ภาควิชาวิศวกรรมเครื่องกล

คณะวิศวกรรมศาสตร์ มหาวิทยาลัยขอนแก่น

ข้อสอบกลางภาค ประจำภาคต้น ปีการศึกษา 2553

วิชา 185 231 Thermodynamics I

วันที่ 6 สิงหาคม 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***	

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

1) Choose the correct answer and fill **X** into the answer sheet

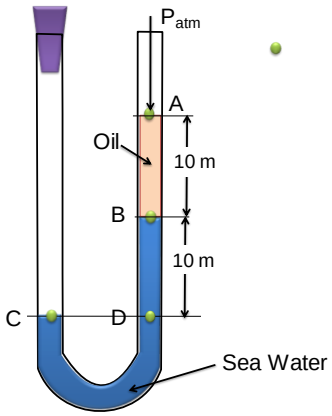
Answer sheet for problem 1

No.	a	b	c	d	e	f
1.1			**X**			
1.2				**X**		
1.3					**X**	
1.4			**X**			
1.5						**X**
1.6	**X**					
1.7						**X**
1.8		**X**				
1.9				**X**		
1.10			**X**			

1.10 ตอบ 2,755.3 kJ/kg ข้อ c เป็นคำตอบที่ใกล้เคียงที่สุด

1.1) Find the absolute pressure of point C.
Let P_{atm} = 1 bar, oil density 800 kg/m^3 and density of sea water = 1300 kg/m^3

a) 118 kPa
b) 206 kPa
c) 306 kPa
d) 418 kPa
e) 518 kPa
f) 506 kPa



1.2) Water at 2 MPa (absolute) and 80 ˚C, the density of the water is

a) 0.001 kg/m^3
b) 0.002 kg/m^3
c) 877.3 kg/m^3
d) 971.8 kg/m^3
e) 786.7 kg/m^3
f) 455.5 kg/m^3

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

1.3) Saturated liquid water 5 kg 200 kPa gage pressure is heated to be saturated steam at constant pressure process. If the atmospheric pressureis 0.1 MPa, the amount of heat transfer to the water is

a) 200.2 kJ/kg
b) 400 kJ/kg
c) 216.38 kJ
d) 5.00 kJ
e) 10.819 MJ
f) 2163.8 kJ

1.4) Saturated liquid-vapor mixture of 5 kg water at P = 0.2 MPa (absolute) with quality x = 1.0 is condensed until the quality becomes x = 0.4. The amount of condensate (liquid) change is

a) 1.0 kg
b) 2.0 kg
c) 3.0 kg
d) 4.0 kg
e) 5.0 kg
f) 0.5 kg

1.5) Air at P_1 = 1 MPa absolute and 200 ˚C is contained in a closed airtight rigid chamber. The whole system is cooled till the temperature drops to 40 ˚C. The final air pressure in the chamber is

a) 1.23 kPa
b) 22.6 kPa
c) 123.8 kPa
d) 287.0 kPa
e) 466.7 kPa
f) 661.7 kPa

1.6) For gas A, the value of gas constant is 300 J/kg ·K while the C_V is 800 J/kg ·K. If the gas receives heat that make the temperature increases by 40 ˚C. Find the change of the specific enthalpy of the gas.

a) 44.0 kJ/kg
b) 33.0 kJ/kg
c) 22.0 kJ/kg
d) 11.0 kJ/kg
e) 5.0 kJ/kg
f) 2.52 kJ/kg

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

1.7) The refrigerant-12 at the temperature of 4˚C and x = 0.3 enters evaporator and leaves with the pressure at 0.32 MPa and 30 ˚C. The change of specific enthalpy is

a) 149.47 kJ/kg
b) 39.76 kJ/kg
c) 189.23 kJ/kg
d) 77.81 kJ/kg
e) 67.78 kJ/kg
f) No correct answer

1.8) To estimate the property (y) of compressed liquid at given pressure and temperature. We estimate the property by using

a) $y = y_{g@T}$
b) $y = y_{f@T}$
c) $y = y_{f@P}$
d) $y = y_{g@P}$
e) $y = y_{fg@T}$
f) $y = y_{fg@P}$

1.9) We can assume that the pressure of the air is uniform in the storage tank because

a) the air is clear in color
b) air density is very high
c) air density is high
d) air density is light
e) the earth is large
f) the tank is closed

1.10) Superheated steam at 0.2 MPa absolute and 270 ˚C, the value of specific internal energy is

a) 2971.00 kJ/kg
b) 3071.80 kJ/kg
c) 2731.20 kJ/kg
d) 2808.60 kJ/kg
e) 2200.78 kJ/kg
f) 3011.32 kJ/kg

