Circuits Lab

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$R_2 = 40\ \Omega$

1. Purpose

The goal of the exercise was to use Kirchhoff's rules to analyze 7 different circuits and calculate current, voltage, and power for each circuit element. For the first 4 circuits, the voltage and current calculations were compared to results obtained using an online circuit simulator. In each case, the voltage across a resistor was calculated with $V = IR$, and the power dissipated by a circuit element with $P = VI$.

2. Results

The following tables contain the theoretical voltage, current, and power for each circuit element for each of the 7 circuits. In addition, there is an annotated circuit diagram for each circuit.

2.1. Circuit 1

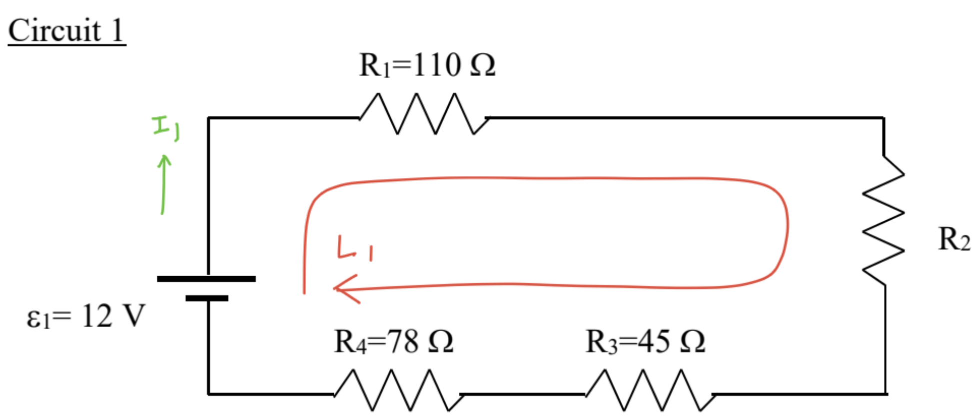

Figure 1. Circuit 1

Table 1. Circuit 1 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	12.0	0.0440	0.527
R_1	4.84	0.0440	0.213
R_2	1.76	0.0440	0.0773
R_3	1.98	0.0440	0.0869
R_4	3.43	0.0440	0.151

$$\mathrm{L}_1 : \mathcal{E}_1 - I_1R_1 - I_1R_2 - I_1R_3 - I_1R_4 = 0$$

$$I_1 = \frac{\mathcal{E}_1}{R_1 + R_2 + R_3 + R_4}$$

$$I_1 = 0.0440 \text{ A}$$

2.2. Circuit 2

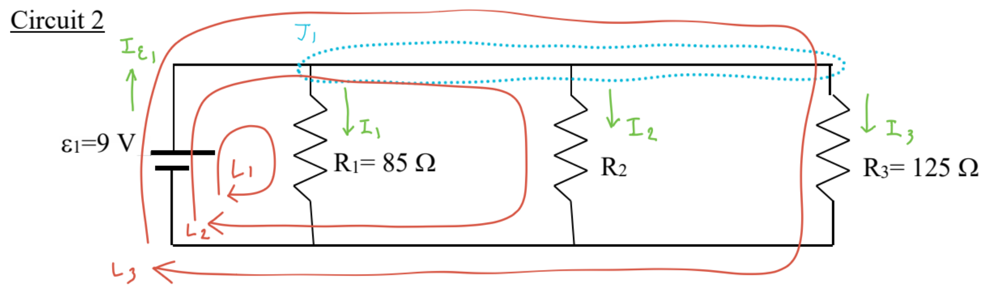

Figure 2. Circuit 2

Table 2. Circuit 2 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	9.00	0.403	3.63
R_1	9.00	0.106	0.953
R_2	9.00	0.225	2.02
R_3	9.00	0.0720	0.648

$$\mathrm{J}_1: \quad I_{\mathcal{E}_1} = I_1 + I_2 + I_3$$
$$I_1 + I_2 + I_3 - I_{\mathcal{E}_1} = 0$$

$$\mathrm{L}_1: \quad \mathcal{E}_1 - I_1 R_1 = 0$$
$$I_1 R_1 = \mathcal{E}_1$$

$$\mathrm{L}_2: \quad \mathcal{E}_1 - I_2 R_2 = 0$$
$$I_2 R_2 = \mathcal{E}_1$$

$$\mathrm{L}_3: \quad \mathcal{E}_1 - I_3 R_3 = 0$$
$$I_3 R_3 = \mathcal{E}_1$$

$$\begin{bmatrix} 1 & 1 & 1 & -1 \\ R_1 & 0 & 0 & 0 \\ 0 & R_2 & 0 & 0 \\ 0 & 0 & R_3 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_{\mathcal{E}_1} \end{bmatrix} = \begin{bmatrix} 0 \\ \mathcal{E}_1 \\ \mathcal{E}_1 \\ \mathcal{E}_1 \end{bmatrix}$$

$$\begin{aligned} I_1 &= 0.106 \text{ A} \\ I_2 &= 0.225 \text{ A} \\ I_3 &= 0.0720 \text{ A} \\ I_{\mathcal{E}_1} &= 0.430 \text{ A} \end{aligned}$$

