CBCS SCHEME

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BME401

Fourth Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026

Applied Thermodynamics

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of Steam Tables and Thermodynamic Data hand book is permitted.
3. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	**M**	**L**	**C**
Q.1	**a.**	Define cut off ratio and Air standard efficiency.	**04**	**L1**	**CO1**
	b.	With usual notations obtain Air Standard efficiency of otto cycle.	**06**	**L2**	**CO1**
	c.	The compression ratio of Diesel cycle is 14, and cut-off ratio is 2.2. At the beginning of the cycle, air is at 0.98 bar and 100° C. Find : i) Temperature and pressure at salient points. ii) Air standard efficiency.	**10**	**L3**	**CO1**
		OR			
Q.2	**a.**	Define the following : i) Indicated power ii) Brake power iii) Friction power iv) Mechanical efficiency	**04**	**L1**	**CO1**
	b.	Explain the process of combustion in SI engine.	**06**	**L2**	**CO1**
	c.	The following data were obtained from a Morse test on a 4 – cylinder, 4 – stroke, S.I engine, coupled to a hydraulic dynamometers operating at constant speed of 1500 rpm. Brake load with all the four cylinders firing = 296 N. Brake load with cylinder No. 1 not firing = 201 N. Brake load with cylinder No. 2 not firing = 206 N. Brake load with cylinder No. 3 not firing = 192 N. Brake load with cylinder No. 4 not firing = 200 N. The brake power in 'KW' is calculated using $BP = \frac{WN}{42300}$ Where, W = Brake load in Newtone. N = Engine speed in rpm. Calculate : i) Brake power ii) Indicated power iii) Friction power iv) Mechanical efficiency	**10**	**L3**	**CO1**
		Module – 2			
Q.3	**a.**	Derive an expression for the efficiency of a Brayton cycle.	**06**	**L2**	**CO2**
	b.	Explain the difference between open cycle and closed cycle gas turbine.	**04**	**L1**	**CO2**
	c.	Air enters the compressor of an ideal air standard Brayton cycle at 100 kpa, 300 k with a volumetric flow rate of 6 m^3/s. The compressor work ratio is 10. The turbine inlet temperature is 1500 k. Determine: i) The thermal efficiency ii) Work ratio iii) Power. Take $\gamma = 1.4$ $C_p = 1.005$ KJ/KgK	**10**	**L3**	**CO2**

		OR			
Q.4	**a.**	With a neat sketch explain the working of Ram jet.	**10**	**L2**	**CO2**
	b.	Discuss the working principle of Rocket propulsion with neat sketch.	**10**	**L2**	**CO2**
		Module – 3			
Q.5	**a.**	List the drawbacks of Carnot vapour power cycle.	**04**	**L1**	**CO3**
	b.	Discuss the effect of i) Boiler pressure ii) Condenser pressure on the performance of a Rankine cycle.	**06**	**L2**	**CO3**
	c.	In a steam power cycle, the steam supply is at 15 bar, and dry saturated. The condenser pressure is 0.4 bar. Calculate the thermal efficiency for i) Carnot vapour power cycle ii) Rankine vapour power cycle Neglect pump work.	**10**	**L3**	**CO3**
		OR			
Q.6	**a.**	With help of neat sketch, explain the working of Reheat Rankine cycle.	**08**	**L2**	**CO3**
	b.	A turbine is supplied with steam at a pressure of 20 bar and Temperature 350° C, The steam is then expands to a condenser pressure of 0.04 bar. Calculate its thermal efficiency. It is desired to improve the efficiency by regenerative feed heating by bleeding steam at 2 bar and heating in an open feed heater. Calculate the percentage improvement in thermal efficiency. Neglect pump work in the above calculation.	**12**	**L3**	**CO3**
		Module – 4			
Q.7	**a.**	List out the desirable properties of refrigerant.	**04**	**L1**	**CO4**
	b.	With help of neat sketch, explain the working principle of vapour compression Refrigeration System.	**06**	**L2**	**CO4**
	c.	A simple vapour compression refrigeration plant produces 5 Tonnes of refrigeration. The enthalpies of the working fluid at inlet to the compressor = 183.19 kJ/kg at exit of compressor = 209.41 kJ/Kg , at exit of the condenser = 74.59 kJ/kg. Estimate : i) The refrigerant flow rate ii) COP of the plant iii)Power required to drive the compressor iv) The rate of heat rejection in the condenser	**10**	**L3**	**CO4**
		OR			
Q.8	**a.**	Define : i) Sensible heating ii) Sensible coding	**04**	**L1**	**CO4**
	b.	With a neat sketch, explain a summer air conditioning system.	**06**	**L2**	**CO4**
	c.	An air conditioning system is designed under the following conditions. Out door conditions: 30° C DBT, 75% RH Required indoor conditions: 22°C DBT, 70% RH. Amount of free air circulated 3,33 m^3 / s. Coil dew point temperature (DPT) = 14°C. The required conditions is achieved first by cooling and dehumidification and then by heating. Estimate : i) The capacity of the cooling coil in Tonnes of refrigeration ii) The capacity of heating coil in KW iii) The amount of water vapour removed in kg /hr.	**10**	**L3**	**CO4**

		Module – 5			
Q.9	**a.**	Define the following with respect to a reciprocating air compressor. i) Volumetric efficiency ii) Adibatic efficiency iii) Isothermal efficiency iv) Mechanical efficiency	**06**	**L1**	**CO5**
	b.	Explain the advantages of multistage compression.	**04**	**L2**	**CO5**
	c.	A 2 – stage air compressor with complete inter cooling delivers air to the mains at a pressure of 30 bar suction conditions are 1 bar of 15°C. If both cylinders have same stroke. Find the ration of cylinder diameter for maximum efficiency. The index of compression is 1.3.	**10**	**L3**	**CO5**
		OR			
Q.10	**a.**	With usual notations derive the expression for critical pressure ratio.	**10**	**L2**	**CO5**
	b.	A turbine having a set of 16 nozzles receives steam at 20bar and 400°C. The pressure of steam at the nozzle exit is 12 bar. If the discharge rate is 260 kg/mm and nozzle efficiency is 90%. Calculate the cross – sectional area at the nozzle exit. If the steam has a velocity of 80 m/s at entry to the nozzle. Fine the percentage increase in discharge.	**10**	**L4**	**CO5**

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Question Paper solution and scheme

