MACHAKOS UNIVERSITY COLLEGE

SECOND SEMESTER EXAMINATION 2018/2019

SECOND YEAR SUPPLEMENTARY EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING

EEE 206 ELECTRICAL MACHINES I

DATE: 21ST AUGUST, 2019 **TIME: 8.00 A.M - 10.00 P.M**

INSTRUCTIONS

This paper consists of **FIVE** questions.

Answer **QUESTION 1** and ANY **OTHER TWO** questions.

Question 1 carries 30 marks and is COMPULSORY.

1. (a) A ferromagnetic core with a relative permeability of 1,500 is shown in Figure Question 1(a). The dimensions are as shown in the diagram, and the depth of the core is 5cm. The air gaps on the left and right sides of the core are 0.05 and 0.07cm, respectively. Because of fringing effects, the effective area of the air gaps is 5% larger than their physical size. There are 300 turns in the coil wrapped around the center leg of the core and the current in the core is 1.0A.

Calculate:

(i) the flux in the left leg of the core
(ii) the flux in the center leg of the core
(iii) the flux in the right leg of the core
(iv) the flux density in each air gap

(10 marks)

(b) The following information is given about the simple rotating loop shown in Figure

Question 1(b)(i) and 1(b)(ii):

$B = 0.4T$	$V_B = 48V$
l = 0.5m	R = 0.4Ω
r = 0.25m	$\omega = 500\ rad/s$

(i) Is this machine operating as a motor or a generator? Explain.
(ii) What is the current i flowing into or out of the machine?
(iii) What is the power flowing into or out of the machine?
(iv) If the speed of the rotor were changed to $550\,rad/s$, what would happen to the current flow into or out of the machine?
(v) If the speed of the rotor were changed to $450\,rad/s$, what would happen to the current flow into or out of the machine?

(10 marks)

(c) A 100 kVA, 8,000/277V distribution transformer has the following resistance and reactances:

$R_P = 5\Omega$	$R_S = 0.005\Omega$
$X_P = 6\Omega$	$X_S = 0.006\Omega$
$R_C = 50k\Omega$	$X_M = 10k\Omega$

The excitation branch impedances are given referred to the high-voltage side of the transformer.

(i) Find the equivalent circuit of this transformer referred to the low-voltage side.
(ii) Find the per-unit equivalent circuit of this transformer.
(iii) Assuming that this transformer is supplying rated load at 277 V and 0.85 p.f, calculate it's input voltage and voltage regulation.
(iv) What are the copper losses and core losses in this transformer under the conditions of part (iii)?
(v) What is the transformer's efficiency under the conditions of part (iii)?

(10 marks)

2. (a) A single-phase power system is shown in Figure Question 2(a). The power source feeds a 100 kVA, 14/2.4 kV transformer through a feeder impedance of $38.2 + j140\Omega$. The transformer's equivalent series impedance referred to its low-voltage side is $0.10 + j0.4\Omega$. The load on the transformer is 90kW at 0.8 p.f lagging and 2,300V.

(i) What is the voltage at the power source of the system?
(ii) What is the voltage regulation of the transformer?
(iii) How efficient is the overall power system?

(10 marks)

(b) Consider a simple power system consisting of an ideal voltage source, an ideal step-up transformer, a transmission line, an ideal step-down transformer, and a load. The voltage of the source is $V_S = 480\angle 0^0 V$. The impedance of the transmission line is $Z_{line} = 3 + j4\Omega$, and the impedance of the load is $Z_{load} = 30 + j40\Omega$.

(i) Assuming that the transformers are not present in the circuit, what is the load voltage and efficiency of the system?
(ii) Assuming that the transformer 1 is a 1:5 step-up transformer, and transformer 2 is a 5:1 step-down transformer, what is the load voltage and efficiency of the system?
(iii) What transformer turns ratio would be required to reduce the transmission line losses to 1% of the total power produced by the generator?

