Second Semester Examination
Academic Session 2017/2018

May/June 2018

EME 422 – Energy Conversion System
[Sistem Penukaran Tenaga]

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.]*

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] (i) Write the half-cell reaction equations (at the anode and cathode) and the net cell reaction equations for each of fuel cells: alkaline fuel cell (AFC), proton exchange membrane fuel cell (PEMFC), solid oxide fuel cell (SOFC), and molten carbonate fuel cell (MCFC).

Tuliskan persamaan-persamaan tindak balas separuh sel (pada anod dan katod) dan persamaan tindak balas bersih sel untuk setiap sel bahan api berikut: sel bahan api alkali (AFC), sel bahan api membran penukar proton (PEMFC), sel bahan api pepejal oksida (SOFC), dan sel bahan api karbonat lebur (MCFC).

(20 marks/*markah*)

(ii) Compare <u>THREE (3)</u> aspects of applications between a proton exchange membrane fuel cell (PEMFC) and a molten carbonate fuel cell (MCFC).

Bandingkan <u>TIGA (3)</u> aspek aplikasi sebuah sel bahan api membran penukar proton (PEMFC) dan sel bahan api karbonat lebur (MCFC).

(30 marks/*markah*)

[b] H_2-O_2 fuel cell is operating at a constant temperature and pressure of 600 K and 1 bar respectively. The fuel cell produces water vapor as a product of combustion. In reference to Table 1[b], calculate:

Sebuah sel bahan api H_2−O_2 beroperasi pada suhu malar 600 K dan tekanan malar 1 bar. Sel bahan api berkenaan menghasilkan wap air sebagai hasil pembakaran. Dengan merujuk kepada Jadual 1[b], kirakan:

(i) the enthalpy of formation.
entalpi pembentukan.

(ii) the entropy of formation.
entropi pembentukan.

(iii) the Gibbs free energy of formation.
tenaga bebas pembentukan Gibbs.

(iv) the fuel cell voltage.
voltan sel bahan api.

$$\Delta h_f = h_f^\circ + \Delta h$$

$$\Delta s_f = (s_T^o)_{H_2O} - (s_T^o)_{H_2} - (s_T^o)_{O_2}$$

$$\Delta G = \Delta h_f - T\Delta s_f$$

$$E = -\frac{\Delta G}{4n_o F}$$

F = 96.487 kJ/V.mol

Table 1[b]
Jadual 1[b]

Element	h_f^o (kJ/kmol)	s_T^o (kJ/kmol)	Δh (kJ/kmol)
Hydrogen	**0**	**151.078**	**8799**
Oxygen	**0**	**226.450**	**9245**
Water vapor	**– 241826**	**213.051**	**104990**

(50 marks/*markah*)

2. [a] (i) With the aid of a diagram, explain the working principle of a pressurized water reactor (PWR) nuclear plant. Label the main components of a PWR nuclear plant.

Dengan bantuan sebuah gambarajah, terangkan prinsip kerja sebuah loji nuklear reaktor bertekanan air. Labelkan komponen-komponen utama loji nuklear reaktor bertekanan air.

(30 marks/*markah*)

(ii) Describe <u>TWO (2)</u> differences between the pressurized water reactor (PWR) and boiling water reactor (BWR) nuclear plant.

Terangkan <u>DUA (2)</u> perbezaan antara loji nuklear reaktor bertekanan air dan loji nuklear reaktor didih air.

(20 marks/*markah*)

[b] (i) Evaluate the suitability of developing a nuclear power plant in Malaysia. Elaborate your answers in terms of (but not limited to) power generated, fuel requirement, logistic and obstacles.

Nilaikan kesesuaian dalam membangunkan sebuah loji kuasa nuklear di Malaysia. Huraikan jawapan anda dalam aspek (tidak terhad kepada) penjanaan kuasa, keperluan tenaga, logistik dan halangan-halangan.

