INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End-Autumn Semester Examination 2023-24

Subject Name: Computer aided Process Engineering — Full Marks: 50

Subject No.: CH31203 — Duration: 3 hr

Department: Chemical Engineering

Specific charts, graph paper, log book etc., required: No

Instructions:

1. Attempt all questions
2. Assume, if necessary, clearly stating the reason
3. Answer all parts of a question together

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1. A typical traffic flow in a network of various one-way streets is illustrated in Figure 1. As shown, there are total four intersections or junction points (also called nodes), namely J_1, J_2, J_3 and J_4. All the numbers given in this figure represent the flow of number of vehicles per minute. Further, arrows show the direction of traffic flow.

(i) Derive the system of algebraic equations.

(ii) Find the five unknowns x_1 through x_5 (where, x = number of vehicles/min) by using a suitable direct method. **[2.5+7=9.5]**

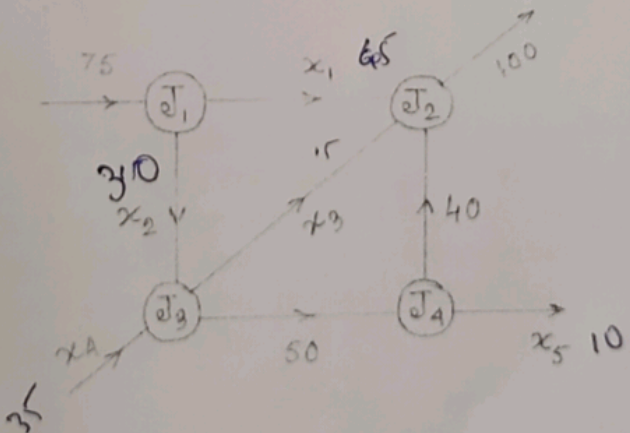

Figure 1. Traffic flow in a network.

2. Solve the following equation: **[3×2+2=8]**

$f(x) = x^{10} - 1$

for the two guess values of 0 and 1.3.

(i) Produce the results of both Bisection and False Position methods for five iterations.

(ii) Which method shows better convergence and why?

3. (i) Highlight the four basic differences between IVP and BVP problems.

(ii) The position (x) and velocity (υ) of the free-falling bungee jumper are represented as:

$$\frac{dx}{dt} = f_1(t, x, \upsilon) = \upsilon$$

[2+(1+7)=10]

$$\frac{d\upsilon}{dt} = f_2(t, x, \upsilon) = g - \frac{c_d}{m}\upsilon^2$$

In which, the gravitational acceleration (g) = 9.81 m/sec^2, the jumper mass (m) = 68.1 kg and the drag coefficient (c_d) = 0.25 kg/m. Report the RK4 formulation and use this method to solve the problem with adopting $x = \upsilon = 0$ at time (t) $= 0$ sec. Integrate to $t = 6$ sec with a step size of 2 sec.

4. One – dimensional heat conduction problem is illustrated in Figure 2. Here, A denotes the heat transfer area, l the slab length, q the heat transfer rate and $\dot{q}$ the rate of heat generation per unit volume.

(i) Adopting suitable assumptions, develop the unsteady state heat conduction model. **[4+6=10]**

(ii) Develop the detailed solution methodology for this IBVP with adopting suitable conditions having no heat generation.

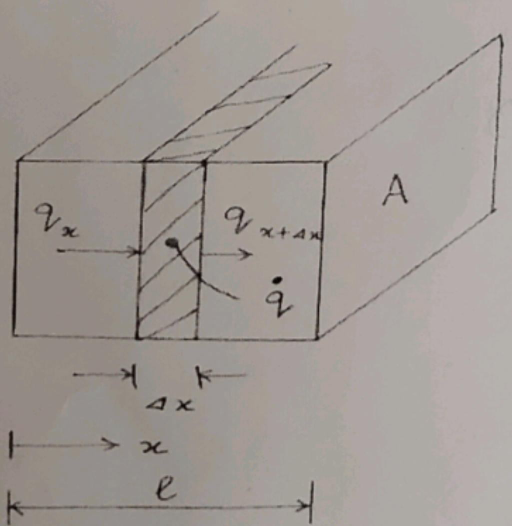

Figure 2. An elemental volume for one – dimensional heat conduction problem.

5. (8 marks) Use the following data to fit a linear least square model. Estimate the uncertainty in slope and intercept. For $T = 61$, estimate the value of t using the model and estimate the uncertainty on your estimate.

Time (t, s)	7.0	7.5	8.0	8.5	9.0	9.5
Temp (T,^{o}C)	53.5	56	58	59	62	64

$$
\begin{aligned}
\hat{q}_o &= mq_i + b \\
m &= \frac{N\sum q_i q_o - \sum q_i \sum q_o}{N\sum q_i^2 - (\sum q_i)^2} \\
b &= \frac{\sum q_o \sum q_i^2 - \sum q_i q_o \sum q_i}{N\sum q_i^2 - (\sum q_i)^2} \\
s_m^2 &= \frac{NSq_o^2}{N\sum q_i^2 - (\sum q_i)^2} \\
s_b^2 &= \frac{\sum q_i \times Sq_o^2}{N\sum q_i^2 - (\sum q_i)^2} \\
sq_o^2 &= \frac{1}{N-2}\sum \left[(mq_i + b) - q_o\right]^2 \\
sq_i^2 &= \frac{sq_o^2}{m^2}
\end{aligned}
$$

.5.5.5

6. (4.5 marks) A well mixed tank of volume V has an inlet and outlet. This tank contains pure water at the beginning. At $t = 0$, we start pumping a dye solution to this tank at a constant volumetric rate F. The concentration of dye in the inlet (C_o)varies according to a specified function $\gamma(t)$. Formulate a DAE [Please note that no credit will be given for any other type of formulation] to describe the variation of tank concentration C. Write the implicit Euler scheme for solving the system of DAE.

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