Electrical Connections

Series and Parallel

Circuits and Capacitors

I. Current, Power, Resistance
- resistivity
- internal resistance

II. Circuit Analysis
- series and parallel
- nodes, loops, switches

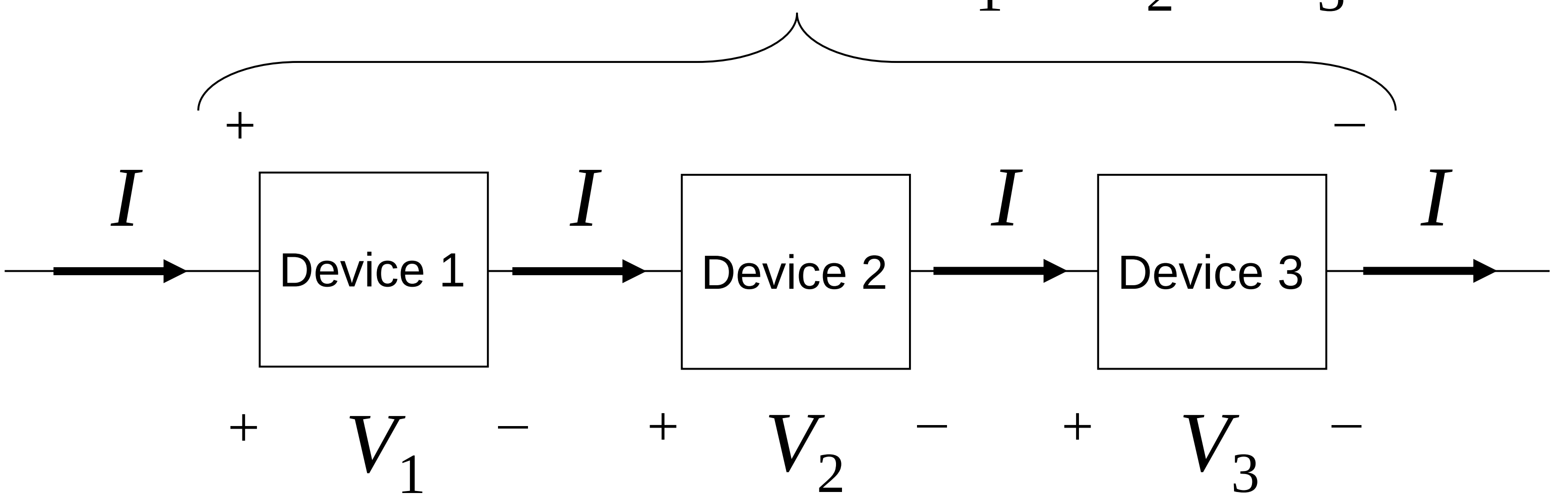
III. Capacitance
- parallel plate capacitor
- capacitors in circuits

	The student will be able to:	HW:
1	Define electric current and the ampere and solve problems relating current to charge and time and to power and voltage.	1 – 3
2	Define resistance, resistivity, and the ohm and Ohm’s Law and solve related problems.	4 – 10
3	Define and apply the concepts of internal resistance and emf to solve related problems with the standard model of the terminal voltage of voltaic cells.	11 – 14
4	Determine resistance for series or parallel combinations of resistors, state and apply Kirchoff’s node and loop rules and solve related problems, including analysis circuits with multiple batteries, resistors, and switches.	15 – 20
5	Define capacitance and relate to charge, voltage and energy to solve related problems involving capacitors in circuits at steady states of charge or discharge and qualitatively describe transitions of such states.	21 – 29
6	State the relation between capacitance, area, separation, and dielectric constant for parallel plate capacitors and solve related problems.	30 – 35

Series Connections

Current passes through each device in a particular order. There is only one path for current to follow.

$$V = V_1 + V_2 + V_3$$

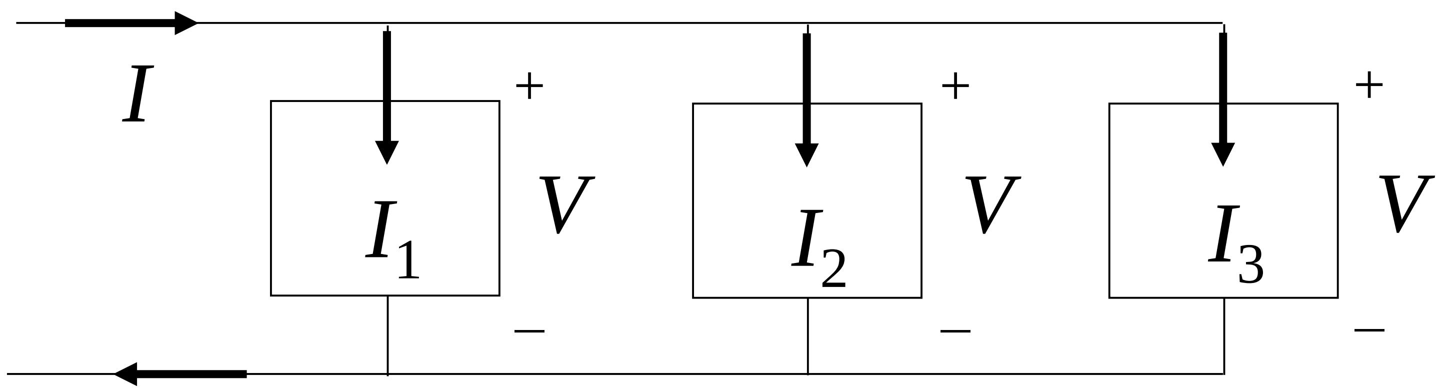


The **current** is the same through each device.

The **voltage** across any set of devices is equal to the sum of the individual voltages.

Parallel Connections

Current passes through the devices simultaneously. There are multiple paths for current to follow.

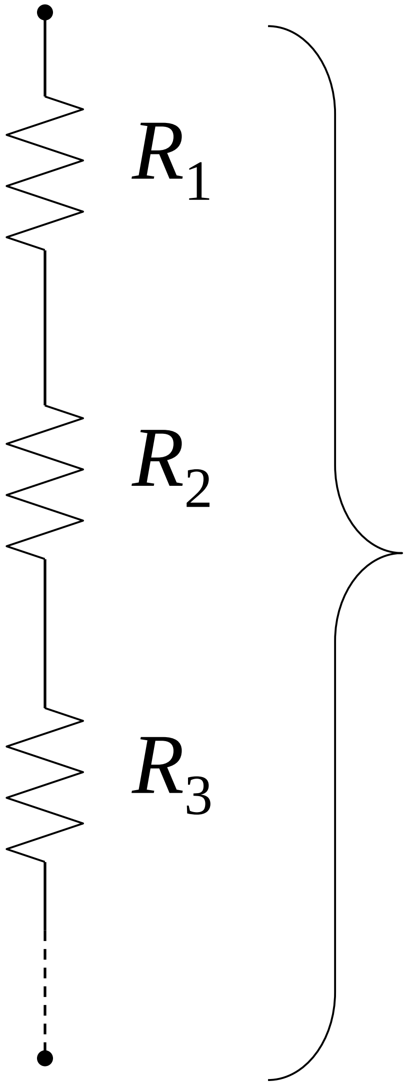


$$I = I_1 + I_2 + I_3$$

The **voltage** is the same across each device.

The **current** through any set of devices is equal to the sum of the individual currents.

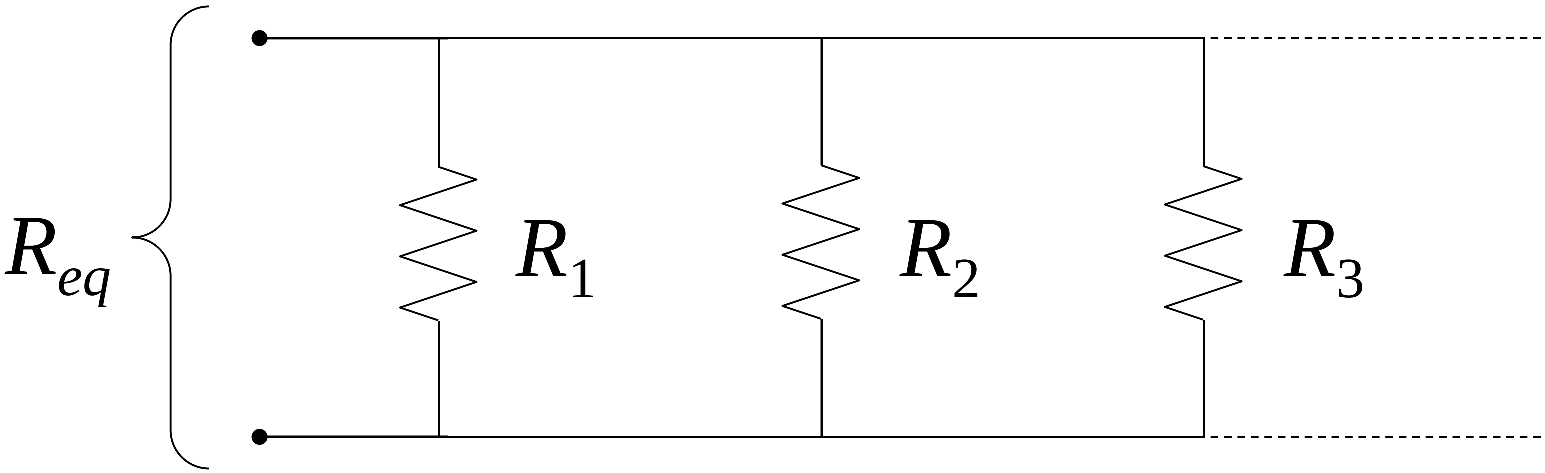
Equivalent Resistance of Series Resistors



$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

The equivalent resistance is *greater* than that of any single resistor in the set.

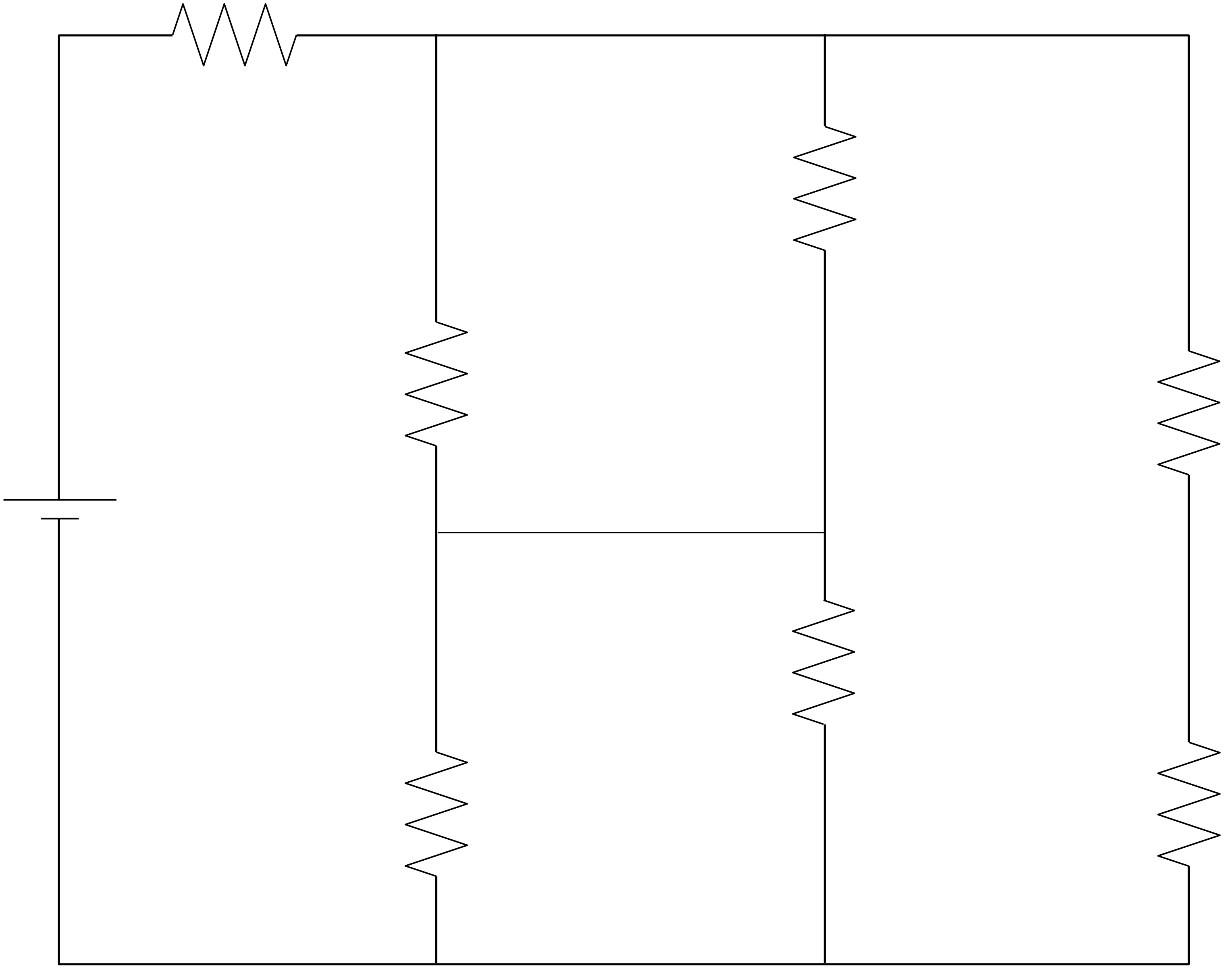
Equivalent Resistance of Parallel Resistors



