First Semester Examination
2019/2020 Academic Session

December 2019 / January 2020

EMH 211 – Thermodynamics
[Termodinamik]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **TEN [10]** printed pages including appendix before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **SEPULUH [10]** mukasurat bercetak beserta lampiran sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

Answer Questions In **English** OR **Bahasa Malaysia**.
*[Jawab soalan dalam **Bahasa Inggeris** ATAU **Bahasa Malaysia**.]*

Answer to each question must begin from a new page.
[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

Note: Thermodynamic Property Tables Booklet is Provided. Thermodynamic Formula is given in the Appendix provided.
Buku 'Thermodynamic Property Tables' dibekalkan. Buku Formula Termodinamik diberikan dalam lampiran.

1. [a] **With the aid of diagram, show that Internal Energy is a property of thermodynamic system.**

Dengan bantuan gambarajah, tunjukkan bahawa Tenaga Dalam adalah sifat sistem termodinamik.

(50 marks/ *markah***)**

[b] **A turbine is shown in Figure 1[b]. The turbine power output is 14MW. Inlet and exit conditions are shown in the figure. Calculate:**

Sebuah turbin ditunjuk pada Rajah 1[b]. Kuasa keluaran turbin adalah 14MW. Keadaan masuk dan keluar ditunjuk pada rajah berkenaan. Kirakan:

(i) **Thermal power loss, Q**
Kehilangan kuasa terma, Q.

(35 marks/ *markah***)**

(ii) **Diameter of pipe entrance.**
Diameter paip masuk. **(15 marks**/ *markah***)**

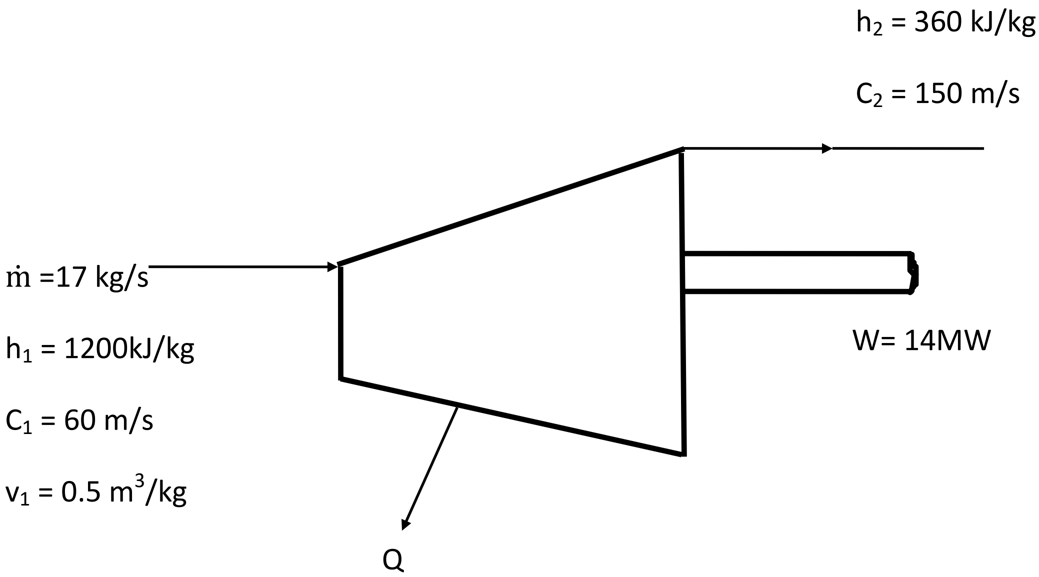

Figure 1[b]
Rajah 1[b]

2. [a] **Refrigerant 134a enters an adiabatic compressor as saturated vapor at 100 kPa at a rate of 0.7 m^3/min and exits at 1 MPa pressure. If the isentropic efficiency of the compressor is 87%.**

Bahan penyejuk 134a memasuki pemampat adiabatik sebagai wap tepu pada 100 kPa pada kadar 0.7 m^3/min dan keluar pada tekanan 1 MPa. Jika kecekapan isentropik pemampat ialah 87%.

