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B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

July 2023 Semester End Main Examinations

Program: B.E. **Semester: VI**
Branch: Chemical Engineering **Duration: 3 hrs.**
Course Code: 19CH6DELD1 **Max Marks: 100**
Course: Numerical Techniques in Chemical Engineering **Date: 12.07.2023**

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

			CO	PO	Marks
		UNIT – I			
1	a)	The following equation gives the internal energy of a certain substance. $$u = 3.64Pv + 90$$ where, u in kJ/kg, v in m^3/kg. A system composed of 3.5 kg of this substance expands from an initial pressure of 500 kPa and a volume of 0.25 m^3 to a final pressure 100 kPa in a process in which pressure and volume are related by the following relation: $$Pv^{1.25} = \text{constant}$$ Find Q, ΔU, and W for the process.	*CO1*	*PO2*	**05**
	b)	A finned (pin fin) pipe having wall temperature 95°C dissipating heat in the environment of temperature 60°C. If the fin tip is insulated, then find the temperature at the tip of the fin. Data: Thermal conductivity= 32 W/m^{0}C, fin length = 60 mm, fin diameter = 12 mm, and heat transfer coefficient = 55 W/m^2 °C.	*CO2*	*PO3*	**05**
	c)	Equilibrium still is purifying benzene and toluene from a small amount of essentially non – volatile impurity. It is initially charged with 20 moles of feed stock of composition x_f = 0.32 mole fraction of benzene. Feed is supplied at a rate of 10 moles per hour. The heat input is adjusted so that the total mole of the liquid in the still remains constant. It is desired to estimate the time required for composition of the overhead product rise to 0.4 mole fraction benzene. The relative volatility of benzene and toluene, α, is 2.48.	*CO1*	*PO2*	**10**
		UNIT – II			
2	a)	Derive temperature profile and heat transfer rate for a steady state multilayer cylinder of constant thermal conductivity.	*CO2*	*PO3*	**06**

	b)	The first order reaction in series is given by the following relation: $$A \xrightarrow{k_1} R \,;\, R \xrightarrow{k_2} S$$ This reaction takes place in a batch reactor starting with pure A. (i) Develop the differential equations in terms of the concentrations C_A, C_R and C_S. (ii) Solve the above equation to find C_R (t).	*CO2*	*PO3*	**10**
	c)	A closed kettle of total surface area A m^2 is heated through this surface by condensing stream at Ts ^{0}C. The kettle is charged with 'm' kg of a liquid at T_0 °C. If the process is controlled by a heat transfer coefficient 'U' W/m °C, how does the temperature vary with time? Assume the teat transfer coefficient is constant.	*CO2*	*PO3*	**04**
		UNIT – III			
3	a)	Diffusion and reaction takes place in a pore of 1 mm in length. The rate constant of the reaction, k = 10^{-3} s^{-1} and the effective diffusivity of species is 10^{-9} m^2/s. Make 5 parts of the pore and determine the concentration at x = 0.6 mm. The concentration at the surface of the mouth of the pore is 1 mol/m^3.	*CO5*	*PO2*	**12**
	b)	Air at 35°C and 1 atm flows through a 3.5 mm diameter tube with an average velocity of 35 m/s. The roughness, ε, is 0.0014 mm. Calculate the friction factor using following equation: $$\frac{1}{\sqrt{f}} = -2log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$ Density of air at 35°C and 1 atm is 1.1455 kg/m^3 and viscosity is 1.895×10^{-5} kg/m s. Apply Newton-Raphson method with initial guess of 0.02 and find friction factor. Determine the result after 2 iterations.	*CO5*	*PO2*	**08**
		OR			
4	a)	Consider a stirred tank heater. It is a 0.5 m tank on its side and 2 m high and is filled with water at 25°C. Water is fed to the tank at a flow rate of 2 L/s and exits out at the same flow rate from the top of the tank. The temperature of the inlet water is 25°C. At time t = 0 s, water in the tank is heated by a coil containing steam whose overall heat transfer coefficient based on the outer area of the coil is 250 W/m^2 K. The outside area of the coil through which heat exchange takes place is 1.5 m^2. The temperature of the steam is 250°C. The specific heat capacity of water is 4184 J/kg K. Find exit water temperature after 10 s using any numerical technique assuming the step length, h =10 s.	*CO5*	*PO2*	**08**
	b)	Consider one-dimensional steady state conduction without heat generation taking place in a rectangular slab. The temperature of the left side of the slab is 150°C and of the right side is 250°C. The length of the slab is 6 cm and the thermal conductivity of the slab	*CO5*	*PO2*	**12**

			is 150 W/cm K. Make five uniform divisions. The governing equation is as given below: $$k\frac{d^2T}{dx^2} = 0$$ Apply discretization method and find TDMA matrix. Solve the matrix and find the temperature at different point of the slab.			
			UNIT – IV			
	5	a)	Derive the continuity equation. $$\frac{\partial(\rho u_x)}{\partial x} + \frac{\partial(\rho u_y)}{\partial y} + \frac{\partial(\rho u_z)}{\partial z} + \frac{\partial p}{\partial t} = 0$$	*CO3*	*PO3*	**08**
		b)	Obtain the difference equation for a multistage counter current liquid-liquid extraction process and solve the equation.	*CO4*	*PO4*	**12**
			OR			
	6	a)	Formulate partial differential equation for Fick's second law of diffusion. $$D_{AB}\nabla^2 C_A + r_A = v \cdot \nabla C_A + \frac{\partial C_A}{\partial t}$$	*CO3*	*PO3*	**08**
		b)	Find the value of $u(x,t)$ satisfying the parabolic equation. $$\frac{\partial u}{\partial t} = 4\frac{\partial^2 u}{\partial x^2}$$ The boundary conditions are $u(0,t) = u(8,t) = 0$ and $u(x,0) = 4x - \frac{1}{2}x^2$, at points $x = i$: $i = 0,1,2,\ldots,8$ and $t = \frac{1}{8}j$: $j = 0, 1, 2, 3, 4,$ and 5.	*CO5*	*PO2*	**12**
			UNIT – V			
	7	a)	A first order reaction is conducted in a CSTR. Find concentration of component "A" in Laplace domain at outlet of the reactor.	*CO6*	*PO4*	**08**
		b)	Derive the transfer function for a single tank liquid level system.	*CO6*	*PO4*	**08**
		c)	A thermometer having a time constant of 0.1 min is at steady state temperature of 90°C. At time t = 0, the thermometer is placed in a temperature bath maintained at 100°C. Determine the time needed for the thermometer to read 98°C.	*CO6*	*PO4*	**04**

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