2.3. Circuit 3

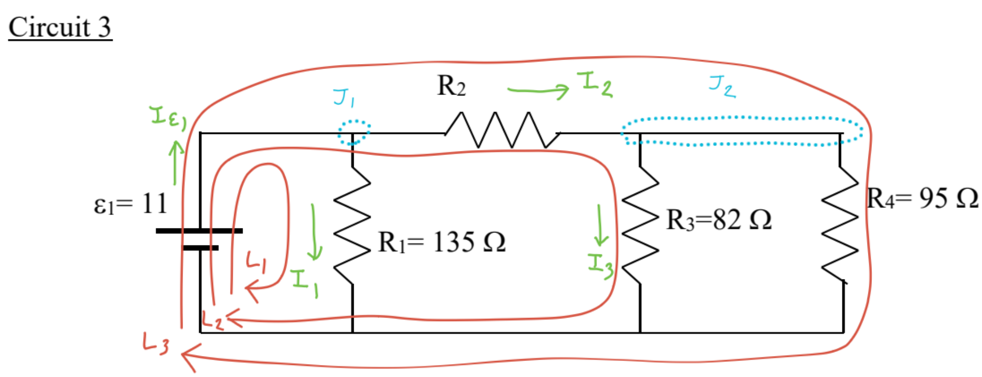

Figure 3. Circuit 3

Table 3. Circuit 3 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	11.0	0.212	2.34
R_1	11.0	0.0815	0.896
R_2	5.24	0.131	0.686
R_3	5.76	0.0703	0.405
R_4	5.76	0.0607	0.350

$$\begin{aligned} \mathrm{J}_1: && I_{\mathcal{E}_1} &= I_1 + I_2 \\ && I_1 + I_2 - I_{\mathcal{E}_1} &= 0 \end{aligned}$$

$$\begin{aligned} \mathrm{J}_2: && I_2 &= I_3 + I_4 \\ && I_2 - I_2 - I_4 &= 0 \end{aligned}$$

$$\begin{aligned} \mathrm{L}_1: && \mathcal{E}_1 - I_1 R_1 &= 0 \\ && I_1 R_1 &= \mathcal{E}_1 \end{aligned}$$

$$\begin{aligned} \mathrm{L}_2: \mathcal{E}_1 - I_2 R_2 - I_3 R_3 &= 0 \\ I_2 R_2 + I_3 R_3 &= \mathcal{E}_1 \end{aligned}$$

$$\begin{aligned} \mathrm{L}_3: \mathcal{E}_1 - I_2 R_2 - I_4 R_4 &= 0 \\ I_2 R_2 + I_4 R_4 &= \mathcal{E}_1 \end{aligned}$$

$$\begin{bmatrix} 1 & 1 & 0 & 0 & -1 \\ 0 & 1 & -1 & -1 & 0 \\ R_1 & 0 & 0 & 0 & 0 \\ 0 & R_2 & R_3 & 0 & 0 \\ 0 & R_2 & 0 & R_4 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_{\mathcal{E}_1} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \mathcal{E}_1 \\ \mathcal{E}_1 \\ \mathcal{E}_1 \end{bmatrix}$$

$$\begin{aligned} I_1 &= 0.0815 \text{ A} \\ I_2 &= 0.131 \text{ A} \\ I_3 &= 0.0703 \text{ A} \\ I_4 &= 0.0607 \text{ A} \\ I_{\mathcal{E}_1} &= 0.212 \text{ A} \end{aligned}$$

