UNIVERSITY OF SWAZILAND

# FACULTY OF SCIENCE
# DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

## SUPPLEMENTARY EXAMINATION JULY 2014

TITLE OF PAPER: **Electrical Machines**

COURSE CODE: **EE 451**

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 14

## Question 1: Solve the following questions (23 marks)

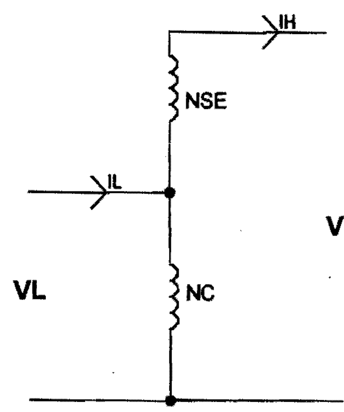
a) The equivalent circuit impedances of a 20 kVA, 2200 V / 220 V, 50 Hz transformer to be determined. The open circuit test and short circuit test were performed and the following data were found. Calculate the impedances of approximate equivalent circuit referred to primary.
(Calculate $R_C, X_M, R_{eqp}, X_{eqp}$)

| Open circuit results | Short circuit results |
|---|---|
| $V_{oc} = 2200V$ | $V_{sc} = 50V$ |
| $I_{oc} = 0.2A$ | $I_{sc} = 8A$ |
| $P_{oc} = 40W$ | $P_{sc} = 170W$ |

**b) 60 KVA, 13800 V / 478 V (line to line) $\Delta - Y$ distribution transformers has equivalent impedance referred to the primary side $Z_{eqp} = 100 + j600\ \Omega$. Find the primary phase voltage at the source $V_{\varphi p}$ and voltage regulation $V_R$ assuming the transformer supplies rated load at 0.8 pf lagging.**

c) 300 VA, 200 V / 20 V transformer to be connected to form a step up autotransformer. Calculate the voltage at the high voltage side of the transformer $V_H$, maximum current at the high voltage side $I_H$, the current in low voltage side $I_L$ and the output volt-ampere $S_{out}$.

(Calculate $V_H, I_H, I_L, S_{out}$)



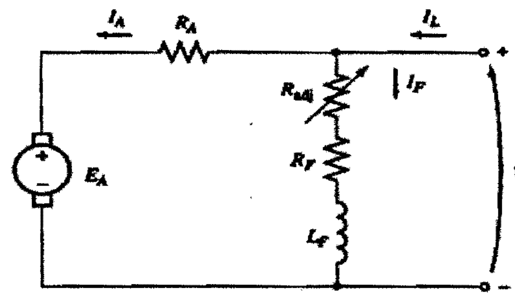
## Question 2: Solve the following questions (27 marks)

**a) A 460 V (line to line) 50 Hz Y connected two pole synchronous generator. The generator has a synchronous reactance of 0.15 Ω and armature resistance of 0.02 Ω. At full load the machine supplies 800 A at pf=0.85 lagging. Calculate the internal voltage $E_A$, the power converted from mechanical to electrical $P_{conv}$, the output power from generator $P_{out}$ and sketch the phasor diagram.**

**b) A 400 V 50 KVA 0.8 pf Δ connected 60 Hz synchronous motor has synchronous reactance 3 Ω and negligible armature resistance. The friction and windage losses are 1.5 KW and core losses= 2 KW. Initially the shaft supplies 20 hp and pf of the machine is 0.8 leading. Calculate the armature current $I_A$, induced voltage $E_A$ and sketch the phasor diagram. (Calculate $I_A$, $E_A$)**

