Written Comprehensive Examination
Mr. Manas Kumar Sahoo (2018MEZ8591)
November 25, 2020 (Wednesday)

Duration: 2 hours Instructions: Attempt all the questions **Marks: 50**

Section A (Prof. J.K. Dutt)

Problem-1

(a) What is the significant characteristic of a linear system? State with a simple mathematical example. (1+1)
(b) Consider the C-R circuit given in the figure 1(a) below. Write the governing equation to find (i) the current in the circuit and (b) the voltage across the plates of the capacitance if a voltage function v(t) is applied from the instant of closing the switch. (2+2)
(c) Define mathematically a Unit Impulse Function (1)
(d) Suppose a linear system is subject to an arbitrary excitation shown by the figure 1(b), where, x(t) is the excitation function and λ is any generic time, at which the magnitude of excitation is given by x(λ). Also suppose that h(t) denotes the unit impulse response (response of the system due to the input of a unit impulse applied at time t=0) of the system. Explain the procedure to derive the response of the system y(t) due to the input x(t), as a convolution of the unit impulse response h(t) and the input x(t). (3)
(e) Prove that the Laplace Transform of the Convolution Integral, obtained in (d), is a multiplication of the Laplace Transforms of the unit impulse response function h(t) and the input function x(t). (5)
(f) Figure 1(c) shows a step voltage input x(t), a special case of the input function given in figure 1(b). Such a pulse may be approximately generated by opening and closing the switch quickly. Suppose initially there is a voltage of 9V between the plates of the capacitor, when the voltage pulse x(t), as shown in figure 1(c), is applied. Find the current in the circuit at t = 0.5 second, i.e when the pulse has been applied half-way and at t = 1.5 second, i.e. 0.5 second after the pulse ends. (5)

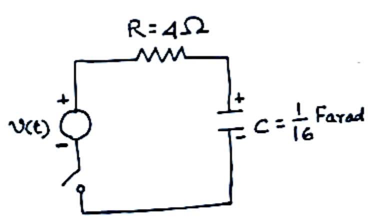


Figure 1(a)

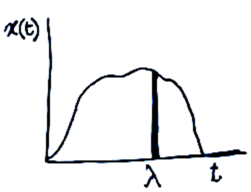


Figure-1(b)

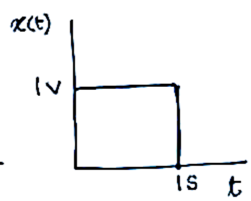
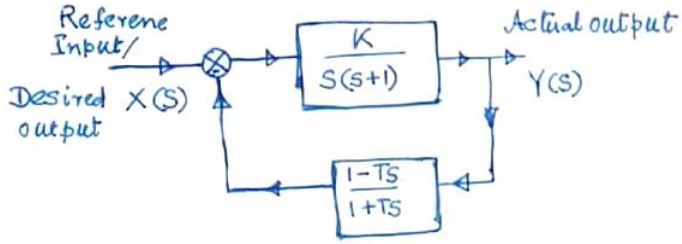


Figure-1(c)

Problem-2

See the figure-2 which shows a block diagram of a control system. The actual output is fed back with a delay modelled by a 1st order Pade' approximation, given as the feedback transfer function, in which T = $2\tau_D$, τ_D being the delay in second. The delay in sending the signal may affect the stability of the control system. Find out the relationship between K and T, for which all the closed loop poles of the system should have real parts ≤ -1. Find the maximum value of 'K' if the delay is 0.5 second. (8+2)



Problem-3

The open loop transfer function of a control system is given by $\frac{(s+1)}{(s+2)(s+3)(s+4)}$. Draw the bode plot by constructing the asymptotes only. Find the gain and phase margins of the system. (5+3)

Problem-4

Suppose for the purpose of attitude control, the equation of motion of a satellite, modelled as a rigid body, is given by $T(t) = J\,\ddot{\theta}(t)$, where $T(t)$ is the time varying torque on the satellite, applied by the thruster and $\theta(t)$ is the time varying angle of the satellite with respect to the inertial axis.

