First Semester Examination
Academic Session 2018/2019

December 2018/January 2018

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.
Buku 'Thermodynamic Property Tables' dibekalkan.

1. **[a] Explain the followings:**
Terangkan perkara berikut:

(i) Thermodynamic cycle.
Kitar Termodinamik.

(ii) Thermodynamic process.
Proses Termodinamik.

(iii) Enthalpy
Entalpi

(iv) Entropy.
Entropi.

(v) Second Law of Thermodynamics according to Clausius Statement.
Hukum Kedua Termodinamik berdasarkan kenyataan Clausius.

(vi) Carnot Cycle.
Kitar Carnot.

(**60 marks**/*markah*)

[b] An electric kettle consumes 240 volts and 8 amp electricity supply. One liter of water is required to be boiled. Assume the temperature of water initially is 25°C. Efficiency of the kettle is 88%. Calculate:

Sebuah cerek elektrik menggunakan 240 volt dan 8 amp bekalan elektrik. Satu liter air perlu dididih. Andaikan suhu asal air ialah 25°C. Kecekapan cerek ialah 88%. Kirakan:

(i) The time taken to boil the water.
Masa yang diambil untuk mendidihkan air.

(ii) The time taken for 0.6 liter of the water to evaporate into steam.
Masa yang diambil untuk 0.6 liter air menyejat menjadi stim.

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

2. [a]

(i) For ideal gas, prove that the change in entropy is:
Untuk gas unggul, buktikan bahawa perubahan entropi adalah seperti berikut:

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

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

(ii) State FOUR (4) characteristics of heat engines. Write the Kelvin-Planck expression of the second law of thermodynamics.
Nyatakan EMPAT (4) ciri-ciri enjin haba. Tuliskan ungkapan Kelvin-Planck hukum kedua termodinamik.

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

(iii) Define Exergy and explain its importance.
Takrifkan Exergi dan terangkan kepentingannya.

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

[b] Steam enters an adiabatic turbine steadily at 3 MPa and 400 °C and leaves at 50 kPa and 100 °C. Given that the power output of the turbine is 2 MW.

Stim memasuki turbin adiabatik secara berterusan pada 3 MPa dan suhu 400 °C dan keluar pada 50 kPa dan 100 °C. Diberikan kuasa keluaran turbin adalah 2 MW.

(i) Calculate the isentropic efficiency of the turbine.
Kirakan kecekapan isentropik turbin.

(**25 marks**/*markah*)

(ii) Calculate the mass flow rate of the steam flowing through the turbine.
Kirakan kadar aliran jisim stim yang mengalir melalui turbin.

(**25 marks**/*markah*)

(iii) Sketch the process on T-s Diagram.
Lakarkan proses tersebut pada Rajah T-s.

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

3. [a] **A closed system containing 2 kg of air undergoes an isothermal process from 600 kPa and 200 °C to 80 kPa.**

Sistem tertutup yang mengandungi 2 kg udara menjalani proses isoterma dari 600 kPa dan 200 °C hingga 80 kPa.

(i) **Calculate the initial volume of this system.**
Kirakan isipadu awal sistem ini.

(**12 marks**/*markah*)

(ii) **Calculate the work done and heat transfer during this process.**
Kirakan kerja yang dilakukan dan pemindahan haba semasa proses ini.

(**12 marks**/*markah*)

(iii) **Sketch the process on T-s Diagram.**
Lakarkan proses tersebut pada Rajah T-s.

(**6 marks**/*markah*)

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

Sebuah omboh silinder pada awalnya mengandungi stim 0.35 kg pada 3.5 MPa dan 250˚C. Kemudiannya, haba dari stim hilang ke persekitaran dan omboh bergerak ke bawah sehingga menghentam dengan penahan (Rajah 3) di mana silinder mengandungi air cecair tepu. Pendinginan terus sehingga silinder mengandungi campuran air pada 200°C.

(i) **Calculate the final pressure and the quality.**
Kirakan tekanan akhir dan kualiti.

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

(ii) **Calculate the boundary work.**
Kirakan kerja sempadan.

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

(iii) **Calculate the amount of heat transfer when the piston first hits the stopper.**
Hitung amaun pemindahan haba apabila omboh pertama menghentam penahan.

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

(iv) **Calculate the total heat transfer.**
Hitung jumlah pemindahan haba.

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

(v) **Sketch the process on P-v Diagram.**
Lakarkan proses tersebut pada Rajah P-v.

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

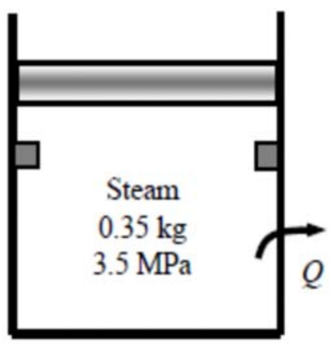

Figure 3
Rajah 3

4. **A dual combustion cycle has a maximum pressure of 80 bar and maximum temperature of 1900°C. Given that the compression ratio is 18:1 and the inlet conditions are 1 bar and 25°C. 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= 0.287 kJ/kgK.**

Sebuah kitar pembakaran duaan mempunyai tekanan maksimum 80 bar dan suhu maksimum 1900°C. Diberi nisbah mampatan adalah 18:1 dan keadaan masukan adalah 1 bar dan 25 °C. Andaikan udara sebagai gas unggul. Diberikan γ=1.4, c_p=1.005 kJ/kgK, c_v= 0.718 kJ/kgK dan R= 0.287 kJ/kgK.

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

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

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

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

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

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

(iv) **Calculate the mean effective pressure, in MPa for the cycle**.
Kirakan tekanana berkesan min, dalam MPa bagi kitaran tersebut.

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

5. **Consider a reheat Rankine cycle operates between pressures of 80 and 0.04 bar, with a superheat temperature of 500°C. Assume that it is expanded in the first turbine until it becomes dry saturated steam. After that, it is reheated to the original superheat temperature and expands through the second turbine.**

Pertimbangkan sebuah kitar Rankine dengan pemanas semula beroperasi antara tekanan 80 dan 0.04 bar, dengan suhu lampau 500°C. Andaikan stim tersebut mengembang dalam turbin pertama sehingga menjadi stim tepu kering. Selepas itu, stim itu dipanaskan semula ke suhu asal lampau dan mengembang melalui turbin kedua.

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

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

(ii) **Calculate the total output work per kg steam.**
Kirakan jumlah kerja terhasil per kg stim.

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

(iii) **Calculate the total heat supplied per kg steam.**
Kirakan jumlah haba yang dibekalkan per kg stim.

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

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

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

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

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

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APPENDIX 1
LAMPIRAN 1

Thermodynamic Formulae Booklet 2019

First law for closed cycle

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

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

$Tds = Pdv + du$

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

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

$$Tds = dh - vdP$$

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

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

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

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:

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