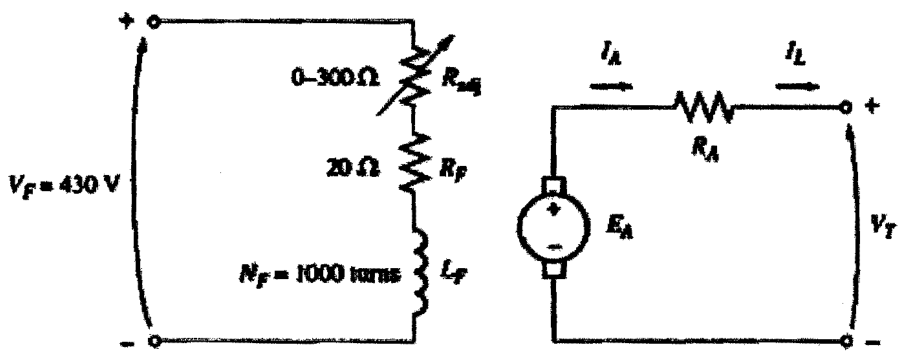
c) **A 40 hp, 200V, 1000 rev/min DC shunt motor has armature resistance $R_A = 0.3\ \Omega$. The field winding has a total resistance $R_F + R_{adj}$ of 50 Ω which produces no load speed at 1000 rev/min. Calculate the speed of the motor expressed in rev/min $n_m$, the motor input power $P_{in}$ and the motor induced torque $T_{ind}$ when the input current $I_L$ is 100 A.**

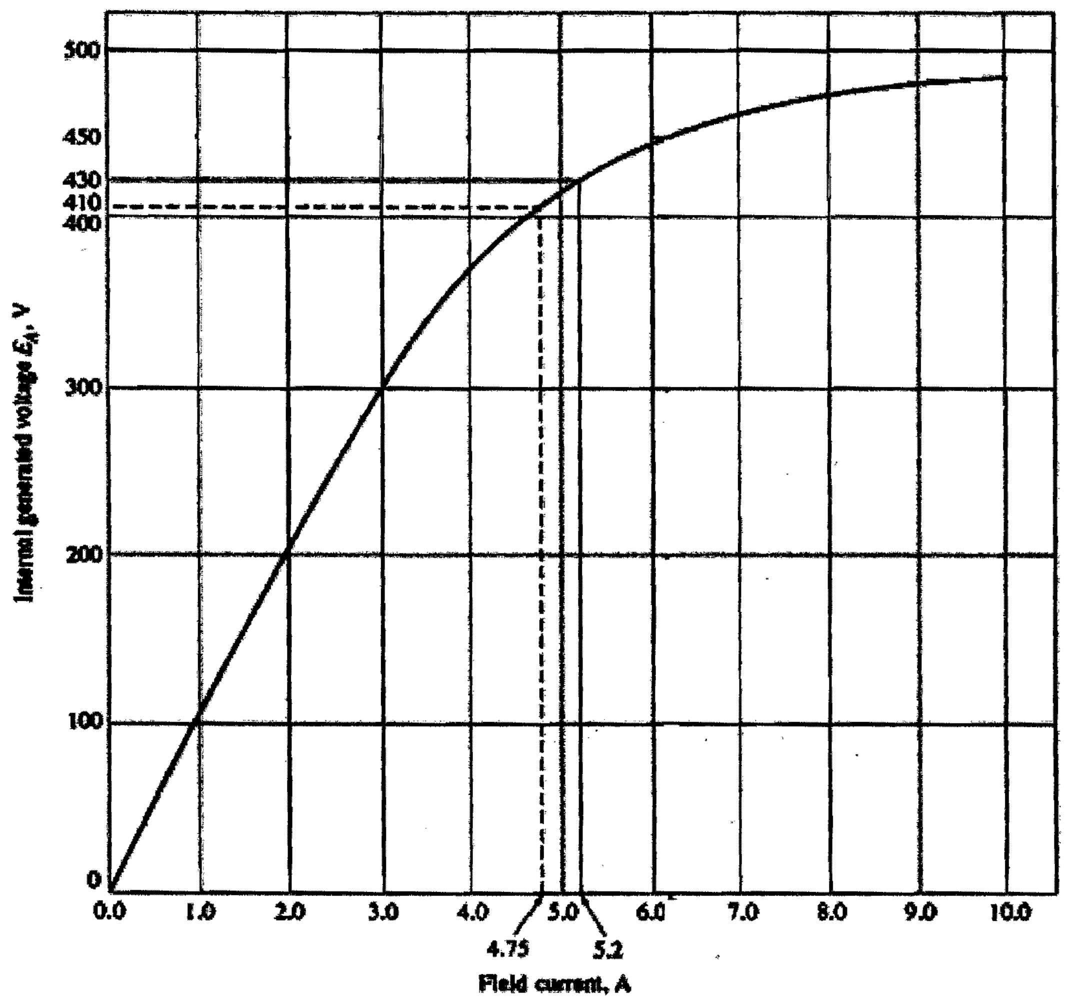
**(Calculate: $n_m$, $P_{in}$, $T_{ind}$ )**



