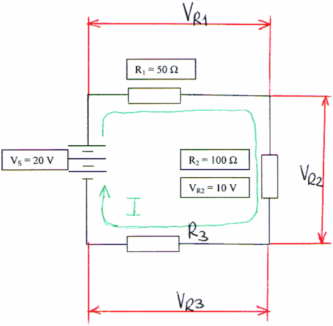
DC ELECTRICAL FUNDAMENTALS TRIAL END-SEMESTER TEST

- This test is **closed** book, calculator permitted.
- Time permitted 1½ hours.
- Answer questions in the spaces provided.
- **60 MARKS TOTAL (70% pass)**
- Clearly label all currents, resistors and voltage drops in the circuits and state any assumptions in order to obtain a full mark
- When calculating values, show clearly all steps, starting with the formula, then substituting with numbers and finally show the measuring units of the obtained result. Otherwise **NO MARKS** are given

Q1) In the circuit below find the unspecified values. **[5 marks]**



To begin with, the circuit has to be clearly labelled.

$$I_T = \frac{V_{R2}}{R_2} = \frac{10}{100} = 0.1\text{A} = 100\text{mA}$$

$$V_{R1} = I_T \cdot R_1 = 0.1 \times 50 = 5\text{V}$$

$$V_{R3} = V_S - V_{R1} - V_{R2} = 20 - 5 - 10 = 5\text{V}$$

$$R_3 = \frac{V_{R3}}{I_T} = \frac{5}{0.1} = 50\,\Omega$$

$P_{R1} = I_T^2 R_1 = (0.1)^2 \times 50 = 0.5\text{W}$ [½ W]

$P_{R2} = I_T^2 R_2 = (0.1)^2 \times 100 = 1\text{W}$ [1 W]

$P_{R3} = I_T^2 R_3 = (0.1)^2 \times 50 = 0.5\text{W}$ [½ W]

nominal resistor power ratings are given in brackets

Q2) In the voltage divider below find the following voltages: **[5 marks]**

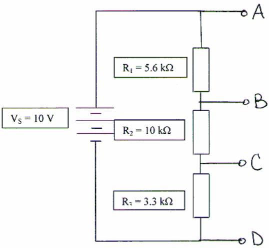
$V_{AD} = ?$

$V_{BD} = ?$

$V_{CD} = ?$

$V_{CB} = ?$

$V_{CA} = ?$



$R_T = R_1 + R_2 + R_3 =$
$= 5.6 + 10 + 3.3 = 18.9\,k\Omega$

$V_{R1} = \frac{R_1}{R_T} V_S = \frac{5.6}{18.9} \times 10 = 2.96V$

$V_{R2} = \frac{R_2}{R_T} V_S = \frac{10}{18.9} \times 10 = 5.29V$

$V_{R3} = \frac{R_3}{R_T} V_S = \frac{3.3}{18.9} \times 10 = 1.74V$

+

double checking: $V_S = 9.99V$

$V_{AD} = V_S = +10V$

$V_{BD} = V_{R2} + V_{R3} = 5.29 + 1.74 =$
$= +7.03V$

$V_{CD} = V_{R3} = +1.74V$

$V_{CB} = -V_{R2} = -5.29V$

$V_{CA} = -(V_{R1} + V_{R2}) =$
$= -(2.96 + 5.29) =$
$= -8.25V$

Q3) A string of five series resistors is connected across a 12 volts battery. Zero volts are measured across all of the resistors except R_2. What is wrong with the circuit? What voltage will be measured across R_2? **[3 marks]**

Ans:

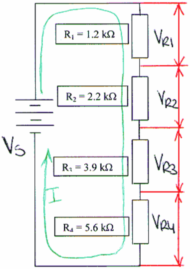
There are two possibilities.

The first one is that R_2 is an open circuit, in which case there is no current flowing in the circuit and 12 V will be measured across R_2.

The second possibility is that all four resistors, except R_2 are short circuited. In this case there will be current flowing in the circuit, which will be limited by the value of R_2 only. Again there will be 12V measured across R_2. The second case is much more improbable, since four shorts in a series circuit are very unlikely to happen simultaneously.