AY: 2025-26

Department: Mechanical Engineering
Subject with Sub. Code: Applied Thermodynamics (BME401)
Name of Faculty: Dr. Shankar Badiger

Semester: IV

Q.No.	**Solution and Scheme**	**Marks**

Module-1

Q1) a) → Cut-off ratio is used in diesel engine.

$$\rho = \frac{\text{volume after the fuel injection}}{\text{Volume at the start of fuel injection}}$$

$$= V_3/V_2$$

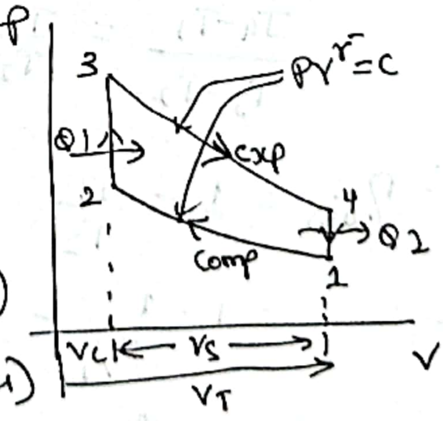
2m

→ Air standard efficiency: To compare performance of different cycles working substance in the cylinder is assumed to be air, & the efficiency of the engine using air as a working fluid is considered. This efficiency is known as air standard efficiency.

2m

b) Otto cycle:

V_c = clearance volume
V_s = stroke "
r_c = compression ratio = $\frac{V_T}{V_c}$



Heat supplied = $Q_1 = mC_v(T_3 - T_2)$

" rejected = $Q_2 = mC_v(T_1 - T_4)$

Heat rejection is −ve

$\therefore Q_2 = -mC_v(T_1 - T_4)$
$= mC_v(T_4 - T_1)$

2m

$$\eta_{air} = \frac{W_{net}}{Q_s} = \frac{Q_s - Q_r}{Q_s} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

$$= 1 - \frac{\cancel{m}\cancel{C_v}(T_4 - T_1)}{\cancel{m}\cancel{C_v}(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} \quad \text{— (i)}$$

Considering adiabatics : (1-2)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} \quad \text{—— a}$$

Process (3-4)

$$[\Rightarrow \frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \text{—— b}$$ 2m

$$a = b$$

$$\therefore \frac{T_2}{T_1} = \frac{T_3}{T_4}$$

$$\frac{T_4}{T_1} = \frac{T_3}{T_2}$$

$$\frac{T_4}{T_1} - 1 = \frac{T_3}{T_2} - 1$$

$$\frac{T_4 - T_1}{T_1} = \frac{T_3 - T_2}{T_2}$$

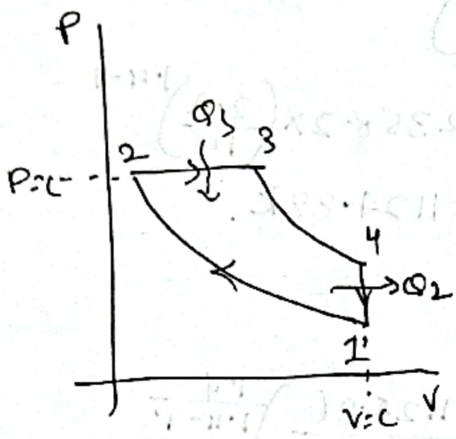
$$\frac{T_4 - T_1}{T_3 - T_2} = \frac{T_1}{T_2} \nearrow$$

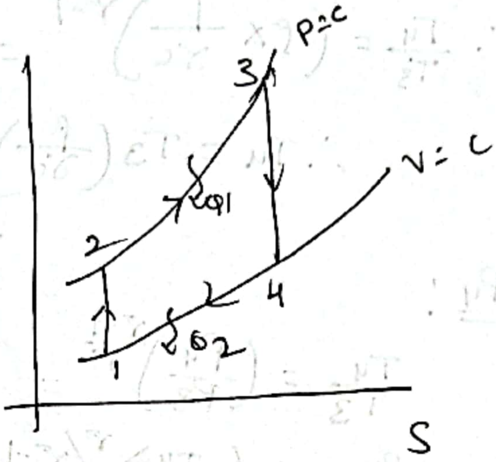
$$\therefore \eta_{air} = 1 - \frac{T_1}{T_2}$$

$$= 1 - \frac{1}{T_2/T_1}$$

$$= 1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}} = 1 - \frac{1}{(r_c)^{\gamma-1}} \; //$$ 2m

c)





2m

$r_c = \frac{V_1}{V_2} = 14$

$\rho = \frac{V_3}{V_2} = 2.2$

$P_1 = 0.98$ bar $= 0.98 \times 10^2$ kN/m^2

$T_1 = 373$k

i) Consider (1-2)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$T_2 = T_1 (r_c)^{\gamma-1} = 373(14)^{1.4-1} = 1071.9\text{k}.$$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma} = 0.98 \times 10^2 \times (14)^{1.4} = 3942.8\text{kN/m}^2$$ 1m

(2-3):

$$P_2 = P_3 = 3942.8\text{kN/m}^2$$

$$\frac{\cancel{P_2} V_2}{T_2} = \frac{\cancel{P_3} V_3}{T_3}$$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}$$

$$\therefore T_3 = T_2\left(\frac{V_3}{V_2}\right) = T_2 \times \rho = 1071.9 \times 2.2$$

$$= 2358.2\text{k}.$$ 1m

(3-4):

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{V_3}{V_2} \times \frac{V_2}{V_4}\right)^{\gamma-1} = \left(\frac{V_3}{V_2} \times \frac{V_2}{V_1}\right)^{\gamma-1}$$

$$\therefore \frac{T_4}{T_3} = \left(\rho \times \frac{1}{r_c}\right)^{\gamma-1} = \left(\frac{\rho}{r_c}\right)^{\gamma-1}$$

$$\therefore T_4 = T_3\left(\frac{\rho}{r_c}\right)^{\gamma-1} = 2358.2 \times \left(\frac{2.2}{14}\right)^{1.4-1}$$

$$T_4 = 1124.88\,K.$$ 1m

P_4 :

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} =$$

$$\frac{P_4}{P_3} = \left(\frac{T_4}{T_3}\right)^{\gamma/\gamma-1} = \left(\frac{1124.86}{2358.2}\right)^{\frac{1.4}{1.4-1}}$$

$$P_4 = P_3 \times (0.47)^{3.5}$$

$$= 3942.8 \times (0.47)^{3.5}$$

$$= 280.63\,kN/m^2$$ 2m

ii) : $\eta_{air} = \frac{Q_1 - Q_2}{Q_1}$

$Q_1 = mc_p(T_3 - T_2) = 1 \times 1.005 \times (2358.2 - 1071.9)$

$= 1292.7\,kJ/kg$

$Q_2 = mc_v(T_4 - T_1) = 1 \times 0.718\,(1124.8 - 373)$

$= 539.79\,kJ/kg$

$\therefore \eta_{air} = 0.58 = 58\%$ 3m

OR

Q.2)

a) i) IP:

It is the power developed inside the engine cylinder by burning the fuel.

