UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION May 2013

TITLE OF PAPER: **Fundamentals of Power Engineering**

COURSE CODE: **EE 351**

TIME ALLOWED: **THREE** HOURS

Student Name:	
Student Number:	

INSTRUCTIONS:

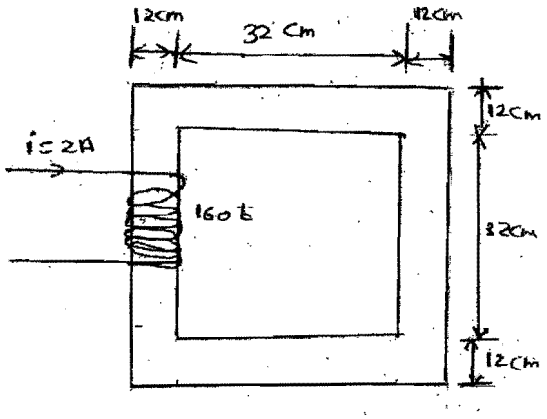
1. Answer all questions.
2. Give your answers on the question paper, and if more space is required, complete your answer on the back of the paper or in your answer book and mention about the place of your answer completion.
3. Put the question sheet inside the answer book upon submission of your exam paper.
   (DON'T FORGET TO SUBMIT BOTH OF THE ANSWER BOOK AND QUESTION PAPER)
4. Marks for different questions are indicated on the beginning of the question.
5. Rough work maybe done in the examination answer book and crossed through.

DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

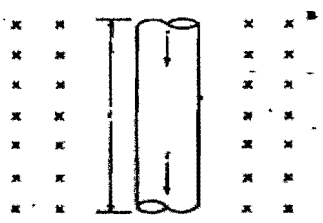
This paper starts at page 1 and ends at page 16.

Question 1: Solve the following questions (26 marks)

a) **A ferromagnetic core is shown in the following figure. Four sides of this core are with uniform width. The depth of the core (into the page) is 14 cm, and the other dimensions are shown in the figure. There is 160 turns coil wrapped around the left side of the core. Assume the relative permeability $\mu_r = 2000$, calculate the magnetic flux produced by 2 A input current, the magnetic field density B and the magnetic field intensity in the core H.**
(Calculate: φ, B, H)

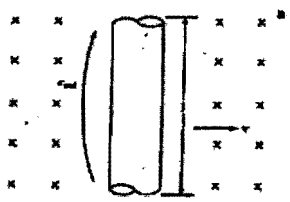


b) **What is the magnitude and direction of induced force on a conductor of a length l= 2 m, carrying a current i=1.5 A from up to down and present in uniform magnetic field density B=0.6 T point to page?**
$F =$
Direction of F:



c) **What is the magnitude of induced voltage on a conductor moving with a velocity v=10 m/sec in uniform magnetic field density B=0.5T point to page, the wire length l=1.8 m?**

$E_{ind} =$



d) **In c before, mention the direction of the induced voltage, magnetic field density and velocity according to the fingers of the right hand.**

Middle point to:

Thump point to:

Index point to:

e) **In three phase connected transformer, each of the three transformers has number of turns in primary $N_p = 180$ turns and number of turns in secondary $N_s = 720$ turns, what will be the ratio between the line to line voltage at the primary to the line to line voltage at the secondary in case of**

- **$\Delta - \Delta$ Connected transformer.**

$$\frac{V_{Lp}}{V_{LS}} =$$

- **$\Delta - Y$ Connected transformer.**

$$\frac{V_{Lp}}{V_{LS}} =$$

- **$Y - \Delta$ Connected transformer.**

$$\frac{V_{Lp}}{V_{LS}} =$$

f) **Three phase $Y - \Delta$ connected transformer bank steps up the generator voltage from 33 KV (line to line) to 220 KV (line to line). Calculate the primary phase voltage, the secondary phase voltage and the transformer turns ratio. (Calculate: V_P, V_S, a)**

g) In the following Δ-Δ connection between sources and loads, if

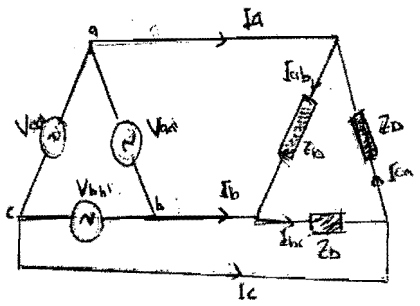
$V_{aa'} = 230\angle 0^\circ \quad V$

$V_{bb'} = 230\angle -120^\circ \quad V$

$V_{cc'} = 230\angle 120^\circ \quad V$

$Z_\Delta = 50 + j100 \quad \Omega$

Calculate the line current in line b I_b and the total three phase complex, active and reactive power supplied to load $S_{3\varphi}, P_{3\phi}, Q_{3\varphi}$.

