UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
SEPTEMBER 2023 SEMESTER

COURSE	**:**	**OAI5012 – HEAT INTEGRATION**
DATE	**:**	**1 DECEMBER 2023 (FRIDAY)**
TIME	**:**	**3:00 PM –6:00 PM (3 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 **FIVE (5)** pages in this Question Booklet including the cover page .

1. As a leading process design consultant, you are assigned to undertake heat integration of a chemical plant to operate with high energy efficiency. The conceptual process design team has provided the extracted process flowsheet, as shown in **FIGURE Q1**.

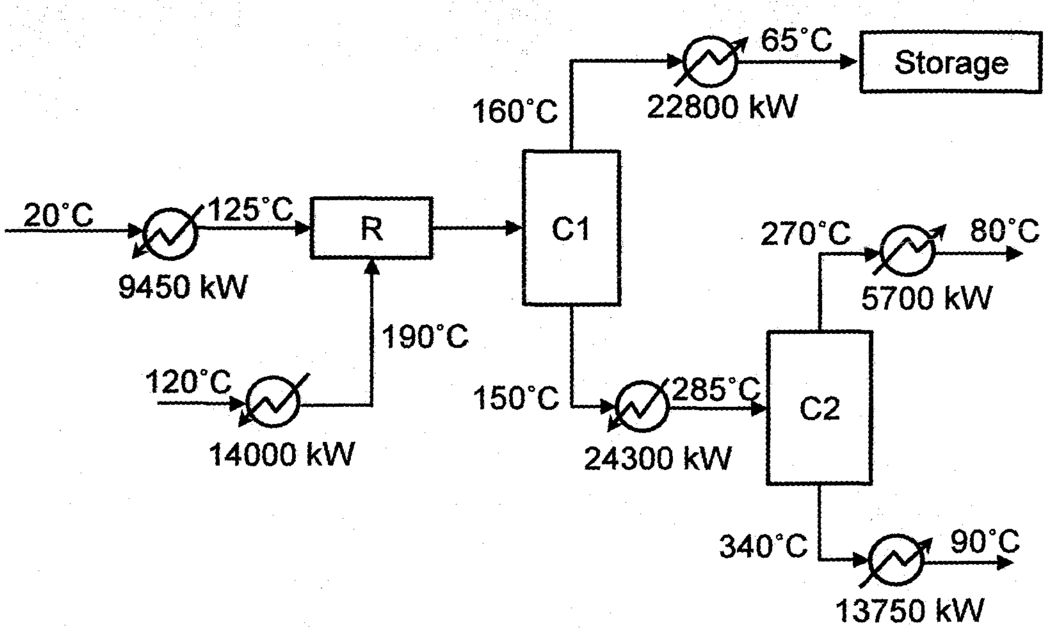

FIGURE Q1

a. Perform Problem Table Algorithm and design a heat exchanger network that satisfies maximum energy recovery if ΔT_{min} is 10°C.

[30 marks]

b. Based on the information given in **TABLE Q1**, determine the minimum total cost of utilities if the plant operates for 330 days per year.

TABLE Q1

Utilities	Temperature (°C)	Cost (RM/kWh)
Flue gas	400	0.060
Hot oil	300	0.170
High pressure steam (HP)	250	0.045
Medium pressure steam (MP)	180	0.035
Low pressure steam (LP)	105	0.025
Cooling water	20	0.230

[20 marks]

2. **FIGURE Q2** shows the Grand Composite Curve for a process with ΔT_{min} = 20°C.