Q4) The following ¼ W resistors are connected in series: 1.2kΩ, 2.2kΩ, 3.9kΩ and 5.6kΩ. What is the maximum voltage that can be applied across the series resistors without exceeding a power rating? Which resistor will burn out first if excessive voltage is applied? **[5 marks]**

Ans:



The maximum current, which can flow through the lowest and the highest value resistors in this series circuit is:

$$I_{1max.} = \sqrt{\frac{P_{R1}}{R_1}} = \sqrt{\frac{0.25}{1500}} = 12.9\,mA$$

$$I_{4max.} = \sqrt{\frac{P_{R4}}{R_4}} = \sqrt{\frac{0.25}{5600}} = 6.68\,mA$$

∴ The maximum current for this series circuit is limited by R_4 and its value is 6.68 mA.

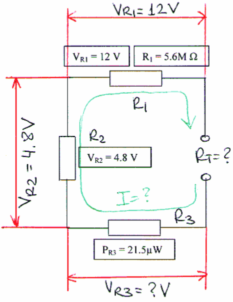
$$R_T = R_1 + R_2 + R_3 + R_4 = 1.2 + 2.2 + 3.9 + 5.6 = 12.9\,k\Omega$$

$$V_{max.} = I_{max} \times R_T = 6.68 \times \cancel{10^{-3}} \times 12.9 \times \cancel{10^{3}}$$

$$V_{max.} = 86.2\,V$$

R_4 will burn out first.

Q5) Find the total resistance in the circuit below. **[5 marks]**



$R_T = ?$

$$I = \frac{V_{R1}}{R_1} = \frac{12}{5.6 \times 10^6} = 2.143\,\mu A$$

$$R_2 = \frac{V_{R2}}{I} = \frac{4.8}{2.143 \times 10^{-6}} = 2.24\,M\Omega$$

$$P_{R3} = I^2 R_3$$

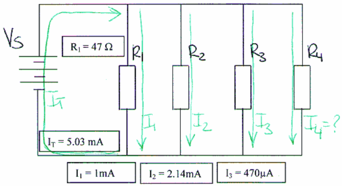
$$R_3 = \frac{P_{R3}}{I^2} = \frac{21.5 \times 10^{-6}}{(2.143 \times 10^{-6})^2} = 4.68\,M\Omega$$

$$R_T = R_1 + R_2 + R_3 = 5.6 + 2.24 + 4.68$$

$$R_T = 12.52\,M\Omega$$

Note: The circuit has to be labelled first.

Q6) Find all unspecified values in the circuit below. **[5 marks]**



$V_S = I_1 \cdot R_1 = 1\times10^{-3} \times 47 = 47\,mV$

$R_2 = \frac{V_S}{I_2} = \frac{47\times10^{-3}}{2.14\times10^{-3}} = 21.96\,\Omega$

$R_3 = \frac{V_S}{I_3} = \frac{47\times10^{-3}}{470\times10^{-6}} = 100\,\Omega$

$I_4 = I_T - I_1 - I_2 - I_3 =$
$= 5.03 - 1 - 2.14 - 0.47 =$
$= 1.42\,mA$

$R_4 = \frac{V_S}{I_4} = \frac{47\times10^{-3}}{1.42\times10^{-3}} = 33.1\,\Omega$

$P_{R1} = \frac{V_S^2}{R_1} = \frac{(47\times10^{-3})^2}{47} = 47\,\mu W$ [1/8W]

$P_{R2} = \frac{V_S^2}{R_2} = \frac{(47\times10^{-3})^2}{21.96} = 100.1\,\mu W$ [1/8W]

$P_{R3} = \frac{V_S^2}{R_3} = \frac{(47\times10^{-3})^2}{100} = 22.1\,\mu W$ [1/8W]

$P_{R4} = \frac{V_S^2}{R_4} = \frac{(47\times10^{-3})^2}{33.1} = 66.7\,\mu W$ [1/8W]

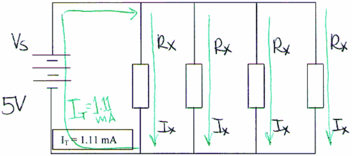
Double checking:

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}} = \frac{1}{\frac{1}{47} + \frac{1}{21.96} + \frac{1}{100} + \frac{1}{33.1}}$

