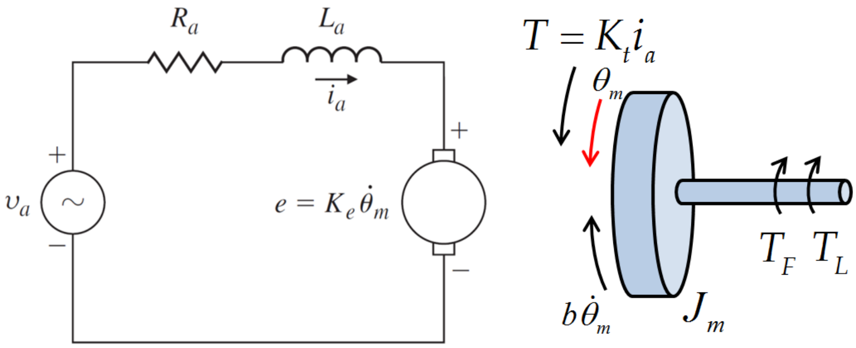
Term Project for Automatic Control

Note:
1) Due date for Problems 1~3: 2022/06/03, 24:00,
   Due date for Problems 4 and 5: 2021/06/15, 24:00
2) File to submit: zip file including the simulation model and report (MS word/Hwp/pdf.)
3) Don't copy. (Those who copied will get 0 point) TAs will open the simulation file.
4) You should describe in detail how you proceed to obtain the result.

Suppose that you're a control engineer for a company and your company is developing a four-legged robot that can walk and do some tasks in dangerous environments. The overall spec of the robot has been decided and your job is to develop a controller for a dc motor that rotates a link attached to one leg.

Follow the design steps described below.

The objective is to control the angular velocity $\omega_m = \dot{\theta}_m$ of the dc motor. The electric circuit and the mechanical parts are shown below. (For detailed description of the model, see the example in the textbook.) Some friction torque T_F and load torque T_L are present.



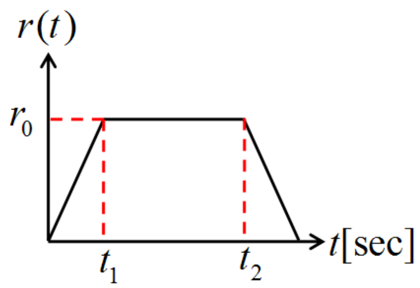
Physical parameters are summarized as follows.
$J_m = 0.05\ \text{kg} \cdot m^2, b = 0.006\ \text{N} \cdot m \cdot sec,\ K_e = 0.05\ \text{V} \cdot sec,\ K_t = 0.05\ \text{N} \cdot \text{m/A}, R_a = 10\ \Omega, L_a = 0.01\ \text{H}$. Note that the values of this problem can be nonrealistic.

1. Modeling [10%]
1) Write the equations of motion for this system. Here, T_F represents friction torque and T_L is some external torque. Find a friction model that is composed of Coulomb friction and viscous friction in the literature and choose the parameters for your model. Explain the friction model.
2) Find the transfer function from v_a to ω_m. (Consider T_F, T_L as disturbance inputs)
3) Using Matlab/Simulink, implement your model.

We would like to design controllers so that $y = \omega_m$ converges to its reference value $r = \omega^*$ and the closed loop system is stable. Let r be the reference for y and suppose the control input is given by (in s-domain) $u(s) = D(s)(R(s) - Y(s))$ where $R(s)$ is the reference input and $Y(s)$ is the output.

2. We would like to solve the problem using a PID controller. [30%]
1) Choose a performance index of the system using overshoot, damping ratio, steady state

error, etc.
2) Design a PID controller (or if you like, you can design P, PI, PD type controller) which satisfies the performance index you chose in 1). Evaluate your controller by simulation. (You can design the controller by analytic method or by trial and error.) Here you don't need to consider the disturbance inputs.
3) Can you apply Ziegler-Nichols Tuning method? If your answer is yes, please try and if your answer is no, please explain.
4) How robust is your controller against disturbances? Use the friction model you've chosen in the modeling section and try several disturbances for T_L (for example, step, ramp, sinusoidal with offset, etc.) and discuss the effect by simulation.
5) How robust is your controller against system parameter change? You may change the system parameters about 10% and do the simulation using the controller designed above. (You should also consider the disturbances used in 4)).
6) Using the controller designed above, select a reference as shown below (you choose t_1, t_2, with $t_2 - t_1 = 1$, and $r_0 \geq 10 * 2\pi\, rad/sec$) and discuss the performance of your controller.



3. We would like to solve the problem using compensators (lead, lag). You use the performance index chosen in Problem 2. [30%]
1) Using root locus method, design a controller which is composed of lead or lag compensators. If you want, you can use more than one compensator.
2) Repeat 4) of problem 2.
3) Repeat 5) of problem 2.
4) Repeat 6) of problem 2.

4. We would like to design a compensator (lead, lag) using the frequency response techniques. [30%]
1) Change the performance index of the closed-loop system you've chosen in Problem 2 into those in the frequency domain (for example, steady state error, phase margin, etc.)
2) Design a compensator which satisfies the performance index you chose in 1). Evaluate your controller by simulation. You should use Bode plots as well as Nyquist plots to design your compensator.
3) Repeat 4) of problem 2.
4) Repeat 5) of problem 2.
5) Repeat 6) of problem 2.

5. You need to submit an additional document (not technical) related this project and this will be announced later.