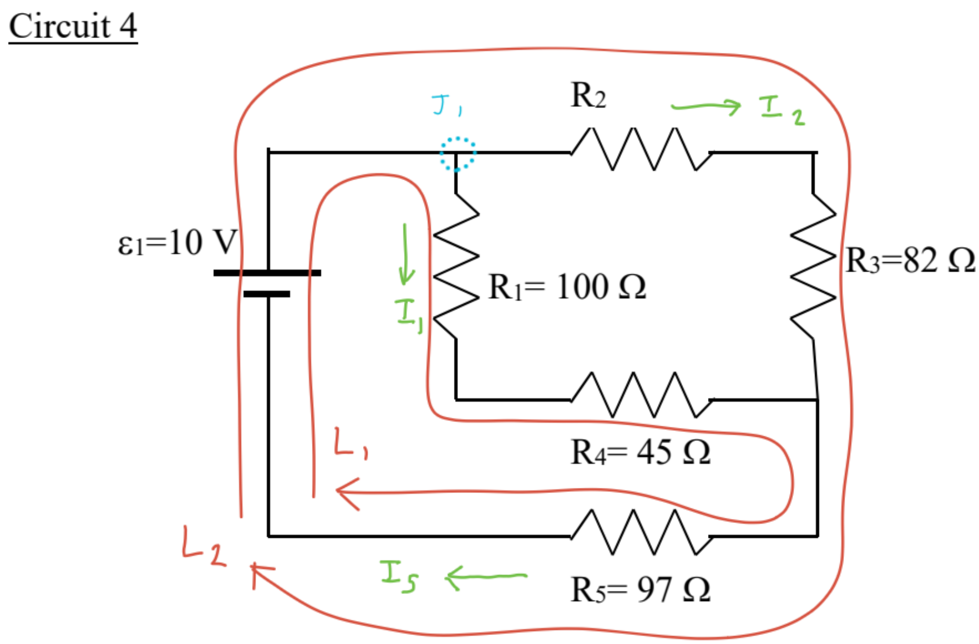

Figure 4. Circuit 4

Table 4. Circuit 4 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	10.0	0.0613	0.613
R_1	2.80	0.0280	0.0783
R_2	1.33	0.0333	0.0443
R_3	2.73	0.0333	0.0907
R_4	1.26	0.0280	0.0353
R_5	5.94	0.0613	0.364

2.4. Circuit 4

$$\text{J}_1: \quad I_5 = I_1 + I_2$$
$$I_1 + I_2 - I_5 = 0$$

$$\text{L}_1: \mathcal{E}_1 - I_1R_1 - I_1R_4 - I_5R_5 = 0$$
$$I_1(R_1 + R_4) + I_5R_5 = \mathcal{E}_1$$

$$\text{L}_2: \mathcal{E}_1 - I_2R_2 - I_2R_3 - I_5R_5 = 0$$
$$I_2(R_2 + R_3) + I_5R_5 = \mathcal{E}_1$$

$$\begin{bmatrix} 1 & 1 & -1 \\ R_1 + R_4 & 0 & R_5 \\ 0 & R_2 + R_3 & R_5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_5 \end{bmatrix} = \begin{bmatrix} 0 \\ \mathcal{E}_1 \\ \mathcal{E}_1 \end{bmatrix}$$

$$I_1 = 0.0280 \text{ A}$$
$$I_2 = 0.0333 \text{ A}$$
$$I_5 = 0.0613 \text{ A}$$

2.5. Circuit 5

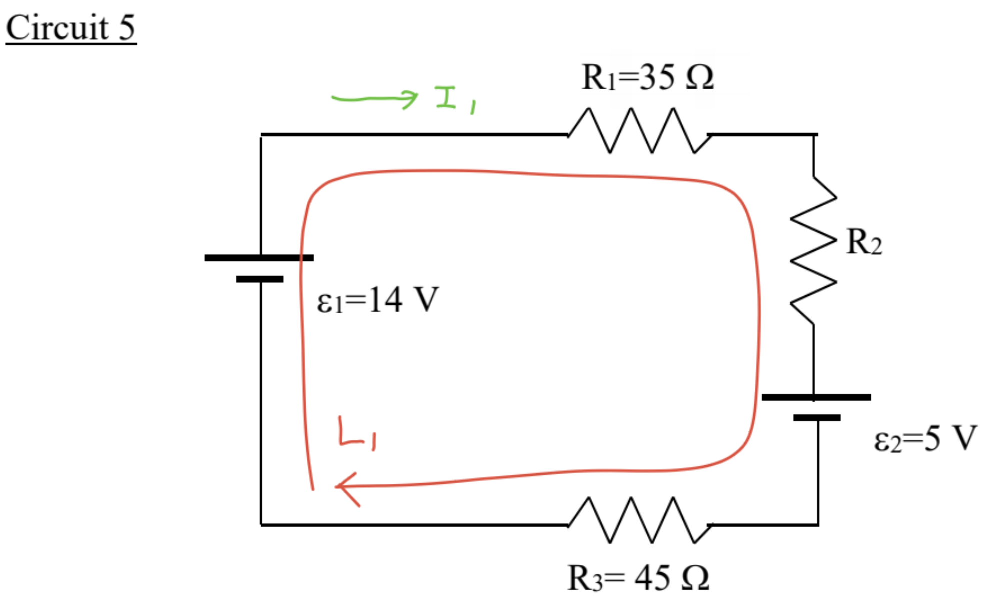

Figure 5. Circuit 5

Table 5. Circuit 5 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	14.0	0.0750	1.05
$\mathcal{E}_2$	5.00	0.0750	0.375
R_1	2.62	0.0750	0.197
R_2	3.00	0.0750	0.225
R_3	3.38	0.0750	0.253

