國立清華大學 105 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(電控組)

考試科目（代碼）：控制系統 (1202)

Q1 **(10%)** Consider the system shown below (Figure 1). Let the PID controller $D(s) = k_p + \frac{k_I}{s} + k_D s$. Determine the steady-state error to a **unit ramp disturbance** input on W(s).

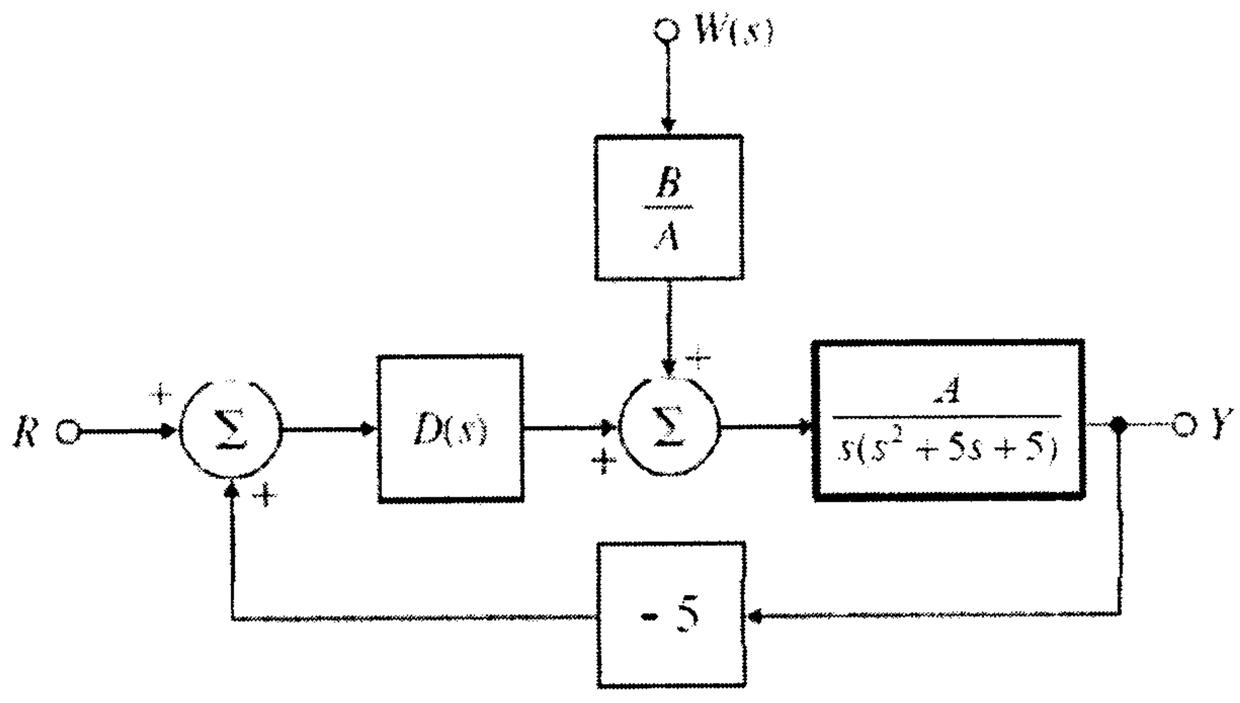


Figure 1

Q2 **(10%)** Roughly sketch the root loci for the pole–zero maps for positive values of the parameter K as shown in Figure 2 (a) and (b). Each pole–zero map is from a characteristic equation of the form $1 + K\frac{b(s)}{a(s)} = 0$ where the roots of the numerator $b(s)$ are shown as small circles ° and the roots of the denominator $a(s)$ are shown as × on the s-plane.

Notes: Figure 2(a) is for a system which is always unstable for all K. Figure 2(b) is for another system which is conditionally stable for different K values.

