Course Code: 1950323 **Roll No:** **MLRS- R19**

MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT

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III B.Tech I Sem Regular End Examination, February 2022

Thermal Engineering – II

(MECH)

Time: 3 Hours. **Max. Marks: 70**

Note: 1. Question paper consists: Part-A and Part-B.
2. In Part – A, answer all questions which carries 20 marks.
3. In Part – B, answer any one question from each unit.
Each question carries 10 marks and may have a, b as sub questions.

PART- A

(10*2 Marks = 20 Marks)

1.	a)	Describe the significance of mean temperature of heat addition.	2M	CO1	BL1
	b)	Write the condition for maximum discharge through the chimney.	2M	CO1	BL4
	c)	What are the preferable conditions for use of convergent divergent nozzle?	2M	CO2	BL2
	d)	How does the degree of under cooling influence the nozzle performance?	2M	CO2	BL3
	e)	Evaluate the degree of reaction for the impulse turbine.	2M	CO3	BL5
	f)	Express the blade speed ratio for maximum performance of reaction turbine.	2M	CO3	BL3
	g)	Illustrate the importance of vacuum efficiency of a steam condenser.	2M	CO4	BL5
	h)	Differentiate between closed and open cycle gas turbines	2M	CO4	BL5
	i)	What is specific impulse? How to estimate it for rocket engines?	2M	CO5	BL4
	j)	Draw the velocity, pressure and temperature variations in all the components of turbojet engine.	2M	CO5	BL5

PART- B

(10*5 Marks = 50 Marks)

2	a)	Draw the schematic, p-h and T-s diagrams of reheat Rankine cycle and explain the improvement in performance of the cycle.	5M	CO1	BL4
	b)	Explain the working of cochran boiler with the help of neat sketch.	5M	CO1	BL3
		OR			
3		In a steam power plant the condition of steam at inlet to the turbine is 40 bar and 400^{0}C and the condenser pressure is 0.1 bar. Two feed-water heaters operate at optimum temperatures of 150^{0}C and 100^{0}C. Determine the quality of steam at turbine exhaust and cycle efficiency.	10M	CO1	BL4
4		Derive the equation for the estimation of mass flow rate for convergent divergent nozzle.	10M	CO2	BL4

OR

5		Steam having pressure of 25 bar and 0.9 dryness is expanded through a convergent – divergent nozzle and the pressure of steam leaving the nozzle is 0.75 bar. Find the velocity at the throat for maximum discharge conditions. Index of expansion may be assumed as 1.135. Also calculate mass rate of flow of steam through the nozzle for maximum discharge condition.	10M	CO2	BL4
6	a)	Draw the combined velocity triangles for reaction turbine with 50% degree of reaction and derive the equations for power developed and blade efficiency.	5M	CO3	BL4
	b)	Describe the importance of pressure velocity compounding of impulse turbine and give the example for the pressure velocity compounded turbine.	5M	CO3	BL5
		OR			
7		In a steam turbine, the steam expands from an inlet condition of 10 bar and 325^{0}C with an isentropic efficiency of 92%. The nozzle is inclined at an angle of 20^{0}C and operates with optimum blade speed ratio. If the blades are symmetrical, Calculate the blade angles and power output from the turbine if the mass flow rate is 0.5 kg/s.	10M	CO3	BL5
8	a)	What are the sources for air leakage in condenser and discuss the ill effects? Explain the methods to minimize the air leakages.	5M	CO4	BL3
	b)	Illustrate the required conditions for the better combustion chamber for the gas turbine.	5M	CO4	BL5
		OR			
9		A closed cycle gas turbine using Argon as the working fluid has a two stage compression with perfect inter cooling. The overall pressure ratio is 9 and pressure ratio in each stage is equal. Each stage has an isentropic efficiency of 85%. The turbine is also two stage with equal pressure ratio with inter change reheat to original temperature. Each turbine stage has an isentropic efficiency of 90%. The turbine inlet temperature is 1100 K and the compressor inlet is 303 K. Find (i) work done per kg of fluid flow (ii) work ratio (iii) The overall cycle efficiency. Properties of argon are C_p= 0.5207 kJ/kg K, Gamma = 1.667 and R = 0.20813 kJ/kg K.	10M	CO4	BL5
10	a)	Explain the working of turbo-jet with the help of neat sketch.	5M	CO5	BL4
	b)	Distinguish between solid and liquid propellant rocket systems based their constructional and operational features.	5M	CO5	BL5
		OR			
11		A turbojet engine is being used to propel an aeroplane with the drag of 3900 N and the coefficient of drag is 0.01835. The wing area is 21.25 m^2, the air consumption per second of the engine is 14.5 kg/s and thrust developed is 8900 N. Calculate the flight velocity and effective jet velocity and also specific thrust.	10M	CO5	BL3

