Distinguish between incompressible and compressible flow. 3

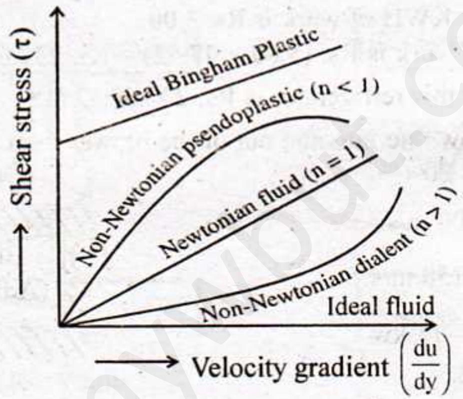
(c) What is the stagnation pressure at a point in a fluid flow?

(d) Two pipes A and B are in the same elevation. Water is contained in A and rises to a level of 1.8m above it. Carbon tetrachloride (Sp. Gr. 1.6) is contained in B. The inverted U-tube is filled with compressed air at 350 kN/m^2 and 27°C. Barometer reads 760 mm of mercury.

Determine :

(i) The Pressure difference between A and B if z = 0.4m, and (ii) The absolute pressure in B. 7

Ans. (a)

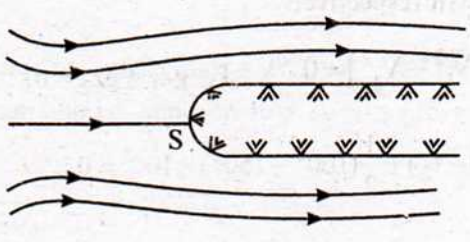


Ans. (b) Incompressible Flow : Incompressible flow is that type of flow in which the density is constant for the fluid flow. Liquids are generally incompressible. Mathematically, for incompressible flow, ρ = constant.

Compressible Flow : Compressible flow is that type of flow in which the density of the fluid changes from point to point or in other words the density (ρ) is not constant for the fluid.

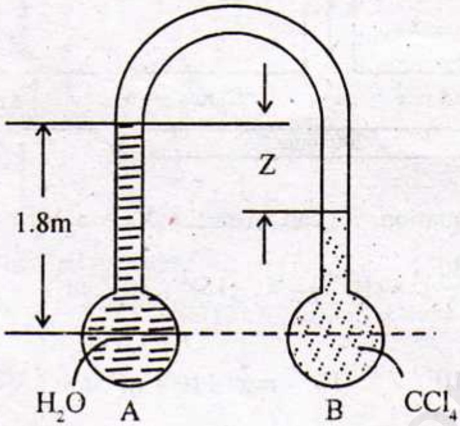
Thus, mathematically, for compressible flow, $\rho \neq$ constant.

Ans. (c) In the figure, the central streamline terminates at S, the head of the obstruction. This is on the account of the



inability of the streamline to take a sudden turn. The fluid flowing along the central streamline stops moving as it reaches the point S. This point is known as stagnation point, where velocity of flow is zero.

Ans. (d)



Sp. gr. of carbon tetrachloride (CCl_4) = 1.6

$z = 0.4$ m

Pressure at A = $P_A + (1.8 \times 10^3 \times 9.81) + (350 \times 10^3)$

Pressure at B = $P_B + (1.8 - 0.4) \times 1.6 \times 10^3 \times 9.81 + 350 \times 10^3$

Equating the pressures along the isobaric line through A and B,

$\therefore p_A + 1.8 \times 10^3 \times 9.81 + 350 \times 10^3 = p_B + (1.8 - 0.4) \times 1.6 \times 10^3 \times 9.81 + 350 \times 10^3$

$(p_A - p_B) = (1.4 \times 1.6 - 1.8) \times 10^3 \times 9.81$

$= 4.3164 \times 10^3$ N/m^2 = Pressure diff. between A and B.

