2017/2018 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)

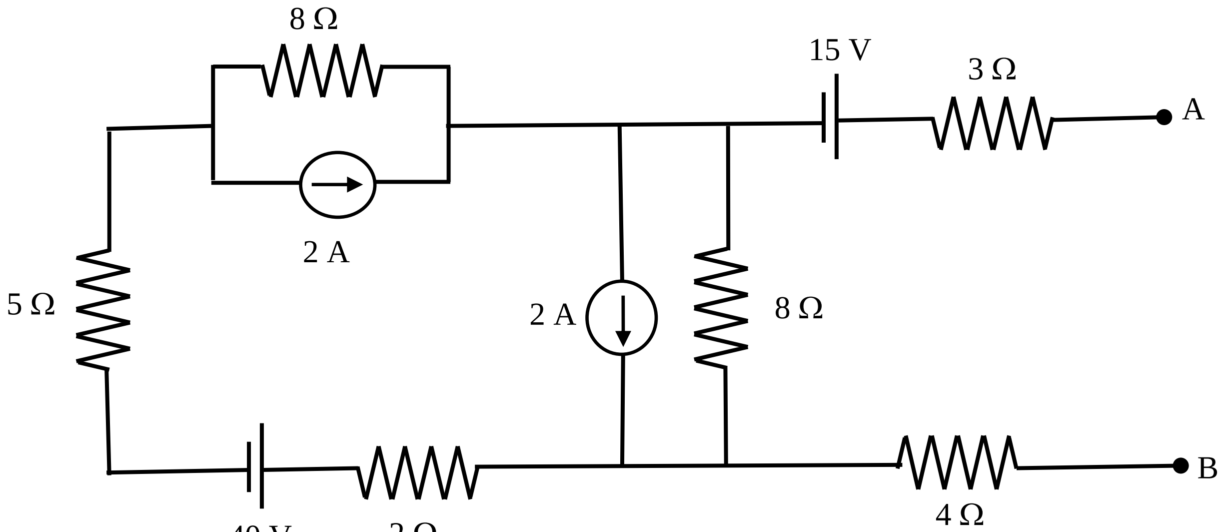

Figure A1

A2. For the circuit shown in Figure A2, convert the star-connected resistors as shown in the dotted box into an equivalent delta-connection, and hence determine the total resistance across terminals X and Y. (10 marks)

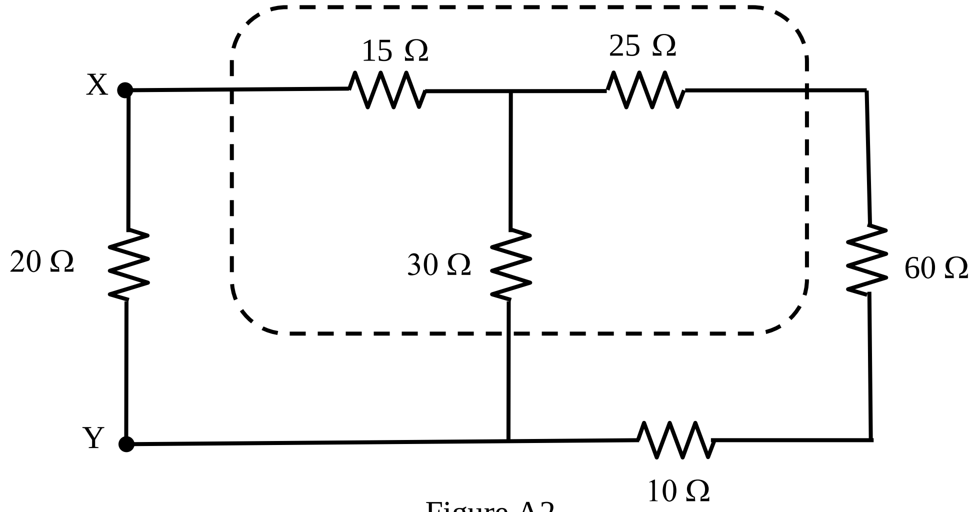

Figure A2

A3. A balanced delta-connected load with a phase impedance of (4 + j8) Ω is connected to a 300 V, 50 Hz, ABC supply. Taking V_{BC} as the reference voltage, calculate the:

(a) phase current (I_{BC}), (4 marks)

(b) line current (I_B), (2 marks)

(c) total apparent and reactive power supplied to the load. (4 marks)

A4. A 400 V, 50 Hz, 3-phase distribution system supplies a 5 kVA load at a power factor of 0.6 lagging. A three-phase capacitor bank of 4 kVA is connected across the load terminals to improve the power factor. Calculate the:

(a) real and reactive power of the load, (5 marks)