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EXAMINATION BRANCH

Academic Year	2021-22
Year & Semester	III - I
Regulation	R-19
Branch	MECHANICAL
Course Code	1950323
Course Name	Thermal Engineering 2
Course Faculty's	K.V. Raghavulu
Course Moderator	K.V. Raghavulu
Date of Exam	17/2/2022
Reporting Time & Sign	1:00 pm.

KEY PAPER

QNO	ANSWER	MARKS
① Ans:	In Rankine cycle, the mean temperature at which heat is supplied is less than the maximum temperature, so that the efficiency is less than that of a Carnot cycle working b/w the same maximum and minimum temperatures. The heat absorption takes place at constant pressure.	2M

QNO	ANSWER	MARKS
2Q:	mass of gases flowing through chimney	
	$m_g = \rho_g A c$	
	$m_g = \frac{P}{R T_g} \cdot A \cdot \sqrt{2g(H_1 - h_1')}$	
	neglecting press. losses in chimney $h_1' = 0$	2M
	$m_g = A \cdot \sqrt{2gH'} \cdot \frac{P}{R T_g}$.	
	put $H_1 = H \sqrt{\frac{m_a}{m_a + 1} \frac{T_g}{T_g} - 1}$	
	$m_g = A \sqrt{2g \left\{ \frac{m_a+1}{m_a} \right\} \frac{T_g}{T_s} - 1} \cdot \frac{P}{R T_g}$	
3Q:	consider the flow in convergent-divergent nozzle. the upstream stagnation conditions are assumed constant, the pressure in the exit plane of the nozzle is denoted by P_E. the nozzle discharges to the back pressure, P_B. the flow rate become maximum for a given nozzle and the stagnation conditions.	2M

QNO	ANSWER	MARKS
d).	when the gas passes through a Nozzle, It's velocity increases on the expense of decrease of It's pressure. Now temperature change is directly proportional to pressure change. so it's temperature decreases due to decrease of it's pressure.	2M
e).	Degree of Reaction: It's the ratio of isentropic enthalpy change in Rotor to the Isentropic enthalpy change in stage.	2M
f).	Blade speed Ratio: it's the ratio of blade speed to the tangential component jet speed. single impulse turbine is known as delaval turbine.	2M
g).	vaccum Efficiency: It's the ratio of actual vaccum in the condenser as Recorded by the vaccum gauge to the ideal vaccum.	2M

QNO	ANSWER	MARKS
h).		

Closed cycle gas turbine	Open cycle gas turbine
1. The compressed air heated in heating chamber.	1. The compressed air heated in combustion chamber.
2. The working fluid is circulated continuously.	2. The working fluid is replaced continuously.
3. High maintenance cost	3. low maintenance cost.
4. blades donot wear	4. blade wear & tear takes place.

2M

I:

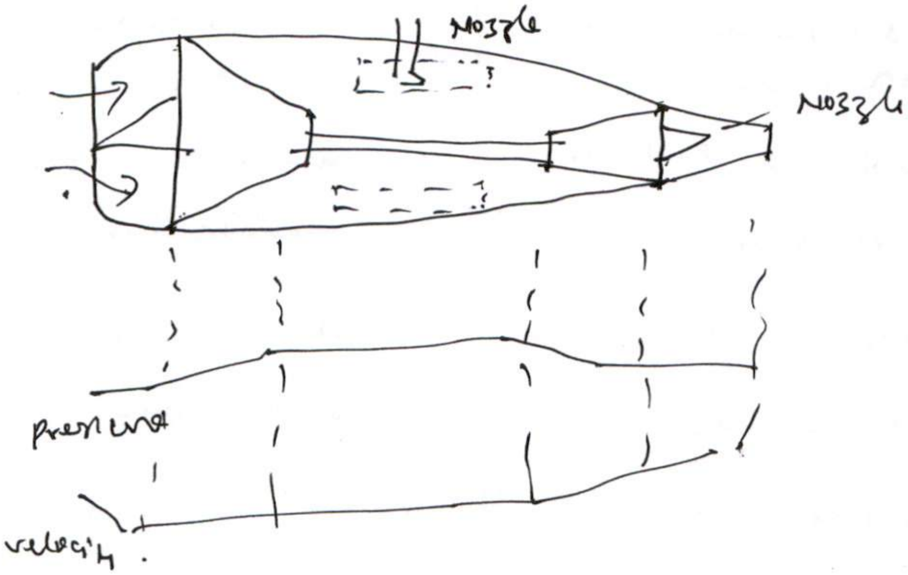
Impulse: The amount of change in an objects momentum.

