ชื่อ-สกุล..............................................................รหัส ............................. เลขที่ ............

1. A gas is compressed from the initial volume of 0.42 m3 to the final volume of 0.12 m3. During the quasi-equilibrium, the pressure change with the volume according to the relation P = aV + b, where V is in m3, a = -1200 kPa/m3 and b = 600 kPa.
   1. Sketch the graph of P-V diagram
   2. What is the meaning of area under the P-V relation?
   3. Using integrating method, calculate the amount of work during this compression process.

**2 Mark**

*V*

*P*

*P1*

*V2*

*V1*

*2*

*1*

*P2*

P = a+bV

Gas

V1 = 0.42 m3

2

a = -1200 kPa/m3

b= 600 kPa

1

V2 = 0.12 m3

**2 Mark**

**System**: gas, Closed system

**1 Mark**

**Assumption**: Ideal Gas, neglect ΔKE, ΔPE

**Solution**

(b) Boundary work: *W = ∫PdV*

**1 Mark**

Therefore, Area under P-V diagram represent 1W2 answer

(c)*1W2 = ∫PdV = ∫(aV+b)dV*

= *a/2[V22-V12] + b[V2-V1]*

*a/2[V22-V12]* = (-1200 kPa/m3)/2 x [0.122 – 0.422] = 97.2 kJ

*b[V2-V1]* = (600 kPa)( 0.12 – 0.42) = - 180 kJ

*1W2* = 97.2 kJ – 180 kJ = -82.8 kJ

**3 Mark**

The work done on the system is 82.8 kJ Answer

**1 Mark**

ชื่อ-สกุล..............................................................รหัส ............................. เลขที่ ............

**2)** Air of amount 2 kg in a rigid container 1.5 m3 receives heat rate at the amount of 0.5 kW for the period of 30 minutes. The gas constant R = 0.2870 kJ/kg•K and the CP = 1.005 kJ/kg•K which are constant. The heating process starts with the temperature of the air at T1 = 27 ˚C. Determine

a) The final temperature (in the unit of ˚C).

b) The value of final pressure (in the form of gage pressure, Pa) if Patm = 1 bar.

*m = 2 kg*

*V = 1.5 m3*

*T1 =27 oC*

*T2 =?*

*P2g = ?*

Qdot = 0.5 kW

Time = 30 min

**2**

**1**

**1 Mark**

**System:** Air, Closed system, Constant volume

**1 Mark**

**Assumption:** Ideal gas

**Analysis:**

**1st Law:**  1Q2 = 1W2 + m(u2-u1), 1W2 = 0

1Q2 = mCv(T2-T1)

Relation: Cp - Cv = R

**2 Mark**

T2 = T1 + 1Q2/mCv (1)

**Heat added,** 1Q2 = Qdot x t (2)

**State 2:** P2V = mRT2 (3)

**2 Mark**

P2g = P2 – Patm (4)

**Solution:**

1Q2 = Qdot x t = (0.5 kW)( 30 mim)(60 s/min)

= 900 kJ

Cv = Cp – R = (1.005 – 0.287)kJ/kgK = 0.718 kJ/kgK

eqn (1),

1Q2/mCv = (900 kJ)/(2kg x 0.718 kJ/kgK) = 626.7 K

T2 = T1 + 1Q2/mCp = (27 oC +273) + 626.7 K = 926.7 K

= 653.7 oC Answer

**2 Mark**

P2= mRT2 / V = (2kg x 0.287 kJ/kgK x 926.7 K) / (1.5 m3)

= 354.7 kPa

= 3.547 Bar

P2g = P2 – Patm = (3.547 – 1.0) Bar = 2.547 Bar

= 254.7 kPa Answer

**2 Mark**

ชื่อ-สกุล..............................................................รหัส ............................. เลขที่ ............

**3.** A piston-cylinder device contains steam initially at 1 MPa, 350oC, 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)*



**1 Mark**

***System*** *Water in the Piston-Cylinder: Closed System: P= const*

***Assumption*** *Neglect change in KE, PE*

***Analysis*** *m = V1/v1*

*-1Q2 until ½ m condensed 🡪 mixture: x2 = mvap/m*

1W2 = *mP1(v2 - v1)*

*1Q2 =U2-U1 +1W2*

**Solution**

**(a) Find mass of the steam:**

State 1 *P1 = 1 MPa, T1 = 350 oC,* Table A-5 *T1 > Tsat --> Superheated vapor*

Table A-6 *v1 =* 0.2825 m3/kg; *u1 =* 2,875.2 kJ/kg

*V1 =* 1.5 m3

*m = V1/v1 =* (1.5 m3)/(0.2825m3/kg)

