Department of Mechanical Engineering
Massachusetts Institute of Technology
2.14 Analysis and Design of Feedback Control Systems
Fall 2004
Assignment #2
Distributed Wednesday September 15
Due in Class: Wednesday, September 22

Reading:
Chapter 2 sections 2.1-2.3 for La Place
The remainder of the chapter should be review for those with 2.003/2.004

Problem 1

Using LaPlace transforms, find the time solution $y(t)\ t \geq 0$ to the following equation:

$$\ddot{y} + 2\dot{y} + 16y = u(t)$$

where u(t) =
a) A unit impulse
b) A step of magnitude A
c) A unit parabola (t^2)
d) A unit cosine

where $\dot{y}(0) = y(0) = 0$

Using MATLAB, plot each of these responses until they reach a steady – state condition.

Problem 2

Nise Problem 2.8

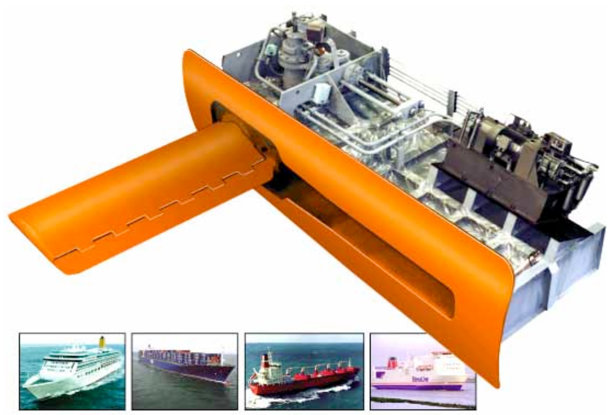
For each of the transfer functions, also fund y(t) assuming u(t) = unit step.

Problem 3

Ship roll stabilization

A common and disconcerting motion of any ship is roll along the long axis of motion. Control systems have been proposed to reduce this motion. They involve adding stabilizing fins on each side of the hull and tiling these to provide compensating roll torques. The figure below, from a manufacturer of such systems, illustrates the problem

Roll Motion of a ship (right) and lack of roll with stabilizer fins (left)



A servo controlled roll fin and hydraulic actuator system

The problem here is to come up with a model for the roll motion that can be used later to design a control system to eliminate roll induced by sea waves. You should not model the fin-actuator system (yet!).

For the model, assume that the output will be the roll angle θ and the input is the torque T applied by the fins (which act like underwater wings, providing lift according to their angle of attack).

The model should also include expected disturbances.

Please provide a feasible form for the model, and be sure it is consistent with what you would observe if you walked over to the boathouse, put a dinghy in the water and rocked it. Once you have the form for the model, explain how you would go about determining the model parameters (i.e. how would you calibrate it).

NB: We do not expect you to have studied hydrodynamics or naval architecture to answer this problem! Only that you have observed this type of roll motion.

Problem 4

Transfer Function for an oven temperature controller

A typical industrial oven is heated by electrical power using dissipation in a resistor. A simple model of the oven, obtained by lumping all of the thermal properties , is given by:

$$C\frac{d\theta}{dt} + K\theta = Q_{in}$$

where C is the lumped thermal capacitance of the oven, K is the net thermal conductivity and θ is the temperature of the oven.

The heat input Qin is provided by the resistance heater and we assume that this "thermal power = electrical power dissipated by the heat resistor R. However, we can only control the voltage supplied to the heater. Thus, we want the transfer function

$$G_{oven} = \frac{\theta(s)}{E(s)}$$

where E is the controlled voltage.

Determine an appropriate *transfer function* assuming that the voltage will be varied over a range = $\pm 20\%E_o$ where E_o is the nominal input voltage and is >>0 (i.e. E is always positive.

Problem 5

Assume you have the transfer function G(s) given below. We want to solve for the response of this function to a unit step input.

$$G(s) = \frac{K(s+z)}{(s+1)(s+2)}$$

at what value of z is the effect of the zero noticeable? You should be able to answer this question simply by looking at the residuals in a partial fraction expansion.

Problem 6

Nise Problem 2.52