UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	:	**OBI5033 – OPERABILITY AND CONTROL**
DATE	:	**10 AUGUST 2024 (SATURDAY)**
TIME	:	**2:30 PM –6:30 PM (4 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. This is an online open-book final examination. Students can refer to online/offline resources including learning materials, textbooks, and other reading materials to answer the questions.
2. Answer **ALL** questions.
3. Only ONE (1) duly completed online answer script submission is permitted. Multiple submissions are **NOT** allowed.
4. You **MUST** upload your answers in **ONE (1) PDF file** in ULearnX as per given guideline and click submit. The **maximum** allowable file size is **100 MB**.
5. Please make sure your answers are clear and readable in the PDF file and name your file as: **"your Examination ID_Course Code"**.
6. Late submission and unclear/unreadable answers will not be accepted.

Note :

i. There are **SIX (6)** pages in this Question Booklet including the cover page and appendix.

1. Steam reforming is a widely used industrial process that converts hydrocarbons, such as natural gas, into hydrogen and methanol through a reaction with steam. This process is fundamental in the production of hydrogen, which is a critical component in various applications, including ammonia synthesis for fertilizers, petroleum refining, and fuel cells for clean energy. Additionally, methanol produced from steam reforming is a versatile chemical used in a wide range of applications, such as formaldehyde production, acetic acid synthesis and as a fuel additive. The process flow diagram (PFD) for this production process is illustrated in **FIGURE Q1 (APPENDIX I)**, with methane serving as the primary raw material.

   a. Propose a complete piping and instrumentation diagram (P&ID) for steam reforming reactor (R-1), methanol synthesis reactor (R-2), syngas pressure swing adsorber (PSA-1) and methanol distillation column (D-1). Justify the rationale behind the chosen control strategies for each of the unit operation.

   [18 marks]

   b. If the process is modified to use carbon dioxide (CO_2) as one of the raw materials instead of steam, propose **ONE (1)** unit operation that needs to be changed or modified, along with a control strategy and justification.

   [7 marks]

2. In the context of a biodiesel production process utilizing palm oil and methanol as raw materials, with sodium hydroxide (NaOH) serving as the catalyst in a batch reactor, it has been observed that the existing feedback control strategy is insufficient. The biodiesel yield is consistently falling short of expectations, primarily due to the improper addition of the reaction mixture, which fails to maintain the correct balance of reactants.

a. Propose an advanced control strategy to enhance biodiesel yield, providing a detailed justification for your approach.

[10 marks]

b. In a redesigned process, zinc oxide (ZnO) is intended to be used as a heterogeneous catalyst to replace NaOH. Given that ZnO is sensitive to poisoning, identify and propose specific control measures to be implemented within the reactor to optimize the conversion.

[15 marks]

3. **FIGURE Q3** shows a schematic diagram of distillation column. The system has a transfer function matrix relating control variables, distillation composition (x_D) and bottom composition (x_B), with possible manipulated variables, reflux flow (R) and steam flow (S), as shown in **EQUATION Q3**.

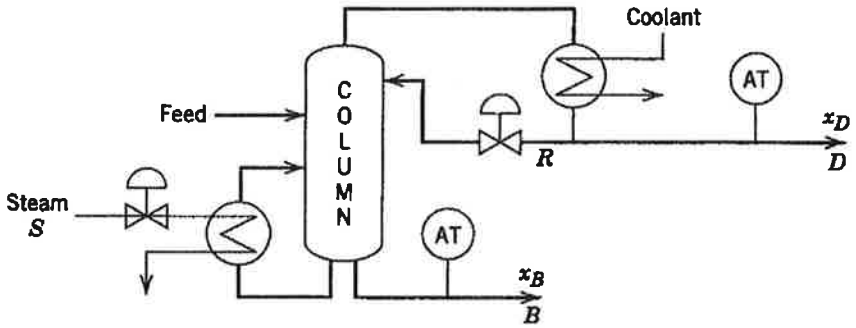


FIGURE Q3: A distillation column system

$$\begin{bmatrix} x_D \\ x_B \end{bmatrix} = \begin{bmatrix} \dfrac{1.6}{(13s+1)} & \dfrac{-1.2}{(15s+1)} \\ \dfrac{-7.5}{37s+1} & \dfrac{23}{(42s+1)} \end{bmatrix} \begin{bmatrix} R \\ S \end{bmatrix}$$

EQUATION Q3

Using an appropriate approach, propose a suitable pairing between the manipulated variables and controlled variables in such a way that minimizes the effect of interaction. Design the decouplers to further minimize the interaction and draw the complete block diagram for the systems including the controller and decoupler blocks.

[25 Marks]

4. a. Four experiments were conducted on a heat exchanger. In each experiment, the steam valve opening (input variable) was changed and the heat exchanger outlet temperature (output variable) was recorded. The dynamic data are given in **FIGURE Q4**. Discuss the result of each experiment, state whether the data can be used for model estimation. If not, state the deficiencies.

