Total: /90

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Section: AB2

Part I. Calibration of Tachometer: ___/5

Computing the Tachometer Gain ___/3

Briefly explain the procedure and the importance of computing the gain for the Tachometer. Why is it important to know K_{tach}?

We get K_{tach} with $\frac{\text{V}_{\text{tach}}}{\omega}$
We will need it for computing ω

Experimental Parameters for the Tachometer. ___/2

V_i (V)	Δt (s)	V_{tach} (V)	ω (rad/s)	K_{tach} (Vs/rad)
5	96.6	1.98	65.04	0.03044
10	41.2	4.66	152.5	0.03055
15	26.4	7.31	238.0	0.03071
			Average	0.03057

Part II. Armature Resistance and Back-EMF: ___/10

Measuring the Armature Resistance and Back-EMF ___/4

Explain the procedure for obtaining the Armature Resistance and the torque gain ($K_v = K_\tau$). Why can we ignore L_a?

We use $(R_a, K_v) = ([\text{I}_a, w] \setminus V_i)'$
We ignore L_a because the voltage there is 0 at steady state

Experimental Values ___/2

V_i (V)	$I_{ss\text{-}a}$ (A)	V_{tach} (V)	ω_{ss}(rad/s)
5	0.26	2.09	68.37
6	0.26	2.65	86.69
7	0.27	3.19	104.36
8	0.28	3.73	122.03
9	0.29	4.26	139.37
10	0.31	4.79	156.7
11	0.33	5.32	174.05
12	0.35	5.83	190.73
-5	-0.26	-2.04	-66.74
-6	-0.27	-2.60	-85.06
-7	-0.28	-3.15	-103.06
-8	-0.28	-3.69	-120.72
-9	-0.29	-4.21	-137.74

-10	-0.30	-4.73	-154.75
-11	-0.31	-5.25	-171.76
-12	-0.33	-5.78	-189.1

Experimental Parameters ___/4

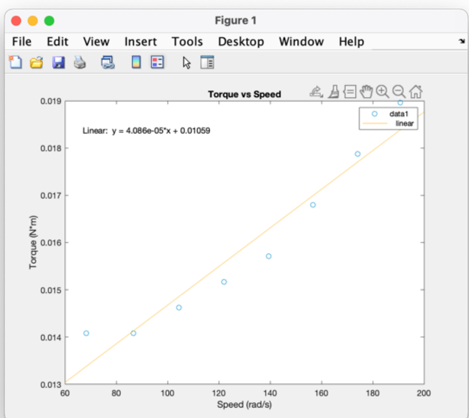
Parameter	Value
R_A (Ω)	5.09
K_V (Vs/rad)	0.0542

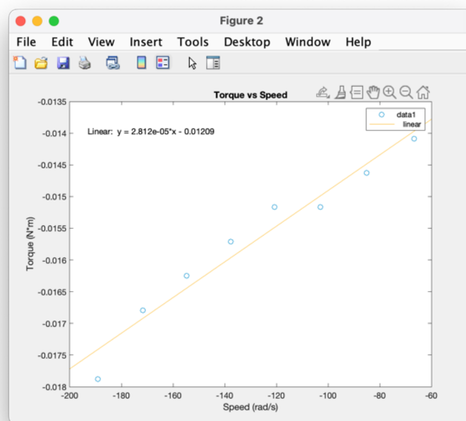
Part III. Constant and Viscous Friction Coefficients: ___/10

Measuring the constant and viscous coefficients ___/6

Explain the procedure for obtaining the friction coefficients. Include equations. Plot the friction torque ($K_\tau I_a$) against ω. Use a different plot for each direction and estimate the Coulomb and viscous coefficients by using a linear fit.

We have K_τ $I_A - (b\omega + c) = 0$ so we can then get b and c with a linear fit





Experimental Values. ___/4

Viscous Coefficient		Coulomb Coefficient	
b^+	0.000041 Nms/rad	c^+	0.010590 Nm
b^-	0.000028 Nms/rad	c^-	-0.012094 Nm

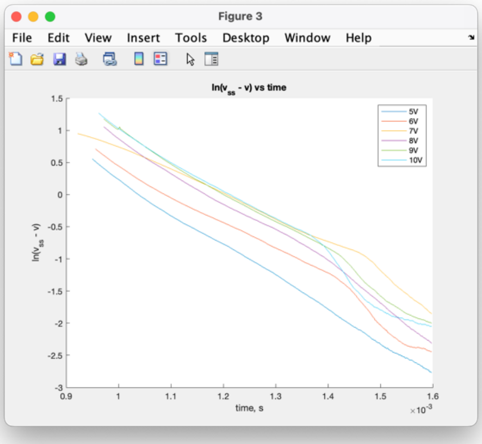
Part IV. Armature Inductance: ___/20

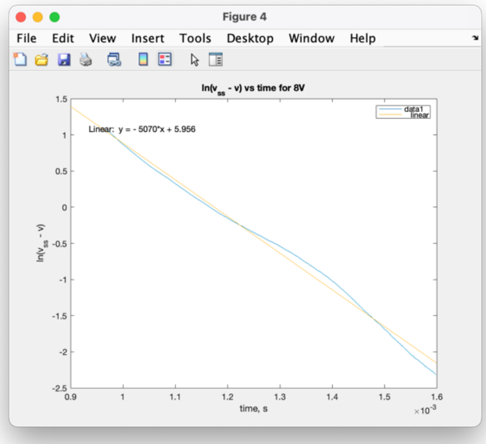
Procedure for Measuring R_s and L_a ___/14

Explain the process of measuring both parameters. Explain how holding the motor still with the rotor-locking attachment allows us to more easily measure La. Include equations (do not forget the logarithm fit).
Include two plots. In the first plot, overlay the linear region for the six sets of data obtained after using the logarithm function (without plotting the linear fit). Then, take one (just one, as an example) of these plots, and do a linear fit showing the equation.

