Q-1) i- Consider the system shown below. It is given that $G(s) = \frac{1}{s+1}$ and $D(s)=4$. Determine the unit step response of the closed-loop system. What is the steady-state error, 2\% settling time and percent overshoot (if any)? Use Matlab to sketch the response and compare the above performance measures with those obtained analytically.

ii- Now, $D(s)$ in part i- is replaced by $D(s)=4 \left(1 + \frac{1}{5s}\right)$ which is a PI (Proportional+Integral) controller. Repeat the required calculations of part i- for the new $D(s)$.

iii- Next, $D(s)$ is replaced by $D(s)=4 \left(1 + \frac{1}{0.4s}\right)$. Repeat again the calculations required above. Compare the performance measures of the three cases and comment on the results obtained. Notice that you are also required to obtain the Matlab sketches of responses in each case.

Q-2) Attitude control of a missile is accomplished by thrust vectoring. The transfer function between the thrust angle $\delta$ and the angle of attack $\Theta$ can simply be represented by: $G(s) = \frac{\Theta(s)}{\delta(s)} = \frac{K}{s^2 - a}$ where $K$ and $a$ are positive constants. The attitude control system together with missile is represented by the following block diagram.

i- Determine the minimum values of $k_\delta$ and $k_s$ in terms of $K$ and $a$, so that the overall system is stable.

ii- Given that $K=10$ and $a=4$, it is desired that the closed-loop system should have the fastest unit step response with no overshoot, and 2\% settling time of 1 sec. Determine the values of $k_\delta$ and $k_s$ and sketch the unit step response using Matlab.

Q-3) A unity negative feedback system has a closed-loop transfer function $T(s)$ given as:

$$T(s) = \frac{Ks + b}{s^2 + as + b}$$

i- Determine the open-loop transfer function $G(s)$.
ii- Now, suppose that $G(s) = \frac{rs+m}{s^2+ns}$ determine $r$, $m$, and $n$ such that the following three conditions are simultaneously satisfied: a) Steady state error to a unit ramp input is equal to 0.04, b) the undamped natural frequency $\omega_n = 5 \text{ rad/sec}$, and c) The unit step response $y(t)$ is of the form: $y(t) = A - e^{-3t}(\delta \cos \omega t + \beta \sin \omega t)$.

iii- Determine $A$, $\delta$, $\omega$, and $\beta$ that corresponds to the values found in part ii-. Evaluate the maximum % overshoot, and compare your theoretical result with that you find using Matlab program.

Q-4) i- The open-loop transfer function of a unity feedback control system is given to be: $G(s) = \frac{K}{(s+2)(s^2+9)}$ where $K$ is a positive constant. Determine whether you should have a positive or negative feedback in order to stabilize the closed loop system. What should be the range of $K$ values for stability?

ii- Consider the polynomial $p(s)$ given below. Determine the roots using the Routh-Hurwitz criteria. Explain your reasoning.

$$p(s) = s^5 + s^4 + s^3 + s^2 - 2s - 2$$

iii- Consider that the characteristic equation of a closed-loop control system is $Q(s)= s^3 + 6.5s^2 + 11s + 4$. Determine the number of closed-loop poles with real parts less than -1.

Note: Please find below a hint on using Matlab for sketching the unit step response of systems:

Given a transfer function $T(s)= \frac{as^2+bs+c}{ds^3+es^2+fs+g}$ the Matlab commands to find its unit step response and sketch it are:

numb=[a b c];
denb=[d e f g];
sysb=tf(numb,denb);
t=0:T;
Y=step(sysb,t);
plot(t,Y)

$x=$ time steps you evaluate the output, $T=$ total time interval you evaluate the output.