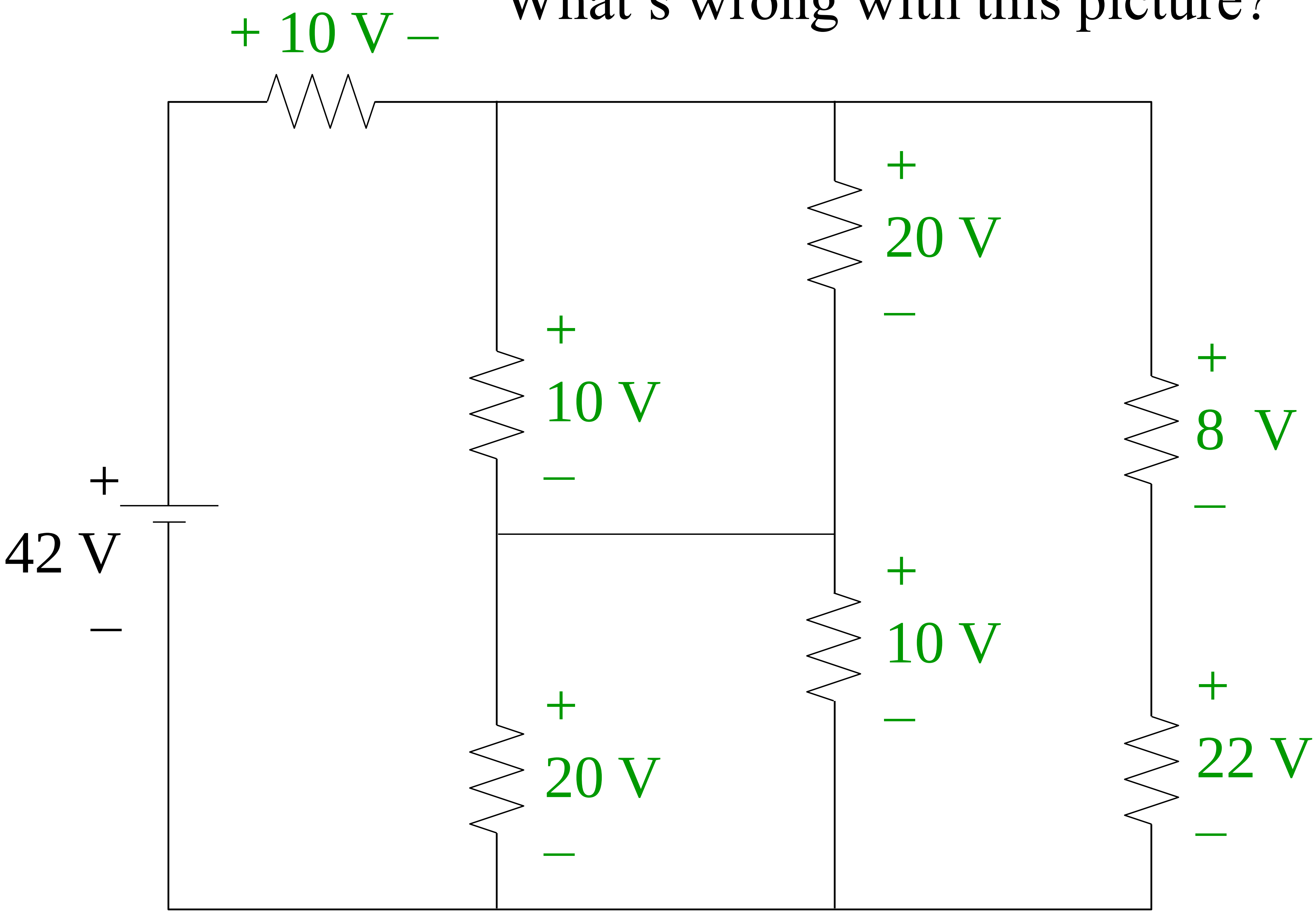
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

The equivalent resistance is *less* than that of any single resistor in the set.

An example circuit…



What's wrong with this picture?



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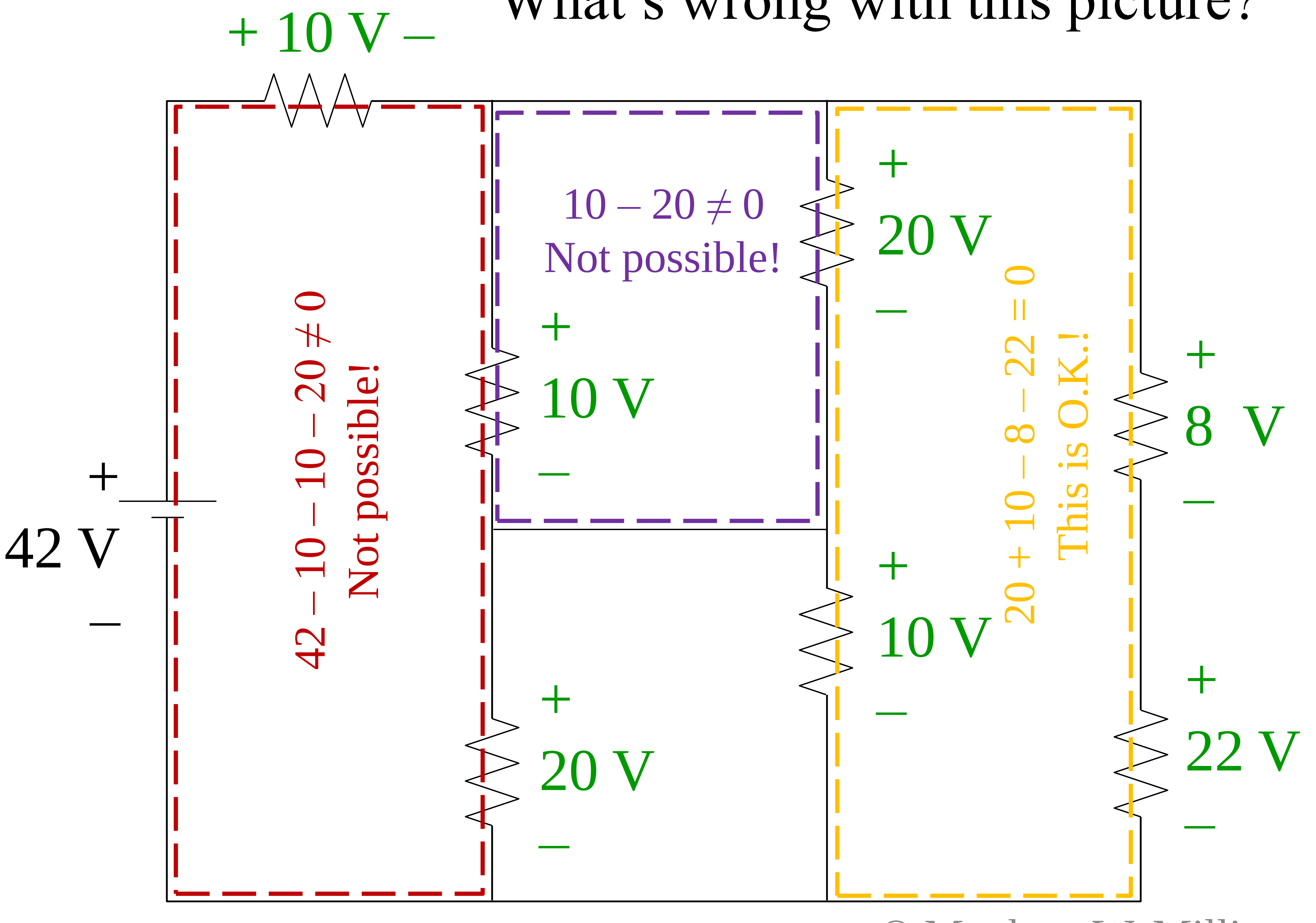


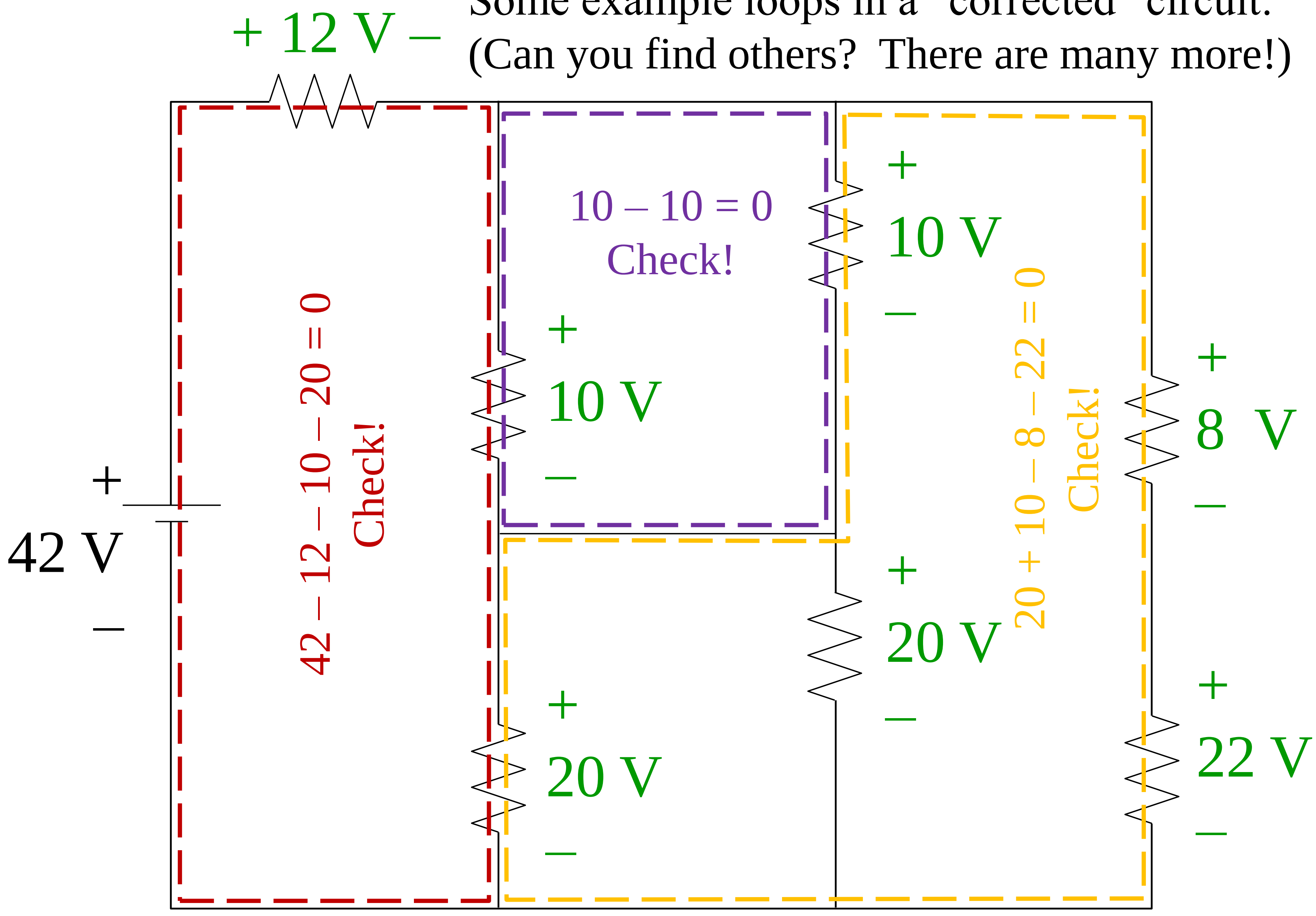
Kirchhoff's Laws

- Loop Rule: The sum of the potential differences across all elements around any loop equals zero.

