注意：考試開始鈴響前，不得翻閱試題，並不得書寫、畫記、作答。

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：動力機械工程學系
乙組(電機控制組)

科目代碼：1202

考試科目：控制系統

一作答注意事項一

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「**國立清華大學試場規則及違規處理辦法**」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：動力機械工程學系 乙組(電機控制組)

考試科目（代碼）：(1202) 控制系統

 *請在【答案卷】作答

Q1 For the system in Figure 1,

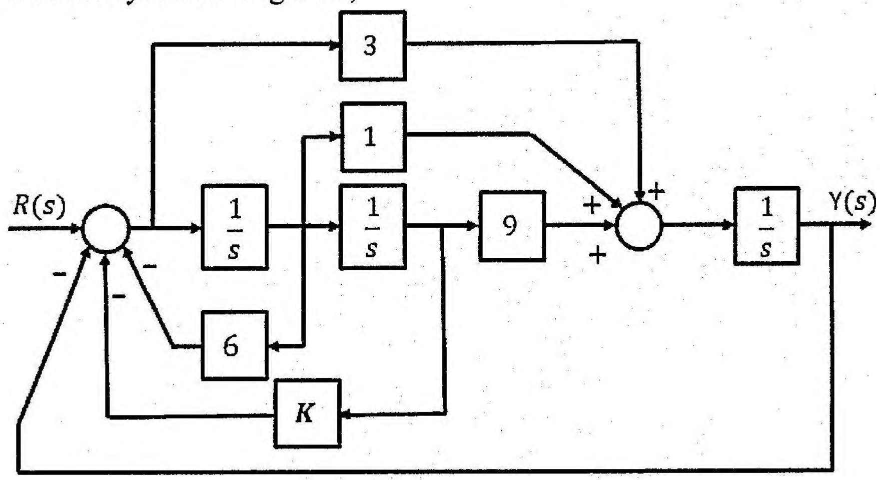

Figure 1

(a) find the transfer function $\dfrac{Y(s)}{R(s)}$. (5 pts)

(b) Sketch the root locus with respect to K, $K > 0$ (5 pts)

Ziegler-Nichols Tuning for the Regulator $D_c(s) = k_P(1 + 1/T_I s + T_D s)$, Based on the Ultimate Sensitivity Method

Type of Controller	Optimum Gain
P	$k_P = 0.5K_u$
PI	$k_P = 0.45K_u$, $T_I = \frac{P_u}{1.2}$
PID	$k_P = 1.6K_u$, $T_I = 0.5P_u$, $T_D = 0.125P_u$

Table 1 Ziegler-Nichols Tuning method

(c) Let's replace K with a **PI controller D_c(s)**. Based on the Ziegler-Nichols Tuning method shown as Table 1, design D_c(s). Give the values of your (k_p, T_I) (10 pts)

(d) With above PI controller D_c(s), determine the **relevant error constant** of closed loop system with respect to reference input *R(s)* (5 pts)

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：動力機械工程學系 乙組(電機控制組)

考試科目（代碼）：(1202) 控制系統

 *請在【答案卷】作答

Q2

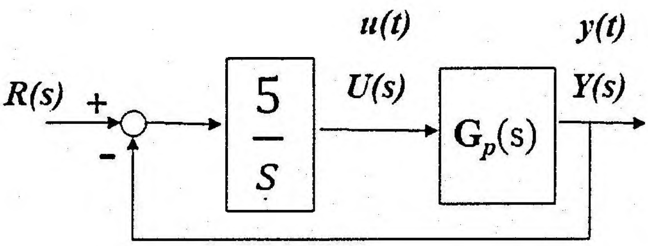

Figure 2

The plant $G_p(s)$ in Figure 2 results in

$$y(t) = 0 \qquad 0 \le t < 1$$
$$= u(t-1) \qquad t \ge 1$$

(a) What is the phase margin PM for the system shown in Figure 2? (5 pts)

(b) Draw the Nyquist plot. Specify the crossover points on the real axis to get points. (10 pts)

(c) Use Nyquist criterion to decide the closed-loop system stability. Give the values of N, P, Z to get points. (5 pts)

(Notes: (c) will be counted only when (b) is correct!)

