Numerical/Computational Methods

1. Consider a system of simultaneous linear, algebraic equations as:

$$
\begin{aligned}
2x_1 + 3x_2 + 3x_3 + x_4 &= 1 \\
x_1 + 2x_2 - 1x_3 &= 2 \\
-x_1 - x_2 + 2x_3 + 2x_4 &= 3 \\
4x_1 + 2x_2 + x_3 + 5x_4 &= 1
\end{aligned}
$$

   Solve for x_1, x_2, x_3, x_4 using any numerical method of your choice.

2. Consider a system of nonlinear, coupled ordinary differential equations:

$$
\begin{aligned}
\frac{dx_1}{dt} &= 2 - 3\sqrt{x_1 - x_2} \\
\frac{dx_1}{dt} &= 3\sqrt{x_1 - x_2}
\end{aligned}
$$

   with t being time in seconds. Starting from initial conditions: $x_1 = 10, x_2 = 0$ at $t = 0$ seconds, perform one step of numerical integration using any method of your choice.

3. Define eigenvalues+eigenvectors of a matrix and compute them for the following matrix:

$$
A = \begin{bmatrix} 1 & 2 \\ 2 & 2 \end{bmatrix}
$$

4. The boiling point of several homologous hydrocarbons is available as in Table 1. We want to fit a straight line relationship between boiling point and number of carbon atoms. Discuss an procedure/method to obtain the intercept and slope of the straight line.

Process Control

1. Given a transfer function $G(s)$ of a process, explain the following:
   (a) How can one determine if the process is stable?
   (b) For a stable process, given a step input of magnitude Δu, how would you determine the final (steady state) value of the response $y(t)$?

2. Write down the PID control law in time domain, i.e. write the relationship between errors $e(t)$ (defined as differences in the set point and actual output at time t) and manipulated variable $u(t)$ (output of controller).

Table 1: Boiling points

Compound	Number of carbon atoms	Boiling point ^{0}C
Methane	1	-162
Ethane	2	-88
Propane	3	-42
n-Butane	4	1
n-Pentane	5	36
n-Hexane	6	69
n-Heptane	7	98
n-Octane	8	126

3. For a process with unknown transfer function, explain how can a first order transfer function approximation be obtained?
4. Draw a block diagram of a closed loop with feedback control, showing elements typically involved in the closed loop.

Chemical Reaction Engineering

1. Consider a CSTR of volume 1 m^3 into which inlet reactant stream of density 50 kg/m^3 is flowing at a mass flow rate of 100 kg/s. Compute the residence time of the reactor.
2. Consider a recycle reactor. Discuss the limiting behaviour of the reactor (i.e. does it tend to PFR or CSTR) as the reflux ratio is varied from 0 to ∞.
3. Consider a liquid phase, first order reaction ($A \rightarrow B$) with rate constant k=4 min^{-1} occurring in a CSTR under steady state conditions. If the inlet and outlet concentrations of the reactant are 0.1 mol/lit and 0.02 mol/lit, respectively, then find the residence time of the reactor.
4. The rate of reaction doubles when the temperature is increased from 400 to 410 K. What can you say about the activation energy of the reaction?

Fluid Mechanics

1. A variable speed centrifugal pump is used to pump water from a sump that is at an elevation below the pump. It is observed that as the height between the sump and the pump is increased the pump begins to show abnormal behavior. Firstly there is an irregular noise as though something is banging the pump casing from inside. With further increase in the height the pump fails to deliver any liquid at its outlet. If however, the height is reduced the pump resumes normal operation. It is also observed that at a given height, there is less sound at higher flow rate, which can be controlled using the RPM of the pump. Discuss possible reasons for this behavior.
2. If the atmospheric pressure at the sea level is 1 bar what is the approximate pressure at a height 200 m above sea level, assuming isothermal atmosphere.
3. What's the pressure inside a gas bubble of radius a, if the pressure outside is P_o and the surface tension is γ?
4. The drag on a spherical particle of radius a in irrotational flow and in stokes flow respectively is (η is the fluid viscosity)

A. 0 and $6\pi\eta a$	B. $6\pi\eta a$ and 0	C. $6\pi\eta a$ and $6\pi\eta a$	D. $4\pi\eta a$ and $6\pi\eta a$.	E. 0 and 0.

Mass Transfer

1. A cooling tower was guaranteed by the manufacturer, based on test data to cool water, at a given mass flow rate, from 43^oC to 25^oC in the monsoon, using ambient air. But the guarantee did not work during an actual run, even when the fan was run at full capacity. Discuss the possible reasons for this?
2. In a leaching operation, various methods (increasing agitation, increasing contact time, etc.) to increase the leach solution concentration did not work and a constant leach solution concentration was obtained. Discuss the possible reason for this behaviour.
3. Your friend, standing at a distance L from you, opens a perfume bottle. If D is the diffusivity of the perfume, what is the approximate time after which you will smell it? Assume that the mass transport occurs solely by diffusion.

Bio Related Questions

1. Plot substrate concentration versus enzyme reaction rate for a typical Michelis-Menton process.

2. Discuss some common mechanisms used by bacteria to regulate their metabolic pathways?

3. What experimental method/instrument would you use to measure the following quantities:

    (a) Secreted cytokine

    (b) Intracellular protein concentration in a blood cell

    (c) Compartmental protein concentration in skin cells

    (d) Number of copies of an RNA

4. How would you create a phosphate buffer?

Theromdynamics

1. State the first and second law of thermodynamics

2. Consider a chemical reaction that has reached equilibrium. To obtain the condition for equilibrium, one sometimes maximizes entropy and at other times minimizes Helmholtz or Gibbs free energy. Explain when you would apply the three conditions.

3. Explain the workings of standard Carnot engine. What is it's efficiency?