淡江大學九十學年度碩士班招生考試試題

系別：機械工程學系　　科目：動 態 系 統

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本試題雙面印製

(各小題所佔分數在括號內，總分爲 100 分)

1. An ideal permanent-magnet DC motor and drive system is depicted in Figure 1. The motor has an inertia, J, and a property of viscous friction coefficient, B. Assume that the field current is constant.
   a. Prove that the induced voltage, e, and the electromechanical force (emf), T_m, can be expressed as functions of motor speed, ω, and armature current, i.

   $$e=k\,\omega$$
   $$T_m=k\,i$$

   Where k is the motor torque constant. **(10 分)**

   b. Show that the dynamic equations of the motor and drive system in Laplace domain are as equations (1) and (2),

   $$V(s)=(R+Ls)I(s)+k\Omega(s) \qquad (1)$$
   $$(Js+B)\Omega(s)+T_L(s)=kI(s) \qquad (2)$$

   The block diagram for these dynamic equations is sketched with input voltage, $V(s)$, and output angular position, $\theta(s)$ as shown in Figure 2. **(10 分)**

   c. Design a current controller with proportional gain K_A to regular the input voltage, $V(s)$. Prove that the motor and drive system can be simplified to be the system as shown in Figure 3, if we choose an ideal current controller with very large value of gain. Note that $i^*(s)$ in Figure 3 is the current command. **(10 分)**

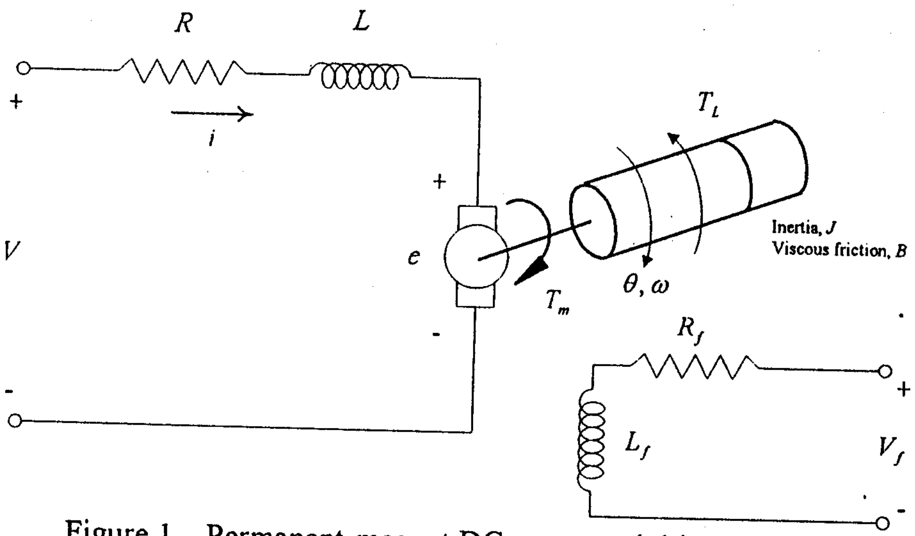

Figure 1　Permanent-magnet DC motor and drive system

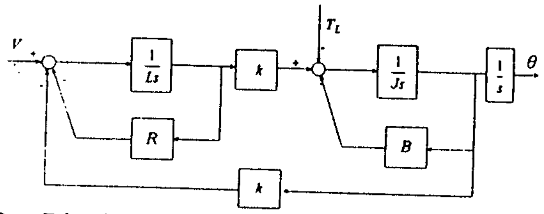

Figure 2　Block diagram of the motor and drive system

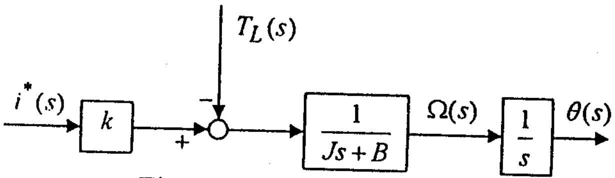

Figure 3　Simplified system

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2. A mass-pulley system shown in Figure 4 has a rotating wheel of inertia J. Two springs and a damper are connected to the wheel using cable without slip on the wheel.
   a. Prove that the dynamic equation of motion for the translational motion x can be expressed

$$(m + J\frac{4}{d^2})\ddot{x} + b\dot{x} + (k_1 + k_2)x = k_1 u \qquad (3)$$

   Where $u(t)$ is the input motion.(10 分)
   b. Determine the natural frequency and damping ratio of this second-order system by using the system properties in Table 1. (10 分)
   c. Plot the open-loop bode diagram for the mass-pulley system, and find the phase margin and gain margin of the system. (10 分)

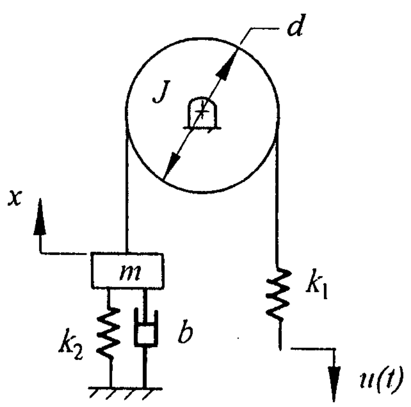

Figure 4　Mass-pulley system

Table 1

J	0.25 kgm^2
m	0.5 kg
k_1	0.5 N/m
k_2	0.1 N/m
b	2.5 N Sec/m
d	0.15 m

3. Consider the *RLC* circuit of Figure 5, which consists of the series connection of a voltage source, $e_s(t)$, a resistor, R=10Ω, a capacitor, C=0.1μF, and an inductor, L.
   a. Prove that the dynamic equation of the circuit in term of capacitor *voltage* $v_c(t)$ can be expressed as

$$LC\frac{d^2 v_c}{dt^2} + RC\frac{dv_c}{dt} + v_c = v_s \qquad \textbf{(10 分)}$$

   b. For a step input voltage source, find the inductance necessary to give a settling time of 2.5 milliseconds. Also find the damping ratio and natural frequency for the *RLC* circuit. (10 分)