(10 marks)

Questions 3 to 5 refer to the following dc motor:

$\boldsymbol{P_{rated} = 30hp}$ | $\boldsymbol{I_{L,rated} = 110A}$
$\boldsymbol{V_T = 240V}$ | $\boldsymbol{N_F = 2,700}$ **turns per pole**
$\boldsymbol{\eta_{rated} = 1,800r/min}$ | $\boldsymbol{N_{SE} = 14}$ **turns per pole**
$\boldsymbol{R_A = 0.19\Omega}$ | $\boldsymbol{R_F = 75\Omega}$
$\boldsymbol{R_S = 0.02\Omega}$ | $\boldsymbol{R_{adj} = 100\ to\ 400\Omega}$

Rotational losses = $\boldsymbol{3,550\ W}$ **at full load**
Magnetization curve as shown in Figure P3
Equivalent circuit as shown in Figure Q3

3. (a) If the resistor R_{adj} is adjusted to 175Ω, calculate the rotational speed of the motor at no-load conditions.

(10 marks)

(b) Assuming no armature reaction, calculate the:

(i) speed of the motor at full load
(ii) speed regulation of the motor

(10 marks)

4. (a) If the motor is operating at full load and if its variable resistance R_{adj} is increased to 250Ω, calculate the new speed of the motor and compare it to the full-load speed with $R_{adj} = 175\Omega$. Assume no armature reaction.

(10 marks)

(b) Assume that the motor is operating at full load and that the variable resistor R_{adj} is again 175Ω . If the armature reaction is 1000 A. turns at full load, what is the speed of the motor?

(10 marks)

5. (a) If R_{adj} can be adjusted from 100 to 400 Ω , what are the maximum and minimum no-load speeds possible with this motor?

(10 marks)

(b) What is the starting current of this machine if it is started by connecting it directly to the power supply V_T? How does this starting current compare to the full-load current of the motor?

(10 marks)

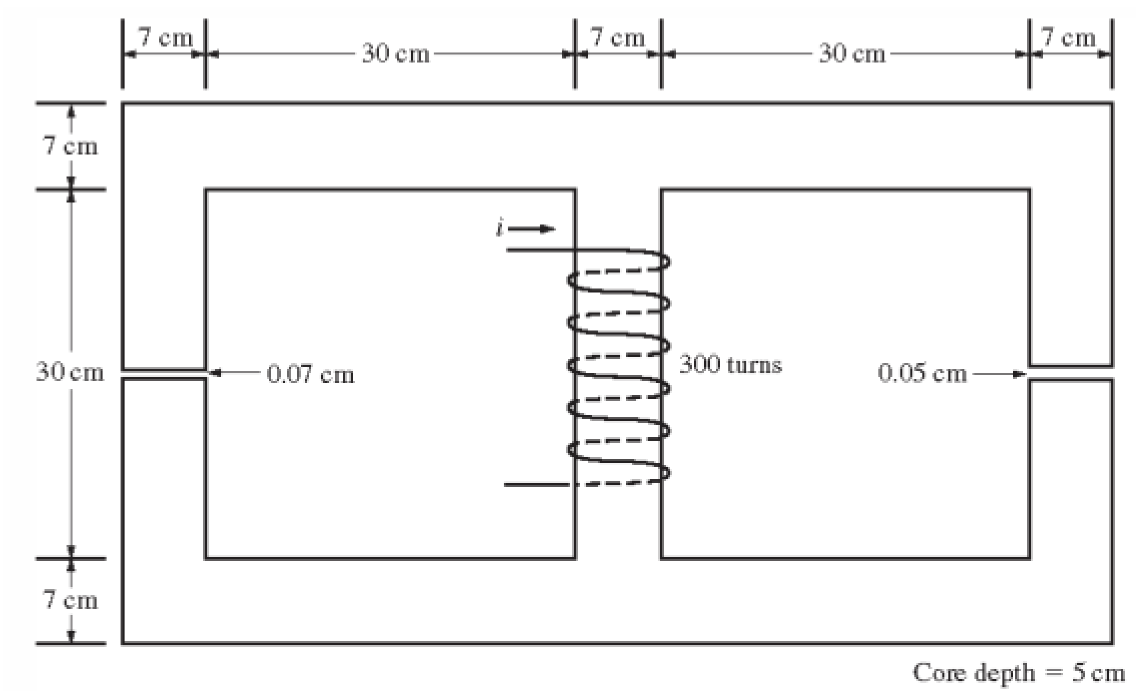

Figure Question 1(a)

