Universidad Pontificia Bolivariana
Facultad de Ingeniería Aeronáutica
Automatic Flight Control
Problem set 6
Frequency Response of Linear Time-Invariant Systems

1. What is a logarithmic scale and why use it?

2. What are the decibels?

3. What is an octave?

4. What is a decade?

5. Express the following amounts in decibels. Try it without using a calculator. To achieve this, use the properties of the logarithm and keep in mind that $log(2) \approx 0.3$.

   (a) 8
   (b) 0.25
   (c) 20
   (d) 40
   (e) 1600
   (f) 512
   (g) 10000
   (h) 5

6. ¿If a system has a gain of 40 decibels, what is the value of this gain in linear terms?

7. ¿How is a Bode plot constructed experimentally?

8. ¿How does each of the following terms contribute to amplitude and phase Bode plot for a system, depending on whether they are in the numerator or the denominator of the transfer function?

   (a) K
   (b) s
   (c) s^2
   (d) $\tau s + 1$
   (e) $(\tau s + 1)^2$
   (f) $\tau^2 s^2 + 2\zeta\tau s + 1$

9. How is an asymptotic Bode diagram obtained analytically?

10. How is a Bode plot interpreted?

11. Construct the amplitude and phase Bode plots of a derivator and an integrator. Interpret these diagrams.

12. For each of the given systems:

    - Factor the transfer function into factors of the type given in problem 7.
    - Rewrite each of these factors in such a way that they are in the general form presented for the corresponding case.
    - In the case of first order factors, clearly indicate the value of the time constant τ, and in the case of second order factors, clearly indicate the value of the damping factor ζ and of the natural frequency w_n.
    - Based on the factors obtained, draw the corresponding asymptotes on the magnitude diagram.
    - Draw the Bode plot approximate magnitude based on the asymptotes plotted in the previous point and taking into account the rules for each type of factor.
    - Draw the approximate phase Bode diagram using the magnitude diagram asymptotes and the rules for each type of factor.

    (a) $H(s) = \frac{Y(s)}{U(s)} = \frac{1}{s}$

    (b) $H(s) = \frac{Y(s)}{U(s)} = \frac{1}{s^2}$

    (c) $H(s) = \frac{Y(s)}{U(s)} = s$

    (d) $H(s) = \frac{Y(s)}{U(s)} = \frac{10(s+2)}{s^2}$

    (e) $H(s) = \frac{Y(s)}{U(s)} = \frac{20}{s(s+2)(s+5)}$

    (f) $H(s) = \frac{Y(s)}{U(s)} = \frac{100e^{-4s}}{s^2 + 20\sqrt{2}s + 100}$

    (g) $H(s) = \frac{Y(s)}{U(s)} = \frac{4s}{s^2 + 4s + 4}$

    (h) $H(s) = \frac{Y(s)}{U(s)} = \frac{s + 100}{s^2 + 4s + 4}$

    (i) $H(s) = \frac{Y(s)}{U(s)} = \frac{s + 10}{10(s+1)}$

    (j) $H(s) = \frac{Y(s)}{U(s)} = \frac{10(s+1)}{s + 10}$

    (k) $H(s) = \frac{Y(s)}{U(s)} = \frac{1000000}{s^3 + 1100s^2 + 1100000s + 1000000}$

    (l) $H(s) = \frac{Y(s)}{U(s)} = \frac{s^2 + 4s + 4}{s^3 + 1100s^2 + 1100000s + 10^8}$

    (m) $H(s) = \frac{Y(s)}{U(s)} = \frac{s + 10}{(s + 100)\,(s + 1000)}$

13. Use Octave or Matlab® to draw the Bode diagrams corresponding to the systems of problems 7 and 11 and verify what has already been obtained manually.

14. Draw the Nyquist diagrams corresponding to the systems in Problems 7 and 11. Use Octave or Matlab®.

15. Draw the Nichols diagrams corresponding to the systems of problems 7 and 11. Use Octave or Matlab®.