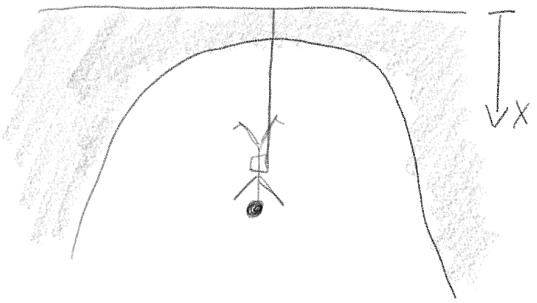
ECE 141 – Midterm
Spring 2020

05/07/20
Duration: 1 hour and 40 minutes

The midterm is open book.
Please carefully justify all your answers.
You are requested to have your camera turned on so that we can see you and your work at all times and until you upload your work to CCLE. We will be recording the exam.
You are not allowed to communicate with others. In particular, you are not allowed to type on your computer, phone, or to use any device that can be employed to communicate with others.
Once you finish the exam, scan it and upload it to CCLE. You can use an app on your phone to scan it.
Note that different students will receive different exams.

Problem 1

We are interested in studying the motion of a bungee jumper as depicted in the following figure.



The position of the jumper is denoted by x.

1. Write down the differential equation that describes the motion of the jumper knowing that, in addition to gravity, there are two forces acting on the jumper: the force caused

by the stretching rope, that we model as a linear spring, and the force created by aerodynamic drag, that we model as being linearly proportional to velocity.

2. If the jumper starts on top of the bridge with zero velocity and lets herself fall, what is the position she will eventually reach?

3. Assume now that we want to customize the jumping experience to the preferences of each jumper. To do so, we can use different ropes resulting in different constants of elasticity in the spring model for the rope. We can also use different jumping suits that result in different constants in the aerodynamic drag model.

   (a) What constants would you choose to have oscillations?

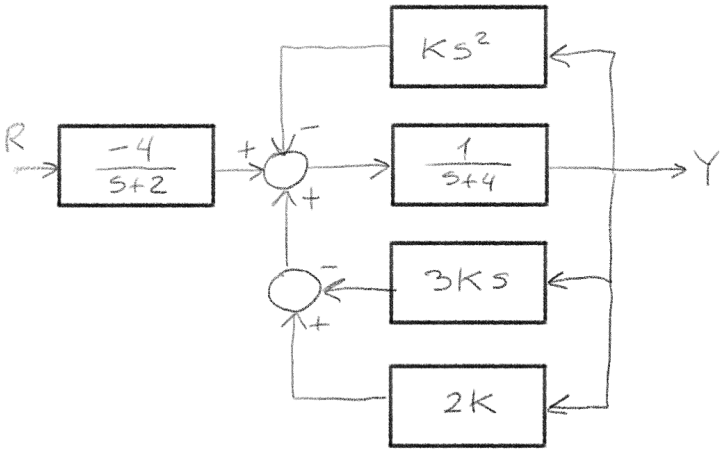
   (b) What constants would you choose to eliminate oscillations?

   (c) What constants would you choose to increase the time spent oscillating and the frequency of the oscillations?

4. Compute the transfer function from gravity's force to x. Using this transfer function as the model of a plant, design the value of the parameters describing the effect of the rope and aerodynamic drag so that the settling time is no greater than 46/5 seconds and the rise time is no greater than 3/5 seconds.

Problem 2

Consider the following diagram.



1. Compute the transfer function from R to Y.
2. For what values of K is this system stable?
3. Design the value of K and, if needed, design an additional controller so that the closed-loop system can track step inputs, i.e., the steady state error to step inputs should be zero.