ภาควิชาวิศวกรรมเครื่องกล

คณะวิศวกรรมศาสตร์ มหาวิทยาลัยขอนแก่น

ข้อสอบปลายภาค ประจำภาคต้น ปีการศึกษา 2554

วิชา 185 231 Thermodynamics I

วันที่ วันพุธที่ 28 กันยายน 2554 **เวลา 08.30 – 11.30 น.**

ผู้ออกและตรวจข้อสอบ: รศ.ดร.สมหมาย ปรีเปรม ผศ.ดร.ปุริมพัฒน์ สุจำนงโตกุล อ.ดร.อัครพล จันทร์อ่อน

คำสั่ง

1. ให้เขียน ชื่อ-สกุล กลุ่ม และที่นั่งสอบ ลงในกระดาษข้อสอบทุกแผ่น
2. ข้อสอบทั้งหมดมี 5 ข้อ ให้ทำทุกข้อ
3. มีตาราง Thermodynamics ให้
4. อนุญาตให้ใช้เครื่องคำนวณที่ไม่มีการบันทึกข้อมูลของรายวิชานี้ไว้
5. ห้ามนำเอกสารใดๆออกจากห้องสอบ
6. ให้ทำข้อสอบในแผ่นข้อสอบของข้อนั้นๆเท่านั้น (สามารถใช้ด้านหลังได้)

ชื่อ-สกุล................. ....รหัส .... Section............ที่นั่งสอบ......... ....

ข้อ	คะแนนเต็ม	คะแนน
1	*10*	
2	*10*	
3	*10*	
4	*10*	
5	*10*	
รวม	***50***	

ชื่อ-สกุล...รหัส .... กลุ่ม.................ที่นั่งสอบ......... ....

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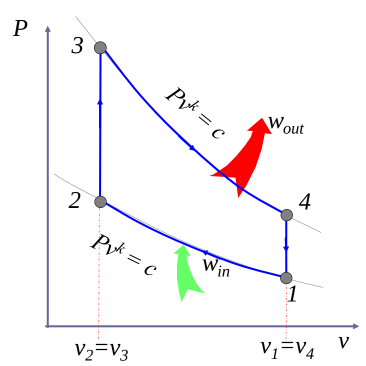
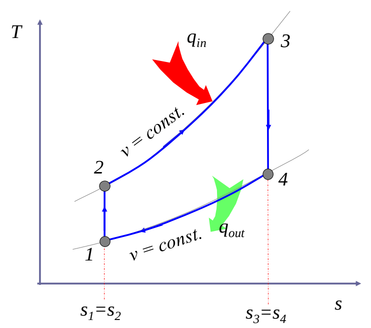
2. An air standard Otto cycle has a compression ratio of 9.0. The state of air at the beginning of the compression process is 80 kPa and 30°C. The heat input during the heat addition process is 1,000 kJ/kg. <u>Calculates by using constant specific heats at</u> **<u>900K</u>**<u>,</u> determine

(a) Write the name of the 4 processes *(1 mark)*
(b) draw the P-v and T-s diagram, *(1 mark)*
(c) the amount of heat rejected per cycle, *(3 mark)*
(d) the net work per cycle, *(1 mark)*
(e) the thermal efficiency and *(1 mark)*
(f) the mean effective pressure. *(2 mark)*
การทำงานที่เป็นระบบ เรียบร้อยและสะอาด *(1 mark)*

Process	Process name	P-v diagram	T-s diagram
1-2	*Isentropic Compression*		
2-3	Constant Volume Heat Addition		
3-4	Isentropic Expansion		
4-1	Constant Volume Heat Rejection		

Solution

Assumption: Air Standard Otto cycle, constant sp.ht.at 900K

Given: P_1= 80 kPa, T1= 30°C, r_v=9; q_H = 1,000 kJ/kg

Constants: Table A-1: R = 0.287 kJ/kgK;
Table A-2(b): C_v = 0.834 kJ/kgK, k = 1.344

therefore: k-1 = 0.344; $r_v^{(k-1)} = 2.1294$ and $r_v^{k} = 19.1647$

To determine Temperature at each state point:

Process 1-2 Isentropic Expansion of ideal gas:

Pv^k = const. and Tv^{k-1} = const. **therefore**

$$T_2\, v_2^{(k-1)} = T_1\, v_1^{(k-1)}$$

$$\mathbf{T_2} = T_1\, (v_1/ v_2)^{(k-1)} = T_1\, r_v^{(k-1)}$$

$$= (303K)(9.0)^{0.344} = \mathbf{645.2\ \ K}$$

Process 2-3 Constant Volume Heat Addition: *($+q_H$ = 1,000 kJ/kg)*

Apply 1st law for a closed system

$${}_2q_3 = {}_2w_3 + (u_3 - u_2) \qquad \text{where } {}_2w_3 = 0 \text{ because v = constant}$$

Therefore, $q_H = {}_2q_3 = u_3 - u_2 = C_v(T_3 - T_2)$

$$\mathbf{T_3} = T_2 + {}_2q_3/C_v$$

$$= (645.2)K + (1{,}000kJ/kg)/ (0.834kJ/kgK) = \mathbf{1{,}844.3\ K}$$

Process 3-4 Isentropic Expansion of ideal gas: Pv^k = const. and Tv^{k-1} = const.

