Name : .... Univ. No. : ....

مدة هذا السؤال 30 دقيقة فقط

Question 1) Answer the following concept questions.

A) Gravimetric analysis of a mixture indicates 2 kg N_2 ; 4 kg O_2 and 6 kg CO_2. This mixture has
Gas constant (R_{mix}) = ~~56.0168~~ 0.23   Molecular weight (M_{mix}) = 30.0685

B) In air standard Diesel cycle, at fixed compression ratio (CR) and adiabatic index (K). Thermal efficiency .....Dec....... as cut-off ratio ↑ Increases Decreases Remains constant

C) What is the relation between compression ratio (CR) and the efficiency of the Otto cycle?
a. Efficiency decreases with increase in compression ratio
b. Efficiency increases with increase in compression ratio
c. Efficiency does not affected by change in compression ratio
d. None of the above

D) How is the efficiency of the SI engine affected by change in specific heat ratio (γ) of the working fluid?
a. The efficiency of the engine increases with increase in specific heat ratio (γ) of the working fluid
b. The efficiency of the engine decreases with increase in specific heat ratio (γ) of the working fluid
c. The efficiency of the engine does not affected by change in specific heat ratio (γ) of the working fluid
d. None of the above

E) What is the effect of regeneration on mean temperature of heat addition in Brayton cycle?

a. mean temperature of heat addition decreases because of regeneration
b. mean temperature of heat addition increases because of regeneration
c. mean temperature of heat addition is not affected by use of regenerator
d. none of the above

F) A mixture of ideal gases of volume V at temperature T, contains n1 moles of gas A, n2 moles of gas B and n3 moles of gas C. What is a correct formula for partial pressure (P_B) of gas B?
a. (P_B) = ((1/3)(n1+n2+n3) RT) / V
b. (P_B) = ((n1 + n3) RT) / V
c. (P_B) = (n2 RT) / V
d. (P_B) = (n2(n1 + n3) RT) / V

$\eta_{th} = 1 - \frac{300}{2000} = 0.85$

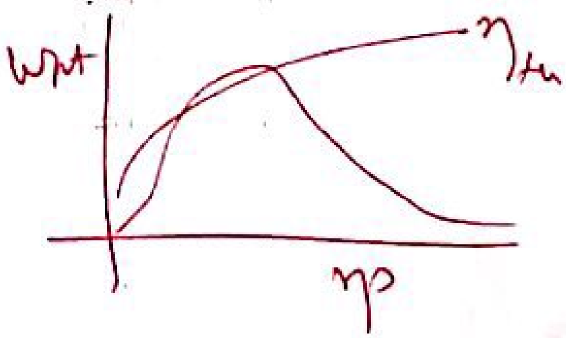
G) A Carnot cycle operates between the temperatures limits of 300 K and 2000 K, and produces 600 kW of net power. The rate of entropy change of the working fluid during the heat addition process is
(a) 0 (b) 0.300 kW/K (c) 0.353 kW/K (d) 0.261 kW/K (e) 2.0 kW/K

$Q_{in} = 570$
$= T_H \Delta S$

H) State two major functions of the following devices in their thermodynamic cycles (your answer should be related to their mechanical function)
Regenerator in Gas Turbine Cycle reduce Q_{in}, inc. η_{th}

Diffuser in Jet engine cycle Collect air, Inc. P inlet for Comp.

Explain with clean figures the effect of pressure ratio on ideal gas turbine cycle efficiency and power output



Question 2) ABET Question. (20 Marks)

Part (A) : Properties of gas mixtures

A mixture that is 10 % Carbon Dioxide, 10 % Carbon Monoxide, 10 % Oxygen, and 70 % Nitrogen *by volume* is trapped inside piston cylinder. It undergoes an adiabatic compression process having a compression ratio of 9:1. If the initial state of the mixture is 300 K and 100 kPa.

Calculate :

1) The mass fraction of the mixture.

2) The mixture's molecular weight and gas constant.

3) The mixture's adiabatic index (Kmix).

4) The final pressure and temperature.

5) The compression work using constant specific heat prenciple.

