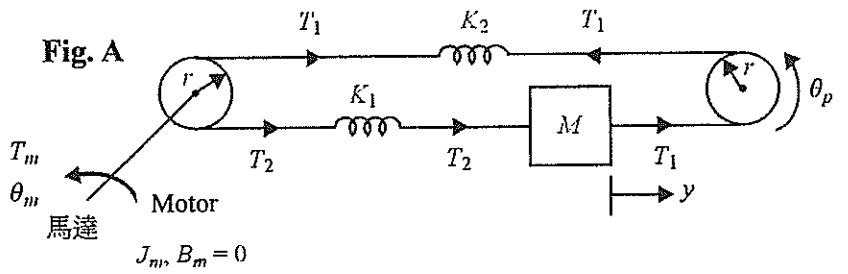
請於答案卷上作答，於試題卷上作答者，不予計分。

1. **Fig. A** shows the diagram of a printwheel system with belts and pulleys. The belts are modeled as linear springs with constants $K_1$ and $K_2$. (1) Write the differential equations of the system using $\theta_m$ and $y$ as the dependent variables. 【計分：5 分】 (2) Write the state equations using $x_1 = r\theta_m - y$, $x_2 = dy/dt$, and $x_3 = \omega_m = d\theta_m/dt$ as the state variables. 【計分：5 分】 (3) Draw a state diagram for the system. 【計分：5 分】 (4) Find the transfer function. 【計分：3 分】 (5) Find the characteristic equation of the system. 【計分：2 分】

**Fig. A**




2. The block diagram of a feedback control system is shown in **Fig. B**. (1) Find the forward-path transfer function $Y(s)/E(s)$ and the closed-loop transfer function $Y(s)/R(s)$. 【計分：6 分】 (2) By direct decomposition, plot the OCF (observability canonical form) state diagram for the transfer function $Y(s)/R(s)$ obtained in (1). 【計分：3 分】 (3) Write the dynamic equations in terms of $\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}r(t)$ and $y = \mathbf{C}\mathbf{x} + \mathbf{D}r(t)$. Find **A**, **B**, **C**, and **D** in terms of the system parameters. 【計分：4 分】 (4) Apply the final-value theorem to find the steady-state value of the output $y(t)$ when the input $r(t)$ is a unit-step function. Assume that the closed-loop system is stable. 【計分：2 分】

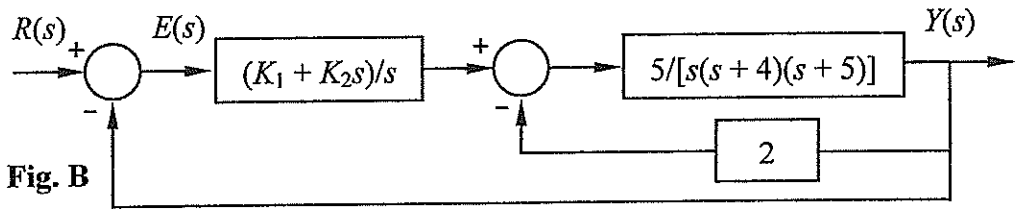



**Fig. B**

3. The forward-path transfer function of a unity-feedback control system is given by

$$G(s) = \frac{K(s+3)}{s(s^2+4s+4)(s+5)(s+6)}$$

(1) Construct the root loci for $K \geq 0$. 【計分：9 分】 (2) Find the value of $K$ that makes the relative damping ratio of the closed-loop system (measured by the dominant complex characteristic equation roots) equal to 0.707, if such a solution exists. 【計分：6 分】

4. For the feedback system shown in **Fig. C**, specify the gain ***K*** and pole location ***a*** of the compensator so that the overall closed-loop response to a unit step input has an overshoot of no more than 25% and a 2% settling time of no more than 0.1 sec. 【計分：15 分】

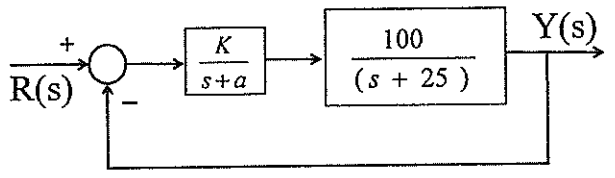



**Fig. C** (Figure for Problem 4)

5. For a certain motor and load, it is determined that $\tau_1 = \frac{1}{60}, \tau_2 = \frac{1}{600}, A = 10$ and $B = 50$. The reference speed is 100 rad/sec. For the open loop system as shown in **Fig. D**, (a) find K and the control voltage $v_a$ needed to get this speed with zero load $w$? 【計分：7 分】 (b) what is the steady state speed if the load is $w$=−0.1? 【計分：8 分】

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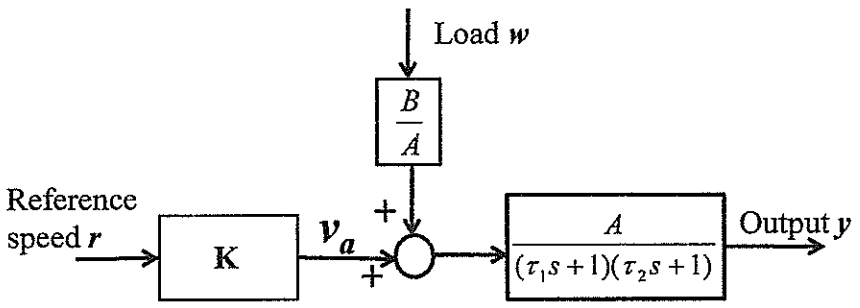


**Fig. D** (Figure for Problem 5)

6. A feedback control structure (shown in **Fig. E**) is used for the motor and load as mentioned in problem 5, where $\tau_1 = \frac{1}{60}, \tau_2 = \frac{1}{600}, A = 10$ and $B = 50$. (a) Find K to improve the ability of the system to reject the steady state disturbances by a factor of at least 100 compared with the open-loop system indicated in problem 5. 【計分：7 分】 (b) If the reference speed is 100 rad/sec, what is the steady state speed with the value of K found in (a) and assuming that $w$=0 ?【計分：8 分】(c) Please discuss the property of feedback control compared with open-loop control based on the results obtained from problem 5(a), 5(b), 6(a) and 6(b). 【計分：5 分】

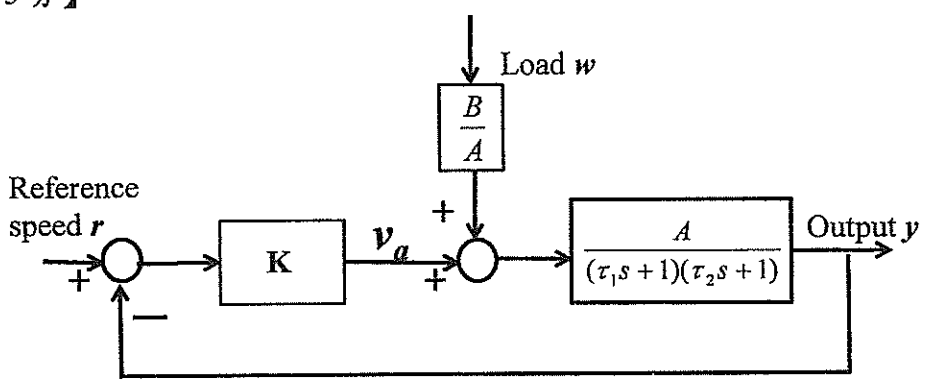


**Fig. E** (Figure for Problem 6)

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