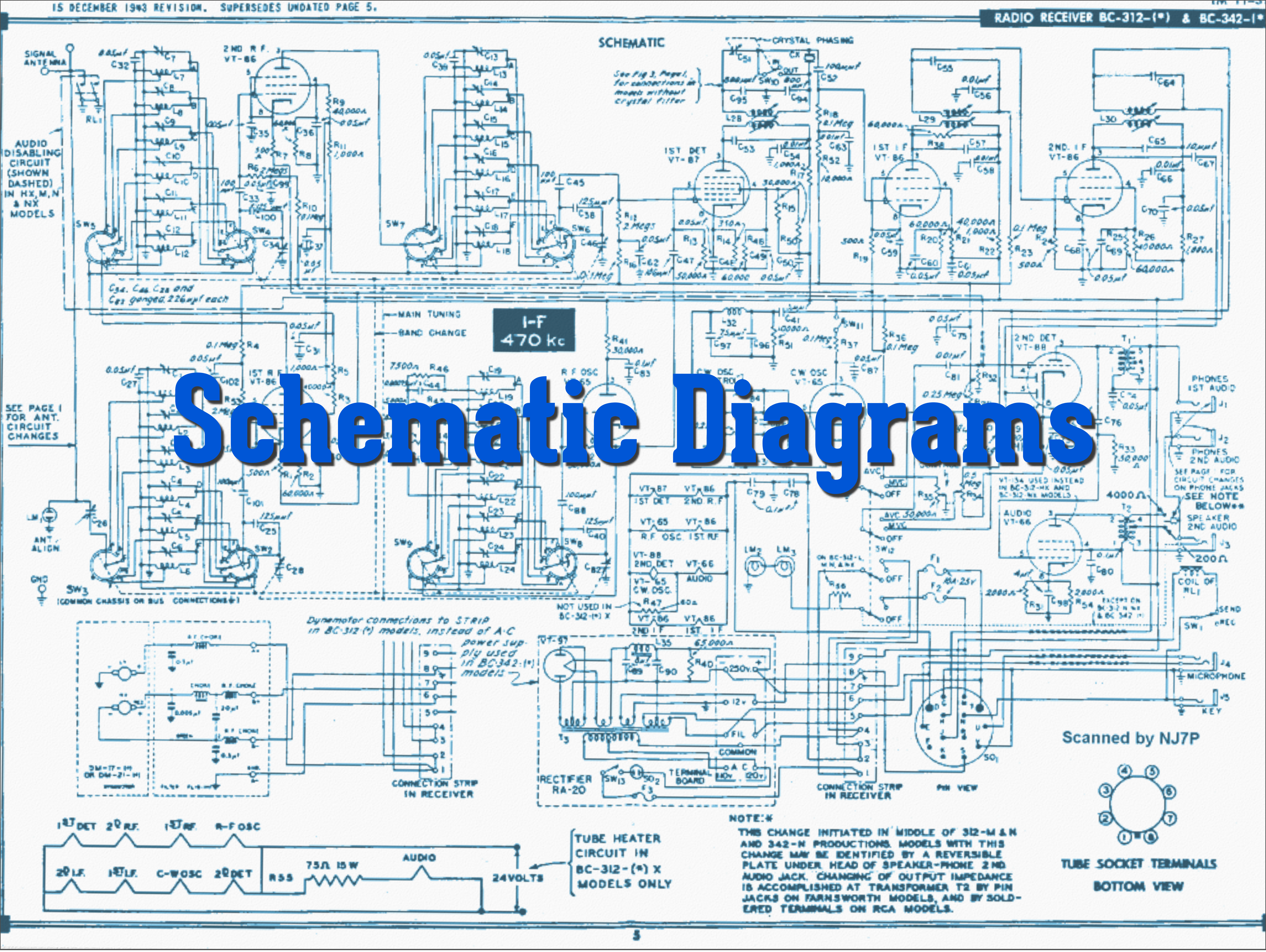
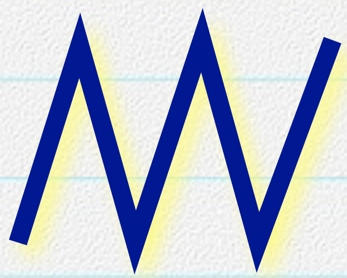
Electric Circuits