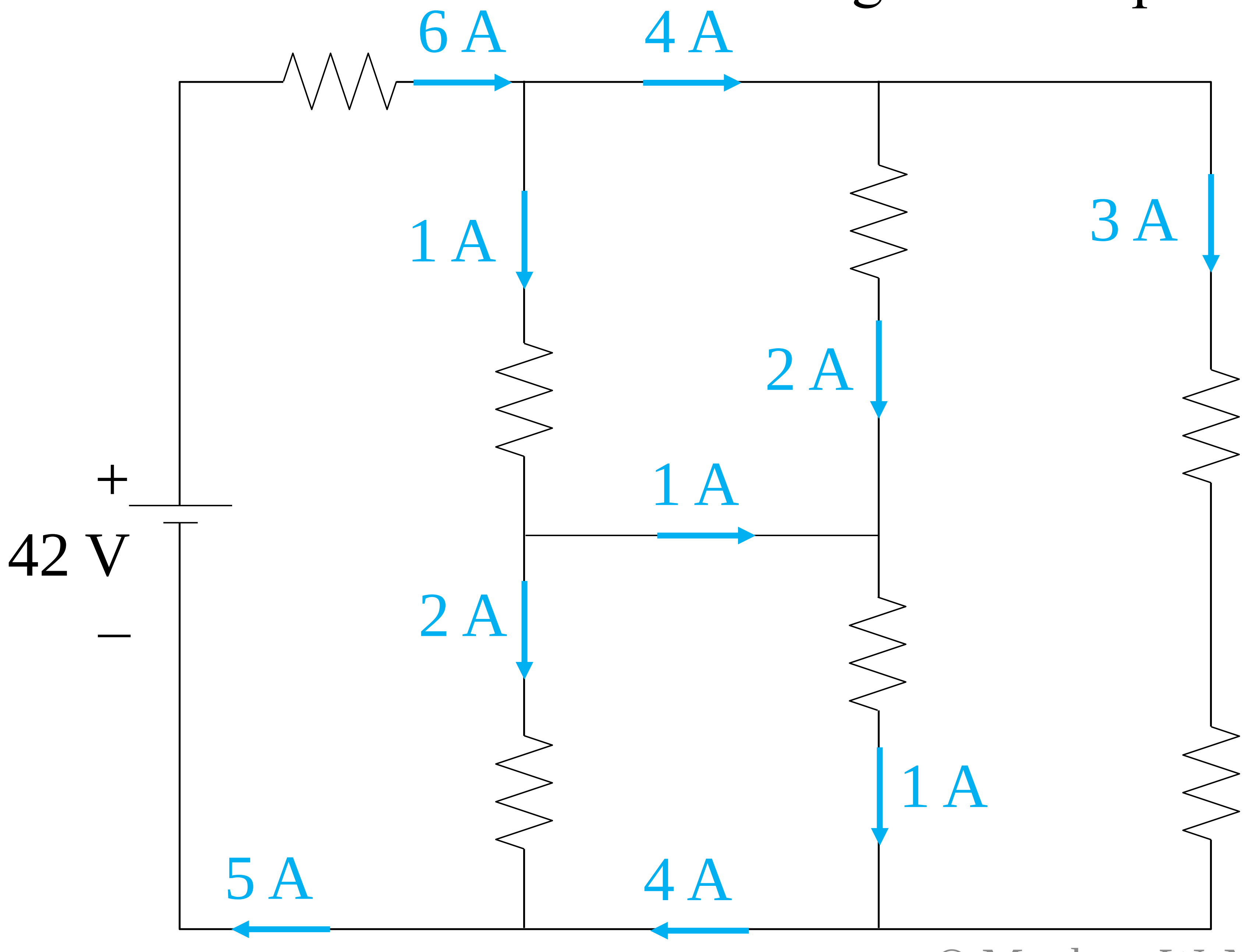
Because energy is conserved!

A "loop" is any pathway through a circuit that starts and ends at the same point. It can have any shape.

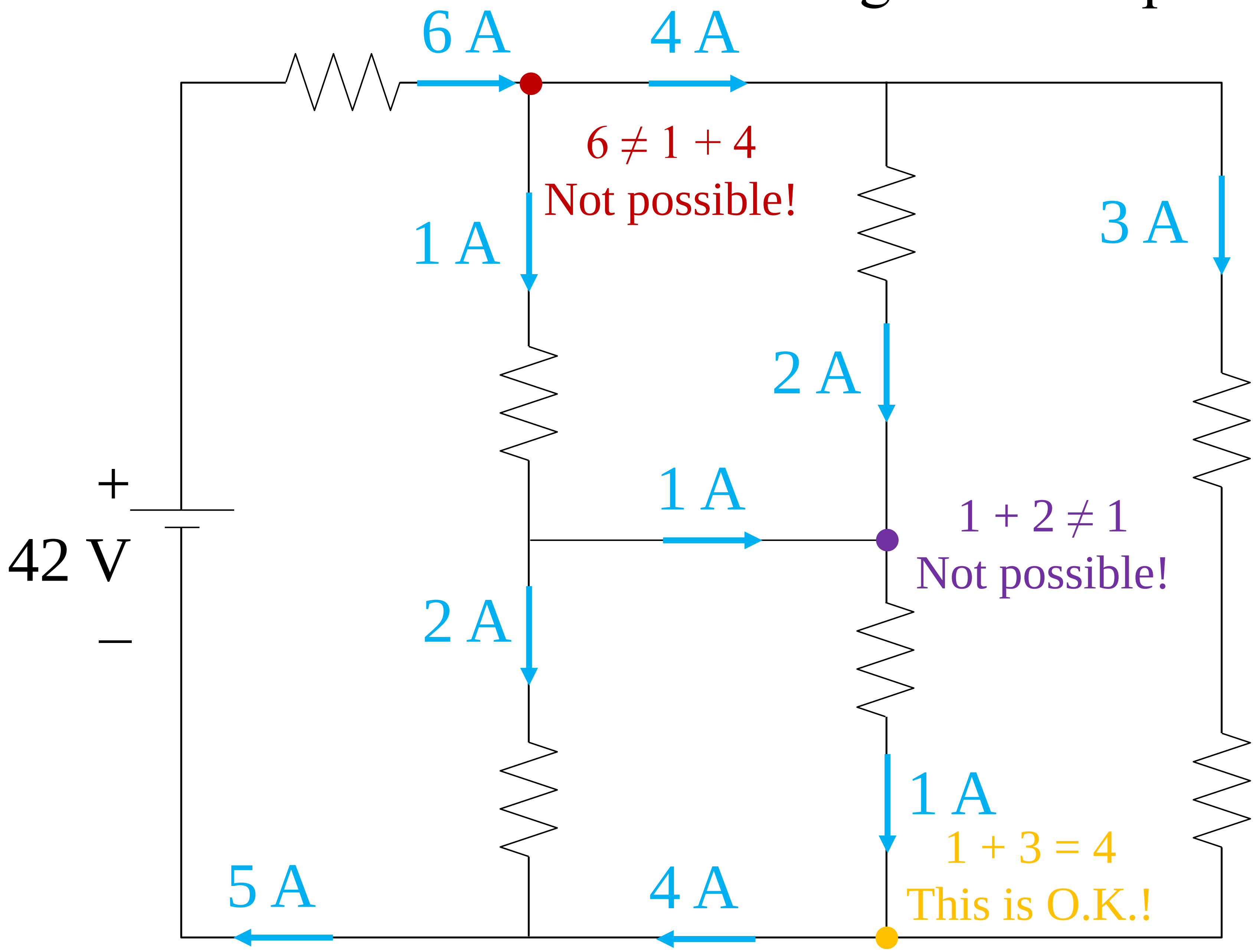
Some example loops in a "corrected" circuit:
(Can you find others? There are many more!)



What's wrong with this picture?



What’s wrong with this picture?

