Physics 2250: Problem Set I

Jeremy Favro

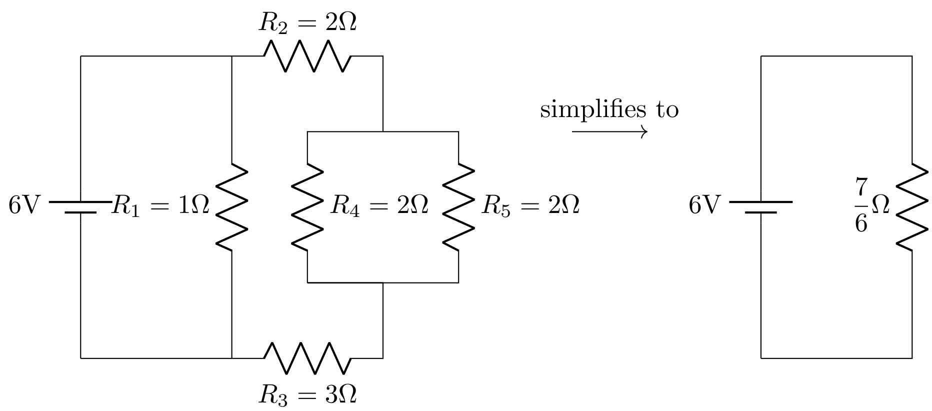
September 13, 2024

Problem 1. Determine the resistance of resistors A and B in the figure (not included here) below. (A: Red, Red, Red, Red; B: Blue, Violet, Green, Brown).

Solution 1. A: $2.2 \cdot 100\Omega \pm 2\% = 2.2\text{k}\Omega \pm 44\Omega$; B: $6.7 \cdot 100000\Omega \pm 1\% = 6.7\text{M}\Omega \pm 6.7\text{k}\Omega$

Problem 2. Consider the 5-resistor circuit shown below. Redrawn using circuitikz for ease of labeling in LaTeX

Solution 2.

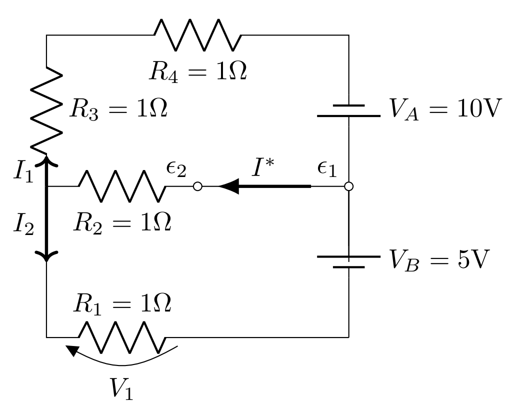


So, $V = 6\text{V}; R_{tot} = \frac{7}{6}\Omega \therefore I_{tot} = 7\text{A}$.
a) $P = IV = 7\text{A} \cdot 6\text{V} = 42\text{W}$

b) By the current divider rule the current entering R_1 is $I_{tot} \cdot \dfrac{R_2 + (\frac{1}{R_4} + \frac{1}{R_5})^{-1} + R_3}{R_{tot}} = 7\text{A} \cdot \dfrac{6\Omega}{7\Omega} = 6\text{A}$ which means that 1A enters R_2 and is evenly split between R_4 and R_5 which both cause a voltage drop of $0.5\text{A} \cdot 2\Omega = 1\text{V}$ because they are of equivalent resistance and by Kirchoff's junction law R_3 therefore experiences the same 1A of current as R_2.

Problem 3. Consider the network shown below. Again redrawn in circuitikz (the voltage drop arrow almost clipping is killing me).

Solution 3.



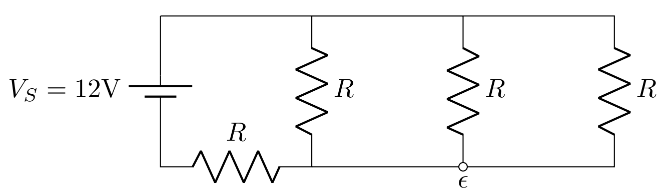
a) Going around the upper loop clockwise and the lower loop counter-clockwise starting at ϵ_1 we get $-I^* R_2 - I_1 R_3 - I_1 R_4 + V_A = 0$ for the upper loop and $-I^* - I_2 R_1 + V_B = 0$ for the lower loop. By KCL we know that $I^* = I_1 + I_2$. Solving the upper loop equation for I_1 we get that $I_1 = \frac{-I^* + 10V}{2\Omega}$. Doing the same for the lower loop equation we get that $I_2 = -I^* + 5$. Therefore

$$
\begin{aligned}
I^* &= \frac{-I^* + 10\text{V}}{2\Omega} - I^* + 5\text{V} \\
2\Omega I^* &= -I^* + 10\text{V} - 2\Omega I^* + 10\text{V} \\
2\Omega I^* &= -3\Omega I^* + 20\text{V} \\
5\Omega I^* &= 20\text{V} \\
I^* &= 4\text{A}
\end{aligned}
$$

So I^* is 4 Amps in the direction of the loops at ϵ_1 (towards R_2)
b) 0V, I think? There's no resistor or anything there, and a wire is to be treated as having zero resistance so it would have zero voltage drop by Ohm's law.
c) Now that we know I^* we can solve the loop equations to get that $I_1 = 3\text{A}$ & $I_2 = 1\text{A}$ so the voltage drop across R_1 is $V = I_2 R_1 = 1\text{V}$

Problem 4. [BONUS] If the source voltage in the figure below is $V_S = 12\text{V}$, what is the potential at node ϵ?

Solution 4.



$$\epsilon = V_S - I_{tot}\, R_{before\,\epsilon}$$

$$
\begin{aligned}
R_{eq} &= \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} + R \\
R_{eq} &= \frac{4R}{3}\Omega
\end{aligned}
$$

$$
\begin{aligned}
I_{tot} &= \frac{V_S}{R_{eq}} \\
I_{tot} &= \frac{12\text{V}}{\frac{4R}{3}\Omega} \\
I_{tot} &= \frac{9}{R}\text{A}
\end{aligned}
$$

$$
\begin{aligned}
\epsilon &= 12\text{V} - \frac{9}{R}\text{A}\frac{R}{3}\Omega \\
\epsilon &= 9\text{V}
\end{aligned}
$$