## Question 3: Solve the following questions (14 marks)

**A separately excited dc generator, 172 KW, 430V, 400 A and 1800 rpm. The DC generator equivalent circuit and its magnetization curve are shown in the following figures. The machine has the following characteristics:**
$R_A = 0.1\ \Omega$, $V_F = 430\,\text{V}$, $R_F = 20\ \Omega$, $R_{adj}$=0 to 300 Ω.



**If $R_{adj} = 63\ \Omega$ and the prime mover speed=1200 rev/min,**

**a) Calculate the no load generator voltage.**

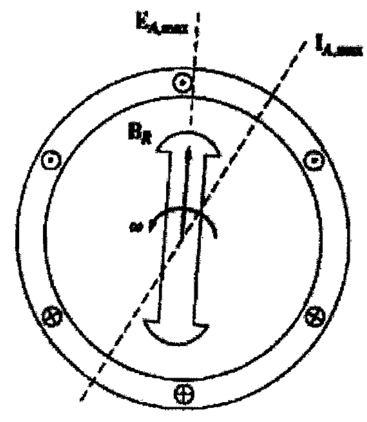
**b) What is the terminal voltage $V_T$ when 2 Ω load connected? (Calculate $V_T$ )**

**c) Calculate the induced voltage $E_A$ to restore $V_T$ at no load value. (Calculate $E_A'$)**

**d) How much the field current and the field adjustable resistance needed to restore $V_T$ at no load value? .**
**(Calculate $I_F$, $R_F$)**

**Question 4: Solve the following questions (14 marks)**

a) **Explain briefly the principle of operation of the synchronous generator.**

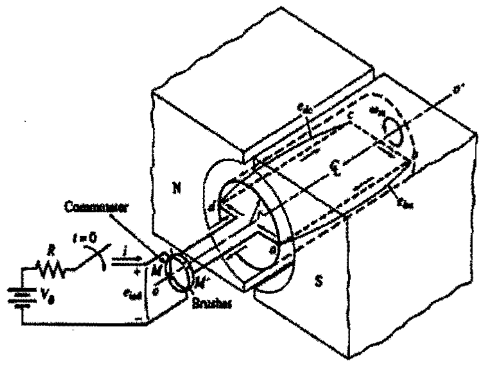


**b) Indicate, for a given phase voltage and load current, will a more internal voltage $E_A$ is needed for leading power factor load or lagging power factor load?**

**c) What is the effect of increasing mechanical load torque on the synchronous motor?**

## Question 5: Answer the following questions (22 marks)

**a) Explain briefly the principle of operation of the DC motor.**



**b) How is possible to control the DC motor speed? Mention about two methods used. Indicate which method is used to control DC motor speed above base speed and which method used to control DC motor speed below base speed.**

**c) Draw the equivalent circuit of the cumulatively compounded motor. Mention the main advantages of the cumulatively compounded motor and the main disadvantage of the differentially compounded DC motor.**

**d) What is the effect of increasing the electrical load on the DC generator terminal voltage?**

**e) How it is possible to increase the DC generator terminal voltage?**

**f) How the terminal voltage in shunt DC generator will build up:**

a) By the voltage source connected to the field winding
b) By the residual flux in the generator

**g) When the number of series winding turns $N_{SE}$ of the cumulatively compounded DC generator is very large, the DC generator is**

a) Flat compounded.
b) Under compounded.
c) Over compounded.

**h) The under compounded DC generator will have**

a) No load voltage > full load voltage.
b) No load voltage < full load voltage.
c) No load voltage = full load voltage.

**i) The differentially compounded DC generator will have**

a) Small drop in terminal voltage as load increased on the generator.
b) Large drop in terminal voltage as load increased on the generator.
c) No change in terminal voltage as load increased on the generator