UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: March 2026

Module Number: EE1301 **Module Name: Fundamentals of Electricity (C-23)**

[Three Hours]

[Answer **all questions**, each question carries **12.5** marks]

Q1 a) States the **Thevenin's theorem** with regard to circuit analysis.

[1.0 Mark]

b) i) By selecting the appropriate nodes, formulate **only** the necessary simultaneous equations to determine all node voltages of the DC circuit shown in Figure Q1(b)-1 using **Nodal Analysis.**

Assume that $\mathbf{V_k}$ ($1 \leq k \leq 10$; $k \in \mathbb{Z}$) represents the electric potential at the point **k** as indicated in Figure Q1(b)-1.

ii) Formulate **only** the necessary simultaneous equations to find all the mesh currents of DC circuit given in Figure Q1(b)-2 using **Mesh Analysis.**

Assume that $\mathbf{I_k}$ ($1 \leq k \leq 4$; $k \in \mathbb{Z}$) denotes the mesh current of the mesh k as indicated in Figure Q1(b)-2.

[6.5 Marks]

c) Use the **superposition theorem** to find the current ($\mathbf{I_0}$) through the resistor of 2 Ω in the DC circuit given in Figure Q1(c). Only **mesh analysis** must be used for all the circuit analysis in this part.

[5.0 Marks]

Q2 a) A single-phase AC source supplies a load as illustrated in Figure Q2(a). The source voltage, load voltage and load current are expressed in (Q2.1), (Q2.2) and (Q2.3), respectively.

$$e_a(t) = E_{am}\sin(\omega t + \delta) - (Q2.1)$$
$$v_L(t) = V_{Lm}\sin(\omega t) - (Q2.2)$$
$$i_L(t) = I_{Lm}\sin(\omega t - \theta) - (Q2.3)$$

i) Is the load inductive or capacitive? Justify your answer.

ii) Find expressions for the phasors of source voltage ($\boldsymbol{E_a}$), load voltage ($\boldsymbol{V_L}$) and load current ($\boldsymbol{I_L}$).

iii) Determine the following parameters of $e_a(t)$.

I) Amplitude

II) RMS value

III) Average value

IV) Frequency

V) Phase angle

iv) Find an expression for the source voltage ($\boldsymbol{E_a}$) in terms of $\boldsymbol{V_L}$ and $\boldsymbol{I_L}$.

v) Draw the phasor diagram of the electric circuit considering **all phasors**.

vi) Considering the phasor diagram obtained in Part a)(v), show that the amplitude of $e_a(t)$ (E_a) can be expressed in (Q2.4).

$$E_a^2 = (V_L + I_L X_S \sin\theta)^2 + (I_L X_S \cos\theta)^2 \quad -(Q2.4)$$

[4.0 Marks]

b) A single-phase AC source supplies a load as illustrated in Figure Q2(b). The RMS voltage of the 50 Hz AC source is 120 V. The load impedance is $30\angle 36^0\ \Omega$.

i) Find the impedances connected across terminals **a** and **b** ($\boldsymbol{Z_{ab}}$).

ii) Calculate the source current (**I$_S$**).

iii) Calculate the voltage across the terminals **a** and **b** ($\boldsymbol{V_{ab}}$).

iv) Find the load voltage and the load current.

v) Draw the phasor diagram of the electric circuit considering **all phasors.**

[4.5 Marks]

c) A 480 V, 50 Hz single-phase AC source supplies a variable load as illustrated in Figure Q2(a). It is found that the amplitude of source voltage (E_a) is directly proportional to the frequency. The reactance of the circuit (Xs) is 3.5 Ω at the nominal frequency. At a certain operating point, the load draws a current of 25 A and the load current lags the load voltage by 36^0.

i) Calculate the load voltage (**V$_L$**).

ii) Calculate the load impedance.

iii) If the system frequency is increased to 60 Hz while keeping the same load impedance, calculate the new source voltage ($\boldsymbol{E_a}$), load voltage ($\boldsymbol{V_L}$) and load current ($\boldsymbol{I_L}$).

