Modified

CBCS SCHEME

USN 18ME42

Fourth Semester B.E. Degree Examination, July/August 2022
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 Thermodynamics data hand book is permitted.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Derive an expression of air standard efficiency of diesel cycle with neat PV and T-S diagrams. **(10 Marks)**

b. An engine with 200mm cylinder diameter and 300mm Stroke length works on diesel cycle. The initial pressure and temperature of air are 0.1 MPa and 27°C. The cutoff is 8% of Stroke volume and compression ratio is 15. Determine :
i) Pressure and temperature at all salient points ii) Air standard efficiency. **(10 Marks)**

OR

2 a. Explain any two methods of deeming frictional power. **(08 Marks)**

b. The following observations were made during one hour test on a single Stroke oil engine.
Bore = 300mm ; Stroke = 450mm ; mass of fuel used = 8.8Kg ;
Calorific value = 41800kJ/Kg ;
Average speed = 200rpm, Mean effective pressure = 5.8 bar, Brake load = 1860N, Mass of cooling water = 650Kg, Temperature rise = 22°C, Diameter of Brake drum = 1.22 m.
Calculate: i) Mechanical efficiency ii) Brake thermal efficiency iii) Draw heat balance sheet on kJ/hr basis. **(12 Marks)**

Module-2

3 a. Derive an expression of optimum pressure ratio for maximum workout put in case of actual Brayton cycle. **(10 Marks)**

b. Air enters the compressor of a gas turbine plant operating on Brayton cycle at 101.325KPa, 27°C. The pressure ratio in the cycle is 6. Calculate the maximum temperature in the cycle and cycle efficiency. Assume $W_T = 2.5W_c$. Where W_T and W_C are the turbine and compressor work respectively. Take r = 1.4. **(10 Marks)**

OR

4 a. With a neat block diagram and T-S diagram, explain how 'regeneration' increases thermal efficiency of gas turbine plant. **(08 Marks)**

b. Air is drawn in a gas turbine unit at 15°C and 1.01bar and pressure ratio is 7. The compressor is driven by the high pressure turbine and low pressure turbine drives a separate shaft. The isentropic efficiencies of compressor and HP and LP turbines are 0.82, 085 and 0.85 respectively. If the maximum cycle temperature is 610°C, find :
i) The pressure and temperature of the gases entering the power turbine
ii) The net power developed by the unit per Kg/sec mass flow.
iii) Work ratio
iv) Thermal efficiency of the unit
Neglect the mass of the fuel and assume the following :
For compression process, C_{Pa} = 1.005 kJ/Kg.K and r = 1.4.
For combustion and expansion process : C_{pg} = 1.15 kJ/Kg.K and r = 1.33. **(12 Marks)**

Module-3

5 a. Discuss the effect of i) Boiler pressure ii) Condenser pressure iii) Super heat on the performance of a Rankine cycle. **(10 Marks)**

b. Steam at 1 bar and 350°C is expanded in a steam turbine to 0.08bar. It them enters the condenser, where it is condensed to saturated liquid water. Assume the turbine and feed pump efficiencies as 80% and 90% respectively. Determine per Kg of steam the network, the heat transferred to the working fluid and Rankine efficiency. **(10 Marks)**

OR

6 a. Sketch and explain the flow diagram and corresponding T-S diagram of practical regenerative Rankine cycle. **(10 Marks)**

b. A reheat cycle has the first stage supply conditions of 70bar and 500°C. The reheat is at 3 bar and to the same temperature.

i) Given that the efficiency of the first stage turbine is 80%, how much energy is added per kg of steam in the reheat coils?

ii) Assume that the same expansion efficiency exists in the second turbine. What is the thermal efficiency, if the condenser pressure is 0.03 bars? **(10 Marks)**

