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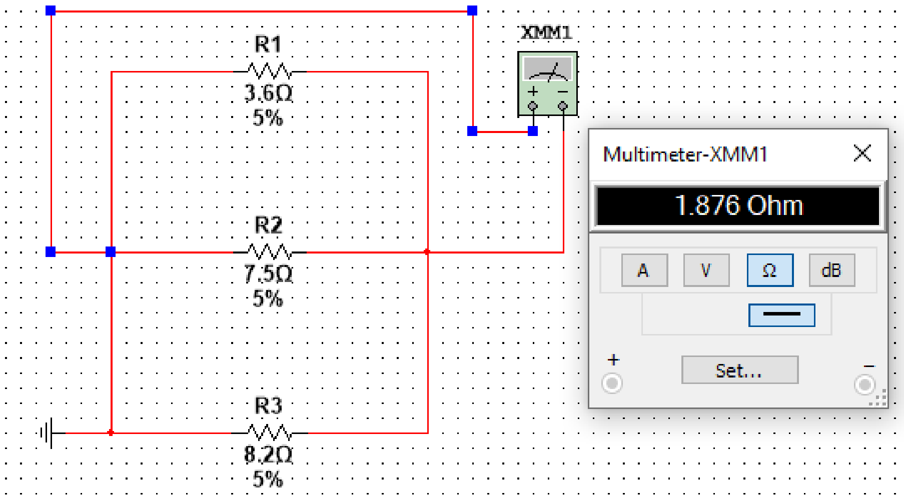
CECS 211 Section 01
Lab 2
2019-09-12–2019-09-17

Question 1



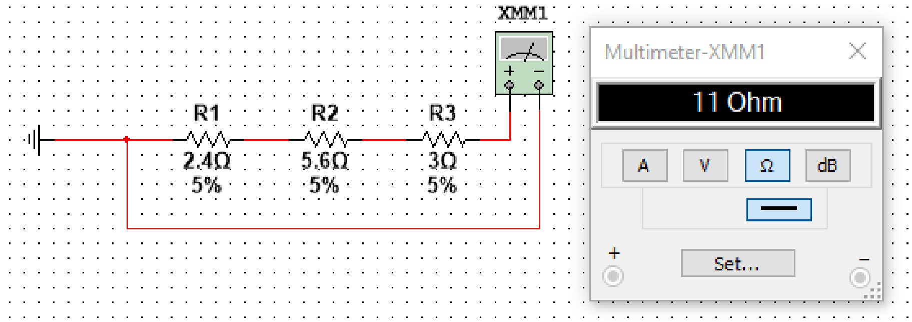
This multimeter reads $1.876\,\Omega$. This is because it is reading the resistances of the three resistors (from top to bottom: $R_1 = 3.600\,\Omega$, $R_2 = 7.500\,\Omega$, and $R_3 = 8.200\,\Omega$) that are in parallel. The formula to calculate the effective value of all three resistors is as follows:

$$R_{\text{net}} = \left(\sum_{i=1}^{n} \frac{1}{R_i} \right)^{-1} \tag{1}$$

Using formula (1) with the above values for R_1, R_2, and R_3 gives us the following result:

$$\begin{aligned}
R_{\text{net}} &= \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)^{-1} \\
&= \left(\frac{1}{3.600\,\Omega} + \frac{1}{7.500\,\Omega} + \frac{1}{8.200\,\Omega} \right)^{-1} \\
&= \left(0.278\,\Omega^{-1} + 0.133\,\Omega^{-1} + 0.122\,\Omega^{-1} \right)^{-1} \\
&= \left(0.533\,\Omega^{-1} \right)^{-1} \\
&= 1.876\,\Omega
\end{aligned}$$

