UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: August 2014

Module Number: EE1301 Module Name: Introduction to Electrical Engineering

[Three Hours]

[Answer **all questions**, each question carries 12 marks]

Q1 a) i) "An electrical circuit can be defined as a closed path composed of active and passive elements through which the current flow is contained". Describe the active and passive elements mentioned in this definition.

ii) Explain the difference between "Nodal Analysis" and "Mesh Analysis".

[1.5 Marks]

b) i) State the maximum power transfer theorem related to DC (Direct Current) circuits.

ii) Consider the circuit illustrated in Figure Q1.1. Assume that the ratio of resistance between the two loads are $R_{L1} : R_{L2} = 1:2$. Calculate the resistance of the loads and the power dissipated at each load, if the voltage source transfers the maximum amount of energy to the circuit.

iii) Comment on the values of the power dissipated at each load if they were connected in series.

[4.5 Marks]

c) Consider the circuit diagram given in Figure Q1.2, where R_{L1} and R_{L2} are the two loads in the circuit. The resistance and voltage values in the circuit are given by,

$R_1 = R_2 = R_3 = R$, $R_{L1} = \alpha R$, $R_{L2} = \beta R$

$E_1 = a E$, $E_2 = b E$

i) Show that the current flowing through the load resistance R_{L1}, is given by

$$I_{L1} = \left[\frac{\beta b + (2\beta + 1)a}{(2\beta + 1)(2\alpha + 1) - \alpha\beta}\right]\left(\frac{E}{R}\right)$$

[Hint : Use the Nodal analysis method]

ii) Calculate the current flowing through R_{L2}.

iii) Determine the voltage ratio between the DC supplies, if the currents flowing through the loads are the same.

[4.0 Marks]

d) Calculate the resultant resistance across the terminals AB of the circuit in Figure Q1.3. All the resistors of the circuit have equal resistances of r.

Note:

If required, use the transformations given below related to Figure Q1.4.

Delta – Star Conversions:

$$R_a = \frac{R_1 R_3}{(R_1 + R_2 + R_3)}, \quad R_b = \frac{R_1 R_2}{(R_1 + R_2 + R_3)}, \quad R_c = \frac{R_2 R_3}{(R_1 + R_2 + R_3)}$$

Star – Delta Conversions:

$$R_{ab} = R_1 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c} = R_a + R_b + \frac{R_a R_b}{R_c}$$

$$R_{bc} = R_2 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a} = R_b + R_c + \frac{R_b R_c}{R_a}$$

$$R_{ca} = R_3 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b} = R_c + R_a + \frac{R_c R_a}{R_b}$$

[2.0 Marks]

Q2 a) i) Describe the TT (Tera - Tera) earthing system using diagrams. Hence, explain the reason for using this system in Sri Lanka.

ii) State the difference between Ring circuits and Radial circuits when wiring the sockets in a domestic wiring system.

[2.0 Marks]

b) Consider the circuit given in Figure Q2.1. A current $I = 1$ A is supplied by the AC (Alternative Current) voltage source operating at 50 Hz.

i) Find the input voltage.

ii) Draw the phasor diagram.

Assume that, the current is neither lagging nor leading.

[Hint : Calculate the resultant impedances across AB and CD to obtain the supply voltage]

[4.0 Marks]

c) i) How do you define the "motor mode" and the "generator mode" of a rotating electric machine?

ii) Give two examples each for the motor mode operation and for the generator mode operation of a rotating electric machine.

iii) What is "air-gap" in a rotating electric machine?

iv) In terms of steady-state operation, how do you differentiate AC asynchronous motors and AC synchronous motors?

[2.5 Marks]

d) i) What is the function of the armature windings in a DC electric motor?

ii) Why is it recommended to have more armature windings in a DC electric generator?

iii) Explain two drawbacks of brushes in a DC electric machine.

iv) What are the advantages and the disadvantages when the field windings are replaced by permanent magnets in a DC electric motor?

[3.5 Marks]

Q3 a) A DC shunt motor is supplied by a 25 V constant DC supply. It has an armature resistance of 10 Ω and a field resistance of 50 Ω. The value of the voltage constant is 0.5 Vs/(A rad). At a certain operating point the motor runs at 625 rpm. Assume that except for copper losses, there are no other types of losses in the motor and the friction torque is negligible.

i) Calculate the load-torque at this operating point.

ii) Calculate the efficiency of the motor at this operating point.

iii) If the load torque calculated in i) is removed from the motor, what is the new steady-state speed of the motor in rpm.

[7.0 Marks]

b) The field circuit of a separately excited DC motor is connected to a constant DC source. A constant 200 V DC supply is applied to the armature terminals. The resistance of the armature circuit is 0.2 Ω. It is observed that the motor produces a 10 Nm torque for an armature current of 10 A. If the torque is increased to 25 Nm, how much speed reduction is expected in the motor?
Assume that except for copper losses, there are no other types of losses in the motor and the friction torque is negligible.

