NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

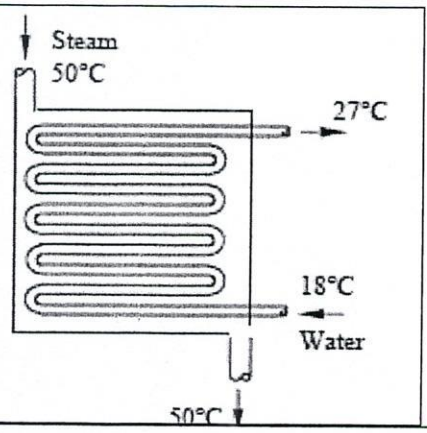
Course Code: CHC401 Full Marks: 30

Course Name: HEAT TRANSFER Time: 90 Minutes

Question Paper No.: NITDGP/CHC401/81 Date of Exam: 25/04/2022

Instructions: Answer all the questions.

Materials to be supplied: Graph paper shall be supplied, if required.

Question No.	Body of the Question	Marks	Mapped CO
1	Nitrogen gas at 2 atm is flowing through the annulus of a double pipe HE made of 25.4 mm OD copper tube [(wall thickness = 2.1 mm, thermal conductivity = 380 W(m.K)] inside a 50.8 mm ID steel pipe. The gas flow is 185 m^3/hr measured at 15^{0}C and 1 atm. Cooling water flows through the copper tube counter current to nitrogen at 1 m/s entering at 10^{0}C. Nitrogen is to be cooled from 120^{0}C to 30^{0}C. The outer surface of copper tube is fitted with 20 longitudinal fins each of height 12.5 mm and thickness 1 mm. Compute the required length of the exchanger, if fouling is expected only inside the copper tube and a minimum dirt factor of 1.75 X 10-4 (m2K)/W has been specified for the same. Maximum permissible pressure drop on tube side and annulus side are 70 kN/m^2 and 20 kN/m^2 respectively. Curve may be supplied as required. Property values: Water (at 12^{0}C) ρ_f = 1000 kg/m^3, μ_f = 1.0 cp, k_f = 0.603 W/(m.K), C_P = 4.178 kJ/(kg.K) Nitrogen C_P = 1.03 kJ/(kg.K) T, K k (W/m.K) μ, c_p 300 0.026 0.018 400 0.0325 0.0223 Assume that the plot of logarithm of viscosity or that of thermal conductivity versus logarithm of absolute temperature is linear. Neglect the effect of pressure on the viscosity and thermal conductivity of nitrogen.	15	CO3
	Answer question number 2 or 3		
2	Steam is condensed by cooling water in the condenser of a power plant. The mass flow rate of the cooling water and the rate of condensation are to be determined. **Assume that:** a. Steady operating conditions exist. b. The heat exchanger is well-insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. c. Changes in the kinetic and potential energies of fluid streams are negligible. 	5	CO2

Course Outcomes

CO1: Illustrate principles and laws of heat transfer of different heat exchanging phenomena

CO2: Solve heat transfer problems of different difficulty levels

CO3: Design and analyze heat transfer equipment

	d. There is no fouling e. Fluid properties are constant The heat of vaporization of water at 50°C is given to be = 2383 kJ/kg and specific heat of cold water at the average temperature of 22.5°C is given to be C_p= 4180 J/kg°C			
3	A counter-flow heat exchanger with one tube pass and one shell pass is used to recover heat from an oil stream at 110^0C. The exchanger and fluid properties are given below. Estimate the outlet oil temperature. m_h=3,000 kg/h $T_{ha} = 110^0$Ccph= 2,300 J/kg^{0}C m_c=2,400 kg/h T_{ca}=25^{0}C c_{pc}= 4,180 J/kg^{0}C U A = 1.65×10^7 W/ ^{0}C		5	CO2
4	Write short notes on the following terms a) Baffle requirement. b) Tube pitch of a shell and tube heat exchanger. c) Film wise condensation provides lesser heat tr. Coefficient than drop wise: why? d) Nusselt Number and its importance? e) State Wien's displacement law and Kirchoff's law		10	CO1

