ภาควิชาวิศวกรรมเครื่องกล

คณะวิศวกรรมศาสตร์ มหาวิทยาลัยขอนแก่น

ข้อสอบปลายภาค ประจำภาคต้น ปีการศึกษา 2553

วิชา 185 231 Thermodynamics I

วันที่ 29 กันยายน 2553 **เวลา 13.00 – 16.00 น.**

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

คำสั่ง

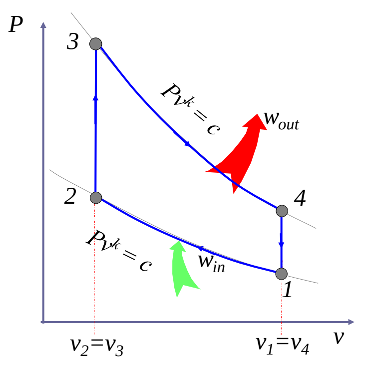
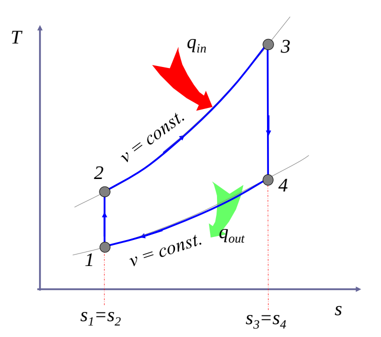
1. ให้เขียน ชื่อ-สกุล กลุ่ม และที่นั่งสอบ ลงในกระดาษข้อสอบทุกแผ่น
2. ข้อสอบทั้งหมดมี 5 ข้อ จำนวน 8 แผ่นรวมทั้งแผ่นนี้ ให้ทำทุกข้อ
3. มีตาราง Thermodynamics ให้
4. อนุญาตให้ใช้เครื่องคำนวณที่ไม่มีการบันทึกข้อมูลของรายวิชานี้ไว้
5. ห้ามนำเอกสารใดๆออกจากห้องสอบ
6. ให้ทำข้อสอบในแผ่นข้อสอบของข้อนั้นๆเท่านั้น (สามารถใช้ด้านหลังได้)

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

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

2. An air standard Otto engine 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 **900 K**,</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 $r_v^k = 19.1647$

Process 1-2 Isentropic Expansion Pv^k = const. and Tv^{k-1} = const.

$P_2 = P_1(r_v^k) = (80kPa)(9.0)^{\wedge 1.344} = 1{,}533.2$ kPa

$T_2 = T_1\, r_v^{(k-1)} = (303K)(9.0)^{\wedge 0.344} = 645.2$ K

Process 2-3 Constant Volume Heat Addition

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

$T_3 = T_2 + {}_2q_3/C_v = (645.2)K + (1{,}000 kJ/kg)/(0.834 kJ/kgK) = 1{,}844.3$ K

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

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

Process 4-1 Constant Volume Heat Rejection

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

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

(d) The net work per cycle, $\mathbf{w_{net}}$ = $q_H - q_L$ = (1,000 - 469.6)kJ/kg **= 530.4 kJ/kg Answer**

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

= (530.4 kJ/kg)/(1,000kJ/kg)*100 = **53.04 %** **Answer**

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

$v_1 = RT_1/P_1 = 1.08701\ m^3/kg$, therefore, $v_2 = v_1/r_v = 0.12078\ m^3/kg$

MEP = (530.4 kJ/kg)/(1.08701- 0.12078) m^3/kg = **548.9 kPa Answer**

Sommai Priprem
10 September 2010

3. An air standard Brayton cycle has a pressure ratio of 14. The air at the compressor inlet is at 27 ^{o}C and 100 kPa. The temperature at the turbine inlet is 1200 K. Calculates by using constant specific heats at 900 K, Determine

(a) Write the name of the 4 processes *(1 mark)*

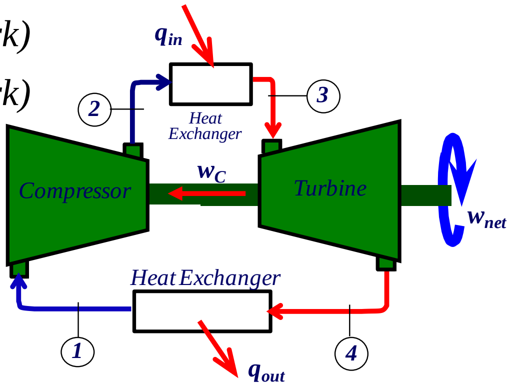
(b) draw the P-v and T-s diagram, *(1 mark)*

