# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER I
## SESSION 2009/2010

| | | |
|---|---|---|
| SUBJECT NAME | : | ELECTRICAL MACHINE AND DRIVE |
| SUBJECT CODE | : | BEE 4123 |
| COURSE | : | 4 BEE |
| EXAMINATION DATE | : | NOVEMBER 2009 |
| DURATION | : | 2 ½ HOURS |
| INSTRUCTION | : | ANSWER ANY FOUR (4) QUESTIONS ONLY |

THIS PAPER CONTAINS OF 7 PAGES

**Q1** (a) Correlate the effect that occurs when current carrying conductor present in a uniform magnetic field with electric motor operation.

(4 marks)

(b) A core with three legs is shown in Figure Q1 (b). The core is used as a device to unlock safety box when it is energized. Its depth is 4 cm and there are 1000 turns on the center leg. The remaining dimensions are as shown in the figure. The air gap at the right side of the core is 0.05 cm and the air gap flux is given by 0.00025 Wb. The core is composed of steel having magnetization relationship given as equation below where H is the magnetic intensity in A turns/m while B is the flux density in Tesla.

$$H = 86.76\, e^{(1.882\, B)}$$

(i) Illustrate the equivalent magnetic circuit for the core. Label the circuit accordingly.
(ii) Assuming no fringing effects, calculate the magnetic field intensity for the air gap.
(iii) Propose the amount of current that should be applied to the coil at the center leg.
(iv) Calculate the reluctance of each legs and the reluctance of the air gap.

(21 marks)

**Q2** (a) (i) List and define the types of losses that occur in a transformer.
(ii) Write down the importance of open-circuit test and short-circuit test of a transformer. Also, with the aid of an appropriate diagram, explain briefly on open-circuit test and short-circuit test of a transformer.

(5 marks)

(b) A 1000 VA 230/115 V transformer has been tested to determine its equivalent circuit. The results of the tests are shown in Table Q2 (b). All data given were taken from the primary side of the transformer.

(i) Develop the equivalent circuit of this transformer referred to the low-voltage side of the transformer.
(ii) Find the transformers voltage regulation and efficiency at rated conditions with 0.8 lagging power factor.
(iii) Compare the voltage regulation and efficiency of a transformer that operates at rated conditions with 0.8 leading power factor to the transformer in Q2 (b) (ii).

(20 marks)

**Q3** (a) Explain the three (3) reasons of the impossibility of the induction motor to operate at synchronous speed.

(6 marks)

(b) A three-phase, 25 hp, 415 V, 50 Hz, 1200 rpm, wound-rotor induction motor is connected to a three-phase, 415 V, 50 Hz supply has the following equivalent circuit parameters:

$R_1 = 0.25\ \Omega$ $X_1 = 1.2\ \Omega$
$R_2 = 0.2\ \Omega$ $X_2 = 1.1\ \Omega$
$X_M = 35.0\ \Omega$

(i) Draw and label the per-phase equivalent circuit of the induction motor.
(ii) Determine the number of poles of the machine.
(iii) Calculate the Thevenin Voltage, $V_{TH}$ and Thevenin Impedance, $Z_{TH}$ of the induction motor. Then, sketch the Thevenin equivalent circuit of the induction motor.
(iv) Determine the starting torque of the machine.
(v) Determine the value of the external resistance required in each phase of the rotor circuit such that the maximum torque occurs during starting.

(19 marks)

**Q4** (a) Explain briefly how to determine the synchronous reactance of a three-phase synchronous generator.

(6 marks)

(b) A 480 V, 200 kVA, 0.8 power factor lagging, 50 Hz, two-pole, Y-connected synchronous generator has a synchronous reactance of 0.25 Ω and an armature resistance of 0.03 Ω. Its friction and windage losses are 6 kW, and its core losses are 4 kW. The field circuit has a dc voltage of 200 V, and the maximum field current, $I_F$ is 10 A. The resistance of the field circuit is adjustable over the range from 20 Ω to 200 Ω. The open circuit characteristic of this generator is shown in Figure Q4 (b). Calculate:

(i) the field current when the generator is running at no load condition
(ii) the internal induced voltage at full load condition
(iii) the field current when the generator is running at full load condition
(iv) the input power of the generator
(v) the speed in rpm
(vi) the torque applied to the generator
(vii) the efficiency of the generator

(19 marks)

**Q5** (a) A DC motor has a no-load speed of 1800 rpm and full-load speed of 1500 rpm. Find the percentage speed regulation of the motor.

