



ENGG 225 - Fundamentals of Electrical Circuits and Machines
Winter 2020 Final Examination

Registrar-Scheduled Final Exam Date
Wednesday, April 29, 2020
Time: 3:30 - 6:30 PM

This is an On-line D2L Quiz

L01 - *Pouyan (Yani) Jazayeri*
L02 - *Norm Bartley*
L03 - *Denis Onen*
L04 - *Anis Haque*

Instructions:

- This is a 3-hour examination in equivalent length; however, you will have 48 hours to complete it, starting 48 hours before the registrar-scheduled end time of 6:30 PM MDT on Wednesday, April 29. The exam **must be submitted no later than 6:30 PM MDT on Wednesday, April 29.**
- You **must complete and upload** the Schulich School of Engineering Academic Integrity Statement. Submit the completed form to Dropbox on D2L before you attempt the exam.
- The examination is open-book.
- There is no calculator restriction. You may use any desktop or laptop computer, smartphone or tablet, **except for communication with other people about the exam.**
- The maximum number of marks is 92, as indicated. The final examination counts 37.5% of the final grade as specified in the approved revised course outline. Please attempt all six questions.
- You must receive at least 35% on the final exam to pass the course.
- Please use at least **three significant figures** in all of your numerical answers.

(Please do not write in this space.)

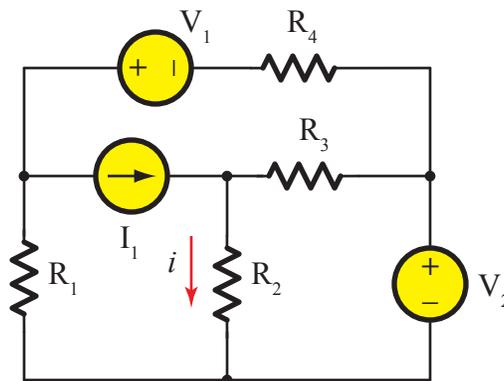
| #1 (28) | #2 (8) | #3 (16) | #4 (10) | #5 (18) | #6 (12) | Total (92) |
|---------|--------|---------|---------|---------|---------|------------|
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[Note: all values indicated in red will be randomized by D2L.]

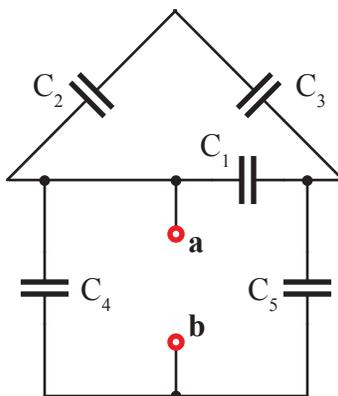
1. [28 marks.] Short questions on a variety of topics.

Parts (a)-(g) below each have an identical weighting of four marks.

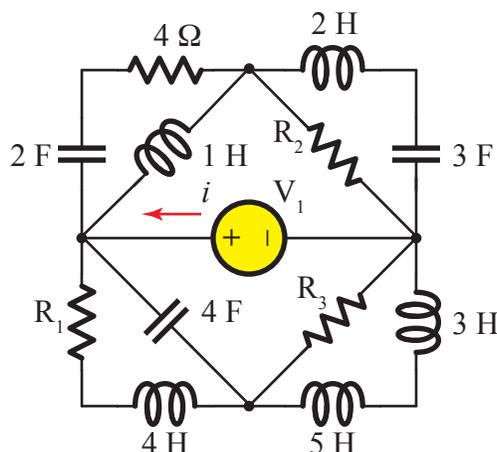
- (a) [4] Recall that determining current and/or voltage using superposition requires determining the current and/or voltage by the effect of individual sources and then by taking the algebraic sum of those individual contributions. In the circuit shown, there are three independent sources. Use the values (in Ohms) $R_1 = R1$, $R_2 = R2$, $R_3 = R3$, $R_4 = R4$, $V_1 = V1$, $V_2 = V2$, and $I_1 = I1$ A. Determine the following currents in Amperes:
- The current i' in R_2 when only the source V_1 is active.
 - The current i'' in R_2 when only the source V_2 is active.



