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 114 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 ：1302

考 試 科 目 ：控制系統

—作答注意事項—

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。

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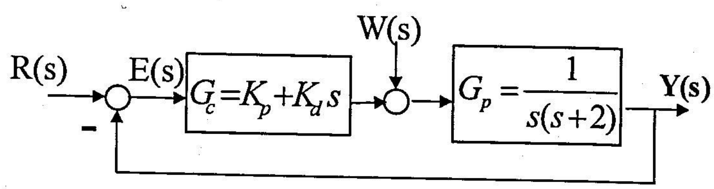
考試科目（代碼）：控制系統(1302)

1. (10 pts) Consider the right closed-loop control system:

Let's design a PD controller of G_c for G_p to satisfy the closed-loop system with the specification



(i) rise time = $0.45 \times \sqrt{2}$ seconds;

(ii) overshoot=4.32%.

Please give your PD controller (K_p , K_d)

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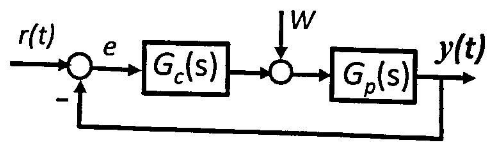
　*請在【答案卷　】作答

2. **(a) (10 pts)** The Nichols Charts on the right show 4 different $G_c(S)G_p(S)$ in above block diagram, where $G_c(s)$=1. Please match A:______; B:______; C:______; D:______; to one of the following system, respectively. (there is no partial credit!)



(1) $G_c(s)G_p(s) = \dfrac{s+1}{s^2(s+10)}$

(2) $G_c(s)G_p(s) = \dfrac{s-1}{s^2(s+10)}$

(3) $G_c(s)G_p(s) = -\dfrac{s-1}{s^2(s+10)}$

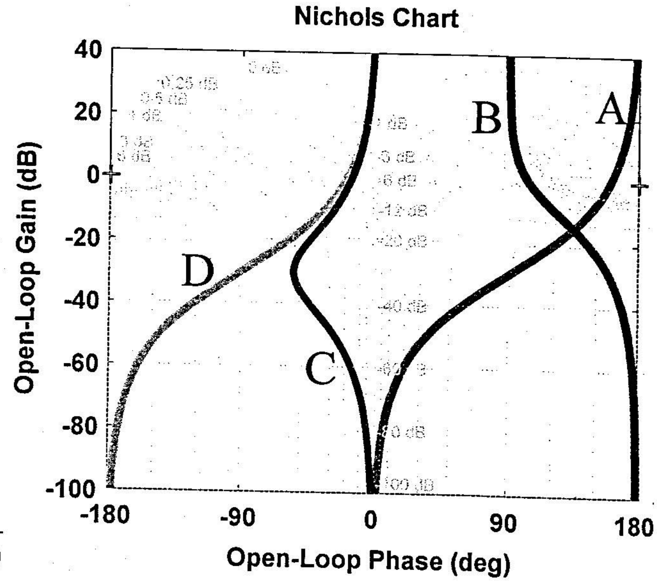
(4) $G_c(s)G_p(s) = -\dfrac{s+1}{s^2(s+10)}$

(5) $G_c(s)G_p(s) = \dfrac{s-1}{s^2(s-10)}$

(6) $G_c(s)G_p(s) = -\dfrac{s-1}{s^2(s-10)}$

(7) $G_c(s)G_p(s) = \dfrac{1}{s\,(s-2)}$

(8) $G_c(s)G_p(s) = -\dfrac{1}{s\,(s+2)}$



(b) (5 pts) Draw the Nyquist plot for **System B** (describe how you get this plot in details)

(c) (5 pts) Use Nyquist criterion to determine the stability of closed-loop system **(System B)**

(d) Change $G_c(s)$=1 to $G_c(s) = K\dfrac{S+Z}{S+P}$ for the same $G_p(s)$ shown at above Nichols Chart B to answer the following problems (d-i) & (d-ii):

(d-i) (15 pts) Design a lead compensator $G_c(s) = K\dfrac{S+Z}{S+P}$ to result in a closed-loop system of 10° Phase Margin. The gain crossover frequency of $G_c\,G_p$ did not change by adding in G_c. ($G_c\,G_p$ and G_p have the same gain crossover frequency). Please give (K, p, z)?