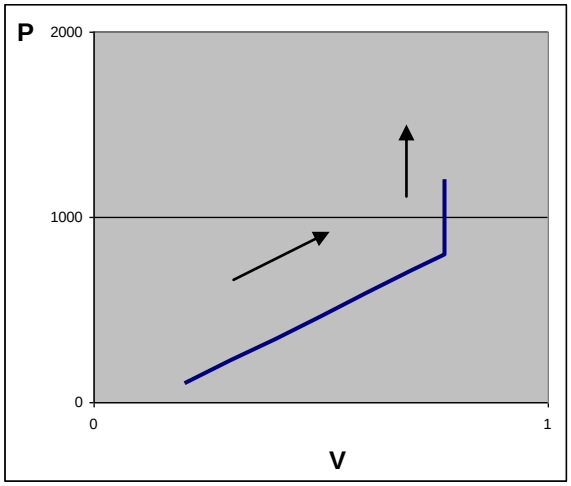
ชื่อ-สกุล.....รหัส ..... กลุ่ม.....ที่นั่งสอบ..... .....

---

2. An ideal gas is heated in a piston-cylinder device. During the process, the pressure changes from 100 kPa to 800 kPa according to the relation $\boldsymbol{P = aV+b}$, where a = 1,220 kPa/m^3 and b is a constant. The final volume of the gas is 0.7738 m^3. Then the gas is heated further but this time the volume is kept constant to the final pressure of 1,200 kPa.

a) Draw a P-V diagram shows the process occurred.
b) Calculate the work done by the system in kJ *using integration method.*

Solution:



a) P-V diagram

b) Work done

$$P = aV + b$$
$$P_2 = aV_2 + b$$
$$800 = (1220 \times 0.7738) + b$$
$$b = 800 - (1220 \times 0.7738) = -144$$

$$V_1 = \frac{P_1 - b}{a} = \frac{100 - (-144)}{1220} = 0.2m^2$$

$$W = \int_{V1}^{V2} (aV + b)dV$$

$$W = \frac{a}{2}V^2 + bV \Big|_{V1}^{V2}$$

$$W = \frac{a}{2}(V_2^2 - V_1^2) + b(V_2 - V_1)$$

$$W = \left(\frac{1220}{2}(0.7738^2 - 0.2^2) - 144 \times (0.7738 - 0.2) \right)$$

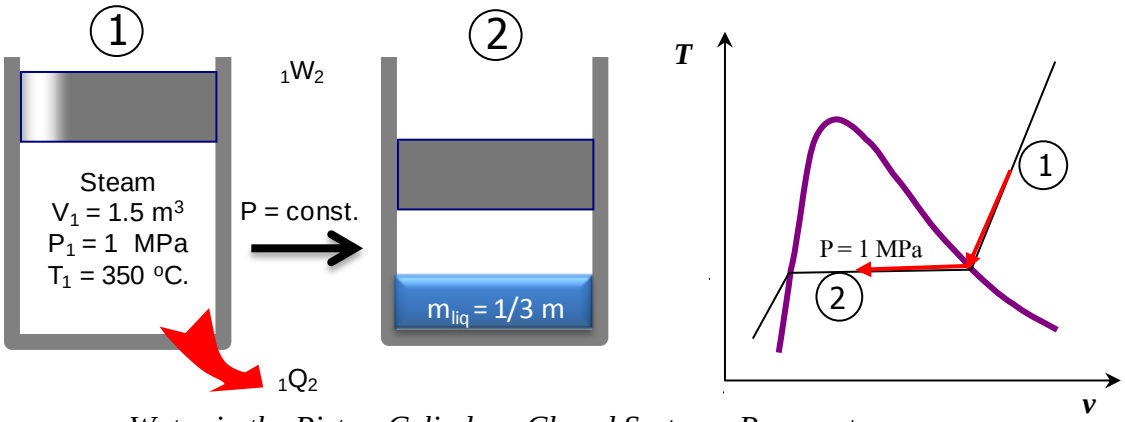
$$W = 258.22kJ$$

ชื่อ-สกุล..... *Sommai Priprem*.....รหัส ..... กลุ่ม.....ที่นั่งสอบ..... .....