(30 marks/*markah*)

(ii) Explain THREE (3) challenges in developing a fusion reactor.
Terangkan TIGA (3) cabaran dalam membangunkan sebuah reaktor lakuran.

(20 marks/*markah*)

3. [a] State at least SIX (6) differences between water-tube and fire-tube boilers.

Nyatakan sekurang-kurangnya ENAM (6) perbezaan antara dandang tiub-air dan dandang tiub-api.

(30 marks/*markah*)

[b] Oil fuel ($C_{10}H_{20}$), with low heating value of 40 MJ/kg was used in a burner. The burner operates at an equivalence ratio (φ) of 0.8 and air flow rate of 1 kg/s.

Bahan api minyak ($C_{10}H_{20}$) dengan nilai haba bahan api 40 MJ/kg digunakan dalam pembakar. Pembakar beroperasi pada nisbah setara (φ) adalah 0.8 dan kadar aliran udara adalah 1 kg/s.

Calculate
Kirakan

(i) Stoichiometric A/F ratio.
Nisbah stoikiometri A/F.

(10 marks/*markah*)

(ii) Actual A/F ratio.
Nisbah sebenar A/F.

(20 marks/*markah*)

(iii) Burner thermal capacity in kW.
Kapasiti haba pembakar dalam unit kW.

(20 marks/*markah*)

(iv) Amount of carbon dioxide emission annually.
Amaun emisi karbon dioksida setahun.

(20 marks/*markah*)

4. The following are the details for a diesel ($C_{12}H_{23}$) fueled combine cycle power plant. Assume 100% isentropic efficiencies for the compressor and the turbines, and same pressure ratio for the compressor and gas turbine. The pump work of the steam cycle is neglected, and gas temperature at HRSG inlet is the same the as the gas temperature at the gas turbine exit.

Berikut adalah perincian sebuah loji janakuasa kitar gabungan yang menggunakan diesel ($C_{12}H_{23}$). Andaikan kecekapan isentropi bagi pemampat dan turbin adalah 100%, dan andaikan nisbah tekanan yang sama untuk pemampat dan turbin gas. Andaikan kerja pam tentu bagi kitar stim diabaikan, dan suhu gas pada masukan adalah sama dengan suhu gas pada keluaran gas turbin.

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

Table 4
Jadual 4

Variable / *Pembolehubah*	**Value/** *Nilai*
Fuel consumption/ *Penggunaan bahan api*	**5 kg/s**
Inlet temperature to the gas turbine plant/ *Suhu masukan ke dalam loji gas turbin*	**25^{o}C**
Maximum temperature in the gas turbine plant/ *Suhu maksimum dalam loji gas turbin*	**1050^{o}C**
Equivalence ratio (φ)/ *nisbah setara(φ)*	**0.5**
Steam pressure / *Tekanan stim*	**50bar**
Steam temperature / *Suhu stim*	**600^{o}C**
Calorific value of fuel / *Nilai kalori bahan api*	**44MJ/ kg**
Condenser pressure of the steam plant / *Tekanan pemeluwap loji stim*	**0.05 bar**
Chimney temperature at HRSG exit / *Suhu cerobong pada keluaran HRSG*	**150^{o}C**
The specific heat capacities at constant pressure for air / *Kapasiti tenaga tentu pada tekanan malar bagi udara*	**1.01 kJ/kg.K**
The specific heat capacities at constant pressure for gas / *Kapasiti tenaga tentu pada tekanan malar bagi gas*	**1.11 kJ/kg.K**
The specific heat ratios for air / *Nisbah haba tentu bagi udara*	**1.4**
The specific heat ratios for gas / *Nisbah haba tentu bagi gas*	**1.33**
The enthalpy at boiler inlet / *Entalpi pada masukan HRSG*	**192 kJ/kg**

[a] Sketch the schematic diagram of the combine power plant and label the main components

Lakarkan gambar rajah skema loji kuasa gabungan dan labelkan komponen-komponen utama

