UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	:	CEB4333 - PROCESS OPTIMIZATION
DATE	:	5 AUGUST 2024 (MONDAY)
TIME	:	9.00 AM - 12.00 NOON (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SIX (6)** pages in this Question Booklet including the cover page .
ii. **DOUBLE-SIDED** Question Booklet.
iii. **Graph paper will be provided.**

1. Burtonville processes 3000 tons of trash per day, at least two-thirds of the trash is burned in either incinerators A, B or C while the remaining city's trash is dumped in a sanitary landfill area. The Superior Court has issued a temporary restraining order under which sulfur dioxide emissions must be limited to 40,000 ppm per day and particulate emissions to 50,000 ppm per day. At present all three incinerators are operating 24 hours every day nonstop. The weekly operating costs for incinerators A, B and C are RM7000, RM4900 and RM6300 accordingly. The capability of each incinerator can be referred to **TABLE Q1.**

TABLE Q1: Capability of each incinerator

		Emission per ton burned	
Incinerator	Capacity (tons/day)	Sulfur Dioxide (ppm/day)	Particulate (ppm/day)
A	1500	15	10
B	1000	12	15
C	1000	18	12

a. Formulate and solve the optimization problem of the above scenario.

[18 marks]

b. Due to several factors, the weekly operating cost will be increased by RM700 for each incinerator. Determine the new optimization solution and calculate the percentage of differences with the solution obtained in **part (a).**

[12 marks]

2. A chemical plant produces two products, ethylene and propylene, from naphtha (a hydrocarbon feedstock) through a process involving cracking and separation stages. For the production of 1 ton of ethylene, 0.5 tons of naphtha are required, and for the production of 1 ton of propylene, 0.3 tons of naphtha are required. The process must adhere to raw material availability and production capacities as outlined in **FIGURE Q2**. To maintain product quality, the mass fraction of ethylene in the final product should be at least 40%, and the mass fraction of propylene should be at least 30%. Formulate and solve the optimization problem.

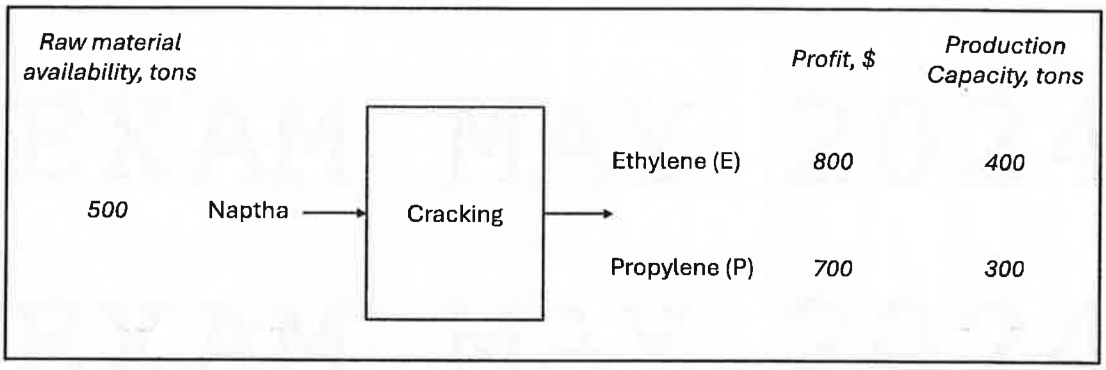

FIGURE Q2 : Simplified Process Flow Diagram

[25 marks]

3. A petroleum refinery is considering six projects aimed at improving operations and profitability. However, due to constraints and limitations, not all projects can be implemented. The projected expenditure, construction hours, and net profit for each project are provided in **TABLE Q3a**. The refinery has a first-year expenditure limit of RM 500,000, a second-year expenditure limit of RM 450,000, and a total of 500 days available for construction.

Additionally, certain requirements must be met before finalizing the project selection:

- At least one project must focus on reducing more than 75% greenhouse gas emissions.
- If a project aimed at reducing more than 80% greenhouse gas emissions is selected, a complementary project focusing on renewable energy generation must also be included. However, if no more than 80% greenhouse gas reduction project is selected, a renewable energy generation project should not be chosen.

TABLE Q3a: Details for each Project

Project	Description	GHG Emission Reduction Projection (%)	1st Year Expenditure	2nd Year Expenditure	Construction Hours	Cost (RM)	Revenue (RM)
1	Upgrade refinery equipment for emissions reduction	85	300,000	0	4,000	100,000	200,000
2	Construct a renewable energy generation facility	95	100,000	300,000	7,000	150,000	300,000
3	Implement carbon capture technology	75	0	200,000	2,000	35,000	75,000
4	Install sulfur recovery unit	30	50,000	100,000	6,000	75,000	160,000
5	Upgrade flare gas recovery system	65	50,000	300,000	3,000	125,000	250,000
6	Subcontract waste disposal	0	100,000	200,000	600	60,000	120,000

a. Develop the objective function subject to the limitations and requirements mentioned above without solving the equations. Then, identify the degree of freedom (DOF) of the formulation and provide suggestions to the company based on the obtained DOF.

[12 marks]

b. A sensitivity report has been generated as shown in **TABLE Q3b**. Analyse the effect of changes in a binding and non-binding constraints to the optimal solution.

TABLE Q3b: Sensitivity Report

Constraint	Status
1	Binding
2	Binding
3	Not Binding
4	Not Binding
5	Binding
6	Not Binding

[8 marks]

4. Plant B is conducting an optimization study to fully utilize the available area for their small storage space. The dimensions of the available area are given in **FIGURE Q4**, where x and y are the length and the width of the area in meters. Using the Lagrange multiplier method, determine the dimensions of the area subject to the constraint equation as follows

$$4000x^2 + 9000y^2 = 36 \times 10^6$$

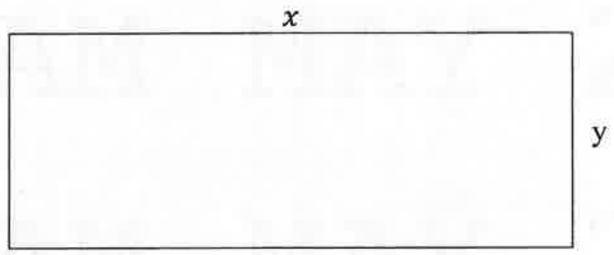

FIGURE Q4: Cross-sectional of available area in Plant B

[25 marks]

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