$IP = \frac{P_m LAN}{60 \times 2}$ — 4 stroke

$= \frac{P_m LAN}{60 \times 1}$ — 2 stroke. 1m

ii) B.P.!

It is the power available at the engine crankshaft. 1m

$$BP = \frac{2\pi NT}{60}$$

iii) F.P:

The power absorbed in mechanical friction in driving the auxiliaries of the engine & pumping power. 1m

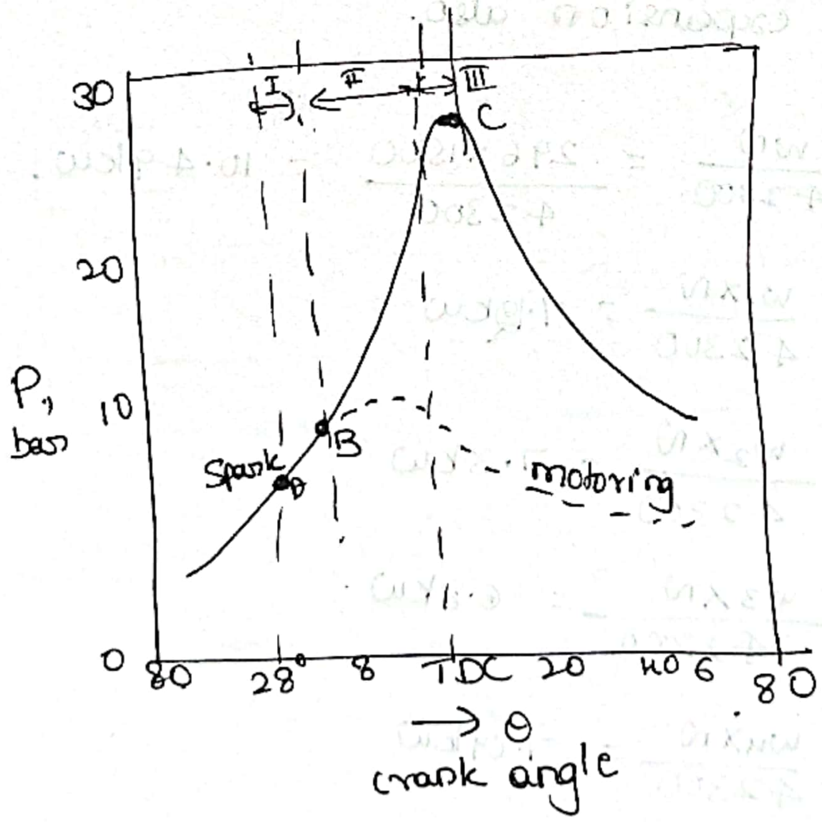
$$IP = BP + FP$$

$$\therefore FP = IP - BP$$

iv) It is the ratio of brake power to the indicated power. 1m

$$\eta_m = \frac{BP}{IP}$$

b)



2m

I: Ignition lag :

→ Growth & development of a semi-propagating nucleus of flame.

→ It is a chemical process depends on nature of fuel, upon both temperature & pressure.

II: Propagation of flame

4M

→ Spread of flame throughout the combustion chamber.

→ Point A is the passage of spark & B the point at which first pressure rise can be detected & C is attainment of peak pressure.

III: After burning,

→ It takes place during expansion. Theoretically it is expected that fuel droplets will burn during expansion also.

c) i) $BP = \frac{WN}{42300} = \frac{296 \times 1500}{42300} = 10.49$ kw.

$BP_1 = \frac{W_1 \times N}{42300} = 7.18$ kw

$BP_2 = \frac{W_2 \times N}{42300} = 7.3$ kw

3M

$BP_3 = \frac{W3 \times N}{42300} = 6.8$ kw

$BP_4 = \frac{W_4 \times N}{42300} = 7.09$ kw

ii) $IP = IP_1 + IP_2 + IP_3 + IP_4$

$\therefore IP_1 = BP - BP_1$

$= 10.49 - 7.12 = 3.37\,kW$

$IP_2 = BP - BP_2 = 3.19\,kW$

$IP_3 = BP - BP_3 = 3.69\,kW$ 3m

$IP_4 = BP - BP_4 = 3.4\,kW$

$\therefore IP = 13.65\,kW.$

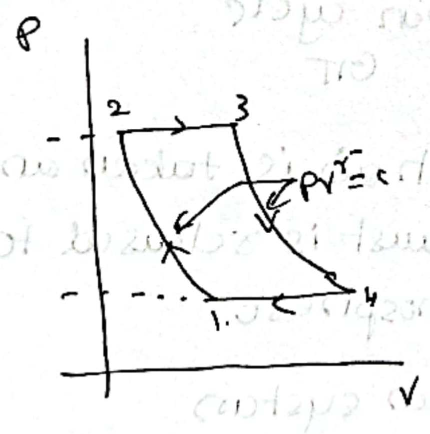
iii) FP: $IP = BP + FP$

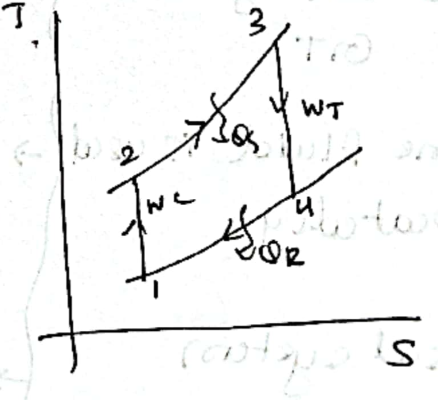
$\therefore FP = 3.16\,kW$ 2m

iv) $\eta_m = \frac{BP}{IP} = \frac{10.49}{13.65} = 76.8\%$ 2m

Module-2

Q.3) a)





