Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15 (2.0 hours)

EEE305 Machine Design

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. From the expression of Lorentz force, show that the torque density of a cylindrical electrical machine can be expressed in terms of the magnetic and electrical loadings, $\boldsymbol{B}$ and $\boldsymbol{Q}$, respectively. List the major assumptions which you make in the derivation. **(5)**

b. Derive an expression for estimating the airgap flux density in an interrior permanent magnet machine with circumferentially magnetized magnets, such as shown in Figure 1. Explain why the air-gap flux density may be higher than the magnet remanence.

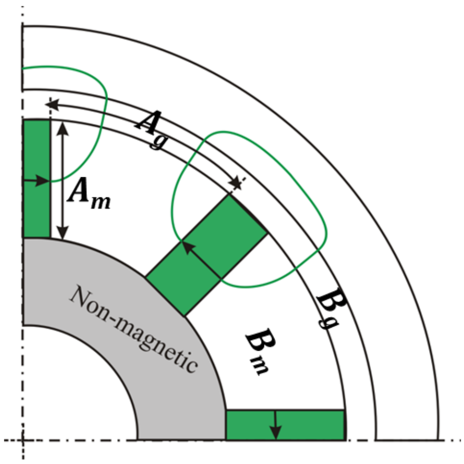

Figure 1 **(6)**

c. Neglecting all the leakage flux, show that when a magnet is required to produce a specific flux density B_g in an air-gap of length L_g and an area A_g, it is possible to minimize the magnet volume required by operating it at its maximum energy product working point $(BH)_{max}$. Explain why this design approach for the magnet is rarely adopted in practical electrical machines. **(5)**

d. List the main factors that affect the iron losses of electrical machines, and explain how the influence of iron losses on high speed machines can be minimised. **(4)**

2. **a.** Derive general expressions for the winding pitch factor, K_p, and the distribution factor, K_d, for both the fundamental and the n^{th} harmonic EMF components. Based on the coil EMF vectors, in order to obtain a maximum winding factor, determine the coil connections for a 3-phase, 12-slot, 8-pole surface mounted permanent magnet machine with single layer windings. **(8)**

b. Show that the winding skew factor can be derived using similar method as for the winding distribution factor. Explain the main advantages and disadvantages of using winding skew. **(4)**

c. A concentric winding which is distributed in the slots over one pole pitch in a machine having evenly spaced slots, as shown in Figure 2. Calculate the winding factor for the fundamental EMF.

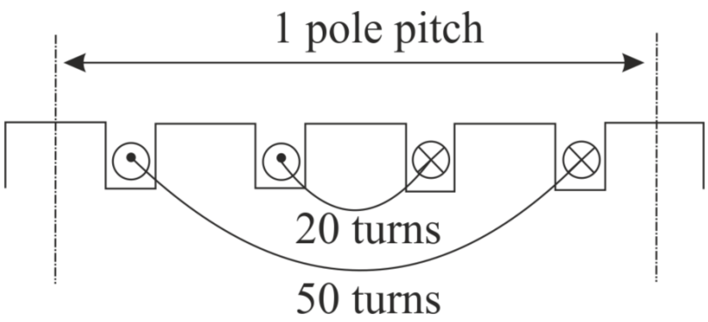

Figure 2

(5)

d. Describe the main advantages and disadvantages of the short-pitched concentrated winding, and the fully-pitched distributed winding. **(3)**

3. A 2-pole permanent magnet DC motor, having its magnet arcs mounted adjacent to the airgap, has the following main dimensions:

Rotor active length $\boldsymbol{L} = 40$ mm
Rotor outer diameter $\boldsymbol{D} = 60$ mm,
Effective air-gap length $\boldsymbol{l_g} = 0.8$ mm
Magnet radial thickness $\boldsymbol{l_m} = 5$ mm
Magnet pole arc = 110^{o}

The magnet material has recoil permeability (μ_r) of 1.1 and its B-H characteristic is shown in Figure 3.

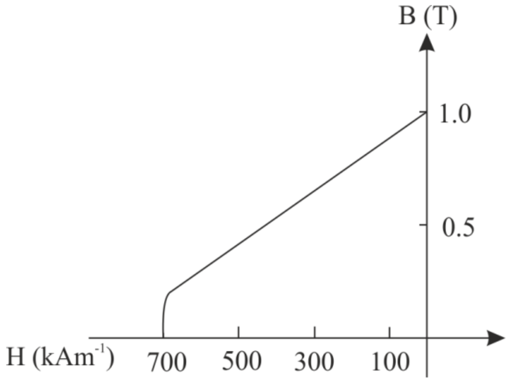

Figure 3 $H_{lim} = 650$ kA/m

a. Use analytical techniques to calculate the flux per pole for the motor. **(5)**

b. If the rotor has a total of 1532 conductors, connected in two parallel paths by the brushes, calculate the speed EMF constant for the motor and the corresponding no-load speed when operating on a 100V dc supply. **(5)**

c. The rotor winding has an effective resistance of 3 Ω, calculate the stall-torque using a dc supply of 100V supply and show whether or not the motor can tolerate the stall under these conditions without demagnetizing the magnets. **(5)**

d. Show graphically the difference between reversible and irreversible demagnetizations. Explain the influence of temperature on the irreversible demagnetization for both Ferrite and NdFeB permanent magnets. **(5)**

4. For a slot shown in Figure 4, specify any assumptions that need to be made in order to derive analytically the expressions of:

a. The coil slot leakage inductance per-unit length for coil 'a' **(5)**

b. The coil slot leakage inductance per-unit length for coil 'b' **(3)**

c. The mutual inductance per-unit length between coils 'a' and 'b' **(7)**

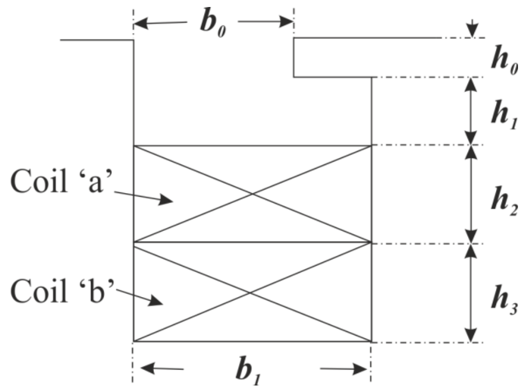

Figure 4 Numbers of turns in the slot for coil 'a' and 'b' are N_a and N_b, respectively.

d. Show graphically the difference between a single layer, concentrated winding and a double layer, concentrated winding. Describe the main advantages of the single layer, concentrated winding over the double layer, concentrated winding. **(5)**

(Full marks will not be given if the appropriate assumptions are not specified)

GJL/JBW