Schematic Diagrams

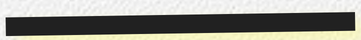


Schematic Icons

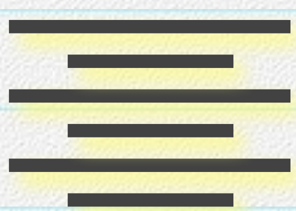


Resistor

Switch



Wire



Battery

Light Bulb

Resistance

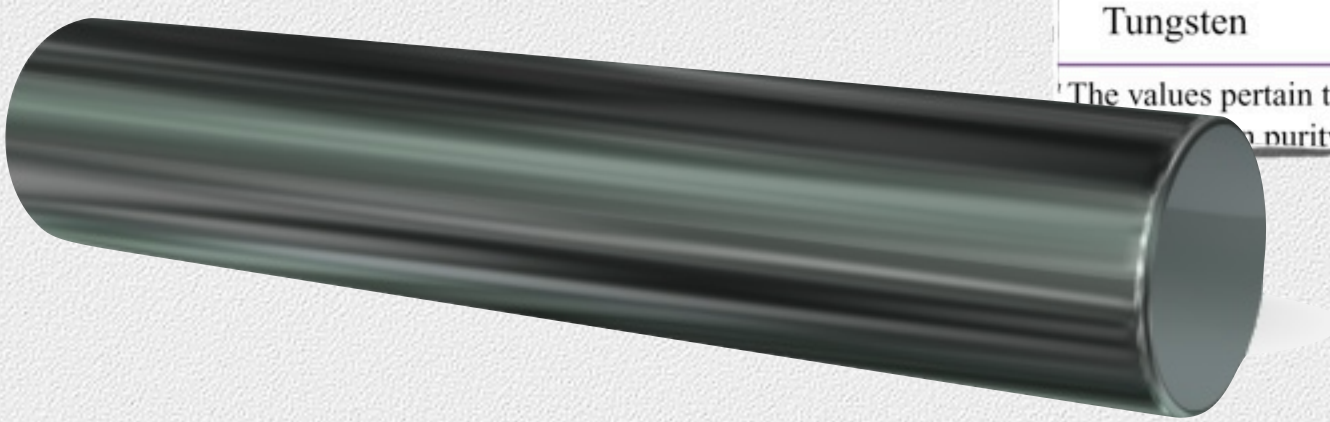
- Resistance Ω
- resistivity Ωm
- length m
- area m²

$$R = \frac{\rho L}{A}$$

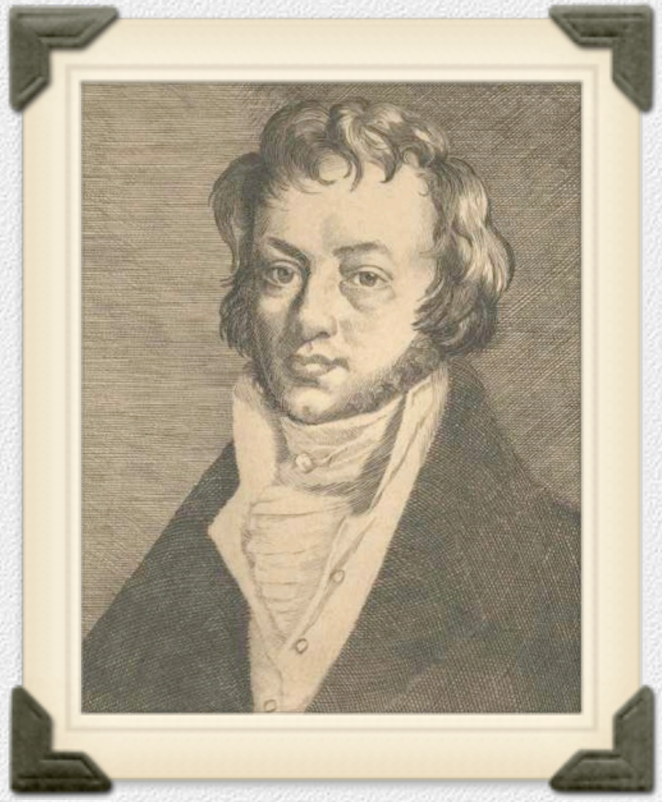
able 20.1 Resistivities of Various Materials

Material	Resistivity ρ $(\Omega \cdot m)$	Material	Resistivity ρ $(\Omega \cdot m)$
Conductors		***Semiconductors***	
Aluminum	2.82×10^{-8}	Carbon	3.5×10^{-5}
Copper	1.72×10^{-8}	Germanium	0.5[b]
Gold	2.44×10^{-8}	Silicon	20–2300[b]
Iron	9.7×10^{-8}	***Insulators***	
Mercury	95.8×10^{-8}	Mica	10^{11}–10^{15}
Nichrome (alloy)	100×10^{-8}	Rubber (hard)	10^{13}–10^{16}
Silver	1.59×10^{-8}	Teflon	10^{16}
Tungsten	5.6×10^{-8}	Wood (maple)	3×10^{10}

The values pertain to temperatures near 20 °C.
n purity.



