FACULTY OF MECHANICAL ENGINEERING
UNIVERSITI TEKNOLOGI MALAYSIA

TEST 2

THERMODYNAMICS SKMM 2413
Session 2015/2016-1

2nd December 2015 (Wednesday)
1 hour and 45 minutes
Answer All Three (3) Questions

QUESTION 1

(a) Answer the following questions:

i. A fixed mass of an ideal gas is heated from 50 to 80°C at a constant pressure of (*i*) 1 bar and (*ii*) 3 bar. For which case of pressure do you think the energy required will be greater? Explain why?

ii. A fixed mass of an ideal gas is heated from 50 to 80°C at a constant volume of (*i*) 1 m^3 and (*ii*) 3 m^3. For which case of volume do you think the energy required will be greater? Explain why?

(4 marks)

(b) Air is contained in a cylinder device fitted with a piston cylinder (Figure 1). The piston initially rests on a set of stops. Initial condition of the air is at 100 kPa and 27°C and occupies a volume of 0.4 m^3. The air is now heated at constant volume to temperature T_2 and pressure of 300 kPa where this pressure is required to move the piston. Then, the heat is transferred to the air at constant pressure to a final temperature of 1200K. Assume air as an ideal gas, R = 0.287 kJ/kg.K and c_v = 0.718 kJ/kg.K. The changes in kinetic energy and potential energy are negligible.

i. sketch both processes on a single *P*-*v* diagram showing the direction of the processes and label the end states as 1, 2 and 3.
ii. calculate the temperature T_2 [K]
iii. determine the mass of the air [kg]
iv. calculate the boundary work done during final process[kJ]
v. determine the amount of heat transferred to the air while the temperature increased to 1200 K[kJ]

(16 marks)

Figure 1

QUESTION 2

a) i) Explain why when the fluid flow through a turbine is considered as steady flow?

ii) What is the difference between a throttling valve and a turbine?

(4 marks)

b) Steam with a mass flow rate of 0.25 kg/s enters an adiabatic throttling valve steadily at 1.4 MPa, 250 ^{o}C and leaves at 1.2 MPa. The steam is then flows steadily into an adiabatic turbine and then exhaust at 10 kPa. If the turbine produces 110 kW power and the potential and kinetic energy of the steam are negligible for both processes, determine:

i) the enthalpy at the inlet and outlet of throttling valve and the enthalpy at the outlet of turbine (kJ/kg),
ii) the temperature at the turbine outlet (^{o}C) and the quality of the steam (if saturated).
iii) in the case of the turbine has a heat loss of 150 kW, calculate the temperature of the steam at the turbine outlet (^{o}C) and the quality of the steam (if saturated).

(16 marks)

QUESTION 3

a) Write the four (4) processes involved to construct a heat engine based on Carnot cycle.

(4 marks)

b) A heat engine received 6000 kW of heat from a high temperature reservoir at 750^{o}C and convert part of the heat as work output. The balance of this heat supplied is being rejected to a low temperature reservoir at 30^{o}C. 35 kW of the work output is used to drive an electric generator and 5 kW to drive a refrigerator. The refrigerator absorbed 1560 kJ/min of heat from a cold space at -5^{o}C and then rejects it at a surrounding of 30^{o}C. Sketch the schematic diagram for the above system.

Determine

i) the thermal efficiency of the heat engine (%),
ii) the coefficient of performance of the refrigerator,
iii) the total heat rejected to the 30^{o}C heat reservoir (kJ/min),
iv) the maximum thermal efficiency of the heat engine (%), and
v) the minimum work input to the refrigerator if the same amount of heat absorbed from the cold space (kW).

(16 marks)

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

No. Kad Pengenalan/No. ISID:........
I.C. No./ISID No.

No. Soalan........
Question No.