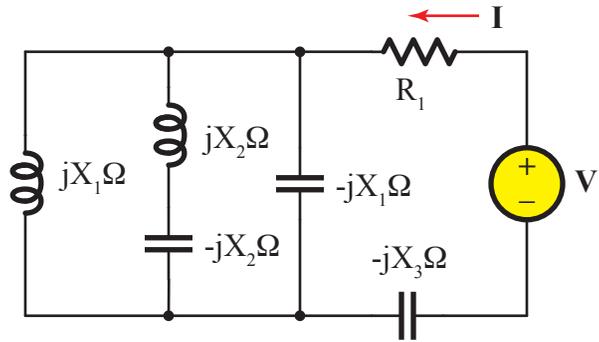
- (b) [4] Determine the equivalent capacitance in Farads between terminals **a** and **b** of the circuit shown. Use the values (in Farads) $C_1 = C1$, $C_2 = C2$, $C_3 = C3$, $C_4 = C4$, and $C_5 = C5$.



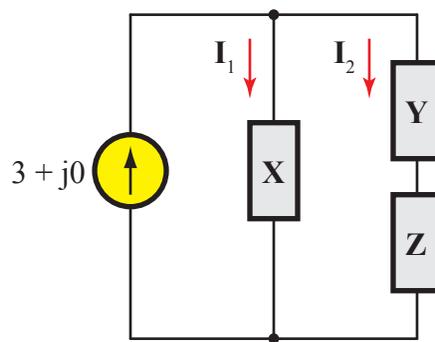
- (c) [4] Consider the circuit shown where the voltage source supplies DC voltage. Determine the current i (in Amperes) as shown in the circuit. Assume all inductors and capacitors used in this circuit are ideal, and that the circuit is in steady-state. Use the values (in Ohms) $R_1 = R1$, $R_2 = R2$, $R_3 = R3$, and voltage $V_1 = V1$ V.



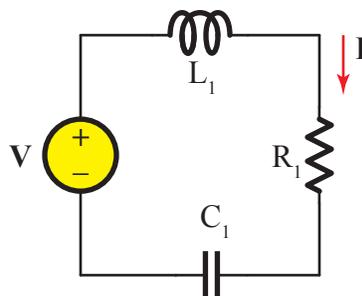
- (d) [4] Find the magnitude of the phasor current $|\mathbf{I}|$ (in Amperes) in the circuit shown. Use the values (in Ohms) $X_1 = \mathbf{X1}$, $X_2 = \mathbf{X2}$, $X_3 = \mathbf{X3}$, $R_1 = \mathbf{R1}$, and voltage $\mathbf{V}_1 = \mathbf{V1} \angle \theta$ V.



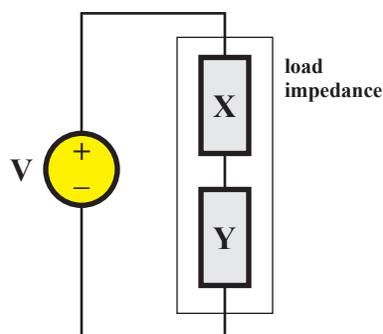
- (e) [4] Determine whether the element X is a resistor, an inductor, or a capacitor in the circuit shown. Use the value $\mathbf{I}_2 = \mathbf{I2} \angle \theta$ A.



- (f) [4] Determine the phasor current \mathbf{I} indicated in the circuit shown, and enter the phase angle θ° of \mathbf{I} in degrees in the range $-180^\circ < \theta \leq 180^\circ$. Use the values $R_1 = \mathbf{R1} \Omega$, $L_1 = \mathbf{L1}$ H, and $C_1 = \mathbf{C1}$ F.

