Engineering **FIRST YEAR**

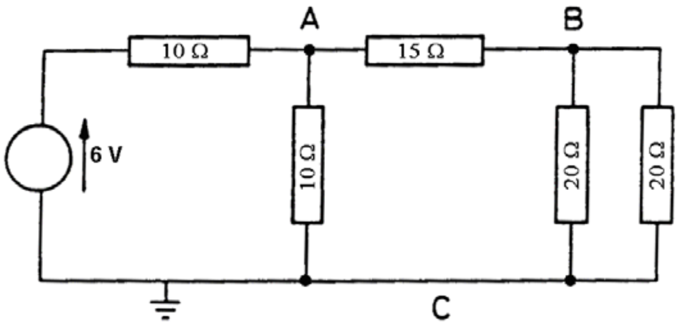
Part IA Paper 3 : Electrical and Information Engineering

LINEAR CIRCUITS AND DEVICES
EXAMPLES PAPER 1

Elementary questions are marked †, questions of Tripos standard * . Where applicable, the lecture material on which the question is based is shown e.g. [L1], [L5-6].

Introductory Question – Resistors in series and parallel – answers on p4

Find the potential difference with respect to earth of nodes *A* and *B* in the circuit below.



Voltage & current generators

† 1. A dc power supply has output voltages of 600 V and 650 V when the output current is 0.4 A and 0.2 A respectively. What simple arrangement of (a) an ideal voltage source in series with a resistance, and (b) an ideal current generator in parallel with a conductance, gives the same relationship between output voltage and current? [L1]

2. Three batteries have open-circuit voltages of 6.5V, 6.5V and 6.0V and when each is individually connected to a 1Ω load the corresponding terminal voltages fall by 0.5V, 0.4V and 0.5V.

(a) Find the internal resistance of each battery.

(b) What is the terminal voltage when the three batteries are connected in parallel in the same sense, –ve to –ve, +ve to +ve? Determine the current flowing in each battery.
(Hint – change the Thévenin model for each battery into the Norton model. These can then simply then be added to give one current generator I and one parallel conductance G, and I/G will be the terminal voltage.)

(c) If this parallel combination is connected to a load of 0.1Ω, what are the new voltages and currents?

(d) With the circuit arrangement of part (c), determine the electrical power dissipated in the load and the batteries. [L2]

Nodal voltage and mesh current analysis

† 3. Repeat Qn 2(b) using Nodal Voltage Analysis to find the terminal voltage. [L2]

† 4. In the circuit of Fig. 1 find the current in the 2 Ω resistor using
(a) a nodal voltage analysis, and (b) mesh current analysis. [L2]

