Assignment 1: System Modeling

ENGR 105: Feedback Control Design
Winter Quarter 2013
Due no later than 4:00 pm on Wednesday, Jan. 16, 2013
Submit in class or in the box outside the door to area of Room 107, Building 550

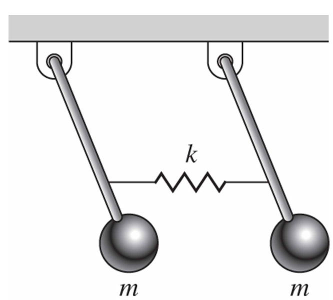
Problem 1. (10 pts.)

Draw a component block diagram (similar to that drawn in class for the thermostat/room temperature control example) for the cruise control of an automobile. Indicate the location of the elements below and give the units associated with each signal. Note that the same physical device many perform more than one of these functions. Define any automotive terms you use, e.g. "The throttle is a valve that directly regulates the amount of air entering the engine".

a. the process
b. the process desired output signal
c. the sensor
d. the actuator
e. the actuator output signal
f. the controller
g. the controller output signal
h. the reference signal
i. the error signal
j. a commonly encountered disturbance (not a car crash!)

Problem 2. (10 pts.)

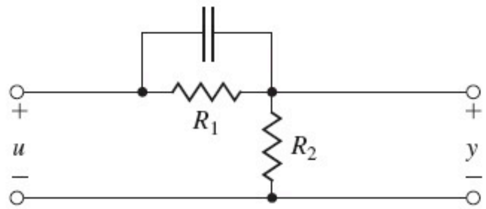
Write the equations of motion for the double-pendulum system shown in the figure below. Assume that the displacement angles of the pendulums are small enough to ensure that the spring is always horizontal. The pendulum rods are taken to be massless, of length l, and the springs are attached three-fourths of the way down.



Problem 3. (10 pts.)

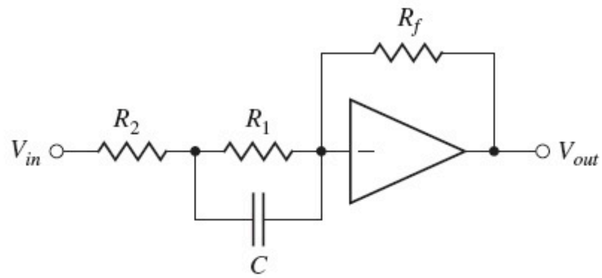
Write the dynamic equations for the circuits shown in the figures below. (These circuits can be used to implement useful controller using analog components, and we'll examine their use later in the course.)

a. passive lead circuit



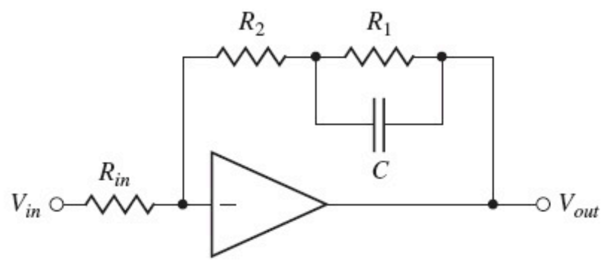
(a)

b. active lead circuit



(b)

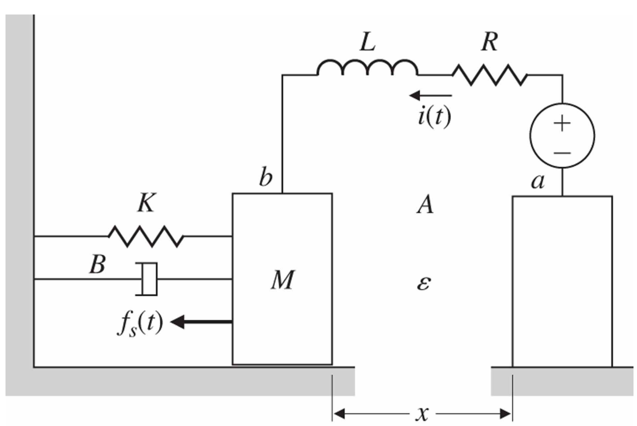
c. active lag circuit



(c)

Problem 4. (10 pts.)

The electromechanical system shown in the figure below represents a simplified model of a capacitor microphone.



The system consists in part of a parallel plate capacitor connected into an electrical circuit. Capacitor plate a is rigidly fastened to the microphone frame. Sound waves pass through the mouthpiece and exert a force $f_s(t)$ on plate b, which has mass M and is connected to the frame by a set of springs and dampers. The capacitance C is a function of the distance x between the plates, as follows:

$$C(x) = \frac{\varepsilon A}{x},$$

where ε is the dielectric constant of the material between the plates, and A is the surface area of the plates. The charge q and the voltage e across the plates are related by $q = C(x)e$. The electrical field in turn produces the following force f_e on the moveable plate that opposes its motion:

$$f_e = \frac{q^2}{2\varepsilon A}.$$

a. Write the differential equations that describe the operation of this system. (It is acceptable to leave in a nonlinear form.)

b. Can one get a useful linear model?

c. What is the output of the system?

Problem 5. (10 pts.)

A typical problem of electromechanical position control is an electric motor driving a load that has one dominant vibration mode. A schematic diagram is shown below. The motor has an electrical constant K_e, torque constant Kt , an armature inductance L_a, and a resistance R_a. The rotor has inertia J_1 and a viscous friction B. The load has inertia J_2. The two inertias are connected by a shaft with a spring constant k and an equivalent viscous damping b (for the relative motion between θ_1 and θ_2). Write the equations of motion, using i as the current in the motor.