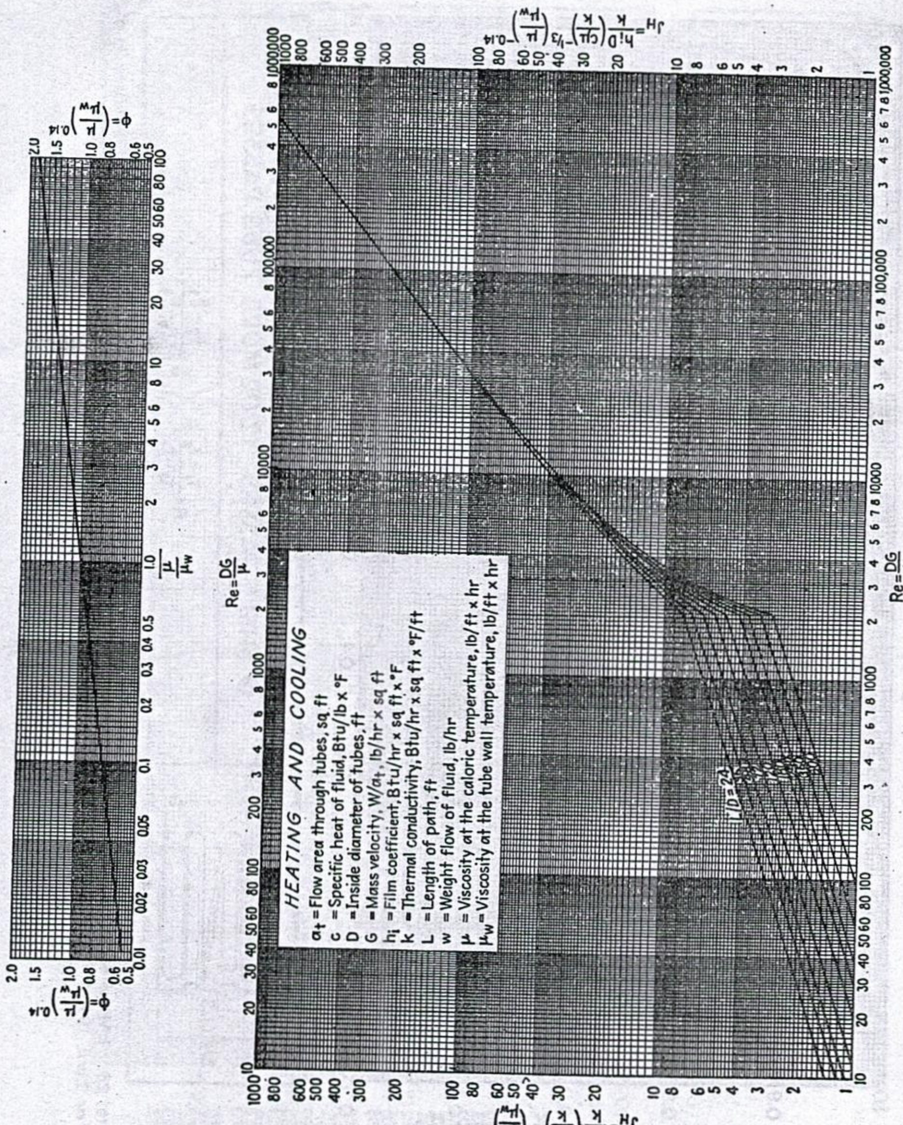


Fig. 24. Tube-side heat-transfer curve. (*Adapted from Sieder and Tate.*)

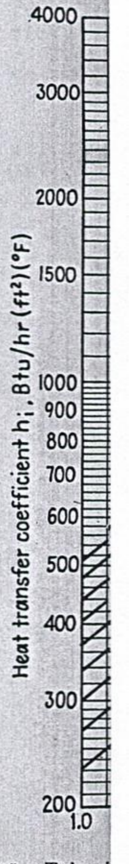


Fig. 25. Tube-si
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NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC402 Full Marks: 30

Course Name: Mechanical Operation Time: 90 Minutes

Question Paper No.: NITDGP/ CHC402/৭ Date of Exam: 26/04/2022

Instructions: Answer all the questions.

Materials to be supplied: Graph paper shall be supplied, if required.