6) The mixture's volume at the start of compression using Ideal and Non-ideal gas equations.

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Part (A) : Gas power cycles

Answer ANY ONE of the following two questions

Air enters the ideal compressor of a regenerative gas-turbine engine at 300 K and 100 kPa, where it is compressed to 800 kPa and 580 K. The regenerator has an effectiveness of 72 percent, and the air enters the turbine at 1200 K. Draw the T-s diagram then determine :

(a) The amount of heat transfer in the regenerator, combustion chamber and rejected to atmosphere.

(b) The turbine and compressor work.

(c) The thermal efficiency,

(d) The back work ratio,

(e) The exergy destroyed in the combustion chamber, and

(f) Draw the variation of thermal efficiency of the cycle (on Y-axis) with regenerator effectiveness (on X-axis).

Assume constant specific heat for air.

OR

A turbojet aircraft is flying with a velocity of 280 m/s at an altitude of 9000 m, where the ambient conditions are 35 kPa and -30°C. The pressure ratio across the compressor is 12, and the temperature at the turbine inlet is 1200 K. Air enters the compressor at a rate of 50 kg/s, and the jet fuel has a heating value of 42,000 kJ/kg. Assuming ideal operation for all components and constant specific heats for air at room temperature.

Calculate :

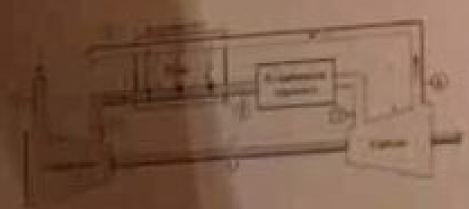
(a) the velocity of the exhaust gases,

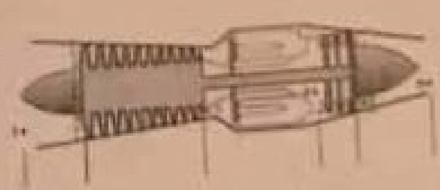
(b) the propulsive power developed,

(c) The propulsion efficiency,

(d) the rate of fuel consumption,

(e) The exergy destroyed in the combustion chamber





Q1) Assume $N_{mix} = 1$ ①

Component	y_i	N_i	M_i	m_i	mf_i	C_p	$mf_i C_{pi}$
CO_2	0.1	0.1	44	4.4	0.1466	0.846	0.12408
CO	0.1	0.1	28	2.8	0.0933	1.04	0.09706
O_2	0.1	0.1	32	3.2	0.1066	0.918	0.09792
N_2	0.7	0.7	28	19.6	0.6533	1.039	0.67887
				30.0 kg			0.9978

0.09792

2) $M_{mix} = \frac{m_{mix}}{N_{mix}} = 30 \text{ kg/kmol}$

3) $R_{mix} = \frac{R_u}{M_{mix}} = \frac{8.314}{30} = 0.2771 \frac{kJ}{kg \cdot K}$

4) $C_{p_{mix}} = \sum mf_i \cdot C_{p_i} = 0.9976$ "

$\therefore C_{v_{mix}} = C_{p_{mix}} - R_{mix} = 0.72056$ "

$\therefore k_{mix} = \left(C_p/C_v\right)_{mix} = 1.3845$

5) $W_{comp} = U_2 - U_1 = C_{v_{mix}} (T_2 - T_1)$

$T_2 = T_1 \, CR^{k_{mix}-1} = 698.278 \text{ K}$

$\therefore W_{comp} = 287.0215$ kJ/kg

6) $V_{mix_{ideal}} = \frac{N_{mix} R_u T_{mix}}{P_{mix}} = 24.942 \text{ m}^3$

CO_2 : $P_R = \frac{100}{739 \times 10.1} = 0.0135$
$T_R = \frac{300}{304.2} = 0.9862$ $\Big\}$ $Z_{CO_2} = 1$

CO : $P_R = \frac{100}{3.496 \times 10^3} = 0.02857$
$T_R = \frac{300}{133} = 2.255$ $\Big\}$ $Z_{CO} = 1$