$R_T = 9.34\,\Omega$

$I_T = \frac{V_S}{R_T} = \frac{47\times10^{-3}}{9.34} = 5.03\,mA$

Q7) Four equal-value resistors are connected in parallel. Five volts are applied to the parallel circuit and 1.11 mA are measured from the source. What is the value of each resistor? **[5 marks]**



$I_T = 4 \times I_X$

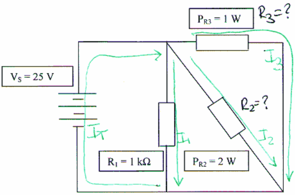
$I_X = \frac{I_T}{4} = \frac{1.11\times10^{-3}}{4}$

$I_X = 277.5\,\mu A$

$R_X = \frac{V_S}{I_X} = \frac{5}{277.5\times10^{-6}}$

$R_X = 18.018\,k\Omega$

Q8) Calculate the currents in the circuit below. **[5 marks]**



Essentialy, the circuit comprises three resistors, connected in parallel. If you cannot see this, draw the equivalent circuit.

$I_1 = \frac{V_S}{R_1} = \frac{25}{1000} = 25\,mA$

$I_2 = \frac{P_{R2}}{V_S} = \frac{2}{25} = 80\,mA$

$I_3 = \frac{P_{R3}}{V_S} = \frac{1}{25} = 40\,mA$

$I_T = I_1 + I_2 + I_3 + I_4 =$

$= 25 + 80 + 40 = \underline{145\,mA}$

Double checking:

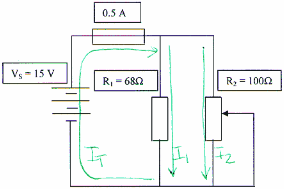
$R_2 = \frac{V_S^2}{P_{R2}} = \frac{25^2}{2} = 312.5\,\Omega$

$R_3 = \frac{V_S^2}{P_{R3}} = \frac{25^2}{1} = 625\,\Omega$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{1000} + \frac{1}{312.5} + \frac{1}{625}} = 172.41\,\Omega$

$I_T = \frac{V_S}{R_T} = \frac{25}{172.41} = \underline{145\,mA}$

Q9) To what minimum value can the 100 Ω rheostat be adjusted before the 0.5A fuse blows? **[5 marks]**



$I_1 = \frac{V_S}{R_1} = \frac{15}{68} = 221\,mA$

The maximum value of $I_T = 0.5A$

$I_T = I_1 + I_2 \quad \therefore$

The maximum value of I_2 is:

$I_2 = I_T - I_1$

$I_2 = 500 - 221 = 279\,mA$

$R_2 = \frac{V_S}{I_2} = \frac{15}{279.10^{-3}} = \underline{53.76\,\Omega}$

Note: Don't get confused that $R_2 = 100\Omega$. This is merely the maximum value of the potentiometer. R_2 is in fact the value you need to find. Assume that the value of the current through the fuse is given, in this case $I_T = 0.5A$.

Q10) Six light bulbs are connected in parallel across 220 V. Each bulb is rated 75 W. What is the current through each bulb and what is the total current? **[5 marks]**

Ans: Let's call the current through each branch I_X. Then the power dissipated in each bulb is:

$$P_X = I_X . V_S \quad \therefore$$

$$I_X = \frac{P_X}{V_S} = \frac{75}{220} = 341\ mA$$

$$I_T = 6 \times I_X = 6 \times 341 = \underline{2.045A}$$

Q11) A certain parallel circuit consists of only ½ W resistors. The total resistance is 1 kΩ and the total current is 50 mA. If each resistor is operating at one-half its maximum power level, determine the following:

[5 marks]

a.) The number of resistors
b.) The current in each branch
c.) The value of each resistor
d.) The applied voltage

Ans. We assume that all resistors are equal value. They operate at ½ of their maximum power rating, therefore each resistor dissipates ¼ W (P_X = 250 mW). Also, we assume that the current in each branch is I_X.

$$V_S = I_T \times R_T = 50 \times \cancel{10^{-3}} \times 1 \times \cancel{10^{3}} = 50V$$

