# UNIVERSITY OF SWAZILAND

## FACULTY OF SCIENCE

**Department of Electrical and Electronic Engineering**

## MAIN EXAMINATION 2016

Title of the Paper:

**Electric Machines**

Course Number: EE451
Time Allowed: Three Hours.

Instructions:
1. The answer has to be written in the space provided in the question book. Use the answer book as a scratch pad. Mark the ID on and hand-in both books
2. Answer all questions, no optional
3. This paper has 9 pages, including this page.

DO NOT OPEN THE PAPER UNTIL
PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

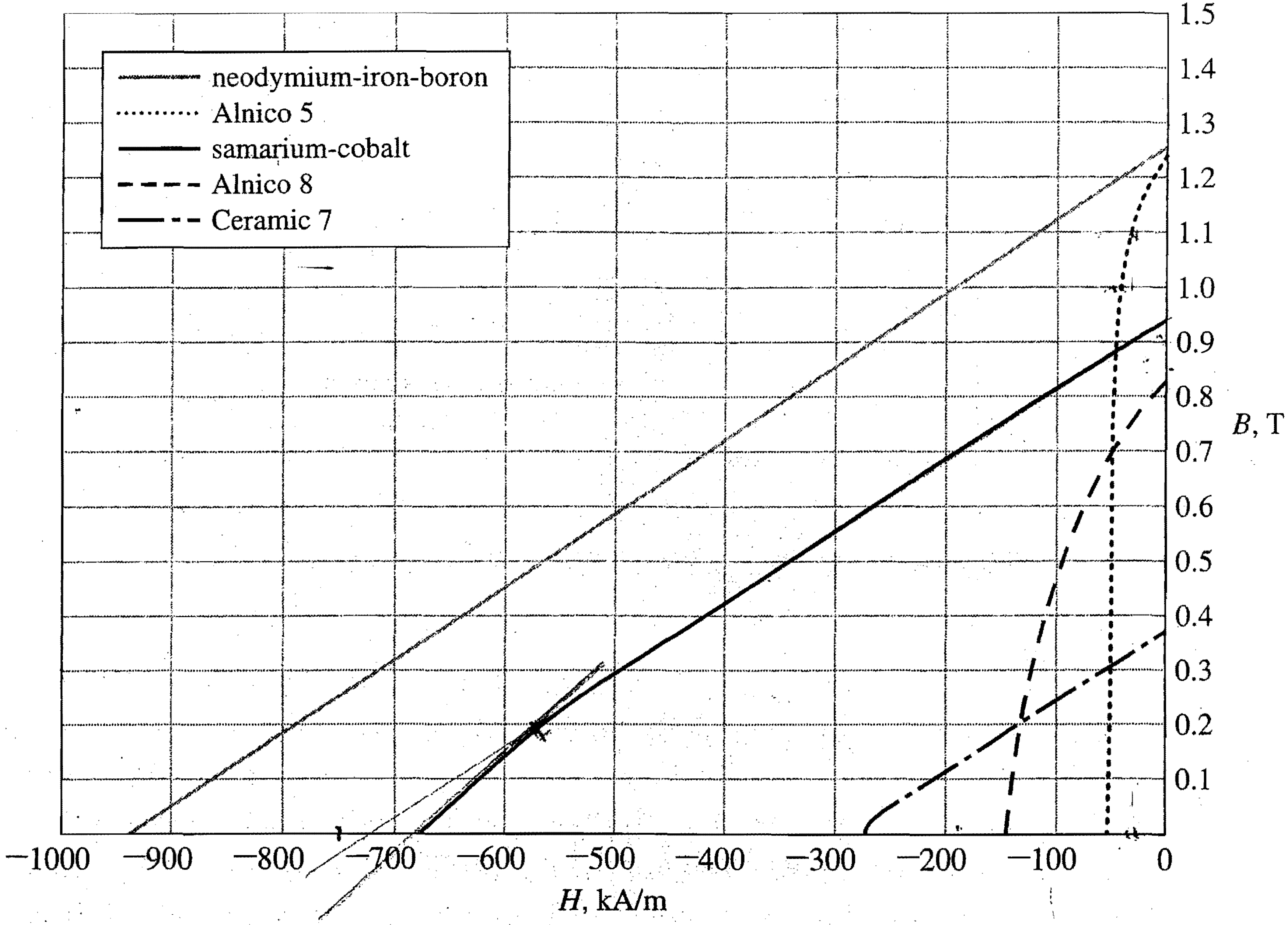


**Figure 1.19** Magnetization curves for common permanent-magnet materials.

**Q1, 20 pts:** It is desired to achieve a time-varying magnetic flux density in the air gap of the magnetic circuit of Fig. Q1-1 of the form:

$$B_g = B_0 + B_1 \cdot \sin(\omega t)$$

where $B_0 = 0.5T$ and $B_1 = 0.25T$. The DC field $B_0$ is to be created by a neodymium-iron-boron magnet, whereas the time-varying field is to be created by a time-varying current, $i(t) = I_1 \cdot \cos(\omega t)$.

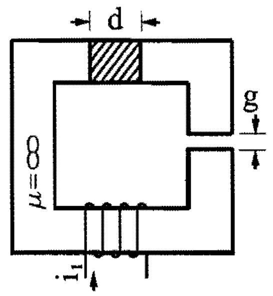

Fig. Q1-1

For $A_g = 6\ cM^2$, $g = 0.4\ cM$, and N= 200 turns, find:

(i). the magnet length d and the magnet area $A_m$ that will achieve the desired dc air-gap flux density and minimize the magnet volume.

(ii). the peak value of the time-varying current, $I_1$, required to achieve the desired time-varying air-gap flux density.