2m

$Q_S = mc_p(T_3 - T_2)$

$Q_R = mc_p(T_4 - T_1)$

$\eta_{air} = \frac{W.D}{Q_S} = \frac{Q_S - Q_R}{Q_S}$

$$= \frac{mc_p(T_3-T_2) - mc_p(T_4-T_1)}{mc_p(T_3-T_2)}$$

$$= 1 - \frac{(T_4-T_1)}{(T_3-T_2)}$$ 1m

from (1-2): $T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = T_1(r_p)^{\gamma-1/\gamma}$ 1m

from (3-4) $\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\gamma-1/\gamma}$

$$T_3 = T_4\left(\frac{P_3}{P_4}\right)^{\gamma-1/\gamma} = T_4\left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$$ 1m

$$= T_4(r_p)^{\gamma-1/\gamma}$$

$$\therefore \eta_{air} = 1 - \frac{T_4-T_1}{T_4(r_p)^{\gamma-1/\gamma} - T_1(r_p)^{\gamma-1/\gamma}}$$

$$= 1 - \frac{1}{r_p^{\gamma-1/\gamma}}$$ 1m

b)

Closed cycle GT	Open cycle GT
→ Same fluid is used repeatedly	→ Fresh air is taken and exhaust is released to atmosphere.
→ Closed system	→ Open system
→ Heat is supplied from external source through heat exchangers	→ Heat is added by direct fuel combustion in combustion chambers.

→ No direct contact with fuel	→ Direct contact with fuel
→ Higher initial cost	→ Lower initial cost
→ Nuclear power plants,	→ Aircraft engine, power generation plants.

c)

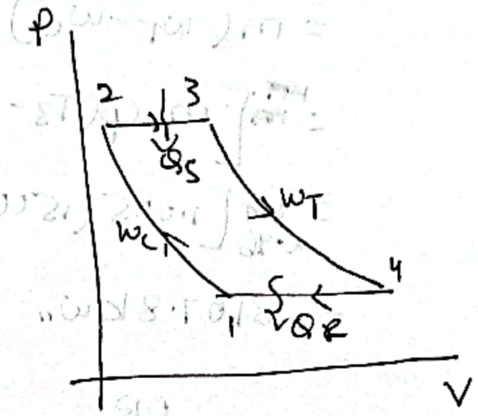
$P_1 = 100 \times 10^3 N/m^2$

$T_1 = 300k$

$V = 6 m^3/s$

$r_p = P_2/P_1 = 10$ 1m

$T_3 = 1500k$



i) $\eta_{th} = 1 - \frac{1}{(r_p)^{\gamma-1/\gamma}} = 0.48 = 48\%.$ 1m

ii) (1-2) : $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

$T_2 = T_1 (r_p)^{\gamma-1/\gamma}$

$= 300 (10)^{1.4-1/1.4}$

$= 579.2k$ 1m

(3-4) : $\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}}$

$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\gamma-1/\gamma} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$

$\therefore \frac{1500}{T_4} = (10)^{\frac{1.4-1}{1.4}}$

$T_4 = 777K.$ 1m

$P_1V_1 = mRT_1$

$m = \frac{P_1V_1}{RT_1} = \frac{100 \times 6}{0.287 \times 300} = 6.96 kg/s$ 1m work ratio $= R_w = 1 - \frac{T_1}{T_3} (R_p)^{\gamma-1/\gamma}$

$= 1 - \frac{300}{1500} (10)^{\frac{1.4-1}{1.4}}$

$= 0.613$ 2m

iii) Power $= m \times W_{net}$

$= m(W_T - W_C)$

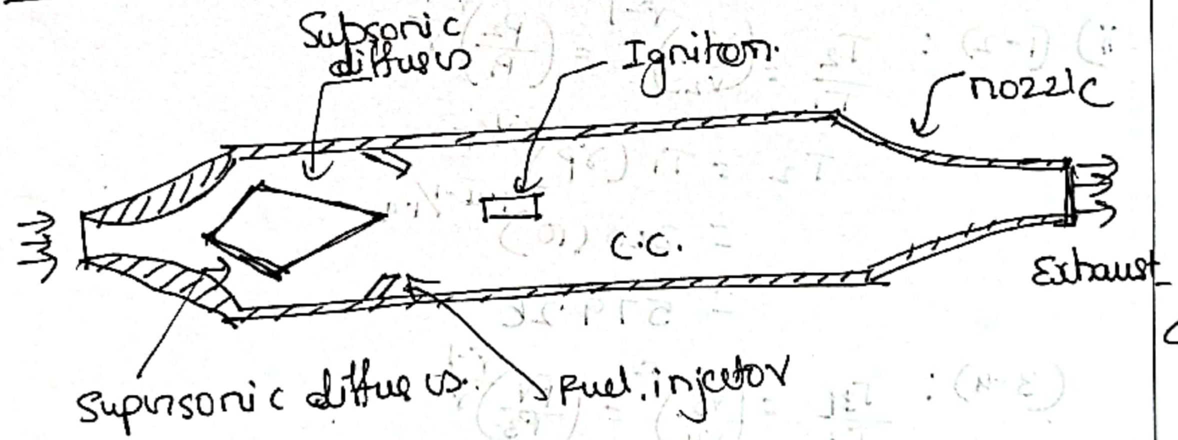
$= m[m_a C_p(T_3 - T_4) - m C_p (T_2 - T_1)]$

$= 6.96[1.005(1500-777) - 1.005(579.2-300)]$

$= 3107.8 \text{ kW}$ 3m.

OR

Q.4) a) **Ramjet** :



4m

→ Ramjet is also called athodyd, Lorin tube or flying stove pipe.

→ These have capacity to fly at supersonic speed.

→ Air enters the ramjet with supersonic speed & is slowed down at sonic velocity in the supersonic diffuser. The pressure suddenly increases in the supersonic diffuser to the formation of shock wave. 6m

The pressure of air is further increased in the subsonic diffuser increasing the temperature of air above the ignition temperature.