(b) power factor after adding the capacitor bank, and (3 marks)

(c) reactive power of the system after power factor improvement. (2 marks)

A5. A 3-phase, 4-wire, 400 V, ABC system supplies an unbalanced star-connected load. Taking V_{BN} as the reference, the line currents flowing into the load are as follows:

$I_A = 5\angle 90^0$ A , $I_B = 10\angle 45^0$ A and $I_C = 6\angle -30^0$ A

Determine the:

(a) phase impedances of the unbalanced star load, and (7 marks)

(b) total real power of the system. (3 marks)

A6. A delta-connected load consists of three similar impedances. When the load is connected to a 3-phase, 4-wire, 250 V, 50 Hz supply, the phase current is 10 A and the power factor is 0.75 lagging.

(a) Draw a circuit diagram showing the connection of a single wattmeter required for measuring the phase power of the delta-connected load. (4 marks)

(b) If the total power consumption of the delta-connected load is measured using the two-wattmeter method, determine the reading of each wattmeter. (6 marks)

SECTION B: 2 QUESTIONS (20 marks each)

B1(a). Design an equivalent circuit using Norton's Theorem across terminals A and B for the network shown in Figure B1. (Include circuit diagrams for finding I_N and R_N)

(17 marks)

(b). Draw the Norton's equivalent circuit. (3 marks)

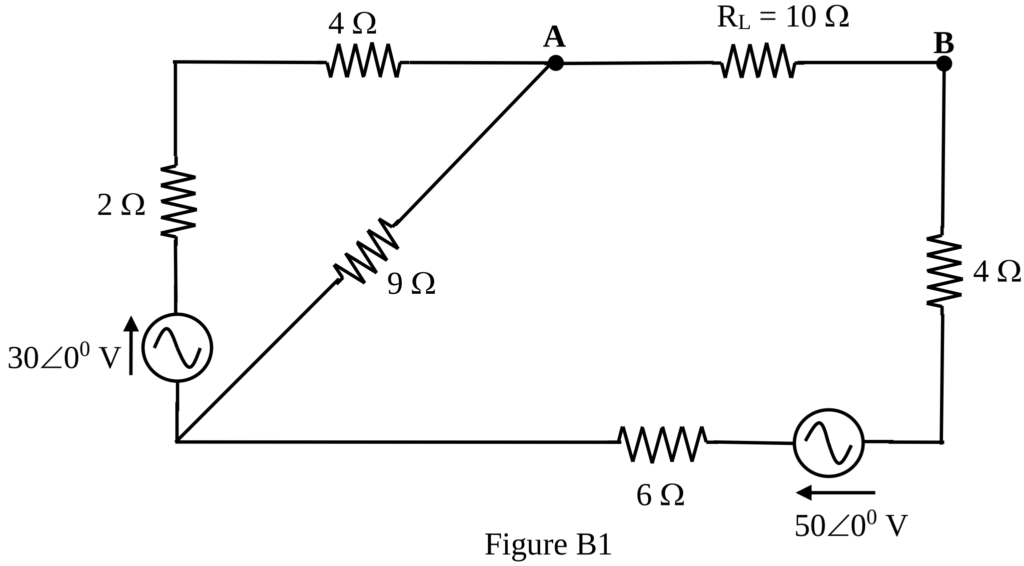

Figure B1

B2. Figure B2 shows a 3-phase star configuration network with equal loads, having a power factor of 0.8 leading. Calculate the:

(a) line voltages (V_{AB}, V_{BC}, V_{CA}), (6 marks)

(b) phase impedance of the star-connected load in polar form, (4 marks)

(c) passive elements that make up each phase of the load. (4 marks)

Draw a phasor diagram showing the line voltages and line currents. (6 marks)