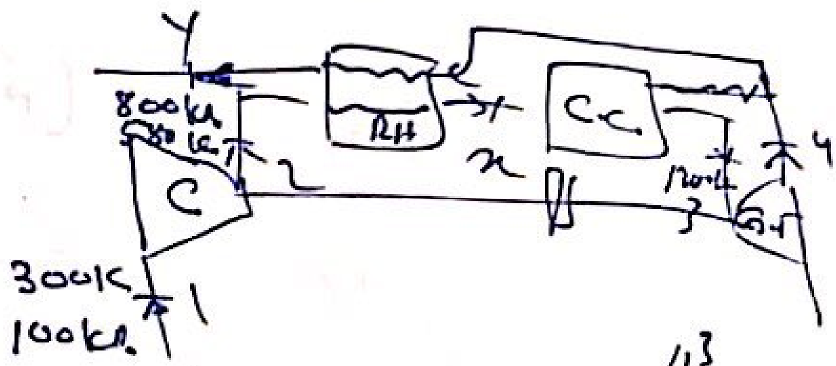
O_2 : $P_R = \frac{0.1}{5.020} = 0.02$
$T_R = \frac{300}{}$ $\Big\}$ $Z_{O_2} = 1$

N_2 : $P_R = \frac{0.1}{3.39} = 0.02949$
$T_R = \frac{300}{126.2} = 2.377$ $\Big\}$ $Z_{N_2} = 1$

$Z_{mix} = \sum y_i Z_i = 1$

$V_{mix\ act} = Z_{mix} V_{ideal} = \underline{\underline{24.942}}$

e>7LY.

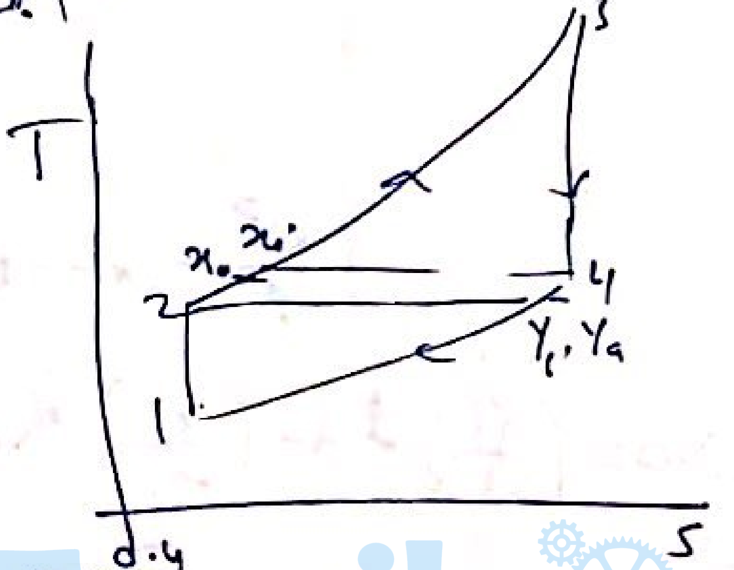


1) 300 K
100 kPa

2) 800 kPa $\Rightarrow r_p = 8$
580 K

3) 1200 K , $P_3 = P_2$

4) $P_4 = P_1$



$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = \left(\frac{1}{8}\right)^{\frac{0.4}{1.4}} \Rightarrow T_4 = 662.483\,K$$

$$\varepsilon_{regen} = 0.72 = \frac{T_{x_a} - T_2}{T_{x_i} - T_2} \quad , \; T_{x_i} = T_4$$

$$\therefore T_{x_a} = 639.366\,K$$

$$\therefore \varepsilon = \frac{T_4 - T_{y_a}}{T_4 - \underbrace{T_{y_i}}_{T_2}} \Rightarrow T_{y_a} = 596.622\,K$$