$$\mathbf{T_4} = T_3/ r_v^{(k-1)} = (1{,}844.3\ K)/(9.0)^{0.344} = \mathbf{866.1\ K}$$

Process 4-1 Constant Volume Heat Rejection
Apply 1st law for a closed system

$_4q_1 = {}_1w_4 + (u_1 - u_4)$ where $_1w_4 = 0$ because v = constant

Therefore, $_4q_1 = C_v(T_1 - T_4) = (0.834\text{kJ/kgK})(303 - 866.1)\text{K} = -469.6$ kJ/kg

(c) The amount of heat rejected per cycle, $\mathbf{q_L} = |{}_4q_1| = \mathbf{469.6\ kJ/kg}$ **Answer**

(d) To determine the net work per cycle, apply 1st law for a cycle

$\mathbf{w_{net}} = \mathbf{q_{net}}$

The net work per cycle, $\mathbf{w_{net}} = \mathbf{q_H - q_L}$

$= (1{,}000 - 469.6)\text{kJ/kg} = \mathbf{530.4\ kJ/kg}$ **Answer**

(e) TheThermal Efficiency, $\boldsymbol{\eta_{th}} = \mathbf{w_{net}/q_H * 100\%}$

$= (530.4\text{ kJ/kg})/(1{,}000\text{kJ/kg})*100$

$= \mathbf{53.04\ \%}$ **Answer**

(f) Mean effective pressure, **MEP** $= W_{net}/(v_1 - v_2)$

State 1: ideal gas equation: $v_1 = RT_1/P_1 = (0.287\text{ kJ/kgK})(303\text{K})/(80\text{kPa})$

$= 1.08701\text{ m}^3/\text{kg}$

therefore, $v_2 = v_1/r_v = 0.12078\text{ m}^3/\text{kg}$

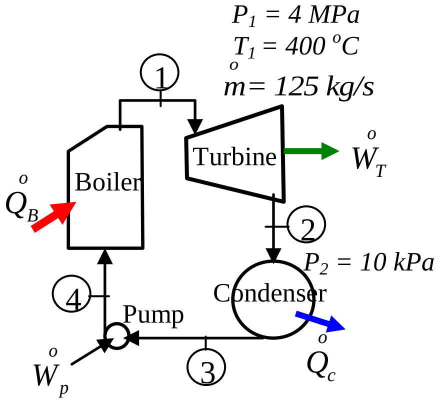
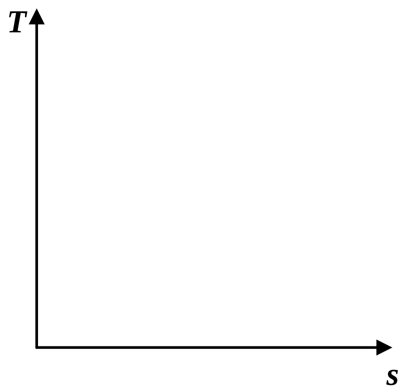
MEP $= (530.4\text{ kJ/kg})/(1.08701 - 0.12078)\text{ m}^3/\text{kg} = \mathbf{548.9\ kPa}$

The Mean Effective Pressure of the cycle, **MEP is 548.9 kPa** **Answer**

Sommai Priprem
13 September 2011

ชื่อ-สกุล...รหัส .... กลุ่ม.................ที่นั่งสอบ......... ....

4) Consider a steam power plant which operates on a simple **ideal Rankine cycle**, as the figure shown below. Steam enters the turbine at 4 MPa and 400°C with a mass flow rate of 125 kg/s. After that it is cooled in the condenser at a pressure of 10 kPa. ***In the given block, write the 4-processes and show the cycle on a T-s diagram with respect to saturation lines, state any assumption made, and determine*** ***(a)*** *the quality of the steam at the turbine exit,* ***(b)*** *the net power output of the power plant in* ***MW****,* ***(c)*** *the rate of heat input to the boiler in* ***MW****, and* ***(d)*** *the thermal efficiency of the cycle. (10 Marks)*

	Processes: 1-2 …………………..……. 2-3 ………………..………. 3-4 …………………..……. 4-1 …………………..…….	

Thermodynamics I 1st semester 2008 Final Examination

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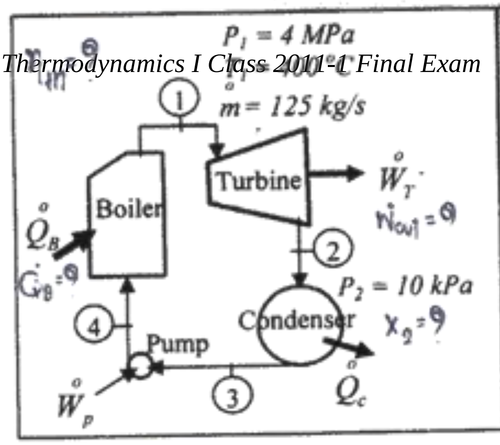
Examiner: *Assoc.Prof.Sommai Priprem, PhD.*