(i) **Calculate the temperature of the refrigerant at the exit of the compressor**
Kirakan suhu penyejuk di keluaran pemampat

(40 marks/*markah*)

(ii) **Calculate the power input in kW**
Kirakan kuasa masukan dalam kW

(10 marks/*markah*)

(iii) **Sketch the process on a T-s diagram.**
Lakarkan proses tersebut pada rajah T-s.

(10 marks/*markah*)

[b] **A piston-cylinder device initially contains 1.5 kg of liquid water at 150 kPa and 20°C. The water is now heated at constant pressure by the addition of 4000 kJ of heat. Calculate the entropy change of the water during this process. Sketch the process on a T-s diagram.**

Sebuah omboh silinder pada awalnya mengandungi 1.5 kg air cecair pada 150 kPa dan 20°C. Air kini dipanaskan pada tekanan malar dengan penambahan haba 4000 kJ. Kirakan perubahan entropi air semasa proses ini. Lakarkan proses tersebut pada rajah T-s.

(30 marks/*markah*)

[c] **State the Kelvin Plank statement and Clausius statement of second law of thermodynamics.**

Nyatakan pernyataan Kelvin Planck dan pernyataan Clausius hukum termodinamik kedua.

(10 marks/*markah*)

3. [a] **A system consists of 2 kg of carbon dioxide gas initially at state 1, where P_1 = 1 bar and T_1 = 300 K. The system undergoes a cycle consisting of the following three processes.**

Sistem terdiri daripada 2 kg gas karbon dioksida pada mulanya di keadaan 1, di mana P_1 = 1 bar dan T_1 = 300 K. Sistem mengalami kitaran yang terdiri daripada tiga proses berikut.

Process 1-2: constant volume to P_2 = 4 bar.

Proses 1-2: isipadu malar hingga P_2 = 4 bar.

Process 2-3: expansion with $Pv^{1.28}$ = constant.

Proses 2-3: pengembangan dengan $Pv^{1.28}$ = constant.

Process 3-1: constant pressure compression to initial state.

Proses 3-1: mampatan tekanan berterusan kepada keadaan permulaan.

(i) **Calculate the total work and total heat transfer for the cycle.**
Kirakan jumlah kerja dan jumlah pemindahan haba untuk kitar.

(40 marks/*markah*)

(ii) **Sketch the cycle on the P-v diagram**
Lakarkan kitaran pada rajah P-v

(10 marks/*markah*)

[b] **A piston-cylinder device initially contains 0.35 kg steam at 3.5 MPa and 250°C. Now the steam loses heat to the surroundings and the piston moves down hitting a set of stops (Figure 3b) at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C.**

Sebuah omboh silinder pada mulanya mengandungi stim 0.35 kg pada 3.5 MPa dan 250°C. Sekarang stim kehilangan haba ke persekitaran dan omboh bergerak ke bawah memukul satu set perhentian (Rajah 3b) di mana titik silinder mengandungi air cecair tepu. Pendinginan diteruskan sehingga silinder mengandungi air pada 200°C.

Calculate:

Kirakan:

(i) **The final pressure and the dryness fraction**
Tekanan akhir dan pecahan kekeringan

(ii) **The boundary work**
Kerja sempadan

(iii) **The amount of heat transfer when the piston first hits the stops**
Jumlah pemindahan haba apabila omboh berhenti

(iv) **The total heat transfer**
Jumlah pemindahan haba

(40 marks/*markah***)**

Sketch:
Lakarkan:

(v) **The process on P-v Diagram.**
Proses tersebut pada rajah P-v.