[5.0 Marks]

Q4 A 460 V split phase single phase induction motor is supplied by a 230/460 V and 50 Hz single phase distribution transformer.

a) i) What are the types of losses that take place in the transformer core during operation?

ii) What precautionary actions can be taken to minimize the above losses?

[2.5 Marks]

b) i) Briefly explain why single phase induction motors do not self-start.

ii) Explain how the split phase single phase induction motor self-starting is achieved.

[3.5 Marks]

c) The self-resistance and the inductance of both the main winding and the starting winding of an induction motor are 12 Ω and 4.77 mH respectively. A 50 μF capacitor is connected to the starting winding of the induction motor. The transformer has the following resistances and reactances.

$R_p = 0.1\ \Omega$ $R_s = 0.05\ \Omega$
$X_p = 0.1\ \Omega$ $X_s = 0.06\ \Omega$
$R_c = 330\ \Omega$ $X_m = 30\ k\ \Omega$

i) Find the equivalent circuit of this transformer referred to the low-voltage side.

ii) Calculate the starting line current of the single phase induction motor.

iii) Determine the voltage regulation and the efficiency of the transformer at the start of the induction motor.

[6.0 Marks]

Q5 a) How does a three phase induction motor induce a torque when the three phase supply is given?

[3.0 Marks]

b) i) Draw the power flow diagram indicating how power flows through an induction motor.

ii) Hence obtain the expressions for the air gap power (P_{AG}), converted power (P_{conv}) and the induced torque (τ_{ind}). Define the notations you have used in your expressions.

[3.0 Marks]

c/b) A 208 V, two-pole, 60 Hz, Δ - connected wound-rotor induction motor is rated at 15 hp. The motor operates a load with a speed of 3420 rpm. The rotational and the core losses of the machine are 250 W and 180 W respectively. Its equivalent circuit parameters are

$R_1 = 0.20\ \Omega$ $R_2' = 0.12\ \Omega$ $X_m = 15\ \Omega$
$X_1 = 0.41\ \Omega$ $X_2' = 0.41\ \Omega$

Note that all the notations have their usual meanings.

i) Find the air gap power (P_{AG}).

ii) Calculate the induced torque (τ_{ind}) and the load torque (τ_{load}).

iii) Calculate the overall efficiency of the machine.

[6.0 Marks]

