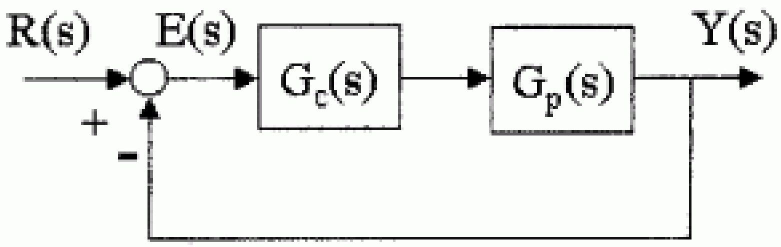
國　立　清　華　大　學　命　題　紙

九十三學年度 動力機械工程 系（所） 乙 組碩士班入學考試

科目 控制系統 科號 1601 共 6 頁第 1 頁 *請在試卷【答案卷】內作答

Prob. (1) Consider the following control problem as shown,



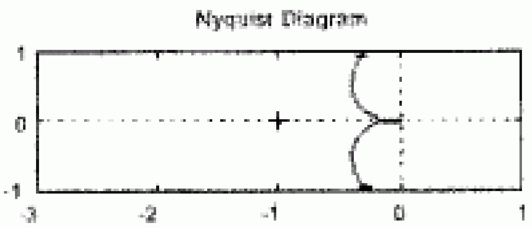
where $G_p(s) = \dfrac{s^2 + 2s + 1}{s^2 + 0.09}$ and $G_c(s) = \dfrac{K}{s}$.

(a) Determine the range of K that will result in a stable closed-loop system. *(5%)*

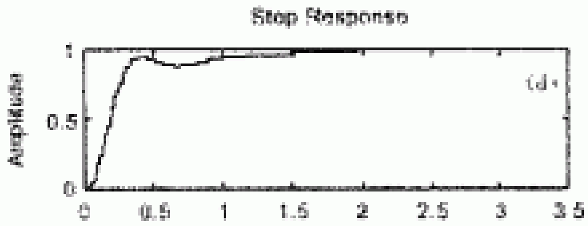
(b) What is the closed-loop oscillation frequency (write down the unit) for marginally stable case? *(5%)*

Prob. (2) Four partial Nyquist plots of open loop stable type 1 transfer functions numbered 1~4. Next to them are plotted in random order the corresponding closed-loop step responses. Match the step responses (a)~(d) to the Nyquist plots. *(5%, Note: no partial credit)*

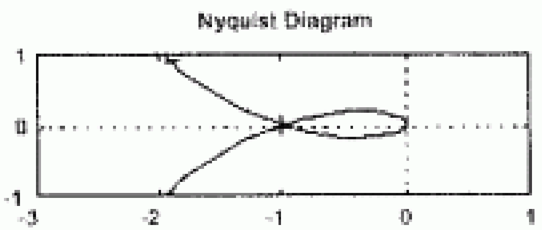
Nyquist	Closed loop Step Response
1	______
2	______
3	______
4	______



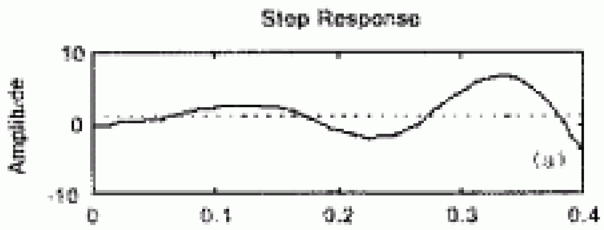
(1)



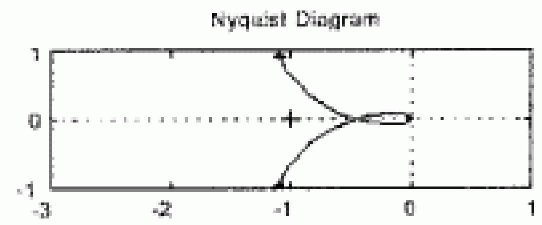
(a)



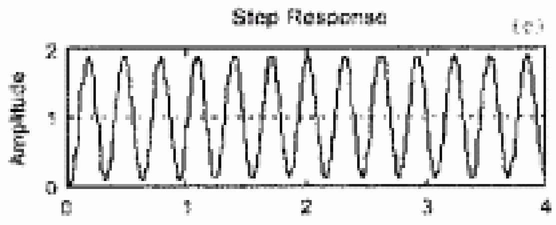
(2)