(2 marks)

(b) Explain why a DC motor should not be started by applying directly its rated voltage across the armature terminals.

(5 marks)

(c) A 240 V, 1500 rpm DC shunt motor draws a current of 65 A during half-load operation. The rotational losses are 1500 W at rated power output. The armature circuit resistance and the field circuit resistance are given as 0.05 Ω and 120 Ω, respectively.

(i) Find the efficiency and torque of the motor under rated condition
(ii) Calculate the speed of the motor if the load is reduced so that the motor draws 75 A while the motor flux remains unchanged
(iii) Repeat Q5(c)(ii) with the same condition except that the flux is decreased by 10% instead of remaining constant

(18 marks)

**Q6** (a) One of the criteria in the induction motor drive selection is the estimation of motor torque. Sketch a speed-torque a characteristic curve for NEMA class 'B' induction motor and indicates the starting torque, pull-up torque, pull-out torque and the full-load torque.

(4 marks)

(b) An electric drive is often designed for bi-directional operation, clockwise and counter-clockwise and it can be represented by a speed versus torque graph consisting of four quadrants. Sketch the four-quadrant graph and explain the operation of each quadrant in terms of motor speed, motor torque, and load torque.

(10 marks)

(c) A drive has following parameters: $J = 10$ kgm$^2$, $T_m = (15 + 0.05N)$ Nm and $T_L = (5 + 0.06N)$ Nm, where N is the speed in rpm. Initially, the drive is working in steady-state. The drive is then braked by electrical braking. Torque of the motor during braking is given by $T_L = (-10 - 0.04N)$ Nm. Calculate the time taken by the drive to stop.

(11 marks)

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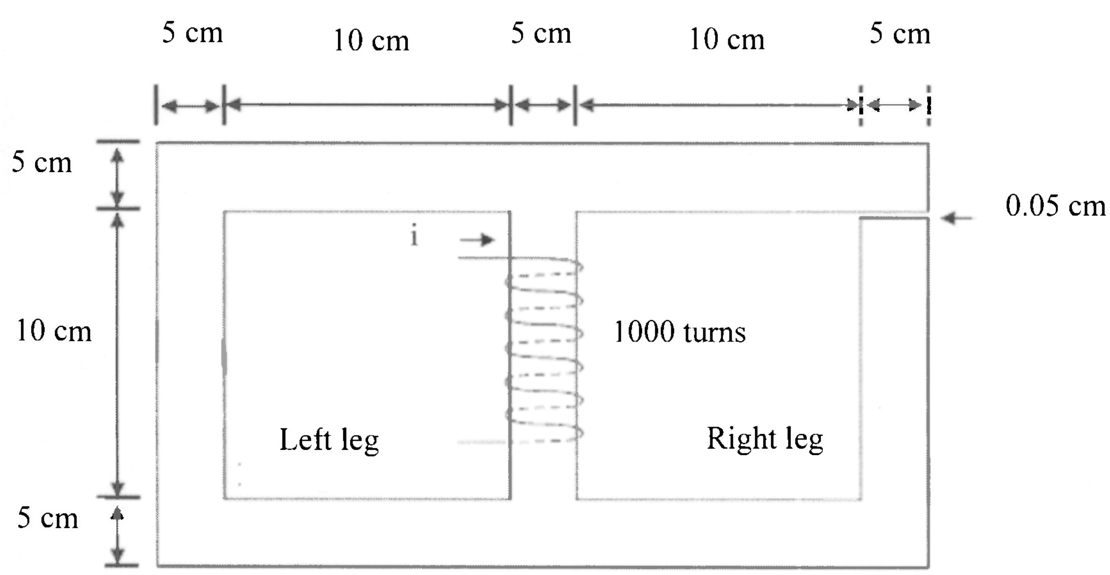


**Figure Q1 (b)**

**Table Q2 (b)**

| Open- circuit test | Short-circuit test |
|---|---|
| $V_{OC} = 230$ V | $V_{SC} = 20$ V |
| $I_{OC} = 0.45$ A | $I_{SC} = 8.5$ A |
| $P_{OC} = 30$ W | $P_{SC} = 45$ W |

