Second Semester Examination
2021/2022 Academic Session

July/August 2022

EME 422 – Energy Conversion System
(Sistem Penukaran Tenaga)

Duration: 2 hours
(Masa: 2 Jam)

Please check that this examination paper consists of <u>SIX</u> (6) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi <u>ENAM</u> (6) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

<u>**Instructions**</u>: Answer ALL **FIVE (5)** questions.

*[<u>**Arahan**</u>: Jawab **LIMA (5)** soalan]*

1. (a) Compare between the ultimate and proximate analysis for solid fuels in terms of:

    (i) analysis outcome and benefits
    (ii) working principle and theory
    (iii) the components and structure of measuring devices.

    (30 marks)

    (b) A gas analyzer used to measure the Volume % of dry exhaust from a combustion chamber showed the following results: 12% CO_2; 5% CO; 0.4% SO_2; 4% O_2 and the balance is N_2.

    Calculate:

    (i)   Chemical formula of the fuel as $(C_nH_mS_p)$

    (30 marks)

    (ii)   Actual A/F ratio

    (10 marks)

    (iii) Stoichiometric A/F ratio

    (10 marks)

    (iv) CO_2 and SO_2 emissions

    (20 marks)

2. A combined cycle power plant is fueled by distillate oil and consists of simple gas and steam turbine cycles. 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. Plant details are in Table Q2.

Table Q2

Variable	Value
Fuel Heating value	40MJ/kg
Fuel input power	8 MW
Inlet temperature to the gas turbine plant	25°C
Maximum temperature in the gas turbine plant	950°C
Actual Air/Fuel ratio	60
Pressure ratio for the gas turbine (and compressor)	17
Maximum steam pressure	20bar
Maximum steam temperature	600°C
Condenser pressure of the steam plant	0.05 bar
Chimney temperature at HRSG exit	120°C
The specific heat capacities (Cp) at constant pressure for air	1.01 kJ/kg.K
The specific heat capacities (Cp) at constant pressure for gas	1.1 kJ/kg.K
The specific heat ratios (k) for air	1.4
The specific heat ratios (k) for gas	1.33
The enthalpy at boiler inlet	192 kJ/kg

(a) Draw the steam cycle on the provided Mollier chart (Appendix 1) and attach the chart with your answer sheet.

(10 marks)

(b) Calculate:

    (i) the net power and efficiency for the gas turbine cycle

(40 marks)

    (ii) the power of HRSG and steam turbine

(30 marks)

    (iii) Total power and overall efficiency the power plant

(20 marks)

3. Biomass with heating value of 17 MJ/kg is used to produce 1 MW electrical power through a gasification-IC gas engine power plant configuration. The IC gas engine efficiency is 30% and power plant overall efficiency is 21%. Data for the power plant economic evaluation are in Table Q3:

Table Q3

Variable	Value
Nominal cost	RM 6000/ kW
Fuel cost	RM 50 per ton
Interest rate	7%
Period of loan	25 years
Period of operation	25 years
Number of workers	20
Average salary per month	RM 4000
Maintenance cost	Same as labour cost
Capacity factor	80%
Power sales by TNB	RM0.35 / kWh

(a) Draw schematic drawing of the power plant.

(10 marks)

(b) Calculate:

   (i) Fuel supply requirement (ton/hr)

(15 marks)

   (ii) Cold-gas gasifier efficiency

(15 marks)

   (iii) Production unit cost for the power plant

(50 marks)

(c) Explain whether the plant is economically feasible or not.

(10 marks)

4. 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. Calculate:

    (i)   the enthalpy of formation
    (ii)   the entropy of formation
    (iii)   the Gibbs free energy of formation
    (iv)   the fuel cell voltage

    $\Delta h_f = \overset{\circ}{h_f} + \Delta h$

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

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

    $E = -\dfrac{\Delta G}{4n_oF}$

    F = 96.487 kJ/Vmole

Element	h_f^o (kJ/kmol)	s_T^o (kJ/kmole)	Δh (kJ/kmole)
Hydrogen	0	151.078	8799
Oxygen	0	226.450	9245
Water (g)	− 241826	213.051	104990

    (100 marks)

5. (a) Explain the differences in the formation of fuel NO, thermal NO, and prompt NO in term generation mechanism. Plot the distribution of these NO formation against the temperature.

    (40 marks)

    (b) Discuss the fuel staging and air staging methods which are used to control the NOx emission. In addition, give ONE (1) advantage and ONE (1) disadvantage of each method.

    (60 marks)

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APPENDIX 1