[4.0 Marks]

Q3 a) A single-phase f Hz AC source feeds a load. The phasors of load voltage, load current and source voltage are $V_L\angle 0^0$, $I_L\angle -\theta^0$ and $E_a\angle\delta^0$, respectively.

i) Write an expression for the apparent load power (complex power) in terms of voltage and current phasors of the load.

ii) Hence, obtain expressions for apparent power, active power, and reactive power of the load.

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

iv) Show that a capacitive load conventionally injects reactive power.

v) A capacitor bank is connected across the source to improve the input power factor. The improved power factor angle is α. Show that the required parallel capacitance (C_p) can be expressed in (Q3.1).

$$C_p = \frac{V_L I_L \cos\theta(\tan\theta - \tan\alpha)}{2\pi f E_a^2} \quad -(Q3.1)$$

[4.5 Marks]

b) A single-phase 50 Hz AC source supplies a 10 kVA load at 0.8 power factor lagging under the rated condition as illustrated in Figure Q3(b). The load voltage is 480 V.

i) Calculate the load current (I_L).

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

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

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

[4.0 Marks]

c) Consider the same circuit given in Figure Q3(b). At another operating point, the variable load mentioned in Section b) draws only 75% of the rated active power, while the **magnitudes of both the load and source voltages remain unchanged.**

i) If the phasors of load voltage, load current and source voltage are $V_L\angle 0^0$, $I_L\angle -\theta^0$ and $V_S\angle\alpha^0$, respectively, draw the phasor diagram of the electrical system including only $\mathbf{V_S}$, $\mathbf{V_L}$ and $\mathbf{I_L}$ phasors.

Hint : Use the expression of $\boldsymbol{V_S}$ *in terms of* $\boldsymbol{V_L}$ *and* $\boldsymbol{I_L}$.

ii) Considering the phasor diagram drawn in Part c) (i), show that the active power drawn by the load (P_L) can be expressed in (Q3.2).

$$P_L = \frac{V_L V_S \sin\alpha}{X_s} \quad - (Q3.2)$$

iii) Calculate the new phase angle of the source.

iv) Calculate the new load current and load power factor.

[4.0 Marks]

Q4 a) Consider a three-phase positive (**abc**) sequence balanced delta-connected (**Δ**) load. If the instantaneous phase current across the terminal **a** and **b** is given by,

$i_{ab}(t) = \sqrt{2}I_P \sin\omega t$.

i) Write expressions for all three instantaneous phase currents.

ii) Show that the phasor of line **a** current is $\boldsymbol{I_a} = \sqrt{3}\, I_P\angle{-30^0}$.

iii) Derive the expressions for three-phase active power, reactive power, and apparent power using both phase parameters and line parameters separately. Use suffix **φ** and ***l*** to denote phase and line quantities, respectively.

[4.0 Marks]

b) A three-phase balanced load is supplied by a positive (ABC) 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 parallel. The resistance of resistor and the reactance of inductor are 9 Ω and 8 Ω, respectively. The voltage across terminals A and B is 420 V.

i) Calculate the per-phase equivalent load impedance.

ii) Calculate the line current of line **A** ($\mathbf{I_A}$).

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

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.

[5.5 Marks]

c) A three-phase 480 V, 50 Hz, positive (abc) sequence, star connected balanced voltage source supplies a 8 kVA three-phase delta connected balanced load at 0.7 power factor lagging under the rated conditions.

i) Calculate the phase current and line current of the load.

ii) Calculate the required per phase parallel capacitance connected at the source side to improve the power factor to 0.9 lagging.

