ECE 32100—ABET Exam (due within 11/30 – 12/4)
The Exam Will Be Graded Orally by Prof. Aliprantis During His Office Hours

The purpose of this exam is to assess attainment of the Learning Objectives of this course. These are related to your ability to:

1. Analyze/design electromagnetic circuits/devices.
2. Understand the concepts and principles of electromagnetic [electromechanical] energy conversion.
3. Understand the concept of time-varying transformations in the analysis of time-varying systems.
4. Analyze dc machines.
5. Understand converters for dc drives.
6. Analyze brushless dc machines.
7. Analyze induction machines.

If answers are incorrect, you will be asked to revise & resubmit, until all questions are correctly answered. If, after the second revision, there still remain incorrect answers, the exam will be considered incomplete. **Failure to complete this exam means that you get an 'F' in this class!**

Instructions:

- *"I certify that I have neither given nor received unauthorized aid on this exam."*
  Write out the above statement at the bottom of this page before you begin your exam, then write your CLASS ID. (Do not write your name.)
- *Write your answers in the space provided in the next pages. Use SI units.*
- *Some questions require calculations. For these questions, show how you obtained the numerical answer in the white space provided below the question.* ***Numerical answers without justification will not be accepted!***

Good luck!

Integrity statement: ____

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CLASS ID: ____________________

- Self-study the review material on phasors in pp. 2–8 in the textbook.
- Self-study example 1D in pp. 28–29 in the textbook.
- Self-study the supplementary material on solving the transformer T-equivalent circuit, which has been posted in Blackboard. (Compared to the circuit found on p. 27 of the textbook, the circuit described in these notes has an additional resistance R_0, which is used to account for hysteresis and eddy current loss.)

Problem 1. A single-phase transformer has the following parameters: turns ratio $N_1/N_2 = 0.1$, $R_1 = R_2' = 1\ \Omega$, $X_1 = X_2' = 7.5\ \Omega$, $R_0 = 2000\ \Omega$, $X_0 = 5000\ \Omega$. The reactances were measured at a frequency of 60 Hz. The winding resistances may be assumed to remain constant with frequency. The core loss resistance R_0 was also measured at 60 Hz, and varies according to the following formula:

$$R_0(f) = R_0 \frac{60}{f},$$

where f denotes operating frequency in Hz. The primary winding is connected to a sinusoidal ac source. The rms value of the source (in V) is equal to the 3 first digits of your class ID, and the voltage has a phase of zero. The source frequency f (in Hz) is equal to the 2 last digits of your class ID.[1] A $10\angle{-40^\circ}$ kΩ load (actual impedance value, at frequency f) is connected across the secondary terminals.

1. Compute[2] the load voltage, $\tilde{V}_2 =$ ______ $\angle$______$^\circ$.
2. Compute the transformer efficiency, $\eta =$ ______%.

[You may attach an additional page for your calculations, if this space is not sufficient.]

[1] If this happens to be '00', you should use digits 4 and 5.

[2] Do *not* use the "approximate" equivalent circuit in these calculations.

Problem 2. Consider two coupled coils in a magnetically linear system, as given in Section 2.8, pp. 86–89 of the textbook, with background information on pp. 42–44 of the textbook. Coil #1 has N_1 = first 2 digits of your class ID. Coil #2 has N_2 = last 2 digits of your class ID.[3] The leakage inductances satisfy $L_{l1} = 0.02L_{m1}$ and $L_{l2} = 0.03L_{m2}$. An experiment is conducted first, where the device is driven at 500 rpm with $i_2 = 1$ A (dc), and the open-circuit voltage that is measured across coil #1 is sinusoidal with a 100 V peak-to-peak value.

1. Calculate $T_e(i_1 = 5 \text{ A}, i_2 = 10 \text{ A}, \theta_r = 45°) =$ ________________.
2. Calculate the main flux path reluctance, $R_m =$ ________________.

[3] If this happens to be '00', you should use digits 4 and 5.

Problem 3. Consider a symmetric 2-phase series rL (or rC) circuit, like the one discussed in Chapter 5 of the textbook. The circuit is in sinusoidal steady-state conditions with $\omega_e = 50$ rad/s. The synchronous reference frame currents are: $I_{qs}^e =$ first digit of your class ID, and $I_{ds}^e =$ second digit of your class ID (in A). The voltages are: $V_{qs}^e =$ third digit of your class ID, and $V_{ds}^e =$ fourth digit of your class ID (in V).[4]

1. Calculate the circuit impedance, $Z = \_\_\_\_ + j\ \_\_\_\_$.
2. If $\omega = 30$ rad/s and $\theta(0) = 0$, then $V_{ds}(t) = -\sqrt{2}\ \_\_\_\_\ \sin[(\ \_\_\_\_\ )t + \ \_\_\_\ ^\circ]$.

[4]If these happen to be '0' simultaneously, you should use digits 4 and 5.

Problem 4. A dc machine has the following parameters: $r_a = 5\ \Omega$, $r_f = 100\ \Omega$, $L_{AA} = 0.02$ H, $L_{AF} = 0.5$ H. The motor is connected to a chopper that operates with duty cycle 40%. The average voltage applied to the armature is $V_a =$ first 3 digits of your class ID (in V). The field winding is connected to the same voltage source as the armature. The switching frequency is 10 kHz.

1. Calculate the stall torque, $T_e(\text{stall}) =$ ________________.
2. Calculate the no-load speed, $\text{rpm}_{\text{no-load}} =$ ________________.
3. Calculate the source voltage, $V_s =$ ________________.
4. For $\omega_r = 125\%$ of the no-load speed, sketch (by hand) a figure similar to Fig. 3.8-3 on p. 135 of the textbook, as accurately as possible. Make sure to annotate the plots with waveform max/min values, etc.

Problem 5. Consider the brushless dc machine of Example 8A, p. 353 in the textbook. Repeat the calculations of Example 8B, p. 360. However, in this problem, set $\omega_r = x\%$ of the no-load speed, where $x =$ the first 2 digits of your class ID.

1. $\omega_r =$ __________ (in rad/s).
2. $T_e =$ __________.
3. $I_{qs}^r =$ __________.
4. $I_{ds}^r =$ __________.
5. $\tilde{I}_{as} =$ ______ $\angle$ ______ $^\circ$.

Problem 6. A six-pole induction motor is connected to a 50-Hz system (somewhere in Europe). The slip is equal to $x.y\%$, where x is the first and y the second digit of your class ID, respectively.

1. What is the speed of the rotor in rpm? ______________
2. What is the frequency of the currents in the stator winding? ______________
3. What is the frequency of the currents in the rotor? ______________