Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

SEVENTH SEMESTER B.TECH (INSTRUMENTATION & CONTROL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

SUBJECT: ROBUST CONTROL [ICE 439]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitably assumed.

1A. Find the corresponding state space model of the system $\boldsymbol{G(s)} = \frac{\mathbf{1}}{\boldsymbol{s^2+s+1}}$ and calculate $\|\boldsymbol{G}\|_2$ via state space method. Also obtained the ∞-norm of the system. **(08)**

1B. Illustrate parametric uncertainty in plant model with example. **(02)**

2A. A plant has transfer function $\boldsymbol{G(s)} = \boldsymbol{e^{-sd}}\frac{\mathbf{1}}{\boldsymbol{s^2+0.4s+1}}$. The delay $\boldsymbol{d}$ is unknown, but lies between $\mathbf{0}$ and $\mathbf{4}$. A proportional feedback controller is implemented with gain $\boldsymbol{K}$. Use small gain theorem to determine the maximum gain K that preserves the stability for all possible values of $\boldsymbol{d}$ and also interpret your answer in terms of the Nyquist criterion. **(05)**

2B. Assume that unity feedback system as shown in Fig. **Q (2B)** is internally stable and $n = \boldsymbol{d} = \mathbf{0}$. Show that if input $\boldsymbol{r(t)}$ is the unit step than $\boldsymbol{e(t)} \to \mathbf{0}$ as $\boldsymbol{t} \to \infty$ if and only if sensitivity transfer function $\boldsymbol{S(s)}$ has at least one zero at the origin. **(03)**

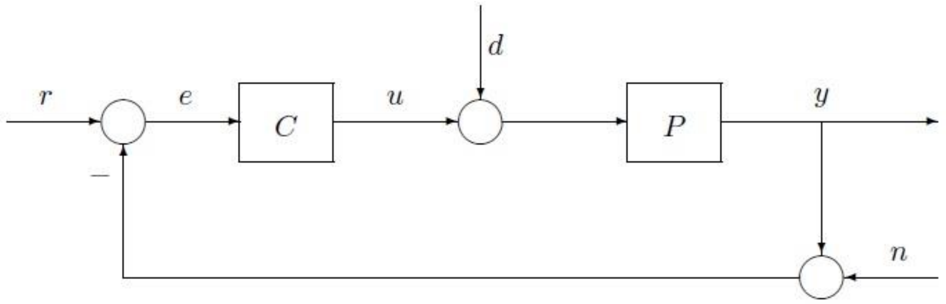

Fig. Q(2B)

2C. Interpret graphically the norm bound performance condition $\|\boldsymbol{W_P(s)S(s)}\|_\infty < \mathbf{1}$ for the feedback control system. **(02)**

3A. Design a controller $\boldsymbol{C}$ for the plant model $\boldsymbol{P}(\boldsymbol{s}) = \frac{\boldsymbol{3}}{\boldsymbol{s-4}}$ of unity feedback system as shown in Fig. **Q(2B)** so that tracking error e goes to 0, when r is a ramp and $n = d = 0$. **(08)**

3B. Show that set of all controllers of plant $\boldsymbol{P} \in \boldsymbol{R\mathcal{H}}_\infty$ for which the feedback system shown in Fig. **Q(2B)** is internally stable is given by $\boldsymbol{C} = \left\{\frac{\boldsymbol{Q}}{\boldsymbol{1-PQ}} : \boldsymbol{Q} \in \boldsymbol{R\mathcal{H}}_\infty\right\}$ **(02)**

4. Establish the necessary and sufficient condition for robust performance in the feedback control system. **(10)**

5A. Consider $\boldsymbol{P}(\boldsymbol{s}) = \frac{\boldsymbol{1}}{\boldsymbol{s}}$ and $\boldsymbol{W_P}(\boldsymbol{s}) = \frac{\boldsymbol{100}}{\boldsymbol{s+1}}$. Perturb $\boldsymbol{P}$ to $\boldsymbol{P}(\boldsymbol{s}) = \boldsymbol{1}/(\boldsymbol{s} + \boldsymbol{\epsilon}), \boldsymbol{\epsilon} > \boldsymbol{0}$. Find the controller **C** (internally stabilizing) so that $\|\boldsymbol{W_P S}\|_\infty < \boldsymbol{1}$. Does the resulting controller **C** solve the performance design problem for the original P? **(05)**

5B. Factor **P** as $\boldsymbol{P} = \boldsymbol{P_1 P_2}$, $\boldsymbol{P_1} = \frac{\boldsymbol{1}}{\boldsymbol{s+1}}$ $\boldsymbol{P_2} = \frac{\boldsymbol{s+1}}{\boldsymbol{s}}$. Solve the performance design problem for $\mathbf{P_1}$; let $\mathbf{C_1}$ be the solution. Set $\mathbf{C} = \mathbf{C_1}/\mathbf{P_2}$**.** Does the resulting **C** solve the performance design problem for the original **P**? If so, explain why. **(05)**

6A. Open-loop plant $\boldsymbol{P}(\boldsymbol{s})$ is strictly proper, has a double pole at $\boldsymbol{s} = \boldsymbol{0}$, and a zero at $\boldsymbol{s} = \boldsymbol{0.1}$. Controller $\boldsymbol{C} = \boldsymbol{C}(\boldsymbol{s})$ stabilizes the feedback system shown in Fig. **Q6(A)** and ensures good tracking (transfer function from $\boldsymbol{r}$ **to** $\boldsymbol{e}$ has gain less than $\boldsymbol{0.1}$) for frequencies up to **1** rad/sec. Find a good lower bound on the maximal gain from $\boldsymbol{r}$ to $\boldsymbol{e}$. **(05)**

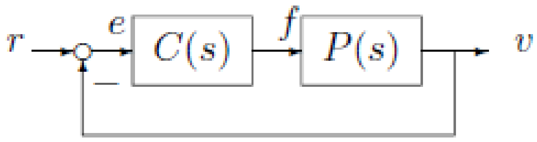

Fig. Q6(A)

6B. Suppose G is stable and $\boldsymbol{G}(\boldsymbol{0})$ is non-singular. For the loop in Fig. Q6(B), find all stabilizing controllers such that the steady-state value of $\boldsymbol{y}$ is zero when $\boldsymbol{v}$ is a step input and $\boldsymbol{w} = \boldsymbol{0}$. **(05)**

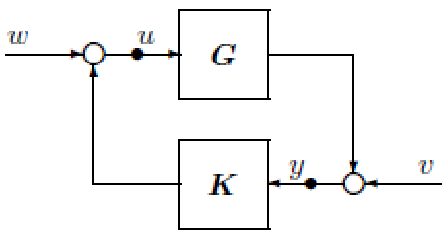

Fig. Q6(B)