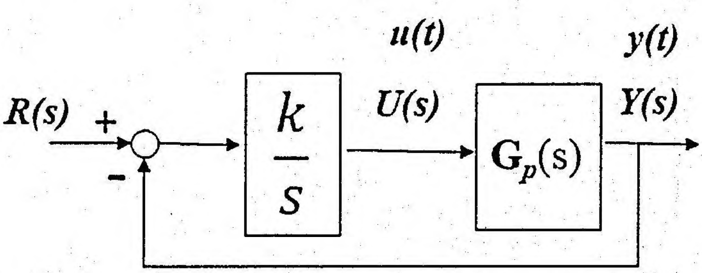

Figure 3

(d) For the system shown in Figure 3, the plant $G_p(s)$ is the same described above and $k > 0$. What is the range of k to result in a stable closed-loop system? (5 pts)

Q3. For the model depicted in Figure 4,

(a) derive the (two) differential equations describing the dynamics of the system (8 pts), and

(b) derive the transfer function $G(s) = \frac{x_2(s)}{F_1(s)}$. (8 pts) Assuming $0 < \delta k \ll k$ and $0 < c \ll 2\sqrt{km}$, roughly sketch the frequency response of $G(s)$. (4 pts)

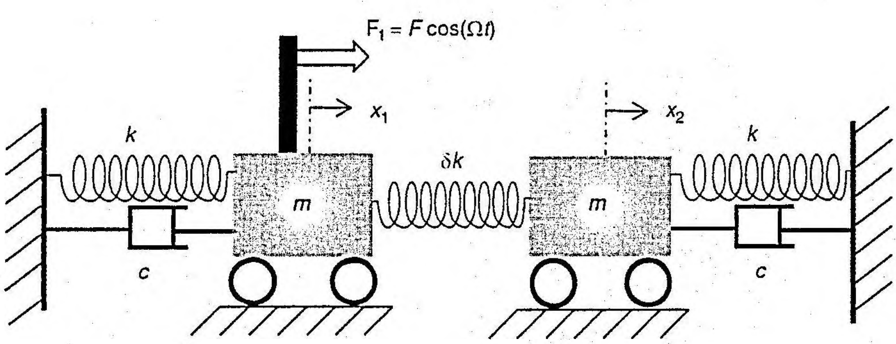

Figure 4

Q4. Consider the plant shown in Figure 5.

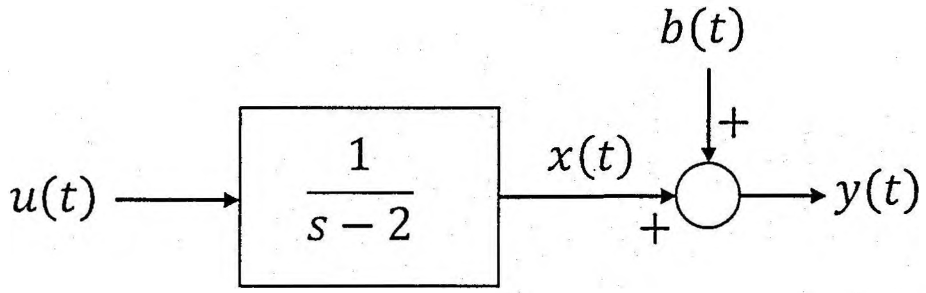

Figure 5

(a) Using $u(t)$ and $b(t)$ as the inputs, $x(t)$ as the state, and $y(t)$ as the output, establish a state-space model of the system. (3 pts)

(b) In Figure 5, $u(t)$ is the control input and $b(t)$ can be treated as the sensor bias. Assume that $b(t)$ is constant but unknown (i.e. $\dot{b} = 0$). Using $\begin{bmatrix} x \\ b \end{bmatrix}$ as the new state vector, derive the state equation and output equation of the augmented system. (5 pts)

(c) Examine the observability of the augmented system in (b). For such an augmented system, construct an observer that generates estimates for x and b using u and y. The observer's characteristic polynomial should be chosen as $\mathrm{E(s)} = s^2 + 8s + 16$. Write down the state equation of the observer as the answer. (7 pts)

(d) Use the results in (c) to implement state-estimate feedback control in the form

$$u(t) = -k\hat{x}(t),$$

where $\hat{x}(t)$ is the observer's estimate of x. What is the controller's transfer function (i.e., $\frac{U(s)}{Y(s)}$)? (7 pts) What is the range of k for the closed-loop system to be stable and what are the closed-loop poles? (8 pts) (Hint: Separation principle.)