THE UNIVERSITY OF BRITISH COLUMBIA

Department of Electrical and Computer Engineering

ELEC 343: Electromechanics

Practice Mid-term Exam for Spring 2020

Topics Covered: Magnetic Circuits, Electromechanical Devices with Motion, and DC Motors

Surname:____

First Name:______________________________________

Student ID:_______________________________________

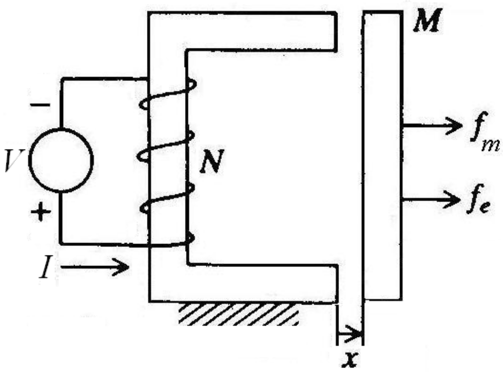
Signature:____

Problem	Points	Max.
1		20
2		20
3		20
4		20
5		20
Total		100

- **Close notes and books.**
- You are allowed to have only a **calculator** and a **pen/pencil.**
- Show you work including **derivations**, **comments**, **assumptions**, and **units** wherever appropriate.
- Use back side of each page or ask for additional pages if you need extra space to write your answers.
- Exams suspected of cheating and/or turned in late will not be marked – **failed exam**.
- You have **60** minutes to answer the following questions:

Problem 1 (20pts):

Consider the magnetic system shown below. The core and air-gap **x** have dimensions and permeability such that the reluctance of the combined magnetizing path is $\Re_m = \Re_c + 2\Re_x = 10^5\ At/Wb$. The coil has 100 turns, dc resistance $r = 2\Omega$, and is connected to a dc source $V_{dc} = 20V$. **It is also known that 20% of the total flux Φ produced by the coil leaks into the air (remember - flux leakage!).**



(a) (3pts) Draw an equivalent **magnetic** circuit, show all reluctances, the direction of mmf and all fluxes

(b) (3pts) Draw an equivalent **electric** circuit, show the direction of current ***I*** and voltage ***V*** (assuming a steady state and a **dc** voltage)

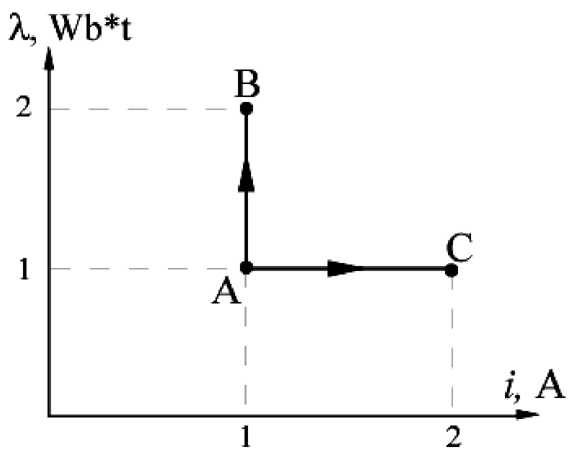
(c) (6pts) Calculate the coil inductance ***L*** and flux linkage λ

(d) (7pts) Assume that the coil is supplied from an **ac** source $V_{ac} = 42.5V(rms)$ with the frequency $\omega = 30 rad/\sec$. Find the rms value of current I_{ac}

(e) (5pts) How does the electromagnetic force f_e and its direction in particular changes with the ac current I_{ac}?

Problem 2 (20pts):

Assume an electromechanical system with one electrical and one mechanical inputs. The system may be assumed **magnetically linear** (similar to a solenoid). The system's state is shown in the $\lambda - i$ figure below, wherein the system can move from point A to point B, and from point A to point C, respectively. Using the numerical values given on this figure, **calculate the change in** W_f, W_c, W_e, and W_m for the two transitions. In other words, complete the Table given below. **Be sure to include the units.** Remember, according to our convention, positive sign (value) of W_e and W_m means into the system.



