1. For each system listed below:

(1.1)

\[ G(s) = \frac{21(s - 1)}{(s + 2)(s^2 + 2s + 2)} \]

(1.2)

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

(1.3)

\[ G(s) = \frac{12}{s(s + 2)(s^2 - 4s + 4)} \]

(1.4)

\[ G(s) = \frac{e^{-2s}(s + 3)}{(s + 10)(s + 1)(s + 2)(s + 18)} \]

(1.5)

\[ G(s) = \frac{10(s + 2)}{s^2(s + 1)(s + 10)} \]

(1.6)

\[ G(s) = \frac{10s(s + 1)}{(s + 2)(s^2 + 3s + 1)} \]

(1.7)

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

(1.8)

\[ G(s) = \frac{e^{-2s}}{10s(s + 1)(s + 2)} \]

i) Using Matlab, find the poles and zeros of the following rational polynomial functions.
ii) Identify the dominant (or slow) stable and unstable poles and dominant (or slow) stable and unstable zeros.

iii) Compute the steady-state gain.

iv) Sketch the unit step response (if the system is stable).

v) Use the Matlab function ”step“ to plot the unit step response.

2. Consider the second order processes

\[(2.1)\]

\[G(s) = \frac{s - 7}{3s^2 + 2s + 7.8}\]

\[(2.2)\]

\[G(s) = \frac{3.3}{5s^2 + 38s + 2}\]

- Evaluate the gain, the time constant (or natural period of oscillation) and damping coefficient for each system.
- Identify each system as overdamped, critically damped or underdamped.
- For all underdamped systems, evaluate the magnitude of overshoot in the unit step response.

3. Consider the second-order system with transfer function

\[\frac{Q_o(s)}{Q_c(s)} = \frac{\tau \omega_n^2(s + 1/\tau)}{s^2 + 2\zeta \omega_n s + \omega_n^2}.\]

Show graphically that, for rise times \(t_r \in \{0.8, 1.0, 1.2, 1.5\}\), and parameters

\[\omega_n = \frac{1.789}{t_r}, \quad \frac{1}{\tau} = \frac{1.6}{t_r}, \quad \text{and} \quad \zeta = 0.89,\]

the system has a “fast” settling time and “small” maximum when a unit step input is applied.

4. Consider a nonlinear system whose dynamics are given by the ordinary differential equation:

\[\frac{d^2y(t)}{dt^2} + y(t)\frac{dy(t)}{dt} + 3y(t) = 7\frac{du(t)}{dt} + (u(t) + 1)^3\]

where \(y(t)\) is the output of the system and \(u(t)\) is the input of the system.

Using this model, perform the following steps:
(4.1) Approximate this model by a linear ordinary differential equation around the equilibrium (i.e. \( \frac{d^2y(t)}{dt^2} = \frac{dy(t)}{dt} = 0 \)) corresponding to a constant input value (i.e. \( \frac{du(t)}{dt} = 0 \)) of \( u = 2 \).

(4.2) Derive the transfer function for this system around the equilibrium.

(4.3) Identify the poles and zeros of the linearized system.

(4.4) Is the system bounded input-bounded output stable?

(4.5) Sketch the unit step response of the system around the equilibrium.