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 113 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 113 學年度碩士班考試入學試題

系所班組別：動力機械工程學系碩士班　乙組(電機控制組)

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　　*請在【答案卷、卡】作答

Q1. The system block diagram is shown on the right (Fig. 1). The Bode plot of the loop gain $G_c\,G_p$ is given below (Fig. 2) for $G_c(s) = kG_{cc}(s)$ at k=1.

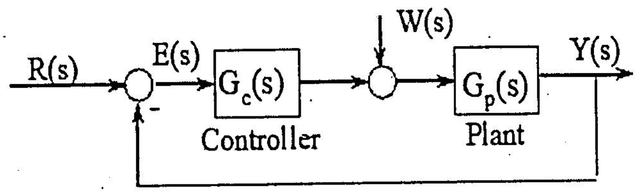

Fig. 1

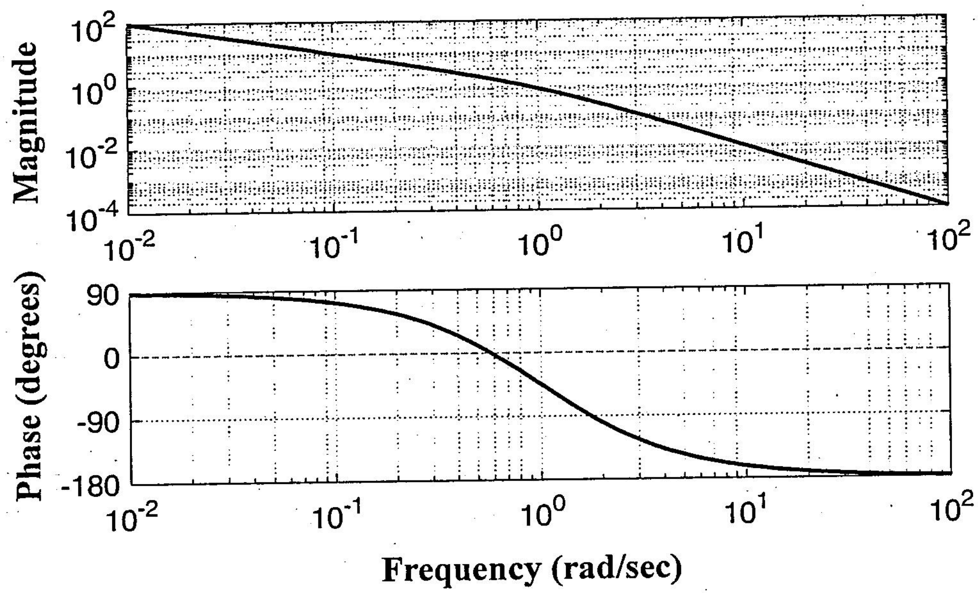

Fig. 2

(a) Write the transfer function of the loop gain $G_c(s)G_p(s)$. (5 pts)

(b) (b1)Draw the Nyquist plot. (10 pts)　(b2)"Calculate" the real axis crossing if there is. (5 pts)

(c) Use Nyquist Criterion to figure out the stability of the closed-loop system. (need to give the values of Z, N, P to get points). (5 pts)

(d) If tuning k as a variable from 0 up to ∞.　What is the range for k to result in a stable closed-loop system, if there is? (5 pts)

Q2.

A system has the open-loop plant transfer function $G(s)=\dfrac{10(s-0.1)}{(s+1)(s-1)}$

(a) Sketch a root locus for the system (a simple root locus sketch is sufficient here). (5 pts)

(b) Based on looking at the root locus, can we use high gain proportional control to obtain a stable closed-loop system? (5 pts)

(c) Suggest a dynamic compensator, $D(s)$, that will result in a stable closed-loop system. Sketch the compensated root locus of $D(s)G(s)$ (again, a simple root locus sketch is sufficient). (5 pts)

Comment on any practical difficulty of implementing your solution. (5 pts)

Q3. Fig. 3 shows a hydraulic system where liquid is stored in an open tank. The cross-sectional area of the tank, $A(h) = A_0 + a_0 h$ where h is the height of the liquid level above the bottom of the tank and A_0 and a_0 are constants. For a liquid of density ρ, the absolute pressure p at the bottom of the tank is given by $p = \rho g h + p_a$, where p_a is the atmospheric pressure (assumed constant) and g is the acceleration due to gravity. The tank receives liquid at a flow rate w_i and loses liquid through a valve at a flow rate w_o in which $w_o = k\sqrt{\Delta p}$. In the current case, $\Delta p = p - p_a$ and k is a positive constant. Take $u = w_i$ to be the control input and $y = h$ to be the output.