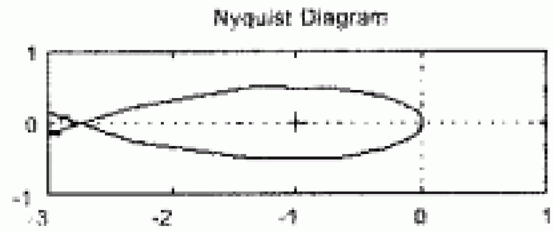
(b)



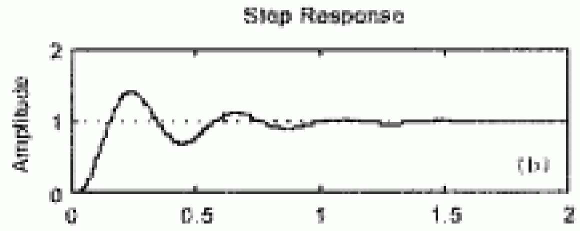
(3)



(c)



(4)



(d)

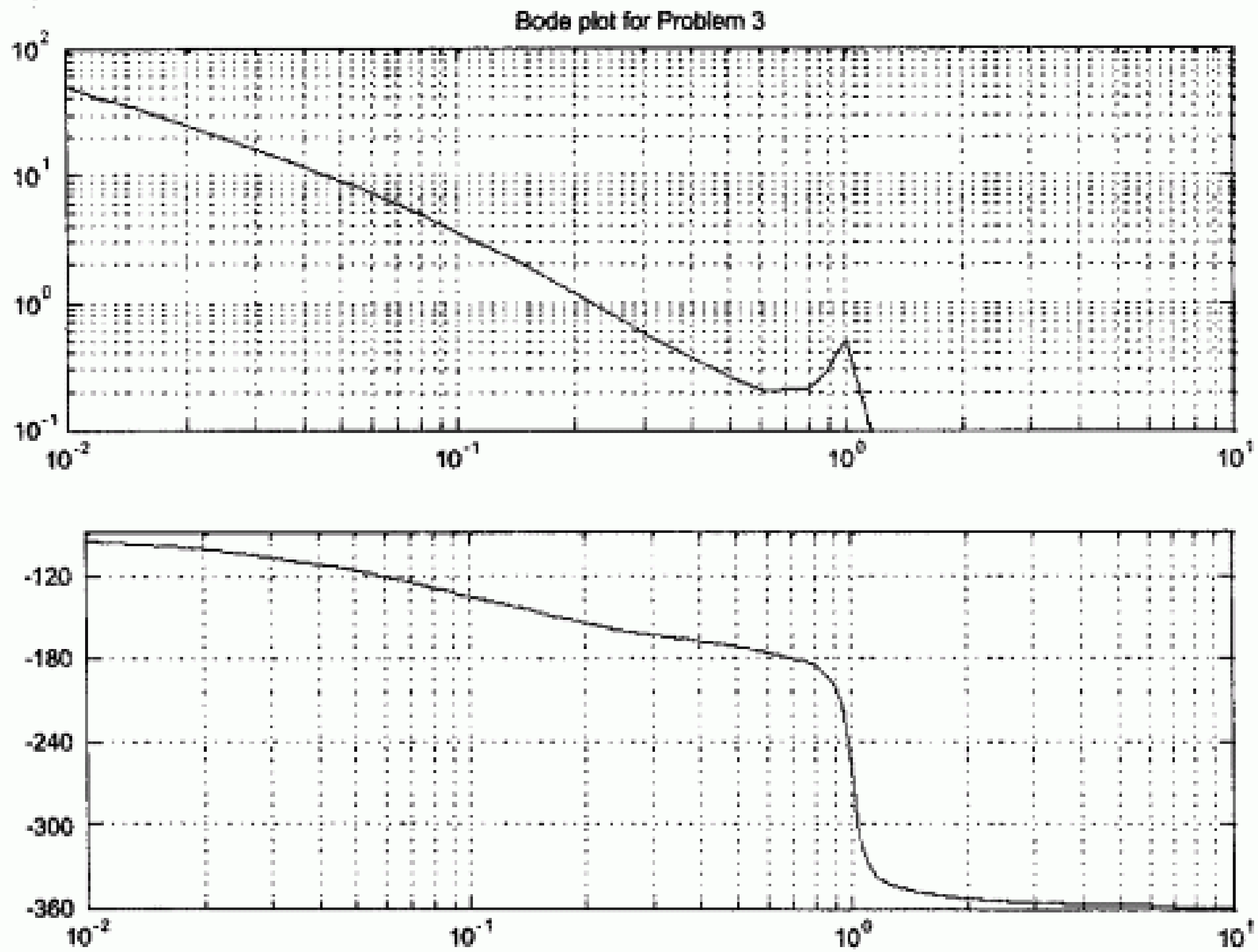
Prob. (3) A standard Bode plot for a stable, minimum phase plant G is given as follows.