Question No.	Body of the Question	Marks	Mapped CO
1.a)	In constant pressure filtration, the rate of filtration follows the relation V=filtrate volume, t=time, K and C = Constant (a) $\frac{dV}{dt} = (KV + C)$, (b) $\frac{dV}{dt} = \frac{1}{(KV+C)}$, (c) $\frac{dV}{dt} = KV$ (d) $\frac{dV}{dt} = KV^2$	2	CO1
1. b)	A centrifugal filtration unit operates at a rotational speed of 'ω' has inner surface of the liquid (density 'ρ_L') located at a radial distance 'R' from the axis of rotation. The thickness of the liquid film is 'δ' and no cake is formed. The initial pressure drop during filtration is (a) $\frac{1}{2}\omega^2 R^2 \rho_L$, (b) $\frac{1}{2}\omega^2 \delta^2 \rho_L$, (c) $\frac{1}{2}\omega^2 \delta \rho_L (2R + \delta)$, (d) $\frac{1}{2}\omega^2 R \rho_L (R + 2\delta)$	2	CO1
1. c)	For a cyclone of diameter 0.2 m with a tangential velocity of 15 m/s at the wall, the separation factor is (a) 2250, (b) 1125, (c) 460, (d) 230	2	CO2
1. d)	A filtration is conducted at constant pressure to recover solids from dilute slurry. To reduce the time of filtration, the solid concentration in the feed slurry is increased by evaporating half the solvent. If the resistance of the filter medium is negligible, the filtration time will be reduced by a factor of (a) 1, (b) 2, (c) 4, (d) 8	2	CO2
1. e)	A centrifuge of diameter 0.2 m in a pilot plant rotates at a speed of 50 Hz in order to achieve effective separation. If the centrifuge is scaled up to a diameter of 1 m in the chemical plant and the same separation factor is to be achieved, what is the rotational speed of the scaled up centrifuge? (a) 15 Hz, (b) 22.36 Hz, (c) 30 Hz, (d) 44.72 Hz	2	CO2
2	With neat sketches, describe the batch sedimentation test required to design the gravity sedimentation tank	4	CO2
3	A rotary drum vacuum filter having 40% submergence of the drum in the slurry is to be used to filter a $CaCO_3$ slurry using a pressure drop of 60 kPa. The solid concentration in the slurry is 0.2 kg solid/kg slurry and the filter cake is such that the ratio of wet cake to dry cake is 1.9. Density and viscosity of filtrate are 970 kg/m^3 and 0.88×10^{-3} Pa.s, respectively.	4	CO2

- **CO1:** Identify principles of separation of liquid-solid, gas-solid, and solid-solid
- **CO2:** Design and analyze mechanical operation equipment
- **CO3:** Compare performances and select type of size separation, solid-liquid separation and size reduction equipment
- **CO4**: Learn industrial applications of size separation, solid-liquid separation, size reduction equipment

	Specific cake resistance α may be taken as $5 \times 10^9 \times (-\Delta P)^{0.3}$ where $(-\Delta P)$ is in Pa and α in m/kg. If the filter cycle time is 300 s, calculate the filter area needed to filter 0.83 kg slurry/s.		
4	Distinguish between gravity sedimentation and centrifugal sedimentation with suitable examples.	4	CO3
5	'Jigs are called 'Reverse classification equipment' since 'Consolidation trickling' takes place in 'Jigging operation' – Explain.	4	CO4
6	Discuss the operation of a Plate and Frame Filter Press. With the help of sketches, show the change of liquid path during filtering and washing of a Plate and Frame Filter Press.	4	CO4

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NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC403 Full Marks: 30

Course Name: Mass Transfer I Time: 1½ Hours

Question Paper No.: NITDGP/CHC403/07 Date of Exam: 27/04/2022

Instructions: Answer any ***Five*** questions taking at least two from each group

Graph paper: Graph paper shall be supplied, if required.