3. A piston-cylinder device contains steam initially at 1 MPa, 350°C, and 1.5 m3. Steam is allowed to cool at constant pressure until one-third of the mass of the steam condensed. Show the process on a T-v diagram with respect to saturation lines *(1 mark)* and determine,

(a) the mass of the steam *(1 marks)*
(b) the quality (*x*) at the final state, *(1 mark)*
(c) the amount of work during the process, *(3 marks)*
(d) the amount of heat transfer. *(3 marks)*

(การทำงานอย่างเป็นลำดับขั้นตอนที่ดี การเขียนอย่างเรียบร้อยดูง่ายและสะอาด 1 คะแนน)



System *Water in the Piston-Cylinder: Closed System: P= const*
Assumption *Neglect change in KE, PE*
Analysis $m = V_1/v_1$
$-{}_1Q_2$ *until ½ m condensed* → *mixture:* $x_2 = m_{vap}/m$
$_1W_2 = mP_1(v_2 - v_1)$
$_1Q_2 = U_2-U_1 + {}_1W_2$

Solution

(a) Find mass of the steam:

State 1 $P_1 = 1$ *MPa,* $T_1 = 350\ ^oC$, Table A-5 $T_1 > T_{sat}$ --> *Superheated vapor*
Table A-6 $v_1 = 0.2825\ m^3/kg$; $u_1 = 2{,}875.2\ kJ/kg$
$V_1 = 1.5\ m^3$
$m = V_1/v_1 = (1.5\ m^3)/(0.2825 m^3/kg)$
the mass of steam is 5.31 kg ***Answer***

(b) Find the steam quality

State 2 $P_2 = P_1 = 1$ *MPa and 1/3m condensed --> mass* $m_{vap} = 1/3m$
therefore; quality, x $= m_{vap}/m = 2/3 = 0.6667$ ***Answer***

(c) Find Work : Boundary work: Process *P =c ;* $_1W_2 = mP_1(v_2 - v_1)$
Table A-5 $v_f = 0.001127\ m^3/kg$; $v_g = 0.19444\ m^3/kg$
$v_2 = v_f + xv_{fg} = (0.001127 + 0.6667 \times 0.19444) = 0.1300\ m^3/kg$
$_1W_2 = (5.31kg)(1000\ kPa)(0.1300 - 0.2825)\ m^3/kg = -809.7\ kJ$
The work done on the system during the process is **809.7 kJ** ***Answer***

(d) Find Heat

1st Law: $_1Q_2 = m(u_2-u_1) + {}_1W_2$
Table A-5 at 1 MPa $u_f = 761.68\ kJ/kg$; $u_{fg} = 1{,}822.0\ kJ/kg$
$u_2 = u_f + xu_{fg} = (761.88 + 0.6667 \times 1{,}822.0) = 1{,}976.3\ kJ/kg$
$m(u_2-u_1) = (5.31kg)(1{,}976.3 - 2{,}875.2)\ kJ/kg = -4{,}772.7\ kJ$
then, $_1Q_2 = (-4{,}772.7\ kJ) + (-809.7\ kJ) = -5{,}582.4\ kJ$
The amount of heat transfer out of the steam is **5,582.4 kJ** **Answer** *Sommai Priprem*

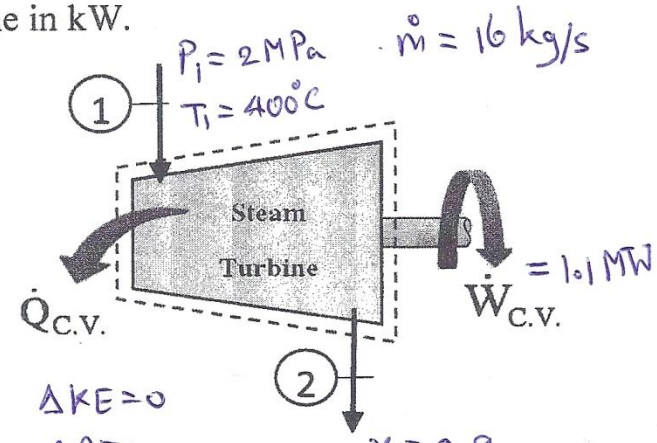
Thermodynamics I Class 2010-1 Midterm Exam 7

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

---

4. A steam turbine operates with 2 MPa absolute pressure and 400 °C at the inlet. The steam exits the turbine at 40 °C and x = 0.9. The mass flow rate of the steam is 16 kg/s. The turbine produces mechanical power by 1.1 MW. Neglect the kinetic and potential energies,

a) write the energy balance equation of this turbine process,
b) determine the total enthalpy change in kW,
c) calculate the rate of heat loss from the turbine in kW.



Solution.

Assumption. S-S-S-F.

state ① ; superheated steam.

$h_1 = 3247.6$ kJ/kg ✓

state ② ; sat. mixture. (40°C)

$h_f = 167.57$ kJ/kg ; $h_{fg} = 2406.7$ kJ/kg.