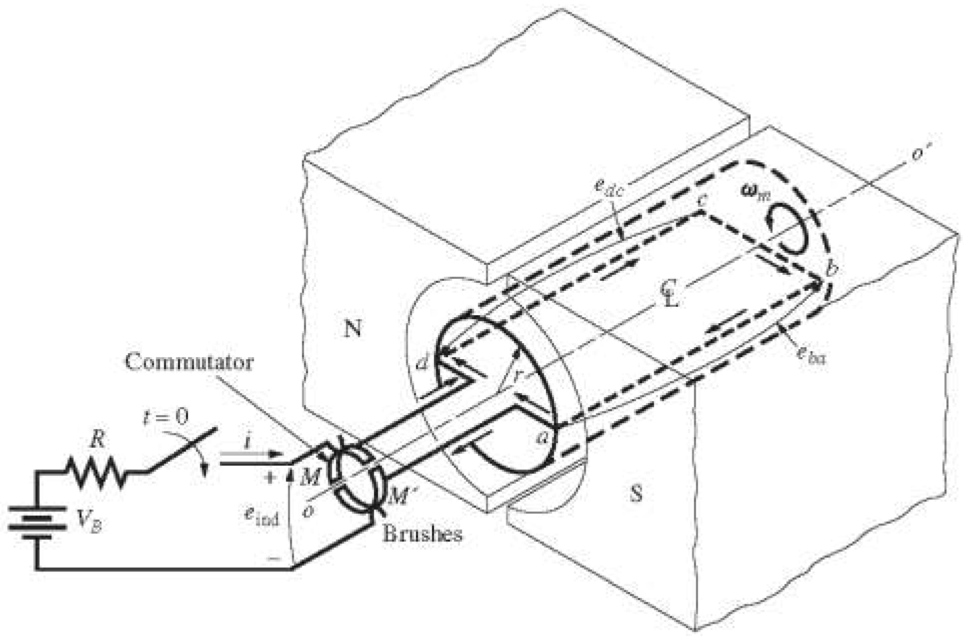

Figure Question 1(b)(i)

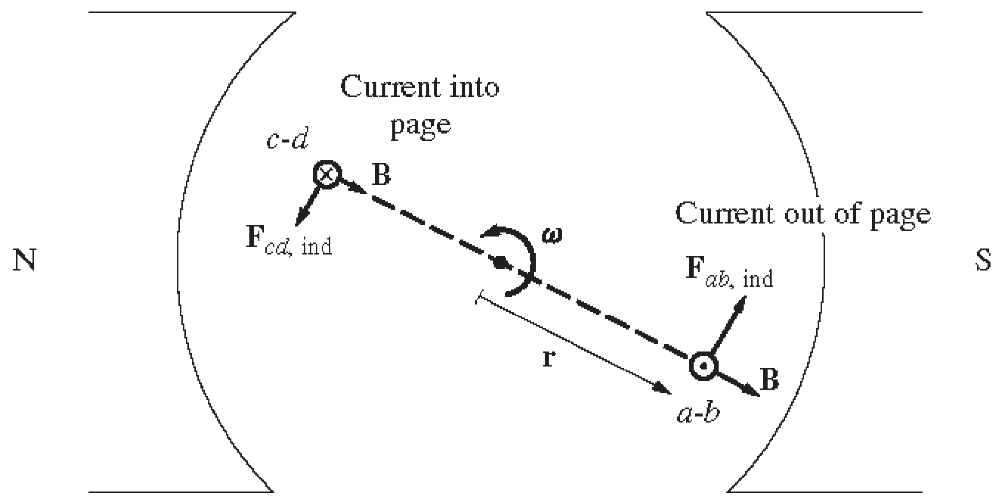

Figure Question 1(b)(ii) [**NB: iron core not shown for clarity**]