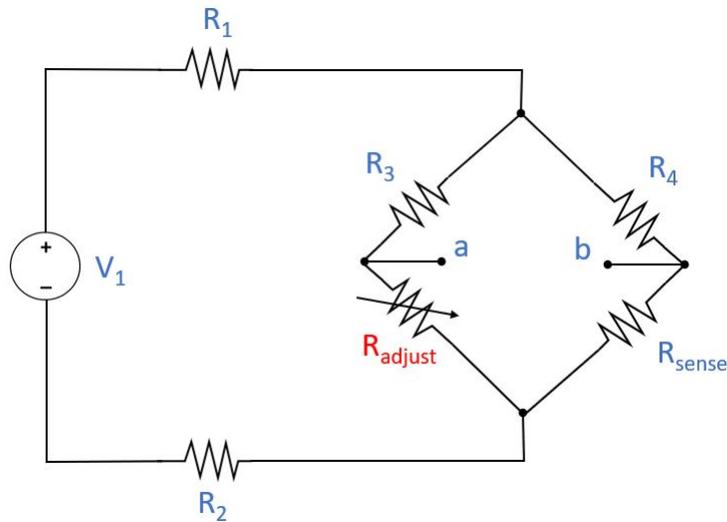


- (g) [4] A load composed of two elements X and Y has a power factor of \mathbf{PF} leading. Given that the element X is a resistor of value $\mathbf{R} \Omega$ and the frequency of the source voltage is \mathbf{f} Hz, determine whether the element Y is an inductor or capacitor. Also, find the value of inductance in mH if it is an inductor or find the value of capacitance in μF if it is a capacitor.

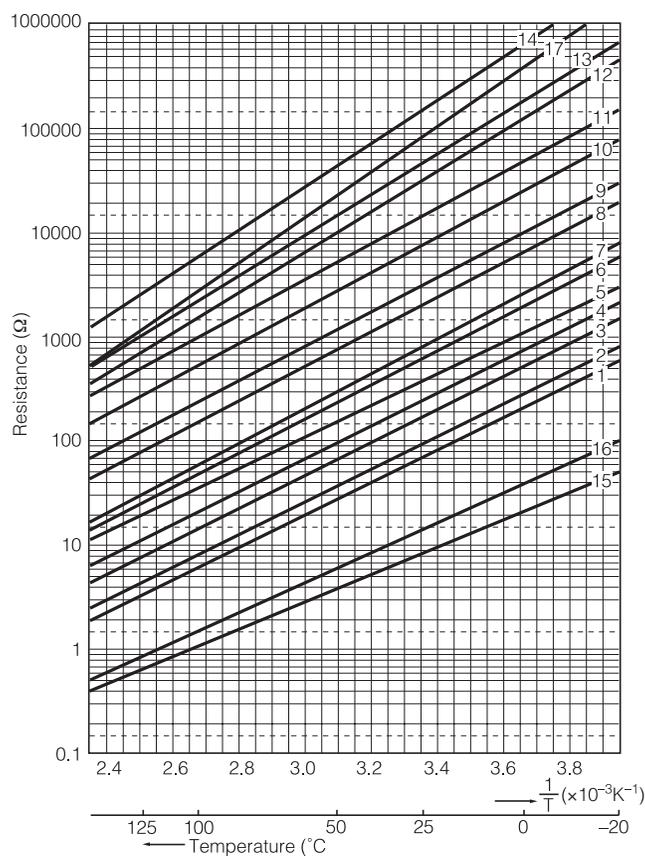


2. [8 marks.] Questions on the Wheatstone bridge circuit.

- (a) [4] The Wheatstone bridge shown is balanced, meaning $V_{ab} = 0$ V. Find the value of R_{adjust} in Ohms. Use the resistor values (in Ohms) $R_1 = R1$, $R_2 = R2$, $R_3 = R3$, $R_4 = R4$, $R_{sense} = RS$, and voltage $V_1 = V1$ V.



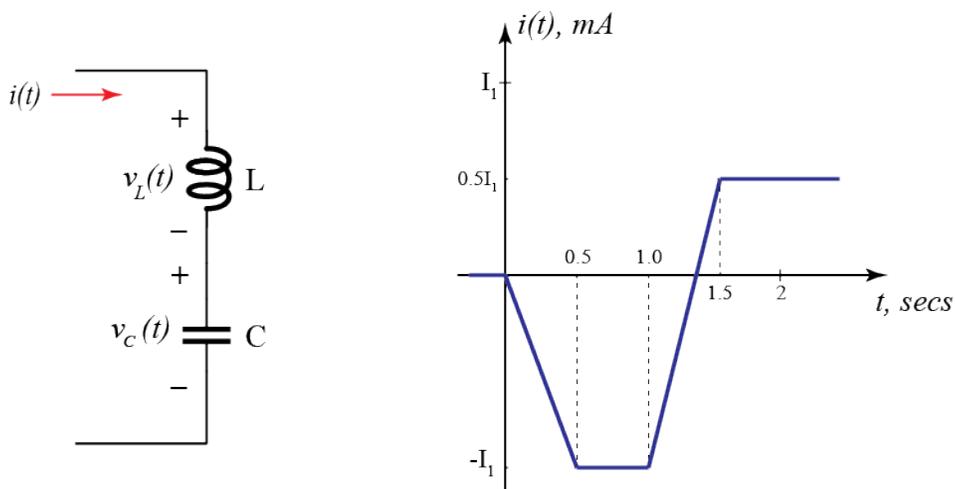
- (b) [4] In Lab 2 you used the Wheatstone bridge circuit with a thermistor to measure the temperature. For this question, we will use the same graph as in Lab 2, but we will use the thermistor plot for [10], instead of [1] as was used in Lab 2. For the thermistor value of $R_{therm} = RT$ Ω , accurately find the temperature in Celsius using plot [10], to ± 2 degrees Celsius.