Absolute pressure in B = $(1.8 - 0.4) \times 1.6 \times 10^3 \times 9.81 + 350 \times 10^3 + 13.6 \times 10^3 \times 76 \times 10^{-3} \times 9.81$

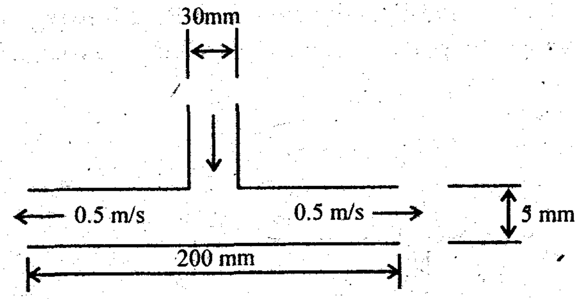
$= 382.114 \times 10^3$ N/m^2 = 382.114 kPa.

Ans. (i) Pressure difference between A and B = 4.3164 kPa.

(ii) Absolute pressure in B = 382.114 kPa.

12. (a) A diffuser consists of two circular parallel plates 200 mm in diameter and 5 mm apart and connected to a 30 mm diameter pipe as shown in fig. below.
If the stream lines are assumed to be radial in the diffuser, what mean velocity in the pipe will correspond to an exit velocity of 0.5 m/s. 5

(b) A venturimeter with inlet and throat diameters are 150 mm and 75 mm respectively, is mounted in a vertical pipe carrying water, the flow being upwards. The throat section is 250 mm above the inlet of the venturimeter. The discharge of the venturimeter is 40 lit/sec. Find the static pressure difference between the inlet and throat section if the coefficient of discharge for venturimeter is 0.96. 10



Ans. (a) From continuity equation, we can write : $a_1V_1 = a_2V_2$

where, a_1 = inlet area $= \pi \left(\frac{30}{2}\right)^2 \times (10^{-6}) = \pi \times (15)^2 \times 10^{-6}\ m^3$.

a_2 = exit area $= 2\pi \times \frac{200}{2} \times 10^{-3} \times 5 \times 10^{-3} = \pi \times 10^{-3}\ m^3$

V_2 = velocity at exit = 0.5 m/s

$\therefore$ Velocity at inlet, $V_1 = \frac{10^{-3}}{15^2 \times 10^{-6}} \times 0 \cdot 5 = 2.22$ m/s

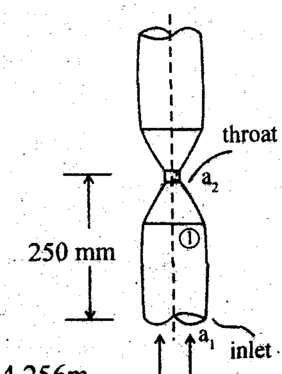
Ans. The mean velocity in the pipe is 2.22 m/s.

Ans. (b) Discharge of the venturimeter $= Q_{act} = 40$ lit/s $= 40 \times 10^{-3}\ m^3/s$.

Coefficient of discharge $= c_d = 0.96$

Inlet diameter $= d_1 = 150$ mm

Throat diameter $= d_2 = 75$ mm



a_1 = inlet area $= \pi\,(d_1/2)^2 = \pi\,(150/2)^2 \times 10^{-6}$

$= 0.017671\ m^2$

a_2 = throat area $= 0.004417\ m^2$

We know, $Q_{act} = C_d \cdot \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \cdot \sqrt{2gh}$,

where h = diff. of pressure heads at sections (1) and (2). $\therefore$ h = 4.256m

$$h = \frac{P_1}{\rho_g} - \frac{P_2}{\rho_g} - 250 \times 10^{-3}$$

where p_1 & p_2 are pressure at sections (1) and (2) respectively.

$\therefore \frac{P_1 - P_2}{\rho_g} = h + 0 \cdot 250 = 4.506$ m $\quad \therefore P_1 - P_2 = 44158.8\ N/m^2 = 44.158$ kPa

Ans. State pressure difference between the inlet and throat section is 44.158 kPa.