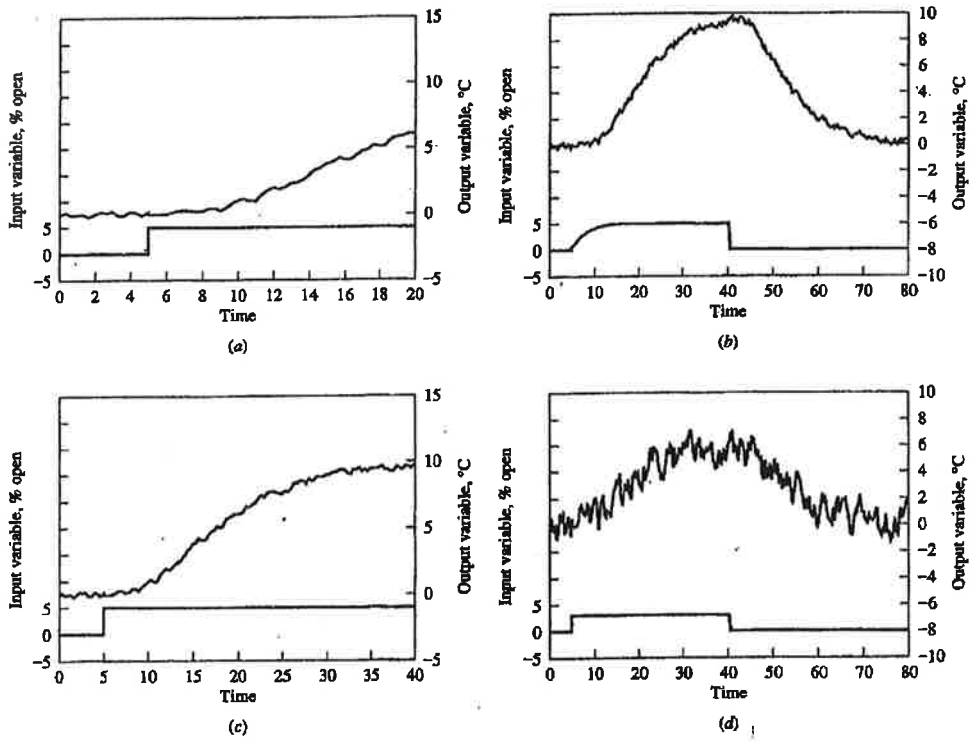


FIGURE Q4: Dynamic data for heat exchanger

[16 Marks]

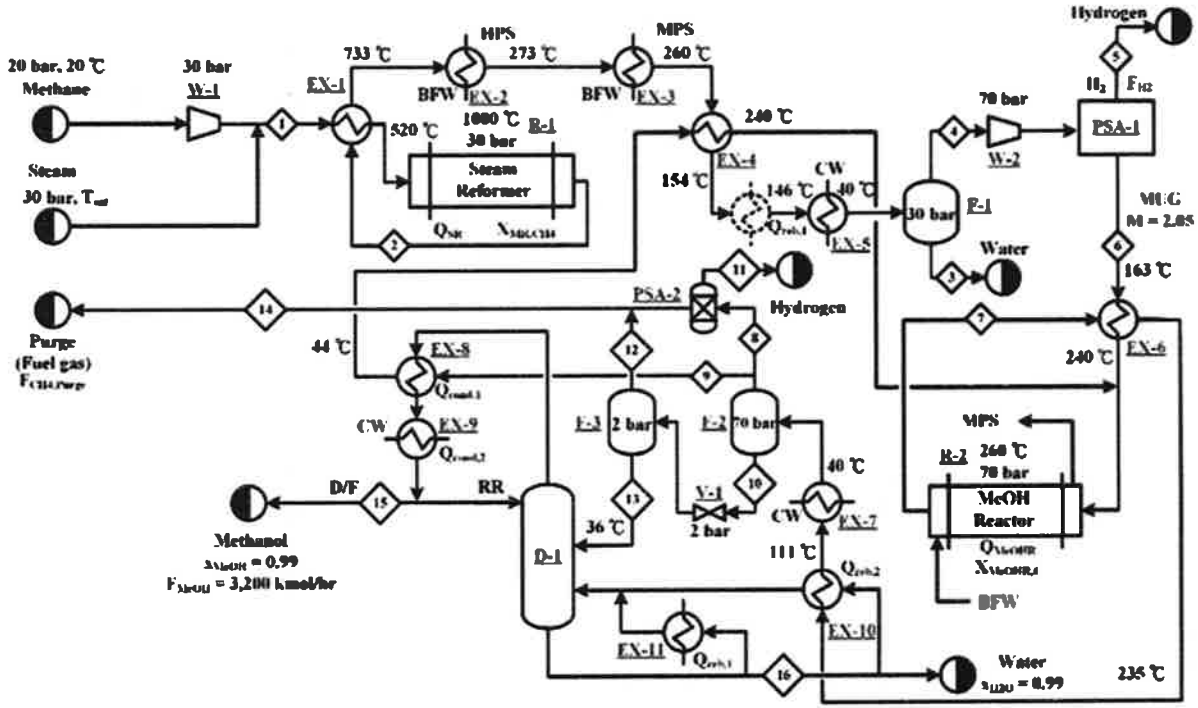
b. Select **ONE (1)** liquid hold-up unit in chemical process plant. Discuss the trade-off between steady-state design economics and dynamic operability in the selected system.

[9 Marks]

-END OF PAPER-

APPENDIX I

W-1 Feed Gas Compressor | R-1 Steam Reforming Reactor | EX-1 ATR Feed Effluent Heat Exchanger | EX-2 Syn Gas Cooler | EX-3 Syn Gas Cooler | EX-4 Syn Gas Cooler | EX-5 Syn Gas Cooler | F-1 Phase Separator | W-2 Syn Gas Compressor | PSA-1 Syn Gas Pressure Swing Adsorber | EX-6 Methanol Reactor Feed Effluent Heat Exchanger



R-2 Methanol Synthesis Reactor | EX-10 Crude Methanol Gas Cooler/Methanol Column Reboiler | EX-7 Methanol Product Gas Cooler | F-2 Phase Separator | F-3 Phase Separator | PSA-2 Purge Gas Pressure Swing Adsorber | D-1 Methanol Distillation Column | EX-8 Methanol Column Condenser/Recycle Gas Heater | EX-9 Methanol Column Condenser | EX-11 Methanol Column Reboiler

FIGURE Q1: Methanol and hydrogen production through steam reforming process