2018/2019 SEMESTER ONE EXAMINATION

Diploma in Aerospace Electronics (DASE) 2nd Year FT
Diploma in Engineering with Business (DEB) 3rd Year FT
Diploma in Electrical & Electronic Engineering (DEEE) 2nd Year FT
Diploma in Engineering Systems (DES) 2nd Year FT
Diploma in Energy Systems and Management (DESM) 2nd Year FT

CIRCUIT THEORY & ANALYSIS

Time Allowed: 2 Hours

Instructions to Candidates

1. The examination rules set out on the last page of the answer booklet are to be complied with.
2. This paper consists of **TWO** sections:

   Section A - 6 Short Questions, 10 marks each.

   Section B - 2 Long Questions, 20 marks each.

3. **ALL** questions are **COMPULSORY**.
4. All questions are to be answered in the answer booklet. Start each question on a new page.
5. Fill in the Question Numbers in the boxes found on the front cover of the answer booklet under the column "Question Answered".
6. This paper consists of 6 pages, inclusive of the formulae sheet.

SECTION A: 6 QUESTIONS (10 marks each)

A1. Using the source conversion method, simplify the circuit shown in Figure A1 to its equivalent voltage source across terminals A and B. (10 marks)

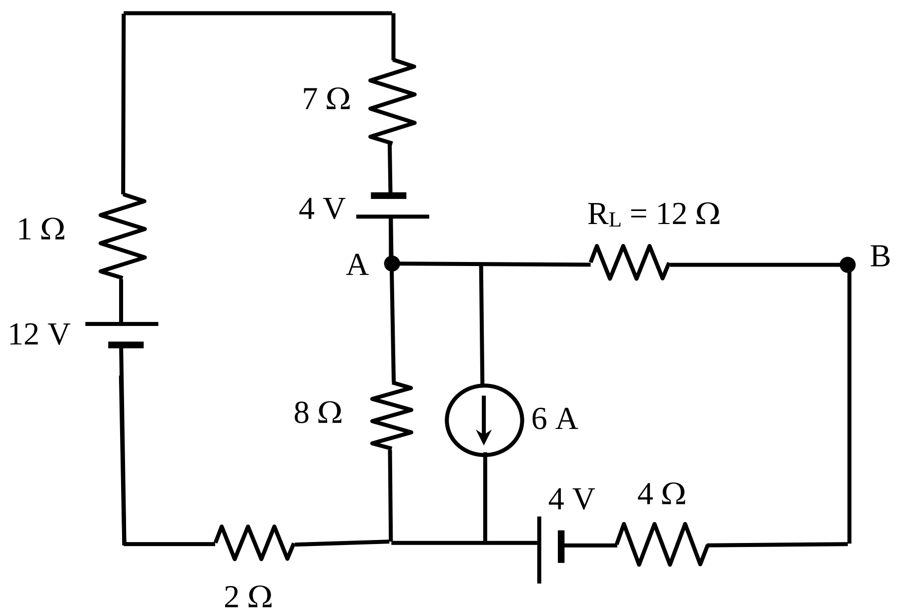


Figure A1

A2. For the circuit shown in Figure A2,

(a) convert the delta-connected resistors as shown in the dotted box into an equivalent star-connection, and (6 marks)

(b) hence determine the total supply current. (4 marks)

