UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

Module Number: ME5302 **Module Name: Electrical Power and Machines**

[Three Hours]

[Answer **all questions**, each question carries **twelve** marks]

Q1. a) Explain what is meant by hysteresis.

[1.0 Marks]

b) Explain how the hysteresis phenomenon causes energy losses in alternating-current (AC) devices?

[2.0 Marks]

c) **Figure Q1 (c)** shows a simple rotor–stator arrangement for a DC motor. The relative permeability of the core is **2000** and is a constant. The effective area of the air gaps due to fringing effects becomes **14 cm²** and everywhere else it is **12 cm²**. How many turns of the wire on the core is required to produce a flux density of **0.1 T** with a field current of **0.1 A**?

[5.0 Marks]

d) Why is it necessary to have an air gap in a motor or generator?

[1.0 Marks]

e) Why isn't it possible to make the air gap arbitrarily small in a practical motor design?

[3.0 Marks]

Q2. A **400 V** single-phase AC generator is used to supply power to a remote village as shown in **Figure Q2 (a).** The same system is later modified by adding two ideal transformers as shown in **Figure Q2 (b)** to elevate the transmission line voltage. The transmission line impedance; $\mathbf{Z}_{Line}$ and load impedance; $\mathbf{Z}_{Load}$ are as specified in the figures.

a) Calculate the voltage at the load end; $\mathbf{V}_{Load}$ and the power loss occurred in the transmission line for the arrangement in **Figure Q2 (a)**.

[2.0 Marks]

b) Calculate the voltage at the load end; $\mathbf{V}_{Load}$ and the power loss occurred in the transmission line for the arrangement in **Figure Q2 (b)**.

[4.0 Marks]

c) Compute the necessary **VAR** rating of the capacitor bank to make unity power factor at the load in Part (b).

[3.0 Marks]

d) Giving the scientific reasons, discuss how the power factor corrections of industrial scale electricity consumers and the high-voltage transmission help reduce electricity distribution costs.

[3.0 Marks]

Q3. A **permanent-magnet DC machine** is used to make a single-wheel robot platform with regenerative braking capability as shown in **Figure Q3 (a)**. The Voltage Converter Unit is capable of maintaining the desired terminal voltage V_T commanded externally. In motor mode operation it draws power from battery and in generator mode operation it recharges the battery. The circuit of the DC machine connected to the voltage converter unit is shown in **Figure Q3 (b)**. The ratio of the DC machine shaft speed to the wheel shaft speed is 25 and the gear unit has negligible losses. The generated EMF; E_g is given by $E_g = 0.25\ \omega$ where ω is the shaft speed of the DC machine in **rad/s**. The armature reaction is negligible.

a) Derive the relationship between wheel rpm; n and the terminal voltage; V_T to turn the wheel against a constant **5 N.m** torque.

[4.0 Marks]

b) Derive the relationship between wheel rpm; n and the terminal voltage; V_T to apply a constant brake torque of **10 N.m** to the wheel.

[4.0 Marks]

c) Calculate the energy stored in the battery while a constant deceleration from **50 rpm** to **25 rpm** of the wheel occurs in 3 seconds assuming that the voltage converter and battery system stores the regenerated energy at **90%** efficiency.

[4.0 Marks]

Q4. A **400 V, 25 kW, 50 Hz, 6-pole, Y-connected** three phase induction motor has the following impedances in ohms per phase referred to the stator circuit as shown in **Figure Q4**: $R_1 = 0.2\ \Omega$, $R_2 = 0.08\ \Omega$, $R_c = 120\ \Omega$, $X_1 = 0.2\ \Omega$, $X_2 = 0.3\ \Omega$, and $X_M = 10\ \Omega$. Above impedances were measured at the rated frequency of 50 Hz. The total rotational losses are estimated to be constant at **1.5 kW**. The rated slip of the motor is **2.0%**. The motor is driven by a variable frequency drive (VFD) which maintains its output voltage to frequency ratio **8 V/Hz**.

a) Calculate the frequency of the VFD that gives **600 rpm** at **2.0%** slip. What is the VFD output phase voltage at this frequency?

[3.0 Marks]

b) Calculate the torque output in **N.m** for the condition in Part (a).

[6.0 Marks]

c) Calculate the approximate value of motor speed in **rpm**, when the load torque is one and half times the value in Part (b) for the same VFD setting. State your assumption(s).

[3.0 Marks]

Q5. a) Briefly explain the main inherent disadvantage in single phase induction motors compared to three-phase induction motors.

[1.0 Marks]

b) Explain three methods used to overcome the disadvantage in part (a).