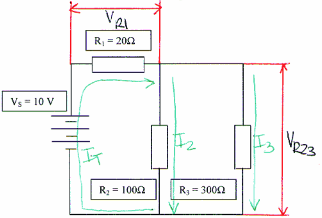
$$I_X = \frac{P_X}{V_S} = \frac{0.25}{50} = 5mA$$

$$\text{number of resistors} = \frac{I_T}{I_X} = \frac{50}{5} = \underline{10 \text{ resistors}}$$

$$R_X = \frac{V_S}{I_X} = \frac{50}{5 \times 10^{-3}} = \underline{10k\Omega} \rightarrow \text{the value of each resistor}$$

Q12) Calculate all missing values in the combinational circuit below.

[5 marks]



$$R_{23} = \frac{R_2 R_3}{R_2 + R_3} = \frac{100 \times 300}{100 + 300} = 75\Omega$$

$$R_T = R_1 + R_{23} = 20 + 75 = 95\Omega$$

$$I_T = \frac{V_S}{R_T} = \frac{10}{95} = 105.26mA$$

$$V_{R1} = I_T R_1 = 105.26 \times 10^{-3} \times 20 = \underline{2.1V}$$

$$V_{R23} = I_T R_{23} = 105.26 \times 10^{-3} \times 75 = \underline{= 7.9V}$$

Double checking:

$$V_S = V_{R1} + V_{R23} = 2.1 + 7.9 = \underline{10V}$$

P.T.O.

$$I_2 = \frac{V_{R23}}{R_2} = \frac{7.9}{100} = 79\,mA$$

$$I_3 = \frac{V_{R23}}{R_3} = \frac{7.9}{300} = 26.33\,mA$$

double checking:

$$I_T = I_2 + I_3 = 79 + 26.33 = 105.33\,mA$$

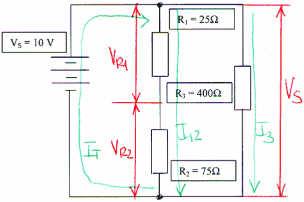
$$P_{R1} = \frac{V_{R1}^2}{R_1} = \frac{2.1^2}{20} = 0.22W\ [1/4W]$$

$$P_{R2} = \frac{V_{R23}^2}{R_2} = \frac{7.9^2}{100} = 0.62W\ [1W]$$

$$P_{R3} = \frac{V_{R23}^2}{R_3} = \frac{7.9^2}{300} = 0.21W\ [1/4W]$$

Q13) Calculate all missing values in the combinational circuit below.

[5 marks]



$$R_{12} = R_1 + R_2 = 25 + 75 = 100\,\Omega$$

$$R_T = \frac{R_{12} R_3}{R_{12} + R_3} = \frac{100 \times 400}{100 + 400} = 80\,\Omega$$

$$I_T = \frac{V_S}{R_T} = \frac{10}{80} = 125\,mA$$

$$I_3 = \frac{I_{12}}{4}$$

$$I_3 + I_{12} = 125$$

$$\frac{I_{12}}{4} + I_{12} = 125$$

$$I_{12} + 4I_{12} = 500$$

$$5I_{12} = 500$$

$$I_{12} = \frac{500}{5} = 100\,mA$$

$$I_3 = \frac{I_{12}}{4} = \frac{100}{4} = 25\,mA$$

$I_{12} + I_3 = I_T$

$V_{R1} = I_{12} R_1 = 0.1 \times 25 = 2.5V$

$V_{R2} = I_{12} R_2 = 0.1 \times 75 = 7.5V$

$V_S = 10.0V$

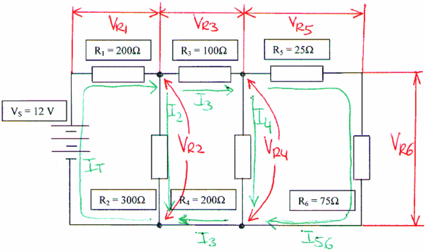
$$P_{R1} = I_{12}^2 R_1 = (0.1)^2 \cdot 25 = 0.25W\ [1/4W]$$

$$P_{R2} = I_{12}^2 R_2 = (0.1)^2 \cdot 75 = 0.75W\ [1W]$$

$$P_{R3} = V_S^2 / R_3 = 10^2/400 = 0.25W\ [1/4W]$$

Q14) Calculate all missing values in the combinational circuit below.