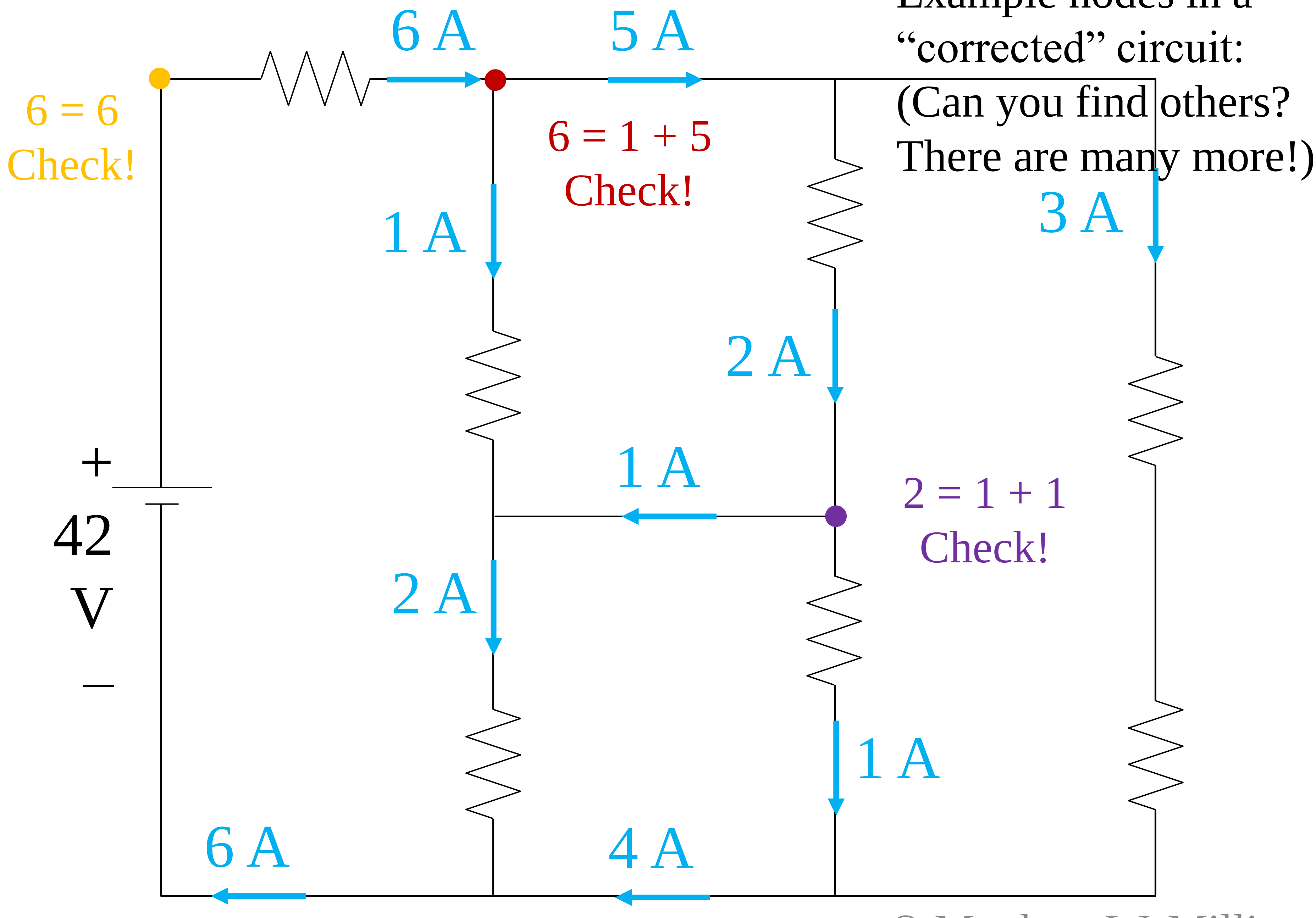


Kirchhoff's Laws

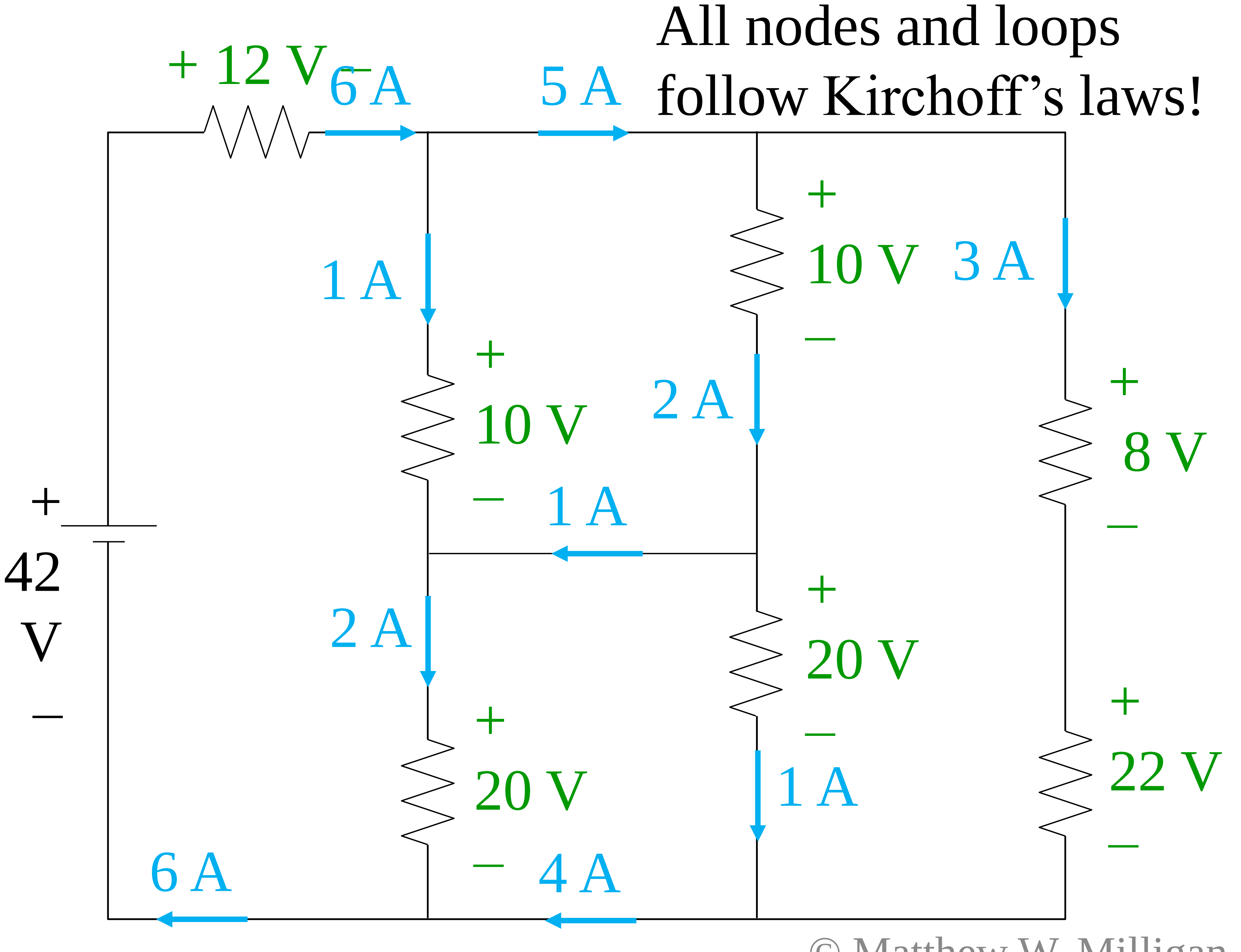
- Loop Rule: The sum of the potential differences across all elements around any loop equals zero.
- Node Rule: The sum of currents entering a node equals the sum of currents exiting a node.

Because charge is conserved!

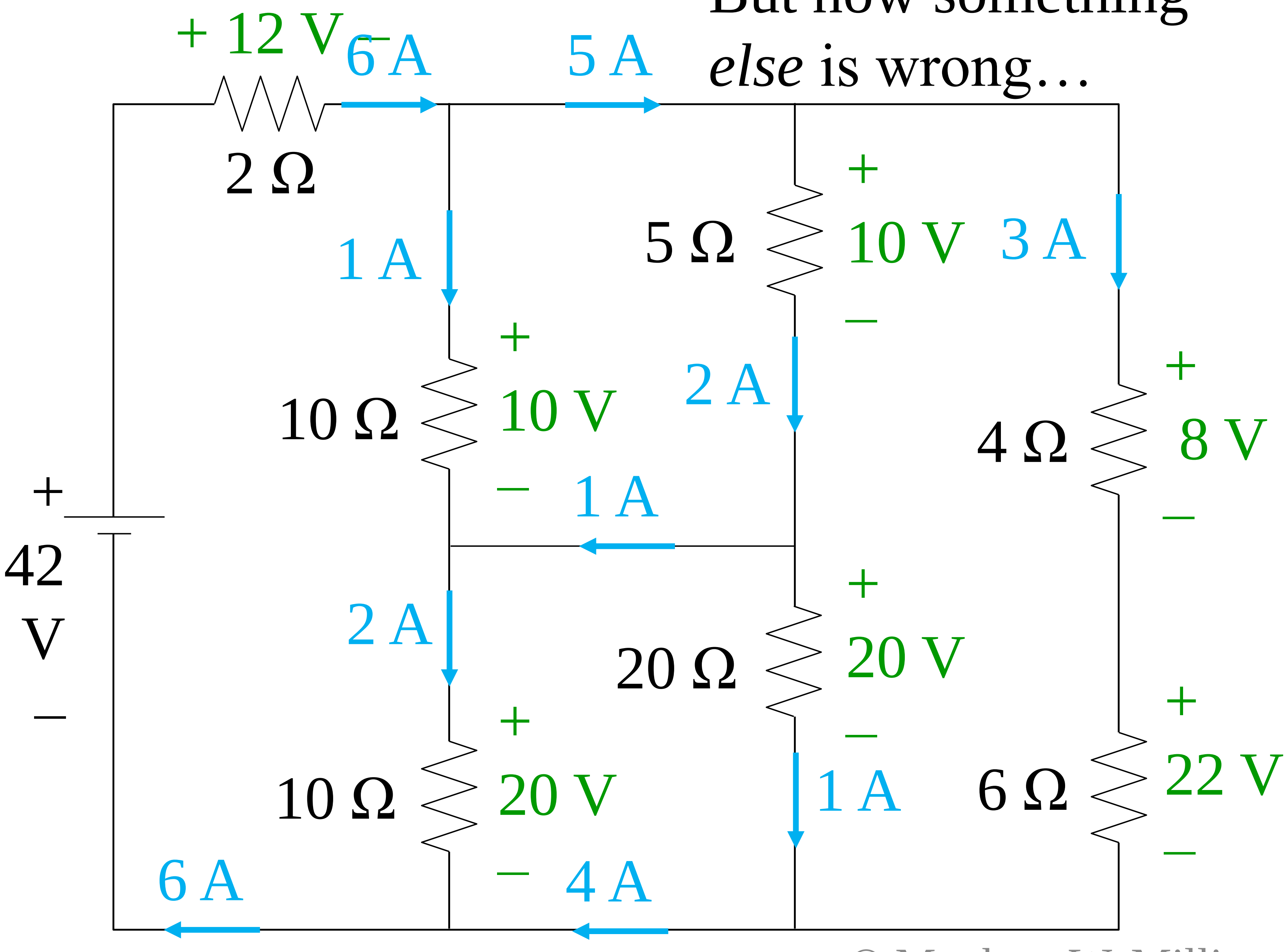
A "node" is any junction in a circuit where two or more wires or other current pathways connect.



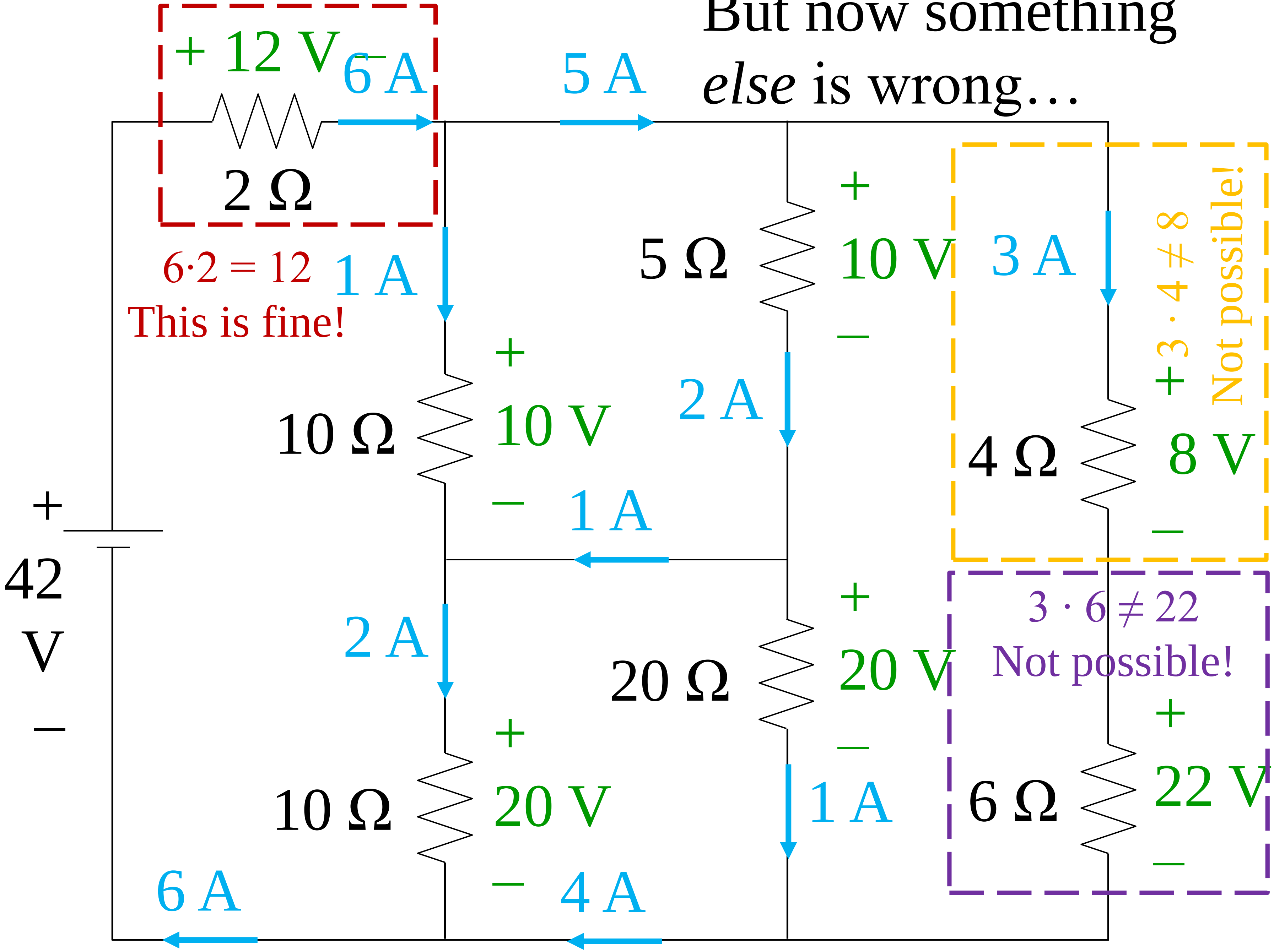
Example nodes in a "corrected" circuit:
(Can you find others? There are many more!)
6 = 6
Check!
6 A
5 A
6 = 1 + 5
Check!
1 A
3 A
2 A
+
42 V
–
1 A
2 = 1 + 1
Check!
2 A
1 A
6 A
4 A