Module-4

7 a. Explain the effect of super heating and under cooling the refrigerant on the performance of vapour compression refrigeration cycle. **(06 Marks)**

b. What are the properties of refrigerants? **(04 Marks)**

c. A vapour compression refrigerator uses methyl Chloride (R – 40) and operates between the temperature limits of -10°C and 45°C. At the entry to the compressor the refrigerant is dry saturated and after the compression it acquires a temperature of 60°C. Find COP of the refrigerator. The relevant properties of R – 40 are as follows :

Saturation temperature	Enthalpy		Entropy	
	Liquid	Vapour	Liquid	Vapour
-10°C	45.4	460.7	0.183	1.637
45°C	133	483.6	0.485	1.587

Also find mass of methyl chloride and power required for a capacity of 15 TOR. **(10 Marks)**

OR

8 a. Define : i) Wet bulb temperature ii) Dew point temperature iii) Relative humidity iv) Specific humidity v) Degree of saturation. **(10 Marks)**

b. Air is to be conditioned from 40° C (DBT) and 50% RH to a final temperature of 20°C (DBT) and 40% RH, by de-humidification process, followed by a reheat process. Assuming that the entire process is at constant pressure of 101.325 KPa, determine :

i) The amount of water to be removed from air

ii) The temperature of air leaving the dehumidifier

iii) Refrigeration in tons for air flow rate of $0.47 m^3/sec$

iv) Heating required in kW. **(10 Marks)**

Module-5

9 a. Derive an expression for minimum work input by two stage compressor with intercooler. **(10 Marks)**

b. A single stage single acting reciprocating air compressor has a bore of 200mm and Stroke of 300mm. It receives air at 1 bar and 20°C and delivers it at 5.5 bar. If the compression follows the law $PV^{1.3} = C$ and clearance volume is 5% of the Stroke volume, determine :

i) Mean effective pressure

ii) Power required to drive the compressor if it runs at 500rpm. **(10 Marks)**

OR

10 a. Derive an expression of critical pressure ratio which gives maximum discharge through the nozzle. **(10 Marks)**

b. Steam at 15bar and 250°C is expanded in a nozzle to 1 bar. For a discharge of 0.5kg/sec find throat and exit diameter for maximum discharge conditions. Assume the nozzle efficiency as 90%. **(10 Marks)**

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Re: Sir, regarding QP Scheme Modifications

"Dr M S Govinde Gowda" <msggowda1964@gmail.com>

September 29, 2022 9:11 AM

To: boe@vtu.ac.in

Dear Sir,
PFA for the corrected and verified scheme and solution for 18ME42-ATD and 18ME43-FM for your kind notice and approval.
With regards

Dr. M.S.Govinde Gowda
Academic Senate Member, VTU **&**
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and
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On Tue, Sep 27, 2022 at 11:19 AM <boe@vtu.ac.in> wrote:

"APPROVED"
Registrar (Evaluation)
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2 / 4

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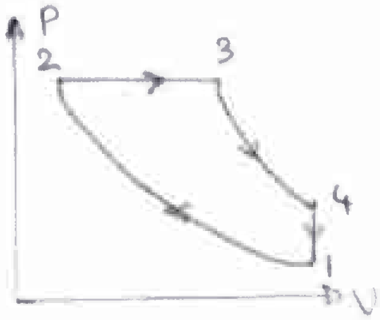
Scheme & Solutions