3. [16 marks.] Questions on inductors and capacitors.

Consider the inductor-capacitor circuit in Fig. P3. Assume that the initial voltage on the capacitor is [randomized] $v_C(t) = V_0$, $t < 0$. The current $i(t)$ through both the inductor and capacitor for $t \geq 0$ is as shown. Use the following values:

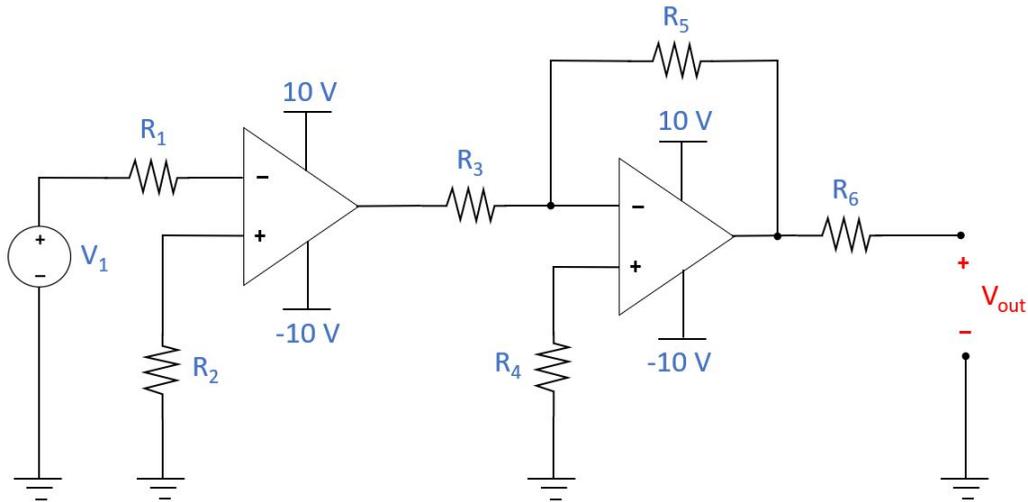
- $L = L1$ mH
- $C = C1$ μF
- $I_1 = I1$ mA
- $T_1 = T1$ msec
- $V_0 = V0$ V



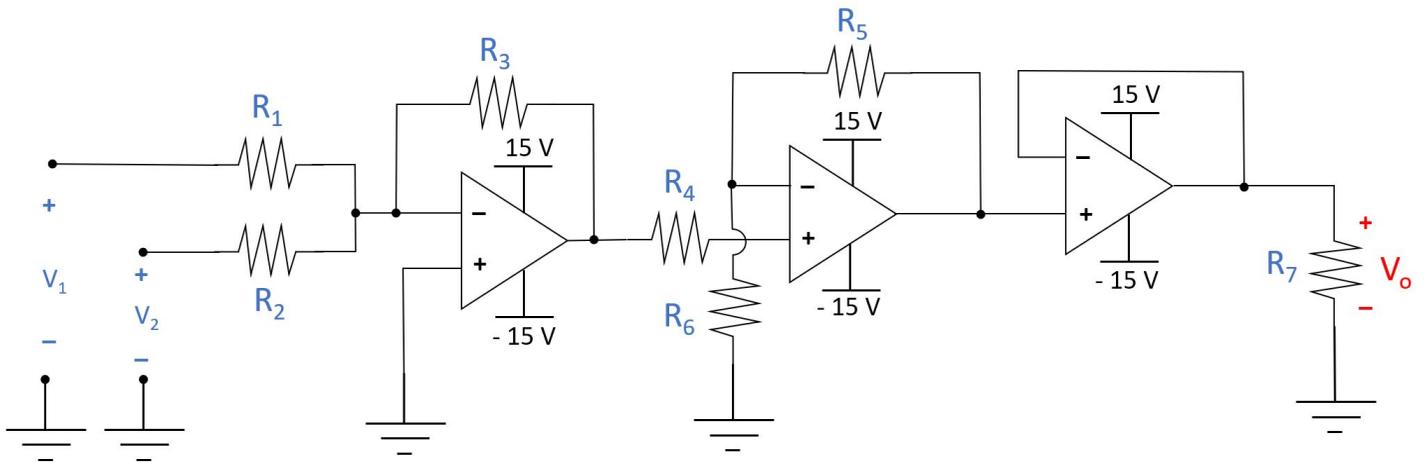
- (a) [2] Calculate the voltage on the inductor $v_L(t)$ in Volts at time $t = 0.125T_1$.
- (b) [2] Calculate the energy in the inductor $w_L(t)$ in Joules at time $t = 0.60T_1$.
- (c) [2] Calculate the power in the inductor $p_L(t)$ in Watts at time $t = 0.60T_1$.
- (d) [2] Calculate the energy in the capacitor $w_C(t)$ in Joules at time $t = 0$.
- (e) [4] Calculate the voltage on the capacitor $v_C(t)$ in Volts at time $t = 0.25T_1$.
- (f) [4] Calculate the voltage *increase* on the capacitor $v_C(t)$ in Volts over the interval $0.25T_1 < t \leq 0.5T_1$ (i.e., compute $v_C(0.5T_1) - v_C(0.25T_1)$).

