Ph.D. Qualifier Examination
Georgia Institute of Technology
Mechanical Engineering
System Dynamics and Controls, Fall 2010

Answer all questions.

Problem 1:

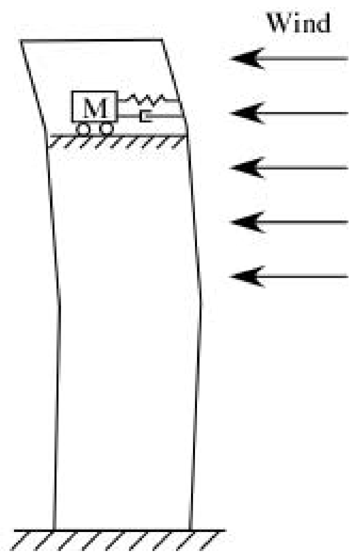


Figure 1: John Hancock Tower.

Figure 1 shows the John Hancock Tower in Boston. When the building was first constructed, sections of the glass siding would fall off in high winds. This was obviously an unacceptable hazard to pedestrians and cars near the building. It was determined that the wind forces were causing the building to deflect so much that connection to the glass siding was being broken. To help reduce building sway, a mass damper was installed near the top of the building, as illustrated on the right side of the figure.

1) Create a simple model that can predict the response of the top of the ORIGINAL building when the wind applies forces to the building.

2) Sketch the building response to a pulse of wind that lasts 5 seconds.

3) What would be the worst type of wind conditions in terms of causing building deflection. Sketch the wind force vs. time and the building response.

3) Modify your simple model to add the effect of the mass damper.

4) How would the mass, spring, and damper parameters effect the response of the modified building? How should the parameter values be chosen?

5) Sketch the modified building response to a pulse of wind that lasts 5 seconds.

6) What are the negative effects of adding such a mass damper?

Answer sheet for Problem 1

Problem 2: Consider a unity-feedback system with the closed-loop transfer function

$$\frac{C(s)}{R(s)} = \frac{Ks + b}{s^2 + as + b},$$

where K, a, b are constants.

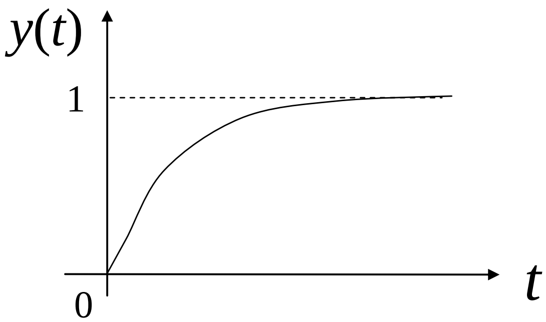
(1) Determine the open-loop transfer function $G(s)$.

(2) Consider a unit-ramp input $R(s)$ to the system. Discuss the condition under which the steady-state error exists. Determine the steady-state error.

Problem 3: Consider the following transfer function:

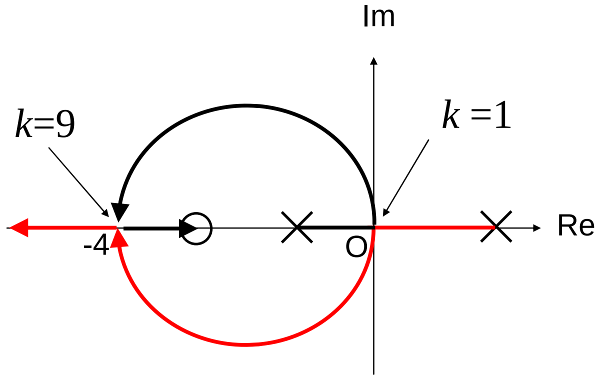
$$G(s) = \frac{k}{s(s^2 + as + a)} \quad (k > 0, a > 0)$$

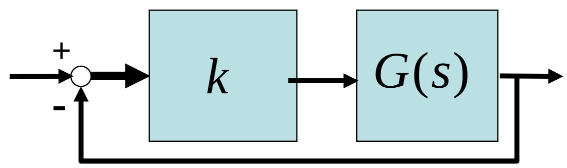
(1) The following graph shows the *unit impulse* response of $G(s)$. Determine the condition on k and a.



(2) Assume that the condition obtained in (1) holds. Determine k and a such that the unity feedback of $G(s)$ is stable with a gain margin of 20dB.

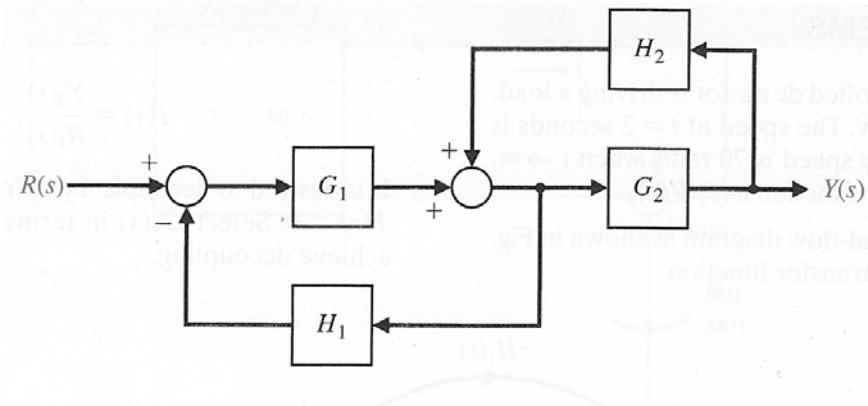
Problem 4: Consider the following root-locus plot of a feedback system. The corresponding open loop transfer function, $G(s)$, has two poles and one zero. One of the poles is located in the right hand side of the s-plane (i.e., unstable pole). There is a break-away point at the origin where k=1 and a break-in point at -4 where k=9. Determine $G(s)$.





Problem 5:

a) The figure shows the block diagram of a dynamic system.
   i) Show how to select G_1 and H_1 so the overall transfer function is unity.
   ii) Discuss any potential problems you see to implementing the solution.



b) In a gravity-free environment, a simple mass-damper-spring dynamic system has the transfer function $1/(ms^2 + bs + k)$.
   i) Prove that this form can still be used when the system is subjected to gravity.
   ii) Clearly identify all assumptions and differences for the two cases.

Extra answer sheet 1

Extra answer sheet 2

Extra answer sheet 3

Extra answer sheet 4