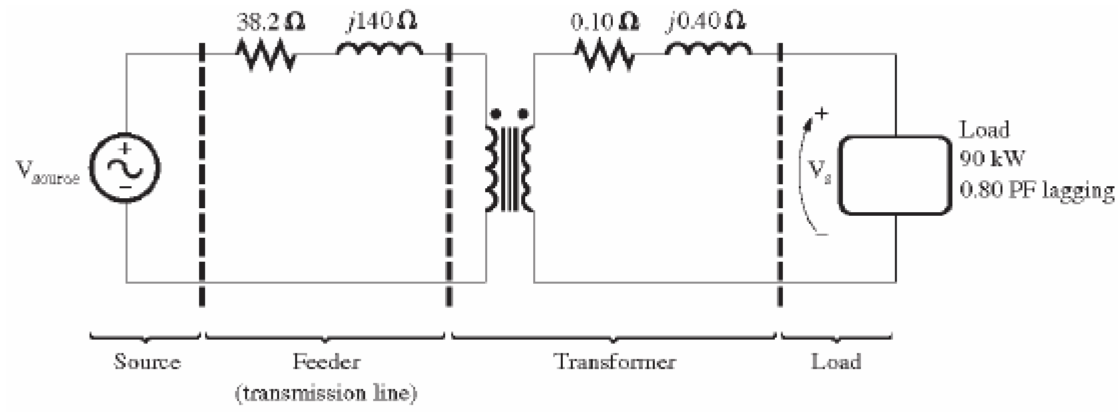

Figure Question 2(a)