4. [10 marks.] Questions on operational amplifier circuits.

- (a) [4] For the circuit shown, and using the resistor values (in Ohms) $R_1 = R1$, $R_2 = R2$, $R_3 = R3$, $R_4 = R4$, $R_5 = R5$, $R_6 = R6$ and the voltage $V_1 = V1$ Volts, determine V_{out} in Volts.

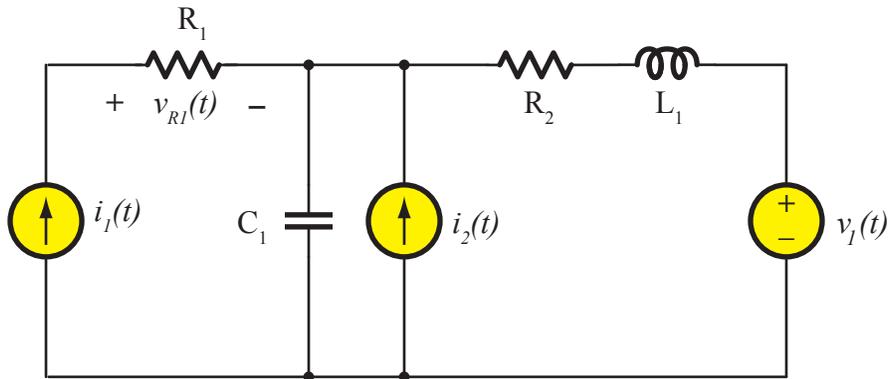


- (b) [6] Using the resistor values (in Ohms) $R_1 = R1$, $R_2 = R2$, $R_3 = R3$, $R_4 = R4$, $R_5 = R5$, $R_6 = R6$, $R_7 = R7$ and the voltages (in Volts) $V_1 = V1$ and $V_2 = V2$, determine V_o in Volts.



5. [18 marks.] Questions on AC circuits.

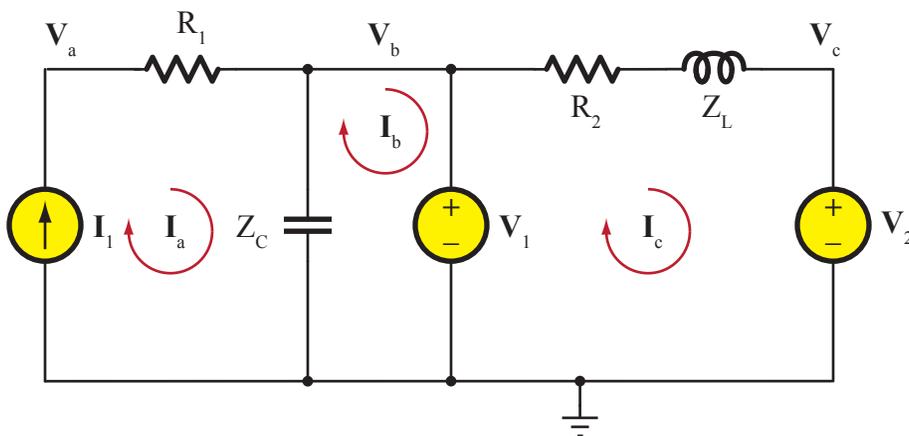
(a) The circuit shown will be used in Part (a).



