1st Assignment:
Introduction to robust control

1. What is robust control theory? And why such theory is useful?

2. What are the features of frequency-domain design tools versus time-domain ones?

3. What are the goals a control designer aspires to achieve?

4. How can we measure the robustness of a system against uncertainty?

5. (Importance of sensitivity function): Consider the standard feedback control system with the following loop transfer function
$$L(s) = \frac{k(s^2+0.1s+0.55)}{s(s+1)(s^2+0.06s+0.5)} e^{-T_\mathrm{d}s}$$
with the gain $k = 0.38$ and time delay $T_\mathrm{d} = 0\,\mathrm{sec}$.
   - Check BIBO stability of the closed-loop system! If it is stable, calculate the stability margins and the crossover frequencies! (you can use *margin*(sys) function in Matlab)
   - Calculate the amount of time delay we can tolerate without violating the stability!
   - Determine the peak of the sensitivity function, i.e. $M_\mathrm{S} = \|S\|_\infty$!

   Assume now the gain $k = 0.6$ and time delay $T_\mathrm{d} = 0.2\,\mathrm{sec}$.
   - Check again the stability of the closed-loop system!
   - What can you conclude from this example?

6. Which requirement the sensitivity function must satisfy for robust stability and robust performance? Can we fulfill this requirement?

7. What are the properties of a loop shaping design technique?

8. Consider the following plant transfer function
$$G_\mathrm{S}(s) = \frac{10}{s(s+2)(s+4)}.$$
Design a controller using a <u>**more direct**</u> loop shaping design technique such that the following performance specifications in time-domain are satisfied:
   - Steady-state position error $e_{1\infty} = 0$
   - Percent overshoot of a unit step reference $e_\mathrm{max} \le 25\%$
   - Rise-time of a unit step response $T_\mathrm{R} \cong 0.4\,\mathrm{sec}$
   - Tracking a ramp reference $r(t) = t\sigma(t)$ with a finite steady-state velocity error $e_{2\infty} = \lim_{t\to\infty} e_2(t) \le 0.2$

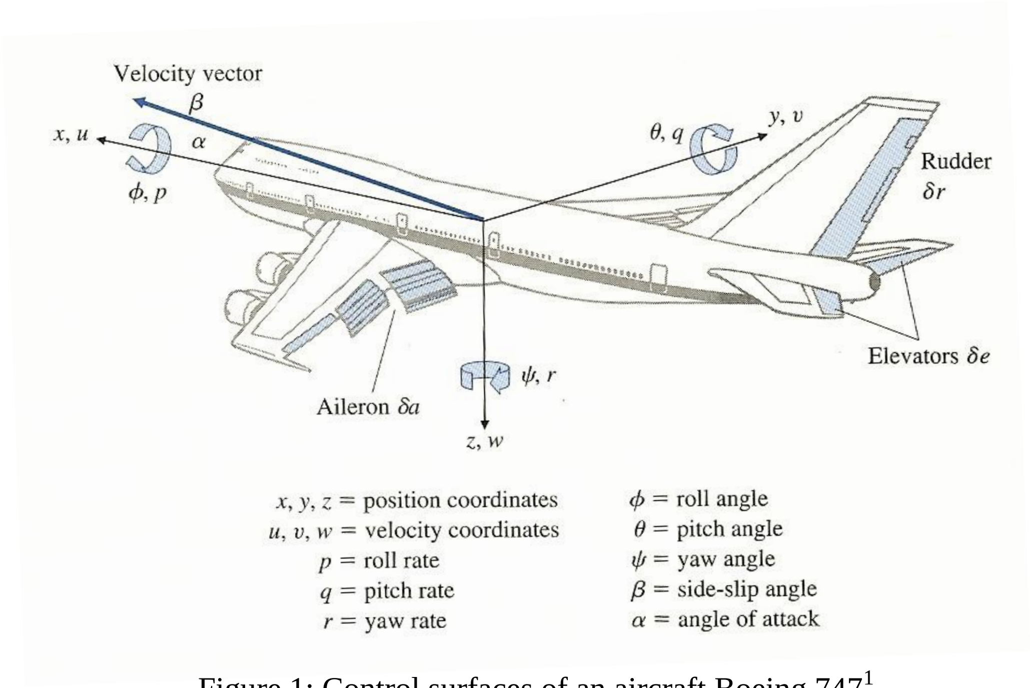

Figure 1: Control surfaces of an aircraft Boeing 747[1]

9. The transfer function between the elevator angle δ_e and altitude h of the Boeing 747 aircraft, see Figure 1, can be approximated as

$$G_{\mathrm{S}}(s) = \frac{h(s)}{\delta_e(s)} = \frac{30(s-6)}{s(s^2+4s+13)}.$$

Design a controller such that the following performance specifications in frequency-domain are satisfied:

- Gain margin $A_{\mathrm{m}} \geq 10\,\mathrm{dB}$
- Phase margin $\varphi_{\mathrm{m}} \geq 35^\circ$
- Gain crossover frequency $\omega_{\mathrm{cg}} \cong 3\,(\mathrm{rad/sec})$
- Slope of the loop transfer function about -1 in the crossover range and -2 or higher beyond it
- Maximum value of the sensitivity function $M_{\mathrm{S}} \leq 2$

// End of Assignment //

[1] Franklin G. F. and et al: Feedback Control of Dynamic Systems, Pearson Prentice Hall, New Jersey, 2006