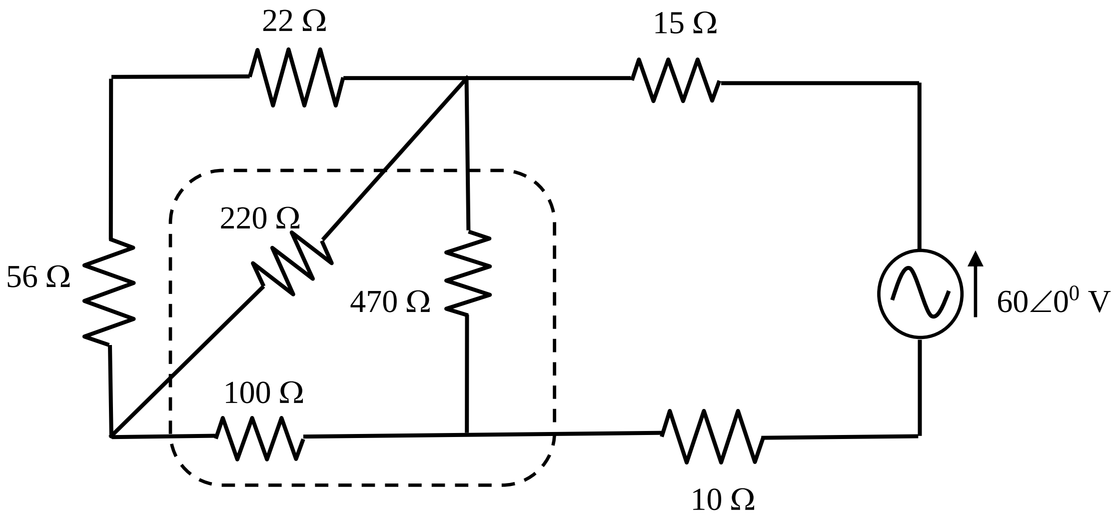


Figure A2

A3. A 3-phase, 4-wire, 100 V, ABC system is applied to a balanced star-connected three-phase load of phase impedance (10 – j8) Ω. Taking V_{CN} as the reference voltage, determine the line currents (I_A, I_B and I_C). (7 marks)

If the one of the phase impedance is open-circuited, comment on the changes in the line currents. (3 marks)

A4. A 3-phase, 200 V, ABC symmetrical supply supplies a delta-connection of 3 equal impedances of $50\angle -75°$ Ω. Taking V_{AB} as the reference voltage, determine the line currents (I_A, I_B and I_C). (6 marks)

Draw a phasor diagram to show the line currents and the reference voltage. (4 marks)

A5. A balanced 3-phase Y-connected load draws 30 kW at a power factor of 0.8 lagging from a 300 V, 50 Hz, three-phase supply. Three identical capacitors connected in star are placed in parallel with the load to give an overall power factor of 0.9 lagging. Calculate the:

(a) reactive power of the Y-connected load, and (2 marks)

(b) per phase reactance of the Y-connected capacitors. (8 marks)

A6. A 3-phase, 4-wire, 300 V, ABC system has the following loads connected between the Neutral and A, B, C lines respectively:

A to Neutral: 2 kW resistive load

B to Neutral: 4 kW load at a power factor of 0.85 leading

C to Neutral: 10 kW load at a power factor of 0.6 lagging

Calculate the:

(a) total apparent, reactive and real power, and (8 marks)

(b) overall power factor of the system. (2 marks)

SECTION B: 2 QUESTIONS (20 marks each)

B1(a). For the network shown in Figure B1,

(i) write the nodal voltage equations for V_A and V_B in matrix form by inspection, and (10 marks)

(ii) determine the voltage across the 4 Ω resistor. (6 marks)

(b). If the 6 A ideal current source is removed, determine total supply current. (4 marks)

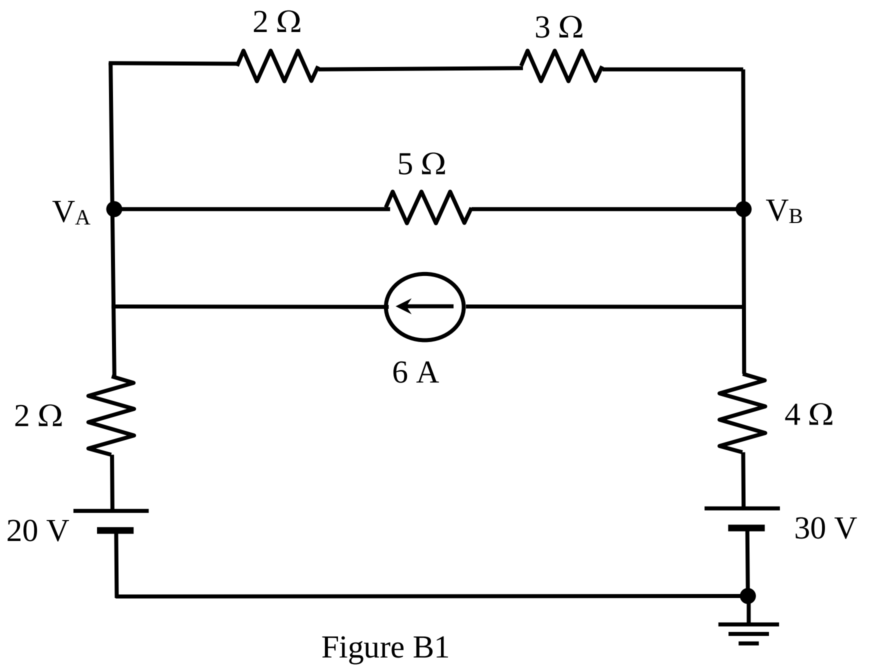


Figure B1

B2(a). A 3-phase, 3-wire, 400 V, ABC system feeds a balanced star-connected load. Given that $I_A = 50\angle 90^0$ A and taking V_{BN} as the reference voltage, determine the:

(i) line currents (I_B and I_C), (4 marks)

(ii) line voltages (V_{AB}, V_{BC} and V_{CA}), and (4 marks)

(iii) phase impedance of star-connected load in polar form. (2 marks)

(b). The total power of the above balanced star-connected load is measured using two-wattmeter method, with the current coils of the wattmeters connected to the 'A' and 'B' lines respectively.

(i) Draw a circuit diagram showing the connections of the two wattmeters to the star-connected load. (4 marks)

(ii) Determine the readings on the two wattmeters and total real power. (6 marks)

- End of Paper –

Formulae

Resistors in series	$R_T = R_1 + R_2 + R_3 + ...$
Resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
Resistors in parallel (for 2 resistors)	$R_T = \frac{R_1 R_2}{R_1 + R_2}$
Voltage Divider Rule	$V_X = \frac{R_X}{R_T} V_S$
Current Divider Rule	$I_1 = \frac{R_2}{R_1 + R_2} I_T$
Source Conversion	$E = I_S R_S$ $I_S = \frac{E}{R_S}$
Mesh Current Analysis	[Z] [I] = [V]
Nodal Voltage Analysis	[Y] [V] = [I]
Delta to Star Conversion	$Z_1 = \frac{Z_A Z_C}{Z_A + Z_B + Z_C}$ $Z_2 = \frac{Z_A Z_B}{Z_A + Z_B + Z_C}$ $Z_3 = \frac{Z_B Z_C}{Z_A + Z_B + Z_C}$
Star to Delta Conversion	$Z_A = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$ $Z_B = Z_2 + Z_3 + \frac{Z_2 Z_3}{Z_1}$ $Z_C = Z_1 + Z_3 + \frac{Z_1 Z_3}{Z_2}$
Inductive Reactance	$X_L = 2\pi fL$
Capacitive Reactance	$X_C = \frac{1}{2 \pi f C}$
Three Phase Star – Connected Load	$V_L = \sqrt{3}\ V_{PH}$ $I_L = I_{PH}$ $Z_{PH} = \frac{V_{PH}}{I_{PH}}$

Three Phase Delta - Connected Load	$V_L = V_{PH}$ $I_L = \sqrt{3}\ I_{PH}$ $Z_{PH} = \dfrac{V_{PH}}{I_{PH}}$
Three Phase Apparent Power	$S_T = 3\ V_{PH}\ I_{PH} = \sqrt{3}\ V_L\ I_L$
Three Phase Active/Real/True Power	$P_T = 3\ V_{PH}\ I_{PH} \cos\phi = \sqrt{3}\ V_L\ I_L \cos\phi$
Three Phase Reactive Power	$Q_T = 3\ V_{PH}\ I_{PH} \sin\phi = \sqrt{3}\ V_L\ I_L \sin\phi$
Power factor	$\text{Power factor} = \cos\phi = \dfrac{P}{S}$
Two-Wattmeter Method	$W_1 = V_L \times I_L \times \cos(\theta - 30^0)$ $W_2 = V_L \times I_L \times \cos(\theta + 30^0)$ $P_T = W_1 + W_2$ $\text{Power factor} = \cos\left(\tan^{-1}\left[\sqrt{3}\left(\dfrac{W_1 - W_2}{W_1 + W_2}\right)\right]\right)$