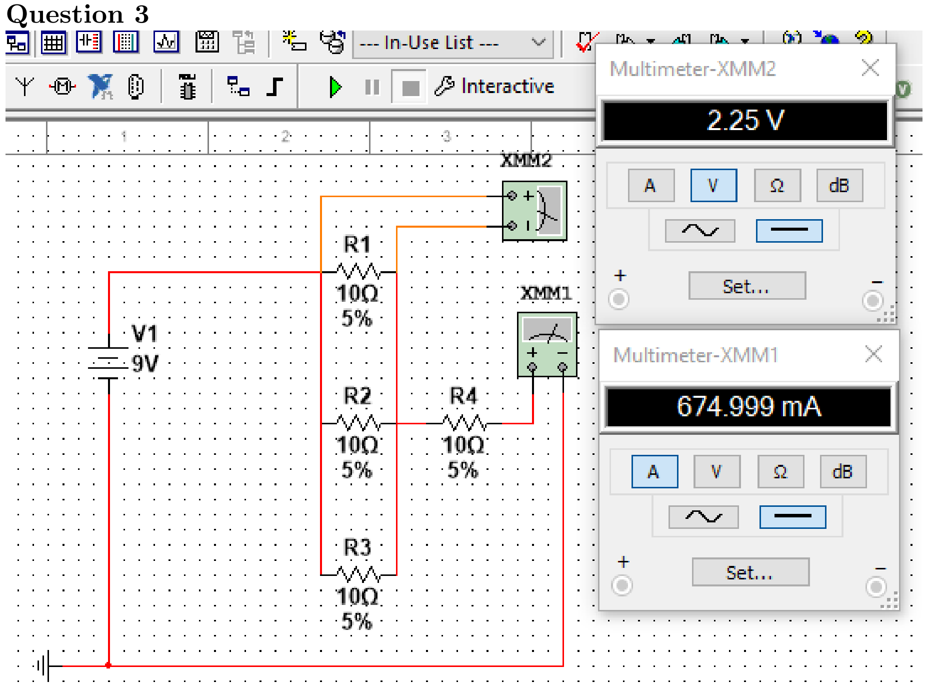
Question 2



This multimeter reads $11\,\Omega$. This is because the three resistors are connected in series ($R_1 = 2.4\,\Omega$, $R_2 = 5.6\,\Omega$, and $R_3 = 3.0\,\Omega$). When resistors are connected in series, the equivalent resistance is simply the sum of all the resistances: $R_{\text{net}} = \sum_{i=1}^{n} R_i$.

$$
\begin{aligned}
R_{\text{net}} &= R_1 + R_2 + R_3 \\
&= 2.4\,\Omega + 5.6\,\Omega + 3.0\,\Omega \\
&= 11\,\Omega
\end{aligned}
$$

Question 3



In this example, XMM1 (reading current) reads $674.999\,\text{mA}$ (which can be rounded up to $675.000\,\text{mA}$, or $0.675\,\text{A}$) and XMM2 (reading voltage) reads

2.25 V. To calculate these values, it is first necessary to calculate the total effective resistance R_{net}. In this complex example, three resistors ($R_1 = R_2 = R_3 = 10\,\Omega$) are placed in parallel with each other, while one more resistor ($R_4 = 10\,\Omega$) is placed in series with the other three. First, it is required to calculate the effective total resistance of R_1, R_2, and R_3 together; next, this intermediate value can be added to R_4 to achieve total resistance.

$$\begin{aligned}
R_{1+2+3} &= \left(\sum_{i=1}^{n} \frac{1}{R_i}\right)^{-1} = \left(\sum_{i=1}^{3} \frac{1}{10\,\Omega}\right)^{-1} \\
&= \left(3 \times \frac{1}{10\,\Omega}\right)^{-1} = \left(\frac{3}{10\,\Omega}\right)^{-1} \\
&= 3.33\,\Omega
\end{aligned}$$

$$\begin{aligned}
R_{\text{net}} &= R_{1+2+3} + R_4 \\
&= 3.33\,\Omega + 10\,\Omega \\
&= 13.33\,\Omega
\end{aligned}$$

With this quantity, we can determine the values displayed on XMM1 and XMM2.

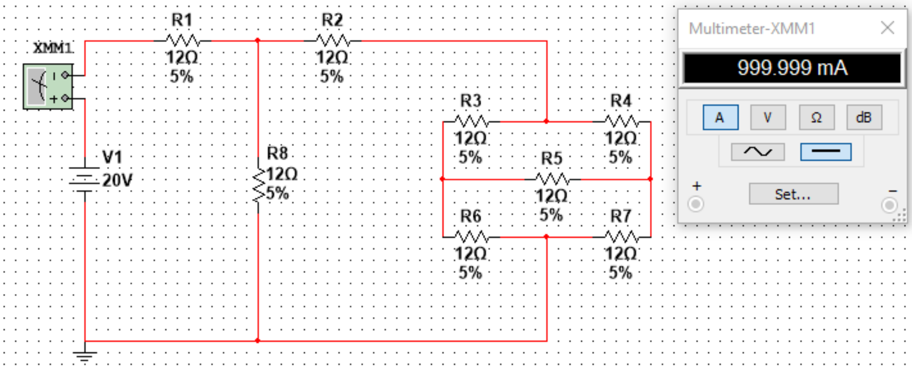
XMM1 is reading the current going through the whole circuit, because it is connected to the very end, where there are no nodes or separations. This makes it possible to use Ohm's Law to calculate the current going through the whole circuit easily.

$$\begin{aligned}
V &= IR \\
I &= \frac{V}{R} = \frac{V_s}{R_{\text{net}}} \\
&= \frac{9\,\text{V}}{13.33\,\Omega} \\
&= 0.675\,\text{A} = 675\,\text{mA}
\end{aligned}$$

XMM2 is reading the voltage going across R_1, R_2, and R_3, which are connected in parallel. We can combine these three resistances into a single equivalent resistance (the quantity R_{1+2+3}, which was calculated earlier), and then use Ohm's Law to solve for the voltage going through all three resistors.

$$\begin{aligned}
V &= IR \\
V_{R_{1+2+3}} &= I_{\text{net}} \cdot R_{1+2+3} \\
&= 0.675\,\text{A} \cdot 3.33\,\Omega \\
&= 2.25\,\text{V}
\end{aligned}$$