(d-ii) (5 pts) For a unit step signal on the disturbance W(s) and the controller G_c from (b-i), what is the steady-state error for signal on e ?

3. Consider a single-input-single-output plant described by

$$\dot{x} = Ax + Bu$$
$$y = Cx.$$

It is desired that y be regulated to a constant value r. To do so, we define an error variable $e = y - r$. Augment $x_I = \int e$ to x and form a new state vector $\bar{x} = [x \quad x_I]^T$.

(a) (5 pts) Write down the state equation for the new state vector $\bar{x}$. (Hint: $\dot{x}_I = e = y - r = Cx - r$.)

(b) (5 pts) Derive the controllability condition for the system you derived in **(a)**. Notice that your answer should be expressed in terms of the A, B, C matrices.

(c) (6 pts) Let $G(s) = \frac{y(s)}{u(s)} = \frac{2}{s^2-2}$. Realize the system in control canonical form and augment the system as you did in part **(a)**. Verify that the augmented system is controllable.

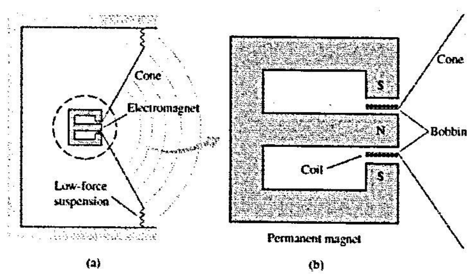
(d) (8 pts) Compute a control gain matrix $\bar{K}$ so that the controller $u = -\bar{K}\bar{x}$ can place the poles of the augmented system in part **(c)** at $-1 \pm j, -7$. **(6 pts)** What are the rise time, overshoot, and the steady state error $\lim_{t\to\infty}(y - r)$ of the closed-loop system?

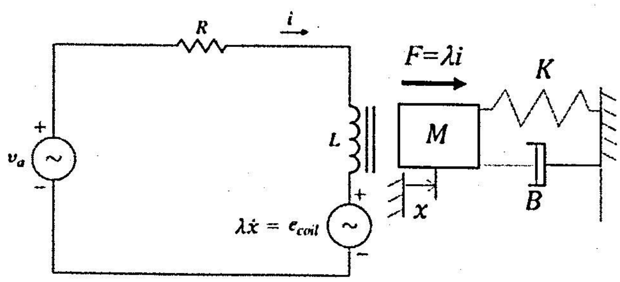
4. A typical geometry for a loudspeaker for producing sound is sketched in Fig. 1(a) and Fig. 1(b). The permanent magnet establishes a radial field in the cylindrical gap between the magnet's poles. The force on the conductor wound on the bobbin causes the voice coil to move, producing sound. The effects of the air can be modeled as if the cone had equivalent mass M, spring constant K, and viscous friction coefficient B. The electro-mechanical dynamics for the loudspeaker is shown in Fig. 1(c) in which v_a is the input voltage, R is the coil resistance, L is the coil inductance, e_{coil} is the back emf voltage, F is the force generated by the voice coil, and finally x is the displacement of the cone. Notice that because of the electro-mechanical interaction, $F = \lambda i$ and $e_{coil} = \lambda \dot{x}$ in which λ is a constant.

(a) **(8 pts)** Using $\boldsymbol{x} = [x \quad \dot{x} \quad i]^T$ as the state vector, $u = v_a$ as the input, and $y = i$ as the output (measurement), write down the state equations and the output equation.

(b) **(5 pts)** Prove that if $K = 0$, one cannot observe x and $\dot{x}$ from the measured current (i).

(c) **(7 pts)** Let the numerical values of M, K, B, R, L, λ all equal 1. Design an observer to estimate $\boldsymbol{x}$ from the measured current (i) so that the estimation errors decay at the rate of e^{-4t}. You should write down the state equations for the observer.





(c)

Fig. 1