Question No.	Body of the Question	Marks	Mapped CO
	Group A		
1	What is Liquid-Liquid extraction? Identify the solute-inert-solvent with a practical example. Describe the salient features and draw a schematic diagram with proper label to show the principle of extraction.	6	CO1
2	Define tie-line in liquid-liquid extraction operation. Show the graphical steps to draw it from the equilibrium data. What is lever arm rule? Show it with labelled diagram.	6	CO2
3	Both distillation and extraction are used for separation of components; identify the situation with two proper examples where liquid-liquid-extraction is preferred over distillation. How to distinguish Extract and Raffinate phase. Discuss the selection criterion of a solvent during liquid-liquid extraction process.	6	CO1
4	During the preparation of caprolactum the caprolactum and $(NH_4)_2SO_4$ both are present in the solution. Discuss the suitable separation technique to separate the caprolactum. Mention the name of process, equipment used, operating conditions, reagents used and any other special information.	6	CO2
	Group B		
5	What do you mean by equilibrium diagram of a ternary system? Classify them as type I and type II. Discuss the effect of temperature on equilibrium diagram for type II system. Hence define the critical solution temperature and discuss its physical significance by a three dimension diagram.	3+3	CO1
6	What is solid-liquid extraction ? State the steps to draw the Ponchon-Savarit diagram. What is its role for solid-liquid extraction problem?	2+4	CO3
7	The equilibrium data for water (A)-acetone (C)-chloroform (B) system are given in table P7. 1.17 kg of chloroform is added to 1 kg aqueous feed containing 20% acetone. Calculate the mass and composition of extract and raffinate phase that will be in equilibrium. Assume single stage	6	CO3
8.	a. Consider the distribution of a solute C in two partially missile liquids- A (carrier) and B (solvent). Calculate the selectivity of separation at plait point b. 100 kg of a 50% solution of C in A (carrier) is in equilibrium with 70 kg of solvent containing 2% of C. At equilibrium the mass of raffinate is 80 kg with 52% A and 8% B in it. Calculate the separation factor of C for a single stage.	2+4	CO3

Course Outcomes
- CO1: Principles of mass transfer for chemical processes
- CO2: Various laws of mass transfer and mass balance of chemical processes
- CO3: Design and analyze mass transfer equipment through problem solution

Table P7

Aqueous phase (mass fraction)				Chloroform phase (mass fraction)		
water	Chloroform	acetone		water	Chloroform	acetone
x_A	x_B	x_C		y_A	y_B	y_C
0.839	0.0123	0.158		0.013	0.701	0.287
0.731	0.0129	0.256		0.022	0.557	0.415
0.623	0.0171	0.361		0.044	0.429	0.527
0.456	0.0511	0.493		0.103	0.284	0.613
0.345	0.0981	0.557		0.186	0.204	0.610

NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC 431 Full Marks: 30

Course Name: Unit Operation of Chemical Engineering- I Time: 90 Minutes

Question Paper No.: NITDGP/CHC 431/1 Date of Exam: 27/04/2022

Instructions:

Q. No.	Body of the Question	Marks	Mapped CO
	Answer any three (03) questions		
1.	a) Write down the 1D heat flux and heat rate equation with explanation. b) Determine the heat transfer through two parallel walls. Take the conductives of B and C as 10 and 6.67 W/mK respectively and assume one dimensional heat transfer. Take of area of B & C = 0.5 m^2. Temperature entering at wall A is 150 ^{0}C and leaving at wall E is 100 ^{0}C. c) Develop the relationship between heat transfer co-efficient: k and h. d) Express the critical Radius of Insulation for Cylinder	10	2,3,5
2.	a) Draw the both boundary layer profiles over a flat plate. b) Steam at T_1= 320 °C flows in a cast iron pipe [k = 80 W/ m.°C] whose inner and outer diameter are D_1= 5 cm and D_2= 5.5 cm, respectively. The pipe is covered with a 3-cm thick glass wool insulation [k = 0.05 W/ m. °C]. Heat is lost to the surroundings at T_2= 5°C by natural convection and radiation, with a combined heat transfer coefficient of h_2= 18 W/m^2 °C. Taking the heat transfer coefficient inside the pipe to be h_1 = 60 W/m^2 °C. i. Determinethe rate of heat loss from the steam per unit length of the pipe. ii. Determine the temperature drop across the pipe shell and the insulation. c) Write down the empirical co-relation for fully developed turbulent flow inside tubes (internal diameter D).	10	2,3,5
3.	a) What is the pitch of a heat exchanger? Mention the layouts of tubes of the heat exchangers. b) How does the magnitude of LMTD compare with the arithmetic average temperature? c) Steam in the condenser of a power plant is to be condensed at a temperature of 30°C with cooling water from a nearby lake, which enters the tubes of the condenser at 14°C and leaves at 22°C. The surface area of the tubes is 45 m^2, and the overall heat transfer coefficient is 2100 W/m^2 · K. Determine the mass flow rate of the cooling water needed and the rate of condensation of the steam in the condenser.	10	2,3,5
4.	a) What is the significance of 'Power law of fluid? Give an account of physical significance of Reynolds no to predict the fluid flow regime. b) The rheological properties of a particular suspension can be approximate reasonably well by either a "power law" or a "Bingham plastic" model and the shear rate range of 10 to 50 s^{-1}. If the consistency coefficient, K is 10 N s n /m^2 and the flow behavior index, n is 0.2 in the power law model. What will the approximate values of the yield stress and of the plastic viscosity in the Bingham plastic model? c) Describe the working principle of any one flow meter.	10	1,5