(a) What is the gain margin GM? What is the corresponding ω_c? *(2%)*

(b) What is the phase margin PM? What is the corresponding ω_g? *(2%)*

(c) What is the unit ramp steady state error constant Kv for this case? *(7%)*

(d) What is the value of gain K such that KG have a phase margin of 40°? *(4%)*

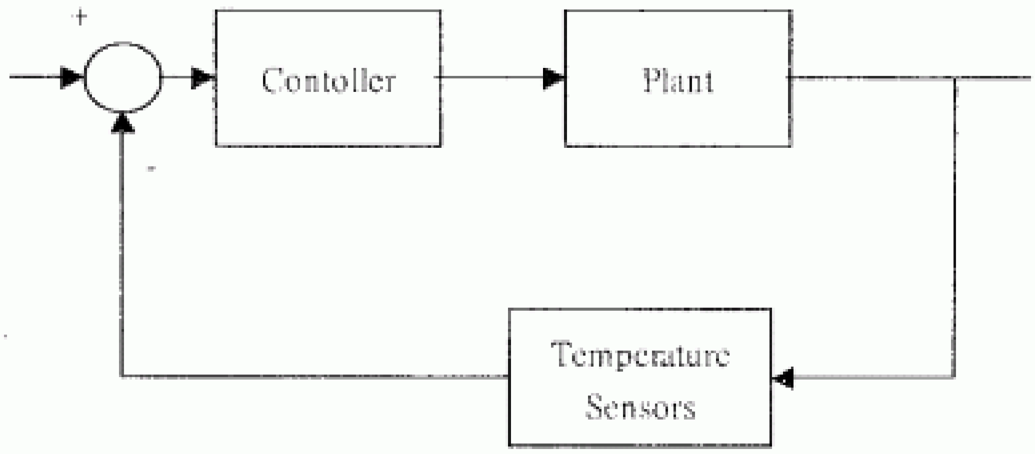


Prob. (4) Alex was assigned to design a temperature control system for a thermal bath employed for his laboratory equipment. He was told to place the temperature sensors as close as possible to the heating elements for better control stability.

(a) Could you verify the above statement by inserting a simple time delay block in the control block diagram with the assumption on the heater being constant gain and the plant being first-order block? *(3%)*

(b) Could you describe the causal stability effects between the plant time constant and the delay time constant? *(5%)*

(c) A thermal shield around the bath is needed for keeping the thermal energy losses to a minimum; could you give possible influences due to the shield on the control responses? *(2%)*



Prob. (5) Please re-order the following steps in correct sequences for constructing a root locus of transfer functions. *(15%, Note: more than five errors will have zero point)*

(a) Draw the asymptotes.
(b) Find the imaginary axis crossing points.
(c) Complete the sketch.
(d) Mark the poles and zeros.
(e) Find the real axis part of the locus.
(f) Compute the departure and arrival angles.
(g) Estimate locations of multiple roots, especially on the real axis, and determine the arrival and departure angles at the locations.