[2.0 Marks]

c) You have been given a three-phase induction motor with the characteristics shown in **Figure Q5 (c).** It is required to design a mixing machine using this motor. The mixer load torque is constant for all the speeds. As a safety measure the motor should never be loaded more than 50% of its maximum available torque. Select the maximum mixer load torque that satisfies the above conditions. Determine the operating motor speed and stator current for your selection?

[5.0 Marks]

d) A synchronous generator with no-load frequency of 51.0 Hz and power-frequency slope of 1 MW/Hz is connected to a load consuming 1 MW. After a second load consuming 1 MW is connected to the generator, a change in frequency was noticed. What value of no-load frequency setting would restore the system frequency?

[4.0 Marks]

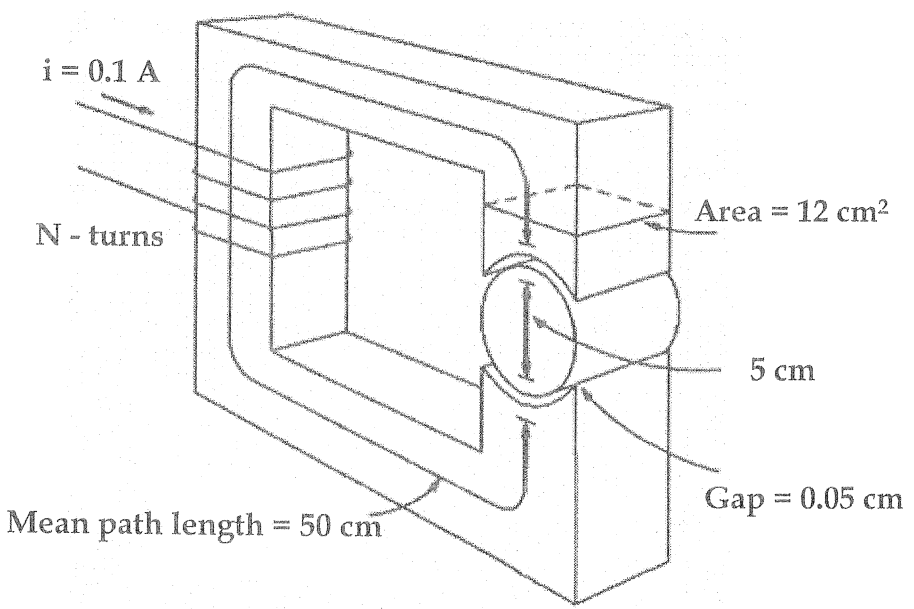

Figure: Q1 (c)

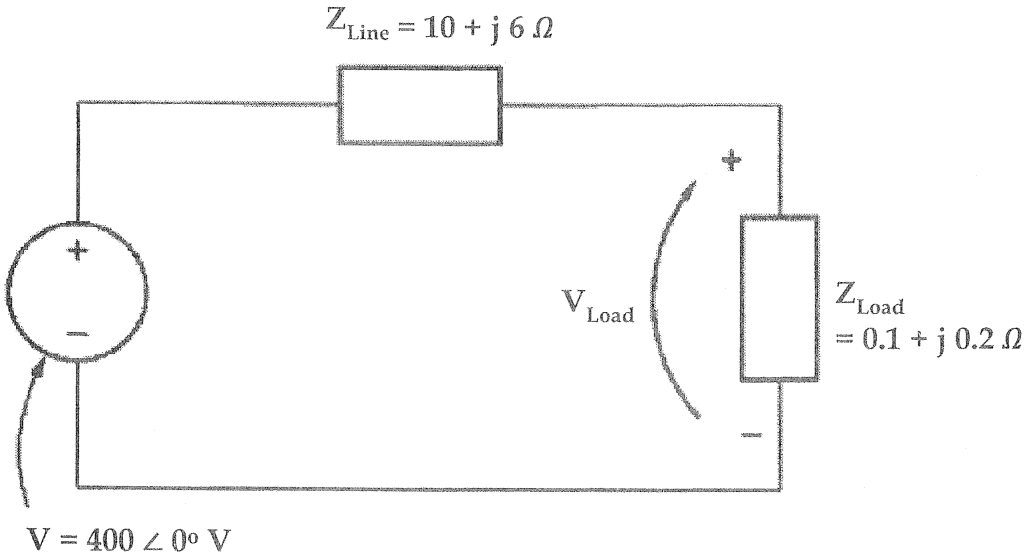

Figure: Q2 (a)

