Second Semester Examination
Academic Session 2018/2019

June 2019

EME 422 – Energy Conversion System
[Sistem Penukaran Tenaga]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **EIGHT** **[8]** printed pages including appendix before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **LAPAN** **[8]** mukasurat bercetak beserta lampiran sebelum anda memulakan peperiksaan.]*

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

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.]

1. [a] **Choose ONE (1) type out of six major nuclear power plant that can be established in Malaysia. Based on your selection, answer the following questions:**

Pilih SATU (1) jenis dari enam loji janakuasa nuklear utama yang boleh ditubuhkan di Malaysia. Berdasarkan pilihan anda, berikan jawapan untuk soalan berikut:

(i) With the aid of a schematic drawing, explain the operating principle of the power plant.
Dengan bantuan sebuah gambarajah, terangkan prinsip kerja sebuah loji kuasa.

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

(ii) Discuss its suitability for Malaysia in terms of: economic aspects (fuel cost and operating efficiency) and environment aspects.
Bincangkan kesesuaiannya di Malaysia dari segi: aspek ekonomi (kos bahan api dan kecekapan operasi) dan aspek alam sekitar.

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

[b] **Elemental analysis of coal is shown below:**

Analisis unsur bagi arang batu adalah ditunjukkan di bawah:

C=80%, H=10%, O=6%, S=0.5%, ash *abu***=3.5%**

Determine/*Tentukan*

(i) A/F ratio for excess air of 20%.
Nisbah udara/ bahan api bagi kelebihan udara 20%.

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

(ii) Amount of carbon dioxide emission annually, for the following case.
Amaun pencemaran karbon dioksida setahun, bagi kes berikut.

- **Power plant output = 1000 kW**
  Keluaran loji.
- **Efficiency of power plant = 25%**
  Kecekapan loji.
- **Heating value of coal = 30MJ/kg.**
  Nilai haba arang batu.
- **Capacity factor = 90%**
  Faktor kapasiti.

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

2. A 100kWe small power plant consist a gasifier and a gasoline engine. The followings are the assumptions made:.

Sebuah lojikuasa kecil 100kWe mengandungi sebuah penggas dan enjin gasolin. Berikut adalah andaian yang dibuat:

i. **Gasoline displacement** *Anjakan minyak gasolin* **100%**.
ii. **Efficiency of the gasifier** *Kecekapan penggas* **70%**.
iii. **Efficiency of the engine** *Kecekapan enjin **25%**.*
iv. **Biomass heating value** *Nilai pemanasan biojisim* **15MJ/kg**.

[a] Sketch the schematic diagram of the plant.
Lakarkan gambarajah skema loji tersebut.

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

[b] Determine the amount of biomass required per hour.
Tentukan amaun biomass yang diperlukan setiap jam.

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

[c] Determine the volumetric flow rate of air for gasification.
Tentukan kadar aliran isipadu udara.

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

[d] Determine the overall efficiency of the system.
Tentukan kecekapan keseluruhan sistem.

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

[e] Determine the specific biomass consumption.
Tentukan penggunaan spesifik biomass.

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

[f] Give <u>THREE (3)</u> reasons for power loss in a gasoline engine fuelled by producer gas and suggest ways to overcome it.
*Berikan **<u>TIGA (3)</u** sebab bagi kehilangan kuasa ini dalam enjin petrol yang menggunakan gas penghasil.*

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

[g] Give<u>THREE (3)</u> advantages and <u>THREE (3)</u> disadvantages of using biomass as an energy source.
*Berikan **<u>TIGA (3)</u** kebaikan dan **<u>TIGA (3)</u** keburukan menggunakan biojisim sebagai sumber tenaga.*

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

3. The following is the data for a 20 MW biomass power plant*:*

Berikut adalah maklumat bagi sebuah loji janakuasa biojisim 20MW.

