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University of Windsor
Mechanical, Automotive, and Materials Engineering
92-217: Applied Thermodynamics
Midterm Examination

Name: [redacted]
Student ID: [redacted]

Read carefully!

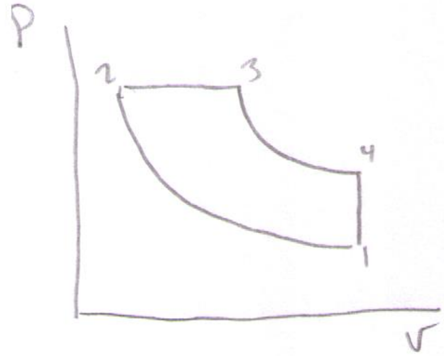
- This is an closed book exam.
- The duration of the exam is 90 min.
- Answer all problems.
- Good luck!

Grading Scale

Q1	4	*/4 marks*
Q2	7	*/11 marks*
Q3	15	*/15 marks*
Total	26	***/30 marks***

1. [4 marks] A six-cylinder 3.2L engine operating on the ideal Diesel cycle takes in air at 94kPa and 20C. The co mpression ratio in the engine is 16 and the cutoff ratio is 1.3. When operating at 2500rpm, this engine produces 280kW output power. Determine the rate of heat addition to the engine.

Assume **constant specific heats** for air. Use c_p = 1.005 kJ/kg.K, c_v = 0.718 kJ/kg·K, k=1.4, R_{air}=0.287kJ/(kg.K) at room temperature.



$P_1 = 94\text{kPa}$

$T_1 = 20°C$

$r = \frac{V_1}{V_2} = 16$

$r_c = \quad = 1.3$

$W_{net} = 280\text{kW}$

$Q_{in} = ?$

$K = 1.4$

$R = 0.287$

$$\eta = 1 - \frac{1}{r^{K-1}}\left(\frac{\varepsilon^{K} - 1}{K(r_c - 1)}\right)$$

$$\eta = 1 - \frac{1}{16^{0.4}}\left(\frac{1.3^{1.4} - 1}{1.4(1.3 - 1)}\right)$$

$\eta = 0.6514$ ✓

$$\eta = \frac{W_{net}}{Q_{in}}$$

$$Q_{in} = \frac{W_{net}}{\eta}$$

$$Q_{in} = \frac{280}{0.6514}$$

$$\boxed{Q_{in} = 429.84\ \text{kW}}$$ ✓

4

7/11

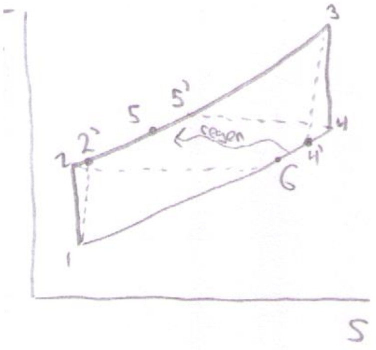
2. [11 marks]A gas turbine engine operates on Bryaton cycle with regeneration using air as working fluid and pressure ratio of 8. The minimum and maximum temperatures in the cycle are 310K and 1150K. Assuming isentropic efficiency of 82% for the compressor and 85% for the turbine and effectiveness 85% for the regenerator determine:

   a) the air temperature at the turbine exit

   b) the net work output

   c) the thermal efficiency

Assume **variable specific heats** for air at different temperatures



a) $T_{4'}$

$$\eta_T = \frac{h_{4a}-h_3}{h_{4s}-h_3}$$

<u>State 3</u>

$T_3 = 1150K$ $\quad P_{r_3} = 138.6$

$$h_3 = \frac{1207.57+1230.92}{2}$$

$h_3 = 1219.25\ KJ/Kg$ ①

<u>State 1</u>

$T_1 = 310K$

$P_{r_1} = 1.5546$

$h_1 = 310.24$ ①

<u>State 4</u>

$$P_{r_4} = \frac{P_{r_3}}{8} \qquad T_4 = 610K$$

$P_{r_4} = 17.325 \approx 17.3$

≈ 617.53

$$r_p = \frac{P_2}{P_1} = \frac{P_{r_2}}{P_{r_1}} = 8$$

$T_1 = 310K$

$T_3 = 1150K$

$h_{4a} = \eta_T(h_{4s}-h_3)+h_3$ ①

$h_{4a} = 707.79$

<u>State 4'</u>

$h_{4'} = 707.79$

$$\frac{T_{4'}-690}{700-690} = \frac{707.79-702.52}{713.27-702.52}$$

$\boxed{T_{4'} = 694.9\ K}$ ①

<u>State 5</u>

$T_5 = \cancel{T_4} = 610K$

$h_5 = h_4 = 61\cancel{7}.53\ KJ/Kg$

$$\varepsilon = \frac{Q_{regen\ act}}{Q_{regen\ max}}$$

$Q_{regen\ act} = (0.85)(h_5-h_2) = 51.3\ KJ/Kg$

b) <u>State 2</u>

$P_{r_2} = (P_{r_1})8$

$P_{r_2} = 12.4368$

$$\frac{h_2-550}{560-550} = \frac{12.4368-11.86}{12.66-11.86}$$ ①

$h_2 = 55\cancel{7}.21\ KJ/Kg$

$$\eta_c = \frac{h_{2s}-h_1}{h_{2a}-h_1}$$

$$h_{2a} = \frac{h_{2s}-h_1}{\eta_c}+h_1$$

$h_{2a} = 611.42\ KJ/Kg$ ①

<u>State 6</u>

$h_6 = h_2 = \cancel{557.21}\ KJ/Kg$

$\frac{15}{15}$

3. [15 marks]A steam power plant operates on ideal Rankine cycle with **one stage** of reheat and has a net power output of 120MW. Steam enters all **two** stages of the turbine at 500C. The maximum pressure in the cycle is 15MPa and the minimum pressure is 5kPa. The **steam** after the first turbine is reheated at 5MPa.

   Determine:

   a) The thermal efficiency of the cycle

   b) The mass flow rate of the steam

Assume **variable specific heats** for steam at different temperatures.

a) $\eta = ?$

$T_3 = T_5 = 500°C$

$P_2 = P_3 = 15\ MPa$

$P_1 = P_6 = 5\ kPa$

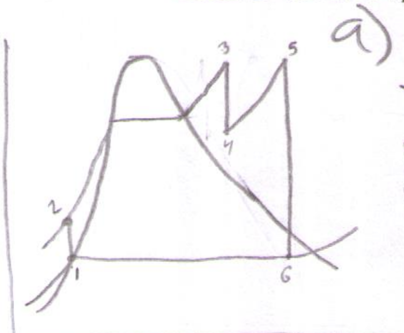
$P_4 = P_5 = 5\ MPa$

$Q_{out} = h_6 - h_1$

$Q_{out} = 1989.77$

$\eta = \frac{Q_{in} - Q_{out}}{Q_{in}}$

$\boxed{\eta = 0.445}$



$= 137.75\ KJ/Kg$

$= S_2 = 0.4762$

tate2 compressed liquid
15MPa

$\frac{\ _2 - 97.93}{0.77 - 97.93} = \frac{0.4762 - 0.2932}{0.5666 - 0.2932}$

$_2 = 153.38\ KJ/Kg$

tate 3 Superheated
15MPa, 500°C

$_3 = 3310.8\ KJ/Kg$

$_3 = 6.3480\ KJ/Kg\,K$

tale 5 Superheated
5MPa, 500°C

$= 3434.7\ KJ/Kg$

$= 6.9781$

State 4 Superheated
@5MPa

$S_4 = S_3 = 6.3480\ KJ/Kg\,K$

$\frac{h_4 - 2925.7}{3069.3 - 2925.7} = \frac{6.348 - 6.2111}{6.4516 - 6.2111}$

$h_4 = 3007.44\ KJ/Kg$

$Q_{in} = (h_3 - h_2) + (h_5 - h_4)$

$Q_{in} = 3584.68\ KJ/Kg$

State 6 Saturated

$S_5 = S_6 = 6.9781$

$S_6 = S_f + X S_{fg}$

$X = \frac{S_6 - S_f}{S_{fg}}$

$X = 0.8212$

$h_6 = h_f + X h_{fg}$

$h_6 = 2127.52\ KJ/Kg$

b) $P = 120MW = 120\ MJ/s$

$W_{net} = Q_{in} - Q_{out} = 1.5949\ MJ/Kg$

$P = \dot{m} W_{net}$

$\dot{m} = P/W$

$\dot{m} = \frac{120}{1.5949}$

$\boxed{\dot{m} = 75.24\ Kg/s}$