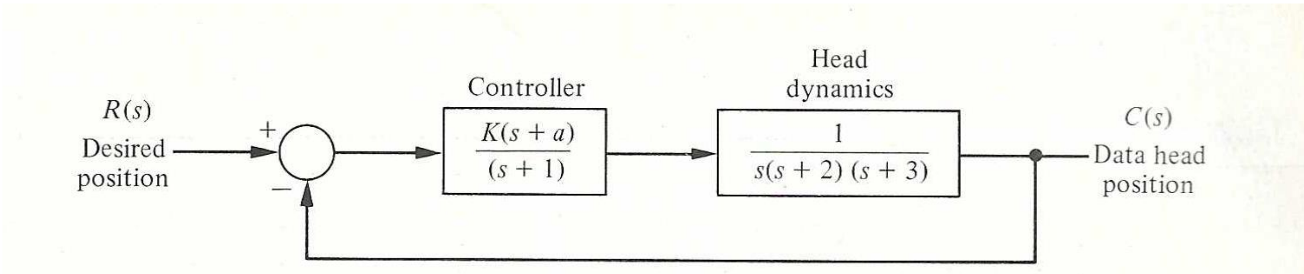
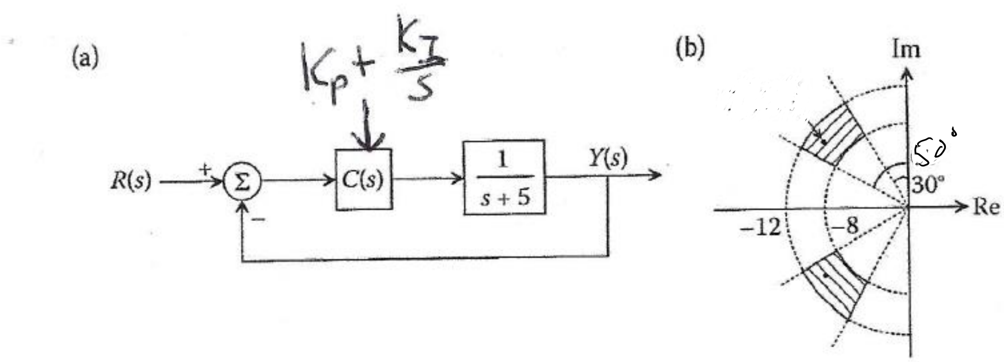
MAE 476: Fall 2022 Midterm 1

1)



The data head of a disk storage device is moved to different positions on the spinning disk and rapid, accurate response is required. A block diagram of a disk storage data head positioning system is shown above. It is desired to determine the range of K and a for which the system is stable. Based on the analysis, choose a value for K and a, find the "type", (0, 1, or 2) of the above system and estimate its pertaining constant error (k_p, k_v, or k_a).

2)



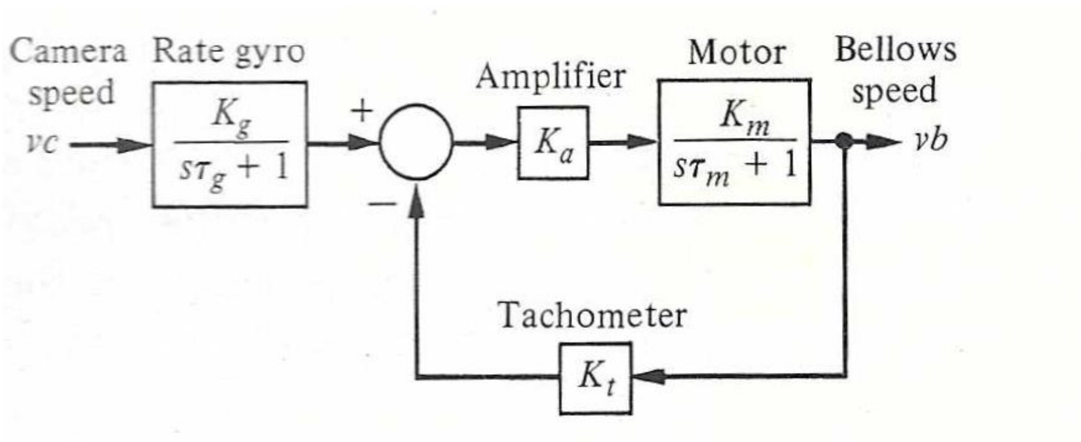
From various homework problems (e.g. 3.34) we can conclude that the transfer function between the applied voltage and angular velocity of the motor, $\dot{\theta}_m$, have the form $G(s) = \frac{k_t/R_a J_m}{s+\frac{b}{J_m}+\frac{k_t k_3}{R_a J_m}}$. Consider the feedback control system shown above where this transfer function is idealized by $G(s) = \frac{1}{s+5}$