Signature of Scrutinizer

Subject Title : Applied Thermodynamics **Subject Code :** 18ME42

Question Number	Solution	Marks Allocated
1 a	Derivation of $\eta_{air} = 1 - \frac{1}{\gamma}\frac{(\rho^{\gamma}-1)}{R_c^{\gamma-1}(\rho-1)}$ PV-TS diagram=2M η=f(temperatures)=4M =4M	10
b)	$V_s = 9.42 \times 10^{-3}\ m^3$ $V_c = 6.73 \times 10^{-4}\ m^3$ $\rho = \frac{V_3}{V_2} = 2.11$ – (3)M $\eta_{air} = 59.82\%$ – (3)M $P_2 = 44.3$ bar $T_2 = 886.25$ K $P_3 = P_2 = 44.3$ bar $T_3 = 1869.98$ K $P_4 = 2.84$ bar $T_4 = 853.32$ K (4)M  **Alternate Method:** $K = \frac{\rho-1}{r_c-1}$ $0.08 = \frac{\rho-1}{15-1}$ $\rho = 2.12$ $Q_S = C_p(T_3 - T_2) = 997.7$ kJ/kg $Q_R = C_v(T_4 - T_1) = 401.4$ kJ/kg $W_{net} = Q_S - Q_R = 596.3$ kJ/kg $\eta_D = \frac{W_{net}}{Q_S} = 59.8\%$	10
2a)	Explanation of any two methods of determining frictional power (4+4)M	8
b)	$BP = 23.76$ kW (2) – $\eta_M = 77.36\%$ (1) – $FP = 30.71$ kW (3) – $\eta_{bth} = \frac{BP}{m_f \times CV} = 23.25\%$ (2) – **Note-1: It is not clear whether it is a single cylinder with 2-stroke or 4-stroke, hence IP and Mechanical efficiency cannot be found out.** **Then BP = 4M and $\eta_{b,th}$=3M** **Note-2: If any one assumed as single/double cylinder with 2-stroke or 4-stroke, accordingly marks to be awarded for IP and Mechanical efficiency.**	

"APPROVED"

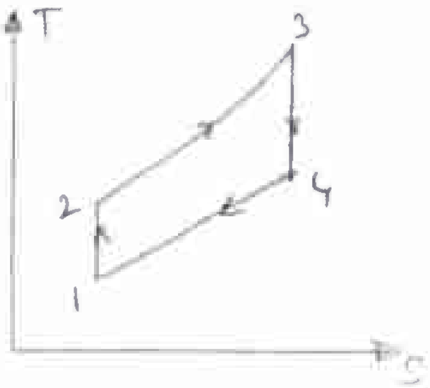
Registrar (Evaluation)

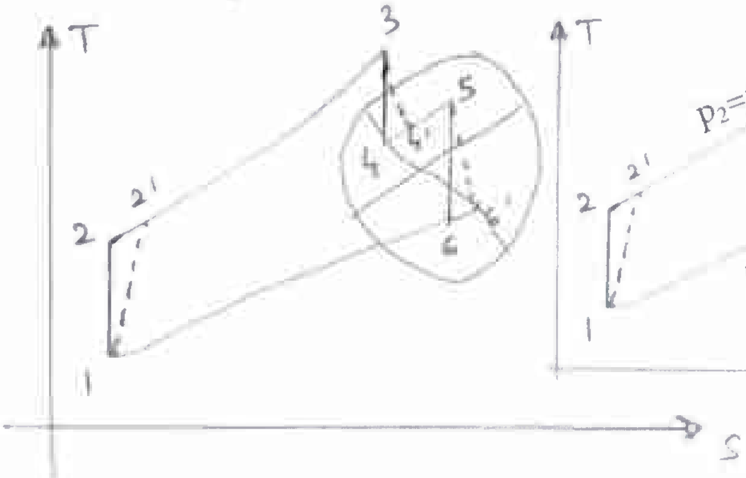
Subject Title : Applied Thermodynamics Subject Code : 18ME42

