國立清華大學 102 學年度碩士班考試入學試題

系所班組別：乙組 (電控組) 動力機械工程學系碩士班

考試科目（代碼）：控制系統 (1202)

 *請在【答案卷、卡】作答

1. You are given a stable system $G(s)=K\dfrac{(1-\frac{s}{z_1})(1-\frac{s}{z_2})......(1-\frac{s}{z_n})}{(1-\frac{s}{p_1})(1-\frac{s}{p_2})......(1-\frac{s}{p_{n+r}})}$ $(K>0)$

   to investigate the "undershoot" phenomenon. (Note: A stable system is said to "undershoot" if it initially starts off in the wrong direction in response to a step input.)

   (a) Find the steady-state value of the output ($y(t)$) when the system is subjected to a step input ($u(t)=u_s(t)$). (1%)

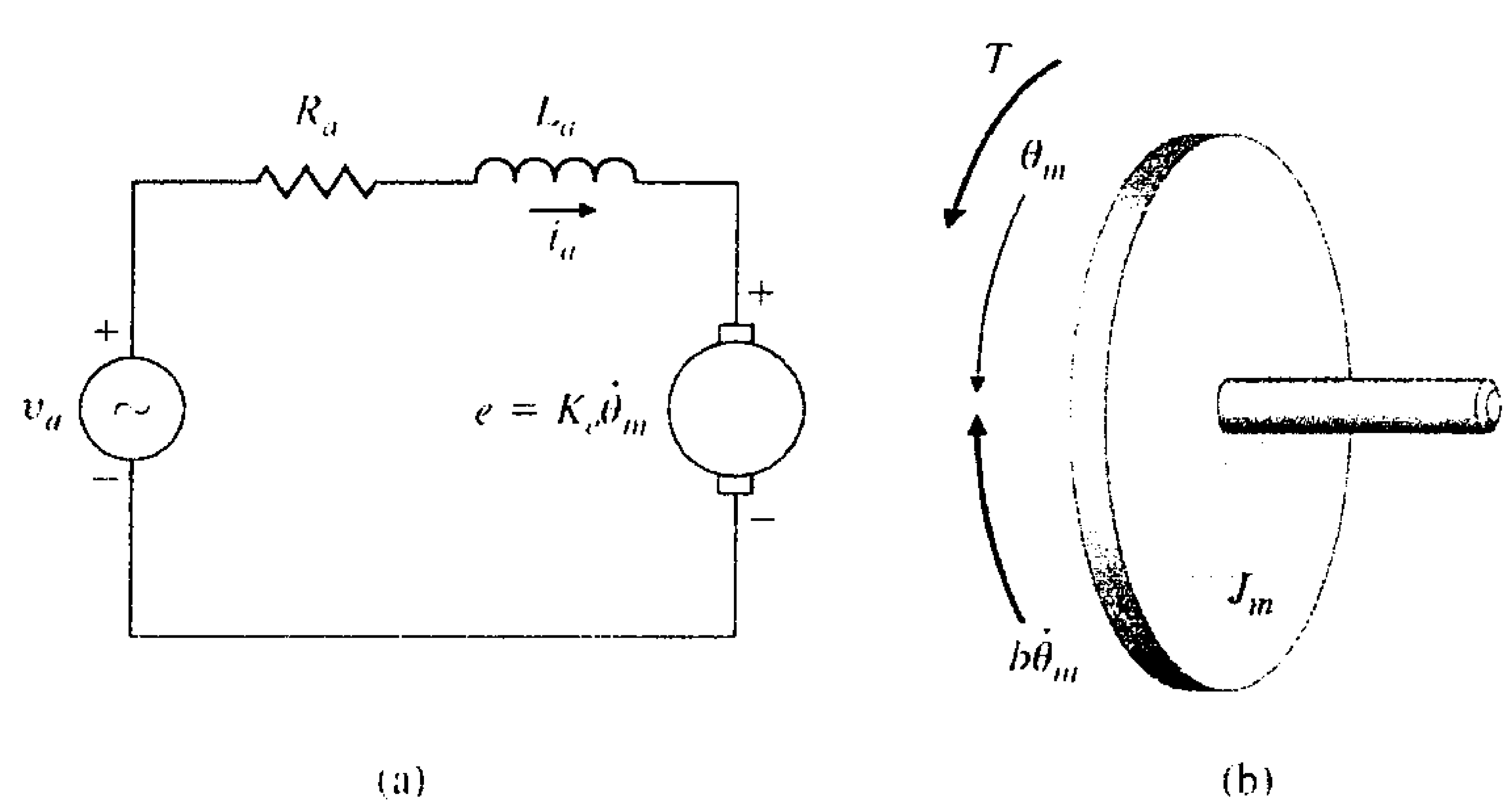
   (b) Assume the system has zero initial conditions. Determine $\dot{y}(0^+)$, $\ddot{y}(0^+)$, ... and $y^r(0^+)$ in response to a step input. (3%)