2M

$$\Delta p = p_f - p_i$$

$$\Delta p = mv_f - mv_i$$

→ Impulse is the product of the force applied to an object and the amount of time applied.

QNO	ANSWER	MARKS
J:	 pressure & velocity distribution in turbojet	2M

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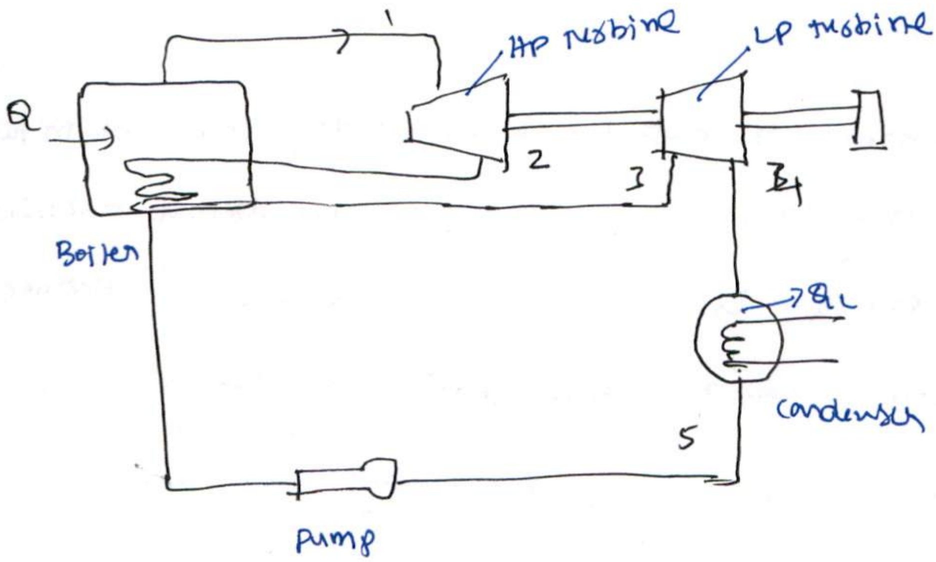
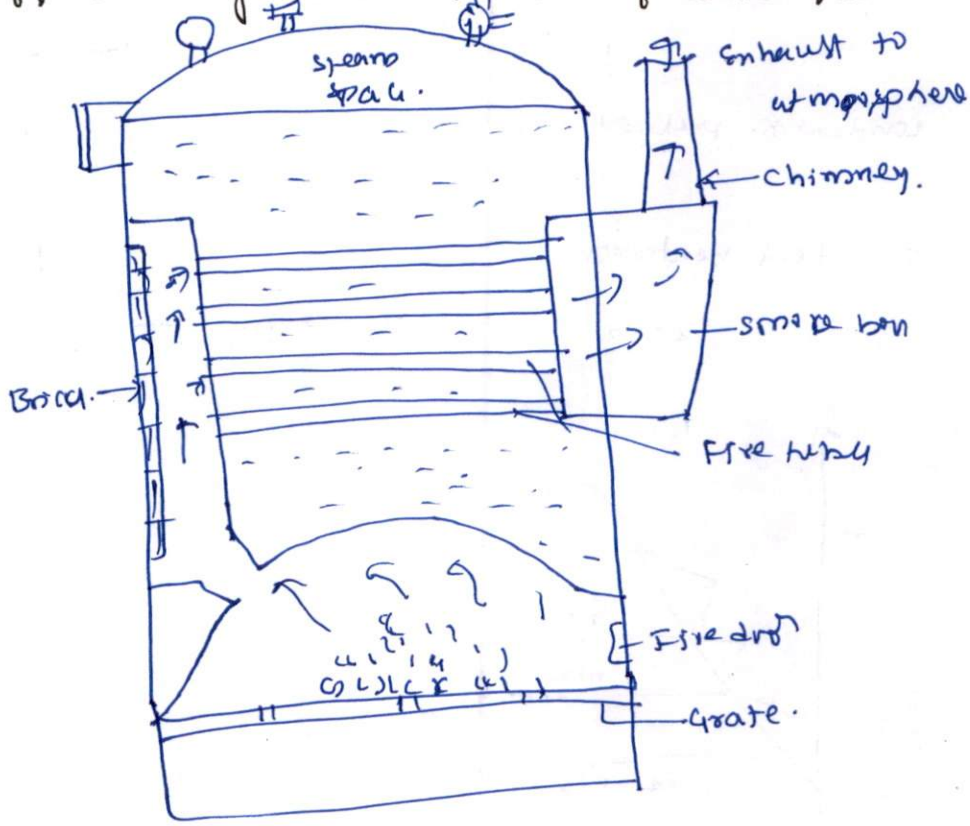
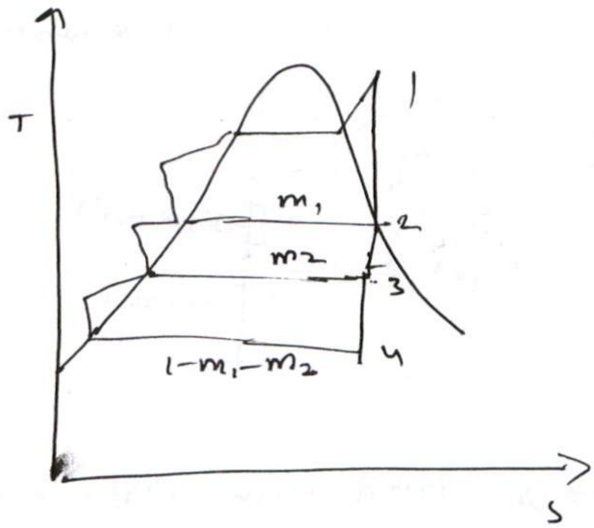
QNO	ANSWER	MARKS
2 (a) Ans:	PART - B It's desirable to keep the steam as dry as possible in the lower pressure stages of the turbine. The dryness fraction at the exhaust should not less than 0.9. The Average temperature can be increased by superheating the steam. However, the expansion in one stage can result in high moisture content in the exhaust steam. The dryness fraction of exhaust steam can be improved by reheating the steam. The steam, after expanding in high pressure turbine, is returned to the boiler for further reheating before expanding in the low-pressure turbine. Reheating occurs at constant pressure and raise the temperature equal to the inlet temperature of the first stage.	5M