(a) Suppose it is desired to improve the stability of the satellite by proportionally feeding back all the states of the system. Find out the constants of proportionality for feeding back the states to achieve a damping factor $\zeta = 0.707$ and a settling time of 1 second. (5)

Problem-5

Suppose the unforced equations of motion of a system in state space is given by

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

Find out the State Transition Matrix and find the response if the initial value (at time t = 0) is given by $\{x_0\} = \begin{Bmatrix} 0 \\ 1 \\ 0 \end{Bmatrix}$ (7)

Written Comprehensive (Open-book) Examination

Mr. Manas Kumar Sahoo (2018MEZ8591)

November 25, 2020 (Wednesday)

Duration: 2 hours Instructions: Attempt all the questions **Marks: 50**

Section B (Prof. SK. Saha)

1. (a) Showing the steps, find $\mathbf{LL}^T$ (Cholesky) decomposition of the following matrix:

$$\mathbf{A} = \begin{bmatrix} 9 & -1 & 2 \\ -1 & 8 & 5 \\ 2 & 5 & 7 \end{bmatrix}$$

(b) Find the solution for the 2nd order differential equation using Runga-Kutta method for the value of $x = 2$.

$y'' - 3y' + 2y = 0$ with initial conditions $y(0) = 4$, $y'(0) = 5$

[10+10 = 20]

2. (a) Mention at least three different ways to specify three-dimensional rotations? Using sketch explain the physical interpretations of the parameters used to represent rotations.
(b) What are DAE and ODE formulations in dynamic modelling? Illustrate using an example.

[5+5 = 10]

3. Derive the Jacobian matrix of a UAV with four rotors. How can you solve inverse kinematics in velocity level? [10]

4. (a) Draw S-N diagrams for ductile and brittle materials.
(b) What is Factor of Safety (FOS) in static and dynamic loading? Illustrate using an example. [2+8=10]

… END …

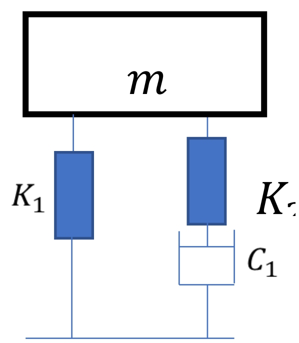
Analyses/Design (AD) Comprehensive Examination
Mr. Manas Kumar Sahoo (2018MEZ8591)
Nov. 25-28, 2020

Submission: Nov. 28, 2011 (Sat), 10am **Marks: 100**

Section A (Prof. J.K. Dutt)

Please refer to the figure below, where the platform of mass '*m*', supposed to be concentrated at the centre of mass, for the purpose of simplicity, is supported on a moving with the help of a suspension designed by a 3-element model as shown. For simplicity, suppose that the platform is restricted to move only vertically by an amount say y(t) with respect to an imaginary inertial frame.

1. Write the equation of motion of the platform with respect to the base. Define the terms suitably (10)
2. Represent it in a non-dimensional form. Define the terms appropriately (5)
3. Supposing that the base moves at an amplitude Y and at a frequency ω, find out the influence of different ratio of non-dimensional values of K_2 and C_1 on the response of the platform with respect to the base. (20)
4. Write a Matlab code to show the influence in step 3 graphically. You may suppose that the frequency of the base varies from 10% to 500% of the natural frequency of the system (15)



Section B (Prof. S.K. Saha)

For Question 3 of your written comprehensive, do the following:

1. Write a MATLAB program to solve the Question 3 of Section B numerically. [20]

2. If a 2-DOF manipulator is placed with a quadrotor what would be its dynamical equations of motion? [Use any formulation] [30]

Scan and submit a hand-written report only with the relevant printout of the plots.

… END