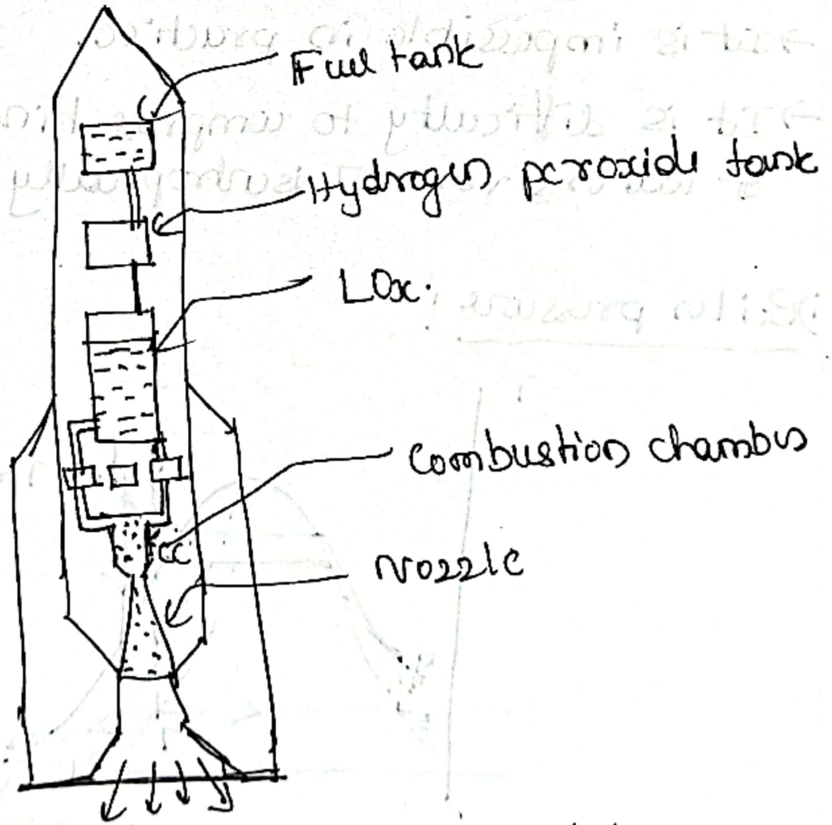
→ The fuel is injected in the combustion chamber through nozzles.

→ The air-fuel mixture is ignited by spark plug.

→ The hot gases are continued to move towards the nozzle & undergo expansion.

→ The pressure energy is converted into K.E.

b) Rocket propulsion :



4m

The thrust required by rocket propulsion is produced by high velocity jet of gases passing through the nozzle. The fuel and oxidizer are both contained in a propelling body and as such it can function in vacuum. The fuel and oxidiser are supplied by the pumps to combustion chamber where the fuel is ignited by electric means. Pumps are driven with the help of a steam a steam turbine. The products of combustion are discharged from the combustion chamber through the nozzle. 6m

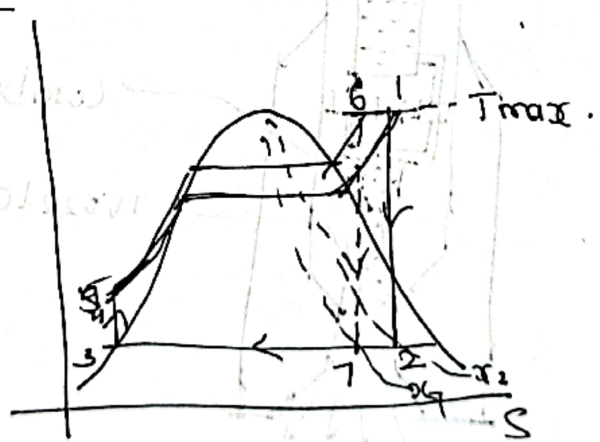
Module-3

Q.5) a) → After condensation 2-, the working fluid is still a mixture of liquid water & vapour. so complete condensation does not ~~[illegible]~~ occure 4m

→ It is impossible in practice.

→ It is difficulty to compress binary mixture of water & vapour isentropically by pump.

b) i) Boiler pressure :



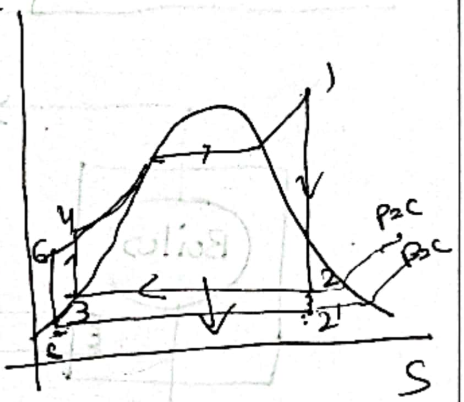
→ When max. temprature is fixed, the pressure increase from P_1 to P_2 in the boiler.

→ The mean temprature of heat addition increases.

→ The moisture content at the turbine exhaust increases.

→ If the moisture content increases, water particles along with vapour coming out of nozzle with high velocity strikes the blade & erode their surface.

Condenser pressure :



→ If condenser pressure is decreased, the turbine work $(h_1 - h_2)$ increases.

→ Increase the η_{th}.

→ Moisture content increases & effects on turbine blade.

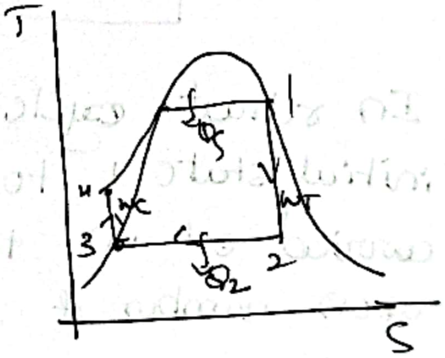
c) At $P = 15$ bar

$t_s = 198.28°C$

$= 471.28k$

at 0.4 bar $t_s = 75.89°C$

$= 348.9k = T_2$ 2m



i) $\therefore \eta_c = 1 - \frac{T_2}{T_1} = 25.96\%$ 2m

ii) $\eta_R = \frac{W_T - \cancelto{0}{W_P}}{Q_S} = \frac{(h_1 - h_2)}{(h_1 - h_4)}$

$h_1 = h_g$ at 15 bar $= 2789.9 kJ/kg$

$S_1 = S_g = 6.44 kJ/kgk$.

