1. (20%) Determine the values of K and α of the closed-loop system in Figure 1 so that the maximum overshoot in unit-step response is 20% and the peak time is 1 sec. Assume that $J = 1$ kg-m^2. [Hint: $\ln(0.2) = -1.609$, $\ln(0.25) = -1.386$, $\ln(0.3) = -1.204$. $\pi = 3.14$]

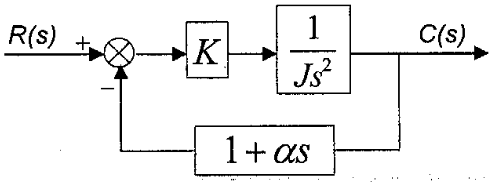

Figure 1

2. Consider the system shown in Figure 2,
   (a) (10%) What value of K will yield a steady-state error in position of 0.01 for an input of $0.2t$?
   (b) (10%) What is the minimum possible steady-state position for the input given in (a). [Hint: Consider that the minimum error will occur for the maximum gain before instability.]

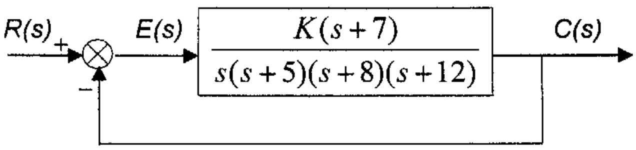

Figure 2

3. (15%) Given a unit feedback system as shown in Figure 3, where r is the reference, y is the output and e is the error. G(s) is the plant.

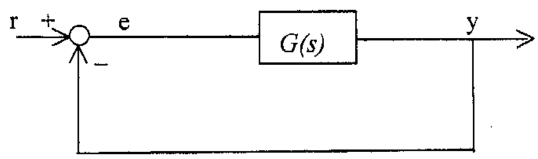

Figure 3

The transfer function G(s) is given as:

$$G(s) = \frac{50}{s(s+1)(s+10)}$$

Please determine the gain margin and the phase margin of the system.

4. (15%) Given the following closed loop system as shown in Fig. 4 where r is the input and y is the output. The transfer function $G(s)H(s)$ is given as:

$$G(s)H(s) = \frac{k(s+3)}{s(s-1)}.$$

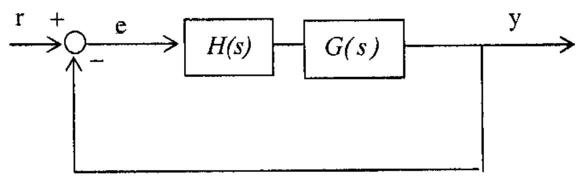

Figure 4

Please use the Nyquist stability criterion to determine the region of k such that the closed loop system is stable. **Note that** you are restricted to use the Nyquist stability criterion to answer the question in order to get the full credits. Other methods such as the root locus or the Routh-Hurwitz table is not allowed.

5. (30%) Consider the following feedback system (Fig. 5)

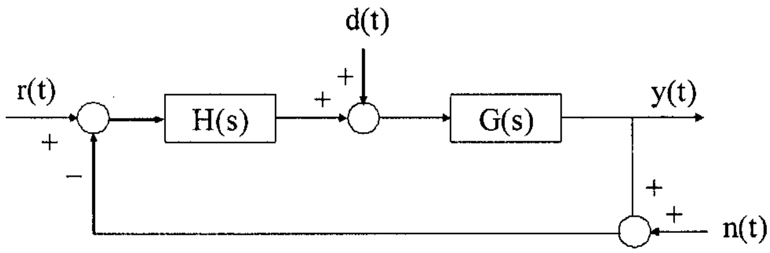

Figure 5

where the plant G(s) is $\dfrac{1}{s(s+1)}$ and H(s) is a controller to be designed and r(.), y(.), d(.), and n(.) respectively represent the command, the output, a disturbance, and a measurement noise.

(a) (5%) Let H(s) = 1. Calculate the position constant of the system and use it to determine the tracking error to a unit-step command r(.) when d(.) = 0 and n(.) = 0.

(b) (5%) Let H(s) = 1, r(.) = 0, n(.) = 0 and d(.) be a step signal. Show that although the system is type one, the response to the step disturbance can not be completely rejected, i.e.,

$$\lim_{t\to\infty} y(t) \neq 0$$

(c) (10%) Let n(.) = 0 and r(.) and d(.) be two step signals. Use the Routh criterion to design a controller H(s) such that we can track the step command r(.) and reject the step disturbance d(.) at the same time.

(d) (10%) Let d(.) = 0 and r(.) and n(.) be two step signals. Show that no matter what H(s) is, it is impossible to track the step command r(.) and reject the step measurement noise n(.) at the same time.