Professor Fearing EECS128/Problem Set 1 v. 1.01 Fall 2019

**Due at 1700, Fri. Sep. 6 on BCourses.**

Note: up to 2 students may turn in a single writeup. Reading Nise 1,2.

1. (20 pts) Case study (Nise 1.4)
   In an aircraft, the roll rate can be controlled by ailerons as shown in Fig. 1. A gyroscope is used to measure actual roll angle rate. Assume a reference input \( r \) (from pilot) is used to specify desired roll angle rate.
   a) Draw a functional block diagram for a roll angle rate control system. Show all blocks and signals, identify input and output transducers, controller and plant.
   b) Suppose the gyro fails (e.g. stuck at maximum full range). Draw a block diagram for a controller which could allow pilot to reasonably handle this case.

2. (20 pts) Static Nonlinearity in Feedback
   A nonlinear amplifier has voltage response \( g(\varepsilon) = 1000 \log(\varepsilon + 1) \). Let \( \delta(t) = 0 \). The nonlinear amplifier is used in a negative feedback system as shown in Fig. 2, with \( k = \frac{1}{3} \).
   a) Assume \( |x(t)| << 1 \). Using Taylor series approximation, show that \( y(t) \approx 3x(t) \).
   b) Consider constant output \( y_1 = 3 \). Without approximations, find the value of input \( x \) corresponding to this output.
   c) Consider constant output \( y_2 = 6 \). Without approximations, find the value of input \( x \) corresponding to this output.
   d) What is the per cent error for b) and c) compared to an ideal gain of 3?
   *Aside: For stable systems with slow dynamics, with sufficient gain, a learned control law can have wide variation with little effect on reward.*

3. (20 pts) Laplace transform review (Nise 2.2)
   For each transfer function below determine \( h_i(t) \).
   i) \( H_1(s) = \frac{1}{s^2 + 14s + 48} \)
   ii) \( H_2(s) = \frac{s}{s^2 + 14s + 48} \)
   iii) \( H_3(s) = \frac{s + 10}{s^2 + 14s + 48} \)
   iv) \( H_4(s) = \frac{1}{s^2 + 6s + 18} \)
   v) \( H_5(s) = \frac{1}{s^2 + 14s^2 + 48s} \)

4. (20 pts) Initial value, final value (Nise 2.2)
   For each of the following Laplace transforms \( Y_i(s) \) determine \( y_i(t = 0^+) \) and if the limit exists, \( \lim_{t \to \infty} y_i(t) \):
   i) \( Y_1(s) = \frac{s}{s+5} \)
   ii) \( Y_2(s) = \frac{s-3}{s+5} \)
   iii) \( Y_3(s) = \frac{(s+3)}{s(s+5)} \)
   iv) \( Y_4(s) = \frac{1}{s(s+5)} \)
   v) \( Y_5(s) = \frac{(s+3)^2}{(s+5)^2} \)

5. (20 pts) Electrical circuit example (Nise 2.4)
   For the circuit in Fig. 3 below, using ideal op-amp assumptions (p. 58 in 6th edition), determine \( H(s) = \frac{v_{out}(s)}{v_{in}(s)} \).