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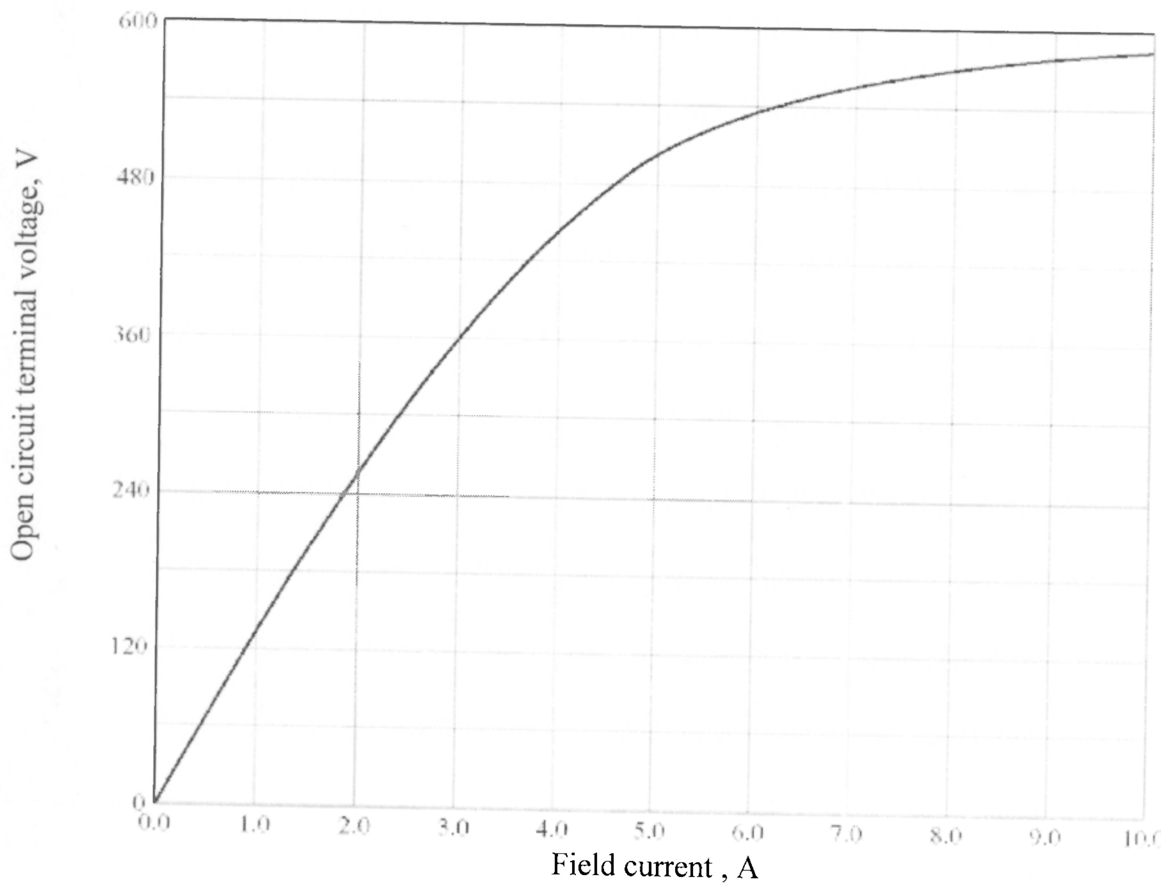


**Figure Q4 (b)**

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**Formulae**

***Magnet:***

$\mu_0 = 4\pi \times 10^{-7}\ H/m$

***Synchronous machine:***

$P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$

$P = \dfrac{3V_\phi E_A \sin\delta}{X_S}$ $\qquad \tau_{ind} = \dfrac{3V_\phi E_A \sin\delta}{\omega_m X_S}$

***Induction motor:***

$P_{conv} = 3I_2^2 R_2\left(\dfrac{1-s}{s}\right)$ $\qquad P_{AG} = 3I_2^2 \dfrac{R_2}{s}$

$\tau_{ind} = \dfrac{P_{AG}}{\omega_{sync}}$ $\qquad \tau_{load} = \dfrac{P_{OUT}}{\omega_m}$

$$\tau_{ind} = \frac{3V_{TH}^2\, {R_2}/{s}}{\omega_{sync}\left[\left(R_{TH} + {R_2}/{s}\right)^2 + \left(X_{TH} + X_2\right)^2\right]}$$

$$s_{max} = \frac{R_2}{\sqrt{R_{TH}^2 + \left(X_{TH} + X_2\right)^2}}$$

***DC motor:***

$E_A = K\phi\omega$ $\qquad \tau_{ind} = K\phi I_A$

$P_{conv} = E_A I_A = \tau_{ind}\omega_m$ $\qquad I_F^{*} = I_F + \dfrac{N_{SE}}{N_F} I_A - \dfrac{\Im_{AR}}{N_F}$

$\omega = \dfrac{V_T}{K\phi} - \dfrac{R_A}{(K\phi)^2}\tau_{ind}$