We use $\ln(v_{ss} - v_0) = \frac{-1}{\tau_e} t + C$ to get τ_e

And use $L_a = \tau_e (R_s + R_a)$ to get L_a





Experimental Parameters ___/6

Parameter	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Average
R_s (Ω)	2.538						0.538
τ_e (s)	0.000199	0.000209	0.000253	0.000197	0.000199	0.000186	0.000207
L_a (mH)	0.001518	0.001598	0.001927	0.001505	0.001522	0.001421	0.001582

Part V. Rotor Moment of Inertia: ___/18

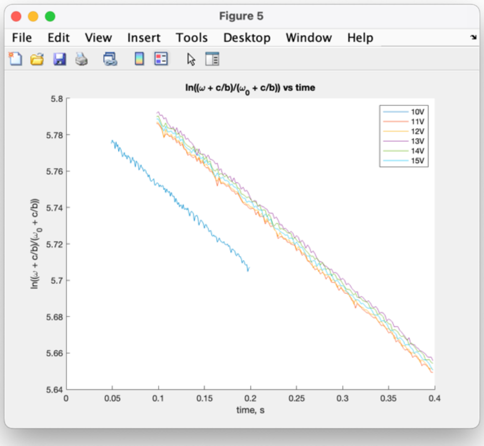
Procedure for measuring the moment of Inertia J ___/14

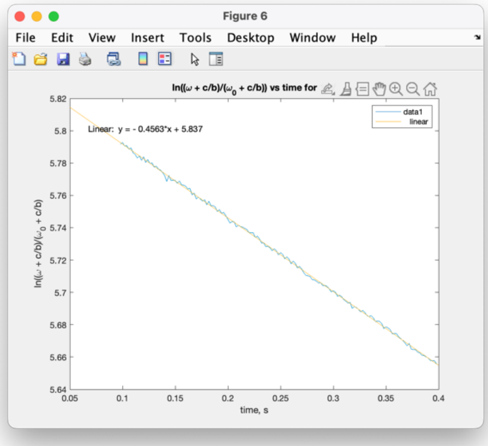
Explain how to obtain J. Include equations for estimating J (use the natural logarithm function to obtain a linear relation between time and the angular velocity of the rotor). Also explain why we need to measure transient behavior to obtain J. Using the estimates found in part III, plot the linear region for the six sets of data on a single graph. Take one of these plots and do a linear fit showing the linear coefficients (i.e. an equation).

$$ln(\omega m + c/b) = \frac{-b}{J} t + C$$

We can get J with a linear fit of t and ω

We measure the transient behavior because $\frac{-b}{J}t$ is 0 at steady state





Experimental Values for J ___/4

Inertia	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Average
J (kg m^2)	0.000089	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009

Part VI. Conservation of Energy: __/12

Prove that K_v=K_τ

1. *Ignoring losses such as friction and applying the conservation of energy law, show that K_v=K_τ are identical. (Hint: electrical power is voltage*current and mechanical power is torque*velocity.)*
2. *Use unit conversions to show that their units in SI are equivalent (units are on page 21 of the lab manual).*

$P = V\,i = \mathrm{K_v}\,\omega\,i$
$\mathrm{P} = \mathrm{T}\,\omega = \mathrm{K}_\tau\,\mathrm{i}\,\omega$
So, $\mathrm{K_v} = \mathrm{K}_\tau$

K_τ has unit $N\ m\ /\ A$
$\mathrm{K_v}$ has unit $V\ s\ /\ rad$
They are the same

Part VII. System Transfer Function: __/10

Transfer Function $\Omega(s)/V_i(s)$ ___/5

Find the second order transfer function (from part e of the prelab). Use the experimental parameter values and compute the pole locations.

$$\frac{0.0542}{1.424\text{E-7}\, s^2 + 4.58\text{E-4}\, s + 3.15\text{E-3}}$$

Poles are -3209.4 and -6.8925

Transfer Function $\Omega_{approx}(s)/V_i(s)$, first order approximation ___/5

Find the first order transfer function approximation of the system when ignoring L_a (set $L_a = 0$). Compute the pole location.

$$\frac{0.0542}{4.57\text{E-4}\, s + 3.15\text{E-3}}$$

The pole is -6.8925

Part VIII: Steady-state response of non-linear system ___/5

Compute the steady-state angular velocity (ω) for a 4V input in V_i. Include the effect of Coulomb friction (c) in your computation.

$V_i K_\tau = \left(bR_A + {K_V}^2\right)\omega + R_A c$

So, $\frac{4}{s} K_V = (bR_A + {K_V}^2)\Omega + \frac{R_A c}{s}$

By final value theorem, the steady state ω is $\frac{4K_V - R_A c}{bR_A + {K_V}^2} = 50$

Attachments (6)

- Friction torque vs. the angular velocity *(to estimate the friction coefficients for positive and negative rotation)* (2 plots).
- Linear region of the six sets of data for inductance L_a (plot).
- One of the six sets of the inductance's data, with a linear fit approximation (plot).
- Linear region of the six sets of data for the Inertia parameter (plot).
- One of the six sets of Inertia data, with a linear fit approximation (plot)