Georg Simon Ohm
1789-1854



André-Marie Ampère
1775-1836

Ohm's Law

$$V = I\,R$$

$$\mathcal{E} = I\,R$$

Potential or Voltage (**V**) in Volts (**V**)

Current (**I**) in Amperes (**A**)

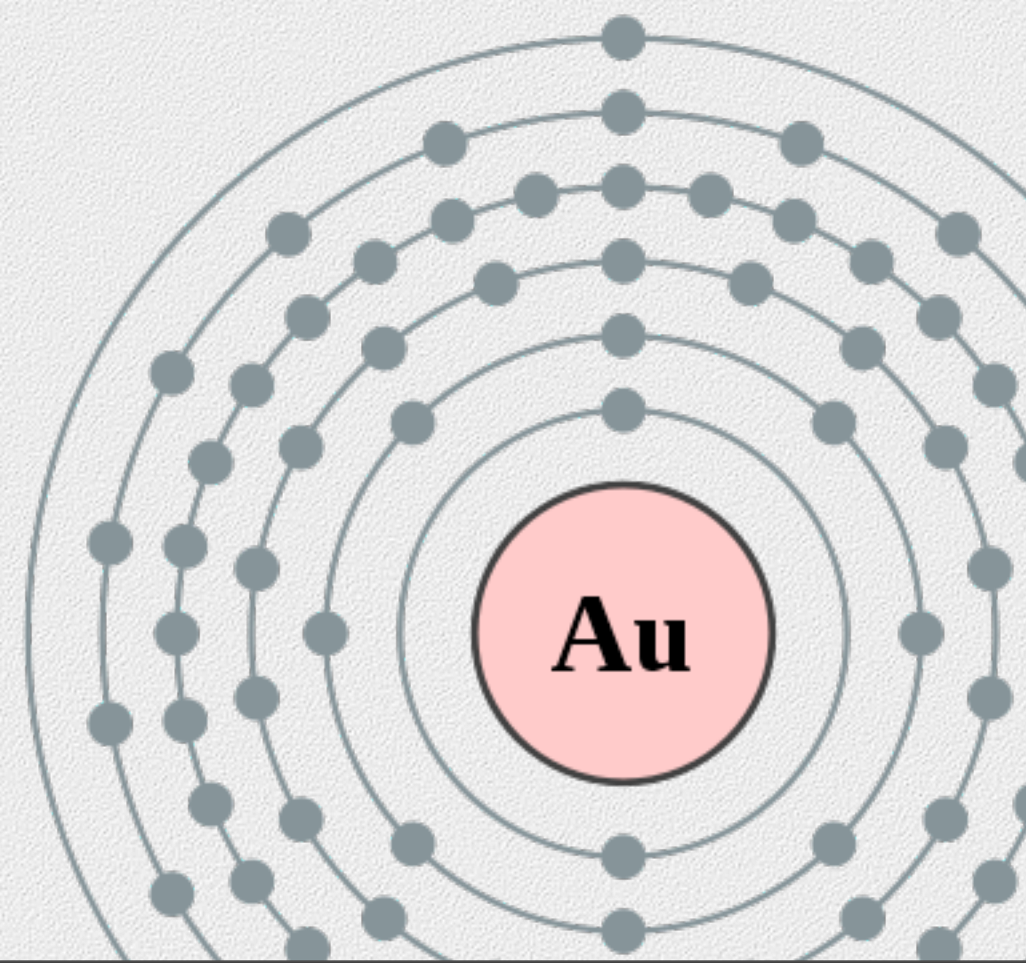
Resistance (**R**) in Ohms (**Ω**)