(20 marks/*markah*)

[b] Calculate/*Kirakan*:

(i) the optimum pressure ratio of the compressor
optimum Nisbah tekanan pemampat

(5 marks/*markah*)

(ii) the actual temperature of the compressor and turbine exits.
suhu sebenar pada keluaran pemampa dan turbin gas

(5 marks/*markah*)

(iii) the powers of the compressor and turbine
kuasa pemampa dan turbin gas

(5 marks/*markah*)

(iv) the net power from the gas turbine cycle
kuasa net daripada kitar turbin gas

(5 marks/*markah*)

(v) the efficiency of the gas turbine cycle
kecekapan kitar turbin gas

(10 marks/*markah*)

(vi) the enthalpy change of the steam at the HRSG
perubahan entalpi stim pada HRSG

(5 marks/*markah*)

(vii) the steam flow rate.
Kadar alir stim

(5 marks/*markah*)

(viii) the power plant thermal efficiency.
kecekapan keseluruhan loji.

(10marks/*markah*)

[c] Propose <u>TWO (2)</u> strategies to increase the combined cycle efficiency significantly.

Cadangkan <u>DUA (2)</u> strategi untuk meningkatkan kecekapan kitar gabungan.

(30 marks/*markah*)

5. [a] The owner of a fuel station that operates 24-hour daily is considering the idea of adding electricity charging station on his premises. The project involves installation of solar panels on the roof of the existing building, large capacity duplex-type energy storage and a few vehicle charging ports as well as a smart electrical and metering system. The station owner is also eligible for the Feed-in Tariff (FiT) incentive provided by the Sustainable Energy Development Authority (SEDA) if he sells his excess power to the grid. For the time being, he pays the station's electricity bill under tariff C1 Medium Voltage Commercial to TNB.

Key indicating data from recent feasibility study are as follows:

Pemilik sebuah stesen bahanapi yang beroperasi 24-jam sehari sedang menimbangkan idea untuk menambah stesen pengecas elektrik di kawasannya. Projek tersebut melibatkan pemasangan panel suria di atas bumbung bangunan sediaada, penyimpan tenaga dua-hala berkapasiti besar dan beberapa portal pengecas kenderaan serta sistem elektrikal dan pemeteran yang bestari. Pemilik stesen juga layak untuk mendapat insentif Tariff Masukan (FiT) oleh Lembaga Pembangunan Tenaga Mapan (SEDA). Pada masa ini beliau membayar bil elektrik stesen beliau di bawah kadar tarif C1 Perdagangan Voltan Sederhana kepada TNB.

Data petunjuk daripada kajian kebolehlaksanaan yang terbaharu adalah seperti berikut:

Total roof area/ *Jumlah luas bumbung:* **8,000 m^2**
Solar panel size/ *Saiz panel suria:* **1.2 m x 0.72 m**
Nominal power per panel/ *Kuasa nominal per panel:* **0.25 kW**
Panel cost/ *Harga panel:* **RM750/unit**
Average daily charging duration/ *Purata tempoh cas harian:* **12 hours**
Overall charging efficiency/ *Kecekapan cas keseluruhan:* **80%**
Energy storage capacity/ *Kapasiti penyimpan tenaga:* **500 kWh**
Energy storage power/ *Kuasa penyimpan tenaga:* **500 kW**
Energy storage cost/ *Harga penyimpan tenaga:* **RM600,000**
Charging port type/ *Jenis portal pengecas:* **100kW DC/22kW AC combo**
Charging port cost/ *Harga portal pengecas:* **RM100,000/unit**
Complete smart system cost/ *Kos sistem bestari lengkap:* **RM150,000**
Complete installation cost/ *Kos pemasangan lengkap:* **RM100,000**
Charging rate per parking bay/ *Kadar caj sepetak parkir:* **RM5/hour**
Parking bay usage/ *Penggunaan petak parkir:* **20 hour/day**
Eligible SEDA FiT rate/ *Kadar kelayakan FiT SEDA:* **RM0.6541/kWh**

(i) Calculate the required number of solar panels.
Kirakan bilangan panel suria yang diperlukan.