$S_1 = S_g = S_2 = S_{f_2} + x_2 S_{fg_2}$

$6.44 = 1.0261 + x_2 \times 6.644$

$x_2 = 0.814$ 2m

$\therefore h_2 = h_{f_2} + x_2 h_{fg_2}$

$= 317.7 + 0.814 \times 2319.2$

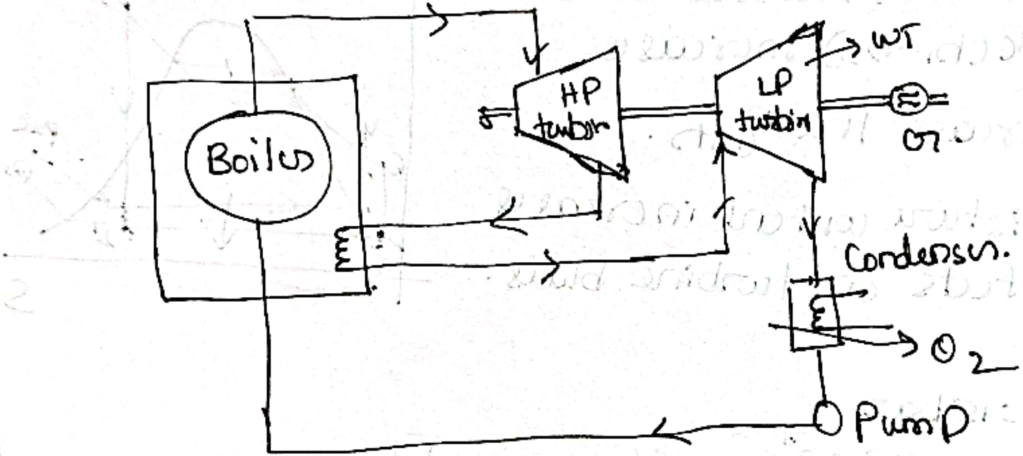
$= 2207.5$ kJ/kg

$h_3 = h_f = 317.7$ kJ/kg $= h_4$

$\therefore \eta_R = \frac{h_1 - h_2}{h_1 - h_3} = 23.55\%$ // 4m

OR

Q.6) a) **Reheat Rankine cycle :**



4m

In reheat cycle, expansion of steam from initial state 1 to the condenser pressure is carried out in two or more steps, depending upon number of reheats used. The steam expands in high pressure (HP) turbine from initial state to approximately the saturated vapour line. The steam is then superheated at a constant pressure in a boiler & the remaining expansion is carried out in a low pressure (LP) turbine. 4m

$h_b = h_f + x_b h_{fg}$

$= 504.7 + (0.9444 \times 2201.6)$

$= 2582.7$ kJ/kg.

Mass fraction of bleed steam

Energy balance:

$m h_b + (1-m) h_f (0.04 \text{ bar}) = h_f (2 \text{ bar})$

$m(2582.7) + (1-m)(125.6) = 504.7$

$\therefore m = 0.154$ 4m

<u>Turbine work</u>:

First stage. $W_1 = h_i - h_b = 554.3$ kJ/kg

Second " $W_2 = (1-m)(h_b - h_2) = 484.8$ kJ/kg

$W_{tot} = 1039.1$ kJ/kg 1m

<u>Heat supplied</u>:

$Q_{in,reg} = h_i - h_f(2 \text{ bar})$

$= 3137 - 504 = 2632.3$ kJ/kg 1m

$$\eta_{th} = \frac{1039.1}{2632.3}$$

$= 0.395$

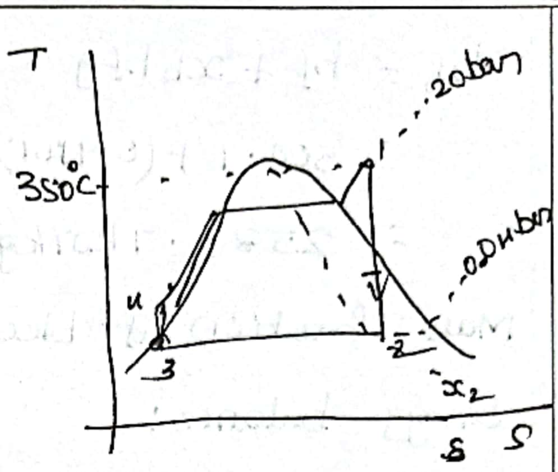
$\eta_{th_{reg}} = 39.5\%$ // 1m

6. b)

At 350°C, 20 bar

$h_1 = 3137$ kJ/kg

$s_1 = 6.813$ kJ/kgK



1m

at 0.04 bar

$h_f = 125.6$ kJ/kg

$h_{fg} = 2406$ kJ/kg

$s_f = 0.436$ kJ/kgk

$s_{fg} = 8.146$ kJ/kgk

$s_1 = s_2$

$s_1 = s_{f_2} + x_2 s_{fg_2}$

$6.813 = 0.436 + x_2(8.146)$

$x_2 = 0.783$

$\therefore h_2 = h_{f_2} + x_2 h_{fg_2}$

$= 2009.6$ kJ/kg

$$\eta_{th} = \frac{W_{net}}{Q_s} = \frac{W_T - \cancel{W_P}^{\approx 0}}{Q_2} = \frac{(h_1 - h_2)}{(h_1 - h_u)} = \frac{1127.4}{3011.4}$$

$= 0.374 = 37.4\%$ 4m

Bleeding steam at 2 bar:

from table:

$h_f = 504.7$ kJ/kg

$h_{fg} = 2201.6$ kJ/kg

$s_f = 1.53$ kJ/kgk

$s_{fg} = 5.597$ kJ/kgk

$$x_b = \frac{s_1 - s_f}{s_{fg}} = 0.94$$

Module-4

Q7)

a) Properties of refrigrant:

→ Should have low boiling point.

→ Low freezing point

→ High latent heat of vapourization.

→ High thermal conductivity.

→ Low viscosity for easy circulation.

→ Low specific volume

→ High electric insulation.

→ Non-toxic

→ Non-flammable.

→ Non-explosive.

→ Non-corrosive.