a) If the desired closed-loop poles are located within the shaded regions shown in the figure, determine the corresponding ranges of ω_n and ζ of the closed loop system. In the figure above theta, θ, should be between 30° and 50°.
b) Choose a point, $p_{1,2}$ within the shaded region. Design a PI controller such that the closed-loop poles are at $p_{1,2}$.
c) Compute the estimated overshoot, M_p, rise time, t_r, and settling time, t_s, pertaining to your chosen $p_{1,2}$

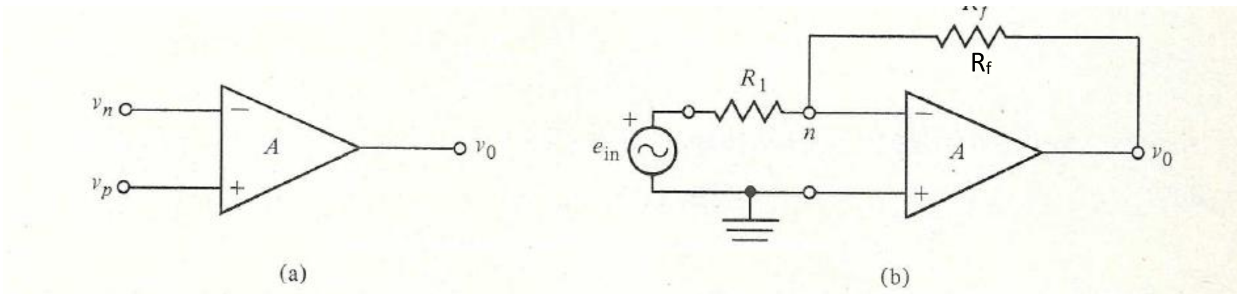
d) Compute the steady-state errors of the plant and the closed-loop system to a unit-step reference input
e) Compute the steady-state error of the closed-loop system to a ramp reference input
f) Set K_I=0 and keep the K_p found in part b); compute the steady-state error of the closed-loop system to a unit-step reference input
g) Set K_I=0, design a **feed forward** control system and compute the steady-state error of the feed forward system to a unit-step reference input.
h) plot the unit step response for parts f) and g)

3) A new 3D dynamic/high resolution surveillance camera is being placed on a A-10 Thunderbolt (warthog) to monitor troop movements. An important issue is to reduce the vibrations of the camera while the airplane goes through sharp maneuvers. The camera is supposed to have a maximum sweeping azimuthal velocity of 30° /sec (π/6 radians/sec). In the questions below, assume K_t=1. Also, assume that the rate gyro is 1, i.e. $\frac{k_g}{s\tau_g+1} = 1.$

   a) Determine the error of the system E(s)
   b) Determine the necessary loop gain K_a K_m K_t when a 1°/sec steady-state error Is allowable while the camera is operating at its maximum azimuthal velocity (Hint: set the magnitude of the step input to 30° /sec)
   c) The motor time constant (τ_m) is 0.50 sec. Determine the necessary loop gain so that the settling time to within 0.5% of the final value v_b is less than or equal to 0.04 sec.



Extra Credit



Open loop

Closed loop

The model symbol of an op amp is shown in the figure above. Recall from MAE 376, due to the high input impedance of the op amp, the amplifier input current is negligibly small. At node n we may write the current equation as $\frac{e_{in}-v_n}{R_1}+\frac{v_o-v_n}{R_f}$=0

Since the gain of the amplifier is G, $v_n=\frac{v_o}{G}$, plugging this into the equation above and solving for v_o, the following is obtained

$$v_o=\frac{G\left(\frac{R_f}{R_1}\right)e_{in}}{\frac{R_f}{R_1}-G}$$

Set K=$\frac{R_1}{R_f}$ and the following transfer function is obtained $T=\frac{v_o}{e_{in}}=\frac{G}{1-GK}$.

The op amp is subject to variations in the amplification G. The sensitivity of the open loop is unity. Find the sensitivity equation for the closed-loop amplifier,S_G^T . Then set G=10^4 and K=0.2 Compare this result to the open loop sensitivity.

Find the sensitivity due to changes in the feedback resistance R1, S_K^T (or the factor K). Comment on this sensitivity, especially when GK>>1.