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 109 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

—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. 作答中如有發現試題印刷不清，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 109 學年度碩士班考試入學試題

系所班組別：動機系乙組

考試科目（代碼）：(1202) 控制系統

　　*請在【答案卷、卡】作答

Q1 A DC motor with the equivalent electric circuit is shown in Figure 1. The rotor has inertia J_m and viscous friction coefficient b. Assume $L_a = 0$ to simplify your calculation! Also $R_a = b = J_m = K_e = K_t = 1$ With the feedback control shown in the block diagram (Figure 2), the whole mechatronic system with feedback control is addressed.

(a) Draw the Nyquist plot for the open-loop gain from *e* to *y* (10 pts)

(b) Use Nyquist criterion to decide the closed-loop system stability (Notes: need to give the values of N, Z, P to get points) (5 pts)

(c) What is the Gain Margin (*G.M.*) of the closed-loop system? What is the Phase Margin(*P.M.*) of the closed-loop system? (Notes: $-180^o < P.M. < 180^o$) (10 pts)

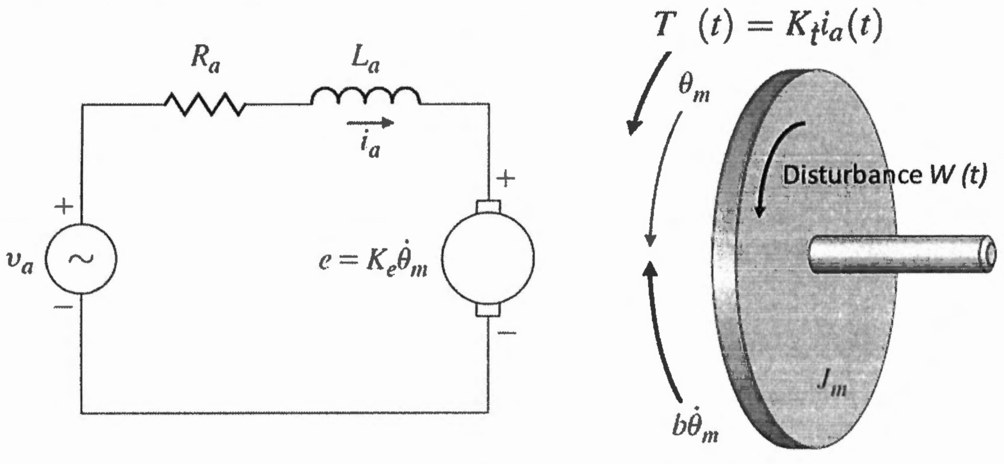

Figure 1

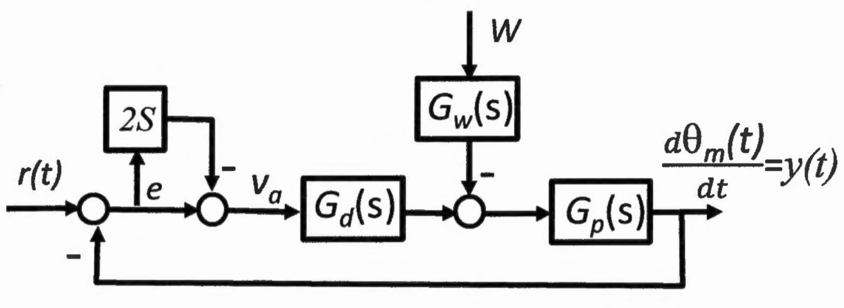

Figure 2

Q2 As shown in block diagram (Figure 3), the controller is $G_c(s) = kG_{cc}(s)$.

(a) The bode plot shown below (Figure 4) is for $G_c(S)G_p(S)$ at ***k=1***. Write the transfer function of the loop gain $G_c(S)G_p(S)$. (10 pts)

(b) Draw the Nyquist plot of $G_c(s)G_p(s)$ (**<u>assume *k=0.5* for part (b)</u>**). (indicate the real axis crossing and show how you get your Nyquist plot to get credit!) (10 pts)

