**Data Provided: None**

The University Of Sheffield.

**DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING**

**Spring Semester 2013-14 (2.0 hours)**

**EEE6140 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.** Derive the expression of torque of a cylindrical electrical machine as a function of the electrical loading Q, the magnetic loading B, the rotor diameter D and the length L. **(4)**

**b.** Derive the expression of torque of an axial flux machine, shown in Figure 1, as a function of the electrical loading Q, the magnetic loading B, the inner and outer diameters $D_i$ and $D_o$, respectively. Describe main differences between a radial flux machine and an axial flux electrical machine.

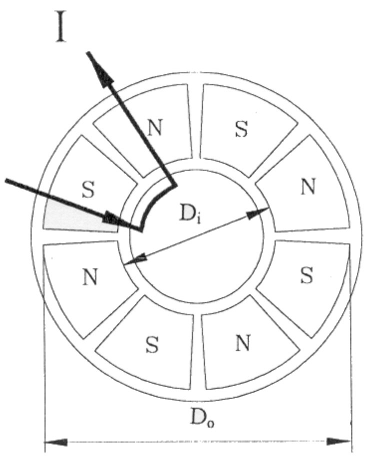


Figure 1 Rotor of axial flux machine **(7)**

**c.** Assuming the radial dimensions of the machine, shown in Figure 2, are increased by a factor of K, determine the relationship between the increase in electrical loading Q and the factor K. The slot number, area and current are $N_s$, $A_s$ and $I_s$, respectively; $D_1$, $D_2$, $D_3$ are the inner diameter of stator, the diameter of slot bottom and the outer diameter of stator, respectively; h and $w_t$ are the slot depth and the tooth width, respectively; and $k_p$ and $J_s$ are the slot filling factor and slot current density (constant), respectively. **(5)**

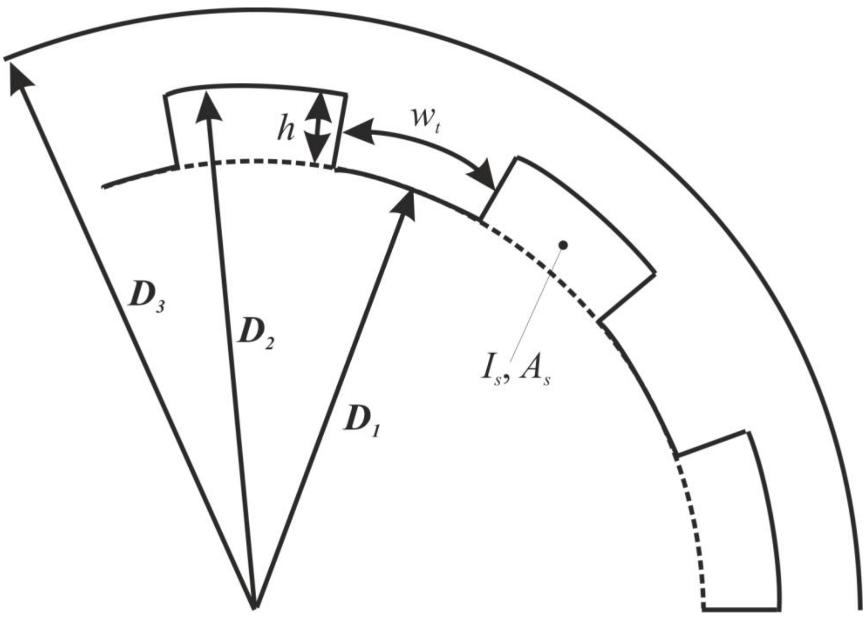


Figure 2 Stator of radial flux machine

**d.** What are the major design factors that will influence the electrical loading Q and the magnetic loading B? **(4)**

**2.** **a.** The magnetic circuit, shown in Figure 3, which has an airgap with a length $l_g$ and area $A_g$, is excited by a permanent magnet with a length $l_m$ and an area $A_m$, a remanence $Br$ and a relative recoil permeability $\mu_r$, and a coil with $N$ turns and current $I$. When current $I$ = 0, calculate the open-circuit airgap flux density. Describe the methods which help increase the airgap flux density and discuss their limitations. List all the assumptions that are made in the derivations.