[3.0 Marks]

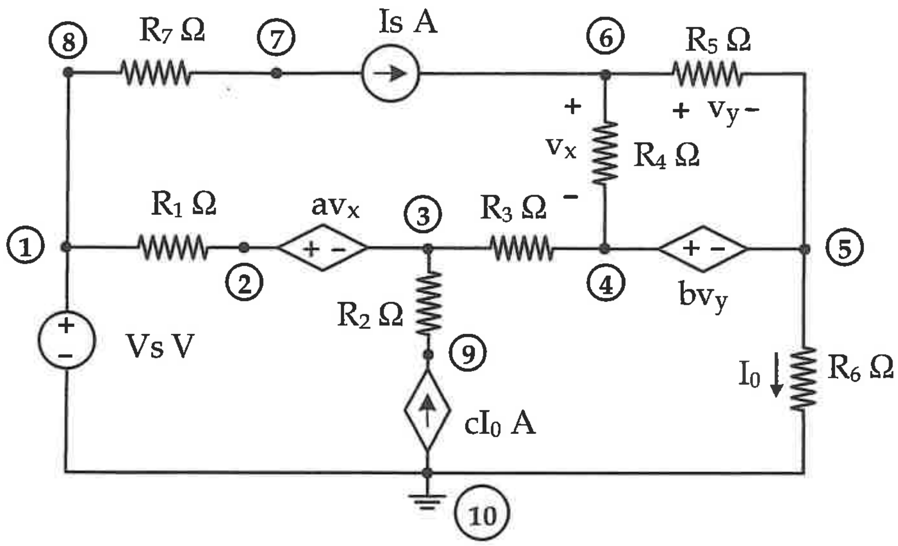

Figure Q1(b)-1

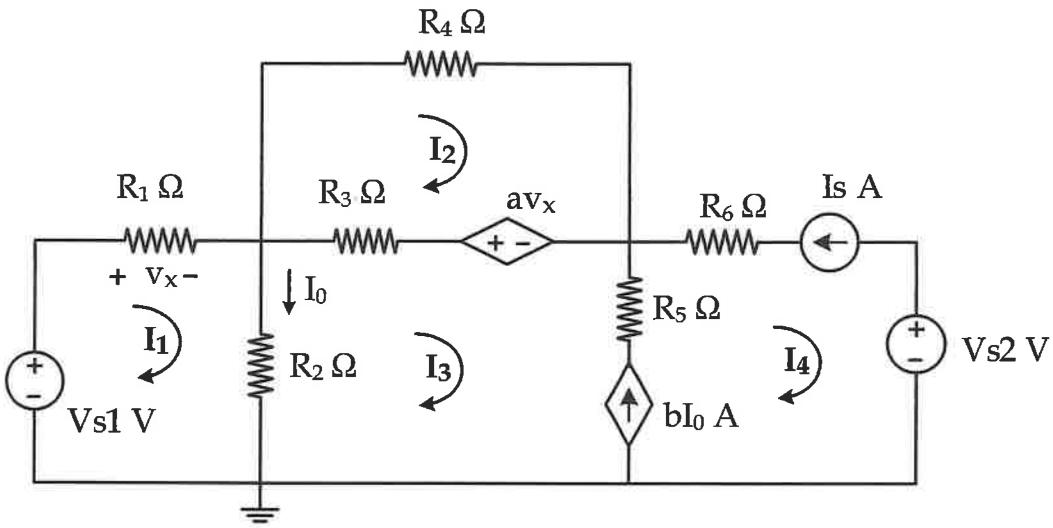

Figure Q1(b)-2

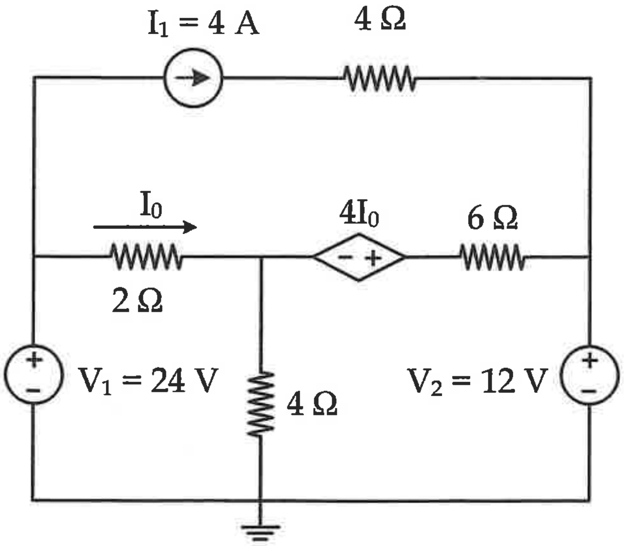

Figure Q1(c)