- i. [2] If $i_1(t) = M \sin(\omega t + (\theta))$, calculate the sum of the magnitude and the phase of \mathbf{I}_1 (phasor representation of $i_1(t)$) when represented in polar coordinates. Show 3 decimal places. No units required.
- ii. [2] If $v_1(t) = (M \cos((\omega t + (\theta)))$ and $C_1 = C$ mF, calculate the sum of the magnitude and the phase of the complex impedance of C_1 when represented in polar coordinates. Show 3 decimal places. No units required.
- iii. [2] If $i_1(t) = M \cos(\omega t + \theta)$, and $R_1 = R$ ohms, $v_{R1}(t)$ leads $i_1(t)$ by how many degrees? Provide an answer in the range between -180° and 180° . A negative angle would indicate that $V_{R1}(t)$ lags $i_1(t)$. For example an answer of -45° would mean $v_{R1}(t)$ lags $i_1(t)$ by 45° . Show 3 decimal places. No units required.

(b) The circuit shown will be used in Part (b).

In this circuit, $I_1 = 5 \angle 0$ A, $R_1 = R1$ Ω , $Z_C = -jC$ Ω , $\mathbf{V}_1 = V1 \angle \theta_1$, $R_2 = R2$ Ω , $Z_L = jL$ Ω , and $\mathbf{V}_2 = V2 \angle \theta_2$.

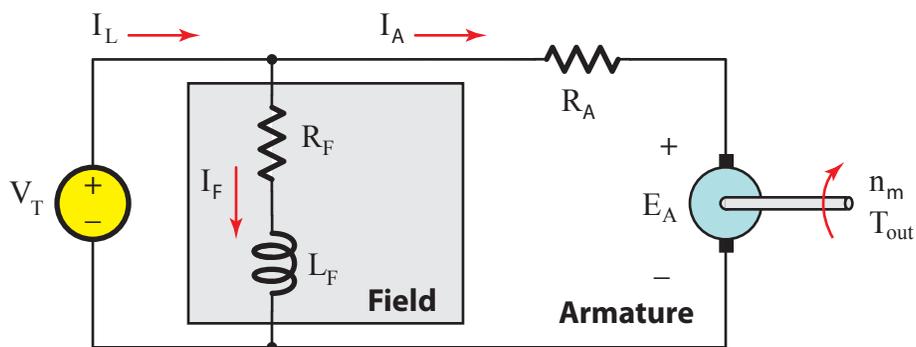


- i. [4] Write the mesh equation for \mathbf{I}_c . What is the total impedance that is used in this equation? Express this impedance in rectangular form $X = a + jb$, and enter your answer as the straight sum of the real and imaginary parts $a + b$. Show 3 decimal places. No units required.
- ii. [4] What is the magnitude of the node voltage \mathbf{V}_a in Volts? Show 3 decimal places.
- iii. [4] What is the apparent power of the capacitor in VA? Show 3 decimal places.

6. [12 marks.] *Questions about DC machines.*

Consider the shunt-connected DC motor shown. The steady-state full-load specifications for this motor are given below. You may assume that the rotational losses for this machine are negligible.

- $V_T = \mathbf{VT}$ V
- $I_L = \mathbf{IL}$ A
- $R_A = \mathbf{RA}$ Ω
- $R_F = \mathbf{RF}$ Ω
- $T_{out} = \mathbf{Tout}$ Nm



- (a) [1] Determine the field power loss P_F in Watts.
- (b) [1] Determine the armature power loss P_A in Watts.
- (c) [2] Determine the induced voltage E_A in Volts.
- (d) [2] Determine the rotation speed n_m in rpm.
- (e) [3] Determine the efficiency η in percent.
- (f) [3] Suppose that a cooling fan is now attached to the motor's shaft, which adds the rotational loss $T_{rot} = \mathbf{Trot}$ Nm. Assuming that this torque is constant (i.e., independent of rotational speed), determine the new motor speed n_m in rpm.