國立臺灣科技大學

115學年度碩士班招生

試題

系所組別：0340機械工程系碩士班丁組

科　　目：系統控制

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(總分為100分;所有試題務必於答案卷內頁依序作答)

1. (10%) Find the inverse Laplace transform of the following transfer function

$G(s) = \frac{9e^{-5s}}{s(s+3)^2}$

2. (15%) Consider the feedback control system whose block diagram is shown in Figure 1. The transfer function of the controlled plant is $G(s) = \frac{1}{s(s^2+2s+2)(2s+1)}$, and the transfer function of the controller is $G_c(s) = s + a$. Please answer the following question.

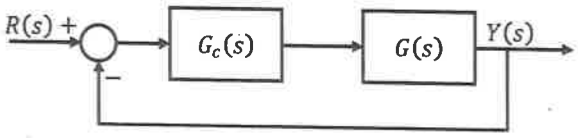

Figure 1

i. Sketch the location of the closed-loop roots if the parameter "a" is varied from 0 to infinity. (5%)

ii. Find the steady-state error of this system if the reference input R(s) is a unit ramp function. (5%)

iii. Find the condition of "a" such that the steady state error of the unit step response becomes non-zero. (5%)

3. (15%) Given the state space system model described by the dynamic equations below:

$$\dot{X}(t) = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -8 & -(3K+2) & -4 \end{bmatrix} X(t) + \begin{bmatrix} 0 \\ 0 \\ K \end{bmatrix} u(t)$$

$$y(t) = [1 \quad 0 \quad 0] X(t)$$

i. Determine the range of K for which the system is stable (5%)

ii. Find the frequency at which the system will oscillate in marginally stable system (5%)

iii. If $K = 1$, find the steady-state value of $y(t)$ for a unit-step input (5%)

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4. (20%) Consider the cart–pole system, aka inverted pendulum system, shown in the Figure 2. A cart of mass $\boldsymbol{M}$ moves horizontally on a frictionless track. A uniform slender rod (inverted pendulum) of mass $\boldsymbol{m}$ and length $\boldsymbol{l}$ is attached to the cart via a frictionless pivot. For small deviations about the upright position, the linearized dynamics are given by

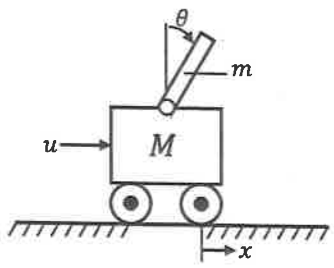

Figure 2

$$(M+m)\ddot{x} + \frac{ml}{2}\ddot{\theta} = u \quad (1)$$

$$\frac{ml^2}{3}\ddot{\theta} + \frac{ml}{2}\ddot{x} - \frac{mgl}{2}\theta = 0 \quad (2)$$

Use this model in the following questions:

i. Assume zero initial conditions. Take the Laplace transform of the linearized model, fnd the transfer function from input force to pendulum angle $G_\theta(s) = \frac{\Theta(s)}{U(s)}$ (8%)

ii. Using the linearized dynamic equations and the select the state variables as $x_1 = \theta,\ x_2 = \dot{\theta},\ x_3 = x,\ x_4 = \dot{x}$, if the parameter values are given as $M = 5[kg],\ m = 1[kg],\ l = 1[m]$ and $g = 10\ [m/s^2]$, determine whether the system is controllable and justify your answer. (6%)

iii. Using the same model and state definitions, and parameter values as in previous question, determine whether the system is observable for the following sensor output $y = \theta$. Justify your answer using a standard observability test. (6%)

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5. (25%) An open-loop system $G(s) = \frac{-s+3}{\sqrt{3}(s+1)}$ is to be evaluated using frequency response. The gain crossover frequency is found to be at $\omega = \sqrt{3}$. Answer the followings:

i. Roughly sketch the Bode plot (using asymptotes is acceptable), including both the magnitude and phase plots. Explicitly express the values of the DC gain, high frequency gain, low frequency phase angle, and high frequency phase angle. (10%)

ii. Find the gain margin and phase margin of this system. (10%)

iii. Since the system has a right half plane zero at 3, comment on whether this zero will affect the counter-clockwise (CCW) encirclement of the critical point on the Nyquist plot of G(s), based on the Nyquist Stability Criteria. That is, how many CCW encirclement of the critical point is needed to ensure closed-loop system stability under unity feedback? (5%)

6. (15%) Consider the block diagram shown below:

i. Find the transfer function $\frac{Y}{R}(s)$ and determine the system type. (10%)

ii. It is observed that the step response of $\frac{Y}{R}(s)$ always show sluggish response, indicating a slow mode always exist with frequency less than 1 rad sec. Explain why this is the case using the characteristics equation or the root locus. (5%)