Alessandro Giuseppe Antonio Anastasio Gerolamo Umberto Volta
1745-1827

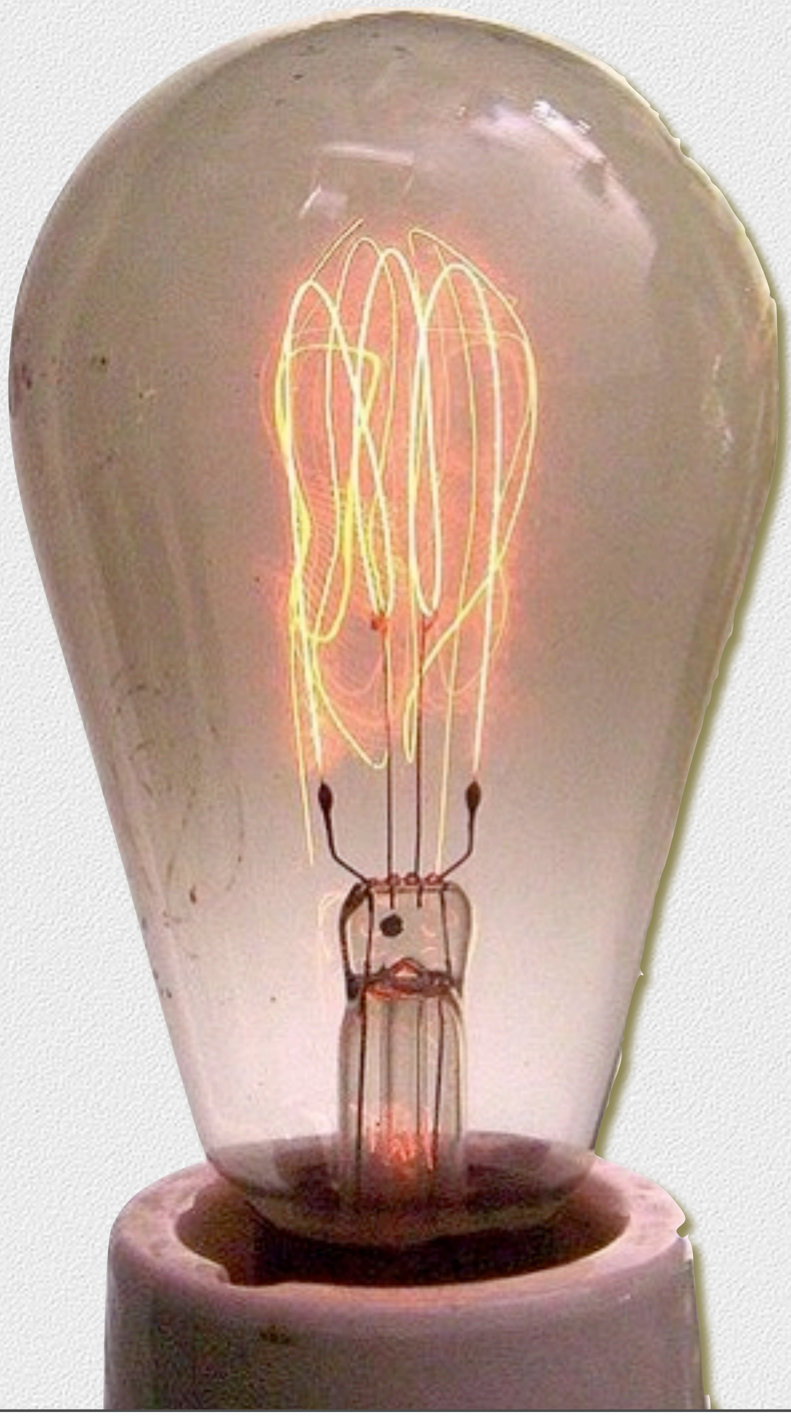
- The charge of a single electron is 1.6021×10^{-19} Coulombs
- or... it would take 6.241×10^{18} electrons to have a Coulomb of charge
- 1 Ampere is a current of that many electrons every second.