(a)

$$q_{regen} = (T_{x_a} - T_2)\,c_p =$$

$$q_{in} = (T_3 - T_2)\,c_p =$$

$$q_{out} = (T_{y_a} - T_1)\,c_p =$$

b) $W_c = c_p(T_2 - T_1) =$

$W_T = c_p(T_3 - T_4) =$

c) $\eta_{th} = \dfrac{W_{net}}{q_{in}} =$

d) $W_{BR} = \dfrac{W_c}{W_T} =$

e) $X_{dest,\,3-x_0} = T_0\left[s_3 - s_{x_0} + \dfrac{q_{out}}{T_H}\right]$

$s_3 - s_{x_0} = c_{p_0}\ln\left(\dfrac{T_3}{T_{x_0}}\right) - R\ln\left(\dfrac{P_3}{P_{x_0}}\right) = 0.63274\ \dfrac{kJ}{kg}$

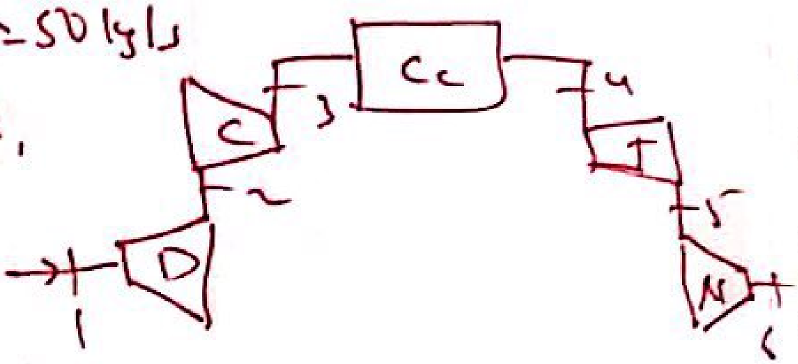
f)

Q2: $V_f = 280 \, m/s$, $h = 9000 \, m$,

$P_1 = 35 \, kPa$, $T_1 = -30 \, C^\circ$, $r_{p_c} = 12$,

$T_4 = 1200 \, K$, $\dot{m}_a = 50 \, kg/s$

$Q_L = 42000 \, \frac{kJ}{kg}$.



Diffuser:

$$T_2 = T_1 + \frac{V_1^2}{2C_p} = 282 \, K$$

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}} = \cancel{36.52} \; 58.927 \; kPa$$

Comp:

$$P_3 = r_p P_2 = 707.16 \, kPa, \quad \frac{T_3}{T_2} = (r_p)^{\frac{k-1}{k}} \Rightarrow T_3 = 573.57 \, K$$

$$W_c = \dot{m}_a C_p (T_3 - T_2) = 14651.4044 \, kW$$

C-C

$$P_4 = P_3, \quad Q_{in} = \dot{m}_a C_p (T_4 - T_3) = 31428.1475 \, kW$$

G.T

$$W_T = W_c \Rightarrow T_5 = T_4 - T_3 + T_2 = \cancel{720.06} \; 908$$

$$P_5 = P_4 \left(\frac{T_5}{T_4}\right)^{\frac{k}{k-1}} = \cancel{158.55} \; 266.934 \; kPa$$

Nozzle

$$T_6 = T_5 \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}} = 508.390\,K$$

(1) $$V_6 = \sqrt{2C_p(T_5 - T_6)} = 896.5\ m/s$$

$= \cancel{896.29}\ m/s$

(2) $$\dot{W}_p = \dot{m}_0 (V_6 - V_1) V_{aircraft} = 8630.927$$

$= \cancel{5211.780925\ kW}$

(3) $$\eta_p = \frac{\dot{W}_p}{\dot{Q}_{in}} = 0.274$$

(4) $$\dot{Q}_{in} = \dot{m}_f Q_{HV} \eta_c \Rightarrow \dot{m}_f = 0.7524\ kg/s$$

$$\dot{X}_{dest} = \dot{m}_a T_0 \left[s_4 - s_3 + \frac{q_{in}}{T_H}\right]$$

(5) $$s_4 - s_3 = C_{P_{avg}} \ln(T_4/T_3) - R \ln(P_4/P_3)$$

$= 0.7418848$

$\therefore \dot{X}_{dest} = \cancel{10003.76}\ kW$

11920.55