i. **Nominal cost** *Kos nominal* **RM 5000 per kW**.
ii. **Interest rate** *Kadar pinjaman* **7%**.
iii. **Period of loan** *Tempoh pinjaman* **25 years**.
iv. **Period of operation** *Tempoh operasi* **25 years**.
v. **Number of workers** *Bilangan pekerja* **20**.
vi. **Average salary per month** *Purata gaji sebulan* **RM 4000**.
vii. **Fuel cost** *Kos bahanapi* **RM 20 per ton**.
viii. **Type of fuel is oil palm waste** *Jenis bahan api adalah sisa kelapa sawit.*
ix. **Heating value** *Nilai pemanasan* **15 MJ/kg**.
x. **Thermal efficiency** *Kecekapan terma* **25%**.
xi. **Maintenance cost/** *Kos penyelenggaraan* **= Labor cost/** *Kos pekerja.*
xii. **Capacity factor** *Faktor kapasiti* **80%**.
xiii. **Power sales by TNB** *penjualan kuasa oleh TNB* **30sen/kWh**.

[a] Determine the production unit cost for plant.
Tentukan unit kos penjanaan.

(70 marks/ *markah***)**

[b] Determine the simple payback period for the plant.
Tentukan jangka bayar balik bagi loji tersebut.

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

4. [a] The latest addition to the coal-fired ($C_{135}H_{96}O_9NS$) Manjung power station is a 1 GW supercritical steam turbine. A reheat coil with additional turbine to increase the plant efficiency. Assume 100% isentropic efficiencies for the turbines and 20% excess air supply to the boiler.

Penambahan terkini ke stesen janakuasa Manjung yang menggunakan arang batu ($C_{135}H_{96}O_9NS$) ialah turbin stim superkritikal 1 GW. Andaikan kecekapan isentropi bagi turbin adalah 100% dan 20% lebihan bekalan udara ke dandang.

Use the provided Mollier chart. Plant details are in Table 4.
Gunakan carta Mollier yang dibekalkan. Perincian loji terdapat pada Jadual 4:

Table 4/*Jadual 4*

Variable / *Pembolehubah*	**Value/** *Nilai*
Air flow rate to the boiler/ *kadar aliran udara ke dandang*	**1000 kg/s**
Calorific value of fuel / *Nilai kalori bahan api*	**32 MJ/ kg**
Maximum steam pressure / *Tekanan stim maksimum*	**300bar**
Inlet temperature to the high and low pressure turbines / *Suhu masukan kepada turbin bertekanan tinggi dan rendah*	**500^{o}C**
Steam dryness (x) at the two turbines exits / *kekeringan stim turbin (x) di kedua-dua keluaran turbin*	**0.85**
The specific volume at boiler inlet / *Isipadu tentu di masukan dandang*	**0.001m^3/kg**
The enthalpy at boiler inlet / *Entalpi di masukan dandang*	**300 kJ/kg**

(i) Intermediate and condenser pressures.
Tekanan perantaraan dan pemeluwap.

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

(ii) Steam flow rate (kg/s).
Kadar aliran stim (kg/s).

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

(iii) Boiler efficiency if it is operating at 20% excess air.
Kecekapan dandang jika ia beroperasi pada 20% lebihan udara.

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

(iv) Required pump power and how many % its consumption from the total plant output.
Kuasa pam yang diperlukan dan berapa % penggunaannya dari jumlah kuasa keseluruhan loji janakuasa.

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

(v) Power plant overall efficiency (including pump power).
Kecekapan keseluruhan loji janakuasa (termasuk kuasa pam).

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

(vi) Discuss another method to increase the overall power plant efficiency.
Terangkan kaedah lain untuk meningkatkan kecekapan keseluruhan loji.

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

[b] Explain the differences between thermoelectric (TE) and thermo-photovoltaic (TPV) power generation devices in terms of: power generation principle, technology limitation and environmental aspects.

Jelaskan perbezaan peranti penjanaan kuasa antara elektrik terma (TE) dan fotovolta terma (TPV) dari segi: prinsip penjanaan kuasa, batasan teknologi dan aspek alam sekitar.

