



UNIVERSITI KUALA LUMPUR
MALAYSIA INSTITUTE OF CHEMICAL AND BIOENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE	: CLB22203
COURSE NAME	: NUMERICAL METHODS IN CHEMICAL ENGINEERING
PROGRAMME NAME	: BACHELOR OF CHEMICAL ENGINEERING TECHNOLOGY
DATE	: 27 JANUARY 2026
TIME	: 9.00 AM – 12.00 PM
DURATION	: 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please **CAREFULLY** read the instructions given in the question paper.
2. This question paper consists of **FIVE (5)** questions. Answer **ONLY FOUR (4)** questions.
3. Write your answers in the answer booklet provided.
4. Answer all questions in English language **ONLY**.
5. Formula table has been appended for your reference.

THERE ARE 4 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

(Total: 100 marks)

INSTRUCTIONS: Answer Four Questions Only.

Use at least 4 decimal places for all calculations.

Please use the answer booklet provided.

Question 1 (done)

Evaluate the root of $f(x) = x^3 - e^{-x}$ by using:

- (a) the bisection method. Start with $a = 0$ and $b = 1$, and calculate until x_5 .
(13 marks)
- (b) the secant method. Start with these two points, $x_1 = 0$, and $x_2 = 1$, and calculate until x_5 .
(6 marks)
- (c) Newton Raphson's method. Start at $x_1 = 0$, and calculate until x_5 .
(Hint: $f'(x) = 3x^2 + e^{-x}$)
(6 marks)

Question 2

Given below is a system of linear equations.

$$4x + y = 4 - z$$

$$x + z = 6 - 5y$$

$$y + 6z = 7 - x$$

- (a) Determine whether the system is diagonally dominant. Proof it.
(6 marks)
- (b) Rewrite the equations following the Gauss-Seidel iterative method.
(6 marks)

- (c) Hence, solve the equations (until $n = 3$) and complete the table below. No need to show detailed calculations.

n	x	y	z	Maximum Error
0	0	0	0	—
1				
2				
3				

(12 marks)

- (d) Write down the solutions.

(1 mark)

Question 3

- (a) A manufacturing company wants to predict the daily production output (y) based on two factors:

- x_1 : Number of skilled workers
- x_2 : Number of machine operating hours

The following data were collected over five days:

Day	x_1	x_2	y
1	2	4	50
2	3	6	65
3	5	5	78
4	6	8	95
5	8	7	110

- Determine the multiple linear regression model that best fits the data.
(12 marks)
- From the model, calculate the production output when $x_1 = 7$ and $x_2 = 6$.
(2 marks)

- (b) The temperature ($^{\circ}\text{C}$) along a thin metal rod varies with a distance x (m) according to the model:

$$T(x) = 2.5x^3 - 1.2x^2 + 0.8e^{0.5x} + 10$$

The rate of change of temperature with respect to distance is required at a specific location to assess thermal stress. Using $h = 0.4$, calculate the first derivative $T'(x)$ at $x = 1.0$, using:

- i. forward difference formula $O(h)$.
(4 marks)
- ii. centered difference formula $O(h^2)$.
(7 marks)

Question 4

- (a) A factory produces goods over a 24-hour production cycle. Its emissions rate of CO_2 (in kg/hour) varies with time due to changes in machinery load and energy use, modeled by:

$$E(t) = 50 + 20 \sin\left(\frac{\pi t}{12}\right) + 10 \cos\left(\frac{\pi t}{6}\right)$$

Where t is the time in hours. Estimate the total CO_2 emissions over the 24-hour cycle:

$$Q = \int_0^{24} E(t) dt$$

Using the following methods:

- i. Multiple Simpson's 1/3 with 12 subintervals.
(5 marks)
 - ii. Multiple Simpson's 3/8 method with 12 subintervals.
(5 marks)
- (b) Consider the first-order ODE:
- $$\frac{dy}{dx} = yx - x^3, \quad 0 \leq x \leq 1.8, y(0) = 1$$
- i. solve the ODE using Euler's method with $h = 0.6$.
(9 marks)

- ii. analytical solution of the ODE is

$$y = x^2 - e^{\frac{x^2}{2}} + 2$$

Calculate the percent relative error between the analytical and numerical solutions. Complete the table below.

x	y_{exact}	$y_{Euler's}$	% Relative Error
0.6			
1.2			
1.8			

(6 marks)

Question 5

A package of seafood is removed from a refrigerated truck and placed in a warehouse. We need to track its temperature rise to ensure it does not exceed safety limits.

- Initial temperature (T_0): 4°C (temperature inside the truck).
- Ambient temperature (T_a): 25°C (temperature of the warehouse).
- Exposure duration: 10 minutes.
- Freshness threshold: The seafood must stay below 10°C to remain fresh.