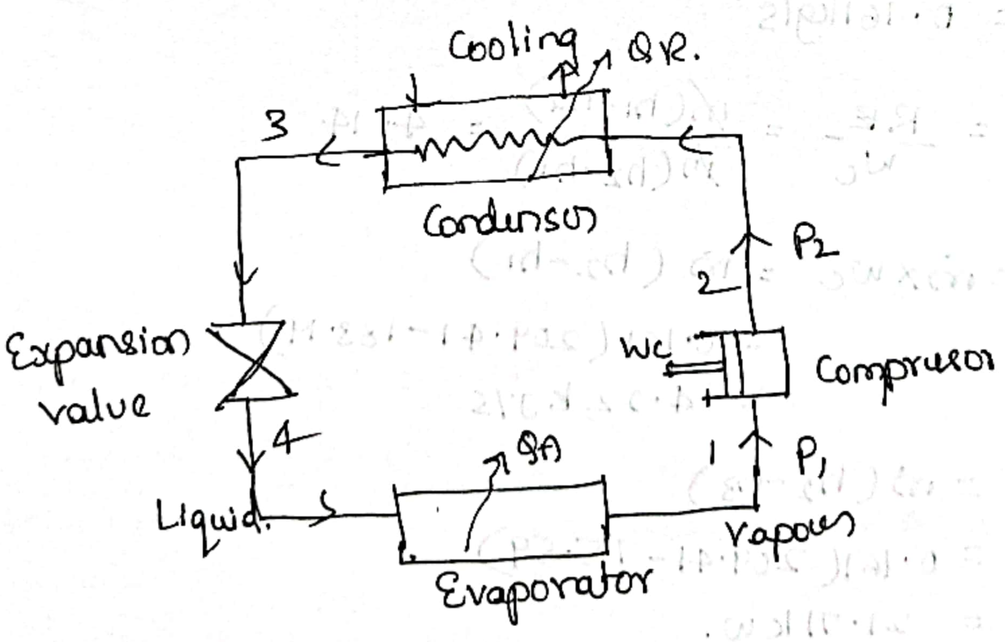
→ Chemically stable.

→ Low cost

→ Easily available.

4M

b)



2M

→ Vapour coming from the evaporator is compressed in compressor to high pressure.

→ The high pressure, high temperature vapour is delivered to condenser. for cooling. 4m

→ High pressure refrigerant is thus expanded into the expansion valve & temperature drops.

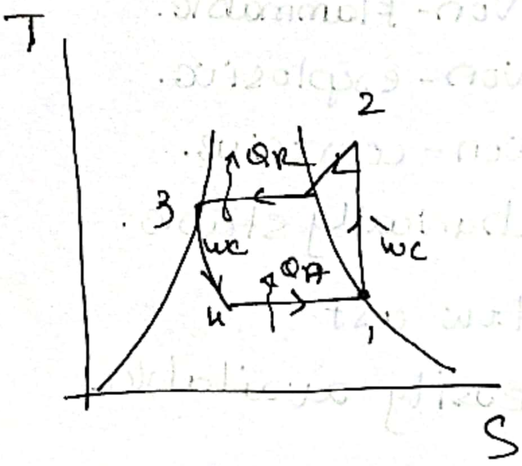
→ The liquid refrigerant with low temperature is passed through the evaporator where it absorbs heat from the objects being cooled & gets evaporated.

c) $RC = 5 \text{ tonnes} = 5 \times 3.5 = 17.5 \text{ kw}$

$h_1 = 183.19 \text{ kJ/kg}$

$h_2 = 209.41 \text{ kJ/kg}$

$h_3 = h_4 = 74.59 \text{ kJ/kg}$



2m

i) $RC = \dot{m} \times RE$

$= \dot{m}(h_1 - h_4)$

$\dot{m} = 0.161 \text{ kg/s}$ 2m

ii) $COP = \frac{RE}{W_c} = \frac{\cancel{\dot{m}}(h_1 - h_4)}{\cancel{\dot{m}}(h_2 - h_1)} = 4.14$ 2m

iii) $P = \dot{m} \times W_c = \dot{m}(h_2 - h_1)$ 2m

$= 0.161(209.41 - 183.19)$

$= 4.22 \text{ kJ/s}$

iv) $Q_R = \dot{m}(h_2 - h_3)$

$= 0.161(209.41 - 75.59)$ 2m

$= 21.71 \text{ kw}.$

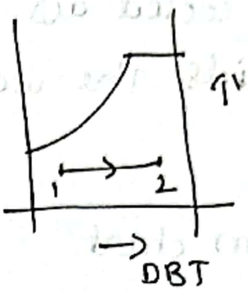
OR

Q.8)

a) Sensible heating:

→ Heating of air without addition or subtraction of moisture.

→ Achieved by passing air through heating coil.

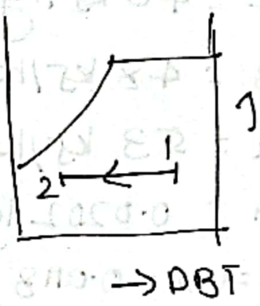


2m

Sensible cooling:

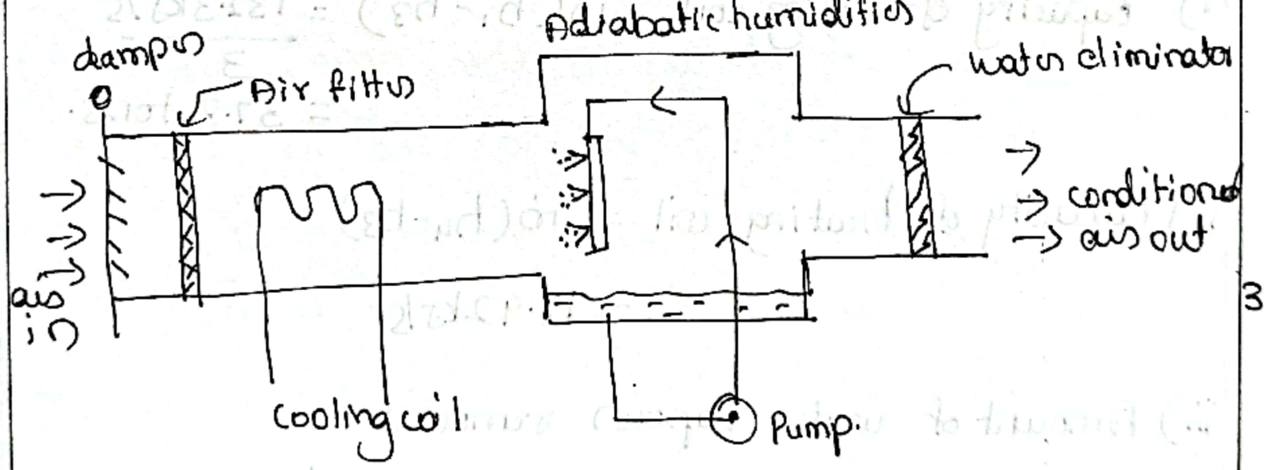
→ Cooling of air without addition or subtraction of moisture.

→ Achieved by passing air over a cooling coil.



