UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: December 2023

Module Number: EE1302 **Module Name: Introduction to Electrical Engineering**

[Three Hours]

[Answer **all questions in Section I** and **only one question** out of two questions in **Section II**, each question carries 12.5 marks]

Section I – Answer all questions.

Q1 a) i) What is a dependent or controlled source in an electric circuit?

ii) What is the difference between super-node and super-mesh with regard to DC circuit analysis?

iii) Find the nodal voltages of the DC circuit given in Figure Q1(a)-1 using **Nodal Analysis.**

iv) Obtain **only** the required simultaneous equations using **Mesh Analysis** considering the DC circuit given in Figure Q1(a)-2.

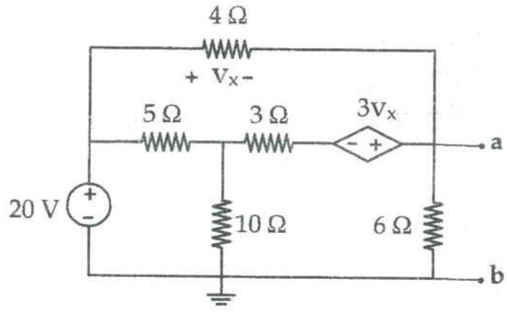

Figure Q1(a)-1

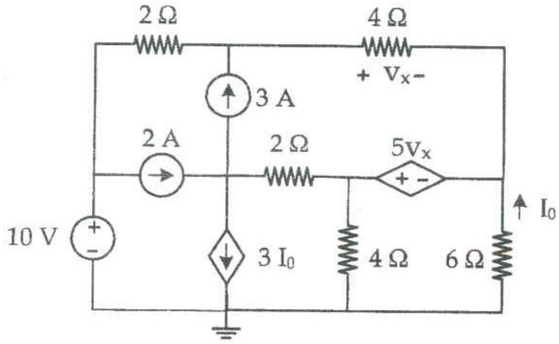

Figure Q1(a)-2

[6.5 Marks]

b) i) For any electric circuit, if an entire circuit is replaced by its Thevenin equivalent circuit except the load, as shown in Figure Q1(b), show that the maximum power transferred to the load (P_{max}) is given by $P_{max} = \frac{V_{TH}^2}{4R_{TH}}$.

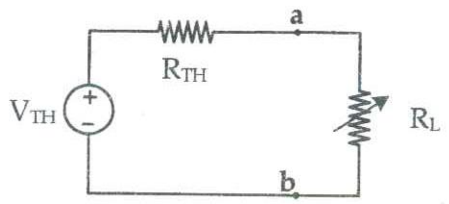

Figure Q1(b)

Note that all the notations have their usual meanings.

ii) Find the Thevenin equivalent circuit across the terminals **a** and **b** in the DC circuit given in Figure Q1(a)-1.

iii) Hence, calculate the maximum power that can be delivered to a load resistor connected across terminals **a** and **b** in the circuit shown in Figure Q1 (a)-1.

[6.0 Marks]

Q2 a) A sinusoid is a signal that has the form of the sine or cosine. A single-phase AC voltage source is given by $v(t) = 24\sin(120t + 30^0)$ V. The sin function is used to derive the phase angle of the sinusoid.

Determine the following parameters of $v(t)$.

i) Amplitude
ii) RMS value
iii) Average value
iv) Form factor
v) Peak factor
vi) Phase angle
vii) Period
viii) Frequency

[2.0 Marks]

b) An inductor consists of a coil of conducting wire. The current through the inductor with the inductance of L is given by $i_L(t) = I_m \sin \omega t$.

i) Briefly explain the behavior of an inductor considering basic electromagnetic principles.

ii) Obtain an expression for the instantaneous inductor voltage ($v_L(t)$).

iii) From the first principles, obtain an expression for the inductive reactance (X_L).

iv) If this inductor is connected in series with a resistor with the resistance of **R** and a single-phase voltage source with the RMS voltage of **V**, sketch the phasor diagram of the electric circuit considering **all phasors**.

[4.0 Marks]

c) Consider the AC circuit given in Figure Q2(c). The RMS voltage of the 50 Hz AC source is 60 V.