The temperature change is modeled by Newton's Law of Cooling.

$$\frac{dT}{dt} = -k(T - T_a)$$

Where:

- T is temperature of the seafood at time t ,
 - T_a is the ambient temperature,
 - $k = 0.05$ is a positive constant.
- (a) Calculate the temperature of the seafood from $t = 0$ to $t = 10$ minutes. Use Euler's method with a step size $h = 1$ minute.
- (b) Based on your calculations, how fast must the seafood be returned to refrigeration to ensure it never exceeds the 10°C freshness limit?

(22 marks)

(3 marks)

END OF EXAMINATION PAPER

FORMULAE TABLE

Percent Relative Error:

$$\varepsilon_t = \left| \frac{\text{current approximation} - \text{previous approximation}}{\text{current approximation}} \right| \times 100\%$$

$$\varepsilon_t = \left| \frac{\text{Exact Value} - \text{Approximate Value}}{\text{Exact Value}} \right| \times 100\%$$

Bisection Method:

$$x_m = \frac{x_a + x_b}{2}$$

Newton-Raphson Method:

$$x_{i+1} = x_i - \frac{f(x_i)}{f'(x_i)}$$

Secant Method:

$$x_{i+1} = x_i - \frac{f(x_i)(x_i - x_{i-1})}{f(x_i) - f(x_{i-1})}$$

Finite Difference Formulas:

(a) First Derivatives:

Forward $O(h)$:	$f'(x) \approx \frac{f(x+h) - f(x)}{h}$
Backward $O(h)$:	$f'(x) \approx \frac{f(x) - f(x-h)}{h}$
Central $O(h^2)$:	$f'(x) \approx \frac{f(x+h) - f(x-h)}{2h}$
Forward $O(h^2)$:	$f'(x) \approx \frac{1}{2h} [-f(x+2h) + 4f(x+h) - 3f(x)]$
Backward $O(h^2)$:	$f'(x) \approx \frac{1}{2h} [3f(x) - 4f(x-h) + f(x-2h)]$
Central $O(h^4)$:	$f'(x) \approx \frac{1}{12h} [-f(x+2h) + 8f(x+h) - 8f(x-h) + f(x-2h)]$

b) Second Derivatives:

Forward $O(h)$:	$f''(x) \approx \frac{1}{h^2} [f(x) - 2f(x+h) + f(x+2h)]$
Backward $O(h)$:	$f''(x) \approx \frac{1}{h^2} [f(x-2h) - 2f(x-h) + f(x)]$
Central $O(h^2)$:	$f''(x) \approx \frac{1}{h^2} [f(x+h) - 2f(x) + f(x-h)]$

Euler's Method:

$$y_n = y_{n-1} + hf(x_{n-1}, y_{n-1})$$

Heun's Method:

$$y_{n+1}^0 = y_n + f(x_n, y_n)h$$

$$y_{n+1} = y_n + \frac{f(x_n, y_n) + f(x_{n+1}, y_{n+1}^0)}{2}h$$

Ralston's Method:

$$y_{n+1} = y_n + \left(\frac{1}{3}k_1 + \frac{2}{3}k_2 \right)h$$

$$k_1 = f(x_n, y_n), \quad k_2 = f\left(x_n + \frac{3}{4}h, y_n + \frac{3}{4}k_1h\right)$$

4th Order RK Method:

$$y_{n+1} = y_n + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)h$$

$$k_1 = f(x_n, y_n), \quad k_2 = f\left(x_n + \frac{1}{2}h, y_n + \frac{1}{2}k_1h\right)$$

$$k_3 = f\left(x_n + \frac{1}{2}h, y_n + \frac{1}{2}k_2h\right), \quad k_4 = f(x_n + h, y_n + k_3h)$$

Multiple Simpson's 1/3 Rule:

$$\int_{x_a}^{x_b} f(x) dx \approx \frac{h}{3} [f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + \cdots + 4f(x_{n-3}) + 2f(x_{n-2}) + 4f(x_{n-1}) + f(x_n)]$$

Multiple Simpson's 3/8 Rule:

$$\int_{x_a}^{x_b} f(x) dx \approx \frac{3h}{8} [f(x_0) + 3(f(x_1) + f(x_2) + \cdots + f(x_{n-2})) + 2(f(x_3) + \cdots + f(x_{n-3})) + f(x_n)]$$

Linear Regression:

$$y = a + bx$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}$$

$$a = \frac{\sum y}{n} - \frac{b \sum x}{n}$$

Polynomial Regression:

$$y = a + bx + cx^2$$

$$\sum y = an + b \sum x + c \sum x^2$$

$$\sum xy = a \sum x + b \sum x^2 + c \sum x^3$$

$$\sum x^2y = a \sum x^2 + b \sum x^3 + c \sum x^4$$

Multiple Linear Regression:

$$y = a + bx_1 + cx_2$$

$$\sum y = an + b \sum x_1 + c \sum x_2$$

$$\sum x_1y = a \sum x_1 + b \sum x_1^2 + c \sum x_1x_2$$

$$\sum x_2y = a \sum x_2 + b \sum x_1x_2 + c \sum x_2^2$$