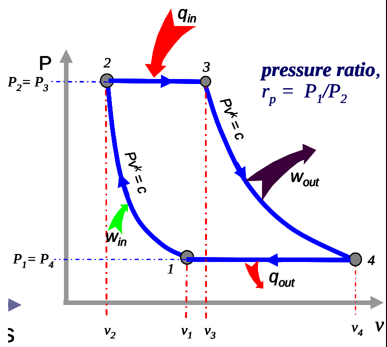
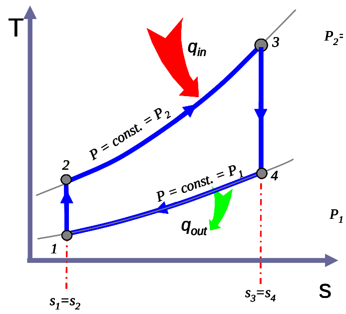
(c) the net work, *(4 mark)*

(d) the heat input, *(2 mark)*

(e) the cycle thermal efficiency. *(1 mark)*

การทำงานที่เป็นระบบ เรียบร้อยและสะอาด *(1 mark)*



Process	Process name	P-v diagram	T-s diagram
1-2	*Isentropic Compression*		
2-3	Constant pressure heat added		
3-4	Isentropic expansion		
4-1	Constant pressure heat rejection		

Solution

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

Given: P_1= 100 kPa, T_1= 27^{o}C, r_p= 14; T_3 = 1,200 K

Constants: Table A-1: R = 0.287 kJ/kgK; Table A-2(b): C_p = 1.121 kJ/kgK, k = 1.344

therefore: (k-1)/k = 0.2560; and $r_p^{(k-1)/k}$ = 1.9650

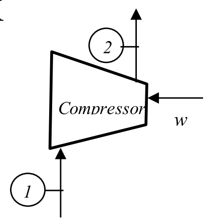
Process 1-2 Isentropic Compression $T/P^{(k-1)/k}$ = const *(determine T_2)*

$T_2 = T_1 * r_p^{(k-1)/k}$ = 300K * 1.9650 = 589.5 K

Process 3-4 Isentropic Expansion $T/P^{(k-1)/k}$ = const *(determine T_4)*

$T_4 = T_3 / r_p^{(k-1)/k}$ = 1200K / 1.9650 = 610.7 K

To determine wc: CV compressor :



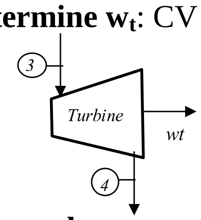
1st Law: Open System, SSSF, q = 0 → $q + h_1 = w + h_2$

$w = h_1 - h_2 = C_p(T_1 - T_2)$

= 1.005kJ/kgK(300-589.5)K = -324.5 kJ/kg

$\mathbf{w_c}$ = |w| = **324.5 kJ/kg**

To determine $\mathbf{w_t}$: CV Turbine : 1st Law: Open System, SSSF, q = 0→ $q + h_3 = w + h_4$



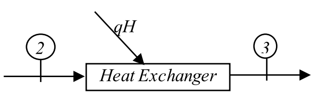
$w = h_3 - h_4 = Cp(T_3 - T_4)$

= 1.121kJ/kgK(1200-610.7)K = 660.6 kJ/kg

w_t = |w| = **660.6 kJ/kg**

(c) **Net work**, w_{net} = $w_t - w_c$ = (660.6 – 324.5)kJ/kg = **336.1 kJ/kg** **Answer**

(d) the heat input, $\mathbf{q_H}$: CV. HE +q : 1st Law: Open System, SSSF, w = 0→ $q + h_2 = w + h_3$



$q = h_3 - h_2 = C_p(T_3 - T_2)$

= 1.121kJ/kgK(1200-589.5)K = 684.4 kJ/kg

heat input, q_H = |q| = **684.4 kJ/kg** **Answer**

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

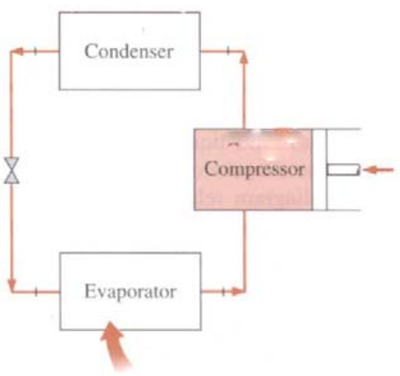
= (336.1 kJ/kg/684.4kJ/kg)*100 = **49.11 %** **Answer**

Sommai Priprem
14 September 2010

5. An ideal vapor compression refrigeration cycle that uses R-12 as its working fluid maintains a condenser at 1000 kPa and the evaporator at 4 ^{o}C.

