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. Determine $\| \quad \|_\infty$ and $\| \quad \|_2$ norms of the system **(08)**

$$G(s) = \begin{bmatrix} \frac{2}{s+10} \\ \frac{20}{s+1} \end{bmatrix}$$

1B. Consider nominal plant $P(s) = \frac{1}{s+a_0}$ and actual plant model $\widetilde{P}(s) = \frac{1}{s+a}$ with $a = a_0 + \delta\delta_m, |\delta| \leq 1$. Assume suitable weighting function W and rewrite uncertain system in the form $\widetilde{P} = P(1 + \Delta W)^{-1}$, where Δ is stable transfer function given by $\Delta = \delta$ with $|\delta| \leq 1$. **(02)**

2A. Derive robust stability condition for the unity feedback control system as shown in **Fig. Q2(A)** **(05)**

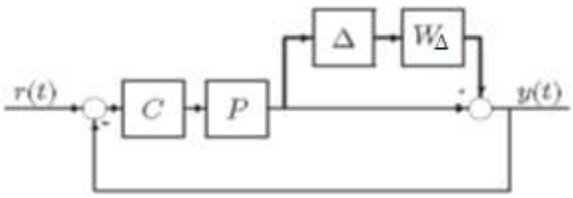

Figure Q2(A)

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

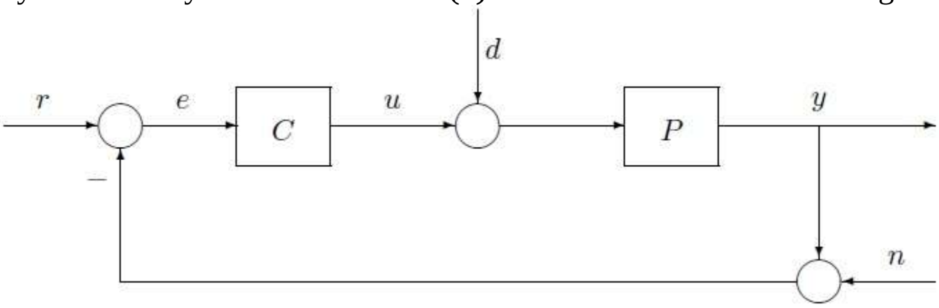

Fig. Q(2B)

2C. Illustrate sensitivity transfer function for the unity feedback control system and show that $\|W_P S\|_\infty < 1 \Leftrightarrow |W_P(j\omega)| < |1 + L(j\omega)|, \forall\, \omega$. **(02)**

3A. Compute an internally stabilizing controller C for plant model $P = \frac{1}{(s-1)(s-2)}$. **(06)**

3B. Show that set of all controllers for which the feedback system shown in Fig. **Q(2B)** is internally stable is given by $C = \left\{\frac{X+MQ}{Y-NQ} : Q \in R\mathcal{H}_\infty\right\}$ **(04)**

4. State and prove small gain theorem with neat diagram **(10)**

5A. For the given weighting functions W_Δ and W_P , derive the conditions on loop function L for the regions A, B and C as shown in the **Fig. Q5 (A)** to satisfy robust performance inequality $\left\| |W_p S| + |W_\Delta T| \right\|_\infty < 1$. **(07)**

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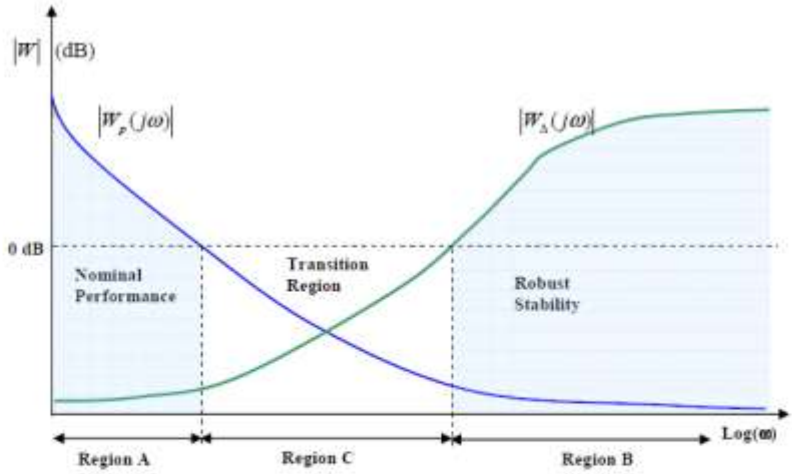

Fig. Q5(A)

5B. Show that $\| |W_P S| + |W_\Delta T| \|_\infty < 1 \Rightarrow \max_\omega \bar{\sigma} \begin{bmatrix} W_P S \\ W_\Delta T \end{bmatrix} < \frac{1}{2}$ **(03)**

6. Consider the standard unity feedback loop as shown in **Fig. Q2 (B)** where r is the reference input, d is the disturbance, n is the noise signal, P is the nominal plant and C is the controller which has to be designed. **(10)**

If $P(s) = \frac{1}{10s+1}, C(s) = K$. Find the least positive gain K so that the followings are all hold:

(i) The feedback system is internally stable

(ii) $|e(\infty)| \leq 0.1$ when $r(t)$ is the unit step and $n = d = 0$,

(iii) $\|y\|_\infty \leq 0.1$ for all $d(t)$ such that $\|d\|_2 \leq 1$ when $r = n = 0$.