2019/2020 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 current source across terminals X and Y. (10 marks)

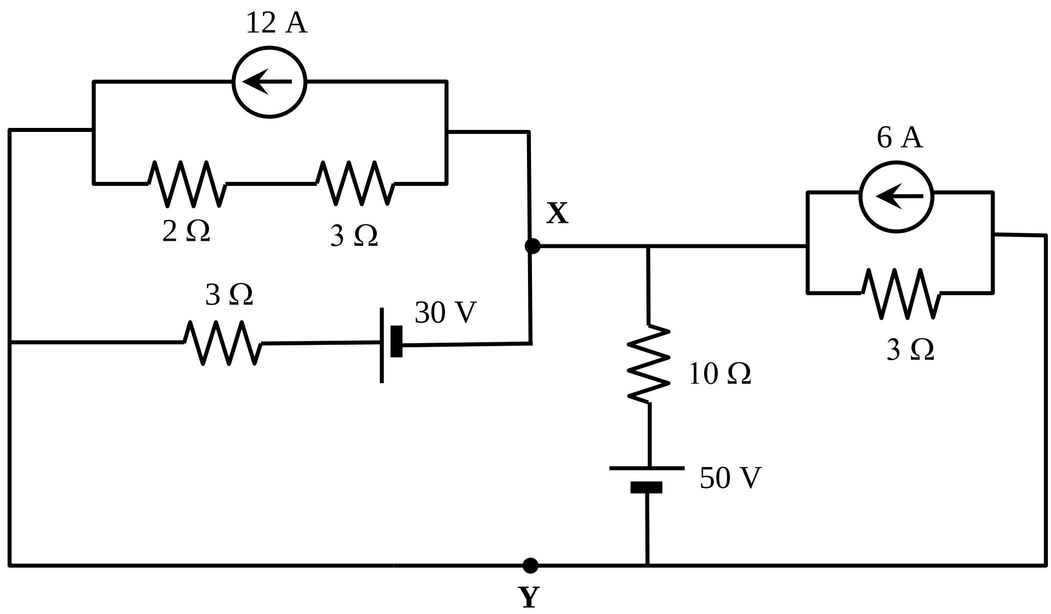


Figure A1

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 calculate the total supply current. (4 marks)

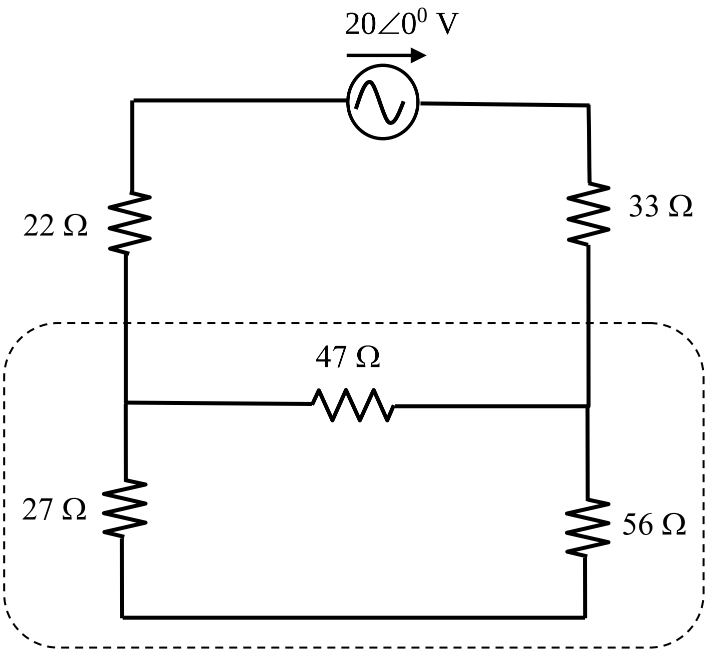


Figure A2

A3. A three-phase balanced star-connected load is connected to a 350 V, 50 Hz, ABC supply. Taking V_{BC} as the reference voltage, the line current I_B is $15\angle{-65^0}$ A.

(a) Calculate the line currents (I_A, I_C), (2 marks)

(b) Calculate the value of the resistance for each phase of the load. (4 marks)

(c) Draw a phasor diagram showing the reference voltage and line currents. (4 marks)

A4. A three-phase, 3-wire, ABC system supplies a delta-connected load of phase impedance (10 - j8) Ω. The line current I_A drawn is found to be $60\angle{-60^0}$ A.

(a) Calculate the line voltage V_{AB}, (4 marks)

(b) Calculate the total real power. (2 marks)

(c) Draw a phasor diagram showing the line current I_A and all the phase currents. (4 marks)

A5. A three phase, four-wire, 415 V system has the following currents flowing <u>towards the loads</u>:

$$I_A = 12\angle{-240^0}\text{ A},\ I_B = 30\angle{40^0}\text{ A and } I_C = 25\angle{-30^0}\text{ A}$$

Taking V_{BN} as the reference voltage, calculate

(a) the neutral current flowing from the load to the supply, (2 marks)

(b) the phase impedances Z_B and Z_C, (4 marks)

(c) the apparent and reactive power in the 'C' phase. (4 marks)

A6. A balanced delta-connected inductive load is connected to a 300 V, 50 Hz, three-phase, 3-wire supply. When using the two-wattmeter method to measure the power supplied to the load, the readings on the two wattmeters are 1500 W and 500 W. Calculate

(a) the total power, (2 marks)

(b) the power factor, (3 marks)