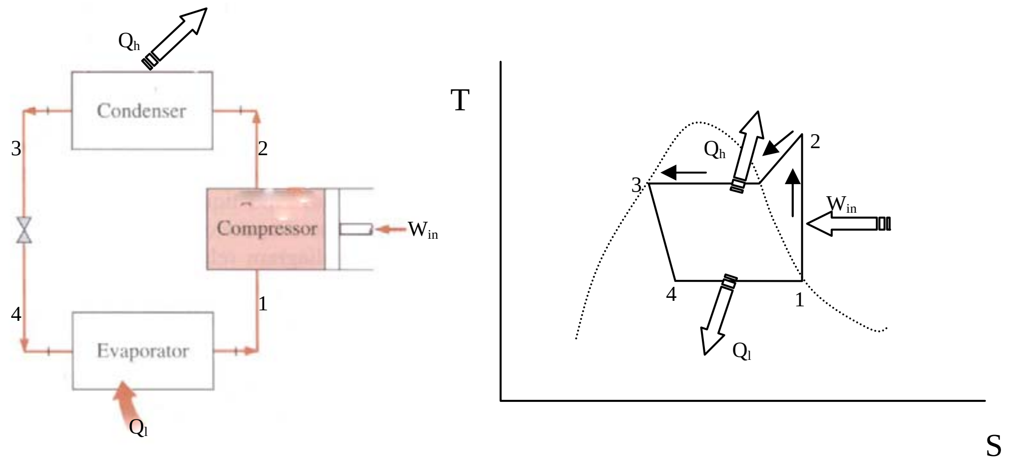
Determine:

a) Draw T-s diagram of this refrigeration cycle and label all parameters: Q, W, P, T and directions of refrigerant flow with respect to the saturation line.
b) The quality of the refrigerant at the evaporator inlet.
c) The cooling capacity.
d) The COP of this refrigerator.



Solution:

a) T-s diagram



$T_4 = T_1 = 4$ ºC
$P_4 = P_1 = ?$

$P_3 = P_4 = 1000$ kPa
$T_3 = T_4 = ?$

Step 1 – 2 is Isentropic : $s_3 = s_4$
Step 3 – 4 is Isenthalpic : $h_3 = h_4$

b) Quality of refrigerant

$$h_3 = h_{f\,@1000kPa} = 76.26 \qquad kJ/kg$$
$$Table \quad A-11$$
$$h_{fg\,@\,4°C} = 149.47 \qquad kJ/kg$$
$$h_{f\,@\,4°C} = 39.76 \qquad kJ/kg$$

$$Isenthalpic \qquad h_3 = h_4$$
$$T_4 = 4°C$$
$$h_4 = h_{f\,@\,4°C} + x(h_{fg\,@\,4°C})$$

$$x = \frac{h_4 - h_{f\,@\,4°C}}{h_{fg\,@\,4°C}}$$
$$x = \frac{76.23 - 39.76}{149.47} = 0.244$$

c) The cooling capacity

$$Q_L = h_1 - h_4$$

$$Table \quad A-11$$
$$h_1 = h_{g\,@\,4°C} = 189.23 \qquad kJ/kg$$

$$Q_L = h_1 - h_4 = 189.23 - 76.26$$
$$Q_L = 112.97 \qquad kJ/kg$$

d) The COP of this refrigerator.

$$COP_R = \frac{Q_L}{W_{in}}$$

$$W_{in} = h_2 - h_1$$

$$Isentropic\ \ compression : s_1 = s_2$$

$$s_1 = s_{g@4°C} = 0.6946 \qquad kJ/kg.K$$
$$Table \quad A-11$$

$$P_2 = 1000kPa$$
$$s_2 = 0.6946 \qquad kJ/kg.K$$
$$Table \quad A-13$$
$$T_2 = 50°C$$
$$h_2 = 210.32 \qquad kJ/kg$$

$$W_{in} = h_2 - h_1 = 210.32 - 189.23$$
$$W_{in} = 21.09 \qquad kJ/kg$$

$$COP_R = \frac{Q_L}{W_{in}} = \frac{112.97}{21.09}$$
$$COP_R = 5.36$$