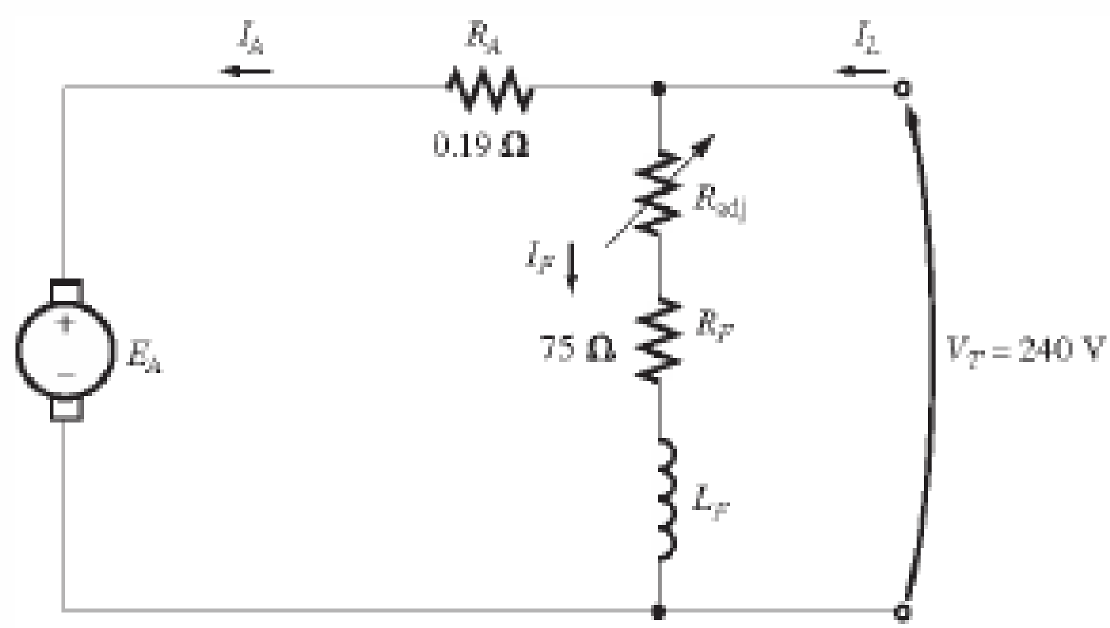

Figure Q3: The Equivalent circuit of the shunt motor in Questions 3 to 5

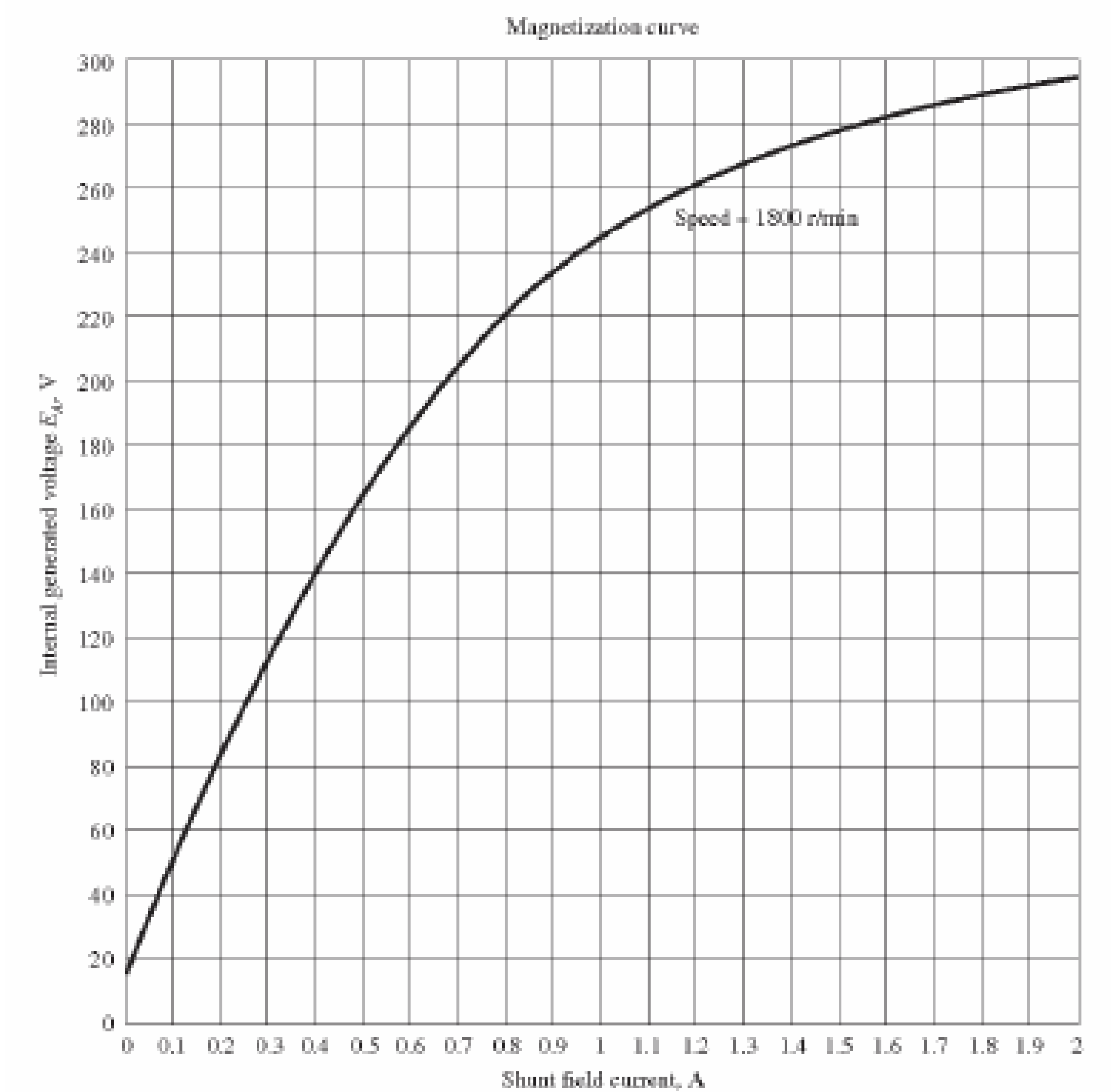

Figure P3: Magnetization curve for the dc motor in Questions 3 to 5. This curve was made at a constant speed of 1,800 r/min.