(30 marks/*markah*)

5. [a] With the aid of a schematic drawing, explain the operating principle of the proton exchange membrane fuel cell (PEMFC) and write the half-cell reaction equations (at the anode and cathode).

Dengan bantuan sebuah gambarajah, terangkan prinsip kerja sebuah sel bahan api membran penukar proton (PEMFC), dan tuliskan persamaan-persamaan tindak balas separa-sel (pada anod dan katod).

(20 marks/*markah*)

[b] Calculate the change in voltage of Hydrogen-Oxygen fuel cell when the operating temperature is elevated from 500 K to 600 K at atmospheric pressure. The fuel cell produces water vapor as a product of the reaction. Use the provided properties tables in the appendix for your calculations.

Kirakan perubahan voltan sel bahan api hidrogen-oksigen apabila suhu operasi dinaikkan daripada 500 K hingga 600 K pada tekanan atmosfera. Sel bahan api menghasilkan wap air sebagai tindak balas produk. Gunakan jadual sifat yang disediakan di lampiran untuk pengiraan anda.

(40 marks/*markah*)

[c] State FOUR (4) of the main causes of incomplete combustion. Select ONE (1) cause then discuss its principle and how to solve it.

*Nyatakan **EMPAT (4)** sebab utama pembakaran tidak lengkap. Pilih **SATU (1)** sebab kemudian bincangkan prinsipnya dan bagaimana untuk menyelesaikannya.*

(20 marks/*markah*)

[d] What is acid rain and how is it formed? Discuss TWO (2) methods to prevent acid rain at the pollution source.

*Apakah hujan asid dan bagaimana ia terbentuk? Bincangkan **DUA (2)** kaedah untuk mengelakkan hujan asid daripada sumber pencemaran.*

(20 marks/*markah*)

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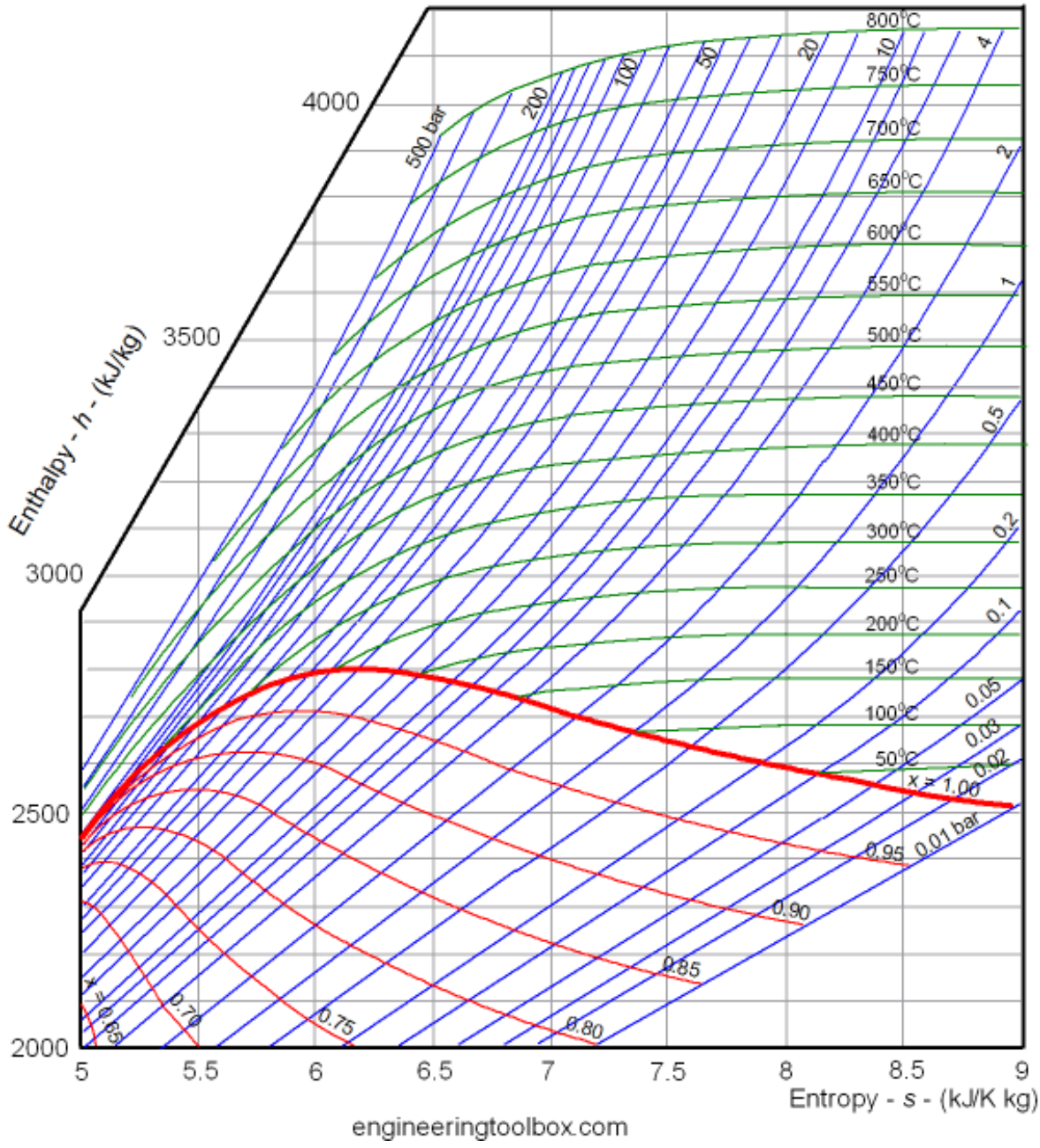
APPENDIX 1
LAMPIRAN 1