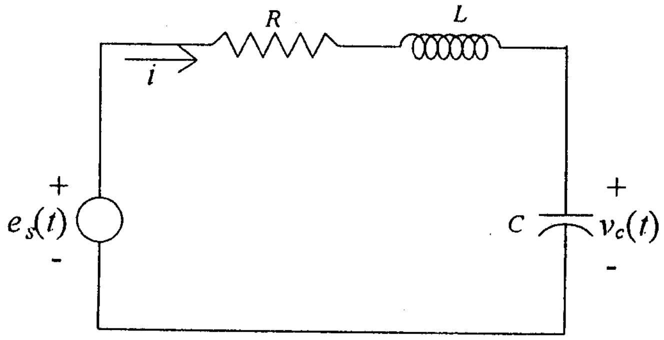

Figure 5　RLC circuit

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4. Consider the dynamic system with unity feedback as shown in Figure 6. The system is of a type-1 system with loop transfer function

$$G(s)=\frac{K}{s(s+a)}$$

The Nichols chart of this second-order system is shown in Figure 7.

a. Sketch the open-loop Bode diagram from Figure 7. Also find the phase margin, ϕ_m, and gain margin, g_m, approximately. (7 分)

b. Calculate is the values of K and a, approximately. (7 分)

c. Determine the damping ratio, ζ, by the following equation

$$\phi_m=\tan^{-1}\frac{2\zeta}{\sqrt{-2\zeta^2+\sqrt{1+4\zeta^4}}}$$

Where ϕ_m is the phase margin. (6 分)

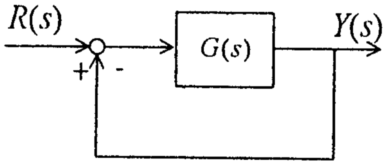

Figure 6　Dynamic system with unity feedback

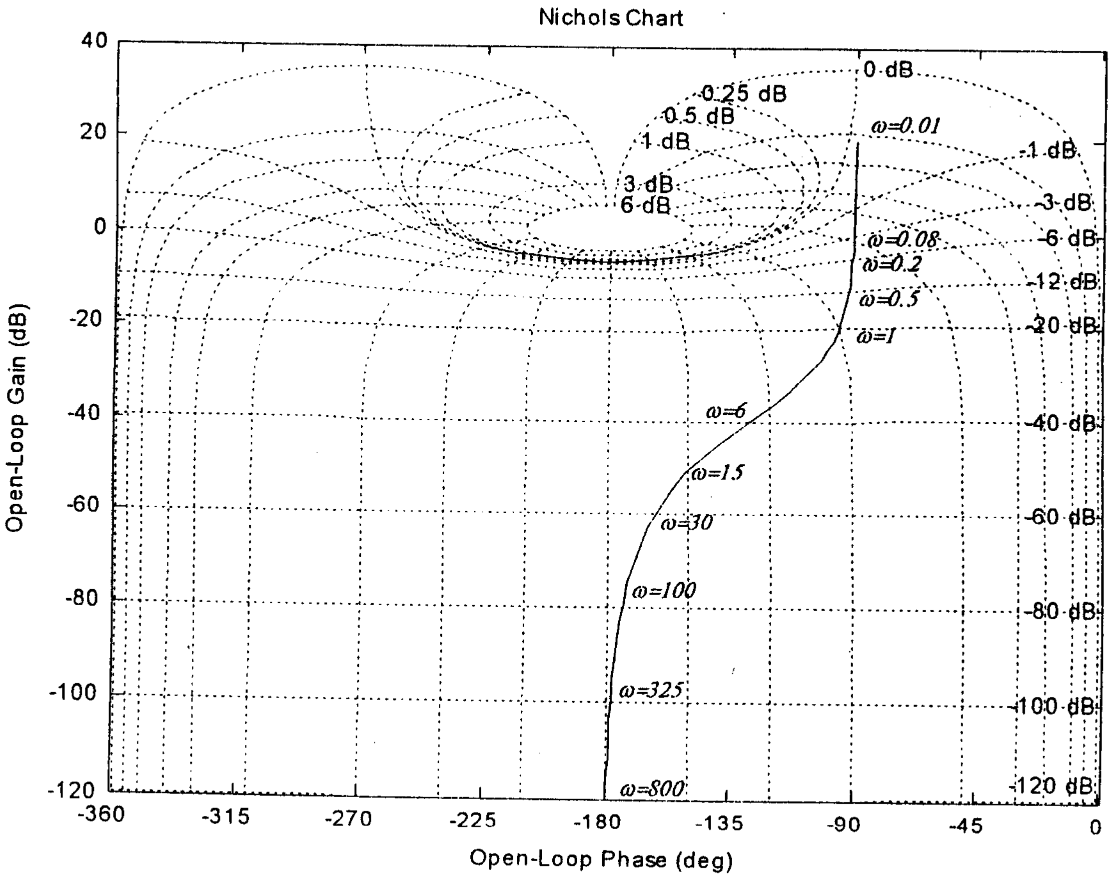

Figure 7　Nichols chart