1. (25%) Consider a linear, time-invariant system whose output response due to a unit step input (i.e., unit step response) is given by

$$1-e^{-t}\cos 2t-0.5\sin 2t$$

(a) (10%) Please verify that the transfer function of the system is

$$G(s)=\frac{5}{s^2+2s+5}$$

(b) (5%) Please find the damping ratio and natural frequency of the system.
(c) (5%) Please estimate the bandwidth of the system.
(d) (5%) Please estimate the 2%-settling time of the system.

2. (25%) As shown in Fig. 1, consider a unity-negative feedback control system with the plant given by

$$G(s)=\frac{5}{s^2+2s+5}$$

and a proportional-integral controller (PI-control) given by

$$C(s)=\frac{k(s+3)}{s}, \qquad k\ge 0$$

(a) (10%) Please find the range of the feedback gain k so that the closed-loop system is bounded-input-bounded-output (BIBO) stable.
(b) (5%) Please find the steady state error of the closed-loop system due to a unit ramp input. Express your answer as a function of k.
(c) (5%) Suppose that $k=0.4$. Please find the dominant poles for the closed-loop system.
(d) (5%) Continue from Problem #(c). Please estimate the percent overshoot of the closed-loop system due to a unit step input. **Note:** You are not required to compute the precise value. Only an estimate with a logical procedure is needed.

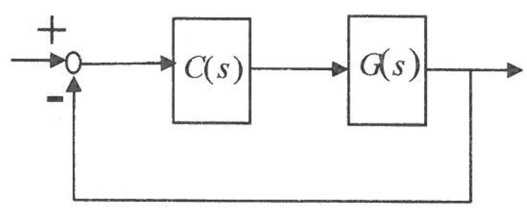

Fig. 1

3. (30%) For a unity feedback system that has the forward transfer function

$$G(s)=\frac{K}{(s+2)(s+4)(s+6)}$$

(a) (10%) Sketch the root locus and its asymptotes.
(b) (10%) Plot the Nyquist diagram.
(c) (5%) Use your Nyquist diagram to find the range of gain, K, for stability.
(d) (5%) Find the gain margin if K=100.

4. (20%) For the plant

$$G(s)=\frac{100(s+10)}{s(s+3)(s+12)}$$

(a) (10%) Find the state equations and output equation for the phase-variable representation.

(b) (10%) Design the state-feedback gains to yield 5% overshoot and a peak time of 0.3 second.