Question 4



Using Ohm's Law, the equivalent resistance for this resistor network can be found algebraically if and only if both the total voltage and the total current are known for the entire circuit. The total voltage is 20 V, and the total current (as given by XMM1) is 999.999 mA, or 1 A.

$$\begin{aligned} V &= IR \Rightarrow R = V/I \\ R_{\text{net}} &= \frac{V_s}{I_{\text{net}}} \\ &= \frac{20\,\text{V}}{1\,\text{A}} \\ &= 20\,\Omega \end{aligned}$$

Question 5

Problem 1

$R_3 = 20\,\Omega$ and $R_4 = 20\,\Omega$ are connected in parallel, while $R_1 = 10\,\Omega$ and $R_2 = 15\,\Omega$ are connected in series with $R_3 + R_4$. This means that it is necessary to calculate R_{3+4} before adding it to R_1 and R_1 and R_2.

$$\begin{aligned} R_{3+4} &= \left(\sum_{i=3}^{4} \frac{1}{R_i}\right)^{-1} \\ &= \left(2 \times \frac{1}{20\,\Omega}\right)^{-1} = \left(\frac{1}{10\,\Omega}\right)^{-1} \\ &= 10\,\Omega \end{aligned}$$

$$\begin{aligned} R_{\text{net}} &= R_1 + R_2 + R_{3+4} \\ &= 10\,\Omega + 15\,\Omega + 10\,\Omega \\ &= 35\,\Omega \end{aligned}$$

The equivalent resistance is $35\,\Omega$.

Problem 2

In this problem, $R_7 = 20\,\Omega$ and $R_8 = 15\,\Omega$ are connected in parallel, and this combo R_{7+8} is connected in series with $R_5 = 7.5\,\Omega$.

$$\begin{aligned}
R_{\text{net}} &= R_5 + R_{7+8} \\
&= 7.5\,\Omega + \left(\frac{1}{20\,\Omega} + \frac{1}{15\,\Omega}\right)^{-1} \\
&= 7.5\,\Omega + \left(0.05\,\Omega^{-1} + 0.067\,\Omega^{-1}\right)^{-1} \\
&= 7.5\,\Omega + \left(0.117\,\Omega^{-1}\right)^{-1} \\
&= 7.5\,\Omega + 8.55\,\Omega \\
&= 16.047\,\Omega
\end{aligned}$$

The equivalent resistance is $16.047\,\Omega$.

Problem 3

The resistors in this network are situated such that R_{13} and the rest of the resistors (which I will call R_a) are connected in parallel. R_a consists of R_{10} and R_{11} in parallel plus R_6 and R_{12} in parallel plus R_9 in series.

$$\begin{aligned}
R_{\text{net}} &= \left(\frac{1}{R_{13}} + (R_a)^{-1}\right)^{-1} \\
&= \left(\frac{1}{R_{13}} + \left(\left(\frac{1}{R_{10}} + \frac{1}{R_{11}}\right)^{-1} + \left(\frac{1}{R_6} + \frac{1}{R_{12}}\right)^{-1} + R_9\right)^{-1}\right)^{-1} \\
&= \left(\frac{1}{10\,\Omega} + \left(\left(\frac{1}{10\,\Omega} + \frac{1}{15\,\Omega}\right)^{-1} + \left(\frac{1}{6.8\,\Omega} + \frac{1}{13\,\Omega}\right)^{-1} + 5.1\,\Omega\right)^{-1}\right)^{-1} \\
&= \left(0.1\,\Omega^{-1} + (6\,\Omega + 4.465\,\Omega + 5.1\,\Omega)^{-1}\right)^{-1} \\
&= \left(0.1\,\Omega^{-1} + 0.0642\,\Omega^{-1}\right)^{-1} \\
&= 6.088\,\Omega
\end{aligned}$$

The equivalent resistance is $6.088\,\Omega$.

Problem 4

Here, $R_{14} = 100\,\Omega$ and $R_{17} = 100\,\Omega$ are in series, and $R_{15} = 100\,\Omega$ and $R_{17} = 100\,\Omega$ are in series, and these two groups are connected in parallel with $R_{19} = 100\,\Omega$.

$$\begin{aligned} R_{\text{net}} &= (R_{14} + R_{17}) \parallel R_{19} \parallel (R_{15} + R_{18}) \\ &= (100\,\Omega + 100\,\Omega) \parallel 100\,\Omega \parallel (100\,\Omega + 100\,\Omega) \\ &= 200\,\Omega \parallel 100\,\Omega \parallel 200\,\Omega \\ &= \frac{1}{\frac{1}{200\,\Omega} + \frac{1}{100\,\Omega} + \frac{1}{200\,\Omega}} \\ &= \frac{1}{0.005\,\Omega^{-1} + 0.01\,\Omega^{-1} + 0.005\,\Omega^{-1}} \\ &= \frac{1}{0.02\,\Omega^{-1}} = 50\,\Omega \end{aligned}$$

The equivalent resistance is $50\,\Omega$.