QNO	ANSWER	MARKS
		
2 b:	The cochran boiler is a multitubular vertical fire tube boiler suitable for producing relatively small amounts of steam at low pressure. The boiler can be operated by solid & liquid fuels. The efficiency of oil fired boiler (75%) is greater than the efficiency of coal fired boiler (70%) - The cochran boiler has horizontal tubes to increase the heating surface. These tubes connect the combustion chamber is connected to fire box with the help of flue tube. The combustion chamber is lined with fire bricks to prevent overheating of boiler shell.	5M

QNO	ANSWER	MARKS
	Internal access to the boiler is provided by a man hole at the top, while the hand holes in the lower section provide access for cleaning and inspection of water space.	



	Working: The boiler is filled with water to a specified level, and fire tubes are completely submerged in water. The fuel is burnt in a furnace having a hemispherical crown. The hemispherical shape deflect the unburnt coal back to the grate and ensure complete combustion.	

QNO	ANSWER	MARKS
3.	Initial pressure = 40 bar Initial temperature = 400 + 273 = 673 K. condensor pressure = 0.1 bar Two feed heaters temperature 150°c & 100°c. x = ? cycle Efficiency?  ∴ m_1 = mass of bled steam at first stage m_2 = mass " at second stage.	5M

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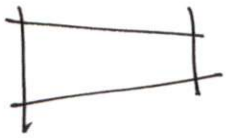
QNO	ANSWER	MARKS
4Q:	Derive the max. mass flowrate of Nozzle:	
Sol:		
	$m = \frac{A_2 V_2}{v_2}$	
	the gain in kinetic Energy = Enthalpy drop	
	$\frac{V_2^2}{2} = \frac{n}{n-1}(p_1v_1 - p_2v_2) = \frac{n}{n-1} p_1v_1\left[1 - \frac{p_2v_2}{p_1v_1}\right]$	
	$\therefore \frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{1/n} = \left(\frac{p_2}{p_1}\right)^{-1/n} \quad \therefore v_2 = v_1 \left[\frac{p_2}{p_1}\right)^{-1/n}$	
	$\frac{V_2^2}{2} = \frac{n}{n-1} p_1v_1\left[1 - \frac{p_2}{p_1}\left[\frac{p_2}{p_1}\right]^{-1/n}\right]$	
	$= \frac{n}{n-1} p_1v_1\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]$	5M
	$V_2 = \sqrt{\frac{2n}{n-1} p_1v_1\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]}$	
	$m = \frac{A_2}{v_2}\sqrt{\frac{2n}{n-1} p_1v_1\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]}$	
	$v_2 = v_1\left(\frac{p_1}{p_2}\right)^{-1/n}$	

QNO	ANSWER	MARKS
	$\therefore m = \frac{A_2}{v_1 \left(\frac{P_2}{P_1}\right)^{-1/n}} \sqrt{\frac{2n}{n-1} P_1 v_1 \left\{1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right.}$ $= \frac{A_2}{v_1} \sqrt{\frac{2n}{n-1} P_1 v_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right.}$ $\therefore \frac{P_2}{P_1} = \left(\frac{n}{n+1}\right)^{\frac{n}{n-1}}$ $m_{max} = \frac{A_2}{v_1} \sqrt{\frac{2n}{n-1} P_1 v_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right.}$ $= \frac{A_2}{v_1} \sqrt{\frac{2n}{n-1} P_1 v_1 \left\{\frac{2}{n+1}\right]^{\frac{2}{n-1}} - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}}$ $= A_2 \sqrt{\frac{2n}{n-1} \frac{P_1}{v_1} \left[\frac{2}{n+1}\right)^{\frac{2}{n-1}} - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}}$ $= A_2 \sqrt{\frac{2n}{n-1} \frac{P_1}{v_1} \left[\frac{2}{n+1}\right]^{\frac{2}{n-1}} \left[1 - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1} - \frac{2}{n-1}}\right.}$ $= A_2 \sqrt{\frac{2n}{n-1} \times \frac{P_1}{v_1} \left[\frac{2}{n+1}\right]^{\frac{2}{n-1}}}$	

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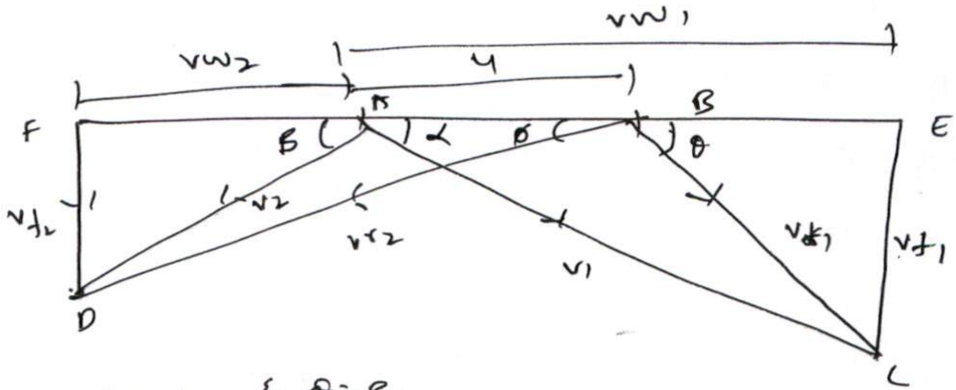
QNO	ANSWER	MARKS
5a: Ans:	Convergent - divergent nozzle $P_1 = 25$ bar $x_1 = 0.9$ $P_3 = 0.75$ $C_2 = ?$ $n = 1.135$ $\frac{P_2}{P_1} = 0.572$ $P_2 = 25 \times 0.572$ $= 14.3$ bar throat velocity : $V_2 = \sqrt{\frac{2n}{n-1} P_1 v_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]}$ $= \sqrt{\frac{2 \times 1.135}{1.135 - 1} 25 \times 10^2 \times 0.1325 \left[1 - \frac{14.3}{25}\right]^{\frac{1.135-1}{1.135}}}$ $= 700$ m/s.	5M

QNO	ANSWER	MARKS
6 (a):	velocity triangles for Reaction turbines:	



$\alpha = \phi$ & $\theta = \beta$.