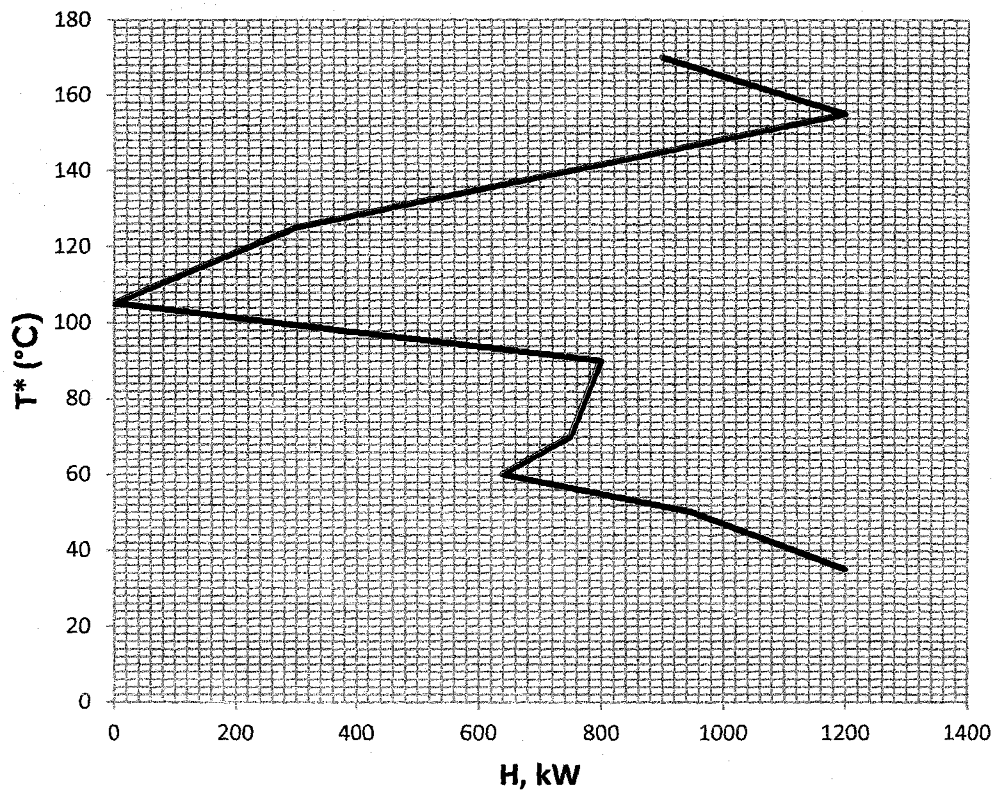

FIGURE Q2

The process also has a requirement for 300 kW of power. Two alternative utility schemes are to be compared economically.

Option 1: A steam turbine with its exhaust saturated at 170°C is to be used for process heating. Steam is generated in the central boiler house at 30 bar with an enthalpy and entropy of 2856.5 kJ/kg and 6.2893 kJ/kg·K, respectively. The generated steam can be expanded in a steam turbine with isentropic efficiency of 85%. The steam data for the turbine exhaust is given in **TABLE Q2a**.

TABLE Q2a

Temperature (°C)	Pressure (bar)	Enthalpy (kJ/kg)		Entropy (kJ/kg·K)	
		Saturated liquid	Saturated vapor	Saturated liquid	Saturated vapor
170	8	719.08	2767.9	2.0417	6.6650

Option 2: A heat pump is to be integrated with the process to satisfy process heating while reducing process cooling. The heat is absorbed at T_C = 70°C and rejected at T_H = 160°C.

The cost of utilities is given in **TABLE Q2b**. Evaluate the two options and recommend the most cost-effective utility scheme for the process.

TABLE Q2b

Utility	Cost ($/kW·hr)
Fuel for steam turbine	0.011
Imported power	0.065
Cooling water	0.004

[30 marks]

3. You are assigned to retrofit the existing heat exchanger network (HEN) shown in **FIGURE Q3**. **TABLE Q3** tabulates the additional information that you may use.

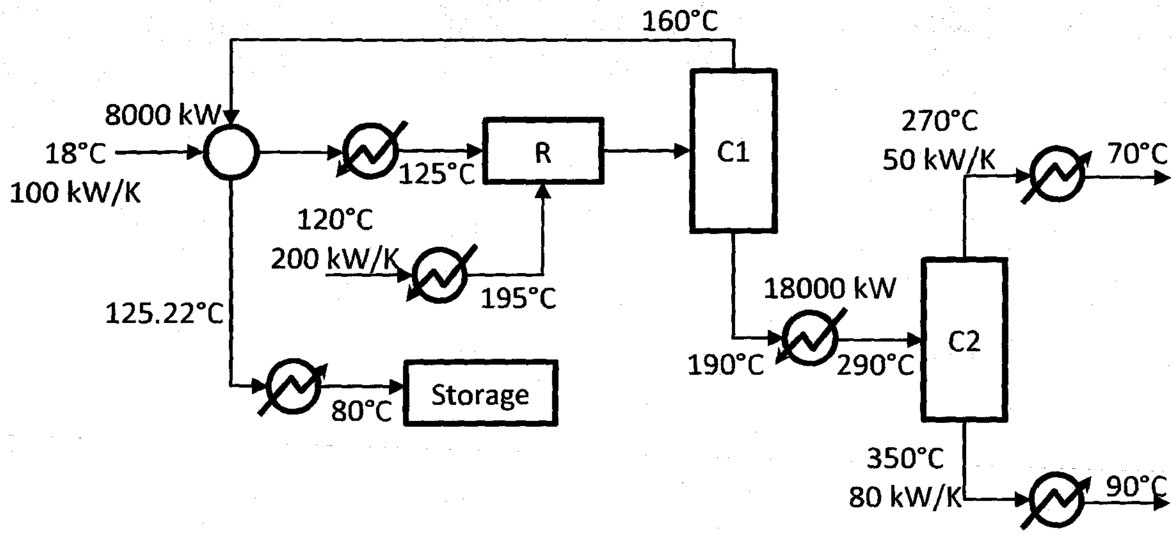

FIGURE Q3

TABLE Q3

Hot pinch temperature, ˚C	160
Cold pinch temperature, ˚C	150
Minimum hot utility, kW	6300
Minimum cold utility, kW	11800

Propose a retrofit HEN design that can achieve the minimum hot and cold utilities for the process. A maximum of only **TWO (2)** new heat transfer units can be added to your retrofit design. Other modifications such as repiping, additional areas and demolition are allowed.

[20 marks]

-END OF PAPER-