Second Semester Examination
2022/2023 Academic Session

July / August 2023

EME 422 – Energy Conversion System
(Sistem Penukaran Tenaga)

Duration: 3 hours
(Masa: 3 Jam)

Please check that this examination paper consists of FIVE (5) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA (5) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FIVE (5)** questions.

*[**Arahan**: Jawab SEMUA **LIMA (5)** soalan]*

Note:
Mollier chart for question 2 as provided in attachment.

...2/-

1. (a) Compare and explain the difference between: (1) carbon neutral, (2) carbon positive and (3) carbon negative cases, within the carbon cycle in atmosphere, in terms of definition and effect on environment, with **ONE** example for each case.

(30 marks)

(b) Biomass fuel ($CH_{1.6}O_{0.5}N_{0.1}S_{0.01}$) is burned in a furnace with 50% excess air.

i. Write the stoichiometric combustion molar reaction.

(10 marks)

Calculate:

ii. Mass % of the fuel elements C, H, O, N, S.

(20 marks)

iii. Stoichiometric and actual A/F ratios.

(20 marks)

iv. Emissions (in kg/kg fuel) of CO_2 and SO_2.

(20 marks)

2. Steam power plant used 10 ton/hr of pulverized coal as fuel with elemental analysis of coal of: C=84%, H=9%, O=5%, S=1%, ash=1%, and heating value of 30 MJ/kg. A boiler with 75 ton steam/hr capacity, which operates using 30% excess air burner. Steam exits the boiler at 600^{o}C and 50 bar. The steam turbine has isentropic efficiency of 85%. Condenser pressure is 0.1 bar and the enthalpy of saturated water is 191.81 kJ/kg. Neglect the pump in your calculations.

i. Draw the process in the attached Mollier chart and submit with your answer script.

(10 marks)

ii. Draw a schematic diagram of the steam power plant.

(10 marks)

iii. Write the molar stoichiometric combustion reaction.

(10 marks)

Calculate:

iv. Stoichiometric and actual A/F ratios for the combustion of coal.

(10 marks)

v. Steam boiler power and efficiency.

(20 marks)

vi. Steam turbine power.

(10 marks)

vii. Steam power plant efficiency.

(10 marks)

viii. Condenser power, and the required water flow to cool down the condenser, if cooling water enters at 30^{o}C and exits at 45^{o}C.

(20 marks)

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3. (a) Discuss the feasibility of biomass power plant in terms of fuel transport, fuel pre-treatment cost and fuel quality.

(20 marks)

(b) A 400 kWe biomass power plant consists of a gasifier, gas cooling-cleaning unit and micro gas turbine (MGT). Cold-gas gasifier efficiency is 75% and MGT efficiency is 20%. Empty fruit bunch (EFB) is used as fuel. Plant details are in Table 3:

Table 3

Variable	Value
LHV for EFB	19 MJ/ kg
EFB cost	RM 50/ton
Unit capital cost	0.073 RM/kWh
Unit labour cost	0.086 RM/kWh
Unit maintenance cost	0.043 RM/kWh
Power plant nominal value	RM 5500/kW
Annual operating hours	8760 hr/year
Duration of the power plant operation	20 Years
Electrical Tariff	RM 0.30 kWh

i. Draw a schematic diagram of the power plant including power (of biomass and producer gas) and efficiency values for each part.

(10 marks)

ii. Calculate unit fuel cost (RM/kWh).

(20 marks)

iii. Calculate unit electricity production cost (RM/kWh).

(10 marks)

iv. Calculate simple payback period (in years).

(10 marks)

v. Discuss the economic feasibility in terms of revenue and operation life span of the power plant.

(30 marks)

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4. (a) Draw a schematic diagram of a high-temperature gas-cooled nuclear reactor. List **TWO (2)** advantages and **TWO (2)** disadvantages of the reactor.

(40 marks)

(b) Given a desired output of 2.0 $MW_{direct\ current}$ and the operating point of 600 mV and 400 mA/cm^2, calculate:

(i) the required area (in m^2) of the fuel cell

(20 marks)

(ii) the number of stacks required assuming a cell area of 1.00 m^2 per cell and 280 cells per stack.

(40 marks)

5. (a) Explain the benefits and harmful effects of excess air during thermal NO formation.

(20 marks)

(b) With the help of diagrams, compare the difference between air staging and fuel staging methods to control NOx.

(20 marks)

(c) Give **ONE (1)** disadvantage of air staging and flue gas recirculation methods on NOx formation.

(20 marks)

(d) Briefly describe burner-out-of-service and flue gas recirculation techniques in reducing NOx emission. Discuss the design aspects and their impacts on the flame and burner characteristics.

(40 marks)

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APPENDIX 1

Mollier chart for question 2