Course Outcomes

- CA1:To Understand fundamentals of fluid dynamics and mechanics
- CA2:Understanding the fundamentals of heat transfer operations
- CA3:To learn design of heat transfer equipment and calculations
- CA4:To develop knowledge of different mechanical operations and their applications
- CA5:To solve related problems of different difficulty levels through tutorials

B.Tech.(CH)
21-22/Reg

2021-22

TRANSPORT PHENOMENA (CHC601)

Full Marks: 30 **Time: 1.5 Hrs.**

- **Answer Q1 and any three questions from the rest**

Q1. Chlorine is being absorbed from a gas in a small experimental wetted wall tower of 13 cm long and 1.4 cm diameter. The absorbing fluid is water, which is moving with an average velocity of 17.7 cm sec^{-1}. What is the absorption rate? Ignore any chemical reaction between chlorine and water. Given, $D_{Cl2\text{-}H2O}=1.26x10^{-5}cm^2sec^{-1}$ and solubility of chlorine in water is 0.823. Deduce the required expression used for solving the problem staring from finding concentration profile.

(5+7)

Q2. (a) Derive an expression for the temperature distribution T(x) in a viscous fluid in steady laminar flow between large flat parallel plates. Both plates are maintained at constant temperature T_O. Take into account explicitly the heat generated by viscous dissipation. Neglect the temperature dependence of μ and k. (6)

(b) A solid body occupying the space from y=0 to y=α is initially at temperature T_O. At time t=0 the surface at y=0 is suddenly raised to temperature T_1 and maintained at that temperature for t>0. Find the time dependent temperature profiles T (y,t). **(Use equation of energy).** (6)

(c) i) Explain analogy between energy transport and mass transport
ii) Prove that $j_A+ j_B =0$ and define all the terms. (3+3)

(d) A droplet of substance A is suspended in a stream of gas B. The drop (radius r_1) is surrounded by a stagnant gas film (radius r_2). Concentrations of A at r_1 and r_2 are X_{A1} and X_{A2} respectively. Find the radial molar flux of A and if the flux is defined as, $N_{Ar}=k_P(P_{A1}-P_{A2})$, obtain k_P for $r_2 \rightarrow \alpha$.

(6)

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NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC 602
Course Name: Petroleum Refining & Petrochemicals
Question Paper No.: NITDGP/CHC 602/1

Full Marks: 30
Time: 90 Minutes
Date of Exam: 19/04/2022

Instructions:

Q. No.	Body of the Question	Marks	Mapped CO
	Group A: **Answer any two (02) questions (Group A) where all questions carry equal weightage of 10 marks**		
1.	Develop a production scheme in the form of flow diagram for production of Ben-free and Lead-free high-octane gasoline from low octane gasoline stock and describe justifying provision of each unit and accessory.	10	1,2,3,4,5
2.	Develop flow diagram of a building up process for manufacturing high octane motor spirit (MS) stock out of otherwise not-so usable small hydrocarbon molecules. Describe type of reactor used, reactions involved, feeding pattern of the reaction ingredients, special provision of temperature control and product separation.	10	1,2,3,4
3.	Explain necessity of vacuum distillation during crude distillation in a petroleum refinery. In a diagram, show collection of various petroleum products from an ADU of crude petroleum indicating average boiling ranges of such products. How does control system of a distillation column automatically take care of the disturbances due to sudden change of feed stock from a light crude to a heavy crude? Explain the series of events.	10	1,2,4,5
4.	Describe manufacture of lubricating oil with flow diagram.	10	1,2,3
	GROUP-B **Answer any one (01) question (Group B)**		
5.	Mention main feed stocks for petrochemical industry. What is the first petrochemical product in India? Describe about different basic properties of polymer. Compare atactic and iso-tactic configuration of polymer. What is BTX and its major sources in the industry? Explain the production route of Nylon 66 polymer.	10	1,2,3,4
6.	What are the major sources of olefins in the industry? Describe about polymerization processes. Explain and compare about process variables for the production of LDPE, LLDPE and HDPE. What are the applications of PTA (Purified terephthalic acid)? Describe the manufacturing process with process flow diagram of PTA.	10	1,2,3,4

