MAE 106 Midterm Exam
Winter 2000

University of California, Irvine
Department of Mechanical and Aerospace Engineering

Problem 1: Motors

a. What type of motor did we analyze in Lecture and did you use in Lab 2?

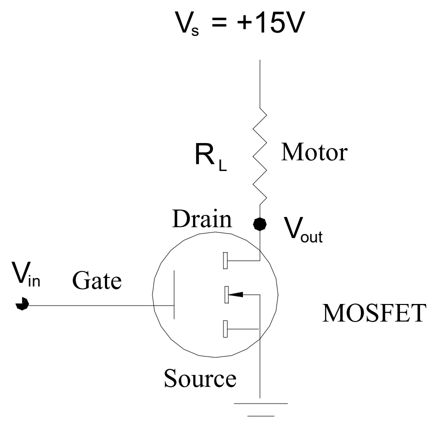
b. Draw the circuit model of such a motor, as presented in class:

c. Assume that the motor shaft is allowed to spin freely. At $t = 0$ a constant voltage V is applied to the motor. Derive an expression for the angular velocity ω of the motor as a function of time. Assume that the inertia of the motor shaft equals J, the motor's torque constant is B, and the current into the motor does not change. (Hint: Based on the model you drew in part b and your knowledge of physics, write a differential equation in terms of ω and solve it).

Problem 2: MOSFETS and Power Control

A circuit for controlling a motor with a MOSFET is shown below. The motor is modeled simply as a resistor. By changing the input gate voltage to the MOSFET, the motor can be made to spin. A table of the MOSFET's drain/source resistance (like the one you generated in lab) is also shown.

V_{in} (volts)	R_{DS} (KΩ)
0	100
1	100
2	90
3	80
3.4	75
3.6	41
3.9	4
4.2	0.1
5.5	0.01



a) To make the motor spin, should the input gate voltage (V_{in}) to the MOSFET be high or low and why?

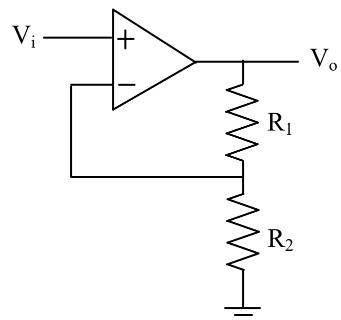
b) Assume R_L = 1KΩ. Calculate V_{out} corresponding to an input gate voltage of 3.9 volts.

c) How many watts of power will the motor consume with the input gate voltage equal to 3.9 volts?

Problem 3: Operational Amplifiers

a) Why are op-amps such as the ones used in lab unsatisfactory for powering most motors?

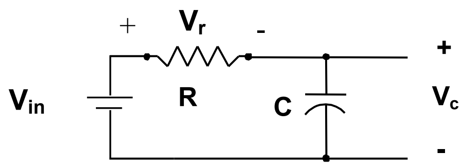
b) Find the relationship between V_o and V_i for the following non-inverting amplifier circuit:



c) Using an op-amp and resistors, design a circuit to amplify *and invert* an input signal by a factor of -100. Show mathematically that your design works.

Problem 4: Filters and Frequency Response

a) Find the transfer function relating V_c to V_{in} for the following filter:

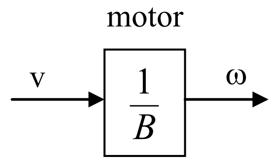


b) What kind of filter is this? Show mathematically.

c) Suppose $V_{in} = \sin t$, $R = 1\ \Omega$ and $C = 1$ Farad. What is $V_c(t)$ Assume $V_c(0) = 0$.

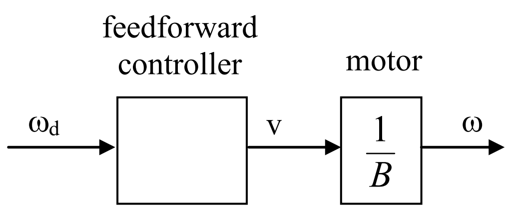
Problem 5: Control Theory

Consider the problem of controlling the velocity of a motor. A simple model of the motor is given by the following block diagram:



where v is the voltage input to the motor and ω is the angular velocity of the shaft.

a) Shown below is a block diagram of an open-loop (i.e. feedforward) controller for the motor, where ω_d is the desired output of the motor. What gain value should the controller box have to make the output equal the desired output? Write the gain in the controller box.



b) What is a disadvantage of an open-loop controller like this one?

c) Draw a block diagram of a feedback controller for the motor. Label all arrows, including the error signal.

d) Assume that the output velocity of the motor is affected by a disturbance such that $\omega = (1/B)v + \omega_e$ where ω_e is the (constant) error in velocity introduced by the disturbance. Prove that your feedback controller, with high enough gain, can cancel the disturbance and make the motor move at the desired velocity ω_d.