All nodes and loops
follow Kirchoff's laws!
+ 12 V –
6 A
5 A
+
10 V
–
3 A
1 A
+
10 V
–
2 A
+
8 V
–
1 A
+
42
V
–
2 A
+
20 V
–
+
20 V
–
+
22 V
–
1 A
6 A
4 A

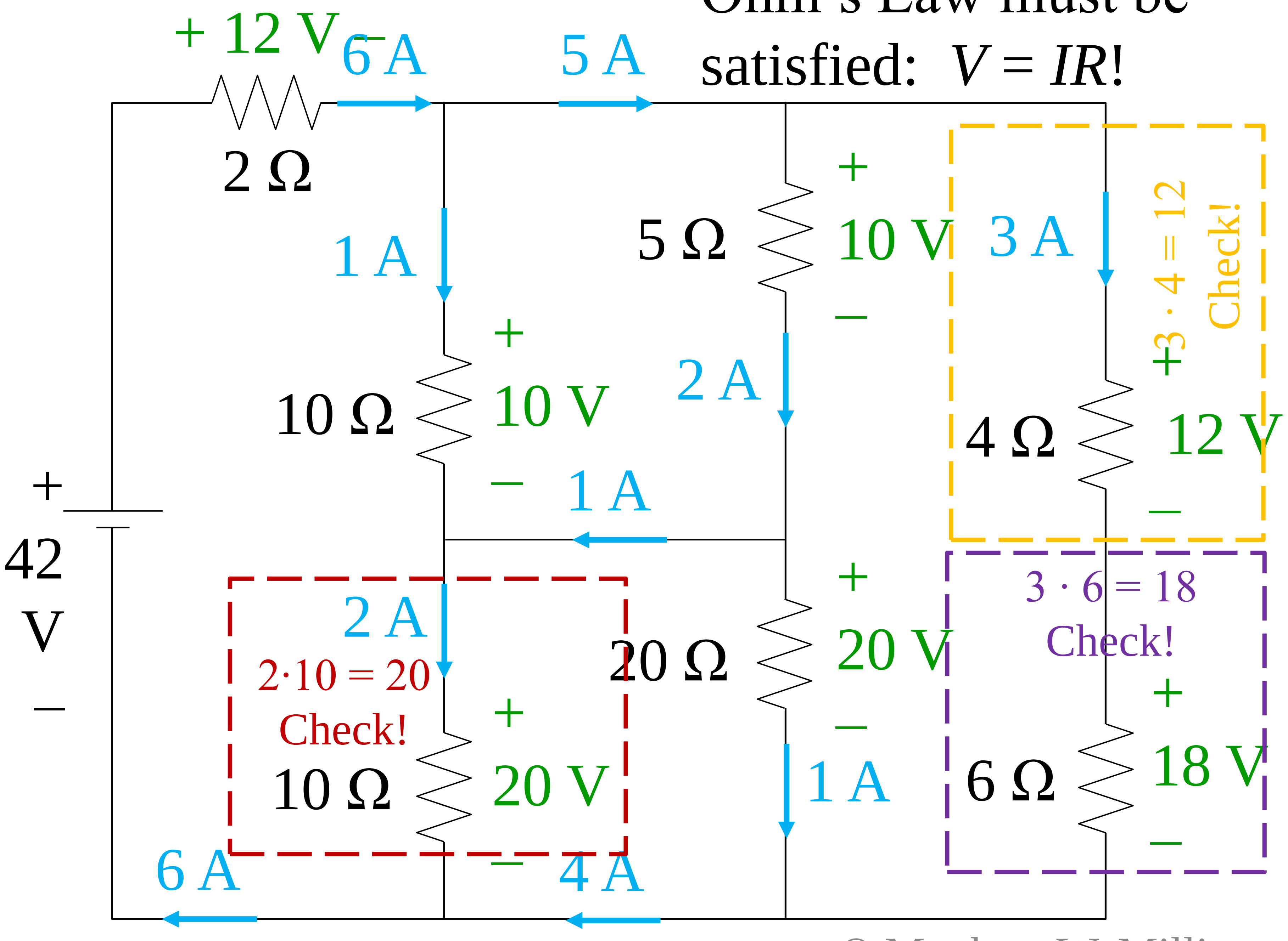
But now something *else* is wrong…



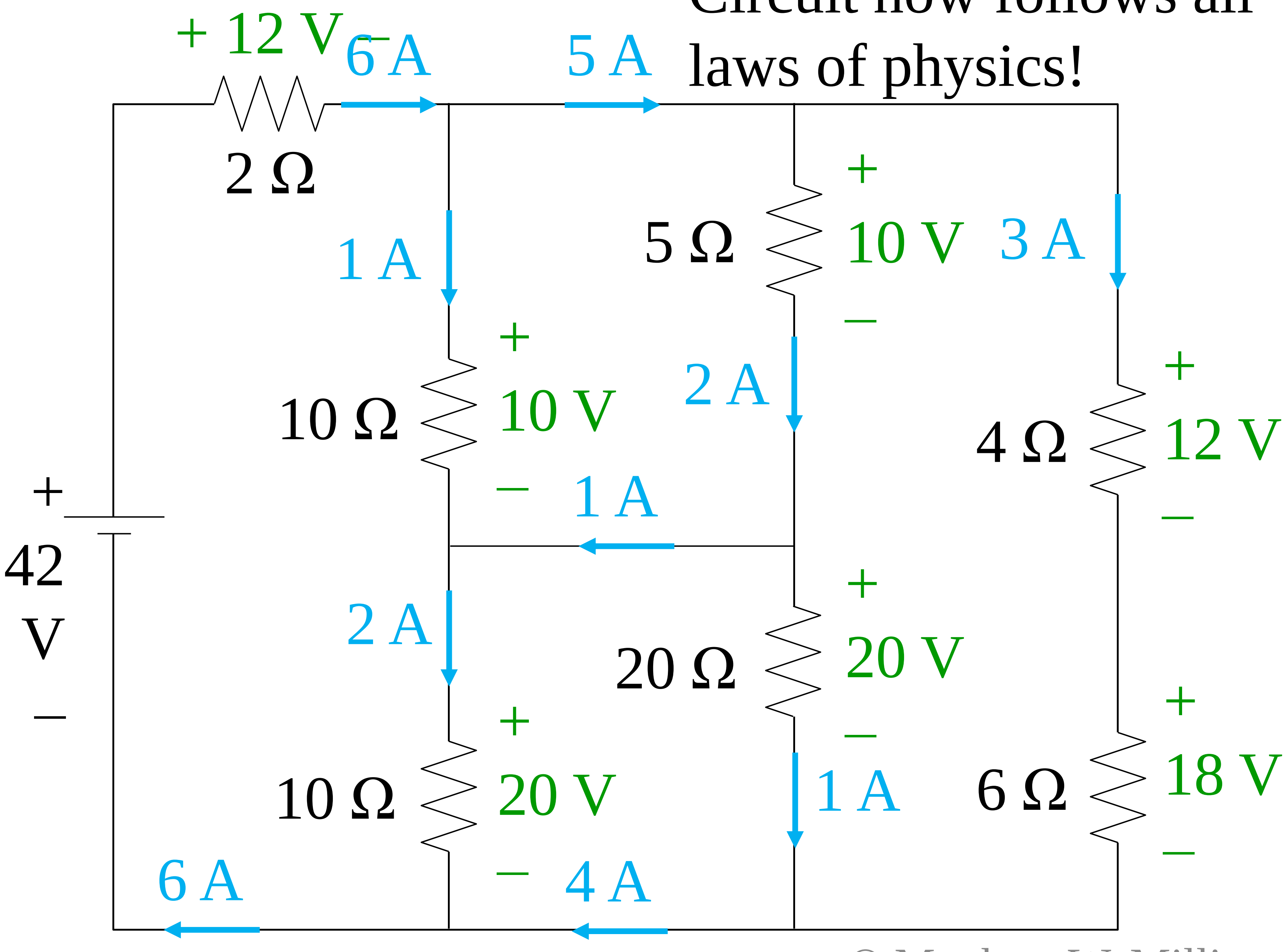
But now something *else* is wrong…



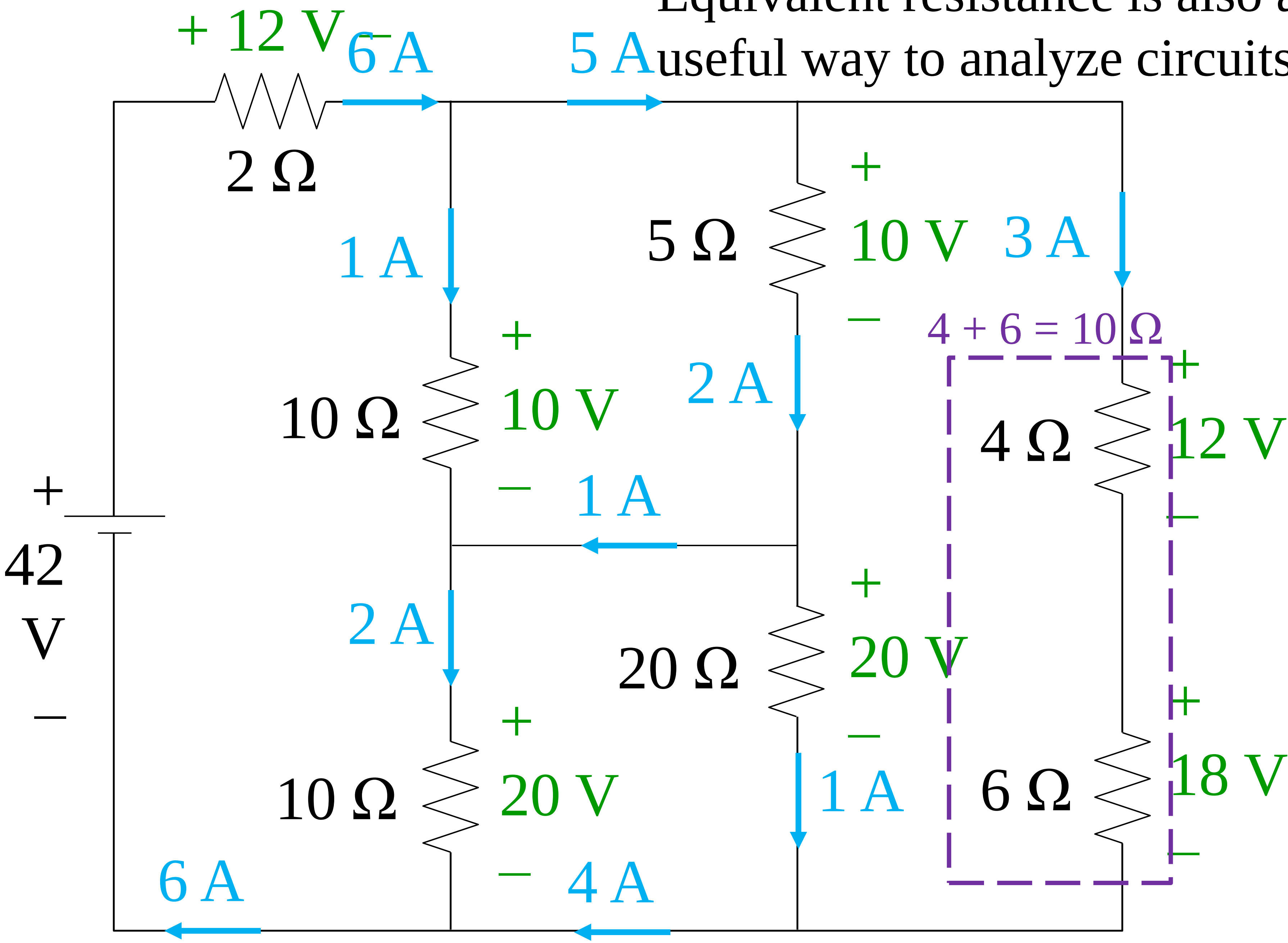
Ohm's Law must be satisfied: $V = IR$!

