V SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, NOV 2017

SUBJECT: DYNAMICS AND CONTROL OF MECHATRONICS SYSTEMS

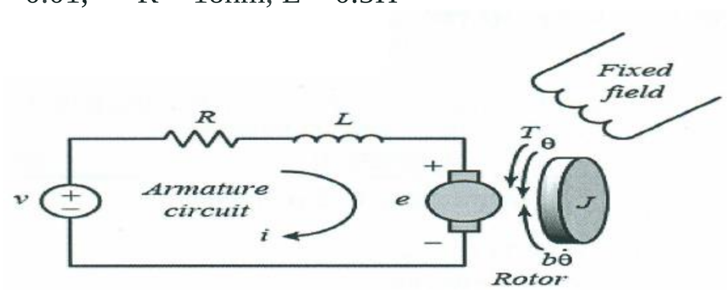
[MTE 4013]

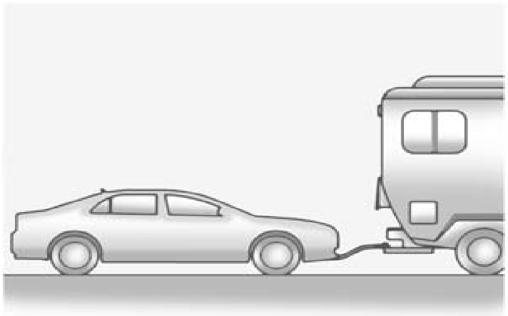
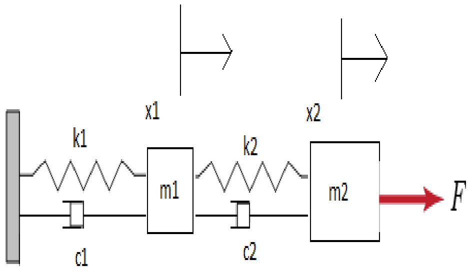
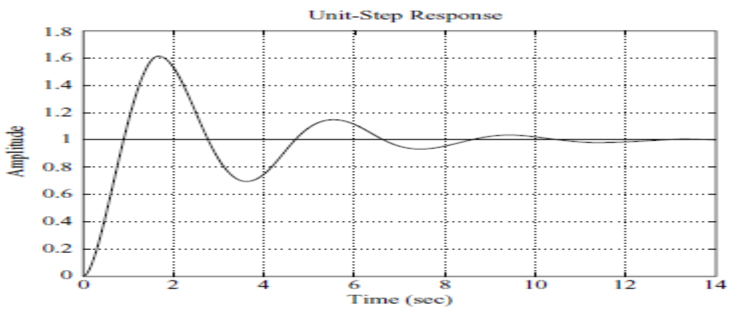
REVISED CREDIT SYSTEM
(24/11/2017)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Data not provided may be suitably assumed
- Graph sheets will be provided

1A.	Mention any four advantages of state space modeling over transfer function modeling?	**03**
1B.	The speed of a milling machine **Fig 1.**, connected to the rotor, is controlled by a DC armature controlled motor. Assuming the ideal actuator and sensor characteristics, model the system in state space domain. The system parameters are: J = 0.01, b = 0.1, Kb = Kt = 0.01, R = 1ohm, L = 0.5H  *Figure 1*	**04**
1C.	Obtain the transfer function model for the system shown in figure 3 and hence find the DC gain of the system.	**03**
2A.	Design a state feedback controller for a system given by the transfer function $(s) = \frac{1}{s^3+6s^2+11s+6}$, to follow the following design specifications. 1. Percent overshoot of y(t) less than 10% to a unit step input r(s) = 1/s. 2. Settling time less than 6 second to a unit step input.	**10**
3A.	Design an optimal control law for the liquid level control system governed by the differential equation, $\ddot{x} + 3\dot{x} + 2x = u$.	**05**
3B.	Obtain the linear state space model of a vehicle on tow given in figure 2 . A mass damper equivalent of the same is shown in figure 3	**05**