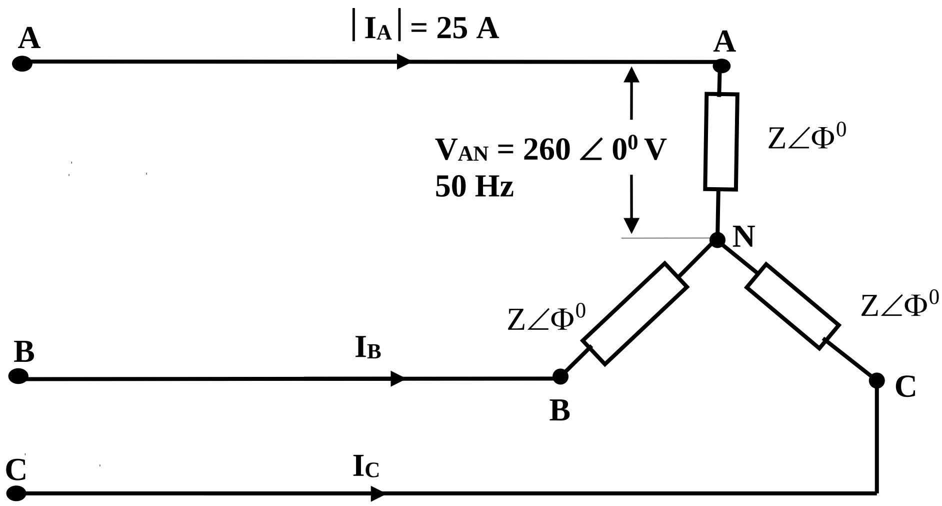

Figure B2

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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	$X_L = 2\pi f L$
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:

A1. V_S = 3.79 V, R =12.22 Ω

A2. $R_1 = 52.5\Omega, R_2 = 63\Omega, R_3 = 105\Omega$

R_{XY} =12.99 Ω

A3. $I_{BC} = 33.56\angle -63.43^0$ A, $I_B = 58.13\angle -93.43^0$ A

$S_T = 30.21$ kVA, $Q_T = 27.02$ kVAr

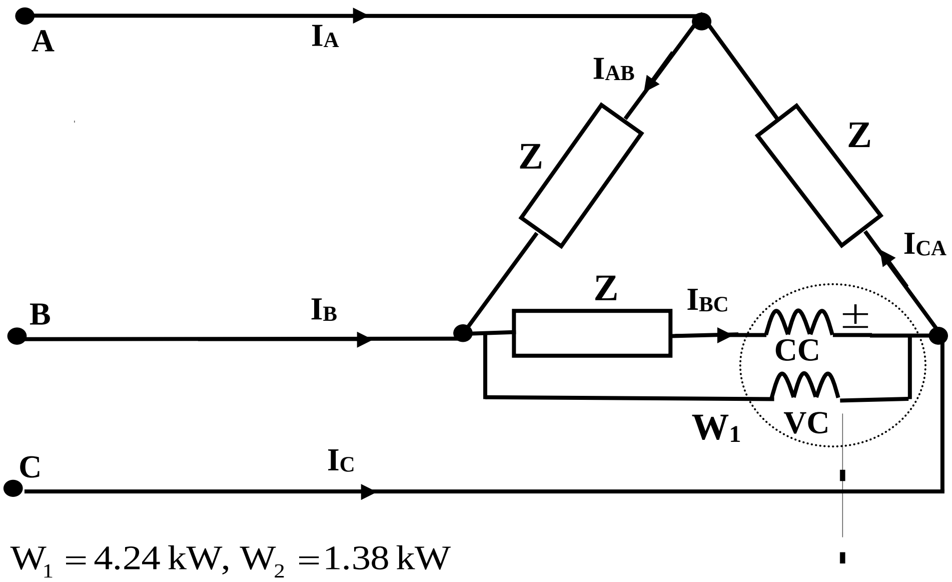
A4. Real Power, P = 3 kW, Reactive Power, Q = 4 kVAr
New power factor = 1
Reactive Power, Q_T = 0 kVAr

A5. $Z_A = 46.19\angle -330^0\ \Omega$ or $46.19\angle 30^0\ \Omega, Z_B = 23.09\angle -45^0\ \Omega,$

$Z_C = 38.49\angle -90^0\ \Omega$

P_T = 2.63 kW

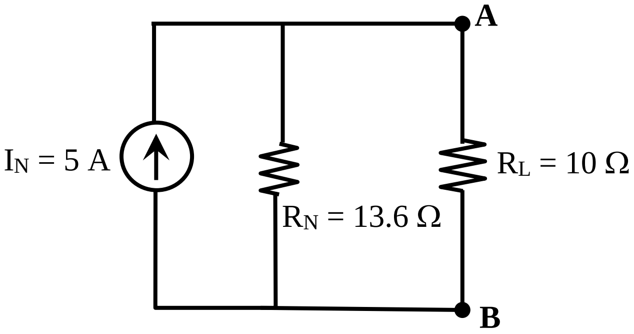
A6.



$W_1 = 4.24$ kW, $W_2 = 1.38$ kW

B1. $I_N = 5$ A, $R_N = 13.6\Omega$

Norton's Equivalent Circuit



B2. $V_{AB} = 450.33\angle 30^0$ V, $V_{BC} = 450.33\angle -90^0$ V, $V_{CA} = 450.33\angle -210^0$ V or $450.33\angle 150^0$ V

$Z = 10.4\angle -36.87^0\ \Omega$,

$R = 8.32\,\Omega$

$C = 510.11\,\mu F$