1. (a) Consider the closed-loop system shown in Figure 1. Let α be a parameter of G(s). Also, let the sensitivities of G(s) and the closed-loop transfer function T(s) with respect to the parameter α be defined by S_α^G and S_α^T, respectively. Show that $S_\alpha^T = \frac{1}{1+G(s)H(s)} \cdot S_\alpha^G$. (10%)

   (b) Let $G(s) = k/[s(s+\alpha)]$ and $H(s) = 1$, in Figure 1. We shall assume that the nominal value of the gain constant k is 10, and that of α is 2. Determine the change in T(s) for a 5% change in the parameter α. Calculate the value for $\omega = 0.5$, and hence determine the change in the steady-state response to the input $r(t) = 2\cos(0.5t)$. (Hint: $\frac{\Delta T(s)}{T(s)} \approx S_\alpha^{T(s)} \cdot \frac{\Delta\alpha}{\alpha}$.) (15%)

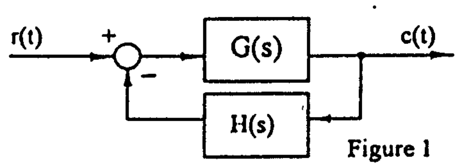

Figure 1

2. Consider the closed-loop system shown in Figure 1, where $G(s) = 1/[s(1+0.5s)(1+s)]$ and $H(s) = 1$. Find the exact gain margin (GM), and determine the stability of the system based on the obtained gain margin. (15%)

3. A rotating load is connected to a field-controlled DC motor with negligible field inductance. A test results in the output load reaching a speed of 100 RPM within 0.1 second when a constant input of 100V is applied to the motor terminals. The output steady-state speed from the same test is found to be 300 RPM. Determine the transfer function $\theta(s)/V_f(s)$ of the motor. (10%)

4. Consider the Type I system shown in Figure 2, where $G(s) = 1/[s(s+1)]$. We would like to design the compensation D(s) to meet the following requirements: (1) The steady-state value of y due to a constant unit disturbance w should be less than 0.8, and (2) the damping ratio $\zeta = 0.7$. Using root-locus techniques:
   (a) Show that proportional control alone is not adequate. (4%)
   (b) Show that proportional-derivative control will work. (4%)
   (c) Find values of the gains K and K_d for $D(s) = K + K_d s$ that meet the design specifications. (12%)

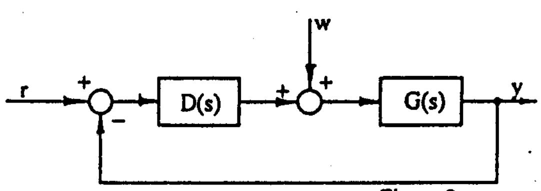

Figure 2

5. Consider the sampled-data system shown in Figure 3. Please determine C(z). (15%)

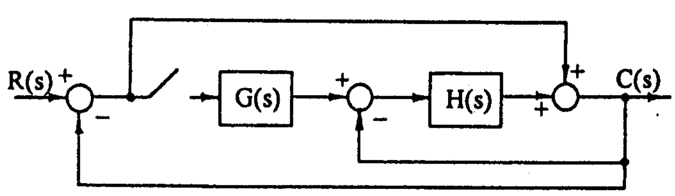

Figure 3

6. Consider a relaxed system whose input (u(t)) and output (y(t)) are related by $y(t) = 0$, for $t \le \alpha$ and $y(t) = u(t)$, for $t > \alpha$, for any u(t), where α is a fixed constant. Please explain and answer the following questions. Is the system linear? Is it time invariant? Is it causal? (15%)