(10 marks/*markah***)**

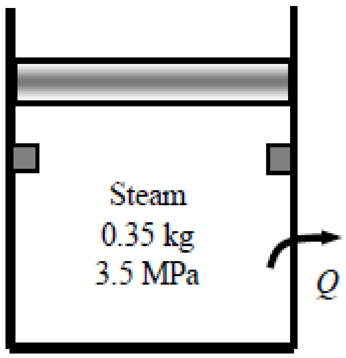

Figure 3 b
Rajah 3 b

4. **One kg of air is taken through a Diesel cycle. It has an initial temperature of 350 K, initial pressure at 100 kPa, compression ratio of 20 and heat addition of 2000 kJ. Assume that the air is modelled as an ideal gas. Given that γ=1.4, c_p= 1.005 kJ/kgK, c_v=0.718 kJ/kgK and R= 0.287kJ/kgK.**

Satu kg udara melalui kitaran Diesel. Ia mempunyai suhu awal 350 K, tekanan awal pada 100 kPa, nisbah mampatan 20 dan penambahan haba sebanyak 2000 kJ. Andaikan udara sebagai gas unggul. Diberikan γ=1.4, c_p=1.005 kJ/kgK, c_v=0.718 kJ/kgK dan R= 0.287kJ/kgK.

(i) **Sketch the cycle on a P-v diagram.**
Lakarkan kitar pada rajah P-v.

(10 marks/*markah***)**

(ii) **Calculate the cut-off ratio.**
Kirakan nisbah pemotongan.

(30 marks/*markah***)**

(iii) **Calculate the cycle thermal efficiency.**
Kirakan kecekapan terma kitar.

(30 marks/*markah***)**

(iv) **Calculate the mean effective pressure for the cycle**.
Kirakan tekanan berkesan min bagi kitaran tersebut.

(15 marks/*markah***)**

(v) **Suggest TWO (2) strategies to increase the cycle thermal efficiency**.
Cadangkan DUA (2) strategi untuk meningkatkan kecekapan terma kitar.

(15 marks/*markah***)**

5. **A steam turbine plant operates on the Rankine cycle with superheat. A boiler pressure is 80 bar and a condenser pressure 0.05 bar. The steam leaves the superheater at 550°C. Assuming that the turbine has an isentropic efficiency of 85% and the feed pump operates isentropically.**

Sebuah loji turbin stim beroperasi pada kitaran Rankine dengan pemanas lampau. Tekanan dandang ialah 80 bar dan kondenser 0.05 bar. Stim keluar dari pemanas lampau pada 550 °C. Andaikan bahawa kecekapan isentropik bagi turbin adalah 85% dan pam suapan beroperasi secara isentropik.

(i) **Sketch the cycle on a T-s diagram.**
Lakarkan kitar tersebut pada rajah T-s.

(10 marks/*markah***)**

(ii) **Calculate the specific net work output.**
Kirakan kerja terhasil bersih tentu.

(30 marks/*markah***)**

(iii) **Calculate the specific heat supplied.**
Kirakan haba tentu yang dibekalkan.

(20 marks/*markah***)**

(iv) **Calculate the specific steam consumption.**
Kirakan penggunaan stim tentu.

(15 marks/*markah***)**

(v) **Calculate the cycle efficiency.**
Kirakan kecekapan kitar.

(15 marks/*markah***)**

(vi) **Compare the cycle efficiency if the turbine operates isentropically.**
Bandingkan kecekapan kitar jika turbin beroperasi secara isentropik.

(10 marks/*markah***)**

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Appendix 1
Lampran 1

Thermodynamic Formulae Booklet 2020

First law for closed cycle

$$\oint \delta Q = \oint \delta W \quad \Longrightarrow \quad Q_{net} = W_{net}$$

Non-flow energy equation

$q - w = (u_2 - u_1)$

Enthalpy equation

$h = u + Pv$

Steady flow energy equation

$q - w = (h_2 - h_1) + 1/2\,(C_2^2 - C_1^2) + g\,(z_2 - z_1)$

specific heat equation

$q = cp\,(T_2 - T_1)$

Joule Law

$du = cv\,dT$

$dh = cp\,dT$

Dryness Fraction equations

$v = v_f + x\,(v_f - v_g)$ or $v = x\,v_g$ (P<20bar)

$h = h_f + x\,h_{fg}$; $u = u_f + x\,u_{fg}$

$s = s_f + x\,s_{fg}$

Cycle efficiency

$$\eta = \frac{w_{net}}{q_h} = \frac{q_h - q_c}{q_h} = 1 - \frac{q_c}{q_h}$$

$$COP_{refrigerator} = \frac{q_c}{w_{net}}$$

$$COP_{heat\,pump} = \frac{q_h}{w_{net}}$$

Entropy

$q = T\,(s_2 - s_1)$; (Isothermal)