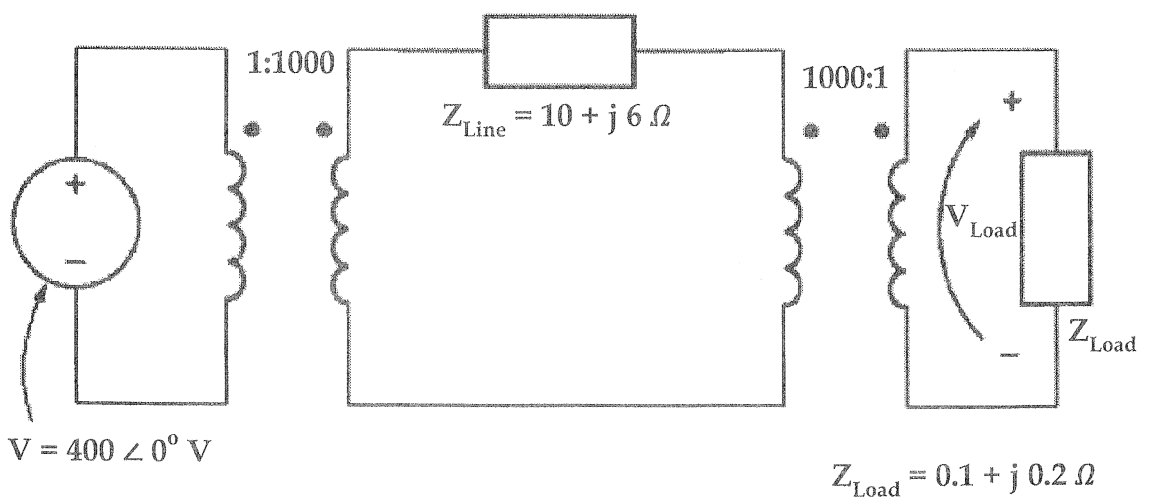

Figure: Q2 (b)

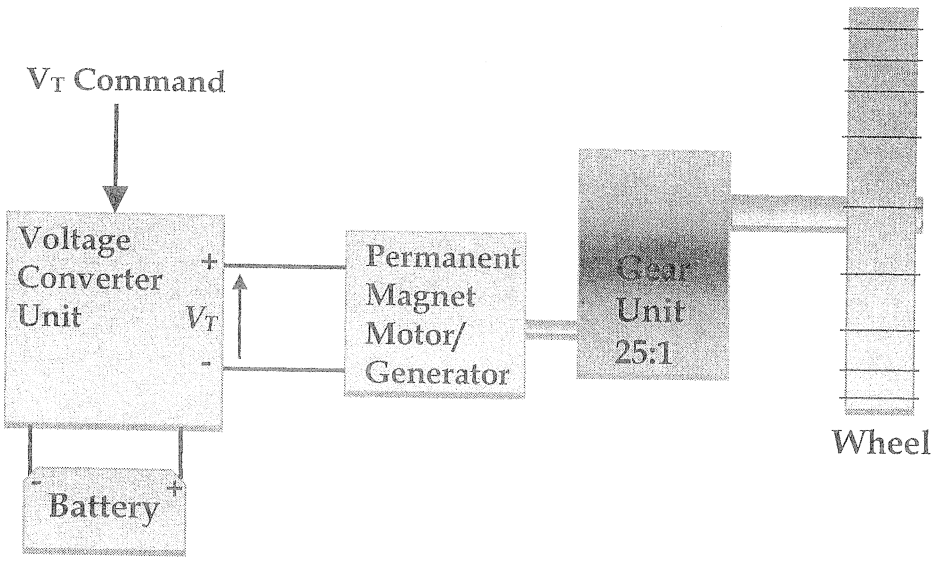

Figure: Q3 (a)

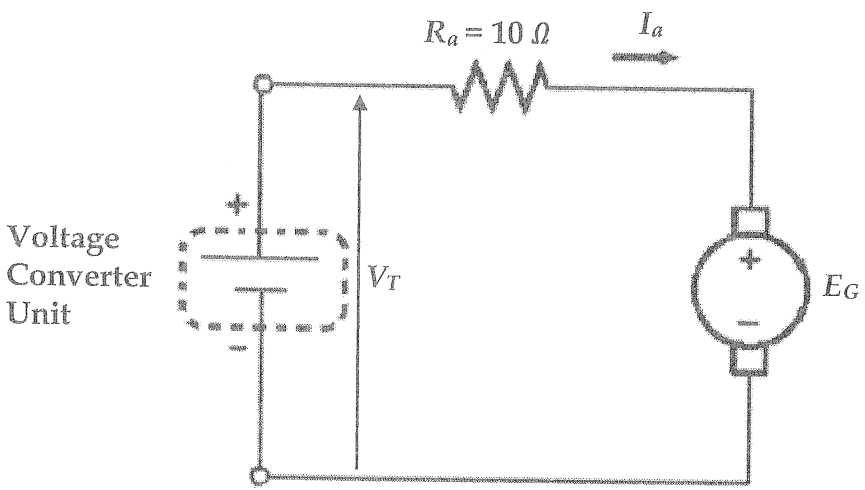

Figure: Q3 (b)

