Prelab	Participation	Lab
$\surd+$ $\surd$ $\surd-$ 0	$\surd+$ $\surd$ $\surd-$ 0	$\surd+$ $\surd$ $\surd-$ 0

Name: ______________________________

6 Lab: Motor Constants

Motors are useful for actuating and controlling systems. Understanding how they work is helpful for designing and building real systems. Two quantities that characterize their function are the ***motor torque constant*** k_m and the ***motor voltage constant*** k_v.

The values of these constants are usually found on a ***motor specification sheet*** that is experimentally determined by the motor's manufacturer. The motors and encoders used in this lab were purchased second-hand. Since the motor constants are not known, we will run an experiment to determine their values.

6.1 PreLab

Next week, you will be run your own MIPSI lab. You will choose a physical system, and use the MIPSI technique, i.e., **M**odel, **I**dentifiers, **P**hysics, **S**implify and Solve, and **I**nterpret your results. To prepare for next week's MIPSI lab, brainstorm 3 physical systems that have an interesting question to be answered and are not a Ph.D. dissertation.

Short system description and question to be answered | Rough system schematic

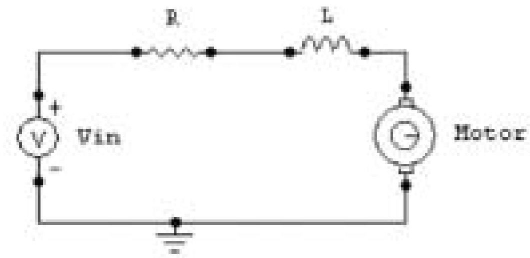
Short system description and question to be answered | Rough system schematic

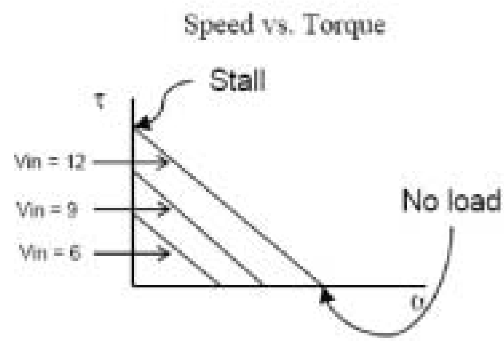
Short system description and question to be answered | Rough system schematic

6.2 Experimental

A useful, simple, schematic of a DC motor is depicted below-left. This simple motor model include the voltage supplied to the motor (v_{in}), the motor's coil resistance (R), the motor's inductance (L), and the motor's back-EMF (electromotive force).

Shown below-right is the presumed linear relationship between motor angular speed ω_m and motor torque T_m. Notice that increasing v_{in} (the voltage supplied to motor) increases the line's offset.





6.2.1 Governing ODEs for a simple motor

Two quantities that characterize their function are the ***motor torque constant*** k_m and the ***motor voltage constant*** k_v. that appear in the following formulas

$$T_m = k_m\, i_m \qquad\qquad v_m = k_v\, \omega_m$$

where T_m is the motor torque, i_m is the current passing through the motor, v_m is motor back-EMF voltage, and ω_m is the motor's angular speed. Find the governing ODEs for a simple motor in terms of v_{in}, torque T_m, k_m, R, k_v, L, and motor speed ω_m. Next, simplify and combine the two ODEs into a single algebraic equation that relates v_{in} and ω_n for constant-speed operation, e.g., set $\frac{di_m}{dt} = 0$ and $\frac{dT_m}{dt} = 0$.

$$\boxed{\qquad\qquad\qquad} = 0$$

$$\boxed{\qquad\qquad\qquad} = 0$$

$$v_{in} = \boxed{\qquad\qquad}$$

6.2.2 Stall torque

Rewrite the algebraic equation when the motor is ***stalled*** $(\omega_m = 0)$, and solve for k_m.

$$v_{in} = \boxed{} \qquad \Rightarrow \qquad k_m = \boxed{}$$

While the motor is ***stalled***, use the multi-meter to measure the resistance of the motor coil at several angular positions.

$$\text{Average Resistance} = \boxed{}\,\Omega$$

Using the motor attached to the cart via the wire, measure the ***stall torque*** for a range of v_{in} from 3-5 volts. Assume that the spring is linear. Note the length of the moment arm. **Do not stall the motor for very long!** The motor will overheat and burn out.

Approx. v_{in}	Measured v_{in}	Cart Displacement	Force	Torque	k_m
3.0					
3.5					
4.0					
4.5					
5.0					
				Average k_m	

6.2.3 No-load angular speed

Rewrite the algebraic equation when there is ***no load*** on the motor $(T_m = 0)$. and solve for k_v.

$$v_{in} = \boxed{} \qquad \Rightarrow \qquad k_v = \boxed{}$$

Using a motor without load, measure the angular speed ω_m of the shaft (using the oscilloscope and a single output channel of the encoder) for a range of v_{in} from 0-6 V.

Note: The oscilloscope shows a peak and a valley for each encoder count. The time between the onset of peaks is the period (X).

$$\omega_m = \frac{\text{count}}{X\,\text{period}(\mu s)}\; 10^6\, \frac{\mu\, s}{s}\; \frac{\text{cycle}}{500\,\text{counts}}\; \frac{2\,\pi\, rad}{cycle} = \frac{12566}{X}\, \frac{rad}{s}$$

Approx. v_{in}	Measured v_{in}	Period X	Angular speed ω_m $(\frac{rad}{s})$	k_v
2				
4				
6				
8				
10				
			Average k_v	

†In lab 1 we found that these motors are dominated by Coulomb friction. Based on the data just taken, find a better estimate for k_v by including a friction loading term, T_f. Also find the magnitude of the frictional loading T_f in N m.

6.2.4 Comparison and verification

Determine the percent error[10] in the difference in your estimates for k_m and k_v.

$$\frac{k_m - k_v}{k_v} * 100 = \quad \%$$

- If k_m and k_v differ more than 10%, why do think that this is the case?
- Which estimate do you think is more accurate and why?
- What measurement would you perform to improve your accuracy?

[10]The definition of "volt" unit leads to (for an ideal DC motor) $k_m = k_v$ when SI units are used.