1. (12 pts) Steady state error (Nise 7.8, review)
   [6 pts] a) Find steady state error for $r(t)$ a unit step input, using input substitution.
   [6 pts] b) Find steady state error for $r(t)$ a unit ramp input, using input substitution.

   Given system:
   \[
   \dot{x} = Ax + Bu = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & -4 & -4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 2 \\ 1 \\ 0 \end{bmatrix} r, \text{ and } y = [1 \ -2 \ 4]x
   \]

2. (10 pts) Positive Feedback Root locus (Nise 8.9)

   The open loop transfer function for a system in unity feedback is given by:
   \[
   G(s) = \frac{k(s^2 + 25s - 100)}{s^2 + 15s + 50}
   \]

   [2 pts] a) Determine the characteristic equation for the closed loop system.
   [8 pts] b) Sketch the root locus with respect to negative values of $k$.

3. (18 pts) PD compensation (Nise 9.3)

   Consider open loop plant
   \[
   G(s) = \frac{10K}{s(s + 10)(s + 20)}
   \]

   with unity feedback.
   [2 pts] a) find $K$ such that overshoot is 10%.
   [8 pts] b) Design a PD controller (i.e. find zero location) such that $T_p \approx 0.2$ sec, with the same 10% overshoot. (Note $K$ may change from part a)).
   [4 pts] c) Hand sketch the root locus for the original system and the system with the PD compensator from part b), and verify with Matlab.
   [2 pts] d) Use Matlab to compare the step response for the closed-loop compensated and uncompensated systems, transient and steady state response.
   [2 pts] e) Find the steady state error for a step for both systems.

4. (23 pts) PID Compensation (Nise 9.4)

   Consider open loop plant
   \[
   G(s) = \frac{K}{(s + 4)^2(s + 2)}
   \]

   with unity feedback.
   [2pts] a. Find the gain $K$ for the uncompensated system to have $\zeta = 0.5$ (Matlab ok). What is the setting time $T_s$?
   [14pts] b. Design a PID controller such that $\zeta = 0.5$ and $T_s < 1.5$ sec, with zero steady state error for a step. (Note that PI effect on transient must be considered). Specify open and closed-loop poles, zeros and gains.
   [5pts] c. Hand sketch the root locus of the original and compensated system, and verify with Matlab (rules1-5.9).
5. (15 pts) Bode Plot (Nise 10.2)
Sketch (by hand) the asymptotes of the Bode plot magnitude and phase for each of the following open-loop transfer functions. For second order poles, note peak magnitude in dB. (For the approximation, be sure to label the trends as $j\omega \to 0$ and $j\omega \to \infty$, as well as the slopes, and the frequency at which the slopes change.) Verify sketch using MATLAB plot with same axes scales, and turn in (log frequency, and magnitude in dB).

\[G_1(s) = \frac{s}{(s+1)^2(s+100)} \quad G_2(s) = \frac{s+1}{s(s+100)} \quad G_3(s) = \frac{1}{s^2+2s+101}\]

6. (22 pts) Nyquist Plot (Nise 10.5)
Consider a closed loop system with unity feedback and gain $k$. The open loop transfer function is:

\[G(s) = \frac{1000\sqrt{10}(s - 10)}{(s + 10)^2(s + 10\sqrt{10})^2}\]

[6pts] a) Hand sketch the asymptotes of the Bode plot magnitude and phase for the open-loop transfer function.
[10pts] b) Hand sketch Nyquist diagram.
[4pts] c) From Nyquist diagram, determine range of $k$ for stability.
[2pts] d) Verify sketches with MATLAB (bode() and nyquist()) and hand in.