[10 marks]



$$I_T = I_2 + I_3$$

$$I_3 = I_4 + I_{56}$$

$$V_{R5} + V_{R6} = V_{R4}$$

$$V_{R3} + V_{R4} = V_{R2}$$

$$V_{R1} + V_{R2} = V_S$$

$R_{56} = R_5 + R_6 = 25 + 75 = 100\,\Omega$

$R_{456} = \dfrac{R_4 \cdot R_{56}}{R_4 + R_{56}} = \dfrac{200 \times 100}{200 + 100} = 66.67\,\Omega$

$R_{3456} = R_3 + R_{456} = 100 + 66.67 = 166.67\,\Omega$

$R_{23456} = \dfrac{R_2 \cdot R_{3456}}{R_2 + R_{3456}} = \dfrac{300 \times 166.67}{300 + 166.67} = 107.14\,\Omega$

$R_T = R_1 + R_{23456} = 200 + 107.14 = \underline{307.14\,\Omega}$

$I_T = \dfrac{V_S}{R_T} = \dfrac{12}{307.14} = 39.07\,mA$

$V_{R1} = I_T \times R_1 = 39.07 \times 10^{-3} \times 200 = 7.81V$

$V_{R2} = I_T \times R_{23456} = 39.07 \times 10^{-3} \times 107.14 = 4.19V$

Double checking: $V_S = V_{R1} + V_{R2} = 7.81 + 4.19 = 12V$

$I_2 = \dfrac{V_{R2}}{R_2} = \dfrac{4.19}{300} = 13.97\,mA$

$I_3 = \dfrac{V_{R2}}{R_{3456}} = \dfrac{4.19}{166.67} = 25.14\,mA$

Double checking: $I_T = I_2 + I_3 = 13.97 + 25.14 = 39.11\,mA$

$V_{R3} = I_3 \times R_3 = 25.14 \times 10^{-3} \times 100 = 2.51V$

$V_{R4} = I_3 \times R_{456} = 25.14 \times 10^{-3} \times 66.67 = 1.68V$

Double checking: $V_{R2} = V_{R3} + V_{R4} = 2.51 + 1.68 = 4.19V$

$I_4 = \dfrac{V_{R4}}{R_4} = \dfrac{1.68}{200} = 8.4\,mA$

$I_{56} = \dfrac{V_{R4}}{R_{56}} = \dfrac{1.68}{100} = 16.8\,mA$

Double checking: $I_3 = I_4 + I_{56} = 8.4 + 16.8 = 25.2\,mA$

$V_{R6} = 3V_{R5}$

$V_{R5} + V_{R6} = 1.68$

$V_{R5} + 3V_{R5} = 1.68$

$4V_{R5} = 1.68$

$V_{R5} = \dfrac{1.68}{4} = 0.42V$

$V_{R6} = 3 \times V_{R5} = 3 \times 0.42 = 1.26V$

Checking: $V_{R4} = 0.42 + 1.26 = 1.68V$

$P_{R1} = \dfrac{V_{R1}^2}{R_1} = \dfrac{7.81^2}{200} = 0.3W$ [1/2 W]

$P_{R2} = \dfrac{V_{R2}^2}{R_2} = \dfrac{4.19^2}{300} = 0.585W$ [1W]

$P_{R3} = \dfrac{V_{R3}^2}{R_3} = \dfrac{2.51^2}{100} = 63mW$ [1/8W]

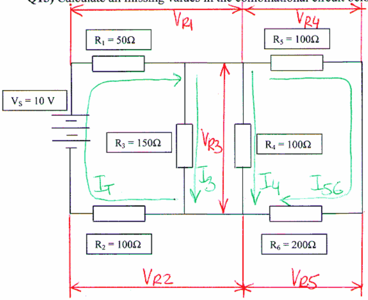
$P_{R4} = \dfrac{V_{R4}^2}{R_4} = \dfrac{1.68^2}{200} = 14mW$ [1/8W]

$P_{R5} = \dfrac{V_{R5}^2}{R_5} = \dfrac{0.42^2}{25} = 7mW$ [1/8W]

$P_{R6} = \dfrac{V_{R6}^2}{R_6} = \dfrac{1.26^2}{75} = 21mW$ [1/8W]

Q15) Calculate all missing values in the combinational circuit below.

