# Part 1A Paper 3: Electrical and Information Engineering,

## ANALYSIS OF CIRCUITS & DEVICES

## EXAMPLES PAPER 1

This examples paper is based on material from lectures 1-4. Where possible, the lectures on which the questions are based are indicated, e.g. [L3]. As usual, questions containing material of tripos standard are marked *.

**Introductory questions**

i) Find the output voltage $V_{OUT}$ across $R_2$ in the circuit of Fig 1(a) as a function of the input voltage $V$.

ii) Find the current $I_{OUT}$ through $R_2$ as a function of the input current $I$ in Fig 1(b).

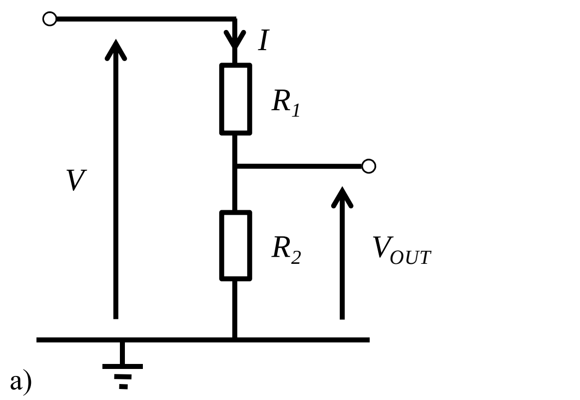


Fig. 1.

1. (a) A DC power supply consists of an ideal voltage source, $V_0$ in series with an internal resistance, $R_S$ as shown in Fig. 2(a). When two different test resistances ($R_{test}$) are connected across the circuit and the voltage across $R_{test}$ and current through $R_{test}$ are measured to be 600 V, 0.4 A and 650 V, 0.2 A, respectively. Determine the quantities $V_0$ and $R_S$. (*Hint: you don't need to know the values of* $R_{test}$)

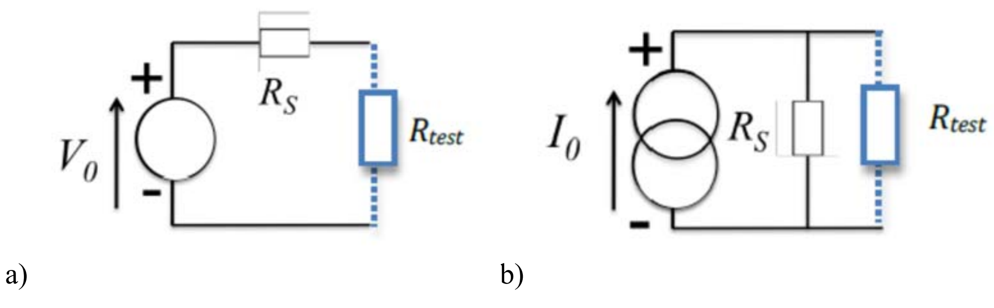


Fig. 2.

(b) Now consider the case where the power supply consists of an ideal current source, $I_0$, in parallel with the internal resistance $R_S$. Assuming that the test output voltages and currents are measured as above, determine the quantities $I_0$ and $R_S$. Is there another way to calculate them from part (a)? **[L1]**

2. Three batteries have DC voltages measured of 6.5 V, 6.5 V and 6.0 V with no load connected. When each battery is individually connected to a 1Ω load, the corresponding voltages across the load drop by 0.5 V, 0.4 V and 0.5 V, respectively.

(a) Determine the internal resistance $R_{SX}$ of each battery.

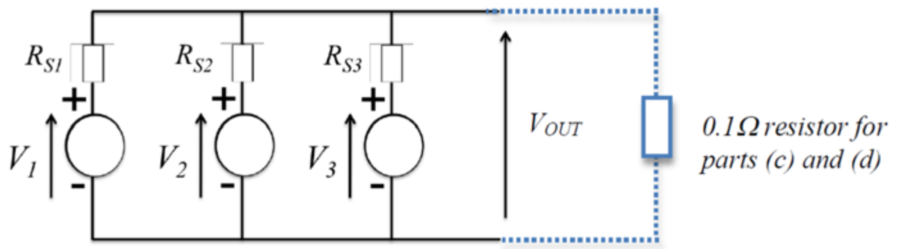


Fig. 2.

(b) What is the output voltage ($V_{OUT}$) when the three batteries are connected in parallel as shown in Fig. 2? What is the current flowing through each internal resistance $R_{SX}$? (*Hint – a Thévenin to Norton equivalent conversion for each battery*)

(c) If this battery pack is now connected to a load of 0.1 Ω, what will be the new output voltage $V_{OUT}$ and the currents flowing through each internal resistance $R_{SX}$?

(d) For the load resistance described in part (c), determine the electrical power dissipated in the load and in each of the batteries. Where is the power dissipated in the batteries? **[L2]**

3. In the circuit of Fig. 3, find the voltage across and current through the 2Ω resistor using (a) Nodal analysis (b) Mesh analysis.

