1. (10%) Consider the closed-loop system (shown in Fig. 1) with

$$P(s)=\frac{1}{s+1},\qquad C(s)=K_1+\frac{K_2}{s}\ .$$

Find the gains K_1 and K_2 such that the real part of closed-loop poles (i.e., Re[s]) satisfy Re[s] < -1 and the steady-state error due to a unit ramp is less than 0.1.

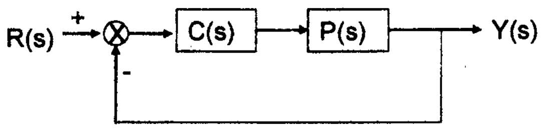

Figure 1

2. (15%) A feedback control system has the structure shown in Fig. 2.

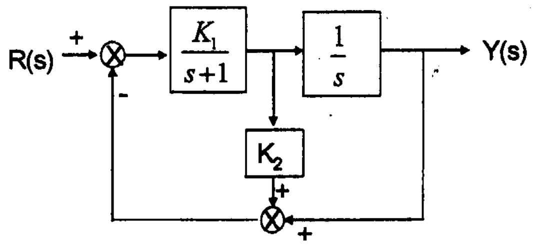

Figure 2

(a) Determine the closed-loop transfer function Y(s)/R(s)

(b) Determine the gains K_1 and K_2 so that the closed-loop response to a unit-step input is critically damped with two equal roots at s = -10.

3. (25%) Consider the closed-loop control system shown in Fig. 3

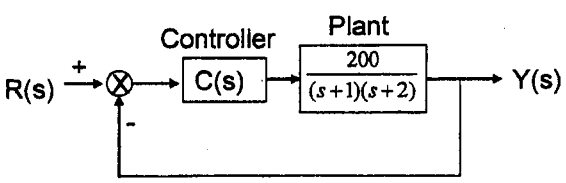

Figure 3

(a) For C(s) = 1, verify that the system is stable and find the steady-state error for the following inputs. (i) unit step (ii) unit ramp

(b) Repeat (a) when C(s) is a PI controller, with C(s) = 1 + 0.1/s

(c) Compare (a) and (b) to show that how the PI affect the steady-state error.

(Continue Problem 3.)

(d) Compare the damping ratio, ξ, of the closed-loop system when C(s) = 1 (P controller) and C(s) = 1 + 0.1s (PD controller)

(e) What is the effect of the derivative term in the PD controller on the settling time, t_s, of the system? Justify your answer by comparing the settling time in (d). Use $t_s = \frac{4}{\xi\omega_n}$. ($\omega_n$ is the natural undamped frequency)

4. **(15%)** Given a closed-loop system as shown in **Fig.P4**, sketch root locus of the system when K is varied from 0 to ∞. Show that by using a PD controller the closed-loop poles can be placed within a region in the s-plane for the dominant roots which have a damping ratio ≧0.707 and settling time ≦ 1 sec.

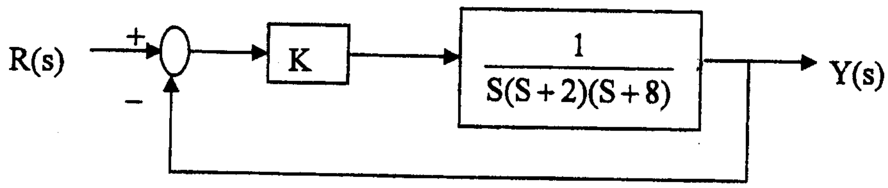

Fig. **P4**

5. **(10%)** The polar plot of a conditional stable system is shown in **Fig. P5** for a specific gain K=1. (a) Determine whether the closed-loop system is stable and find the number of roots (if any) in the right-half s-plane. GH(s) has no poles in the right-half s-plane. (b) If it is unstable adjust value of K such that the closed-loop system is stable.

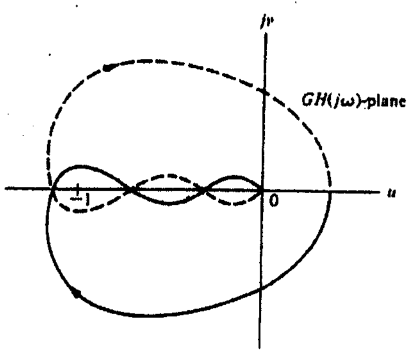

Fig. P5

6. **(25%)** A vertical takeoff (**VTOL**) aircraft is an inherently unstable vehicle and requires an automatic stabilization system. An attitude stabilization system for a VTOL aircraft is shown in **Fig. P6.** At 40 knots, the dynamics of the vehicle are approximated by G(s).

$$G(s) = \frac{10}{(s^2 + 0.36)}$$

The actuator and filter has a transfer function of $G_1(s)$

$$G_1(s) = \frac{K_1(s+8)}{(s+2)}$$

(a) Draw the Bode diagram of the loop transfer function when the gain $K_1 = 2$ (b) Determine the resonant frequency and the maximum amplitude of the resonant peak of the closed-loop system. (c) Estimate the damping ratio of the system.

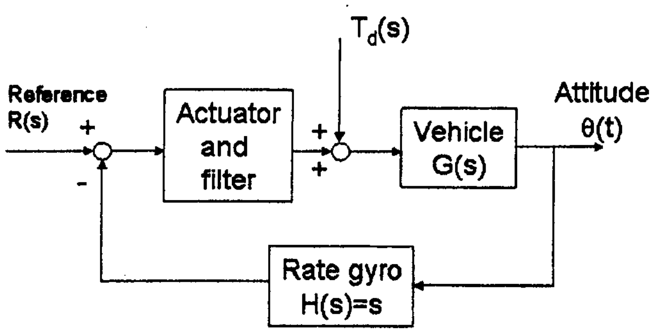

Fig. P6