Ph.D. Qualifier Examination
Georgia Institute of Technology
Mechanical Engineering
System Dynamics and Controls, Spring 2011

Answer all questions.

Problem 1: Consider a unity-feedback system with the open-loop transfer function

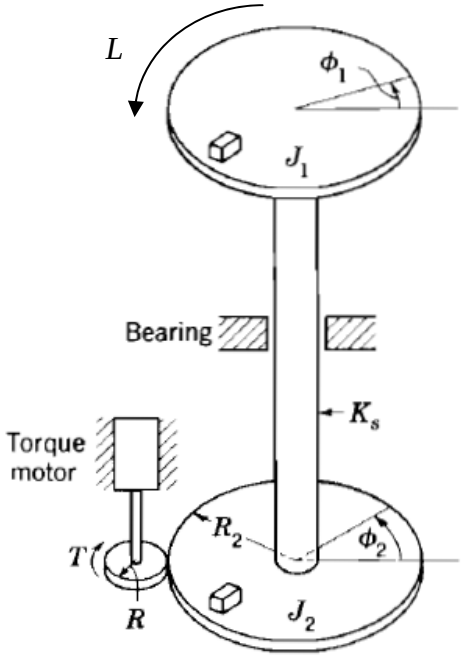
$$G(s) = \frac{s+3}{s^2+2s+2}.$$

Suppose the initial conditions of the output *y(t)* are $y(0_-) = 1, \dot{y}(0_-) = 1.$ Consider a unit-step input to the system. Find the output.

Problem 2: The figure shows part of a stable platform used for inertial-navigation. A torque motor drives a disk connected to a flexible shaft connected to a second disk with a torque load *L*.

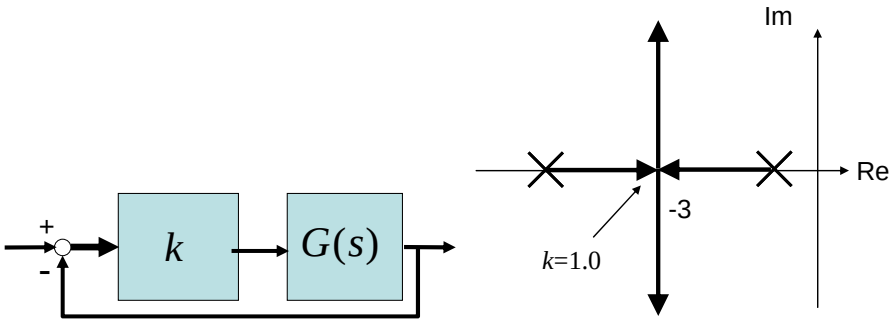
a. Derive a transfer function equation relating the input torque *T* and load *L* to the angle ϕ_1. Angle ϕ_2 should not appear in the result. Make sure that any transfer functions are expressed as the ratio of polynomials where the coefficient of each polynomial power is explicit.

b. Use the result in a. to determine the corresponding differential equation for a no-load condition with a sinusoidal input.



Answer sheet for Problem 2

Problem 3: Consider the following feedback system with a feedback gain *k*. The open loop transfer function, *G*(*s*), has two stable poles and no zero. The unit step response of the open-loop transfer function, *G*(*s*), converges to 0.125. On the root-locus plot, there is a break-out point at -3 when *k*=1. Determine *G*(*s*).



Problem 4: In commercial ports, like the one shown in Figure 1, ships dock next to large cranes that work quickly to unload them. The cranes are massive and expensive, typically costing $10-15 million. These facilities require both sufficiently deep water for the large cargo ships to navigate and firm soil on which to operate the cranes.

Balloon-based cargo transfer could reduce the dependency on established port infrastructures. Using balloons for ship-to-shore transfer would eliminate the need for traditional docks and cranes. A sketch of such a system is shown in Figure 2. A hot-air balloon provides the upward lifting force, while cables connected to the balloon reel in and out to control the balloon position. The cargo is suspended below the balloon by hoist cables.

Figure 1: Port of Seattle.

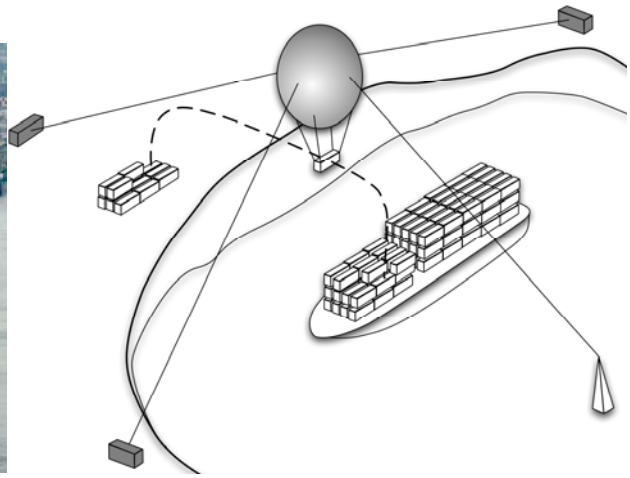


Figure 2: Balloon Unloader.

1) Create a simple model that can predict the cargo response when the balloon is centered between all 4 cables. Assume the tension from all 4 cables is the same in this configuration.

2) Sketch the payload response when all four cables are reeled out and lengthened by 1m over a period of 2 seconds?

3) Sketch the payload response when only l cable is lengthened by 1m over a period of 2 seconds?

4) As the cables are lengthened by reeling them out, the oscillation frequencies of the system will change. Sketch the relationship between cable length and oscillation frequency. Consider only the two dominant oscillation frequencies of the system.

5) Sketch the relationship between the frequencies and the mass of cargo that is being transferred.

6) Suppose a strong gust of wind hits the system when the balloon is near the ship. Sketch the response to this disturbance and state how it might be dangerous.

Answer sheet for Problem 4

Extra answer sheet 1

Extra answer sheet 2

Extra answer sheet 3