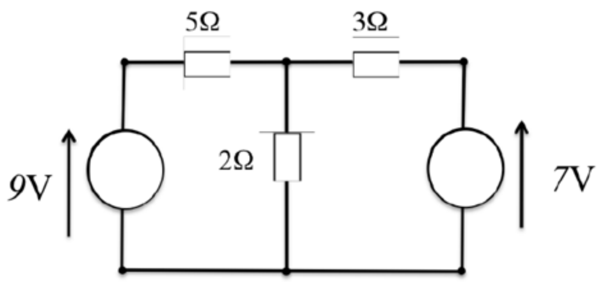


Fig. 3

4. Determine the current through the 2Ω resistor in the circuit shown in Fig. 4 using nodal voltage analysis.

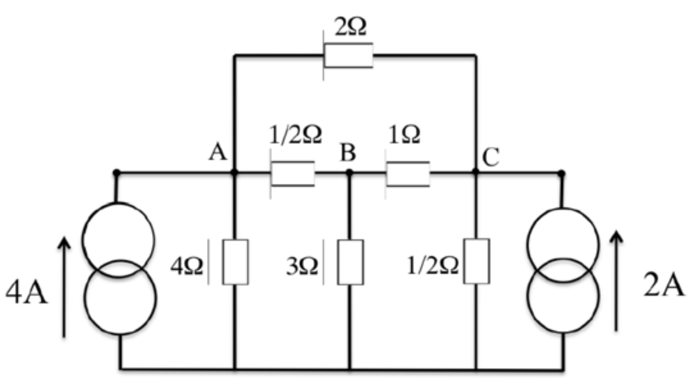


Fig. 4

5. Another way to solve Q4 is using a star-delta transformation (see databook) at Node B. Use this transformation reduce the number of nodes and simplify the problem. A Norton to Thévenin transformation can then be used to reduce the maths further. [L4]

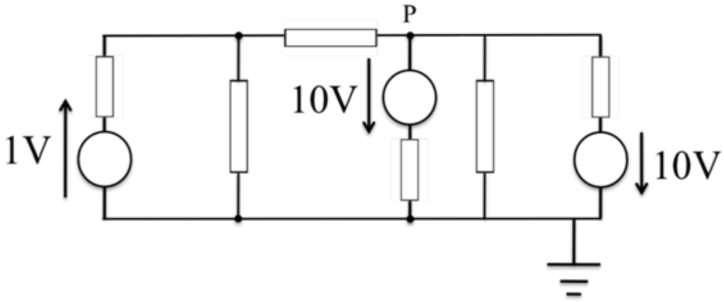


Fig. 5

6. For the circuit shown in Fig. 5, 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 only requires two voltage unknowns. Hence calculate the potential of point P with respect to ground, assuming that all resistors are 1 Ω. **[L4]**

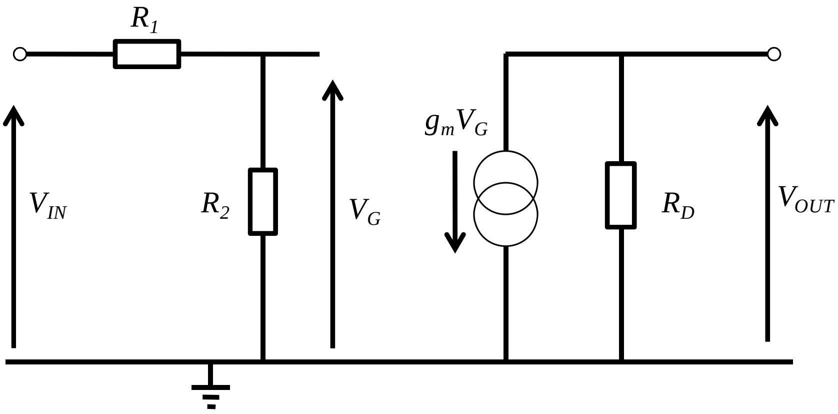


Fig. 6.

7. The circuit in Fig. 6 represents a type of transistor amplifier, where the internal current source depends on the value of the voltage $V_G$ in the circuit. The parameter $g_m$ and resistor $R_D$ are internal properties of the amplifier and depend on the choice of transistor. Calculate the gain G of the amplifier ($G = V_{OUT}/V_{IN}$) as a function of the circuit components. What are the units of $g_m$?

8. A multimeter set to measure voltage is as show in Fig.7. The meter has an internal resistance of $r$ = 500 Ω and a series multiplier resistance $R_M$. Calculate the value of $R_M$ when the multimeter is set to its 10 V range and it requires 100 µA current to register a full scale reading on the meter.

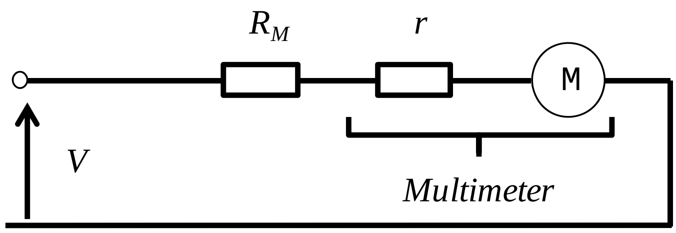


Fig. 7.

The same multimeter, on its 10 V range, is to be used to measure $V_{OUT}$ in the circuit in Fig.1a, with $V$ = 20 V, $R_1 = R_2 = 100$ kΩ. Calculate the expected value of $V_{OUT}$ and the actual voltage measured at $V_{OUT}$ when the multimeter is connected. How can this problem be minimised?

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Answers

Introductory question $V_{OUT} = \frac{R_2}{R_1+R_2}V$, $I_{OUT} = \frac{R_1}{R_1+R_2}I$.

1. (a) 700V, 250Ω; (b) 2.8A, 250Ω

2. (a) 0.0833Ω, 0.0656Ω, 0.0909Ω; (b) 6.36V, 1.73A, 2.19A, -3.92A; (c) 5.04V, 17.5A, 22.3A, 10.6A; (d) 254W, 25.5W, 32.6W, 10.2W

3. 4V, 2A

4 & 5. $V_A$ = 4V, $V_C$ = 2V, Current = 1A

6. 4 loops; $V_P$ = -59/11V (-5.36V)

7. $G = \frac{V_{OUT}}{V_{IN}} = -\frac{g_m R_2 R_D}{R_1+R_2}$

8. $R_M$ = 99.5 kΩ, $V_{OUT}$ = 10 V, Measured $V_{OUT}$ = 6.66 V.