Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL

A Constituent Institution of Manipal University

I SEMESTER M.TECH. (CHEMICAL ENGINEERING)
END SEMESTER EXAMINATIONS, December 2023

SUBJECT: Advanced Control Theory [CHE5114]

REVISED CREDIT SYSTEM

Date: 02/12/2023 Time: 3 Hours (09:30 AM to 12:30 PM) MAX. MARKS: 50

Instruction to Candidates:
- Answer **ALL** questions
- Missing data may be suitably assumed

1A	Analyze the working principles of the cascade control scheme and discuss its merits and demerits.	03
1B	Justify the following argument: Although virtually all physical systems are nonlinear, much of chemical process control focuses on linear systems.	03
1C	Design the steady-state and dynamic feedforward controllers (for disturbance rejection and set point tracking) for the systems with transfer function between manipulation and controlled output *$G_p(s)$* and transfer function between disturbance and controlled output *$G_d(s)$*. Assume *$G_m(s)$* and *$G_v(s)$* =1. $$G_p(s)=\frac{5}{s^2+3s+2}; \qquad G_d(s)=\frac{1}{5s+1}$$ Comment on the designed controller.	04
2A	Justify the inclusion of the Smith predictor scheme to enhance the closed-loop performance in process industries and further assess the design philosophy of the Smith predictor.	03
2B	Examine the various tuning methods that exist in the literature (minimum three) used to design of controllers.	03
2C	Formulate the procedure for designing a de-coupler for 2x2 system in detail, and you are expected to show the block diagram of 2x2 system with a designed de-coupler.	04
3A	The characteristic equation for a specific closed-loop digital control system is given as: $$1+0.2z^{-1}-0.2z^{-2}-0.2z^{-3}+0.5z^{-4}=0$$ Evaluate the stability of the control system using Jury's method.	05
3B	The following sixth-order transfer function was obtained by linearizing the original set of ordinary differential equations used to model an industrial chemical reactor: $$g(s)=\frac{10.3}{(1.5s+1)^5(15s+1)}$$ The indicated time constants are in minutes. To design a practical controller, this model is further simplified to: $$g_1(s)=\frac{10.3\,e^{-7.5s}}{15s+1}$$ Design a controller for this process by direct synthesis, using the transfer function *$g_1(s)$*, for τ_r = 5.0 min. Introduce a first-order Pade's approximation for the delay element *in the controller.* What further approximation will be required in order to reduce the result to a standard PID controller? Can you justify such an approximation?	05
4A	Conclude that Auto Regressive with Exogenous input (ARX) model of the form $$\begin{aligned}y(k) &= b_1u(k-d-1)+\ldots+b_mu(k-d-m)\\ &-a_1y(k-1)-\ldots-a_ny(k-n)+e(k)\end{aligned}$$ able to quantify the deterministic and stochastic components of the form: $$y(k)=G(q^{-1})u(k)+H(q^{-1})e(k)$$	02

4B	Consider the following system $x(k+1)=\begin{bmatrix}1/4 & 1/4\\ -1/4 & 0\end{bmatrix}x(k)+\begin{bmatrix}-2\\ 1\end{bmatrix}u(k)+w(k);\ \ y(k)=\begin{bmatrix}1 & 0\end{bmatrix}x(k)+v(k)$ It is desired to develop a state feed feedback control law of the form $u(k)=-Gx(k)$. Evaluate the controller gain matrix 'G' such that the poles of $(\Phi-\Gamma\mathrm{K})$ are placed at $\lambda=-0.25\pm j0.25$	04
4C	Develop the parameter estimation problem for the output error (OE) model structure given below. You are expected to demonstrate all the steps. $\mathrm{x}(k)=\dfrac{b_1q^{-1}+b_2q^{-2}}{1+a_1q^{-1}+a_2q^{-2}}\mathrm{q}^{-1}\mathrm{u}(k)\ ;\ \ \mathrm{y}(k)=\mathrm{x}(k)+\mathrm{v}(k)$	04
5A	Consider a recursive estimator of the form $\hat{\mathrm{x}}(k+1)=\Phi\hat{\mathrm{x}}(k)+\Gamma\mathrm{u}(k)+\mathrm{Le}(k)$ Where estimation error *(e(k)* is defined as $\mathrm{e}(k)=\mathrm{y}(k)-C\ \hat{\mathrm{x}}(k)$ $=\mathrm{y}(k)-\hat{\mathrm{y}}(k)$ and true process dynamics (deterministic case) as $x(k+1)=\Phi\ x(k)+\Gamma\ u(k)$ $y(k)=C\ x(k)$ Evaluate an estimator gain matrix (***L***) such that an estimation error reduces to zero as quickly as possible and justify the answer.	03
5B	Consider a system $x(k+1)=\Phi\ x(k)+\Gamma\ u(k)+H\ \ d(k)$ $y(k)=C\ x(k)$ The above system is observable if the initial state can be uniquely estimated from output observations. Prove that the initial state can be uniquely estimated from measurements of inputs and outputs if the following rank condition is satisfied.. $rank\begin{bmatrix}C & C\Phi & C\Phi^2 & \ldots & .. & C\Phi^{n-1}\end{bmatrix}^T=n$ Where *'n'* state dimension	03
5C	Formulate the parameter estimation problem for third order Auto Regressive with Exogenous input (ARX) model with d=1 as linear least square parameter estimation problem. $\mathrm{y}(k)\ +a_1y(k-1)+a_2y(k-2)+a_3y(k-3)=b_1u(k-2)+b_2u(k-3)+b_3u(k-4)+e(k)$	04

****