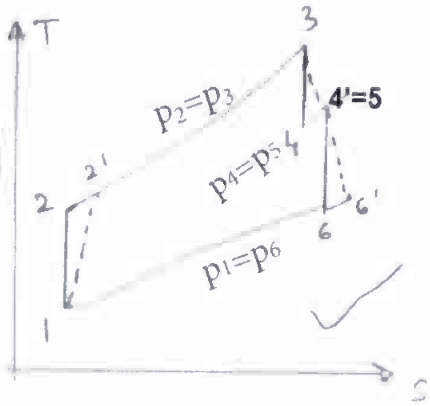
Question Number	Solution	Marks Allocated
	Heat balance sheet on KJ/hr basis	
	(balance sheet table below)	12
3a)	Derivation of $R_p = \left[\eta_c \eta_T \frac{T_3}{T_1}\right]^{\frac{\gamma}{2(\gamma-1)}}$ =4M PV or TS diagram=2M η=f(temperatures)=4M	10
b)	$T_2 = 500.53$ K – (2)M $T_4 = 750$K – (2)M $T_3 = 1251$K (2)M $\eta = 40\%$ (4)M	10
	OR	
4a)	Explanation of regeneration process to increase the thermal efficiency. – (6)M T-S diagram & block diagram (2) M	8
b)	(T-S diagrams below)	

Heat I/P	%	Heat O/P	KJ/hr	%
Heat supplied by fuel $Q_s = 367.8\times10^3$ KJ/hr	100	a) Q_{BP}	85.53×10^3	23.2
		b) Q_{CW}	59.85×10^3	16.1
		c) Q_{UA}	232.43×10^3	60.4
367.8×10^3	100	Total	367.87×10^3	100

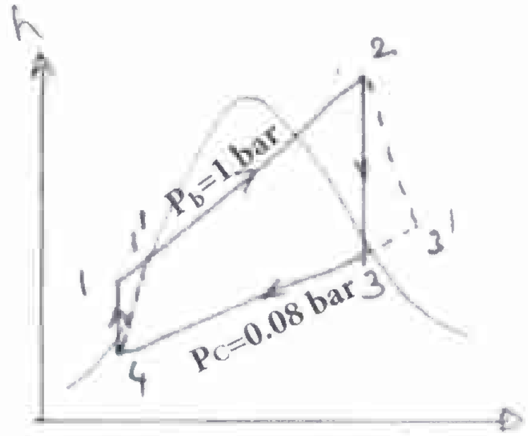
–(5)







Subject Title: Applied Thermodynamics   Subject Code: 18ME42

Question Number	Solution	Marks Allocated
	$T_2 = 502.16$ K	
	$T_2' = 549.17$ K	
	$W_C = -262.47$ kJ/kg — (2) —	
	$T_4' = 654.76$ K $= T_5$ $T_4 = 614.48$ K	
	$P_4 = P_5 = 1.656$ bar	
	W_{HPT} = Turbine work = 262.47 kJ/kg — (2)	
	T_6 = ~~543.05~~ 580.5K K T_5 = ~~614.44~~ 654.76K K	
	T_6' = ~~553.75~~ 591.7 K K	
	Turbine work, W_{LPT} = ~~69.79~~ 72.1 kJ/kg kJ/kg — (2)	
	Network, $W_{net} = 72.1$ kW — (2) —	
	Work ratio = 0.21 — (2) —	
	η = ~~20.73~~ 18.8% — (2) —	12
5 a)	Effect of (i) boiler pressure — (3)	
	with appropriate sketches (ii) Condenser pressure — (3)	
	(iii) Super heat — (4) —	10
b)		
	From ~~steam table~~ Molier Chart	
	at P = ~~20~~ 1 bar bar &	
	t = 350°C	
	h_2 = ~~3138.6~~ 3170 kJ/kg	
	h3 = 2630 kJ/kg	
	S_2 = ~~7.1044~~	
	From steam table at P_c=0.08 bar	
	v_f=0.001084 m³/kg	
	h_f=h_4=173.9 kJ/kg	
	$S_2 = S_3$ State 3 is in the superheated state	
	~~$S_2 = S_{f_3} + x_3 S_{fg_3}$~~	
	~~$x_3 = 0.85$~~	