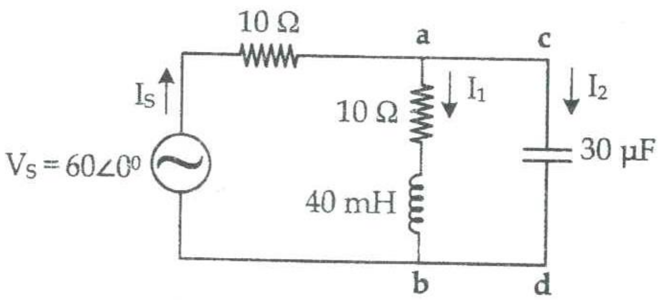

Figure Q2(c)

i) Find the impedances connected across terminals **a** and **b** (Z_{ab}) and **c** and **d** (Z_{cd}), separately.

ii) Calculate the source current (I_S).

iii) Find the currents I_1 and I_2 through impedances Z_{ab} and Z_{cd}, respectively.

iv) Calculate the voltage across the terminals **a** and **b** (V_{ab}) and **c** and **d** (V_{cd}), separately.

v) Draw the phasor diagram of the electric system given in Figure Q(c) including $\mathbf{I_S}$, $\mathbf{I_1}$, $\mathbf{I_2}$, $\mathbf{V_S}$, $\mathbf{V_{ab}}$, $\mathbf{V_{cd}}$ phasors.

[6.5 Marks]

Q3 a) Consider a positive (**abc**) sequence balanced star-connected (**Y**) three phase supply. If the instantaneous voltage of phase **a** is given by $v_{an}(t) = \sqrt{2}V_P \sin \omega t$.

i) Write expressions for the instantaneous voltages of phase **b** and phase **c**.

ii) Show that $V_{ab} = \sqrt{3}\, V_P \angle 30^0$.

iii) The line-to-line voltage of lines **a** and **b** of a positive sequence star-connected (Y) balanced three-phase supply is given as $v_{ab}(t) = 208\angle 60^0$ V. Draw the phasor diagram showing the line-to-line voltages and phase voltages of the three-phase supply.

iv) A three-phase star-connected (Y) balanced load draws a line current of I_Y from a balanced three-phase source. What is the line current, if the same load is connected in delta (Δ) configuration and supplied by the same three-phase source.

[4.0 Marks]

b) A three-phase star-connected (Y) balanced load is supplied by a positive sequence balanced three-phase supply as illustrated in Figure Q4(b). The per-phase load impedance consists of a resistor and an inductor connected in series. The resistance of resistor and the reactance of inductor are 25 Ω and 32j Ω, respectively. The line-to-line voltage across terminals **a** and **b** is 400 V.

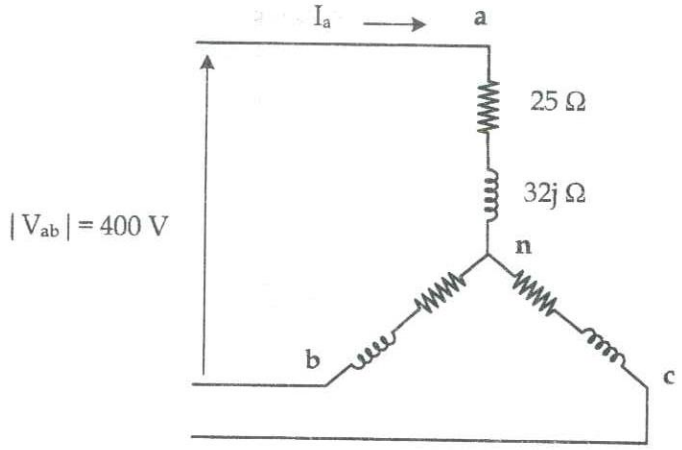

Figure Q4(b)

i) Calculate the per-phase equivalent load impedance.

ii) Calculate the line current of line **a** (I_a).

iii) Sketch the three-phase phasor diagram showing all the line-to-line voltages, line currents and phase voltages.

iv) What is the power factor of the load.

v) Calculate the total active power, reactive power and apparent power drawn by the three-phase load.

vi) If a capacitor bank is installed at the load end which can supply half of the reactive power requirement of the load, what is the improved power factor of the system?

