1. Consider the unity feedback system with $G(s) = K / [(s+3)(s+5)]$.
   (a) Show that this system cannot operate with a settling time of 2/3 second and a percent overshoot of 1.5% with a simple gain adjustment. (10%)
   (b) Design a lead-compensator so that the system meets the transient response characteristics of part (a). Specify the compensator's pole, zero, and the required gain.. (10%)

2. The closed-loop transfer function of a control system is

$$T(s) = \frac{s^2 + K_1 s + K_2}{s^4 + K_1 s^3 + K_2 s^2 + 5s + 1}$$

   Determine the range of K_1 in order for the system to be stable. What is the relationship between K_1 and K_2 for stability? (15%)

3. Consider a digital system described by

$$x(k+1) = Ax(k) + Bu(k)$$
$$y(k) = Cx(k)$$

   For the case that $u(k)$ is not zero, derive the conditions for observability. (15%)

4. The dynamics of an armature controlled DC motor are described by the following equations

$$\frac{d\theta}{dt} = \omega$$
$$J\frac{d\omega}{dt} = K_a i_a$$
$$L\frac{di_a}{dt} = -Ri_a - K_b\omega + v_a$$

   where θ is the angular displacement, ω is the speed, i_a is the armature current, J is the armature moment of inertia, R is the armature winding resistance, L is the armature inductance, K_a and K_b are constants. The control input is the voltage v_a and it is assumed that the angular speed is the output. Is the system controllable? Is the system observable? (16%)

5. Find the state transition matrix for $A(t) = \begin{bmatrix} -1 & \cos t \\ 0 & 0 \end{bmatrix}$. (10%)

6. Answer the following short questions
   a. What is the significance of the sensitivity function in feedback control? (6%)
   b. A compensator is described by $G_c(s) = \frac{1+\alpha\tau s}{\alpha(1+\tau s)}$ for some α and τ. What is the maximal phase angle of the compensator as a function of α? (6%)
   c. What is a nonminimum phase system? What are the difficulties in feedback control design if the open-loop system is of nonminimum phase? (6%)
   d. Given the Bode diagram of the open loop system (in a unity feedback configuration), what feedback information can you deduce? (6%)