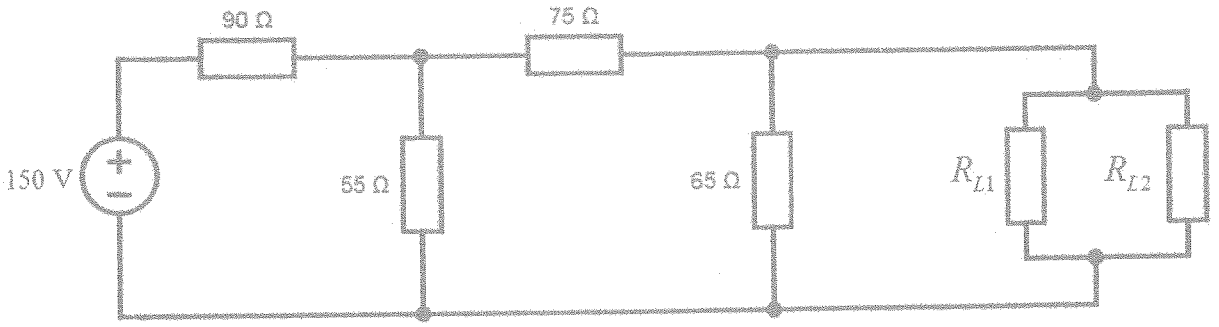

Figure Q1.1

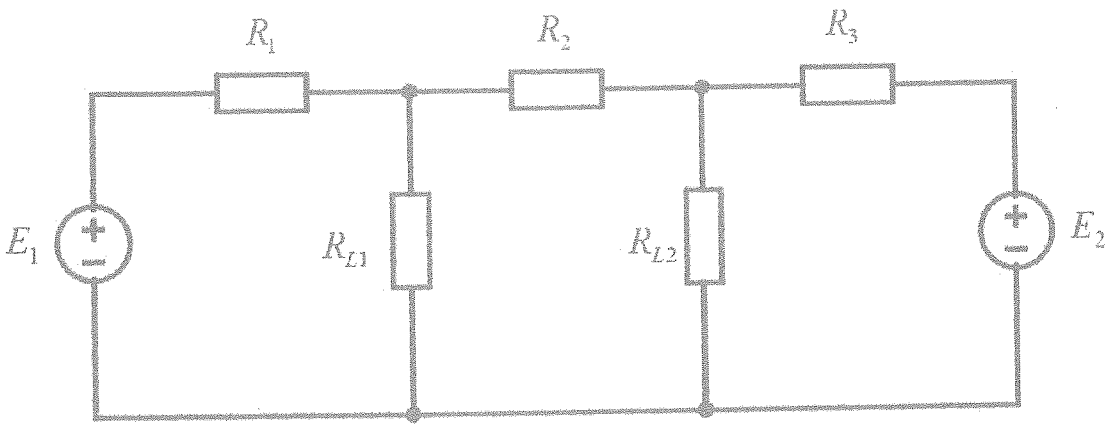

Figure Q1.2

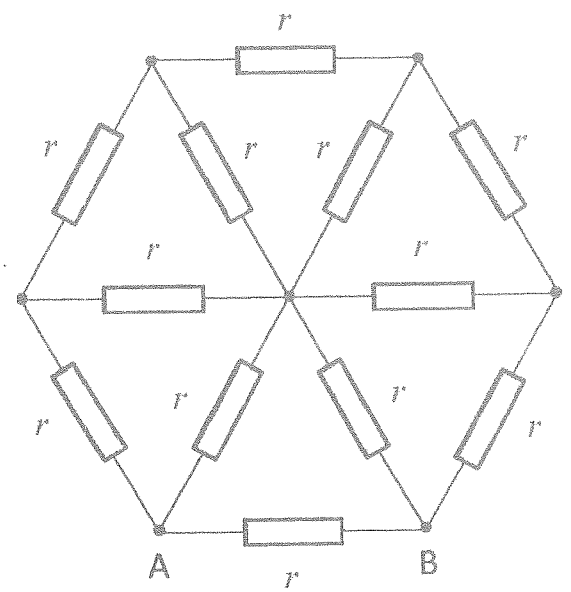

Figure Q1.3

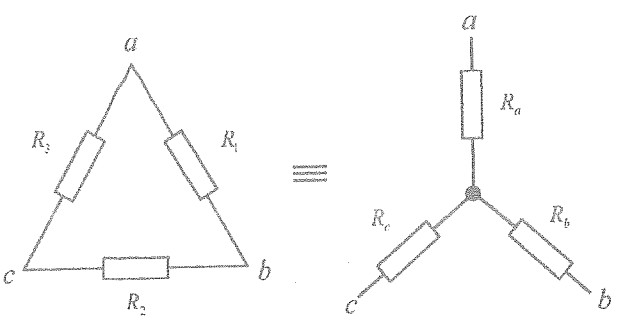

Figure Q1.4

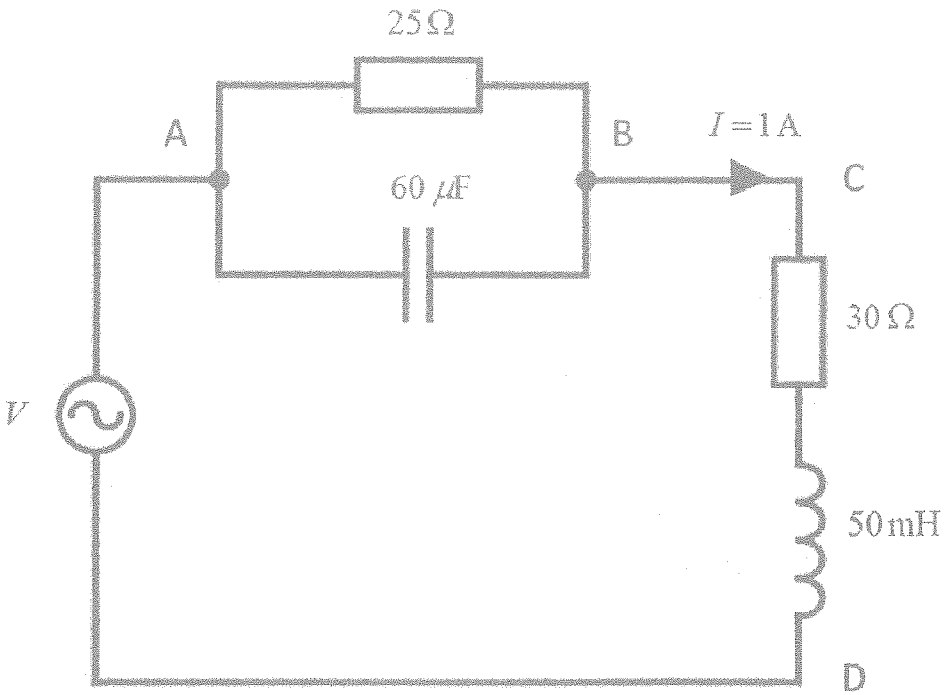

Figure Q2.1