2m

b) Summer air conditioning:



3m

Such a system are used for hot and dry outdoor conditions like Nagpur, Delhi, Bhopal etc. Comfort required is 24°C DBT & 60% RH. The air is passed through a cooling coil & its temprature is reduced up to 2 by sensible cooling. The air coming out 3m from the cooling coil is passed into adiabatic humidifier. Here water vapours are sprayed into the cooled air & is humidified. The water eliminator avoids the water particles moving with air.

c)

From chart

$h_1 = 83$ kJ/kg of dry air

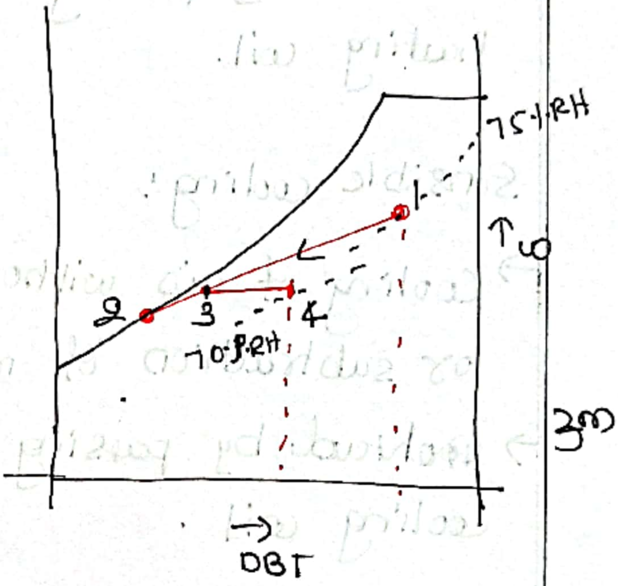
$h_2 = 40$ kJ/kg "

$h_3 = 48$ kJ/kg "

$h_4 = 53$ kJ/kg "

$\omega_1 = 0.0202$ kg/kg "

$\omega_3 = \omega_4 = 0.0118$ kg/kg "



3m

$\dot{m} = \frac{V}{v_1}$?

$v_1 = 0.85 + \left(\frac{53}{68} \times 0.05\right) = 0.88\ m^3/kg$ 1m

i) Capacity of cooling coil $= \dot{m}(h_1 - h_3) = \frac{132.3\ kJ/s}{3}$

$= 37.8$ tons. 2m

ii) Capacity of heating coil $= \dot{m}(h_4 - h_3)$

$= 18.92$ kJ/s 2m

iii) Amount of water vapour removed

$= \dot{m}(\omega_1 - \omega_3) = 0.0317$ kg/s 2m

$= 114.3$ kg/h.

Module - 5

Q9)
a)

i) $\eta_{vol.} = \frac{\text{Actual free air delivered}}{\text{Swept volume or stroke volume}}$ 1.5m

ii) $\eta_{ad} : \frac{\text{work done with reversible adiabatic compression}}{\text{work done with irreversible adiabatic compression}}$ 1.5m

iii) $\eta_{iso} = \frac{\text{Isothermal work input}}{\text{Actual work input}}$ 1.5m

iv) $\eta_{mech} = \frac{\text{Indicated power of compressor}}{\text{Input power to the compressor}}$ 1.5m

b)

→ cylinder design made comparatively easy, since there is no risk of high pressure.

→ The pressure and temperature range can be maintained due to cooling of air. 4m

→ Improved lubrication due to reduced temperature

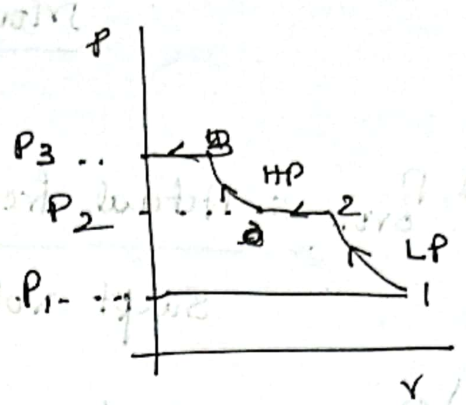
→ work done in compressing air is reduced.

→ Isothermal compression can be achieved.

c) $P_2 = \sqrt{P_1 P_3}$

$= \sqrt{1 \times 30}$

$= 5.47$ bar



2m

$PV^n = C$

$P_1 V_1^n = P_2 V_2^n$

$\frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{1/n} = (5.47)^{1/1.3} = 3.71$ 4m

Stroke is same.

$V \propto D^2$

$\frac{V_1}{V_2} = \frac{D_1^2}{D_2^2}$ $\therefore$ $\frac{D_1}{D_2} = \sqrt{\frac{V_1}{V_2}} = \sqrt{3.71} = 1.93.$ 4m

OR

Q.10) For SFEE

$V = \sqrt{2c_p(T_1 - T_2)}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

$\therefore V = \sqrt{2c_p T_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}$ 3m

$\dot{m} = \rho V A$

$\rho = \frac{P}{RT}$

$\therefore \dot{m} = \frac{P_2}{RT_2} \times A \times \sqrt{2c_p T_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}$ 3m condition for max. discharge:

$$\frac{d(\dot{m})}{d(P_2/P_1)} = 0.$$

solving. $\left(\frac{P_2}{P_1}\right)_{critical} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$ // 3m

b) $N = 16$

Inlet : $P_1 = 20$ bar. $T_1 = 400°C$

Exit : $P_2 = 12$ bar

$m = 260$ kg/min $= 4.33$ kg/s

$\eta_n = 90\%$

$V_1 = 80$ m/s , $\gamma = 1.3$, $R = 461$ J/kgk

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$T_2 = T_1 (P_2/P_1)^{\frac{\gamma-1}{\gamma}} = 0.88 \times 673 = 598.3k.$ 2m

$$\eta_n = \frac{V_2^2 - V_1^2}{2c_p(T_1 - T_2)}$$

$c_p = \frac{\gamma}{\gamma-1} \times R = 1998$ J/kgk. 2m

$$\therefore 0.9 = \frac{V_2^2 - 80^2}{2 \times 1998 (673 - 598.3)}$$

$V_2 = 524.6$ m/s.. 2m

$\rho_2 = \frac{P_2}{RT_2} = 4.35$ kg/m^3

$\dot{m} = \rho V A$

$4.33 = 4.35 \times 524.6 \times A$

$A = 0.00189\ m^2$

A per nozzle $= 0.001897/16 = 0.0001186\ m^2$ // — 4m

—x—x—

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