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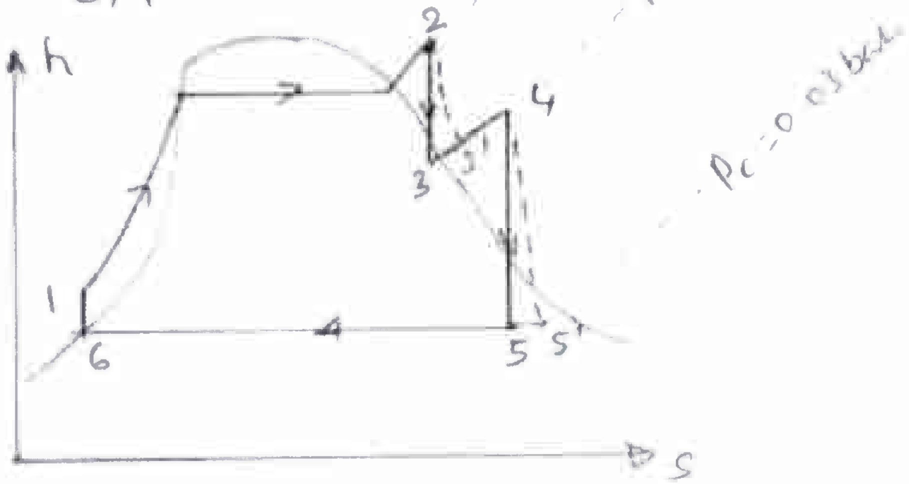
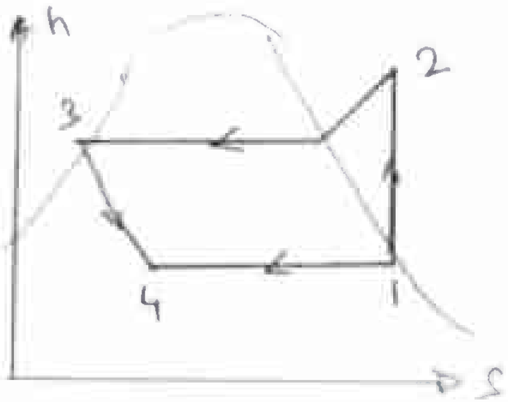
Question Number	Solution	Marks Allocated
	$\eta_T = \dfrac{h_2 - h_3'}{h_2 - h_3}$ $\therefore$ $h_3' =$ ~~2406.13~~ 2738 kJ/kg — (2) —	
	Actual Pump work, $W_p = v_f (P_t - P_c) \times 10^2 / \eta_p$	
	$W_p =$ ~~1.007~~ 0.1 kJ/kg — (2) —	
	Also, Pump work $= h_1 - h_4'$	
	$\therefore$ $h_1' =$ ~~175.9~~ 174 kJ/kg	
	Pump efficiency, $\eta_p = \dfrac{h_1 - h_4}{h_1' - h_4}$ $\therefore$ $h_1' =$ ~~176.13~~	
	Turbine work, $W_T = h_2 - h_3'$ $W_T =$ ~~732.46~~ 432 kJ/kg (2)	
	Heat Supplied, $Q_s = h_2 - h_1' =$ ~~2962.49~~ 2996 kJ/kg — (2) —	
	~~Rankine~~ Net work done, $W =$ ~~730.45~~ 431.9 kJ/kg kJ/kg	10
	Rankine $\eta = \dfrac{W}{Q_s} =$ ~~24.65%~~ 14.4% — (2) —	
	Note: Any small variations can be treated as correct answer	
6 a)	Flow diagram — (3) T-s diagram — (2) Explanation — (5)	10
b)		