CARTA MOLLIER



APPENDIX 2
LAMPIRAN 2

Enthalpy of formation, Gibbs function of formation, and absolute entropy at 25°C, 1 atm

Substance	Formula	$\bar{h}_f^\circ$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K
Hydrogen	$H_2(g)$	0	130.68
Nitrogen	$N_2(g)$	0	191.61
Oxygen	$O_2(g)$	0	205.04
Water vapor	$H_2O(g)$	−241,820	188.83
Water	$H_2O(\ell)$	−285,830	69.92

Ideal-gas properties

	water vapor, H_2O		hydrogen, H_2		oxygen, O_2	
T K	$\bar{h}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K	$\bar{h}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K	$\bar{h}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K
298	9,904	188.720	8,468	130.574	8,682	205.033
300	9,966	188.928	8,522	130.754	8,736	205.213
320	10,639	191.098	9,100	132.621	9,325	207.112
340	11,314	193.144	9,680	134.378	9,916	208.904
360	11,992	195.081	10,262	136.039	10,511	210.604
380	12,672	196.920	10,843	137.612	11,109	212.222
400	13,356	198.673	11,426	139.106	11,711	213.765
420	14,043	200.350	12,010	140.529	12,314	215.241
440	14,734	201.955	12,594	141.888	12,923	216.656
460	15,428	203.497	13,179	143.187	13,525	218.016
480	16,126	204.982	13,764	144.432	14,151	219.326
500	16,828	206.413	14,350	145.628	14,770	220.589
520	17,534	207.799	14,935	146.775	15,395	221.812
560	18,959	210.440	16,107	148.945	16,654	224.146
600	20,402	212.920	17,280	150.968	17,929	226.346

$$\bar{h}_f = \bar{h}_f^\circ + \Delta\bar{h}$$

$$\bar{g}_f = \bar{h}_f - T\,\bar{s}^\circ$$

$$\Delta\bar{g}_f = \bar{g}_f \text{ of products} - \bar{g}_f \text{ of reactants}$$

$$E = \frac{-\Delta\bar{g}_f}{zF} \quad ; \quad \mathbf{F = 96,485\ kC/kmol}$$