EE321 Exam 5
Spring 2009

Notes**: There are five questions.**

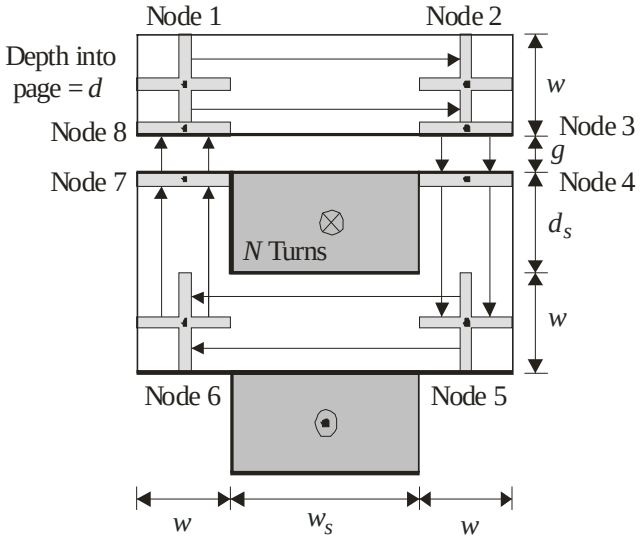
You must show work for credit.

Some problems have more information than is needed.

The last two pages of Exam 4 have trigonometric identities. You can tear these off if more convenient.

May the flux be with you …

1. Consider the UI core shown below. Consider the following parameters: $w = 1$ cm; $w_s = 5$ cm; $d_s = 2$ cm; $d = 5$ cm; $g = 1$ mm; $N = 100$. The relative permeability of the magnetic material is 1000. Recall that the permeability of free space is $4\pi 10^{-7}$ H/m. Neglecting fringing and leakage flux, as we did in class, find the maximum current for the device if the flux density is to be limited to 1.2 T. (20 pts; A score of 12 pts {raw} satisfies ABET Objective 1)



2. The flux linkage equation of an electromechanical device is

$$\lambda_1 = 2i_1 + \frac{5}{3+x^2}(1-e^{-2(i_1+2i_w)})$$
$$\lambda_2 = 4i_2 + \frac{10}{3+x^2}(1-e^{-2(i_1+2i_w)})$$

where $i_1 \geq 0$ and $i_2 \geq 0$. These equations yield the flux linkage in Vs for currents in A and displacement in meters. Compute the force if $i_1 = 2$ A and $i_2 = 3$ A at $x = 1$ m. (20 pts; A score of 12 pts {raw} satisfies ABET Objective 2)

3. Consider a dc machine fed from a dc/dc converter. The input to the dc converter is 100 V. The transistor and diode switch drops are 2 V and 1 V, respectively. The machine parameters are $r_a = 0.1\Omega$, $L_{aa} = 3$ mH, and $k_v = 0.1$ V/s. The rotor speed is 6000 RPM, the duty cycle is 0.7, and the switching frequency is 5 kHz. At what speed does operation become discontinuous ? (20 pts; A score of 12 pts {raw} satisfies ABET Objective 5) [POST EXAM NOTE: The clause in red above is in error. As a result I discounted this question, and made all problems worth 25 pts. All objective 5 ABETs were considered to be passed]

4. A synchronous PM machine starts as an induction machine and then operates as a permanent magnet synchronous machine. If flux linkage equations are expressed

$$\boldsymbol{\lambda}'_{abr} = (L_{lr} + L_{ms})\mathbf{i}'_{abr} + L_{ms}\begin{bmatrix} \cos\theta_r & \sin\theta_r \\ -\sin\theta_r & \cos\theta_r \end{bmatrix} i_{abs} + \lambda_m \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

Transform this equation to the rotor reference frame defined by

$$\mathbf{f}'^{r}_{qdr} = \mathbf{K}^{r}_{r}\mathbf{f}'_{abr}$$

$$\mathbf{K}^{r}_{r} = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

$$\mathbf{f}^{r}_{qds} = \mathbf{K}^{r}_{s}\mathbf{f}_{abs}$$

$$\mathbf{K}^{r}_{s} = \begin{bmatrix} \sin\theta_r & -\cos\theta_r \\ \cos\theta_r & \sin\theta_r \end{bmatrix}$$

Note: These are not the flux linkage equations or transformations we used in class. The answer will have similarities but also differences to the results we obtained in class.
(20 pts; A score of 12 pts {raw} satisfies ABET Objective 3).

5. A 4-pole 3-phase brushless PM machine has the following parameters: $r_s = 0.02\,\Omega$, $L_{ss} = 2$ mH, $\lambda_m^{'} = 0.05$ Vs. It is desired to obtain a torque of 20 Nm at a speed of 5000 rpm. What is the best possible motor efficiency that could be obtained ? (20 pts; A score of 12 pts {raw} satisfies ABET Objective 4)