   (c) Using the results in (a) and (b), prove that the system "undershoots" if it has an odd number of real right-half plane zeros. (5%)

   (d) Let the number of real right-half plane zeros of $G(s)$ be m. Determine the phase of $G(j\omega)$ for $\omega\to\infty$. (5%)

2. The equation of motion for the DC motor shown in the following figure is given as

$$J_m\ddot{\theta}_m+(b+\frac{K_tK_e}{R_a})\dot{\theta}_m=\frac{K_t}{R_a}v_a$$



Assume that

$J_m = 0.01 kg.m^2$
$b = 0.001 N.m.\sec$
$K_e = 0.02 V.\sec$
$K_t = 0.02 N.m/A$
$R_a = 10\Omega$

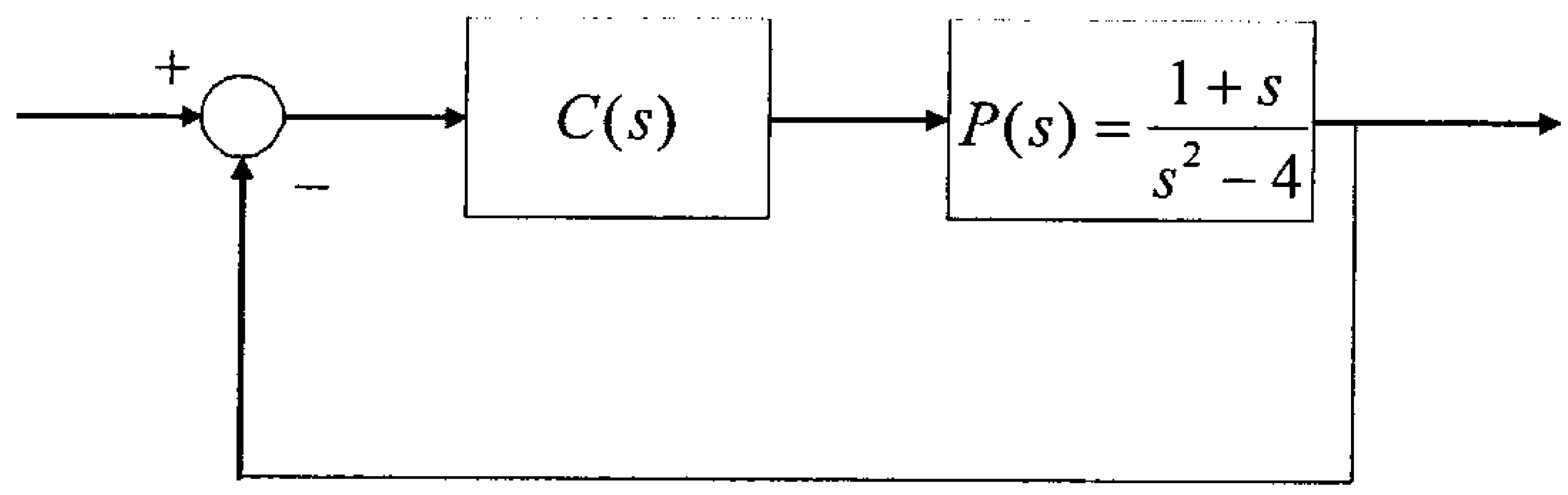
(a) Show how the equation of motion is derived. Explain why K_e and K_t have identical numerical values. (5%)