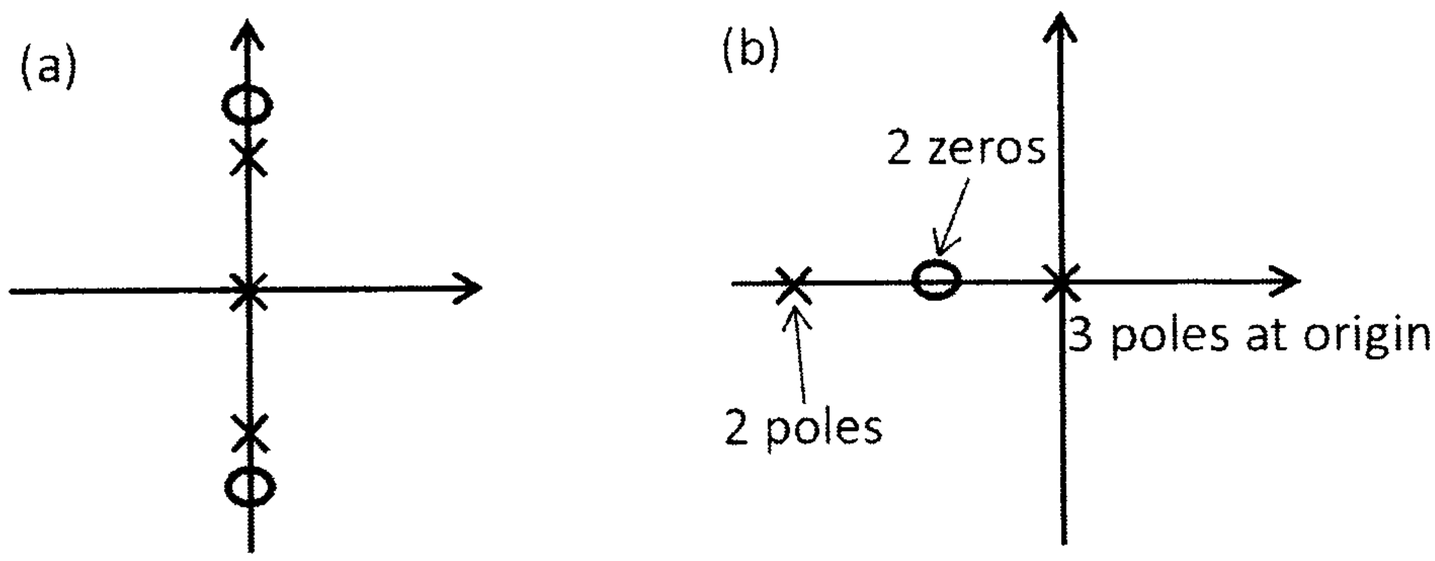
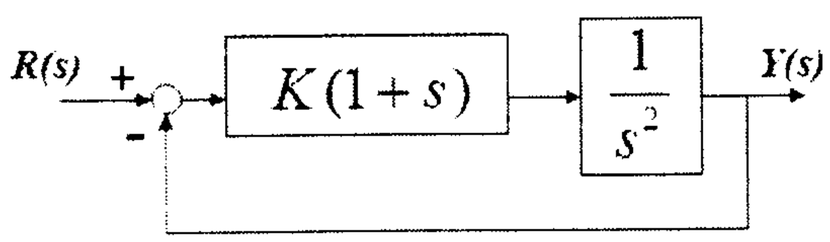


Figure 2

Q3 (a) (5%) Draw Root Locus for Case A and B as shown in Figure 3.

(b) (10%) Compare the overshoot for Case A and B under the condition of same K value. (the same, Case A>B, or Case A<B). Clearly explain your reasons to get points! (wrong/or no explanation will result in no point.)

Case A:



Case B:

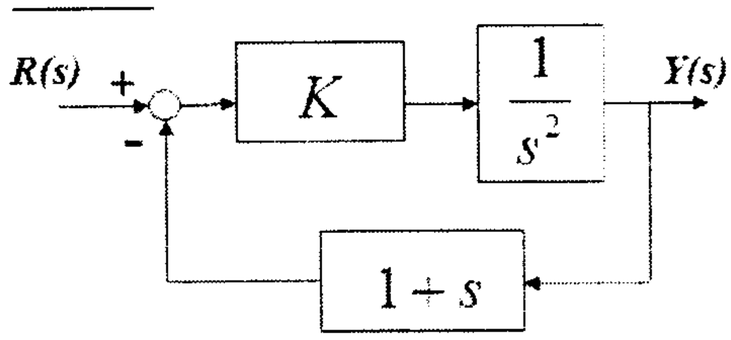


Figure 3

Q4 (15%) List all the controllers, which can satisfy all the following specifications, from these three candidates.

(1) Proportional Controller $G_c(s) = G_{c1}(s) = k_p$

(2) PI Controller $G_c(s) = G_{c2}(s) = k_p + \frac{k_I}{s}$

(3) PID Controller $G_c(s) = G_{c3}(s) = k_p + \frac{k_I}{s} + k_D s$

Please give your analysis and the conditions on k_p, k_I, k_D to satisfy all the specifications in details to get the points.

Specifications-

(i) maximum overshoot (Mp) no more than 5%

(ii) rise time (t_r) no more than 0.1 sec

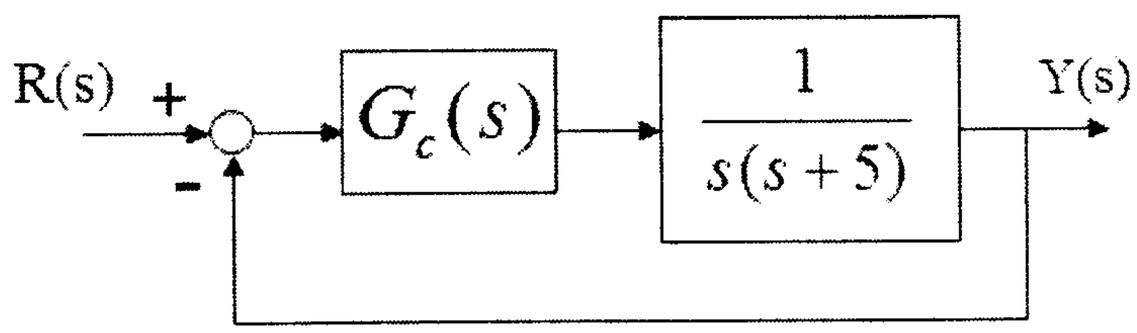


Figure 4

Q5 (15%) The system shown in Figure 5 represents the controlling balance of a personal transporter, the applied force f represents the tangential force on the transporter wheels. For small angle, the equation of motion becomes