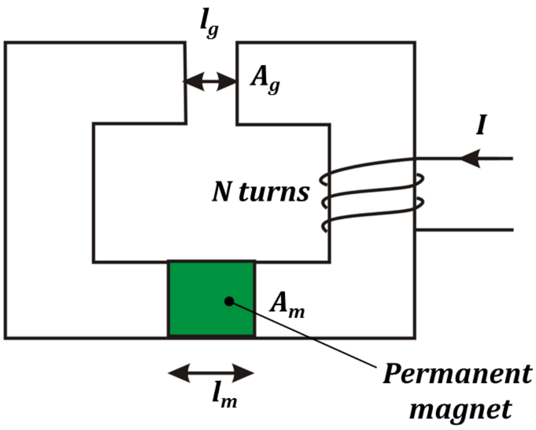


Figure 3 Magnetic circuit **(8)**

**b.** Derive the relationship between the magnet volume and the air-gap volume. Show graphically when the maximum energy product in magnets is achieved. **(4)**

**c.** Now $I \neq 0$, draw the demagnetization curve of the magnets and calculate the minimum magnet length to avoid irreversible demagnetization. **(4)**

**d.** Show graphically the difference between the reversible and irreversible demagnetizations. Explain the influence of temperature on the irreversible demagnetization for both Ferrite and NdFeB permanent magnets. **(4)**

**3.** **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. Explain why a short-pitched winding is often preferred in practice when compared to long-pitched winding. (Both short-pitched and long-pitched windings are distributed windings). **(6)**

**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. **(5)**

**c.** Employing coil EMF vectors, determine the coil connections for a 3-phase, 12-slot, 14-pole alternate teeth wound permanent magnet machine which has a non-overlapping winding, i.e. concentrated coils, in order to obtain a maximum winding factor. **(4)**

**d.** Employing coil EMF vectors, determine the coil connections for a 3-phase, 9-slot, 10-pole all teeth wound permanent magnet machine which has a non-overlapping winding, i.e. concentrated coils, in order to obtain a maximum winding factor. **(5)**

**4.** **a.** Figure 4 shows a simple reluctance machine which consists of a stator equipped with a single coil of height $h_2$, a width $b_2$, and a number of turns $N$. The machine has a rotor of height $h_1$ and width $b_0$, and separated from the stator by two identical airgaps of length $h_0$. Furthermore, the width of the air section (unwound section) of the slot is $b_1$ and $b_0 > h_1$. Calculate the winding inductance per-unit length of the machine, specifying any assumptions that should be made. (full marks will not be given if the assumptions are not listed).

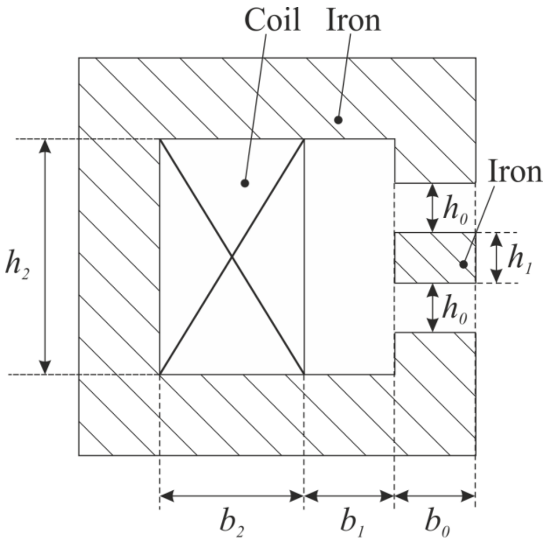


Figure 4 Simple reluctance machine **(8)**

**b.** The rotor shown in Figure 4 rotates to another position (90 deg. mech.), as shown in Figure 5, where the rotor surfaces are always parallel to stator teeth surfaces. Based on the assumptions given in **4.a**, calculate the winding inductance per-unit length of the machine.

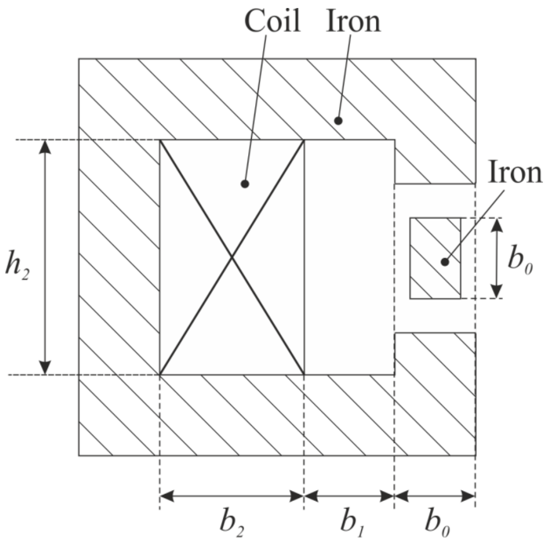


Figure 5 Simple reluctance machine **(8)**

**c.** Based on the results obtained from **4.a** and **4.b**, suggest possible ways to increase the winding inductance. **(4)**

**GJL/KA**