※ 注意：請於試卷內之「非選擇題作答區」作答，並應註明作答之題號。

1. A state diagram of a control system is given in Fig. A, where a and b are constants. (1) Write the dynamic equation of the system.【計分：3 分】(2) Determine the conditions on a and b so that the system is completely controllable and observable.【計分：4 分】(3) Let $a = 4$ and $b = 3$, (i) find the transfer function $Y(s)/U(s)$【計分：3 分】and (ii) determine the state-transition matrix $\phi(t)$ of the system.【計分：10 分】

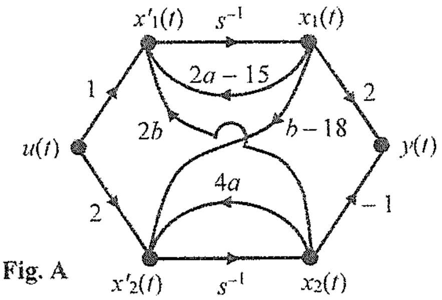

Fig. A

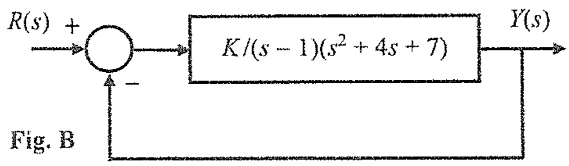

Fig. B

2. A unity feedback control system is shown in **Fig. B**. (1) Determine the range of gain K for stability.【計分：3 分】(2) Sketch the root loci of the control system.【計分：6分】(3) Verify that the formulas of describing three root-locus branches are straight lines.【計分：6分】

3. The voltage equation of a dc motor is written as

$$e_a(t) = R_a i_a + L_a \frac{di_a(t)}{dt} + K_b \omega_m(t)$$

where $e_a(t)$ is the applied voltage; $i_a(t)$, the armature current; R_a, the armature resistance; L_a, the armature inductance; K_b, the back-emf constant; $\omega_m(t)$, the motor velocity; and $\omega_r(t)$, the reference input voltage. Taking the Laplace transform on both sides of the voltage equation, with zero initial conditions and solving for $\Omega_m(s)$, we get

$$\Omega_m(s) = \frac{E_a(s) - (R_a + sL_a) I_a(s)}{K_b}$$

which shows that the velocity information can be generated by feeding back the armature voltage and current. The block diagram in **Fig. C** shows a dc-motor system, with voltage and current feedbacks, for speed control.

(1) Find the transfer functions $\left.\frac{\Omega_m(s)}{\Omega_r(s)}\right|_{T_L=0}$ and $\left.\frac{\Omega_m(s)}{T_L(s)}\right|_{\Omega_r=0}$, respectively.【計分：6 分】

(2) Let K_1 be a very high gain amplifier. Show that when $H_i(s)/H_e(s) = -(R_a + L_a s)$, the motor velocity $\omega_m(t)$ is totally independent of the load-disturbance torque T_L.【計分：3 分】

(3) Find the transfer function between $\Omega_m(s)$ and $\Omega_r(s)$ ($T_L = 0$) when $H_i(s)$ and $H_e(s)$ are selected as in part (2).【計分：6 分】