(ii) Calculate the total income from parking bay usage per year.
Kirakan jumlah pendapatan daripada penggunaan petak parkir setahun.

(iii) If the station owner sells half of the harnessed solar energy, calculate his total income per year.
Jika pemilik stesen menjual separuh daripada tenaga suria yang dijana, kirakan jumlah pendapatannya setahun.

(iv) Calculate the total investment cost for the above project.
Kirakan jumlah kos pelaburan untuk projek di atas.

(v) Using a simple payback period without the interest, calculate the number of years the project would break-even.
Dengan menggunakan kaedah tempoh bayar balik mudah tanpa bunga, kirakan bilangan tahun projek tersebut dapat pulang modal.

(vi) Is the project worth it? Justify with a strong reason.
Adakah projek tersebut berbaloi? Wajarkan dengan satu alasan yang kukuh.

(50 marks/*markah*)

[b] Study the recent trend in the final electricity generation and consumption chart in Malaysia as shown in the Figures 5(b-i) and (b-ii) below. Based on the year 2010 as reference, estimate the projected electricity consumption in the year 2050 and how it can be supplied by different mix of energy generation. Suggest what percentage of energy generation shall be contributed by renewable resources. Justify the impacts to consumers and the environment for your choice of energy generation.

Perhatikan trend terbaharu berkaitan carta penjanaan dan penggunaan elektrik mutakhir di Malaysia seperti Rajah-rajah 5(b-i) dan (b-ii) di bawah. Berdasarkan tahun 2010 sebagai rujukan, anggarkan unjuran penggunaan elektrik bagi tahun 2050 dan bagaimana ia dapat dibekalkan oleh kepelbagaian penjanaan tenaga. Cadangkan apakah peratusan penjanaan tenaga yang patut disumbang daripada sumber boleh diperbaharui. Wajarkan impak-impak terhadap pengguna dan alam sekitar bagi pilihan penjanaan tenaga yang dipilih.

(50 marks/*markah*)