**1 Mark**

***the mass of steam is 5.31 kg Answer***

**(b) Find the steam quality**

State 2 *P2 = P1 = 1 MPa and 1/3m condensed --> mvap= 1/3m*

**1 Mark**

therefore; quality, x = mvap/m = 2/3 = 0.6667 ***Answer***

**(c) Find Work** : Boundary work: Process *P =c ; 1W2 =* *mP1(v2 - v1)*

Table A-5 *vf*  = 0.001127 m3/kg; *vg* = 0.19444 m3/kg

*v2 = vf + xvfg* = (0.001127 + 0.6667x 0.19444) = 0.1300m3/kg

*1W2*  = (5.31kg)(1000 kPa)(0.1300 - 0.2825) m3/kg *=* -809.7 kJ

**3 Mark**

The work done on the system during the process is **809.7 kJ** ***Answer***

**(d) Find Heat**

1st Law:  *1Q2 = m(u2-u1) +1W2*

Table A-5 at 1 MPa *uf =* 761.68 kJ/kg; *ufg =* 1,822.0 kJ/kg

*u2 = uf  + xufg*  = (761.88 + 0.6667 x 1,822.0) = 1,976.3 kJ/kg

*m(u2-u1) =* (5.31kg)(1,976.3 - 2,875.2) kJ/kg *=* -4,772.7 kJ

then, *1Q2 =* (-4,772.7 kJ) + (-809.7 kJ) *=* -5,582.4 kJ

**3 Mark**

The amount of heat transfer out of the steam is **5,582.4 kJ Answer**

Sommai *Priprem*

**1 Mark**

ชื่อ-สกุล..............................................................รหัส ............................. เลขที่ ............

**4.** Steam flows steadily through a turbine. The inlet conditions of the steam are 15 MPa, 650°C, and 200 m/s, and the exit conditions are 10 kPa, 90 percent quality, and 50 m/s. The mass flow rate of the steam is 150 kg/s. Heat loss from the turbine is 15 kJ/kg steam. State any assumptions made. Show the process on a T-v diagram with respect to saturation line and determine

*(a)* the change in kinetic energy,

*(b)* the power output of the turbine.

*Wcv*

***Turbine***

*1*

*2*

*P1 = 15 MPa*

*T1 = 650 C*

*V1 = 200 m/s*

*m = 150 kg/s*

*P2 = 10 kPa*

*x2 = 90%*

*V2 = 50 m/s*

*ΔKE = ?*

*Wcv = ?*

*q = 15 kJ/kg*

***Solution***

***Assumption****: SSSF process, ΔPE = 0*

***Analysis****:*

**1 Mark**

*ΔKE = m(ke2-ke1) (1)*

*1st law: q + h1 + ke1 = w + h2 + ke2*

*w = q + (h1-h2) - (ke1-he2) (2)*

**1 Mark**

*W = mw (3)*

*Property:*

*State 1: P1 = 15 MPa, T1 = 650 C*

*T > Tsat --> superheat*

*Table A-6, v1 = 0.0268 m3/kg*

**1 Mark**

*h1 = 3,712.30 kJ/kg*

**2 Mark**

*State 2: P2 = 10 kPa, x2 = 90 % --> mixture*

*P1*

*T*

***1***

***2***

*P2*

*v*

*v1*

*v2*

*Table A-5 vf = 0.001452 m3/kg,*

*vg = 0.018026 m3/kg*

*v2 = vf + x vfg =* ***0.0163686 m3/kg***

*hf = 191.83 kJ/kg, hfg = 2392.8 kJ/kg*

**1 Mark**

*h2 = hf + xhfg =* ***2,345.35 kJ/kg***

***T-v diagram:*** *State 1 🡪 superheated vapor at P1*

*State 2 🡪 Mixture at P2 and v2 < v1*

*(a) ΔKE = m(ke2-ke1)*

*(ke2-ke1) = 1/2{(50m/s)^2 - (200m/s)^2)}/1000 = -18.75* ***kJ/kg***

*m = 150 kg/s*

**1 Mark**

*ΔKE = m(ke2-ke1) = (12 kg/s)(-1.95 kJ/kg) = -2,812.50 kW*

***Change in kinetic energy (decreased)*** *=* ***2,812.5 kW*** *Answer*

*(b) from eqn 2**w = q + (h1-h2) - (ke1-he2)*

*q = -15 kJ/kg*

*(h1- h2) = 3712.3 kJ/kg - 2345.35 kJ/kg*

*= 1367.0 kJ/kg*

*ke1-ke2 = 18.75 kJ/kg*

*w = (-15kJ/kg)+(1,367.0kJ/kg)-(-18.75kJ/kg)*

*= 1,370,7 kJ/kg*

*W = mw = (150 kg/s)( 1,370,7kJ/kg)*

*=*  ***205,605 kW***

**2 Mark**

***Power output from the turbine is******205.6 MW***  *Answer*

*Sommai Priprem, July 2012*

**1 Mark**