THE UNIVERSITY OF BRITISH COLUMBIA

Department of Electrical and Computer Engineering

EECE 365: Applied Electronics and Electromechanics

Final Exam / Sample-Practice Exam
Spring 2008
April 23

Topics Covered: Magnetic Circuits, Electromechanical Devices with Motion, DC Motors, AC Power and Transformers, Induction Motors, Synchronous Motors, Brushless DC Motors, Stepper Motors

Surname:______________________________________

First Name:_____________________________________

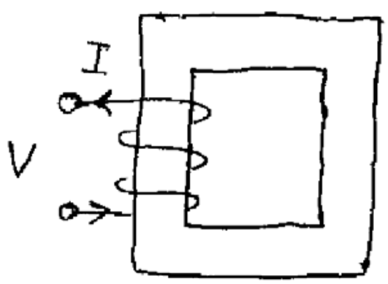
Student ID:_____________________________________

Signature:______________________________________

- **Close notes and books.**
- You are allowed to have only a **calculator,** a **pen/pencil, and two double-sided pages of hand-written formulas**.
- 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 **90** minutes to answer the following questions:

Problem	Points	Max.
1		
2		
3		
4		
5		
6		
7		
8		
9		
Total		100

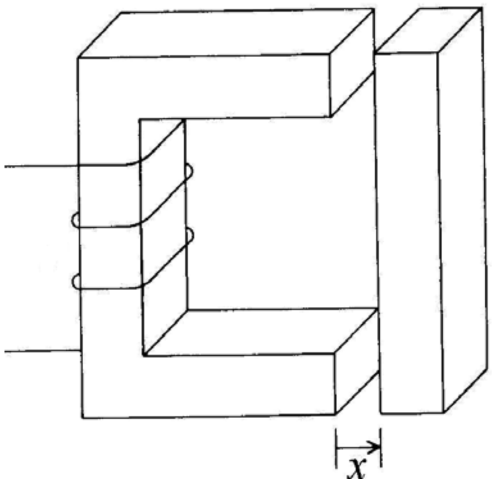
Problem 1:
Consider the magnetic system shown below. The core has permeability and dimensions such that the reluctance of magnetizing path is $\Re_m = 10^5\ At/Wb$. The coil has 100 turns, dc resistance of $3\,\Omega$, and is connected to a dc source $V_{dc} = 12V$. It is also known that 10% of the total flux Φ produced by the coil leaks into the air.



(a) Draw an equivalent **magnetic** circuit, show the direction of mmf and the fluxes
(b) Calculate flux linkage λ, and inductance L
(c) Find the rms value of current if the coil is supplied from an ac source $V_{ac} = 12V(rms)$ with the frequency $f_e = 5.093 Hz$

Problem 2:

Consider an electro-mechanical device shown in the figure. You can use common approximations as we did in class and assume magnetically-linear core. The air-gap between the core and the plunger is denoted by x (which has units of meters). Assume that total inductance of this device may be approximated as $L(x) = 0.15 + \dfrac{5 \cdot 10^{-6}}{x^2}$ H, and the dc resistance r is $20\,\Omega$.



(a) Sketch the equivalent **magnetic** circuit and label all elements

(b) Sketch the equivalent **electric** circuit and label all elements

(c) Express the electromagnetic force $f_e(x, I_{dc})$

(d) What value of dc voltage V_{dc} and dc current I_{dc} should be applied to the coil in order to produce a force of $25Nm$ when the plunger has air-gap of 2 mm?

(e) Calculate the energy stored in the system for part (d)

Problem 3:

Consider a **Permanent-Magnet DC motor** with the following parameters: rated voltage $V_t = 240$ V; armature resistance $R_a = 1.2\,\Omega$, and friction torque $T_{fric} = 0.5 Nm = const$.

(a) When the motor drives a mechanical load of 9.5Nm it draws a current of 10 A. Calculate the induced armature emf E_a and torque constant K_t

(b) Assume that mechanical load has increased to $T_m = 19.5 Nm$. Calculate the motor speed n in rpm, speed regulation *SR* in %, and efficiency η also in %

Problem 4:

Consider a 115V series-connected DC motor with the following parameters: armature resistance $R_a = 1\Omega$; and field winding resistance $R_f = 2\Omega$. The motor is supplied from a dc source $V_t = 115$ V and is operating under nominal load at speed $n = 3000$ rpm drawing armature current $I_a = 5$ A.

(a) Draw an equivalent circuit
(b) Calculate the induced back emf, E_a
(c) Calculate the torque at zero speed (starting torque), T_{start}

Problem 5:

A 1.5-kVA, 60-Hz, step-up transformer has two windings with $N_1 = 1000$ and $N_2 = 2000$ turns, respectively. The leakage reactances are $X_1 = 2\Omega$, $X_2 = 8\Omega$ (each quantity is referred to its own side), and the magnetizing reactance $X_{m2} = 400\Omega$ (referred to the secondary side). The core and copper losses can be ignored. Assume 120V is applied to the primary side:

(a) Calculate the open-circuit primary current $I_{1,oc}$ and the secondary voltage $V_{2,oc}$ (their rms values)

(b) Assume a resistive load $R_{Load} = 40\Omega$ is connected to the secondary side. Calculate the resulting currents (rms) in each winding. Also calculate the input power-factor angle φ in degrees

Problem 6:

Consider a 60Hz, 208V (line-to-line), Y-connected, NEMA Clsass B Squirrel-Cage Induction Motor with the following per-phase parameters: $R_1 = 1\Omega$, $R_2 = 1.5\Omega$, $X_1 = X_2 = 3\Omega$, and $X_m = 40\Omega$ (all referred to the stator). The motor is supplied with the nominal (rated) voltage and is driving a mechanical load. The speed of the motor shaft is n = 855 rpm. You can neglect core losses and use an approximate equivalent circuit. Recall that $T_e = 3\frac{1}{\omega_{syn}} \cdot (I_2)^2 \cdot \frac{R_s}{s}$. Determine the following:

(a) Number of poles ***P*** and slip ***s***

(b) Input stator current I_1, power factor PF, and total three-phase input power P_{in}

(c) Developed electromagnetic torque T_e

(d) Assume the friction torque is 5% of the developed torque T_e. Calculate the useful mechanical load torque T_m and the motor efficiency η in %

Problem 7:

Consider a 3-phase, 60Hz, 208V (line-to-line) 14-pole **Permanent Magnet Round-Rotor Synchronous Motor** with the following parameters: per-phase stator resistance and synchronous reactance are $R_a = 1\,\Omega$ and $X_s = 10\,\Omega$, respectively. Assume that the motor outputs mechanical power $P_m = 1676\,\mathrm{W}$ and power factor is one.

(a) Sketch an equivalent **electric circuit** (per-phase)

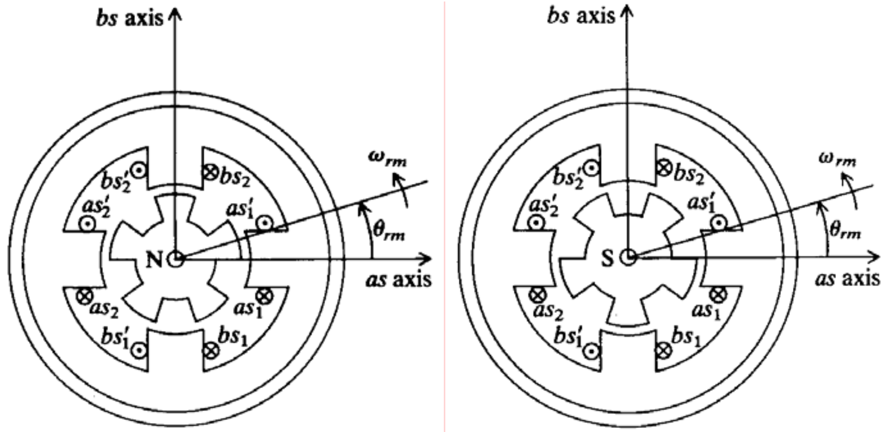
(b) Calculate the motor shaft is n in rpm, induced voltage E_f, and the rotor angle δ in degrees

(c) Assume mechanical rotational losses $P_{mech\_loss} = 50W$, calculate the efficiency η

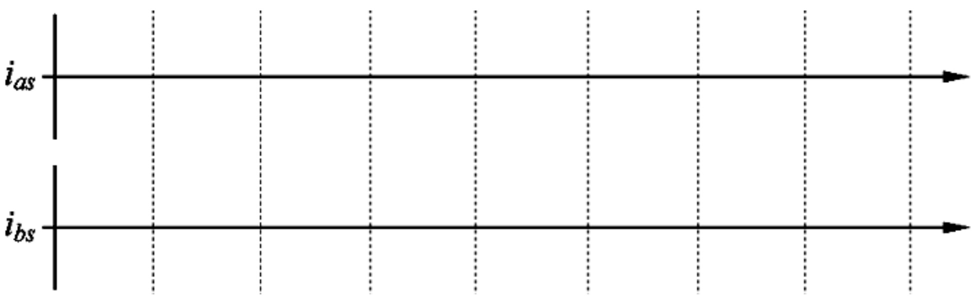
Problem 8:

(a) Consider a 2-phase **PM Stepper Motor** shown here. The rotor initial position is as shown corresponds to the phase ***bs*** energized.

Sketch the sequence of currents i_{as} and i_{bs} to drive this motor at **half-step** in **CW** direction assuming phase ***bs*** is energized first to positive value.



Front Back

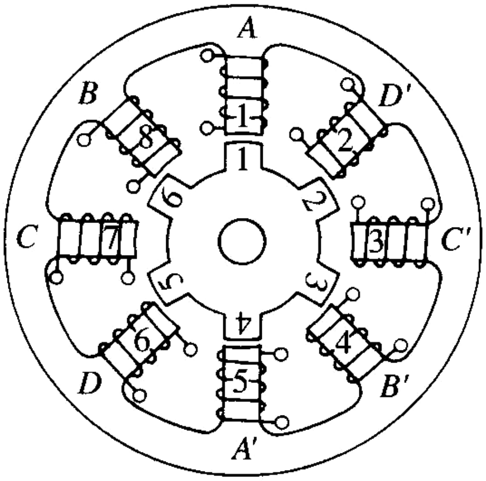


(b) Assume a standard (one phase energized at a time) full-step operation with duration of current pulses $T_{step} = 1/f_{step} = 0.01\text{sec}$. Calculate rotor mechanical speed n in rpm

(c) List all classes/types of stepper motors that we discussed in class:

(d) List some of the factors that limit the stepping rate (or speed) at which a given stepper motor can operate: We discussed this in class and you have observed that in Lab-5.

Problem 9:
Consider a single-stack stepper motor shown below. Complete the following table:



2pts	Stator tooth pitch	
2pts	Rotor tooth pitch	
3pts	Step length	
3pts	Number of steps per revolution (Resolution)	
3pts	Assume sequence of pulses as B – C – D – A, determine the direction of rotation (**CW** or **CCW**)	
3pts	Assume you have a 4-phase pulse generator to supply this motor. The generator produces 12 pulses per second per phase (48 pulses per second total). What is the motor speed in **rpm**?	