Circuit 6

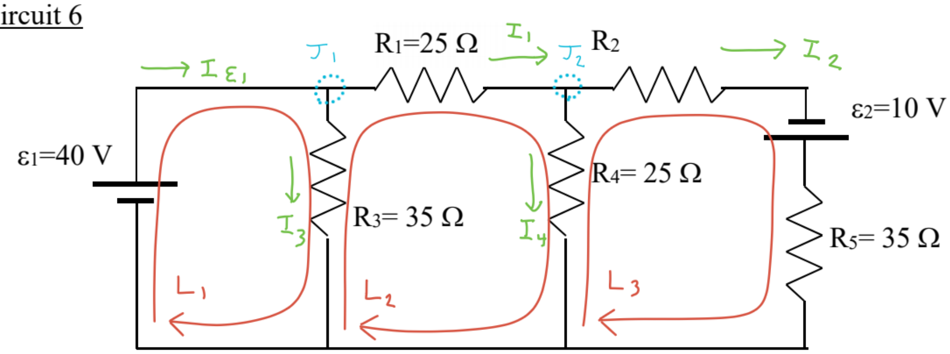

Figure 6. Circuit 6

Table 6. Circuit 6 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	40.0	2.11	84.6
$\mathcal{E}_2$	10.0	0.343	3.43
R_1	24.3	0.971	23.6
R_2	13.7	0.343	4.70
R_3	40.0	1.14	45.7
R_4	15.7	0.629	9.88
R_5	12.0	0.343	4.11

Circuit 7 (It is recommended to solve this circuit using a matrix.)

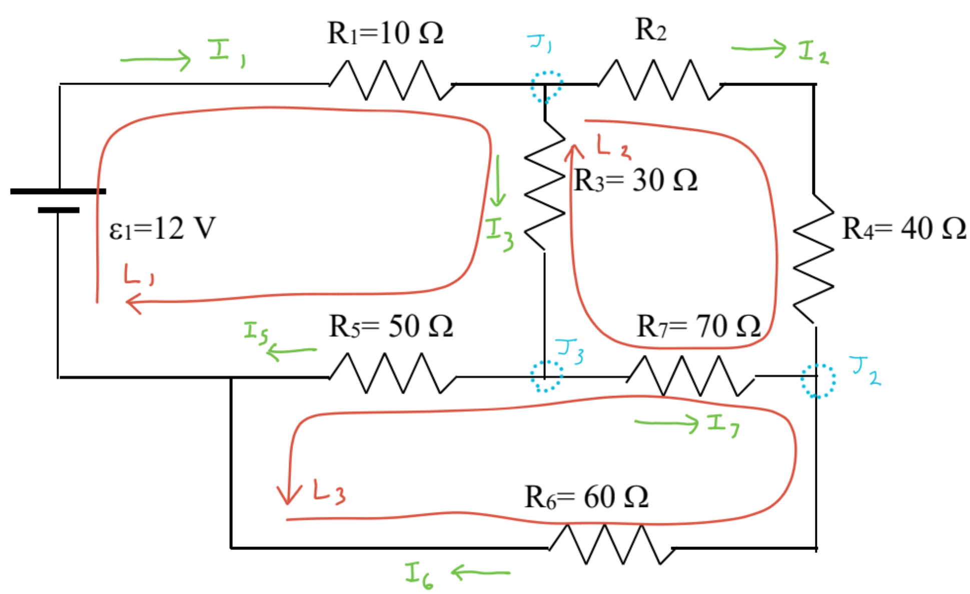

Figure 7. Circuit 7

Table 7. Circuit 7 V, I, and P

	V (V)	I (A)	P (W)
$\mathcal{E}_1$	12.0	0.200	2.40
R_1	2.00	0.200	0.399
R_2	2.58	0.0646	0.167
R_3	4.05	0.135	0.547
R_4	2.58	0.0646	0.167
R_5	5.95	0.119	0.709
R_6	4.83	0.0806	0.390
R_7	1.12	0.0160	0.0179

2.6. Circuit 6

2.7. Circuit 7

3. Conclusion

4. Citations

[1] Karen Schnurbusch, *Physics 4B Lab Book*, Mt. San Antonio College, 2023, pp. 71-74.
[2] Karen Schnurbusch, *Physics 4B Equations*, Mt. San Antonio College, 2023, pp. 4, 5.