Transition	From A to B	From A to C
(4pts) Change in coupling field energy, ΔW_f		
(4pts) Change in co-energy, ΔW_c		
(4pts) Change in electrical input, ΔW_e		
(4pts) Change in mechanical input, ΔW_m		
(3pts) The energy was taken from **(and how much)**		
(3pts) The energy was supplied to **(and how much)**		

Problem 3 (20pts):

Assume that on your electric bike you have a **Permanent-Magnet DC Machine** with the armature resistance $R_a = 0.2\,\Omega$. When the motor is connected to a 12-V battery it draws the armature current $I_a = 0.5$ A and the shaft speed is $n = 1000$ rpm **CCW** at no load. The battery voltage and friction torque can be assumed constant.

(a) (10pts) Calculate the torque constant K_t and the friction torque T_{fric}

(b) (10pts) Assume that you are going downhill at a constant speed and using regenerative braking to charge the battery. Calculate the external mechanical torque T_m required to produce the charging current of 10A. In what direction, **CW** or **CCW**, should this torque be applied? What is the resulting shaft speed n in **rpm** and efficiency of the energy recovery $\eta(\%)$?

Problem 4 (20pts):

A 24V battery-operated **electric drill** has a **Series DC Motor** with the armature resistance $R_a = 0.4\Omega$; and field winding resistance $R_f = 0.6\Omega$. When the drill spins by itself (not drilling anything, just working against the friction of the gearbox, T_{fric}) it draws current $I_a = 1$ A and the shaft speed is $n = 1000$ rpm.

(a) (5pts) Draw an equivalent circuit and label all elements. Find the friction torque T_{fric}

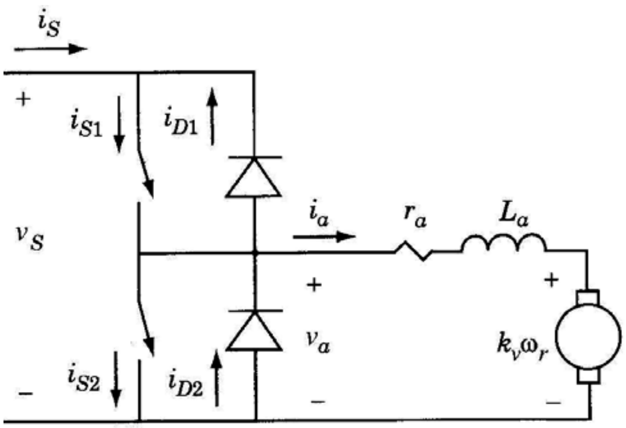
(b) (5pts) To start drilling an aluminum plate the motor needs to develop initial torque of 100 N*m. Calculate the torque at zero speed (**starting torque**) that this drill can develop, T_{start}. Conclude whether or not this drill can be used for this job?

(c) (5pts) During the nominal drilling the mechanical torque is only $T_m = 10$ N*m. Assume friction torque $T_{fric} = const.$ (same what you found in part (b)). Determine the current I_a and electric power P_{in} drawn from the 24V battery.

(d) (5pts) For continuous nominal drilling operation, the motor has to have speed of at least 100 rpm for the cooling fan to dissipate the heat, P_{loss}. Calculate the motor speed ***n*** in rpm, P_{loss} and efficiency $\eta(\%)$? Conclude whether or not this drill would have a sufficient cooling to work continuously?

Problem 5 (20pts):

Assume a PM DC motor is driven by a PWM converter shown below. The motor shaft is connected to a constant speed mechanical system (load) with $\omega_r = 10\, r/s$. The motor parameters are $k_v = 0.5 Vs/r$ and $r_a = 1\Omega$. The converter is supplied form a 10 V dc source. Initially, in **Mode 1**, the duty cycle $d = 0.6$ (60% on and 40% off). The corresponding voltage and current waveforms are depicted on the figure below (first interval), wherein the average values of the voltage $\bar{v}_a = 6V$ and current $\bar{i}_a = 1A$ are also shown. Assume that the duty cycle has changed to 0.4 (40% on and 60 off), as shown on the figure. This is a new steady-state operation in **Mode 2**:



(a) (5pts): Determine whether machine is **Motoring** or **Generating** in each **Mode?** and circle appropriate

(b) (5pts): Find the value of the average voltage $\bar{v}_a$ for the **Mode 2** and show it on the figure

(c) (5pts): Sketch the steady-state waveform of the current $\bar{i}_a$ in Mode 2 and find/show its average value

(d) (5pts): The diode D1 has been removed. How would that change the operation when $d = 0.6$ and when $d = 0.4$?