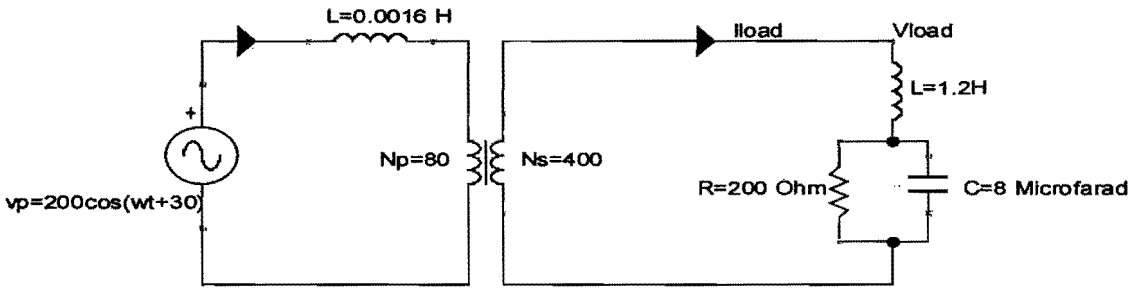


h) **List three methods that can be used to increase the voltage level in power systems when an under voltage is detected in the system.**

i) **Draw a typical configuration for distribution system.**

Question 2: Solve the following questions (21 marks)

A 50 Hz single phase transformer, has the number of turns in primary N_p=80 turns, number of turns in secondary N_s=400 turns, the primary source voltage $v_p = 300\cos(314.16t + 30^\circ)$. A load connected to the secondary is RLC circuit given in the following figure. The resistance of the load is R=200 Ω, the inductance of the load is L=1.2 H and the capacitance of the load is C=8 μF. The source has negligible resistance and an inductance L=0.0016 H. Calculate:



a) **The primary voltage V_p in phasor form.**

b) **The source impedance in the primary Z_g.**

c) **Total load impedance in the secondary Z_{load}.**

d) **The primary current I_p.**

e) **The load current I_{load}.**

f) **The load voltage in phasor form and instantaneous form.**

g) **The active and reactive power drawn at the load.**

h) **The active and reactive power absorbed/supplied in the inductor. (Calculate: P_L, Q_L)**

i) The active and reactive power absorbed in the resistor.
(Calculate: P_R, Q_R)

j) The active and reactive power absorbed/supplied in the capacitor.
(Calculate: P_C, Q_C)

Question 3: Solve the following questions (17 marks)

a) Explain briefly the principle of operation of three-phase induction motor.

b) What is the effect of increasing mechanical load torque on the induction motor?

c) **Explain how you can control the induction motor speed.**
Note: You need to draw torque speed characteristic for each method.

Question 4: Solve the following questions (36 marks)

A 400V (line to line voltage), 25 hp, 60 Hz, two poles, Y connected induction motor, has the following impedances in ohms per phase referred to stator circuit.

$R_1 = 0.6\Omega$

$R_2 = 0.4\Omega$

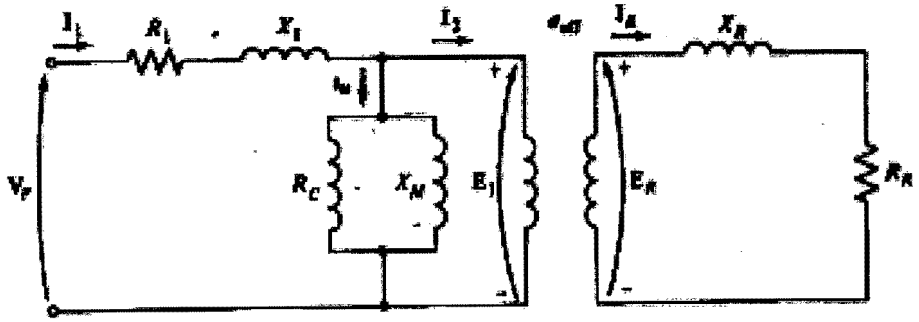
$X_1 = 1.2\Omega$

$X_2 = 0.7\Omega$

$X_M = 50\Omega$

$s = 0.025$

The total rotational losses are 800W. The motor slip is 0.025 at rated voltage and rated frequency.



a) Calculate the synchronous speed in rpm (n_{sync}) and rad per sec (ω_{sync}).

b) Calculate the motor speed in rpm (n_m) and rad/sec (ω_m).

c) Calculate the rotor current frequency f_r.

d) Calculate the total impedance of the circuit Z_{tot}.

e) Calculate the stator phase voltage and current.

$V_\varphi =$

$I_1 =$

f) Calculate the motor power factor P_f.

g) Calculate the motor input power P_{in}.

h) Calculate the motor stator copper losses P_{scl}.

i) Calculate the air gap power P_{ag}.

j) Calculate the rotor copper losses P_{rcl}.

k) Calculate the power converted from electrical to mechanical P_{conv}.

l) Calculate the motor output power P_{out}.

m) Calculate the induced torque T_{ind}.

n) Calculate the load torque T_{load}.

o) Calculate the motor efficiency ς.

p) Calculate the equivalent thevenin voltage V_{th} as seen from two points where the rotor circuit connects.

q) Calculate the equivalent thevenin resistance and thevenin reactance as seen from two points where the rotor circuit connects.
(Calculate: R_{th}, X_{th})

r) Calculate the rotor current referred to stator I_2.

s) Calculate the slip at which the maximum torque occurs and the corresponding speed in rpm.
(Calculate: s_{max}, n_{max})

t) Given the main equation for T_{max}, calculate the maximum induced torque.

$$T_{max} = \frac{3V_{th}^{\ 2}}{2\omega_{syn}\left[R_{th} + \sqrt{R_{th}^{\ 2} + (X_{th} + X_2)^2}\right]}$$

u) Given the main equation for T_{start}, calculate the starting induced torque.

$$T_{start} = \frac{3V_{th}^{\ 2} R_2}{\omega_{syn}\left[(R_{th} + R_2)^2 + (X_{th} + X_2)^2\right]}$$

v) Draw the torque speed characteristic of induction motor indicating:

- **The starting torque.**
- **The maximum torque and the speed at which maximum torque occurs.**
- **The induced torque and the corresponding motor speed.**
- **The synchronous speed of motor.**