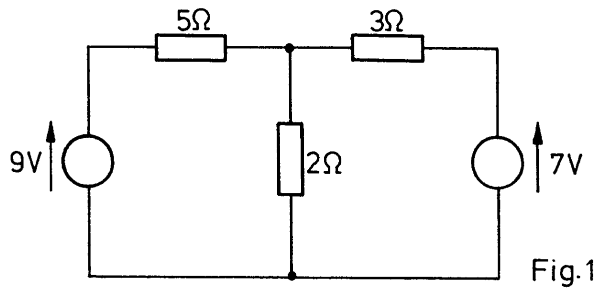


Fig.1

5. Determine the current in the 2Ω resistor in the circuit of Fig. 2 using nodal voltage analysis. [L2]

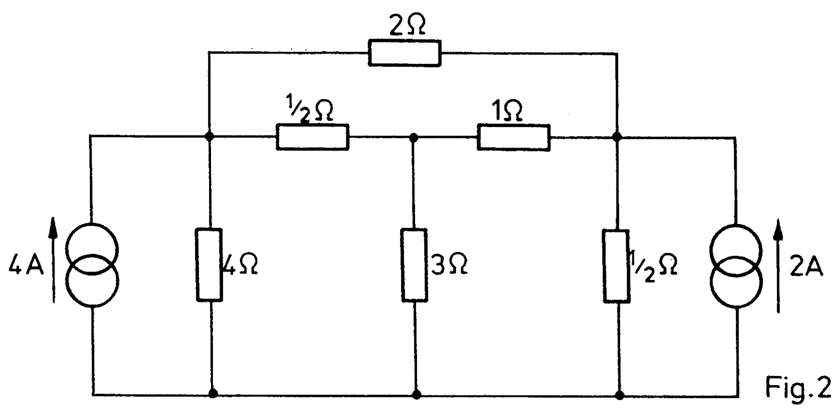


Fig.2

6. In the circuit of Fig. 3 find, using mesh analysis, the loop currents I_1, I_2, I_3 in terms of the source voltages V_1 and V_2. [L3]

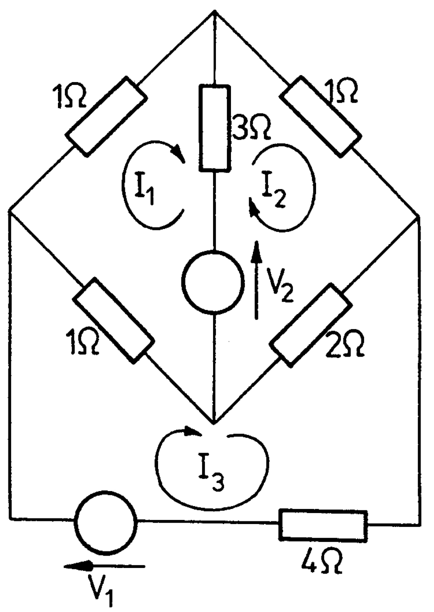


Fig.3

7. For the circuit of Fig. 4, determine the number of independent loops required to find the currents flowing if the method of mesh analysis is used. By converting the voltage sources into their Norton equivalents, show that nodal analysis requires two voltage unknowns. Hence calculate the potential of point P with respect to point O if all resistors have a value of 0.5 Ω. [L4]

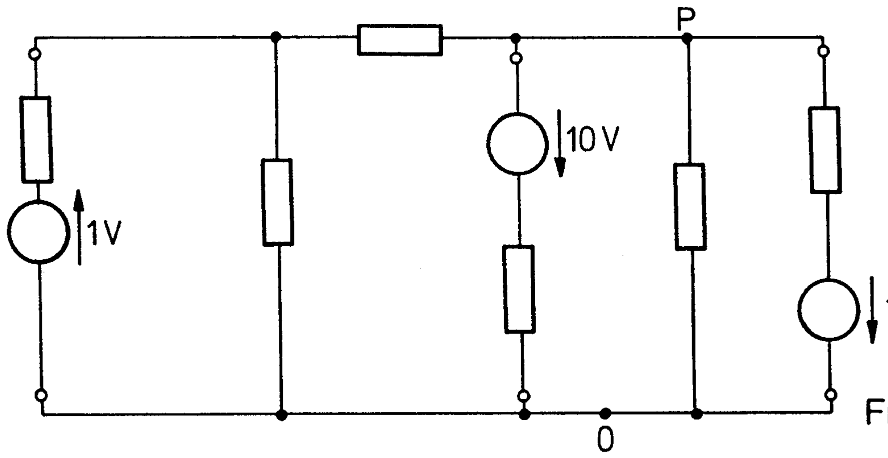


Fig.4

Additional questions. These are best tackled when you have completed Qns 1-7. Your supervisor should advise.

* 8. Repeat Qn.5, using a star-delta transformation of the centre three resistors (1/2 Ω, 1Ω and 3Ω). Use the star-delta transformation equations in the Electrical Data Book. Note that this will reduce the 3 mesh points to 2 so fewer equations will solve the problem. A Norton to Thévenin transformation on each of the current sources reduces the maths still further.

9. In the circuit of Fig. 6, find the current in X for $V_1 = 7V$.

(HINT: Starting at the right hand side of the circuit, assume a current of 1A flows in resistor X, and work out the potential drops back to the voltage source. Then use scaling.)

