

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular), Nov.-Dec. 2015
B. Tech in EE Engineering, Semester VII

Roll No.....

COURSE CODE: EE726

Time: 3 hours

Max. Marks: 100

COURSE TITLE: Advanced PID control

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

10

- i. In exponential series form the state transition matrix is
(a) $e^{-[A]t}$ (b) $e^{[A]t}$ (c) $e^{[A]}$ (d) $e^{-[A]}$
- ii. For second order system with an initial condition of $\begin{bmatrix} 1 \\ 2 \end{bmatrix}$ without any external input, the state transition matrix for the system is given below:

$$\Phi(t) = \begin{bmatrix} e^{-2t} & 0 \\ 0 & e^{-t} \end{bmatrix}$$

The state of the system at the end of one second is

- (a) $\begin{bmatrix} 0.135 \\ 0.735 \end{bmatrix}$ (b) $\begin{bmatrix} 0.135 \\ 0.368 \end{bmatrix}$ (c) $\begin{bmatrix} 0.271 \\ 0.735 \end{bmatrix}$ (d) $\begin{bmatrix} 0.135 \\ 1.47 \end{bmatrix}$
- iii. With reference to state space representation of the equation,

$$\frac{d^2y(t)}{dt^2} + \frac{2dy(t)}{dt} + 3y(t) = u(t). \text{ The matrices A}$$

and B are,

(a) $A = \begin{bmatrix} 0 & 1 \\ -3 & -2 \end{bmatrix}; B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

(b) $A = \begin{bmatrix} -2 & -3 \\ 0 & 1 \end{bmatrix}; B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

(c) $A = \begin{bmatrix} 0 & -2 \\ 1 & -3 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

(d) $A = \begin{bmatrix} -2 & 0 \\ 1 & -3 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

- iv. A control system represented by $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$

and $y = [1 \ 1] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ the transfer function is

(a) $\frac{s}{s+1}$

(b) $\frac{1}{s+3}$

(c) $\frac{1}{s+1}$

(d) $\frac{s}{s^2+4s+3}$

- v. The state model is given as $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$. If the input is unit step, the time response is

(a) undamped

(b) under damped

(c) critically damped

(d) over damped

vi. An autonomous state equation is $\dot{x} = [A][x]$ where, $[A] = \begin{bmatrix} 0 & 2 \\ 8 & 0 \end{bmatrix}$. the poles are located at

(a) $j4, -j4$

(b) $-4, 2$

(c) $j2, -j2$

(d) $-8, 4$

vii. The characteristic equation for a system having state equation

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 4 \\ -2 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u \text{ is}$$

(a) $s^2 + 5s + 8 = 0$

(b) $s^2 + 4s + 3 = 0$

(c) $s^2 + 4s + 5 = 0$

(d) $s^2 + 4s + 2 = 0$

viii. For the system $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 2 & 0 \\ 0 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} r(t)$ and $y = \begin{bmatrix} 4 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$

Where $r(t)$ is a unit impulse function. Having initial conditions as nil, the output y is determined as...

(a) $y(t) = 2e^{2t}$

(b) $y(t) = 4e^{2t}$

(c) $y(t) = 2e^{4t}$

(d) $y(t) = 4e^{4t}$

ix. For the homogeneous state equation

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -3 & 1 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

With $\begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} = \begin{bmatrix} 2 \\ -1 \end{bmatrix}$

The steady state value of x is

(a) $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$

(b) $\begin{bmatrix} -2 \\ -1 \end{bmatrix}$

(c) $\begin{bmatrix} -1 \\ 3 \end{bmatrix}$

(d) $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$

x. For the matrix

$$[A] = \begin{bmatrix} 1 & 4 \\ -2 & -5 \end{bmatrix}$$

The eigen values are

(a) $\lambda_1 = -1, \lambda_2 = -3$

(b) $\lambda_1 = -1, \lambda_2 = -4$

(c) $\lambda_1 = -2, \lambda_2 = -4$

(d) $\lambda_1 = -1, \lambda_2 = -2$

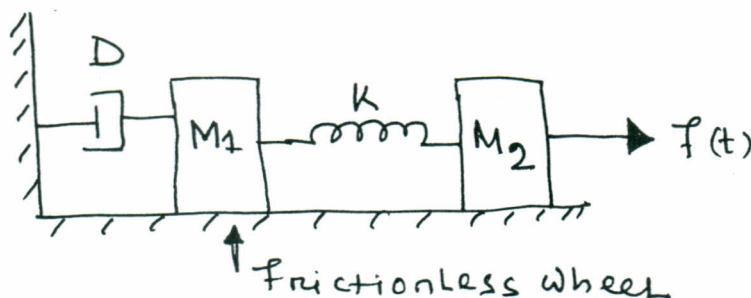
Q.2 Short answer type questions (4 questions @ 2.5 marks)

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- What are the advantages of state space technique?
- Define state, state variable and state vector.
- Differentiate incidental and intentional nonlinearities by giving example from each category.
- Write down the properties of STM, $\phi(t)$.

Q.3A Derive the state variable model for the system shown in the fig. below

05



Q.3B Obtain the transfer function if state model is given by

05

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Q.4A A linear time invariant system is characterized by the homogeneous state equation.

05

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -2 & 1 \\ 0 & 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

The initial state is $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$

Find the resolvent matrix $\Phi(s)$, state transition matrix $\Phi(t)$.