	 *Figure 2*  *Figure 3*	
4A.	A quarter car suspension state space system model is given by the following $$\dot{X} = \begin{bmatrix} 0 & 1 \\ -3 & -2 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U; Y = [1\ 0] + [0]U$$ The following transformation is applied on the states, X = PZ, where P = $\begin{bmatrix} 1 & 1 \\ -2 & -1 \end{bmatrix}$. i) Find the new state space system given by $\dot{Z} = MZ + NU$ & $Y_{new} = GZ$. ii) Show that $e^{At} = P\, e^{Mt}\, P^{-1}$	**3**
4B.	Write the matlab code to i) Enter a linear system of $\dot{X} = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U; Y = [1\ 0] + [0]U$ ii) Plot the system natural response given by for $X_0^T = [1\ 0]$. iii) Plot the response of the system states to a user defined input given by u(t) = 5 + 0.2 t, where t is time in sec	**4**
4C.	The automatic active OL cruise control system is responding to the cruise command changes as shown in the figure 4. The customer want an improved performance and the design engineer is given a task of designing a PID feedback controller using a suitable algorithm	**3**
	 *Figure 4*	
5A.	A shock absorber system is having a nonlinear spring dynamics and is given as $\ddot{x} + x + (1 - x)\dot{x} = u$. Obtain a linear state space model around its equilibrium point.	**3**
5B.	Check whether the following Lyapunov function is a valid candidate function for the system $\ddot{x} + x + (1 - x)\dot{x} = u$.	**4**
	$V(x) = 2x_1^2 + x_2^2 + 4x_1x_2$, for $x_1 \geq 0$, x_2 is unconstrained.	
5C.	Synthesis a Lyapunov function for the linearized system (in 5A) $\ddot{x} + x + (1 - x)\dot{x} = u$. to check the stability of the system.	**3**

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1A.	a) Considers initial states b) MIMO systems c) Organized controller designs d) More stability analysis e) Response analysis	**1 m each**
1B.	$J\ddot{\theta} + b\dot{\theta} = Ki$ $L\frac{di}{dt} + Ri = V - K\dot{\theta}$	**1m**
	$\frac{d}{dt}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix} = \begin{bmatrix} -\frac{b}{J} & \frac{K}{J} \\ -\frac{K}{L} & -\frac{R}{L} \end{bmatrix}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L} \end{bmatrix} V$ $y = \begin{bmatrix} 1 & 0 \end{bmatrix}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix}$	**0.5+1+1m**
	Substitution	**0.5m**
1C.	**G(s) = C $(sI-A)^{-1}$B+D**	**1m**
	$P(s) = \frac{\dot{\Theta}(s)}{V(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \qquad [\frac{rad/sec}{V}]$	**1m**
	Dc gain with s = 0, 0.099	**1m**
2A.	**A =** $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$**, B =** $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ $\boldsymbol{C} = [\,\mathbf{1\ 0\ 0}\,]\boldsymbol{D} = [\mathbf{0}]$	**2m**
	Controllability of the pair(A,B) = = $\begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & -6 \\ 1 & -6 & 25 \end{bmatrix}$	**1m**
	Zeta = 0.6, wn = 1, req poles = [-0.6-0.8i -0.6+0.8i -5] Adding extra pole	**4m**
	Pole placement |sI-An| = |A-B*K|	**2m**
	K = [-1 -4 0.2] u = -Kx	**1m**
3A.	System state space model A = $\begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ B = $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$ C = [1 0] D = [0]	**1**

	Assume Q = $\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$ R =[1]	**1**
	Ricatti eqn $A^TP+PA - PBR^{-1}B^TP+Q = 0$	**1**
	P = $\begin{bmatrix}1.2 & 0.2\\ 0.2 & 0.2\end{bmatrix}$, K = [0.236 0.236]	**2**
3B.		
4A	$\dot{\boldsymbol{Z}} = \begin{bmatrix}\mathbf{1} & \mathbf{2}\\ \mathbf{-3} & \mathbf{-3}\end{bmatrix}\boldsymbol{Z} + \begin{bmatrix}\mathbf{-1}\\ \mathbf{1}\end{bmatrix}\boldsymbol{U}; \boldsymbol{Yn} = [\mathbf{1}\ \mathbf{1}]\boldsymbol{Z} + [\mathbf{0}]\boldsymbol{U}$ **M = $P^{-1}AP$; N = = $P^{-1}B$; G = C P**	**2**
	Z(t) = e^{Mt} **Z(0)** **$P^{-1}X(t) = e^{Mt} P^{-1}X(t)$** **$X(t) = P\, e^{Mt} P^{-1}X(t)$; also $X(t) = e^{At} X(0)$**	**1m**
4B	Enter A,B,C,D Define sys =ss(a,b,c,d) Xo = [1 0] T = 0:0.1:10 Y = initial(sys,xo,t) U = zeros(size(t)) U = 5+0.2*t Y2 = lsim(sys,xo,u,t)	**1m+1m+2m**

4C.		