Course Outcomes
CO1: Understanding technical, economic, environmental and international market issues in petroleum refining business
CO2: Understanding correlation of petroleum properties with system design and operation
CO3: Understanding design and safe operation of complex refinery units for various petroleum products
CO4: Knowledge of application of Chemical Engineering Principles in one of most relevant industrial sectors of the economy
CO5: Ignited minds with passion for innovation and sustainable development

NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC603 Full Marks: 30

Course Name: Process Modelling and Simulation Time: 1:30 Hours

Question Paper No.: NITDGP/CHC603 Date of Exam: 21/04/2022

Instructions: All parts of a question must be written in one place. The group name and Question No appear on each page top.

Materials to be supplied: Graph paper shall be supplied, if required.

Group-A			
Question No.	Body of the Question	Marks	Mapped CO
1	a) Write down three dimensional continuity equation and reduced it for steady and incompressible flow. b) What are the dependent variables and independent variables in the Navier-Stokes equations? c) Define Lumped parameter model and distributed parameter models with examples. d) Define and explain degree of freedom of a chemical process. e) What is the main difference between the linear model and nonlinear model? Explain with example?	2×5	CO1
2	a) Consider the exothermic reaction (A → B) taking place in the double pipe plug flow reactor. The fluid is incompressible. Cooling water is circulated in the shell side of the reactor to absorb the excess heat generated for the exothermic reaction. Develop the model equations that describes the concentration and temperature distributing in the plug flow reactor. OR b) Develop the mathematical model for a compartmental distillation column considering variation in liquid holds up in each compartment (including reflux drum and column base). State all the assumptions made by you.	10	CO2
	Group B answer any One (10 Marks)		
3	Provide one example of a process model which will produce the system of non-linear algebraic equation, Boundary value ordinary differential equation and a partial differential equation. Discuss the detail solution steps for any one case stated above	5+5	CO3
4	Consider the following model equation for heating up a small spherical coal particle by the process of heat transfer by convection and radiation. $4000\frac{dT}{dt} = 50(T_M - T) + 4.5 \times 10^{-8}(T_M^4 - T^4)$ The temperature T is (K). at t=0 the particle was at room temperature of 25 ^{0}C and T_M = 500^{0}C. Use a suitable technique to estimate the time dependent temperature profile in graphical presentation. Show the detail calculation for five time steps by choosing a suitable time step.	10	CO4

Course Outcomes

CO1: Understanding the principle of mass, energy and momentum conservation equations.

CO2: Concept of steady state and unsteady state model equations

CO3: Numerical techniques to solve Algebraic, ODE and PDE

CO4: Solution of various model equations and graphical presentation

NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Even Semester End-term Examination, 2021-22

Course Code: CHC631

Course Name: PROCESS CONTROL & INSTRUMENTATION

Full Marks: 30

Question Paper No.: NITDGP/CHC631/ 701

Time: 90 Minutes

Date of Exam: 23/04/2022

Instructions: Answer all the questions.

Materials to be supplied: Graph paper shall be supplied, if required.

Question No.	Body of the Question	Marks	Mapped CO
1	Discuss the 'saturation phenomena' in the Proportional (P) Controller. When a P controller behaves as an on-off controller, and why?	4	CO2
2	When do you recommend using Air to Close and Air to Open valve in any bioprocess/biotechnology? Justify your recommendation with a suitable schematic diagram.	5	CO2
3	Discuss the inherent valve characteristics and find out the relation between the fraction of maximum flow and the stem position for an equal-percentage valve	4	CO2
4	Consider the characteristics equation of the fourth-order system $s4+8s3+18s2+16s+5 = 0$ Check the stability of the system using Routh-Hurwitz criteria.	4	CO2
5	Explain the following terms: Corner frequency, Cross-over frequency, Gain Margin, and Phase Margin graphically.	4	CO3
6	Deduce the amplitude ratio and the phase angle of a PID controller.	4	CO3
7	Draw a Bode plot for the PID controller.	5	CO3

Course Outcomes

CO2: Analyse and apply the knowledge of linear closed-loop systems.

CO3: Develop working knowledge of control system by frequency response