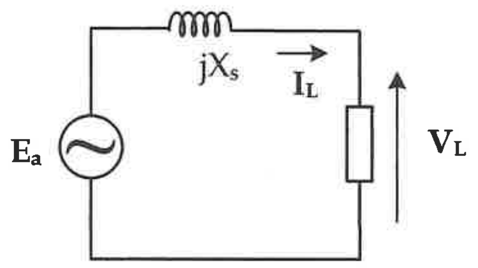

Figure Q2(a)

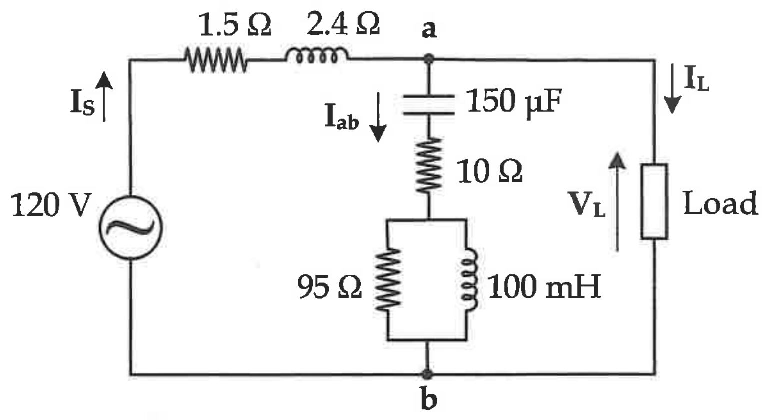

Figure Q2(b)

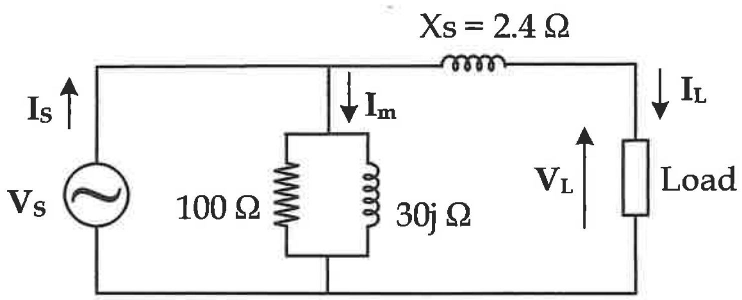

Figure Q3(b)

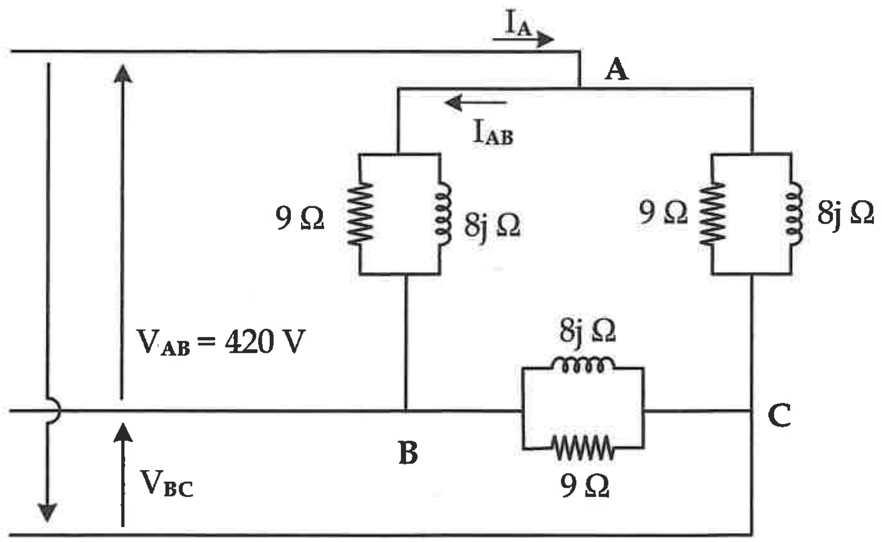

Figure Q4(b)