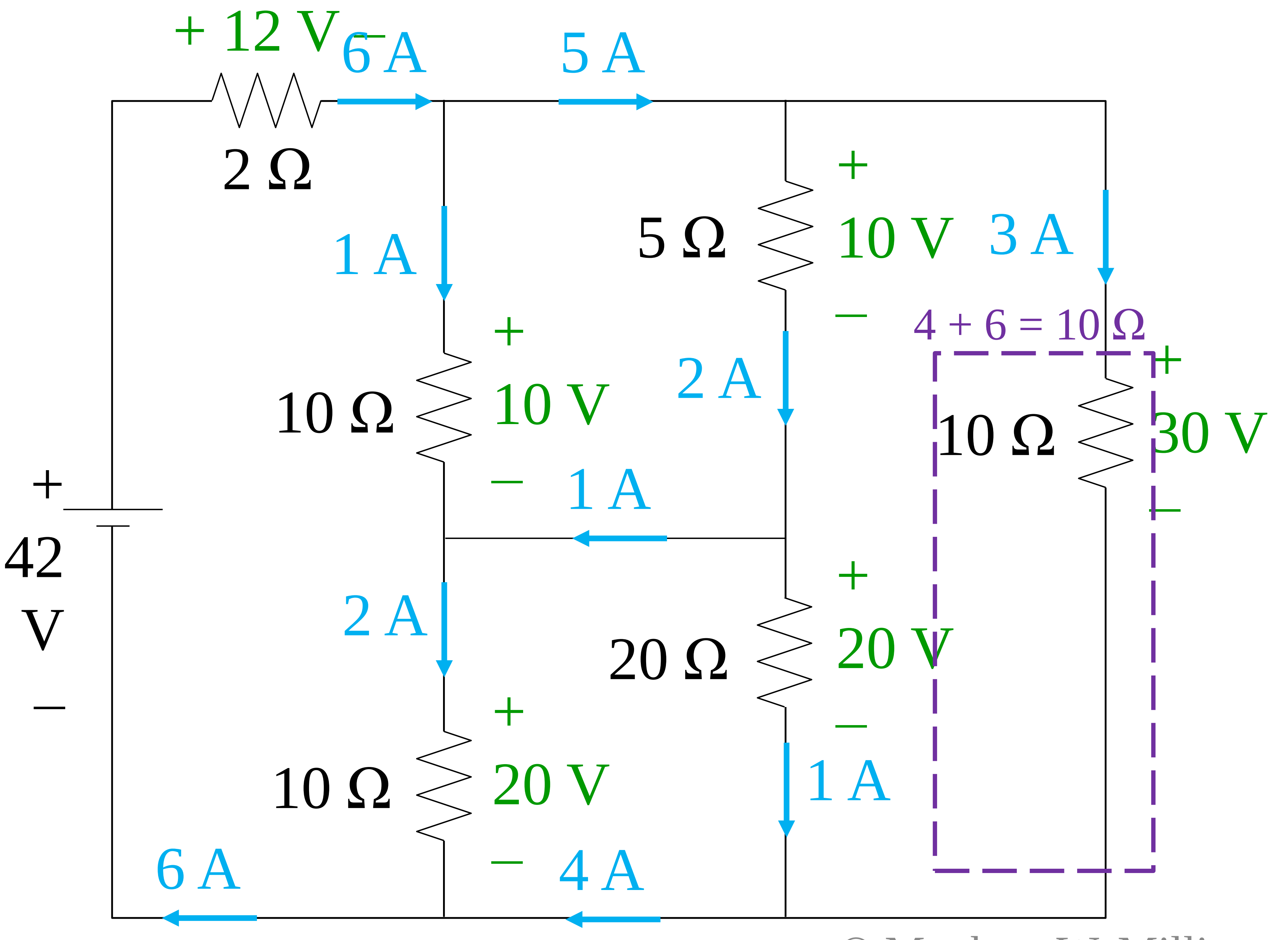


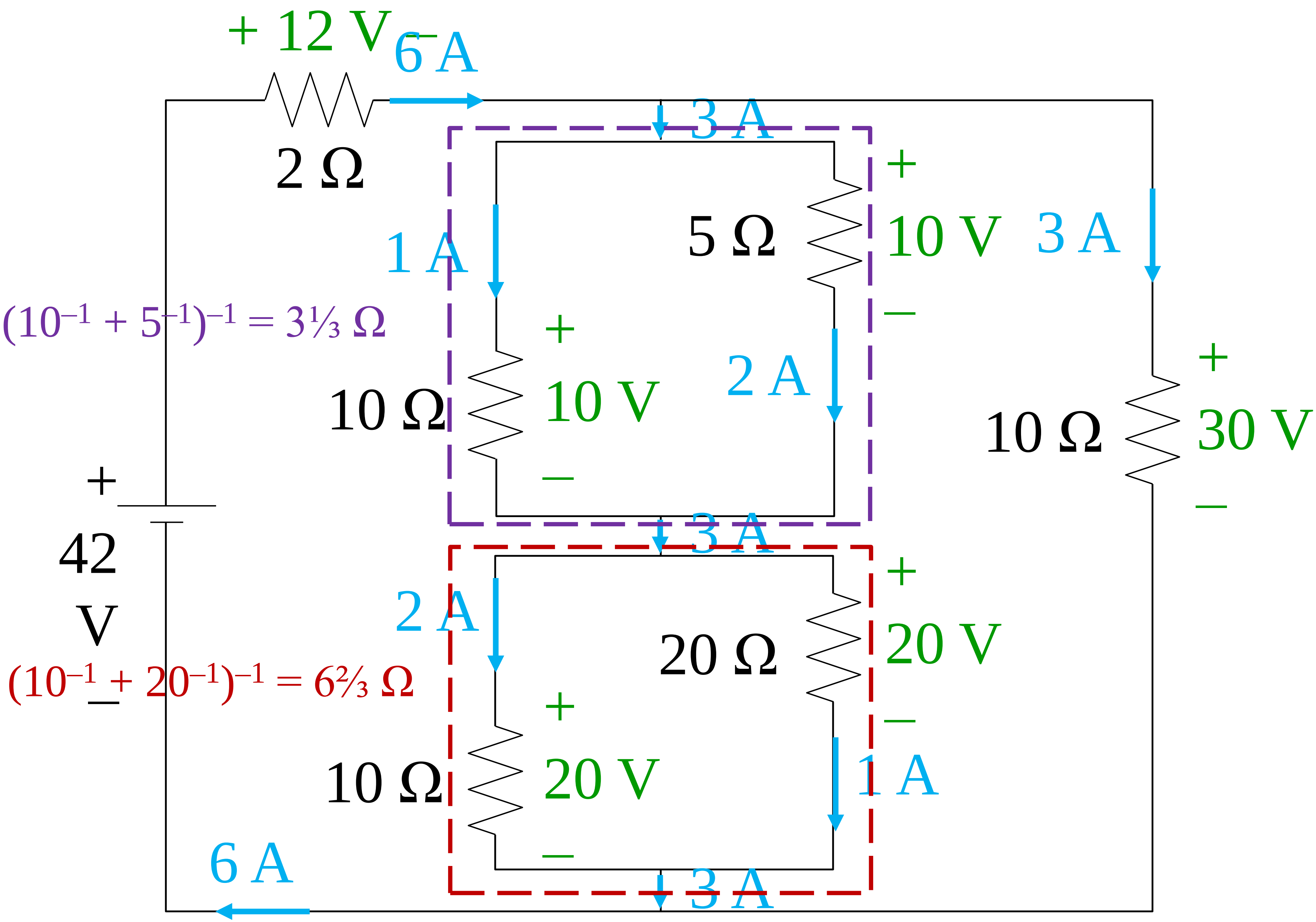
Circuit now follows all laws of physics!

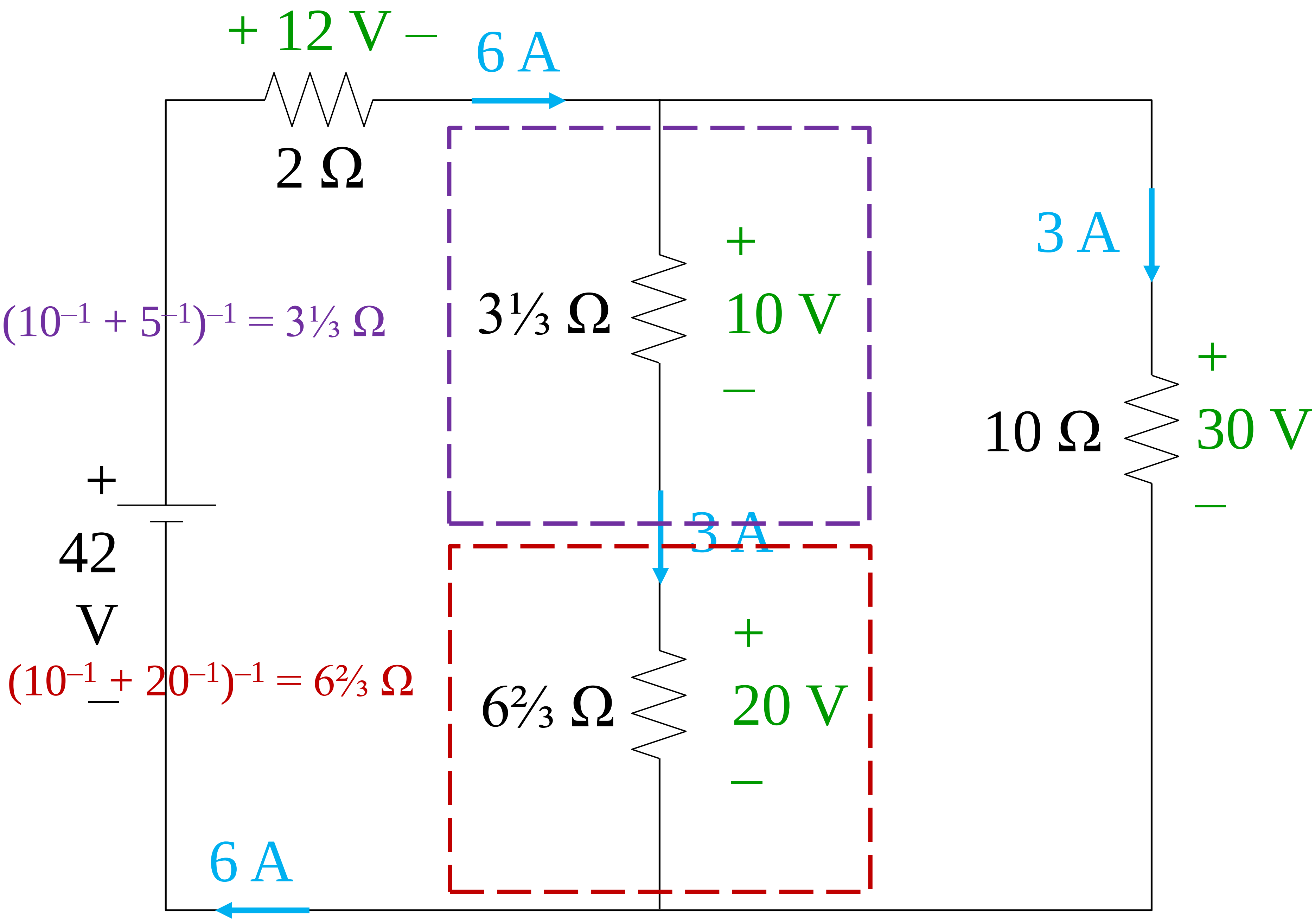


Equivalent resistance is also a useful way to analyze circuits:

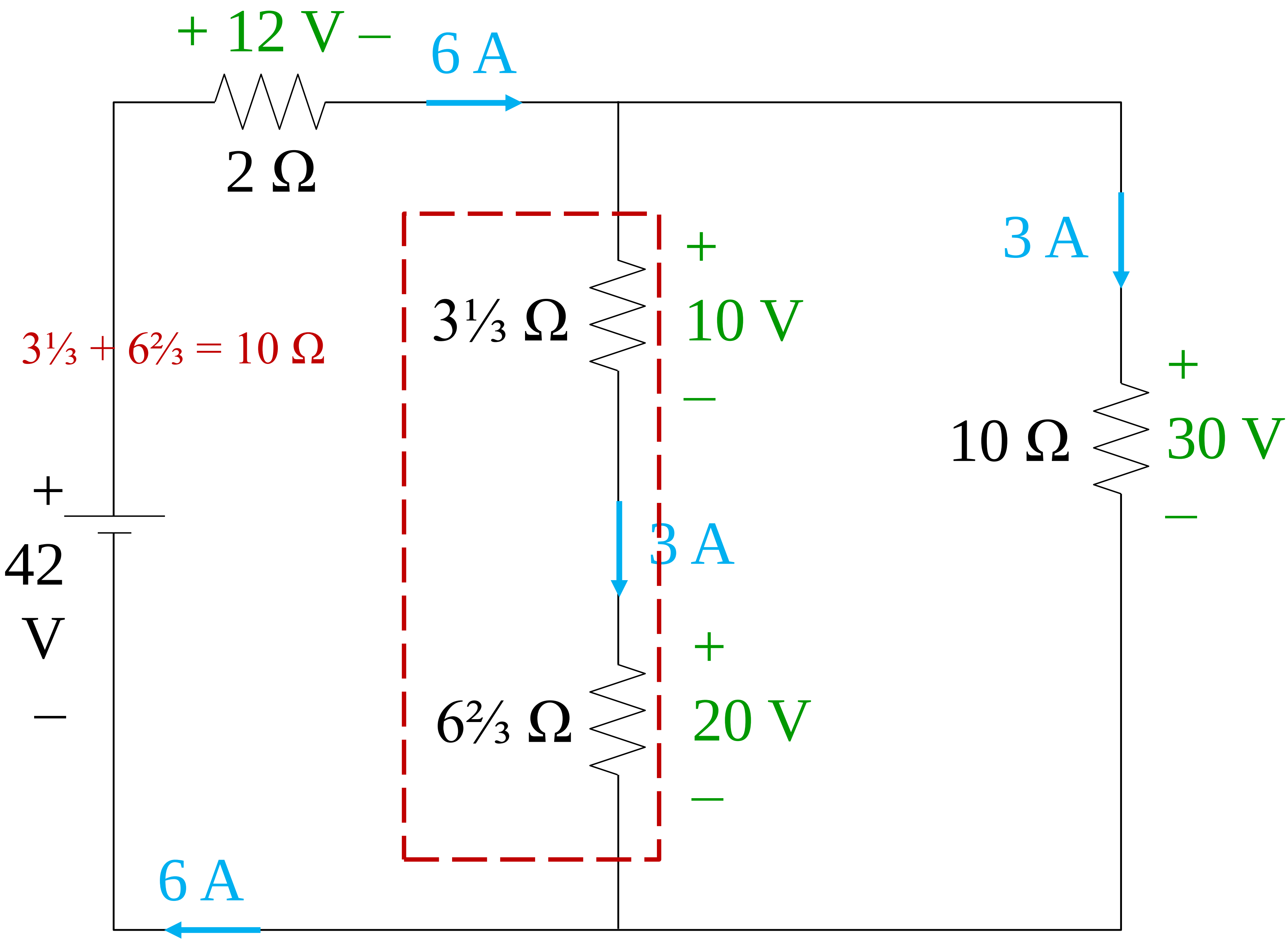



+ 12 V –
6 A
5 A
2 Ω
1 A
5 Ω
+
10 V
–
3 A
4 + 6 = 10 Ω
+
10 Ω
10 V
–
2 A
10 Ω
+
30 V
–
1 A
+
42 V
–
2 A
+
20 Ω
20 V
–
+
10 Ω
20 V
–
1 A
6 A
4 A

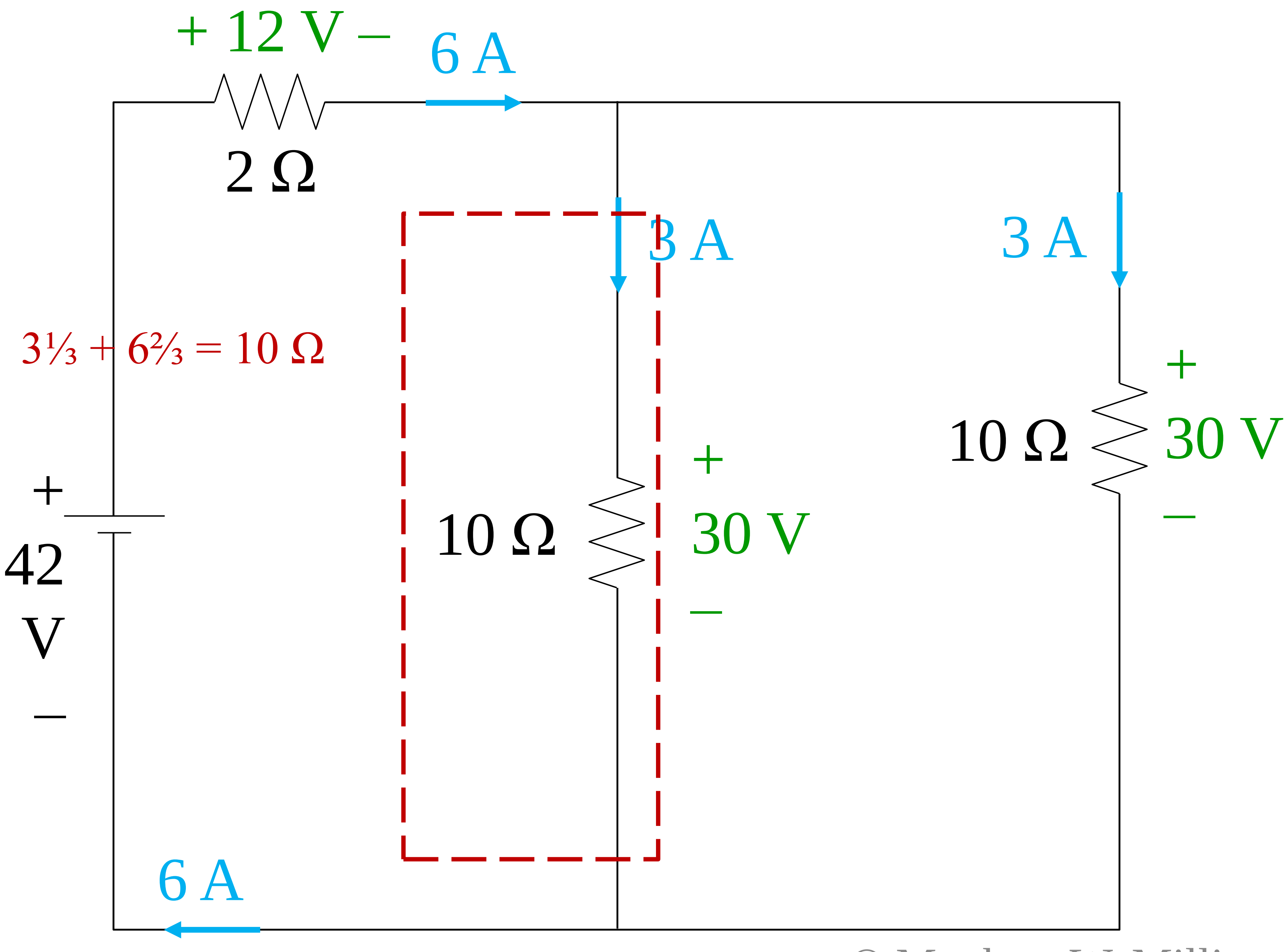

+ 12 V –
6 A
2 Ω
3 A
5 Ω
+
10 V
–
3 A
1 A
(10⁻¹ + 5⁻¹)⁻¹ = 3⅓ Ω
+
10 Ω
10 V
–
2 A
+
10 Ω
30 V
–
+
42 V
–
3 A
2 A
+
20 Ω
20 V
–
(10⁻¹ + 20⁻¹)⁻¹ = 6⅔ Ω
+
10 Ω
20 V
–
1 A
6 A
3 A

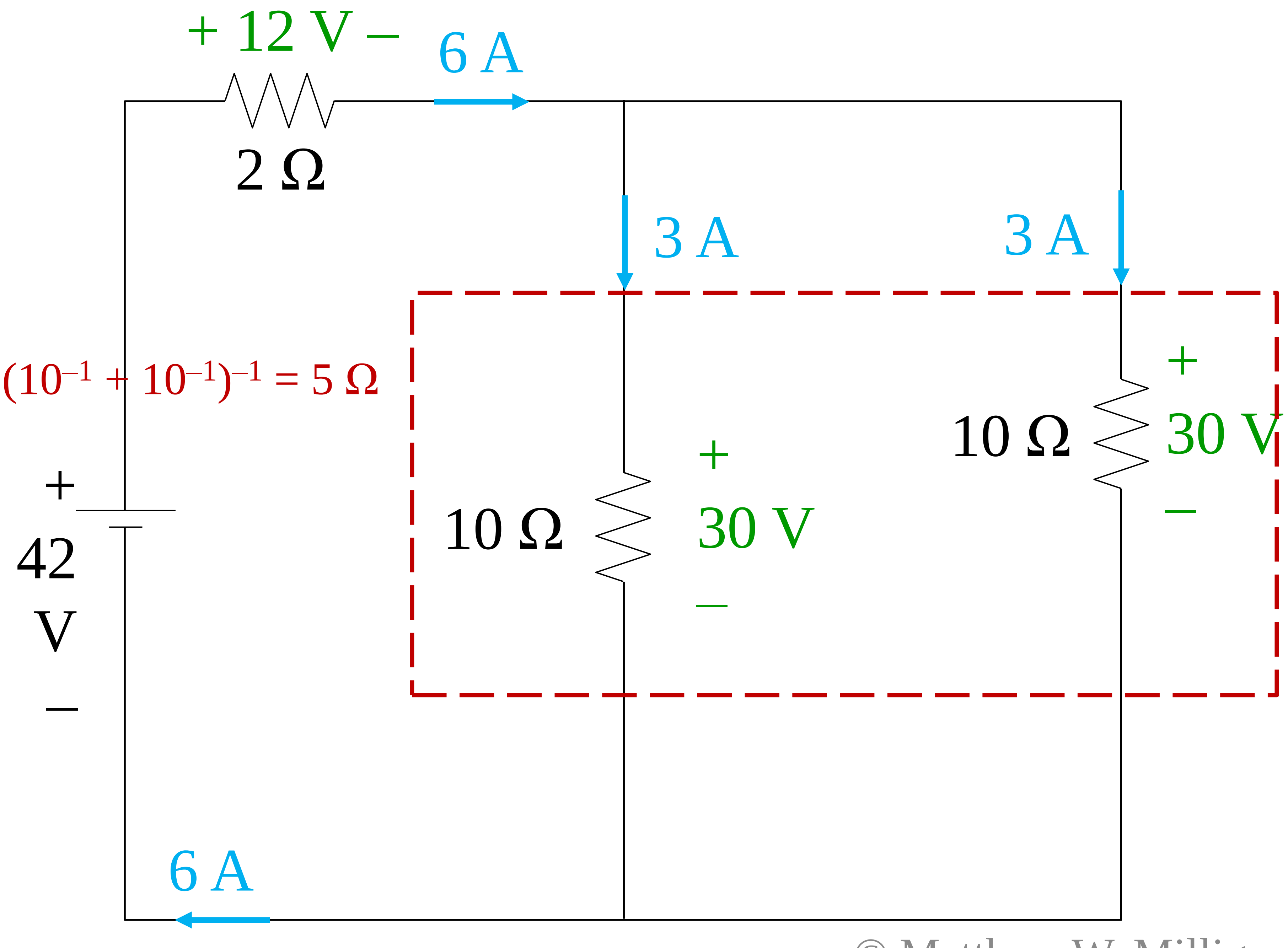


+ 12 V –
6 A
2 Ω
3 A
+
(10⁻¹ + 5⁻¹)⁻¹ = 3⅓ Ω
3⅓ Ω
10 V
–
+
10 Ω
30 V
–
+
42 V
–
3 A
+
(10⁻¹ + 20⁻¹)⁻¹ = 6⅔ Ω
6⅔ Ω
20 V
–
6 A