[8.5 Marks]

Section II - Answer only one question out of the two.

Q4 a) The instantaneous power p(t) absorbed by an element is the product of the instantaneous voltage $v(t)$ and the instantaneous current $i(t)$ across the element. Here, $v(t) = V_m \cos(\omega t + \theta_v)$ and $i(t) = I_m \cos(\omega t + \theta_i)$.

i) Starting from instantaneous power $p(t)$, show that the average power dissipated at the element is,

$$P_{avg} = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos(\theta_v - \theta_i)$$

ii) If we consider that voltage phasor as the reference, express the Apparent power in terms of voltage and current phasors. Hence, obtain expressions for apparent power, complex power, active power, and reactive power.

iii) Draw the power triangle clearly indicating apparent power, active power, and reactive power.

iv) Define the power factor.

v) Using the results in Part ii) and Part iii), show that a capacitive load conventionally injects the reactive power.

[5.0 Marks]

b) A 10 KVA, 50 Hz load is rated at 0.8 power factor lagging. The load voltage must be kept at 480 V. The rated load is supplied by a 50 Hz single-phase voltage source by an electric circuit as illustrated in Figure Q3(b).

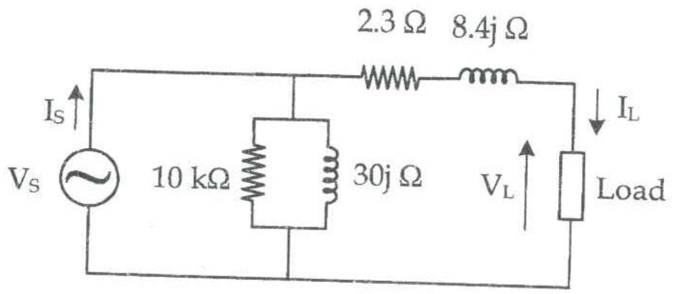

Figure Q3(b)

i) Calculate the load current (I_L).

ii) Calculate the source voltage, source current and input power factor.

iii) Draw the phasor diagram indicating the phasors for load voltage, load current, source voltage and source current.

iv) Find the real, reactive and apparent power supplied by the source.

v) Calculate the required parallel capacitance to improve the input power factor to 0.9 lagging.

[7.5 Marks]

Q5 a) i) What are the main protective mechanisms used in a domestic electrical installation? Write one protective device for each protective mechanism.

ii) What is the difference between neutral earthing and equipment earthing?

iii) What are the three basic earthing systems available? Using suitable sketches, briefly explain how they differ from each other.

iv) What are the main types of electric circuits employed in a domestic electrical installation?

v) Final electric circuits of a domestic installation are protected with Miniature Circuit Breakers (MCBs). Briefly explain the operation of an MCB during short circuit and overloading faults.

vi) Briefly explain the operation of a Residual Current Circuit Breaker (RCCB) in the event of leakage fault in the domestic installation.

[6.0 Marks]

b) The switch of the RLC circuit shown in Figure Q5(b) is closed for a significant time and it opens at t=0.

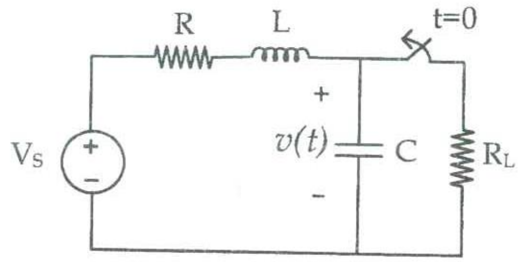

Figure Q5(b)

i) Derive the deferential equation which governs the behavior of the voltage across the capacitor for $t \geq 0$.

ii) Obtain the characteristic equation of the given DC circuit in Figure Q5(b).

iii) If the DC circuit is critically damped, show that,

$$\left(\frac{R}{2L}\right)^2 = \frac{1}{LC}.$$

iv) If $R_L = 5\ \Omega$, $R = 6\ \Omega$, $L = 1$ H, $C = 1/9$ F and $V_S = 25$ V, find the total response of the capacitor voltage $v(t)$ for $t > 0$.

v) Find the inductor current $i(t)$ for $t > 0$.

[6.5 Marks]