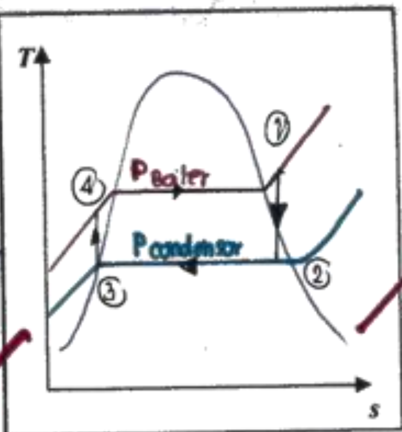
Processes:

1-2 Isentropic expansion

2-3 $-q_L$ P=constant

3-4 Isentropic compression

4-1 $+q_H$ P=constant



System: Ideal Rankine cycle.

a) the quality of the steam at the turbine exit.

Analysis proces ① → ② Isen. expan. $+w_T$

CV. Turbine ; 1st law ; Open System , SSSF

$\cancel{q} + h_1 = w_T + h_2$

$w_T = h_1 - h_2 \rightarrow$ ①

state ① [illegible] : Table A-5

Table A-5 @ $P_1 = 4$ MPa and $T_1 = 400$ C

$T_1 > T_{sat}$ => Super heat

Table A-6 @ $P_1 = 4$ MPa and $T_1 = 400$ °C หา h_1

$h_1 = h$ @ $P_1 = 4$ MPa = 3213.6 kJ/kg

$s_1 = s$ @ $P_1 = 4$ MPa = 6.7690 kJ/kg-k

state ② [illegible] @ $P_2 = 10$ kPa and $s_1 = s_2 = 6.7690$ kJ/kg·k

Table A-5 $s_f < s_2 < s_g$ => mixture

$h_2 = h_f + x_2 h_{fg} \rightarrow$ ②

หา x_2 จาก Table A-5

$s_2 = s_f + x_2 s_{fg}$

$x_2 = \dfrac{s_2 - s_f}{s_{fg}}$

h_f = 191.83 kJ/kg

h_{fg} = 2392.8 kJ/kg

s_f = 0.6493 kJ/kg·k

s_{fg} = 7.5009 kJ/kg·k

$x_2 = \dfrac{(6.7690 - 0.6493) \text{ kJ/kg·k}}{7.5009 \text{ kJ/kg·k}}$

x_2 = 0.816

Ans. the quality of the steam at turbine exit (x_2) = 0.816

b) the net power output of the power plant

Analysis จาก ② h_2 [illegible]

h_2 = 191.83 kJ/kg + (0.816)(2392.8 kJ/kg)

h_2 = 2144.355 kJ/kg

จาก ① w_T = (3213.6 − 2144.355) kJ/kg

w_T = 1069.245 kJ/kg

$\dot{W}_{out} = \dot{m}(w_T)$ = (125 kg/s)(1069.245 kJ/kg)

$\dot{W}_{out}$ = 133.66 MW

Ans. the net power output $(\dot{W}_{out})$ = 133.66 MW

c) the rate of heat input to the boiler

Analysis process ④ → ① $+q_H$ P=constant ; CV. Boiler

1st law ; $q_H + h_4 = \cancel{w} + h_1$

$q_B = h_1 - h_4 \rightarrow$ ③

process ③ → ④ Isentropic compression

CV. Pump ; 1st law ; Open System ; SSSF

$\cancel{q} + h_3 = w_p + h_4$

$w_p = h_3 - h_4 \rightarrow$ ④

state ③ Sat. liquid Table A-5

$h_3 = h_f$ @ P_3 = 10 kPa = 191.83 kJ/kg

$v_3 = v_f$ @ P_3 = 10 kPa = 0.00101 m³/kg

จาก ④ fluid => liquid $v_3 = v$ = constant

$w_p = v_3(P_3 - P_4)$

w_p = (0.00101 m³/kg)(10 − 4000) kPa

w_p = |−4.03 kJ/kg| = 4.03 kJ/kg

จาก ④ หา h_4

−4.03 kJ/kg = 191.83 kJ/kg − h_4

h_4 = 195.86 kJ/kg

จาก ③ q_B = (3213.6 − 195.86) kJ/kg = 3017.74 kJ/kg

$\dot{Q} = \dot{m} q_B$ = (125 kg/s)(3017.74 kJ/kg) = 377.22 MW

Ans. the rate of heat input to the Boiler $(\dot{Q}_B)$ = 377.22 MW

d) the thermal efficiency of cycle

Analysis : $\eta_{th} = \dfrac{w_{net}}{q_H} \times 100\% \rightarrow$ ⑤

$w_{net} = w_T - w_p$ = (1069.245 − 4.03) kJ/kg

w_{net} = 1065.215 kJ/kg

จาก ⑤ $\eta_{th} = \dfrac{1065.215 \text{ kJ/kg}}{3017.74 \text{ kJ/kg}} \times 100\%$

= 35.3%

Ans. the thermal efficiency (η_{th}) = 35.3%