(iii). If replace the magnet with a dc current, $I_0$, in the coil, find $I_0$.

**Q2, 10 pts:** There are 3 coils in a magnetic circuit, $N_1$, $N_2$, and $N_3$ carrying respectively a current $I_1$, $I_2$, and $I_3$. The polarities among the coils are shown in Fig. Q2-1 by the reference of the core and winding direction. Find:

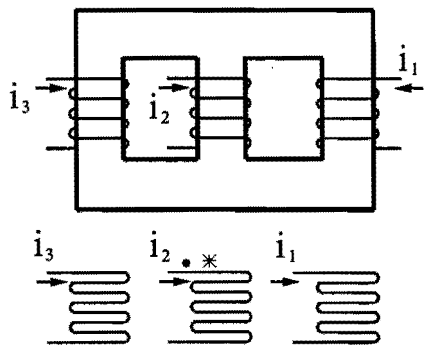


Fig. Q2-1

(i). At the bottom of Fig. Q2-1, there is no reference of winding direction and hence a "dot" convention is adopted to show coupling direction. On Fig. Q2-1, mark the proper terminals of coil 2 and 1 with a 'dot'; of coil 2 and 3 with a 'star' to carry the direction information from the top to the bottom figure.

(ii). The flux $\Phi_2$ and $\Phi_{2t}$

(iii). $L_2$, $L_{23}$, and $L_{21}$

(iv). Give the coils terminal voltages, $V_1$, $V_2$, and $V_3$, relation to the currents in matrix form.

**Q3, (20pts):** A 75-KVA 24000:400-V 3-φ transformer, Δ-Y connected is under a performance test. A short-circuit test gives the instrument readings: 480V, 1.804A, and 620W. An open-circuit test gives instrument readings: 400V, 5.4A, and 580W. Find:

(i). the copper loss and the iron loss.

(ii). the series parameters of the transformer

(iii). the parallel parameters of the transformer

(iv). Are you able to divide the primary and the secondary series components values under reasonable tolerance. Draw the equivalent circuit of the transformer.

**Q4, (20 pts):** Given a 3-φ, Y connected induction motor is rated at 380 V, 15 KW, 50Hz, and 4-pole. The friction windage and core loss is assumed to be a constant independent of load at 400 W. The motor is operated under rated terminal voltage and frequency. The motor constants are:

$R_1=0.6$, $R_2=0.3$, $X_1=2.7$, $X_2=0.5$, and $X_M=27\ \Omega$

Evaluate the performance at a rated slip of 5% (Equivalent ckt is essential and helpful):

(i). motor speed,

(ii). stator current,

(iii). out put shaft torque and power,

(iv). motor power factor and efficiency.

**Q5, 10 pts:** Fig. Q5-1 shows a cross-sectional sketch of a machine having a rotor winding f and two identical stator windings "a" and "b" with turns N whose axes are in quadrature. The uniform air gap between rotor and stator is "g", its equivalent cross-sectional area "Ag", and the material of the core $\mu \to \infty$. The stator windings are energized by a balanced two-phase currents:

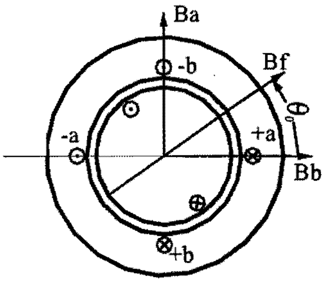

Fig. Q5-1

$i_a = I_a \cdot \sin\omega t \qquad i_b = I_b \cdot \cos\omega t$

(i). Derive the resultant flux density in the air gap $B_g$

(ii). Explain any specialty of the field.

**Q6, 10 pts:** A system shown in Fig. Q6-1 is energized under the 50 Hz power source. The synchronous motor has 4 poles and drives the interconnected shaft in the clockwise direction. The induction machine has 6 poles and its stator windings are connected to the source such that as to produce a counter-clockwise rotating field (in opposite to the rotation of the synchronous motor). The machine has a wound rotor whose terminals are brought out through slip rings.

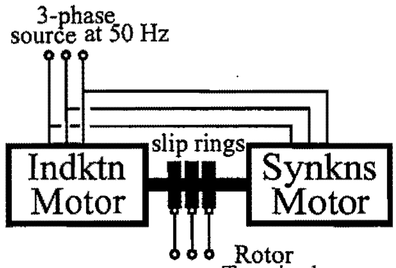

Fig. Q6-1

(i). At what speed does the motor run?

(ii). What is the frequency of the voltage produced at the slip rings of the induction motor? What is "s" now and in what operating mode if rotor is shorted properly?

(iii). What will be the frequency of the voltages produced at the slip rings of the induction motor if two leads of the induction motor stator are interchanged, reversing the direction of rotation of the resultant rotating field? Again what is "s" now and in what operating mode if rotor is shorted properly?

**Q7, 10 pts:** The torque of a 2-phase permanent-magnet stepping motor of the form in Fig. Q7-1 can be expressed as:

$$T_{mch} = T_0(i_1 \cdot \cos\theta_m + i_2 \cdot \sin\theta_m)$$

where $T_0$ is a positive constant that depends upon the motor geometry and properties of the permanent magnet.

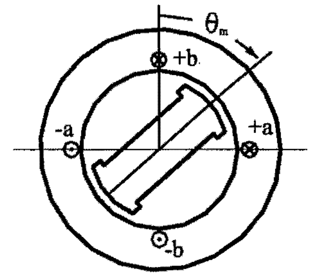

Fig. Q7-1

Calculate the rest (zero torque) positions which will result if the motor is driven by a DC current such that each phase current can be set equal to three values $-I_0$, $0$, and $+I_0$. Using such a drive what is the motor step size?