[15 marks]



$R_{56} = R_5 + R_6 =$

$= 100 + 200 = 300\Omega$

$\frac{1}{R_{3456}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_{56}} =$

$= \frac{1}{150} + \frac{1}{100} + \frac{1}{300}$

$R_{3456} = 50\Omega$

$R_T = R_1 + R_2 + R_{3456} =$

$= 50 + 100 + 50 =$

$= 200\Omega$

$I_T = \frac{V_S}{R_T} = \frac{10}{200} = 50mA$

$V_{R1} = I_T \times R_1 = 0.05 \times 50 = 2.5V$

$V_{R2} = I_T \times R_2 = 0.05 \times 100 = 5V$

$V_{R3} = I_T \times R_{3456} = 0.05 \times 50 = 2.5V$

double checking:
$V_S = V_{R1} + V_{R2} + V_{R3} =$
$= 2.5 + 5 + 2.5 = 10V$

$I_3 = \frac{V_{R3}}{R_3} = \frac{2.5}{150} = 16.67\,mA$

$I_4 = \frac{V_{R3}}{R_4} = \frac{2.5}{100} = 25\,mA$

$I_{56} = \frac{V_{R3}}{R_{56}} = \frac{2.5}{300} = 8.33mA$

Double checking:
$I_T = I_3 + I_4 + I_{56} =$
$= 16.67 + 25 + 8.33 = 50mA$

$V_{R4} = I_{56} \times R_5 = 8.33 \times 10^{-3} \times 100 = 0.833V$

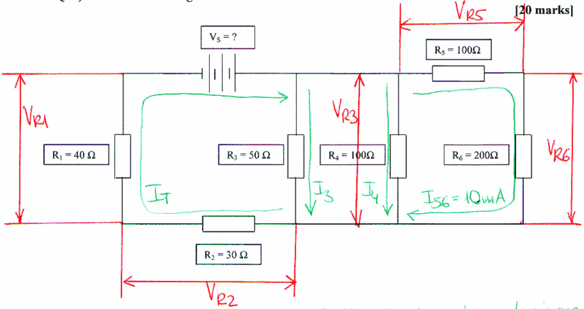
$V_{R5} = I_{56} \times R_6 = 8.33 \times 10^{-3} \times 200 = 1.667V$

double checking:
$V_{R3} = V_{R4} + V_{R5} =$
$= 2.5V$

Find the power ratings by yourself.

Answers: $P_{R1} = 125mW$ [1/8W], $P_{R2} = 250mW$ [1/4W];
$P_{R3} = 41.67mW$ [1/8W]; $P_{R4} = 62.5mW$ [1/8W];
$P_{R5} = 6.9\,mW$ [1/8W], $P_{R6} = 13.9mW$ [1/8W].

Q16) Calculate all missing values in the combinational circuit below. **[20 marks]**



In this circuit the value of the battery is not given, so finding the total resistance is not going to help. However, the value of the current I_{56} is given (10mA), so we can solve the circuit going backwards.

$V_{R5} = I_{56} \times R_5 = 0.01 \times 100 = 1V$

$V_{R6} = I_{56} \times R_6 = 0.01 \times 200 = 2V$

$V_{R3} = V_{R5} + V_{R6} = 1 + 2 = 3V$

$I_3 = \frac{V_{R3}}{R_3} = \frac{3}{50} = 60mA$

$I_4 = \frac{V_{R3}}{R_4} = \frac{3}{100} = 30mA$

$I_T = I_3 + I_4 + I_{56} = 60 + 30 + 10 = 100mA$

$V_{R1} = I_T \times R_1 = 0.1 \times 40 = 4V$

$V_{R2} = I_T \times R_2 = 0.1 \times 30 = 3V$

$V_S = V_{R1} + V_{R2} + V_{R3} = 4 + 3 + 3 = \underline{10V}$

Also, please don't forget to find the power ratings of all resistors by yourself :)

END OF TEST

(Check your work!)