$\therefore h_2 = h_f + x\, h_{fg} = 167.57 + (0.9)(2406.7)$

$= 2333.6$ kJ/kg

a) Energy Balance

$$\dot{Q} - \dot{W} = \Delta H + \cancel{\Delta KE}^{\,0} + \cancel{\Delta PE}^{\,0} \quad -① \checkmark$$

2 Marks.

b) $\Delta H = \dot{m}(h_2 - h_1) = 16(2333.6 - 3247.6)$ kg/s · kJ/kg

$= -14,624$ kW ✓

4 Marks

e) From Energy Balance ;

$\dot{Q} - (+1100) = -14624$

$\dot{Q} = -13524$ kW ✓ 4 Marks.

ชื่อ-สกุล..... *Sommai Priprem*.....รหัส ..... กลุ่ม.....ที่นั่งสอบ..... .....

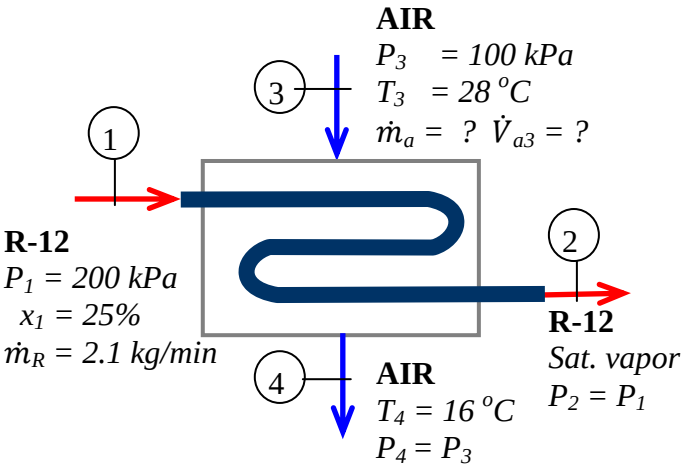
---

5. Refrigerant-12 enters the evaporator of an air conditioner at 200 kPa with a quality of 25% at a rate of 2.1 kg/min and leaves as saturated vapor at the same pressure. Air enters at 100 kPa and 28°C. It is required that the air leaves the evaporator at 16°C at 100 kPa. Assume air as an ideal gas and use constant specific heat at 300 K in the calculation. State any assumption made*(1 marks)*. Determine

(a) the mass flow rate of the air (in kg/min) and, *(6 marks)*

(b) the volume flow rate of the air at inlet (in m^3/min). *(3 marks)*

(การทำงานอย่างเป็นลำดับขั้นตอนที่ดี การเขียนอย่างเรียบร้อยดูง่ายและสะอาด เป็นองค์ประกอบในการพิจารณาให้คะแนนด้วย)



System: CV The evaporator : R-12 and Air
Assumption: SSSF process;
$Q_{cv} = 0$; $W_{cv} = 0$
and neglect ΔKE and ΔPE
Solution:
1st Law:

$$\dot{Q}_{cv} + \sum \dot{m}_i h_i = \dot{W}_{cv} + \sum \dot{m}_e h_e$$

$$[\dot{m}_1 h_1 + \dot{m}_3 h_3] = [\dot{m}_2 h_2 + \dot{m}_4 h_4]$$

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_r; \quad \dot{m}_3 = \dot{m}_4 = \dot{m}_a$$

$$\dot{m}_a (h_3 - h_4) = \dot{m}_r (h_2 - h_1)$$

$$\dot{m}_a C_{pa} (T_3 - T_4) = \dot{m}_r (h_2 - h_1)$$

$$\dot{m}_a = \frac{\dot{m}_r (h_2 - h_1)}{C_{pa} (T_3 - T_4)} \quad (1)$$

$$\dot{V}_3 = \dot{m}_a v_3; \quad v_3 = \frac{R_a T_3}{P_3} \quad (2)$$

R-12-side data and calculations			
State 1 mixture			
P_1	=	200	kPa
x_1	=	25%	
m_r	=	2.1	kg/min
From **Table A-12** at 200 kPa			
h_f	=	24.57	kJ/kg
h_{fg}	=	157.5	kJ/kg
h_1	=	63.945	kJ/kg
State 2 Saturated vapor: Tablre A-12			
P_2	=	140	kPa
$h_2 = h_g$	=	182.07	kJ/kg
$m_r(h_2-h_1)$	=	**248.06**	**kJ/min**

Air-side data and calculations			
State 3 and 4 Ideal gas			
P_3	=	100	kPa
T_3	=	28	C
T_4	=	16	C
From table A-2 at 300K			
C_p	=	1.005	kJ/kgK
$C_p(T_3-T_4)$	=	**12.06**	**kJ/kg**
Substitute in equation (1) and (2)			
m_a	=	**20.57**	**kg/min** *Answer*
R	=	0.287	kJ/kgK
v_3=RT/P	=	0.86387	m^3/kg
V_{dot} = mv	=	**17.77**	**m^3/min** *Answer*

Sommai Priprem