(b) Suppose feedback is added to the system so that it becomes a position servo device such that the applied voltage is given by $v_a = K(\theta_r - \theta_m)$ where K is the feedback gain. What is the maximum value that can be used if an overshoot $M_p < 20\%$ is desired? (4%)

(c) What values of K will provide a rise time of less than $4\sec$? (Ignore the M_p constraint. (4%)

(d) The motor drives a mechanical load via a gear train with a reduction ratio of 20. Assume that the load has the inertia of $10kg-m^2$ and the inertia for the gear train is negligible. Compute the total inertia seen from the motor side. (3%)

3. A unity control system is given below:



(a) Assume proportional control is used that $C(s) = k_p = 5$. Use Nyquist plot to examine the closed-loop stability. (6%) What are the phase margin (5%)

(b) and the gain margin (3%)?

(c) In order to eliminate the steady-state error to a step input, proportional+integral control is used instead. In this case, $C(s) = \frac{k(s+2)}{s}$ is chosen. Use Nyquist analysis to determine an appropriate control gain k that can stabilize the system. (6%)

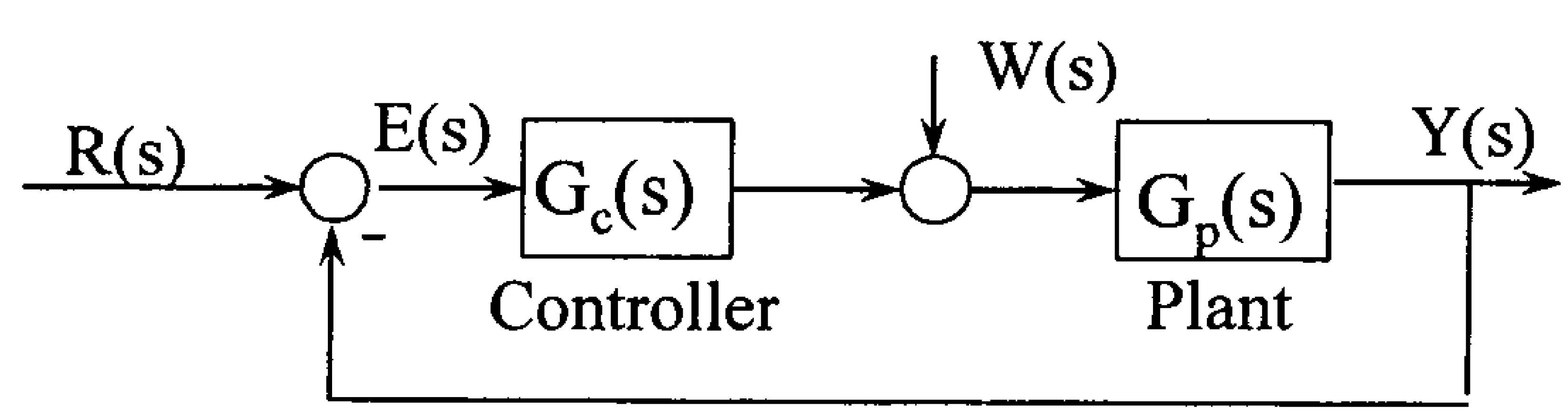
4. The system with the following open-loop transfer function is given

$$kG(s)=k\frac{(s+10)(-s+10)}{(s+5)^2(-s+5)^2}$$

(a) Sketch the root locus with respect to k (Assume k > 0) (15%)

(b) Assume k > 0. Is the root locus for this system a 180° root locus or a 0° root locus ? (5%)

5.



Consider the system with the open-loop transfer function

$$G_p(s)=\frac{(s^2+10)}{s^2(s^2+11)}$$

(a) Assume that because the complex pole-zero locations are somewhat close that we can approximate the dominant behavior as second-order. Design a lead compensator $G_c = K_c\frac{(s+z)}{(s+p)}$ for $G_p(s)$ to satisfy the specifications (i) ξ=0.2; (ii) settling time $t_s \cong 1\,\text{sec}$. Please give your lead compensator (K_c, p) with a chosen z = 2 .(20%)

(b) Sketch the compensated root locus with the lead compensator included in the loop. (5%)

(c) For a unit step input on R(s) and the lead compensator from (a), what is the steady-state error for the signal on E(s) as shown in above block-diagram feedback system? (5%)