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

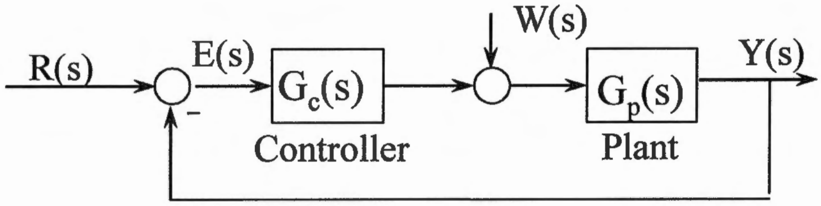

Figure 3

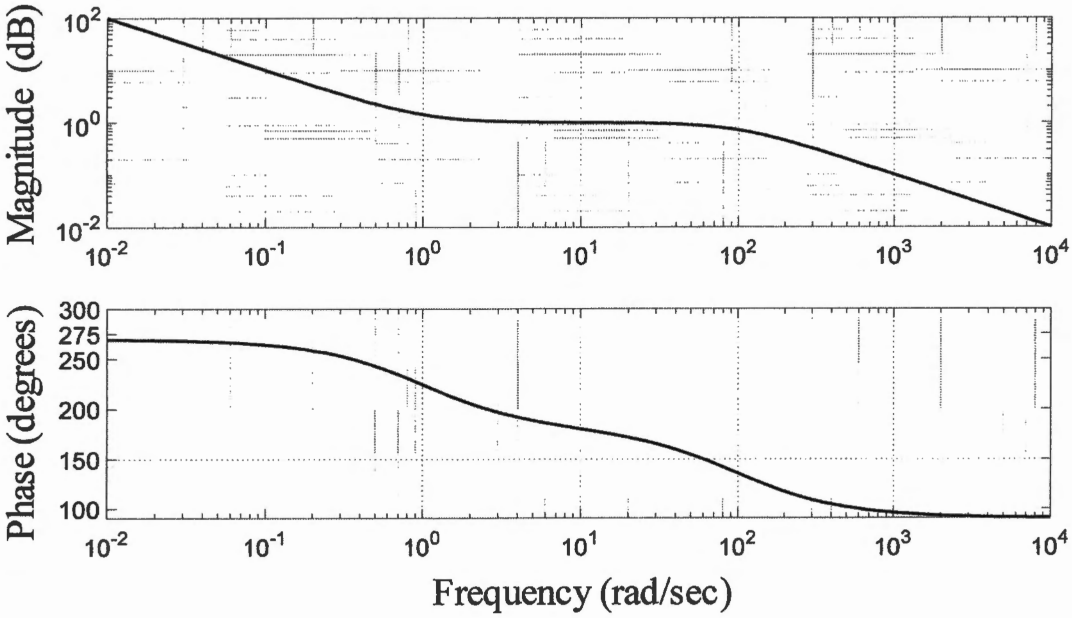

Figure 4

國立清華大學 109 學年度碩士班考試入學試題

系所班組別：動機系乙組

考試科目（代碼）：(1202) 控制系統

 *請在【答案卷、卡】作答

Q3 Shown in Figure 5 is the inverted-pendulum schematic of a bicycle model. In the model, θ denotes the tilt angle of the bicycle, θ_b is the measurement bias (which is not used in this problem) and δ is the turning angle of the handle for balancing and cornering control.

(a) The differential equation describing the inverted-pendulum dynamics is given by $\ddot{\theta} = 9\delta + 3\dot{\delta} + 16\theta$. Derive the transfer function $G(s) = \frac{\theta(s)}{\delta(s)}$ for the system. (2 pts)

(b) What is the controllable canonical realization of $G(s)$ in the state space form? (3 pts)

(c) Let $\boldsymbol{x} = [\theta \quad \dot{\theta} \quad \delta]^T$, $u = \dot{\delta}$, and $y = \theta$. Derive the state-space equation $\dot{\boldsymbol{x}} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{B}u$, $y = \boldsymbol{C}\boldsymbol{x} + \boldsymbol{D}u$. What are the $\boldsymbol{A}, \boldsymbol{B}, \boldsymbol{C}, \boldsymbol{D}$ matrices? Examine the controllability and observability of the realization. (5 pts)

(d) For the realization in (c), compute a state feedback matrix $\boldsymbol{K}$ so that the control law $u = -\boldsymbol{K}\boldsymbol{x}$ can place the closed-loop poles at $-1, -1, -10$. (7 pts)

(e) The controller you design in (d) can be put in the block diagram form in Figure 6. What is control transfer function $C(s)$? What type controller is this? (PD, PI, Lead, Lag….) (8 pts)

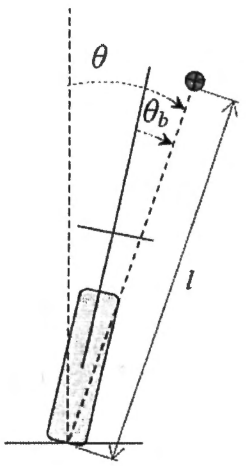

Figure 5

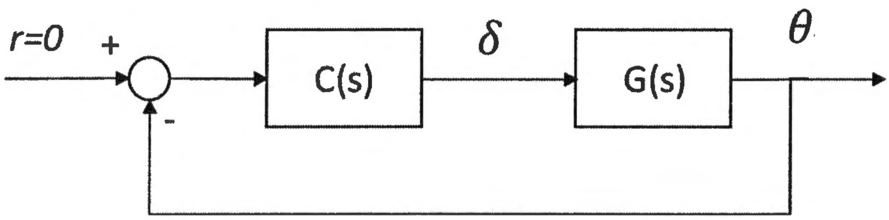

Figure 6

國立清華大學 109 學年度碩士班考試入學試題

系所班組別：動機系乙組

考試科目（代碼）：(1202) 控制系統

　　*請在【答案卷、卡】作答

Q4 Plot the root loci of the following characteristic equation as K varies from zero to infinity.

$$1+\frac{K}{s^4+12s^3+64s^2+128s}=0$$

On the root loci, please clearly indicate

(a) the open loop poles and zeros (Note: The polynomial $s^3+12s^2+64s^1+128$ has one of its roots at -4.), (3 pts)

(b) the segment(s) of root loci on the real axis, (1 pts)

(c) the angles of the asymptotes and their intersection, (3 pts)

(d) the points where the root loci cross the imaginary axis and the corresponding K, (4 pts)

(e) the approximate breakaway point(s), (4 pts) and

(f) the angles of departure at the complex poles. (5 pts)

(g) Also use the root loci to approximately determine the K so that the complex roots near the origin have a damping ratio of $\varsigma = 0.707$. (5 pts)