α = outlet angle of fixed blade

ϕ = " of moving blade

β = inlet angle of fixed blade

θ = inlet angle of moving blade — 5M

① Power output $= \frac{m\,(V_{w1} \pm V_{w2})\,u}{1000}$

② Blade Efficiency : $\frac{(V_{w1} - V_{w2})\,2u}{V_1^2}$

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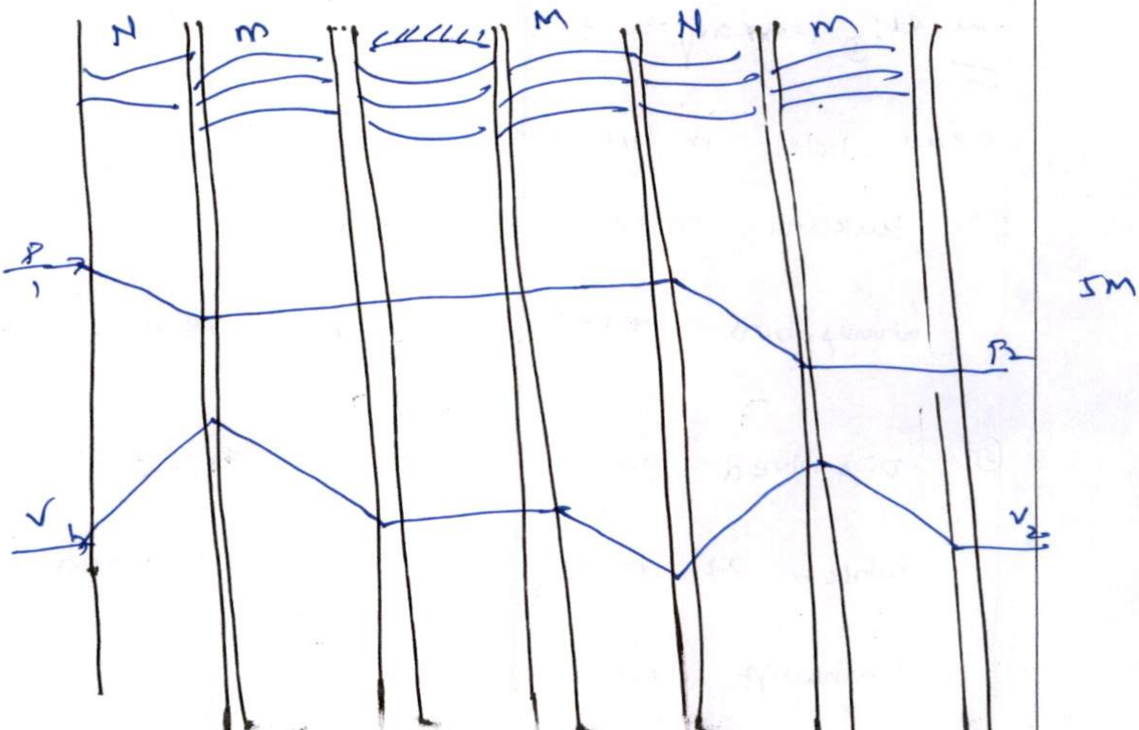
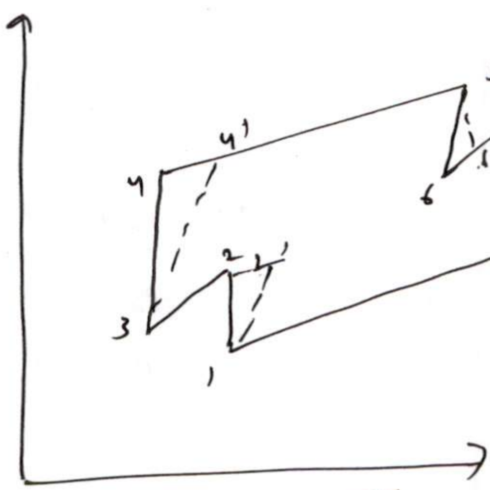
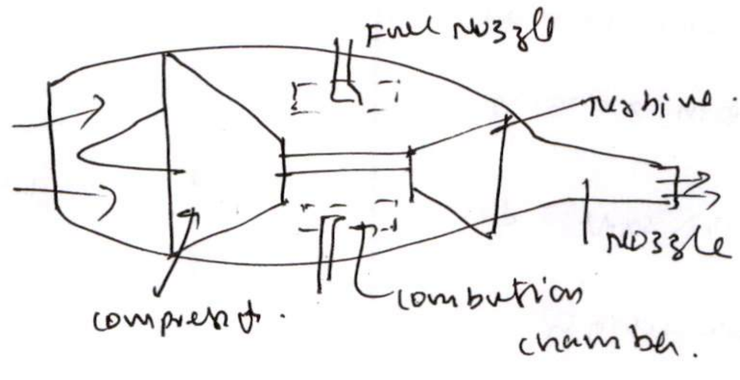
QNO	ANSWER	MARKS
6 b:	the speed of turbine may Reduced by splitting up the available Energy by arranging two 'or' more simple velocity-compounded turbines in series on the same shaft. the total pressure drop is then Effected in two 'or' more stages. Thus it involves combination of velocity & pressure compounding. therefore it is reffered as velocity - Pressure compounding.	