(c) the phase impedance of the delta-connected load in polar form. (5 marks)

SECTION B: 2 QUESTIONS (20 marks each)

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

(i) write the mesh current equations for I_1 and I_2 in matrix form by inspection, and hence (9 marks)

(ii) determine the voltage across terminals X and Y. (8 marks)

(b). If the $4\angle 0^0$ V supply is short-circuit, determine the total supply current. (3 marks)

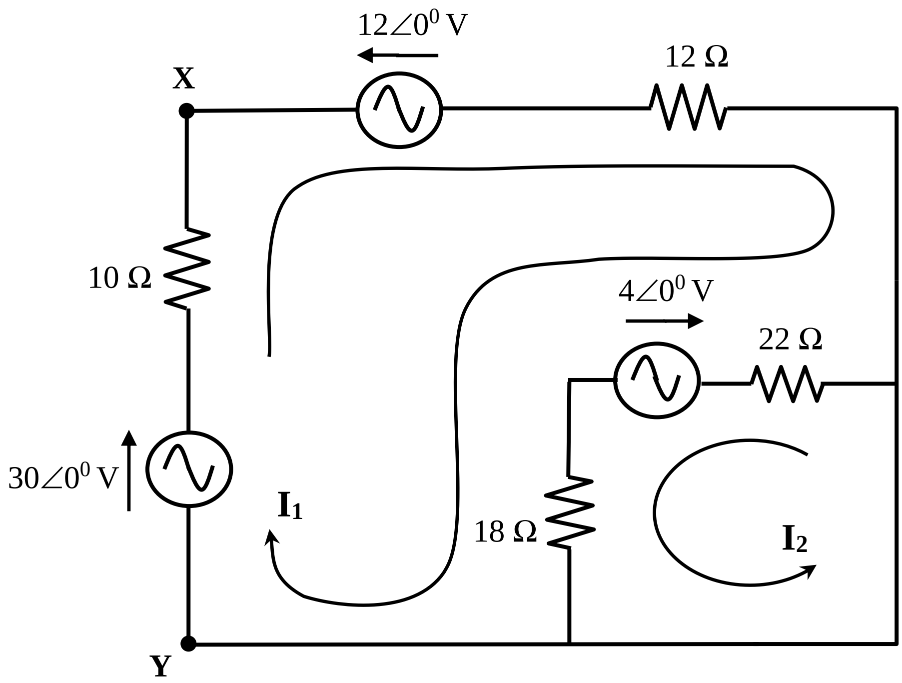


Figure B1

B2(a). A balanced star-connected load of phase impedance (6 + j8) Ω is connected to a three-phase, 3-wire, 400 V, ABC system. Determine

(i) the power factor, (3 marks)

(ii) the total apparent, real and reactive power of the star-connected load. (8 marks)

(b). A 10 kVAR three-phase capacitor bank is connected across the load terminals, determine

(i) the overall apparent, real and reactive power, (6 marks)

(ii) the new power factor. (3 marks)

- End of Paper –

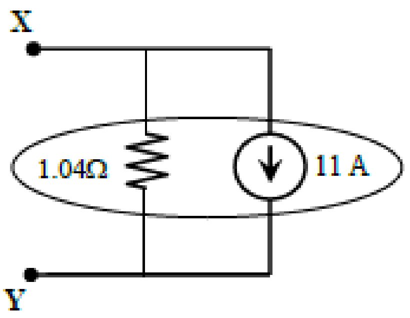
Formulae

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 (for 2 resistors)	$I_1 = \frac{R_2}{R_1 + R_2} I_T$
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:

A1



A2

(a) $R_1 = 9.76\Omega$; $R_2 = 11.63\Omega$; $R_3 = 20.25\Omega$

(b) $I_T = 0.24$ A

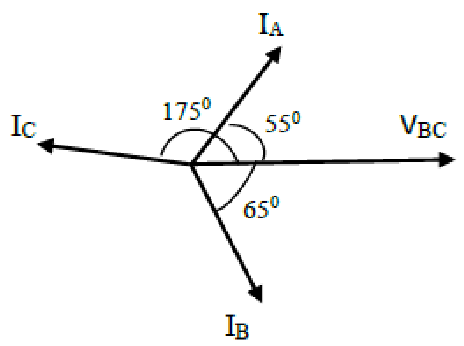
A3

(a) $I_A = 15\angle -305^o$ or $15\angle 55^o$ A

$I_C = 15\angle -185^o$ or $15\angle 175^o$ A

(b) $R_{PH} = 11.03\ \Omega$

(c)



A5

(a) $I_N = 42.28\angle 23.97^o$ A

(b) $Z_B = 7.99\angle -40^o$

$Z_C = 9.58 \angle -90^o$

(c) S_C = 5.99 kVA

Q_C = 5.99 kVAR

A6

(a) PT = 2 kW

(b) power factor = 0.756 lagging

(c) $Z_{PH} = 102.04 \angle 40.89^o$

B1

(a)

(i) $$\begin{bmatrix} 62 & 40 \\ 40 & 40 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 14 \\ -4 \end{bmatrix}$$

(ii) V = 21.8 V or -21.8 V

(b) I_T = 0.82 A

B2

(a)

(i) Power factor = 0.6 lagging

(ii) S_T = 16 kVA P_T = 9.6 kW Q_T = 12.8 kVAR

(b) S_T = 10 kVA P_T = 9.6 kW Q_T = 2.8 kVAR

(ii) new power factor = 0.96 lagging