$$ML\ddot{\theta} - (M+m)g\theta = f$$

Design a PD control law to maintain θ near zero.
The specifications are $\zeta=0.707$, settling time (2% in 4 τ) is 10 sec. with $M=40$ *slugs*, $m=8$ *slugs*, $L=20$ *ft*, and $g=32.2$ *ft/sec*^{2}.

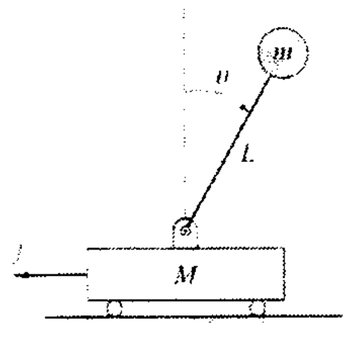


Figure 5

Q6 (15%) A certain system has two-coupled subsystems. One subsystem is a rotational system with the equation of motion as

$$50\frac{dw}{dt} + 10w = T(t)$$

Where T(t) is the torque applied by an electric motor which is a field-controlled motor as the second subsystem, the equation of motion is

$$0.001\frac{di_f}{dt} + 5i_f = v(t)$$

Where $v(t)$ is applied voltage, and i_f is the field current in amperes. The motor constant is $K_T=25\ Nm/A$. Obtain the damping ratio z, time constant and undamped nature frequency w_n.

Q7 (20%) Consider the bode diagram of a dynamic system, its frequency response are as shown in Figure 7.

(a) Determine the relative order of the system. (5 pts)

(b) Is it a minimum phase system? (5 pts)

(c) What are the dampings of pole(s) and zero(s)? (5pts)

(d) Give an estimated transfer function of this dynamical system. (5 pts)

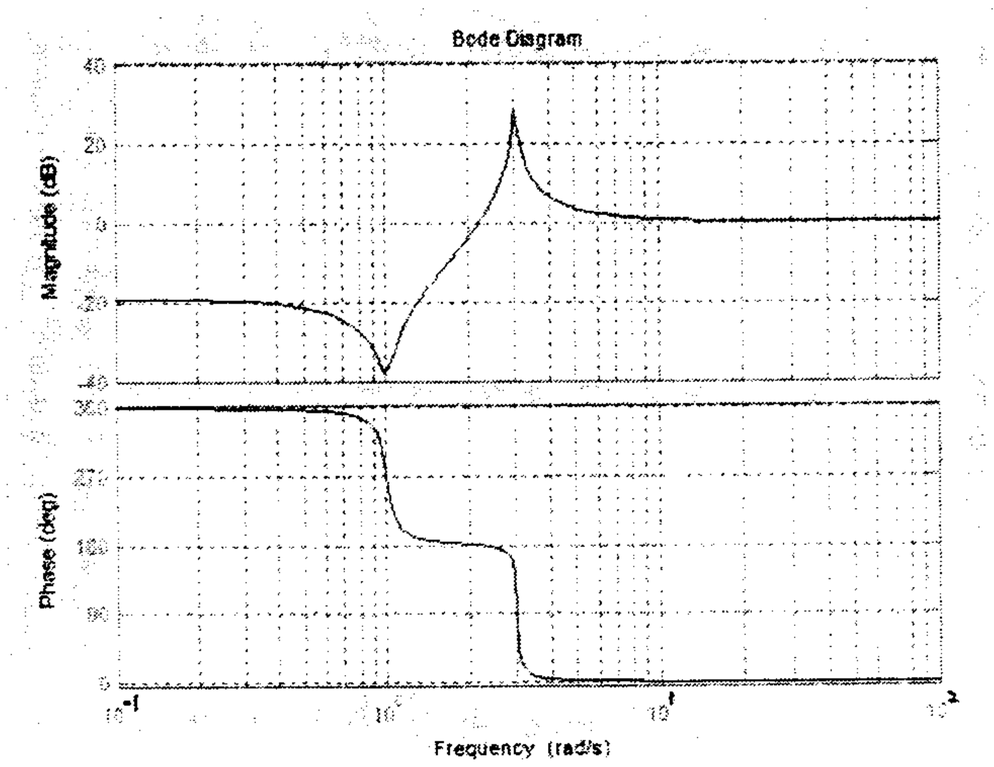


Figure 7