Gibbs Equation

$Tds = Pdv + du$

$Tds = dh - vdP$

Ideal gas

Characteristics equation

$PV = mRT$

specific heat of an ideal gas

$$\gamma\ (or\ k) = \frac{Cp}{Cv}\ ;\ Cp = \frac{\gamma R}{\gamma - 1}\ ;$$

$$Cv = \frac{R}{\gamma - 1}$$

Polytrophic process $(PV^n = \text{constant})$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n \ \text{and}\ \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{n-1/n} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

$$W(kJ) = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{mR(T_2 - T_1)}{1-n};(n>1)$$

$$W(kJ) = P_1V_1.\ln\frac{V_2}{V_1} = mRT.\ln\frac{V_2}{V_1};(n=1)$$

$$Q(kJ) = W(\gamma - n)/(\gamma - 1);(n>1)$$

Adiabatic process $(PV^{\gamma} = \text{constant})$

Specific entropy of an ideal gas

$s_2 - s_1 = R\ln(v_2/v_1) + cv\ln(T_2/T_1)$

$s_2 - s_1 = cp\ln(v_2/v_1) + cv\ln(P_2/P_1)$

$s_2 - s_1 = cp\ln(T_2/T_1) - R\ln(P_2/P_1)$

Specific exergy of a closed system

$x = (u - u_o) + P_o(v - v_o) - T_o(s - s_o)$

Specific exergy of an open system

$x = (h - h_o) - T_o(s - s_o) + K.E + P.E$

$$\eta_{isentropic\ expantion} = \frac{W_{actual}}{W_{isentropic}}$$

$$\eta_{isentropic\ compression} = \frac{W_{isentropic}}{W_{actual}}$$

Specific exergy change of the process

$\Delta x = x_2 - x_1 = (h_1-h_2) - T_0(s_1-s_2) + \Delta KE + \Delta PE$

Second Law Efficiency:

$$\eta_{II} = \frac{W_{irr}}{X} = \frac{\eta}{\eta_{rev}} = \frac{W}{W_{rev}} = \frac{COP_{rev}}{COP}$$

Carnot Cycle

$Q_{12} = m R T_1 \ln(v_1/v_2) = W_{12}$
$Q_{23} = m\, cv\, (T_3 - T_2)$
$Q_{34} = mRT_3 \ln(v_4/v_3) = W_{34}$
$Q_{41} = m\, cv\, (T_4 - T_1) = Q_{23}$

$$\eta_{carnot} = 1 - \frac{|Q_c|}{Q_h} = 1 - \frac{T_c}{T_h}$$

Stirling Cycle

$Q_c = Q_{12} = mRT_1 \ln(v_1/v_2) = W_{12}$
$Q_{23} = m\, cv\, (T_3 - T_2)$
$Q_h = Q_{34} = mRT_3 \ln(v_4/v_3) = W_{34}$
$Q_{41} = mcv\, (T_4 - T_1) = Q_{23}$

$$\eta_c = 1 - \frac{|Q_c|}{Q_h} = 1 - \frac{T_1}{T_3}$$

$$Work\ ratio = \frac{W_{34} - W_{12}}{W_{34}} = 1 - \frac{T_1}{T_3} = \eta_c$$

Ericsson Cycle

$Q_c = Q_{12} = mRT_1 \ln(P_2/P_1) = W_{12}$
$Q_{23} = m\, cp\, (T_3 - T_2)$
$Q_h = Q_{34} = mRT_3 \ln(P_3/P_4) = W_{34}$
$Q_{41} = mcp\, (T_1 - T_4)$

$$\eta_{ericsson} = 1 - \frac{|Q_c|}{Q_h} = 1 - \frac{T_1}{T_3}$$

Closed Brayton/Joule Cycle

$W_{12} = m\, cp\, (T_1 - T_2)$
$Q_h = Q_{23} = m\, cp\, (T_3 - T_2)$
$W_{34} = m\, cp\, (T_3 - T_4)$
$Q_c = Q_{41} = m\, cp\, (T_1 - T_4)$

$$\eta_c = \frac{W_{net}}{Q_h} = \frac{Q_{net}}{Q_h} = 1 - \frac{(T_1 - T_4)}{(T_3 - T_2)}$$