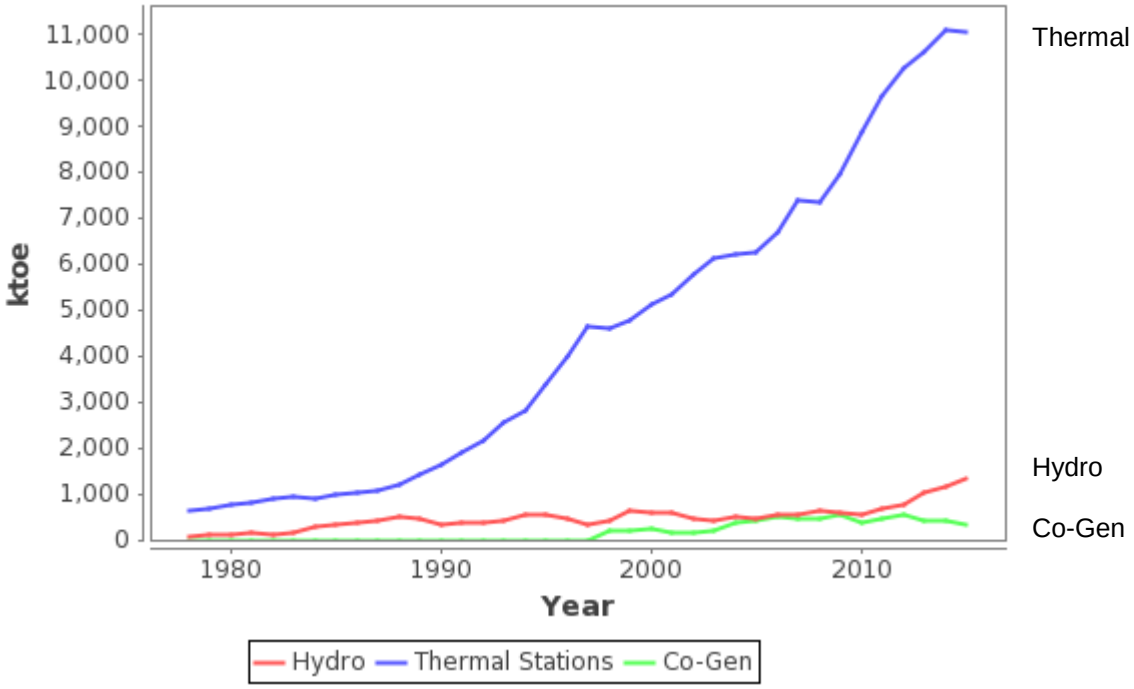

Figure 5(b-i): Malaysia Electricity Generation Mix
Rajah 5(b-i): Gabungan Penjanaan Elektrik di Malaysia

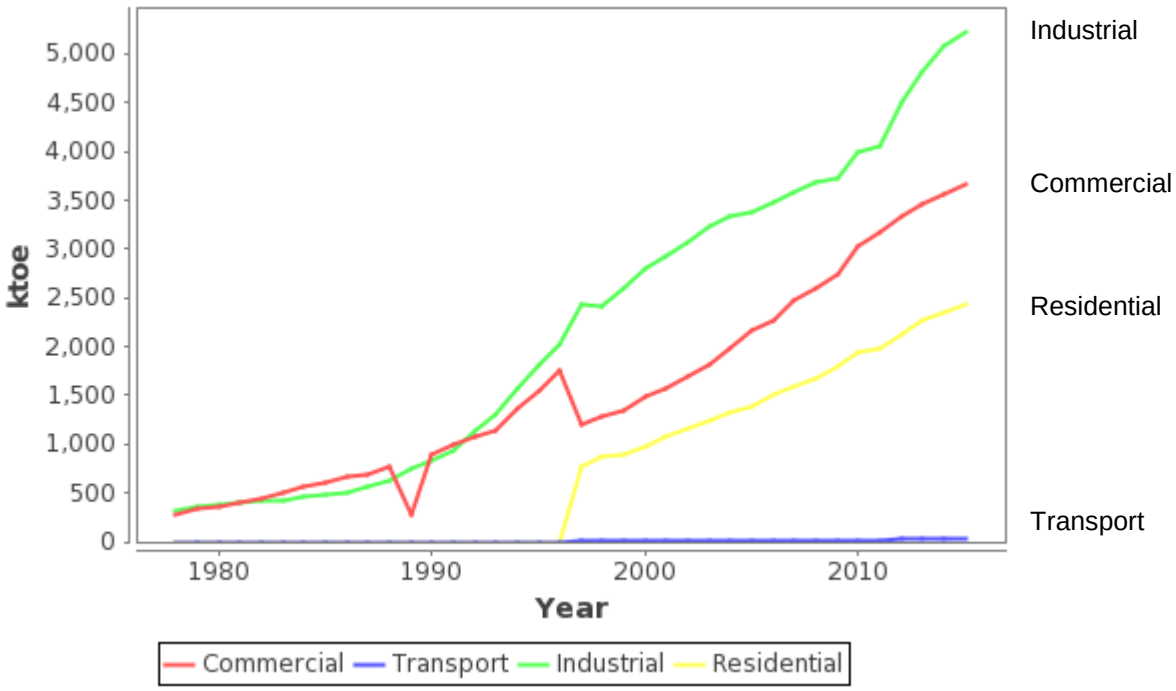

Figure 5(b-ii): Malaysia Electricity Consumption by Sector
Rajah 5(b-ii): Penggunaan Elektrik di Malaysia Mengikut Sektor

APPENDIX 1
LAMPIRAN 1

CARTA MOLLIER