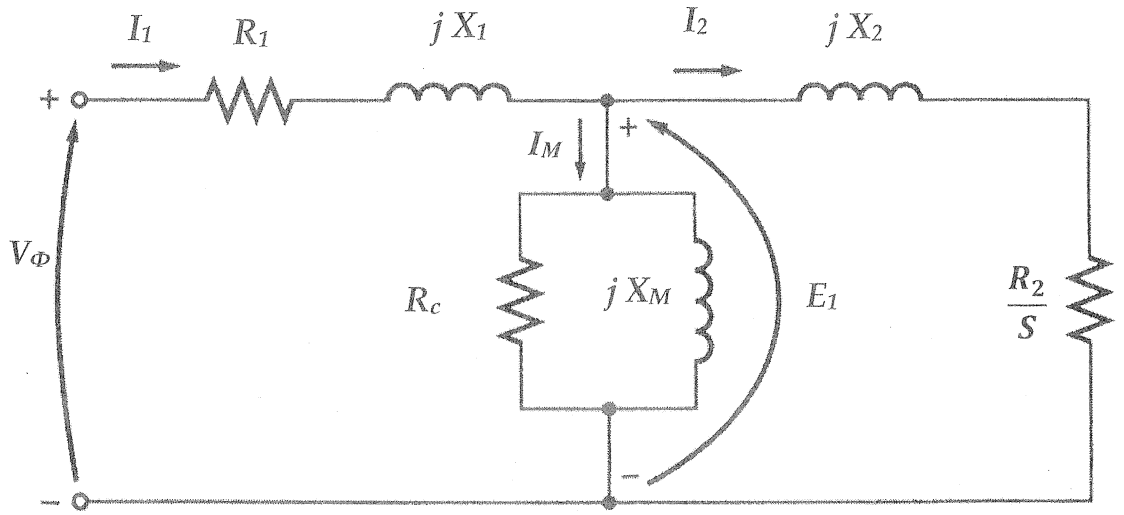

Figure: Q4

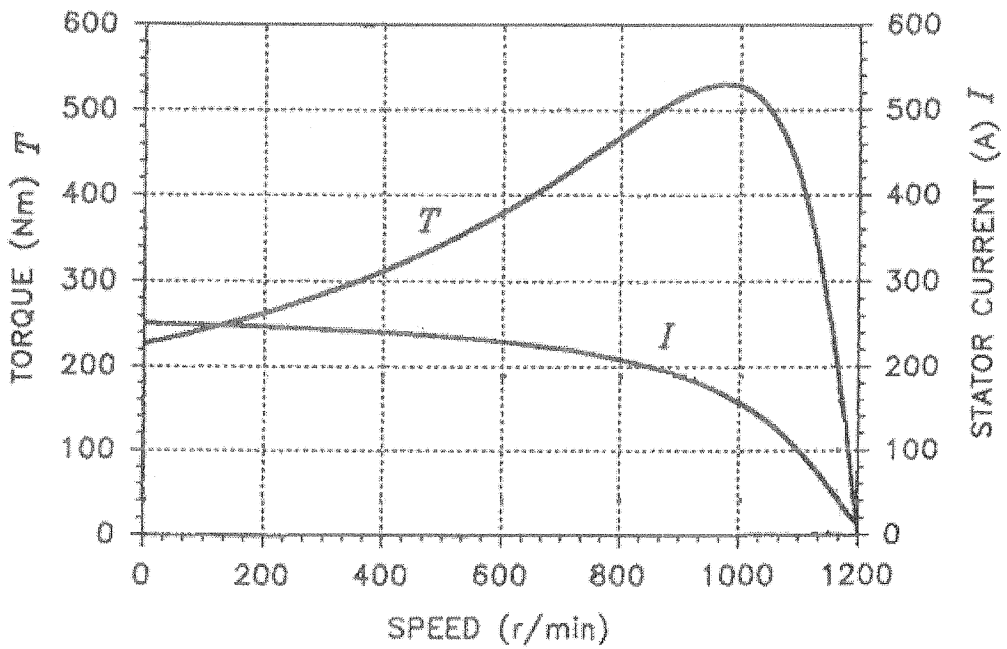

Figure: Q5 (c)