QNO	ANSWER	MARKS
8: a'	The condenser has high vaccum, therefore air leakages occurs in the condenser. The main sources of air leakage in the condenser are: (i) leakage of air from atmosphere at the joints of the parts which are at pressure less than atmosphere (ii) Air is coming from the boiler along the steam. sources: ① leakage through packing glands and very small holes in the shell ② leakage through joints and vents from atmosphere relief valve and other accessories. ③. Dissolved gases or air in boiler feed water, which ultimately enter the condenser with exhaust steam.	5M

QNO	ANSWER	MARKS
8 b:	Basic Requirement of good combustion chamber: 1. High compression ratio. 2. Small 'or' no Excess air. 3. No dead pockets. 4. An optimum degree of turbulence. 5. High volumetric Efficiency.	5M
9: An:	 $\frac{P_4}{P_1} = 9$ $P_2 = \sqrt{9 \times 1} = 3$	3M

QNO	ANSWER	MARKS
	$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ $= \left(\frac{3}{1}\right)^{\frac{1.4-1}{1.4}} \times 303$ $= 700\,K.$ $\frac{T_2'-T_1}{T_2-1} = 0.85$ $T_2' = 725\,K.$ $T_5 = 1100\,K.$ ∴ perfect inter cooling. $T_1 = T_3$; $T_4' = T_2'$ compressor work $= 2 \times (T_2' - T_1)$ $= 2 \times (725 - 303)$ $= 700\,KJ/kg.$ $\frac{T_5}{T_6} = \left(\frac{P_5}{P_6}\right)^{\frac{\gamma-1}{\gamma}}$ $P_4 = P_5 = 9$ $P_8 = 1\,bar$ $P_6 = 3$ $T_6 = 620\,K.$ $\frac{T_5 - T_6'}{T_5 - 6} = 90\%.$ $T_6' = 646\,K.$	

QNO	ANSWER	MARKS
	turbine work: $cp(T_5 - T_6') + cp(T_7 - T_8')$ = 1558457 k. Efficiency: $\frac{\text{Net work done}}{\text{Heat supplied}}$ = 34.94%.	
10(a)	Turbojet:  - turbojet engines are commonly used for aircraft propulsion. the basic components of turbo jet engine consists of diffuser, generator, turbine & nozzle.	5M

QNO	ANSWER	MARKS
	→ air enters the diffuser which is placed before the compressor. In the diffuser the passenger of air rises above the atm. air due to decrease in air velocity. the pressure rise associated with with decrease in velocity is called ram Effect. The air is then compressed in a compressor which is driven by the turbine.	
10(b):	diff b/w solid & liquid propellent rocket systems:	
	Solid Propellent Rockets / **liquid propellent Rockets.**	
	① Fuel and oxidizer are permitted to form a charge / ①. liquid fuel and oxidizer are stored seperatly.	
	②- used for short duration / ②. used for long duration.	
	③. simple design / ③. complex in design.	5M
	④. Difficult to control / ④. Easy to control	
	⑤. Bigger size. / ⑤. smaller size	
	⑥. Easy to handle / ⑥. Difficult to handle.	