Reg. No.									

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

V SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, NOVEMBER 2018
SUBJECT: LINEAR CONTROL THEORY [ELE 3101]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 19, November 2018** **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Semi log graph sheet will be provided.

1A. The block schematic of a ship steering system is shown in **Fig. Q1A**. $Y(s)$ is the actual ship's course while $R(s)$ is the desired course. The course of the ship is realized by varying the rudder angle $A(s)$. Using suitable block reduction techniques, obtain the final transfer function of the system. ***(03)***

1B. For the bridged T - network shown in **Fig Q1B**, prove that:

$$\frac{V_0}{V_{in}}(s) = \frac{1 + 2R_1Cs + R_1R_2C^2s^2}{1 + (2R_1 + R_2)Cs + R_1R_2C^2s^2}$$

Also, sketch the pole zero diagram for the same by taking $R_1 = 0.5\Omega$; $R_2 = 1\Omega$ and $C = 0.5\ F$ ***(03)***

1C. A mechanical system is as shown in **Fig. Q1C**. It is subjected to a known displacement $x_3(t)$ with respect to the reference. Assuming the initial conditions to be zero, determine the two independent equations of motion in Laplace domain and further, derive the transfer function $\frac{X_1}{X_3}(s)$. ***(04)***

2A. From the fundamentals, derive the transfer function of the active network shown in **Fig Q2A**. Also determine the conditions for which the considered network behaves as:

a) Phase lead compensator
b) Phase lag compensator ***(03)***

2B. In a unity feedback control system, the plant transfer function in the forward path is given as:

$$G_p(s) = \frac{K}{s(s+10)}$$

Determine the value of the proportional gain $'K'$ which results in the overall system having a damping ratio of 0.25. ***(03)***

2C. Lasers can be used to drill the hip socket for the appropriate insertion of an artificial hip joint. The use of lasers for surgery requires high accuracy for position and velocity response. Consider the system shown in **Fig Q2C**, which uses a DC motor manipulator for the laser. Design the laser manipulator control system such that the amplifier gain K must be adjusted so that the steady-state error for a ramp input, $r(t) = At$ (Where $\mathrm{A} = 1\mathrm{mm/s}$), is less than or equal to 0.1 mm, all the while maintaining a stable response. ***(04)***

3A. A control system with a PI controller is shown in **Fig Q3A**. Select the appropriate controller gains so that the overshoot to a unit step input is equal to 5% and the velocity constant K_v is equal to 5. ***(03)***

3B. Justify appropriately whether, the transfer function $G_c(s) = {(s+4)}/{(s+2)}$ can indeed function as a lag compensator. Further, determine the frequency at which the phase of $G_c(s)$ is maximum. ***(03)***

3C. Consider a unity feedback system with the plant transfer function given as:

$$G(s) = \frac{K}{s(s+7)}$$

Considering the input to be a unity step function, design a suitable PID controller which will ensure that the system operates with a peak time that is two-third that of the controlled system all along, ensuring a percentage overshoot of 15% with zero steady state error. ***(04)***

4A. Design a Phase lead compensator using frequency domain approach (**use the provided semi-log graph sheet**) for a negative unity feedback system with plant transfer function given as:

$$G(s) = \frac{K}{s(s+10)(s+1000)}$$

so as to satisfy the following design specifications:

a) Phase margin is at least 45^0
b) Static error constant = $1000\ s^{-1}$ ***(03)***

4B. A unity feedback system having an open loop transfer function given by the following expression is operating with a dominant pole damping ratio of 0.707

$$G(s) = \frac{K\ (s+6)}{(s+2)(s+3)(s+5)}$$

Design a suitable PD controller so as to reduce the settling time by a factor of 2. ***(03)***

4C. The block diagram of output speed control system of electrical power from a turbine and generator pair is shown in **Fig Q4C**. Sketch the Nyquist diagram and using Nyquist criterion determine the range of K for the system to be stable. ***(04)***

5A. For the electrical circuit shown in **Fig. Q5A**, derive the mathematical model in state space phase variable form. Also determine the expression for the output voltage $V_0(s)$ in Laplace domain. Assume that the circuit is in steady state with the following specifications:

- The initial current is zero
- The initial capacitor voltage is zero ***(03)***

5B. Consider a system to be represented by the following matrices:

$$A = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix}\ and\ B = \begin{bmatrix} 0 \\ 6 \end{bmatrix}\ \text{and}\ C = [1 \quad 0]$$

- Determine whether the system is controllable and observable
- Derive the transfer function of the system assuming zero initial conditions
- Plot the system response for a unit step input for $\boldsymbol{0 \le t \le 5s}$ ***(03)***

5C. For the system shown below, design a state feedback controller such that the compensated system has an overshoot of 10% and settling time of 3secs. Further design an observer which is ten times faster than the designed controller.