(a) Compute the volume of the liquid as a function of h. (3%)

(b) Using h as the state variable, determine the state model. (Hint: Rate of volume change= $w_i - w_o$) (7%)

(c) Find u_0 (steady-state input u) that is needed to maintain the output at a constant h_0. (3%)

(d) Assume $u = u_0 + \delta u$ and $h = h_0 + \delta h$ in which δ represents a small perturbation. Linearize the state model in (b) around $u = u_0$ and $h = h_0$. What is the open-loop pole of the system? Is the system open-loop stable? (12%)

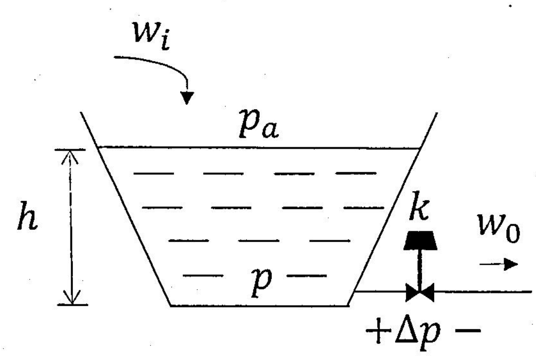

Fig. 3

Q4. To devise the balancing controller for the autonomous bicycle, Fig. 4 models the lateral dynamics of the bicycle as an inverted-pendulum system. In the model, θ denotes the tilt angle of the bicycle, and δ is the steering angle of the handle. The task is to design a controller to make the tilt angle $\theta(t)$ follow a reference command $r(t)$.

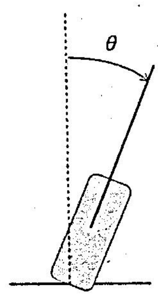

Fig. 4

(a) The differential equation describing the inverted-pendulum dynamics is given by $\ddot{\theta} = 2\theta + \delta + \dot{\delta}$. Define $\dot{\delta}$ as the control input, $x = [\theta \quad \dot{\theta} \quad \delta]^T$ as the state vector, and the measurement output $y = \theta$. Derive the state equations for the system. Examine its controllability and observability. (3 pts)

(b) Assume that all of the states $\begin{bmatrix}\theta \\ \dot{\theta} \\ \delta\end{bmatrix}$ can be measured. Design a control law

$$\dot{\delta} = \bar{N} \cdot r - K_1 \cdot \theta - K_2 \cdot \dot{\theta} - K_3 \cdot \delta, \qquad (1)$$

where $\bar{N}, K_1 \sim K_3$ are control gains, so that the closed-loop transfer $G_{r\theta}(s)$ is given by $G_{r\theta}(s) = \frac{1}{s^2+2s+1}$. (7 pts)

(c) Consider the dynamic equation $\ddot{\theta} = 2\theta + \delta + \dot{\delta}$ using $u = \delta + \dot{\delta}$ as the control input, and $y = \theta + \theta_b$ as the measurement in which θ_b is an unknown, constant offset. Construct an observer to estimate θ, $\dot{\theta}$, θ_b using u and y. The observer you design should have poles located at $-10, -10, -10$. (10 pts) (Hint: Consider the state equation for $[\theta \quad \dot{\theta} \quad \theta_b]^T$.)

(d) Shows that the control law $u = -K_1 \cdot \hat{\theta} - K_2 \cdot \hat{\dot{\theta}}$, where $\hat{\theta}$ and $\hat{\dot{\theta}}$ are the estimates of θ and $\dot{\theta}$ by the observer designed in (c), can stabilize the system (i.e, $\theta(\infty) = \dot{\theta}(\infty) = 0$, for any $\theta(0)$ and $\dot{\theta}(0)$) if $K_1 > 2, K_2 > 0$. (5 pts)