Muka surat........
Page

Jangan tulis apa-apa di ruangan ini
Do not write anything in this column

Q1 a) $T_1 = 50^\circ C$, $T_2 = 80^\circ C$

$P = C$, $P_1 = P_2 = 100\ kPa$

$P_1 = P_2 = 300\ kPa$

$Q_{12} = (h_2 - h_1) = C_p(T_2 - T_1)$

Regardless what is the P, Q_{12} is still the same. — 2

b) $T_1 = 50^\circ C$, $T_2 = 80^\circ C$

$V = C$, $V_1 = V_2$

$V_1 = V_2 = 1m^3$

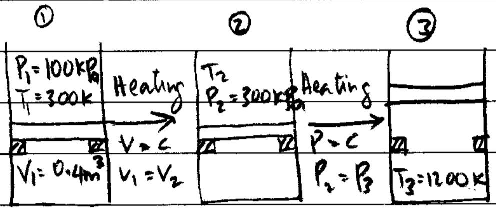
$V_1 = V_2 = 3m^3$

$Q_{12} = C_v(T_2 - T_1) + \cancel{W_{12}}^{0}$

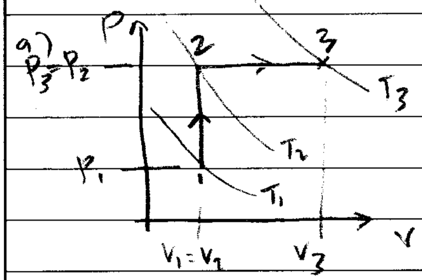
$Q_{12} = f(T_1 \,\&\, T_2)$

Regardless what is the V, Q_{12} is still the same. — 2

Q2



a)



— 2

b) $\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$, $T_2 = T_1 \frac{P_2}{P_1}$ — 1

$T_2 = \frac{300 \times 300}{100} = 900K$ — 1 (2)

c) $m = \frac{P_1 V_1}{R T_1}$ — 1

$= \frac{100 \times 0.4}{0.287 \times 300} = 0.4645\ kg$ — 1 (2)

d) $W_{23} = P_2(V_3 - V_2)$ — 1

$V_3 = \frac{mRT_3}{P_3}$ — 1

$= \frac{0.4645 \times 0.287 \times 1200}{300}$

$= 0.5332\ m^3$ — 1

$W_{23} = 300(0.5332 - 0.4)$

$= 39.96\ kJ$ — 1 (4)

e) $\Sigma Q = Q_{12} + Q_{23}$ — 1

$Q_{12} = mC_v(T_2 - T_1) + \cancel{W_{12}}^{0}$ — 1

$= 0.4645 \times 0.718(900 - 300)$

$= 200.11\ kJ$ — 1

$Q_{23} = mC_p(T_3 - T_2)$ — 1

$C_p = C_v + R$

$= 0.718 + 0.287$

$= 1.005\ kJ/kg\ K$

$Q_{23} = 0.4645 \times 1.005(1200 - 900)$

$= 140.05\ kJ$ — 1

OR

$Q_{23} = mC_v(T_3 - T_2) + W_{23}$

$= 0.4645 \times 0.718(1200 - 900) + 39.96$

$= 140.01\ kJ$

$\Sigma Q = 200.11 + 140.05$

$= 340.16\ kJ$. — 1 (6)

Q1		Q2		
4	+	16	=	20
4		16		20

No. Kad Pengenalan/No. ISID: ....
I.C. No./ISID No.

No. Soalan .... Muka surat ....
Question No. *Page*

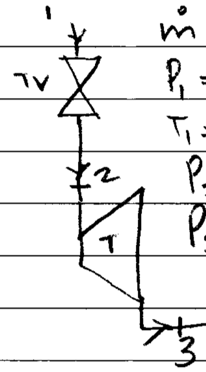
Jangan tulis apa-apa di ruangan ini
Do not write anything in this column

a) i) when $T_{min} = T_{max}$ — 2

ii) - Throttle valve no work — 2

- Turbine produced work — 2

(6)

b) 

$\dot{m} = 0.25\,kg/s$

$P_1 = 1.4\,MPa$

$T_1 = 250°C$

$P_2 = 1.2\,MPa$

$P_3 = 10\,kPa$

$Q_{12} = Q_{23} = 0$

$\dot{W}_{23} = 110\,kW$

$\Delta KE = \Delta PE = 0$

i) At 1400 MPa, $T_s = 195.04\,°C$ — 1

$T_1 > T_{sat}$ ∴ s.h.v — 1

$h_1 = 2927.9\,kJ/kg$ — 1

$h_2 = h_1 = 2927.9\,kJ/kg$ — 1

SFEE 2-3:

$h_2 = h_3 + w_{23}$

$h_3 = h_2 - w_{23}$ — 1

$= h_2 - \frac{\dot{W}_{23}}{\dot{m}}$

$= 2927.9 - \frac{110}{0.25}$

$h_3 = 2487.9\,kJ/kg$ — 1 (6)

ii) At 10 kPa, $h_{f_3} < h_3 < h_{g_3}$

∴ sat. mixture — 1

$T_3 = T_{sat}$ @ 10 kPa — 1

$= 45.81\,°C$ — 1

$x_3 = \frac{h_3 - h_{f3}}{h_{fg_3}}$ — 1

$x_3 = \frac{2487.9 - 191.81}{2392.1}$

$= 0.9599$ — 1 (5)

iii) SFEE: 2-3

$\dot{Q}_{23} = 150\,kW$

$h_2 = h_3 + w_{23} + Q_{23}$

$h_3 = h_2 - \frac{\dot{W}_{23}}{\dot{m}} - \frac{\dot{Q}_{23}}{\dot{m}}$ — 1

$= 2927.9 - \frac{110}{0.25} - \frac{150}{0.25}$

$h_3 = 1887.9\,kJ/kg$ — 1

At 10 kPa, $h_{f_3} < h_3 < h_{g_3}$ — 1

∴ sat. mixture — 1

$T_3 = T_{sat}$ @ 10 kPa — 1

$= 45.81\,°C$ — 1 [6]

$x_3 = \frac{h_3 - h_{f3}}{h_{fg_3}}$ — 1

$= \frac{1887.9 - 191.81}{2392.1}$

$= 0.7090$ — 1 [2]

(8)

(25/25)

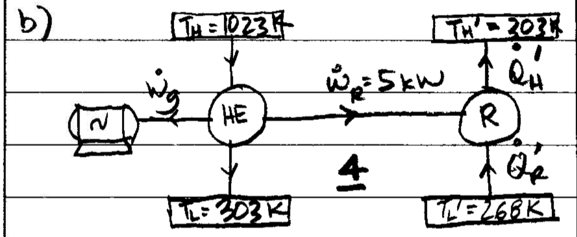
No. Kad Pengenalan/No. ISID: ....
I.C. No./ISID No

No. Soalan ... Q3
Question No.

Muka surat ....
Page

Jangan tulis apa-apa di ruangan ini
Do not write anything in this column

b)



$\dot{W}_g = 35\,kW$; $\dot{W}_R = 5\,kW$
$\dot{Q}_H = 6000\,kJ/min$; $\dot{Q}'_L = 1560\,kJ/min$

i) $\eta_{th} = \dfrac{\dot{W}_{net}}{\dot{Q}_H}$ —— 1

$\dot{W}_{net} = \dot{W}_g + \dot{W}_R$
$= 35 + 5$
$= 40\,kW$ —— 1

$\eta_{th} = \dfrac{40 \times 60}{6000} \times 100$
$= 40\%$ —— 1

ii) $COP_R = \dfrac{\dot{Q}'_L}{\dot{W}_R}$ —— 1

$= \dfrac{1560}{5 \times 60}$
$= 5.2$ —— 1

iii) $\dot{Q}_L = \dot{Q}_H - \dot{W}_{net}$ —— 1
$= 6000 - (40 \times 60)$
$= 3600\,kJ/min$ —— 1

iv) $\eta_{th_{max}} = 1 - \dfrac{T_L}{T_H}$ —— 1

$= \left(1 - \dfrac{303}{1023}\right) \times 100$
$= 70.38\%$ —— 1

v) $\dot{W}_{R_{min}} = \dfrac{\dot{Q}'_L}{COP_{R_{max}}}$ —— 1

$COP_{R_{max}} = \dfrac{1}{\frac{T_H'}{T_L'} - 1}$ —— 1

$= \dfrac{1}{\left(\frac{303}{268}\right) - 1}$
$= 7.66$ —— $\frac{1}{2}$

$\dot{W}_{R_{min}} = \dfrac{1560}{60} \times \dfrac{1}{7.66}$
$= 3.39\,kW$ —— $\frac{1}{2}$

a)
1-2 : Reversible isothermal expansion —— 1
2-3 : Reversible adiabatic expansion —— 1
3-4 : Reversible isothermal compression —— 1
4-1 : Reversible adiabatic compression —— 1