Prob. (6) In frequency-response design of control systems, there are typical compensation techniques given as followings that are employed for improving the plant dynamic performances. Please draw the corresponding frequency responses of each compensator. *(5%, Note: gain and phase diagram must be drawn)*

(a) PD compensation. $D(s) = K(T_D s + 1)$

(b) Lead compensation. $D(s) = K\dfrac{Ts+1}{\alpha Ts+1}, \alpha < 1$

(c) PI compensation. $D(s)=\dfrac{K}{s}\left(s+\dfrac{1}{T_I}\right)$

(d) Lag compensation. $D(s)=K\dfrac{Ts+1}{\alpha Ts+1}, \alpha>1$

(e) PID compensation. $D(s)=\dfrac{K}{s}\left[(T_D s+1)(s+\dfrac{1}{T_I}\right]$

Prob. (7) Consider the plant defined by the following state-space description

$$\dot{x}(t)_{n\times 1}=Fx(t)+Gu(t)_{1\times 1}$$
$$y(t)_{1\times 1}=Hx(t)+Ju(t)_{1\times 1}$$

where

(i) eigenvalues of F are：+2, +1, -4, -3±6j, -23±28j, -300±428j,

(ii) $\det\begin{bmatrix} sI-F & -G \\ H & J \end{bmatrix}=0$ for s=+2, -6, -23±28j,

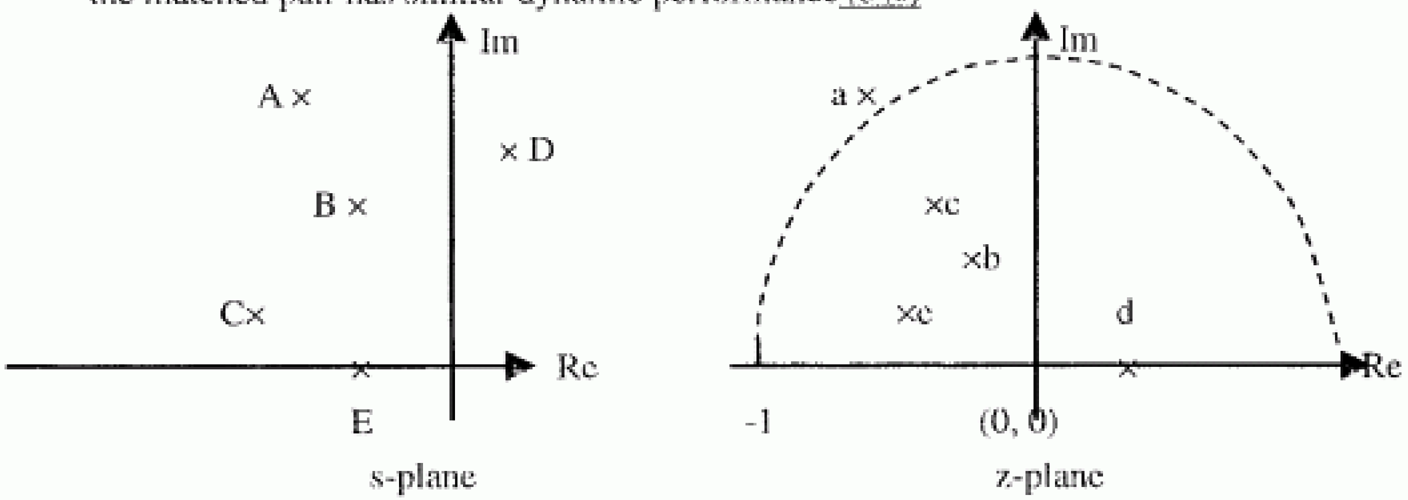
(iii) $\mathrm{rank}(C_X)=9$, C_X is the controllability matrix,

(iv) $\mathrm{rank}(O_X)=6$, O_X is the observability matrix,

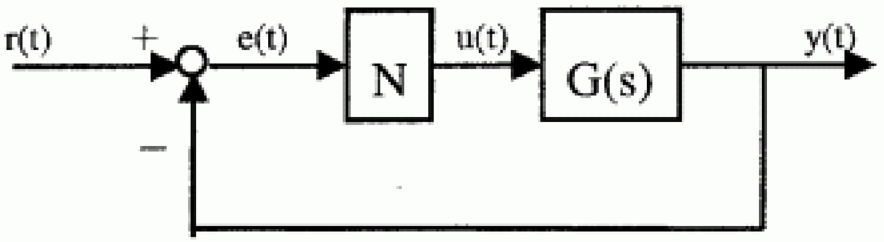
Please answer the following questions with brief rationality: *(2% each)*

(A) What are the system poles of the plant?
(B) What are the system zeros of the plant?
(C) What is the transfer function of the plant?
(D) Is the plant completely controllable?
(E) Is the plant completely observable?
(F) Is it possible to design an asymptotic observer?
(G) Is it possible to design a stable direct full state feedback control law?
(H) Is it possible to stabilize the plant with output dynamic feedback?
(I) Is it possible to stabilize the plant with an observer-based state feedback control?