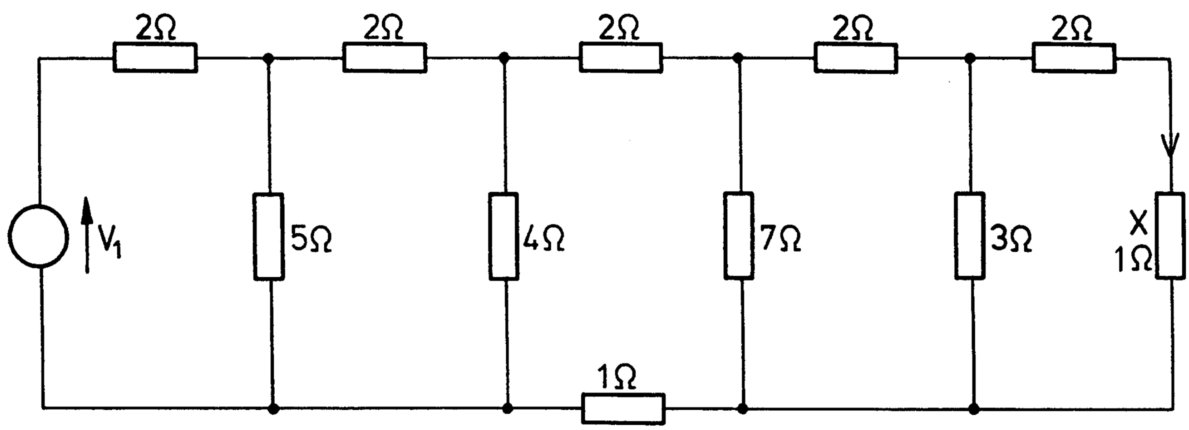


Figure 6

* 10. Note that the method suggested for solving Qn. 9 is simple numerically only because of the given resistor values. Consider the following alternatives:

(a) If mesh current analysis were used, how many unknown currents are there in the circuit of Fig. 6? Do <u>not</u> write the equations (or solve them).

(b) If nodal voltage analysis were used, what is the smallest number of unknown voltages to put on the circuit to solve the problem. Note that it is allowable to remove the 1Ω at the centre bottom of the circuit if the 2Ω above it is increased to 3Ω - as far as determining the current in X is concerned. Discuss this with your supervisor if necessary.

(c) If V_1 = 7 V and the 2Ω and 5Ω resistors connected to V_1 were replaced by a single Thévenin generator V_2 and series resistance R_2 feeding the rest of the circuit, find values for V_2 and R_2. If the next 2Ω and 4Ω are now added to V_2 and R_2, what single Thévenin generator V_3 and R_3 is equivalent to the left half of the circuit?

Go on in this way to determine the current in X. Note that <u>no</u> simultaneous equations have to be solved as in (a) or (b). [L1-4]

ANSWERS

Introductory question. 2.5 V, 1.0 V

1. 700 V, 250 Ω; 2.8 A, 4 mS.

2. 0.0833 Ω, 0.0656 Ω; 0.0909 Ω; 6.36 V, 1.73 A, 2.19 A. –3.92 A; 5.04 V, 17.5 A, 22.3 A, 10.6 A; 254.0 W, 25.5 W, 32.6 W, 10.2 W

3. 6.36 V

4. 2 A

5. 1 A

6. $(12\,V_1 - 15\,V_2)/109$; $(13\,V_1 + 11\,V_2)/109$; $(21\,V_1 + V_2)/109$.

7. 4; 2; –5.37 V.

8 1 A

9. 0.125 A.

10. 5; 4; 5 V, 1.43 Ω; 2.69 V, 1.85 Ω; 1.59 V, 2.86 Ω; 0.61 V, 1.86 Ω, 0.125 A

Tripos Questions

1997 Paper 3, Q3
1999 Paper 3, Q3
2001 Paper 3, Q1
2002 Paper 3, Q2(a), (b)
2004 Paper 3, Q3(a)
2005 Paper 3, Q1

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