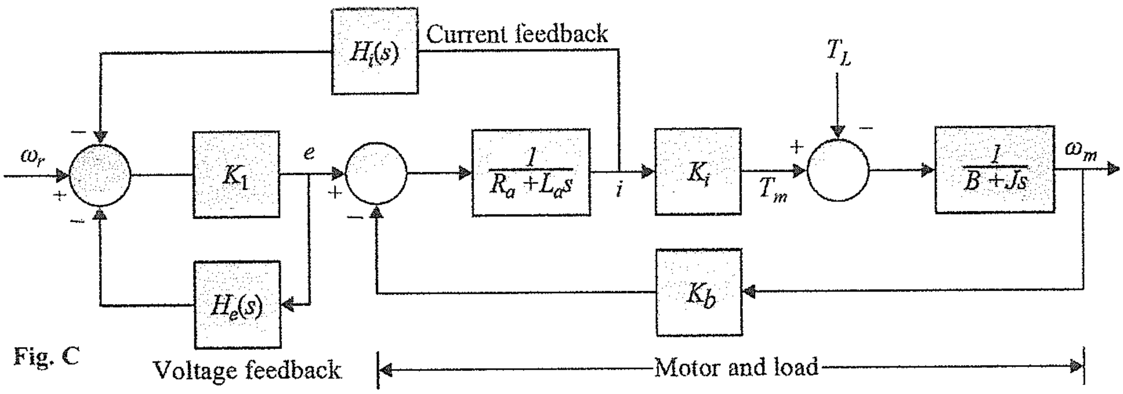

Fig. C

4. **Fig. D** shows a single-link robot driven by a DC servomotor. To amplify the torque τ_m generated by the motor, a gear transmission with gear ratio n (i.e. n= teeth number of Gear 2 / teeth number of Gear 1) is used between the motor shaft and the robot link. Let I_m be the moment of inertia of the motor shaft and Gear 1 combination, and I_L be the moment of inertia of the robot link together with Gear 2. A rotational damper of coefficient b_m is placed at the end of Gear 1 to model the possible viscous friction.

(a) What is the relation between the motor speed ω_m and the link speed ω_L, and determine the equivalent moment of inertia referred to the motor shaft. (5%)

(b) Using τ_m as the control input and the rotation angle (say, θ) of the link as output, obtain the transfer function describing the dynamic relation between the torque τ_m and the output angle θ. (5%)

(c) If I_m=0.01$Kg{\cdot}m^2$, I_L=1$Kg{\cdot}m^2$, n=10, b_m=0.001 $Kg{\cdot}m^2/s$, determine the system type and find the impulse response and step response of the single-link robot respectively (15%)

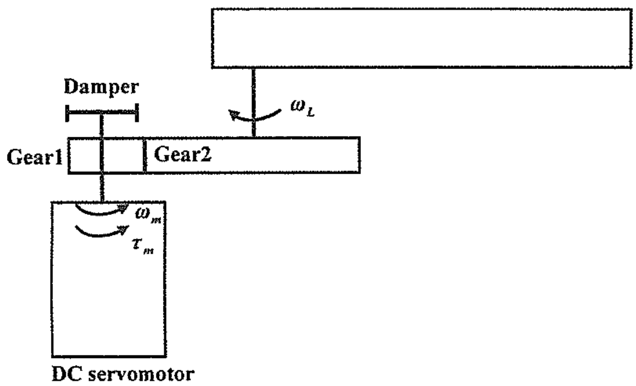

Fig. D

5. Consider a second order system G(s) (in **Fig. E**), of which the nominal value of the parameter A=0.1. Please design a feedforward gain K and PD controller so that the response of the closed loop system can satisfy the **both** specifications listed below: 【計分：15 分】

(1) rising time ≦ 0.1sec, overshoot ≦ 10%, steady state error ≦ 5% for the unit step reference command r

(2) disturbance rejection for the unit step w to 5% within 0.1 sec.

If the parameter A varies between 0.05~0.15, can you design a controller so that the closed loop system can still achieve the above specifications? 【計分：10 分】

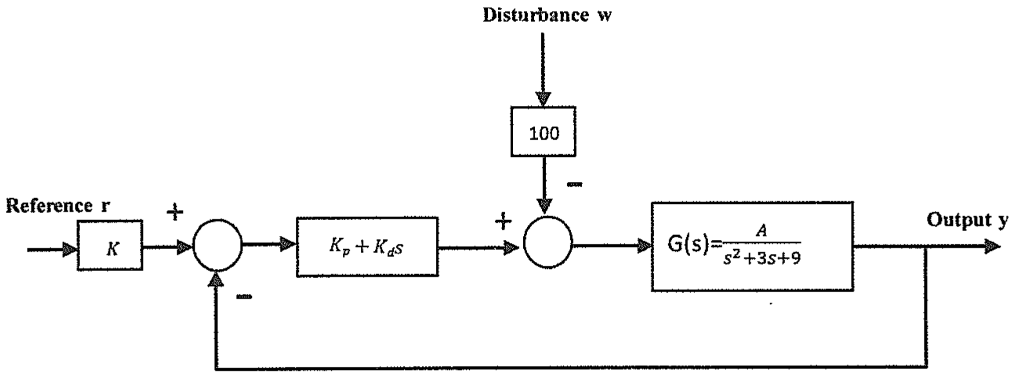

Fig. E

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