Reg. No.									

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

VI SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
MAKE UP EXAMINATIONS, JUNE 2018
SUBJECT: CONTROL SYSTEM DESIGN [ELE 4013]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 22nd June 2018** **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Use of MATLAB is permitted.

1A. Given the uncompensated unity feedback system with $G(s) = \frac{K}{s(s+7)}$, is operating with a closed loop response that has 15% overshoot.

a. Evaluate the steady state error for unit ramp input
b. Design a lag compensator to improve the steady state error by a factor of 20.
c. Evaluate the steady state error of the compensated system.
d. Realize the lag compensator using passive circuit. ***(05)***

1B. Consider the unity feedback system with $(s) = \frac{K}{s(s+50)(s+120)}$, use frequency domain methods to design a lead compensator to yield K_V=40, with phase margin of 48°. Clearly write the design procedure for the design of lead compensator. ***(05)***

2A. A system is described by the transfer function$(s) = \frac{5s^2+14s+8}{s^3+9s^2+23s+15}$, develop a state models in i) controllable canonical form ii) observable canonical form iii) diagonal canonical form. Draw the state diagram for diagonal form and hence assess the controllability and observability of the system. ***(08)***

2B. Explain the concept of Model reference control with a neat block diagram and relevant equations. ***(02)***

3A. Design a linear state feedback controller that places the system poles at $s = -1 \pm j3 \ and \ s = -5$

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -15 & -23 & -9 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u \quad y = [1 \quad 0 \quad 0]x$$

Also design an observer which is 5 times faster than the control loop.
Draw the state diagram of system with controller and observer. ***(06)***

3B. State and explain jump resonance and limit cycle of nonlinear systems ***(04)***

4A. Determine the stability of the equilibrium point of the following system

$$\dot{x_1} = x_2 \;\; ;$$

$$\dot{x_2} = -2x_1 - 2x_1^3 - 3x_2$$

Choose the Lyapunov function $V(x) = x_1^4 + 2x_1^2 + x_2^2$ ***(04)***

4B. State and explain i) boundedness and ii) asymptotically stable with respect to Lyapunov stability. ***(02)***

4C. For the unity feedback system with $G(s) = \dfrac{4}{s^3 + 6s^2 + 8s + 4}$, design A PID controller using Zeigler Nichols method so that the closed loop system has maximum overshoot between 15% to 10%, and settling time less than 3 sec. Find the range of $K_P, K_I \& K_D$ ***(04)***

5A. Using the describing function analysis, predict the existence of the limit cycle for the system with saturation non-linearity and linear plant with transfer function $G(s) = \dfrac{16}{s(s+2)^2}$.

The describing function for the non-linear element is $G_N = \dfrac{k}{\pi}[2\beta + \sin 2\beta] \; for \; M \geq 2$, $G_N = k \; for M < 2$, with input $m(t) = M \sin \omega t$, k =5 is the slope. Draw the input- output waveform.

Also determine the amplitude and frequency of the limit cycle. Assess the stability of the limit cycle. ***(05)***

5B. What is meant by completely state Controllable? ***(02)***

5C. A continuous time system described by $\dot{x} = Ax + Bu$, where $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix}$ &

$B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$, performance index $J = \int_0^\infty (x^T Q x + u^T R u)dt$, $R = 0.01$, $Q = \begin{bmatrix} 100 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$,

solve for i) the positive definite solution matrix 'P' of the Riccati equation ii) the optimal feedback gain matrix 'K' and iii) the eign values of A-BK ***(03)***