Question Number	Solution	Marks Allocated
	From Mollier chart, $h_2 = 3400$ kJ/kg $h_3 = 2650$ kJ/kg, $h_4 = 3500$ kJ/kg $h_5 = 2480$ kJ/kg — (2) — Pump work, $W_p = V_f [P_1 - P_6] \times 100$ $W_p = 7.01$ kJ/kg (2) — But $W_p = h_1 - h_6$ $\therefore h_1 = 108$ kJ/kg From tables, $h_6 = h_{f6} = 101$ kJ/kg $\eta_{t_1} = \frac{h_2 - h_3'}{h_2 - h_3} = 0.8$ $\therefore h_3' = $ ~~2400~~ 2800 kJ/kg $W_{T1} = 600$ kJ/kg $\eta_{t_2} = \frac{h_4 - h_5'}{h_4 - h_5} = 0.8$ $\therefore h_5' = 2684$ kJ/kg ✓ (2) — $W_{T2} = 816$ kJ/kg Energy added in reheat coil $= h_4 - h_3'$ $Q_B = h_2 - h_1 = 3302$ kJ/kg $Q_{RH} = $ ~~600~~ 700 kJ/kg (2) — $Q_S = Q_B + Q_{RH} = 4008$ kJ/kg Thermal $\eta = \frac{W_T - W_P}{Q_S} = 35\%$ ✓ (2) — **Note: Small variations in reading the enthalpies shall be treated as correct values to award full marks**	10
7 a)	(i) Effect of super heating — (3) **With appropriate** (ii) Effect of under cooling — (3) **P-h or T-s diagram**	6
b)	Desirable properties of refrigerant (4)	4
c)	 $T_1 = 263$ K $T_2' = T_3 = 318$ K $T_2 = T_{sup} = 333$ K	

Question Number	Solution	Marks Allocated
	$S_1 = S_2$ $S_{g_1} = S_{g_2} + c_p \ln \frac{T_{sup_2}}{T_{2'}}$ $c_p = 1.09$ $h_1 = h_{g_1} = 460.7 \ kJ/kg$ $h_2 = h_{g_2'} + c_p(T_{sup} - T_{sat_2}) = 500 \ kJ/kg$ $h_3 = h_{f_3} = 133. = h_4$ — (4) — (i) $COP = \frac{h_1 - h_4}{h_2 - h_1} = 8.38$ — (2) — (ii) Mass of methyl chloride $= \frac{\text{Capacity}}{\text{Heat absorbed}}$ $= \frac{15 \times 3.516}{h_1 - h_4}$ $m_f = 0.16 \ kg/sec$ (2) (iii) Power Supplied, $P = \frac{\text{Capacity}}{COP}$ $P = 6.29 \ kW$ (2) or $P = m(h_2 - h_1) = 0.16(500 - 460.7) = 6.29kW$	10
8 a)	Definition (2×5)	10
b)	From chart $\omega_1 = 0.023$ $v_1 = 0.92 \ m^3/kg$, $h_1 = 103 \ kJ/kg$ $\omega_A = 0.06$ $h_A = 21 \ kJ/kg$ $t_A = 6°c$ $\omega_2 = 0.06$ $h_2 = 35 \ kJ/kg$ $m = 0.51 \ kg/sec$ — (3) — (i) Amount of water removed, $\omega_1 - \omega_2 = 0.017$ (2) (ii) Temperature of air leaving the de-humidifier $T_A = 6°c$ (01)	

Question Number	Solution	Marks Allocated

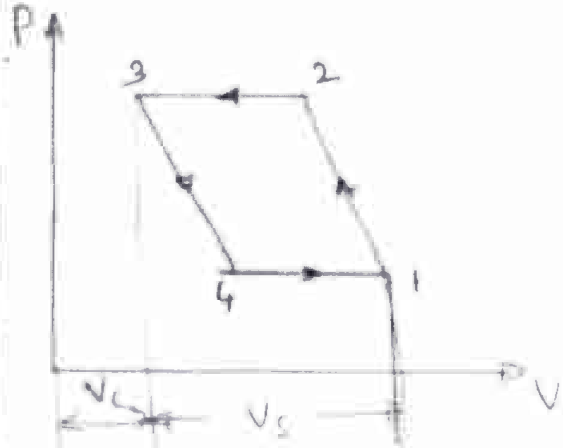
(iii) Refrigeration, = 11.94 tons (2)

(iv) Heating coil capacity = ~~6.643~~ 7.14 kW (2) — 10

Note: Full marks shall be awarded if small variations in enthalpies readings.