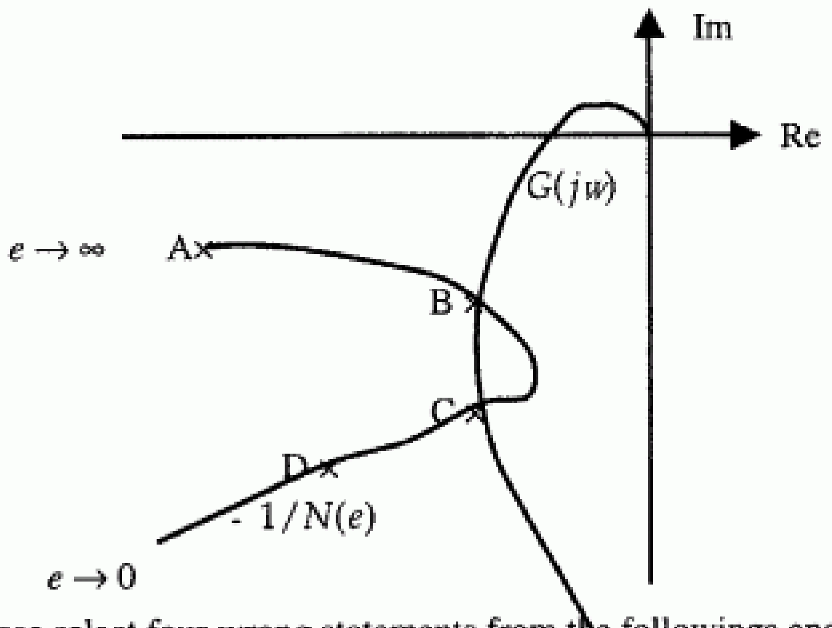
Prob. (8) Shown below are the pole locations of an analog control system T(s) and those of a digital control system T(z). Please match pole locations of T(s) with pole locations of T(z) such that the matched pair has similar dynamic performance *(5%)*



Prob. (9) Consider the nonlinear control system shown below, where N is a nonlinear element whose describing function N(e) depends on the amplitude e of the error signal e(t), and G(s) is a stable, linear dynamic process.



The describing function of N(e) and the Nyquist plot of $G(jw)$ are shown below with two intersection points at B and C, which corresponds two points $G(jw_B)$ and $G(jw_C)$ on the Nyquist plot of $G(jw)$. Please also notice that, at points A, B, C, D, $e = e_A$, $e = e_B$, $e = e_C$, $e = e_D$ respectively, while $w = w_A, w_B, w_C, w_D$.



Please select four wrong statements from the followings and briefly justify your choice: *(8%)*

(A) The control system is stable when $e_C < e(t) < e_B$.

(B) The control system is stable when $e_B < e(t)$.

(C) The control system is stable when $e_C > e(t)$.

(D) For non-zero initial responses with r(t)=0 and $e(0) > e_B$, the steady state output response has an oscillation frequency $w = w_B$.

(E) For non-zero initial responses with r(t)=0 and $e(0) < e_B$, the steady state output response has an oscillation frequency $w = w_C$.

(F) For non-zero initial responses with r(t)=0 and $e(0) < e_C$, the control system is unstable and there will be no steady state output even at $t \to \infty$.

(G) For non-zero initial responses with r(t)=0 and $e(0) > e_B$, the control system is unstable and there will be no steady state output even at $t \to \infty$.

(H) For non-zero initial responses with r(t)=0 and $e(0) < e_C$, the control system is locally unstable, but the system will eventually goes into a steady state output at $t \to \infty$.

Prob. (10) Consider the plant given below

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\omega_0^2 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$

$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} - 12u(t)$$

(A) Please design a reduced order state estimator L for the plant whose error dynamics has a pole at $s = -10w_0$. *(3%)*

(B) Give the state space description of this estimator. *(3%)*

(C) Give a complete block function diagram of this estimator and indicate the values of all gain elements. *(3%)*

(Below is BALNK)