ANSWERS

1. $V_S = 15.54$ V (B +ve), $R_S = 8.44\ \Omega$

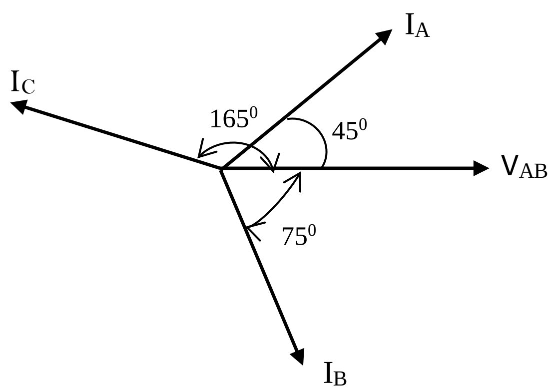
2. $R_1 = 27.85\ \Omega$, $R_2 = 59.49\ \Omega$, $R_3 = 130.89\ \Omega$

   $I_T = 0.42\ \angle 0^0$ A

3. $I_A = 4.51\angle -81.34^0$ A, $I_B = 4.51\angle -201.34^0$ A or $4.51\angle 158.66^0$, $I_C = 4.51\angle 38.66^0$ A

   If the one of the phase impedance is open-circuited, that particular line current is 0 A and the values of the other two line currents remain the same.

4. $I_A = 6.93\angle 45^0$ A, $I_B = 6.93\angle -75^0$ A, $I_C = 6.93\angle -195^0$ A or $6.93\angle 165^0$ A



5. Reactive Power, Q = 22.5 kVAR
   $X_C = 11.28\ \Omega$

6. $P_T = 16$ kW, $Q_T = 10.85$ kVAR, $S_T = 19.33$ kVA
   Power Factor = 0.828 lagging

B1(a). $$\begin{bmatrix} \frac{1}{2}+\frac{1}{5}+\frac{1}{5} & -\left(\frac{1}{5}+\frac{1}{5}\right) \\ -\left(\frac{1}{5}+\frac{1}{5}\right) & \frac{1}{4}+\frac{1}{5}+\frac{1}{5} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} \frac{20}{2}+6 \\ \frac{30}{4}-6 \end{bmatrix}$$

$V_{4\Omega} = -11.76$ V or 11.76 V

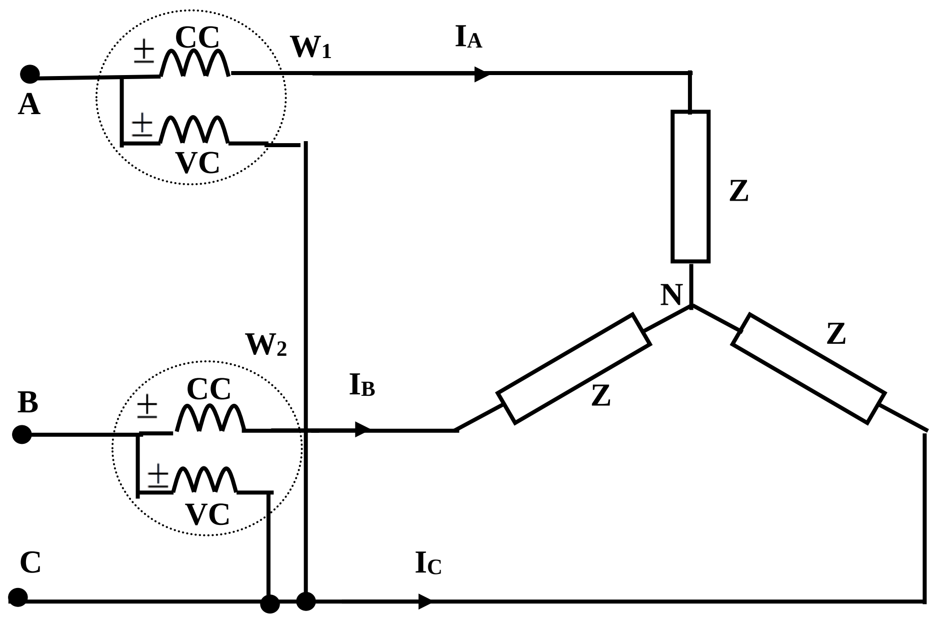
(b). $I_T = 1.18$ A or -1.18 A

B2(a). $I_B = 50\angle -30^0$ A, $I_C = 50\angle -150^0$ A

$V_{AB} = 400\angle -210^0$ V or $400\angle 150^0$ V, $V_{BC} = 400\angle 30^0$ V, $V_{CA} = 400\angle \text{-}90^0$ V

$Z = 4.62\angle 30^0\ \Omega$

(b).



$W_1 = 20$ kW, $W_2 = 10$ kW, $P_T = 30$ kW