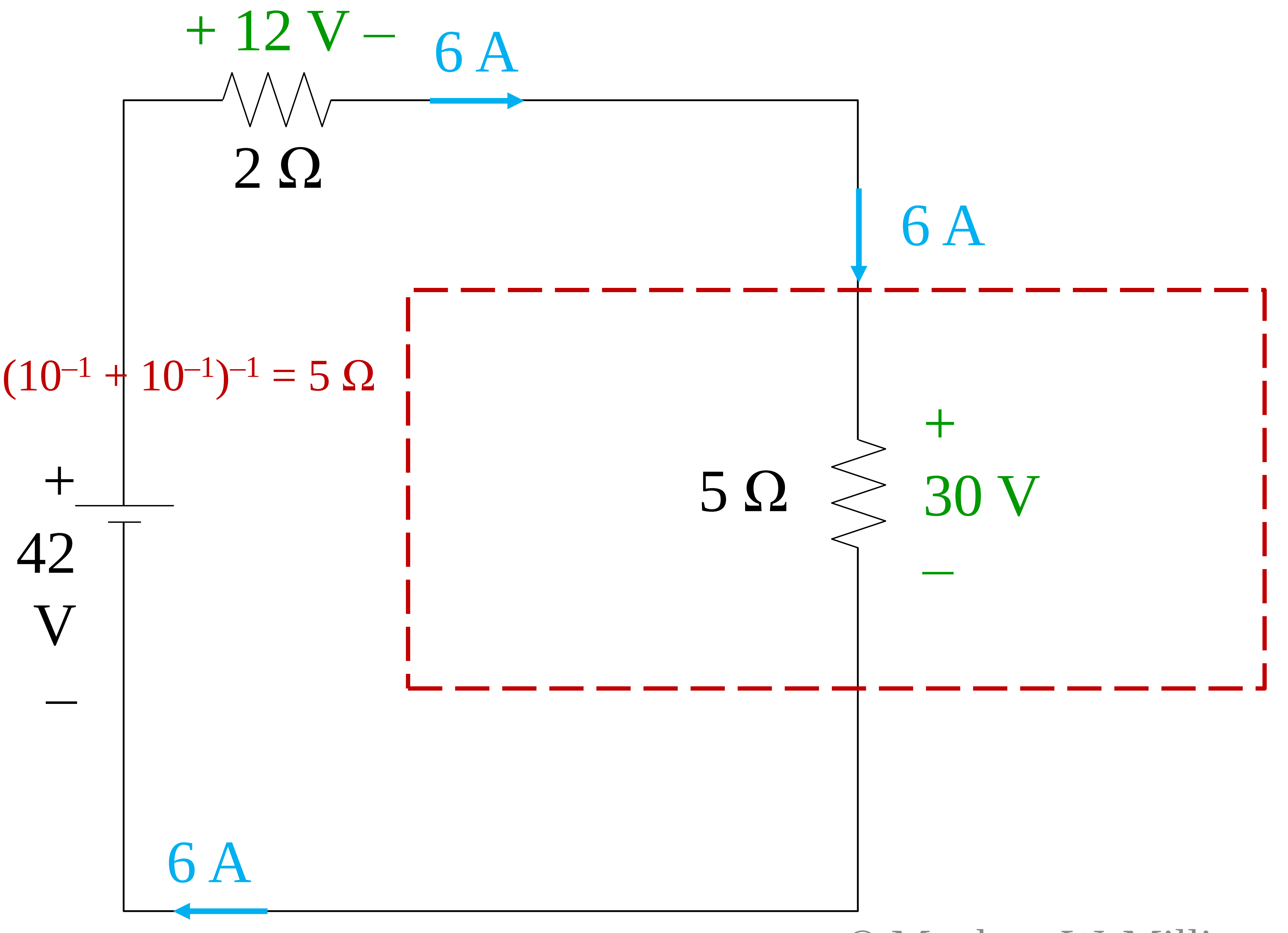


+ 12 V –
6 A
2 Ω
3⅓ Ω
+
10 V
–
3 A
3⅓ + 6⅔ = 10 Ω
+
42 V
–
3 A
+
10 Ω
30 V
–
6⅔ Ω
+
20 V
–
6 A

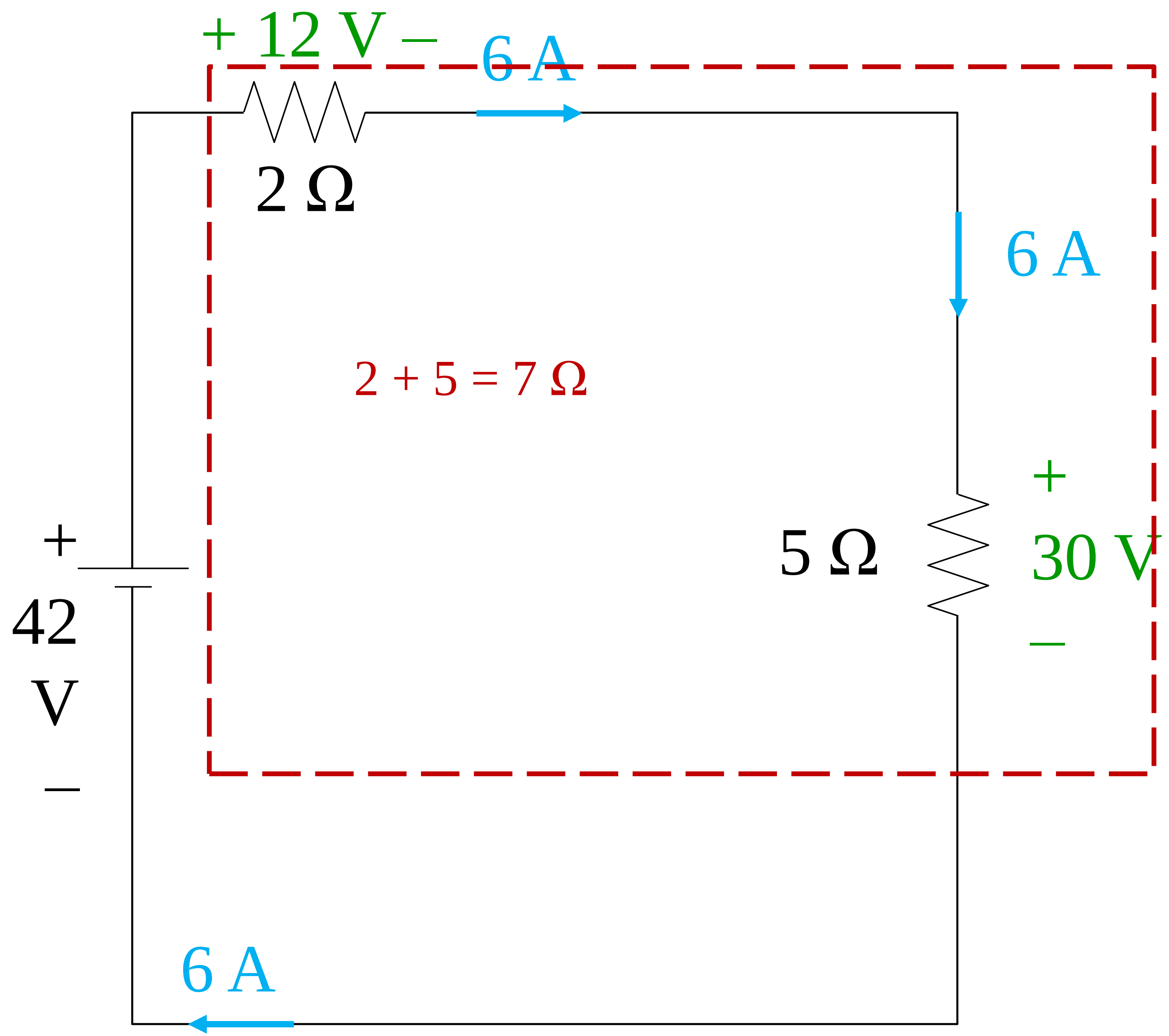

+ 12 V −
6 A
2 Ω
3 A
3 A
3⅓ + 6⅔ = 10 Ω
+
10 Ω
30 V
−
+
42 V
−
10 Ω
+
30 V
−
6 A

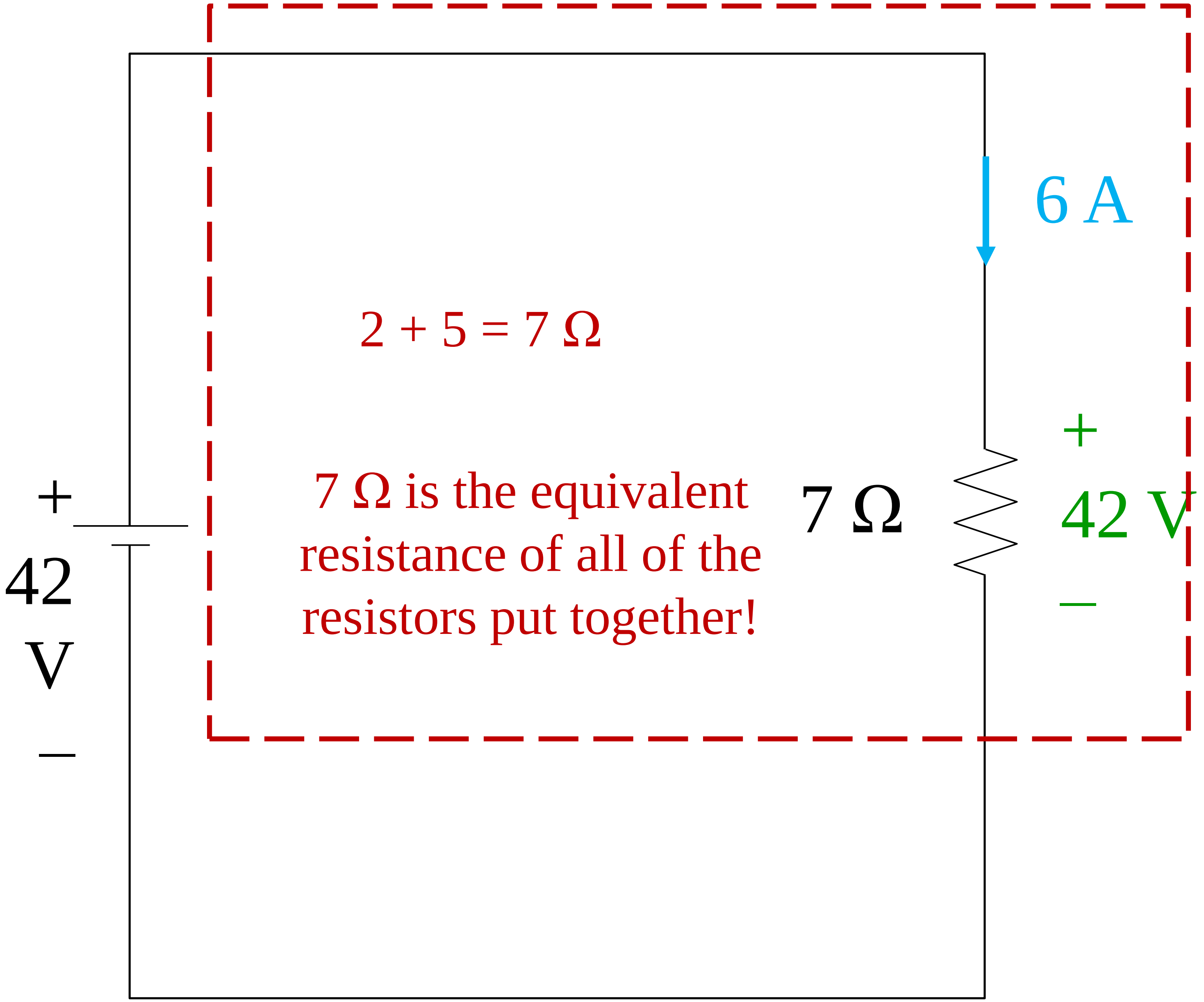


+ 12 V –
6 A
2 Ω
3 A
3 A
(10⁻¹ + 10⁻¹)⁻¹ = 5 Ω
+
30 V
–
10 Ω
+
42 V
–
10 Ω
+
30 V
–
6 A



+ 12 V –
6 A
2 Ω
6 A
(10–1 + 10–1)–1 = 5 Ω
+
42
V
–
5 Ω
+
30 V
–
6 A


+ 12 V −
6 A
2 Ω
6 A
2 + 5 = 7 Ω
+
42
V
−
5 Ω
+
30 V
−
6 A


6 A
2 + 5 = 7 Ω
7 Ω is the equivalent resistance of all of the resistors put together!
7 Ω
+
42 V
–
+
42
V
–