$\eta = 1 - \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}}$ (Applicable for isentropic processes only)

$$Work\ ratio = \frac{W_{34} - W_{12}}{W_{34}} = 1 - \frac{T_1}{T_3}(r_p)^{\frac{\gamma-1}{\gamma}}$$

Otto Air Standard Cycle

$W_{12} = mcv\, (T_1 - T_2)$

Diesel Standard Air Cycle

$Q_{12} = Q_{34} = W_{41} = 0$
$Q_p = Q_{23} = mcp(T_3 - T_2)$
$Q_s = Q_{41} = mcv(T_1 - T_4)$
Cycle efficiency,

$$\eta_D = 1 - \frac{|Qs|}{Qp} = 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)} = 1 - \frac{1}{r_v^{\gamma-1}}\left(\frac{\beta^\gamma - 1}{\gamma(\beta - 1)}\right)$$

$r_v = (v_1/v_2)$ = compression ratio
$\beta = (v_3/v_2)$ = volume ratio or cut-off ratio

Mixed Cycle (Dual combustion cycle)

$Q_{12} = 0$
$Q_{23} = mcv\, (T_3 - T_2)$
$Q_{34} = mcp\, (T_4 - T_3)$
$Q_{51} = mcv\, (T_1 - T_5)$
$r_v = (v_1/v_2)$ = compression ratio
$r_p = (P_3/P_2)$ = pressure ratio
$\beta = (v_4/v_3)$ = volume ratio, cut-off ratio
Cycle efficiency,

$$\eta_m = 1 - \frac{|Q_c|}{Q_h} = 1 - \frac{|Q_{51}|}{(Q_{23} - Q_{34})}$$

Mean Effective Pressure – MEP (P_m)

$w_{net} = P_m\, (v_1 - v_2)$

Rankine Cycle (Simple & Superheated Cycle)

$w_{12} = -(h_2 - h_1)$
$q_{23} = -(h_3 - h_2)$
$w_{34} = -(h_4 - h_3) = -v_{f3}\, (P_4 - P_3)$
$q_{41} = h_1 - h_4$

Efficiency,

$$\eta = \frac{w_{12} - |w_{34}|}{q_{41}}$$

$$Work\ Ratio = \frac{w_{12} - |w_{34}|}{w_{12}}$$

Rankine Reheat Cycle:

$Q_h = Q_{23} = m\,cv\,(T_3 - T_2)$ $W_{34} = m\,cv\,(T_3 - T_4)$ $Q_c = Q_{41} = m\,cv\,(T_1 - T_4)$ $\eta_c = 1 - \frac{\|T_1 - T_4\|}{(T_3 - T_2)}$ $\eta_o = \frac{w_{net}}{q_{net}} = 1 - \frac{q_c}{q_h}$ $\frac{T_2}{T_1} = \frac{T_3}{T_4} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = r_v^{\gamma-1}$ $pv^{\gamma} = Tv^{\gamma-1}$ = constant $r_v = \frac{Swept\ volume + Clearance\ volume}{Clearance\ volume} = \frac{v_1}{v_2}$ Otto cycle efficiency, $\eta = 1 - \frac{1}{r_v^{\gamma-1}}$	$\eta = \frac{(w_{12} + w_{78}) - \|w_{34}\|}{q_{41} + q_{27}}$ Specific Steam Consumption = 1 /w_{net} (kg/kJ) or Specific steam consumption=3600/w_{net} (kg/kWh)
	Vapour Compression Cycle $COP = \frac{\|q_{41}\|}{\|w\|} = \frac{h_1 - h_4}{h_2 - h_1}$ Refrigerating effect: $q_{41} = (h_1 - h_4)$ (kJ/kg)