9 a) Derivation, $W = 2\frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_3}{P_1}\right)^{\frac{n-1}{2n}} - 1\right]$ — 10

b)



$V_s = 0.00942\ m^3$

$V_c = 5\%\ V_s$

$= 0.00047\ m^3$

$V_1 = V_c + V_s$

$= 0.00989\ m^3$

$P_3 V_3^n = P_4 V_4^n$ $\quad \therefore V_4 = 0.00174\ m^3$ (2)

Volume of air delivered, $V_a = V_1 - V_4$

Work done by the compressor = W

$W = \frac{n}{n-1} \cdot P_1 V_a \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$

$W = 1702$ N-m or (1)

(i) Mean effective pressure $= \frac{WD}{V_s}$

$\therefore P_m = 1.807$ bar (3)

(ii) Power required, $P = \frac{WD \times N_c}{60} \times \frac{1}{1000}$ — 10

$P = 14.19$ kW (3)

Alternative Method:

$\rho_1 = \frac{p_1}{RT_1} = 1.19\ kg/m^3$

$\dot{Q} = V_1 \frac{N}{60} = 0.068\ m^3/s$

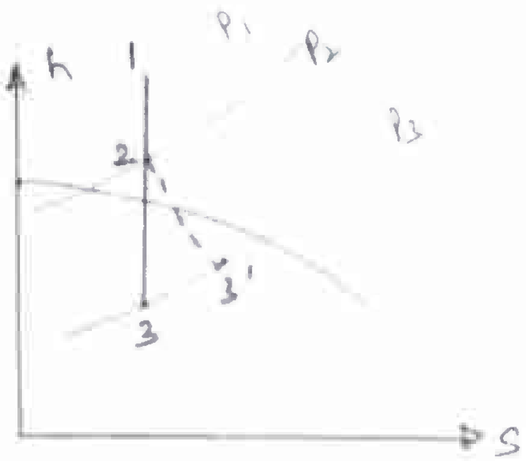
$\dot{m} = \dot{Q}\rho_1 = 0.081\ kg/s$

$W = \frac{n}{n-1} RT_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]$

$= 175.64$ kJ/kg

$P = \dot{m}W = 14.23$ kW

Subject Title : Applied thermodynamics Subject Code : 18ME42

Question Number	Solution	Marks Allocated
10 a)	Derivation $\frac{P_2}{P_1} = \left[\frac{n+1}{2}\right]^{\frac{n}{1-n}}$	10
b)		

$$\frac{P_2}{P_1} = \left[\frac{2}{n+1}\right]^{\frac{n}{n-1}} = 0.545 \qquad \therefore P_2 = 8.175 \text{ bar}$$

From h-s diagram,

At $P_1 = 15$ bar & $T_1 = 250°c$, $h_1 = 2920$ kJ/kg — (2) —

At $P_2 = 8.175$ bar, $h_2 = 2800$ kJ/kg

$T_{sup} = 180°c$

$v_2 = 0.3$ m³/kg (2).

At $P_3 = 1$ bar $h_3 = 2440$ (1) —

Velocity at Throat, $V_2 = 44.72\sqrt{h_1 - h_2}$

$V_2 = 489.88$ m/sec

$m = \frac{A_2 V_2}{v_2}$ $A_2 = 3.06 \times 10^{-4}$ m²

$\therefore$ $d_2 = 0.019$ m — (2) —

$\eta_z = \frac{h_2 - h_{3'}}{h_2 - h_3}$ $\therefore h_{3'} = 2476$ kJ/kg

Velocity at exit, $V_{3'} = 44.72\sqrt{h_1 - h_{3'}} = 942.3$ m/sec

$d_3 = 0.031$ m (3) — 10

—x—

Approved by

Dr. M.S. Govinde Gowda
Chairman,
BOE, Mechanical Board, VTU.

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