Q.4B What are the common nonlinearities? Describe in detail with diagram.

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Q.5A Diagonalize the system whose state model is given below.

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$$\dot{x} = \begin{bmatrix} 3 & 4 \\ 2 & 1 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$\text{And } y = \begin{bmatrix} 8 & 1 \end{bmatrix} x$$

Q.5B The transfer function of a system is given by

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$$\frac{y(s)}{u(s)} = \frac{s+1}{(s+2)(s+3)(s+4)}$$

For the state space description of the above system in the form $\dot{x} = Ax + Bu; y = Cx + Du$

Determine A, B, C and D such that A is in diagonal form.

Q.6A Determine the time response of the following system.

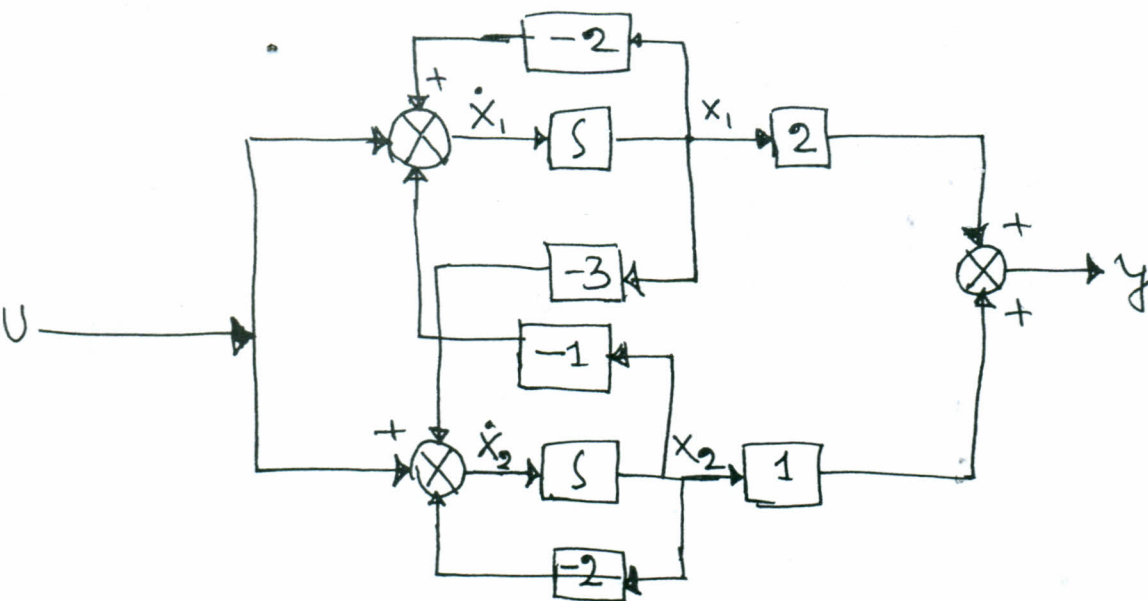
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$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(t)$$

$x^T(0) = \begin{bmatrix} 1 & 0 \end{bmatrix}$ and $u(t)$ is a unit step occurring at $t = 0$.

Q.6B Determine the transfer function of the system

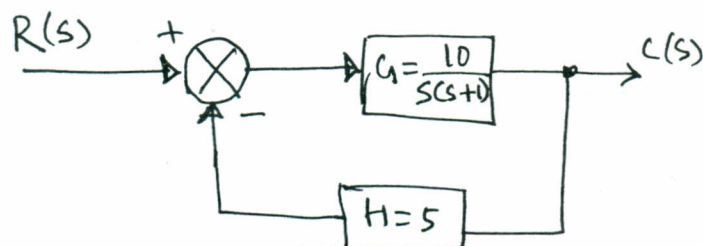
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OR

Q.6B For the system shown in the figure given below, calculate the sensitivity of the closed loop transfer function w.r.t to G and H for $\omega = 1 \text{ rad/sec}$.

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Q.7A A system is characterized by the transfer function

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$$\frac{Y(s)}{U(s)} = \frac{2}{s^3 + 6s^2 + 11s + 6}$$

Determine the controllability and observability of the system.

Q.7B Determine the stability of the system

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$$\dot{x} = Ax$$

Where $A = \begin{bmatrix} -1 & -2 \\ 1 & -4 \end{bmatrix}$ using Lyapunov's direct method.

OR

Q.7B The system is given by

05

$$\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= -x_1 - x_2^3 \end{aligned}$$

Investigate the system stability by lyapunov's method using the lyapunov function

$$v = x_1^2 + x_2^2$$

Q.8A What is describing function analysis?

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Derive the describing function for

- (i) on-off nonlinearity
- (ii) Dead-zone nonlinearity

Q.9A Discuss the advantages and disadvantages of feedback with special reference to. 10

- (i) Gain
- (ii) Reduction of parameter variation
- (iii) Control over system dynamics
- (iv) Control of the effects of disturbance signals

Q.9B Use Ziegler-Nichols rules for finding the P, PI and PID controller settings for a plant whose transfer function model is given by 10

$$G(s) = \frac{6}{(s+1)(s+2)(s+3)}$$

The controller in the forward path has provisions for P, PI and PID controller settings. Perform the controller settings and find the corresponding closed-loop transfer function and the response of the closed-loop system subjected to a unit-step input.

OR

Q.9B Write short notes on

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- (i) Jump resonance
- (ii) Limit cycles