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u\ ;\ y = [1 \quad 0]x$$ ***(04)***

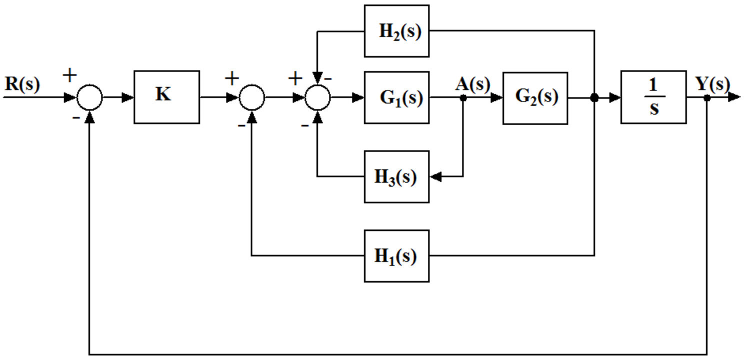

Fig. Q1A

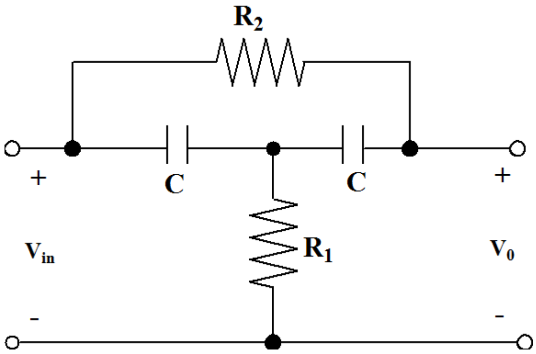

Fig. Q1B

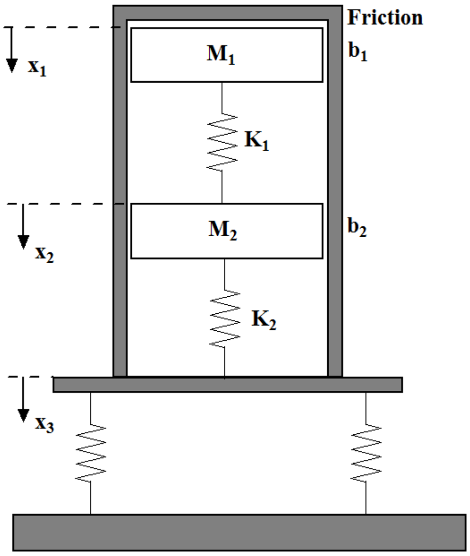

Fig. Q1C

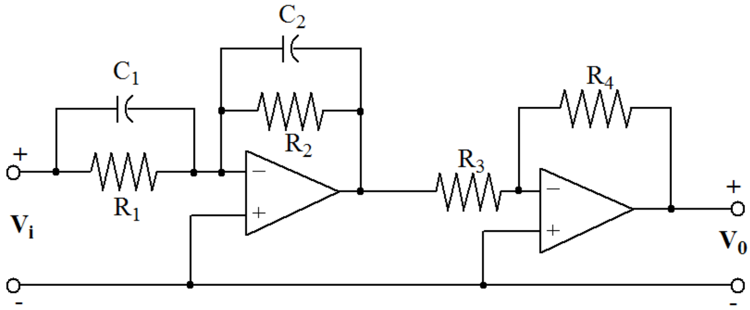

Fig. Q2A

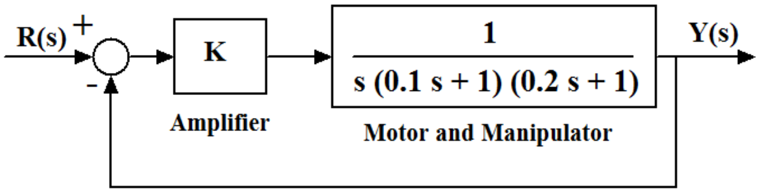

Fig. Q2C

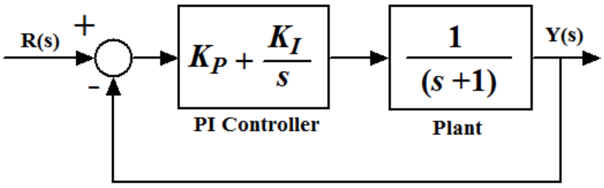

Fig. Q3A

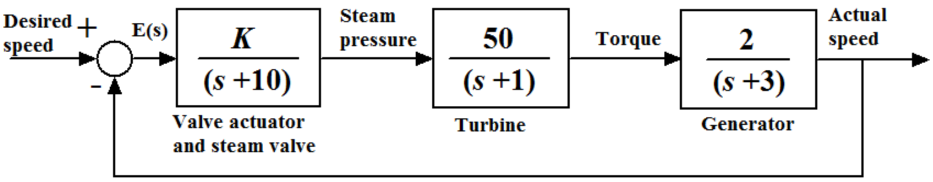

Fig. Q4C

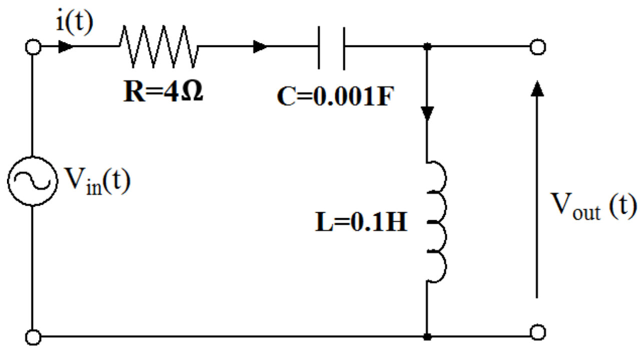

Fig. Q5A