1. (10%) Consider a unity-feedback control system as shown in Fig. 1 with a plant transfer function $G(s) = \frac{15}{s(s+2)(s+50)}$ and a proportional controller K_P. Determine (i) the range of K_P for closed-loop stability by applying the Routh criterion, (ii) the type of the unity-feedback system and (iii) its corresponding steady-state tracking error for a unit-step command, i.e., $y^*(t) = 1$.

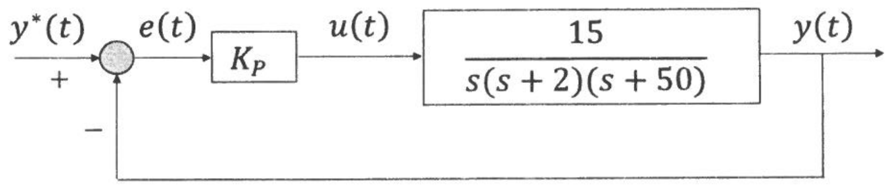

Fig. 1

2. (20%) Consider another feedback control system as shown in Fig. 2 with $K_P = 10$.

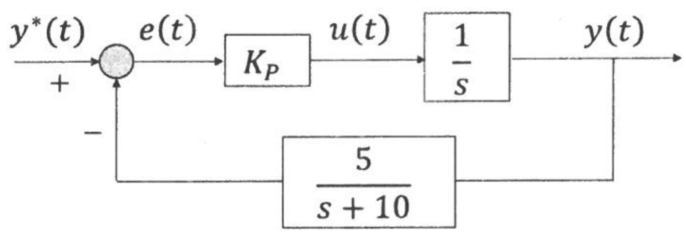

Fig. 2

(a) (5%) Determine steady-state tracking error $\lim_{t\to\infty}(y^*(t) - y(t))$ for a unit-step command $y^*(t) = 1$.

(b) (10%) Estimate its transient performance in terms of every applicable performance index such as the time constant, rise time, peak time, %OV, and/or settling time.

(c) (5%) It can be shown that there is a zero in the close-loop transfer function. What will this extra zero affect your estimate of the transient performance in (b)?

3. (20%) Consider the following dynamic system of a permanent magnetic DC motor where $K_m = 2\frac{V}{\frac{rad}{s}} = 2\ \frac{N.m}{A}$ is the motor constant, $L = 0.012\ H, R = 0.6\ \Omega, J = 12\ kg.m^2, B = 10\ \frac{N.m}{\frac{rad}{s}}$ are the inductance and resistance of the motor coil and the inertia and viscous damping coefficient of the rotational load, respectively. When a motor voltage v is applied, the coil current i and motor speed ω change.

$$L\frac{di}{dt} + Ri = v - K_m\omega$$

$$J\frac{d\omega}{dt} = K_m i - B\omega$$

(a) (5%) Determine the transfer function from the input voltage v to the output motor speed ω.

(b) (5%) (i) Can we apply the final-value theorem of the Laplace transform to determine the steady-state motor speed ω_{ss} when a unit-step command voltage v is applied and why? (ii) If can, calculate the steady-state speed ω_{ss} when $v = 1$ V.

(c) (10%) (i) Show that the system is a dominantly 1^{st}-order system. That is the dynamic response of the system can be approximated as that of a first order system. (ii) Then, what is the transfer function of the approximate 1^{st} order system? (iii) What is the approximate time constant? (iv) Will the actual time constant be faster or slower than the approximate time constant and why?

4. (25%) Given the unit-feedback system with

$$G(s) = \frac{K}{s(s+3)(s+9)}$$

Plot the root locus and find the breakaway points, asymptotes.

5. (25%) (a) (15%) Sketch the Bode asymptotic magnitude and phase plots for the function.

$$G(s) = \frac{10(s+10)}{(s+1)(s^2+10s+25)}$$

(b) (10%) Find the approximate gain margin and phase margin using the Bode plot in (a).