Charles-Augustin de Coulomb
1736-1806

Electric Charge



Power

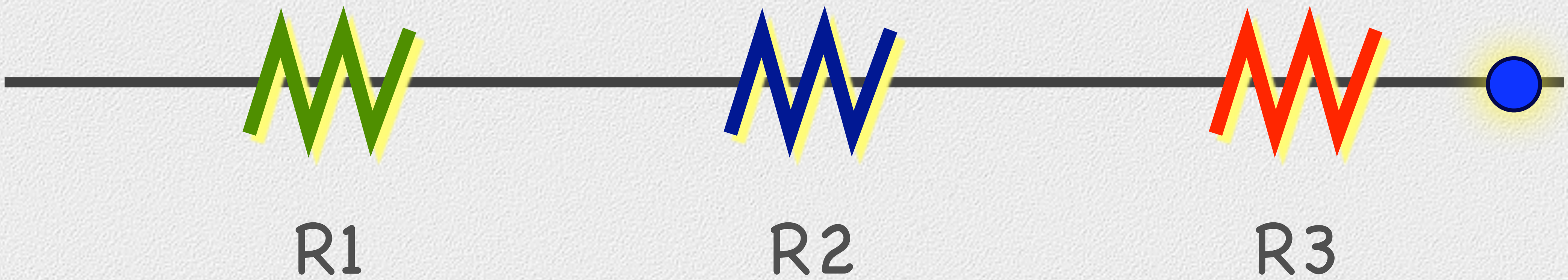


$$P = IV$$

$$P = V^2/R$$

$$P = I^2R$$

Resistors in Series



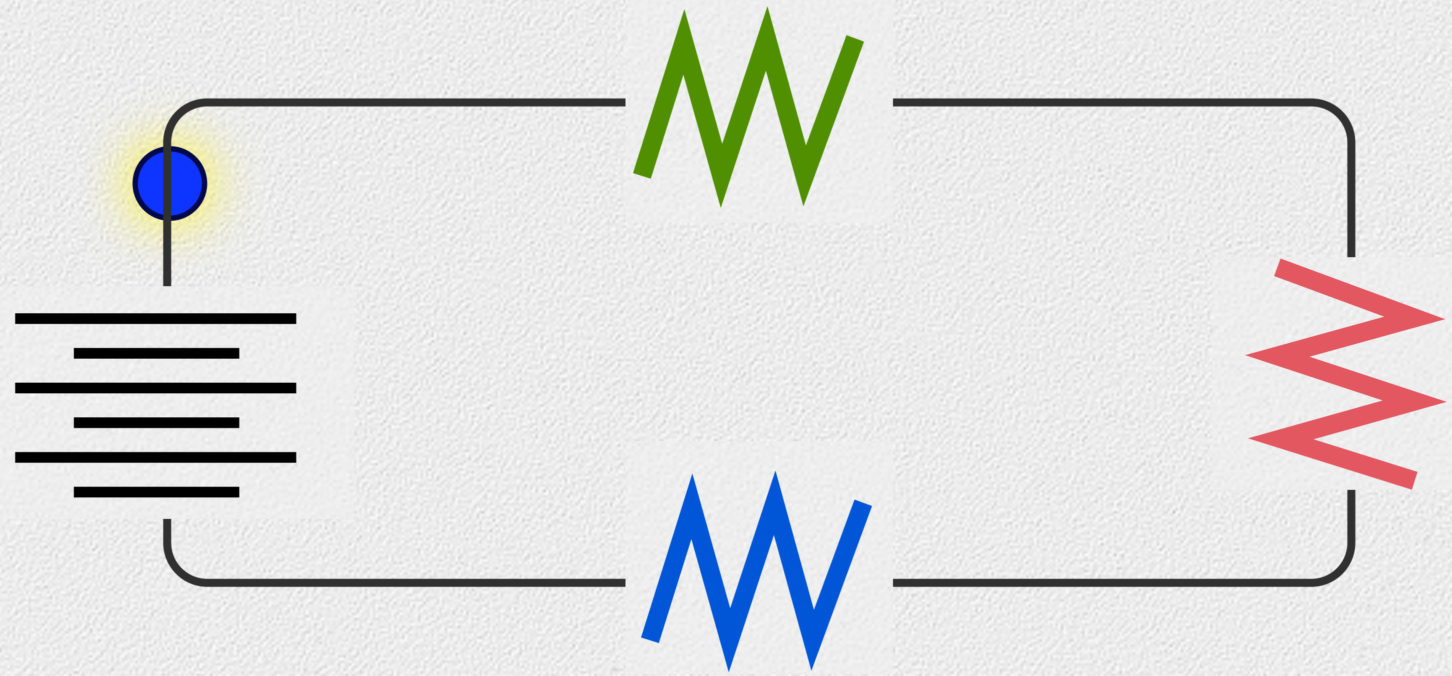
- The Charges have to "fight" through every resistor. This decreases the total current.

Voltage: $V_T = V_1 + V_2 + V_3$

Current: $I_T = I_1 = I_2 = I_3$

Resistance: $R_T = R_1 + R_2 + R_3$

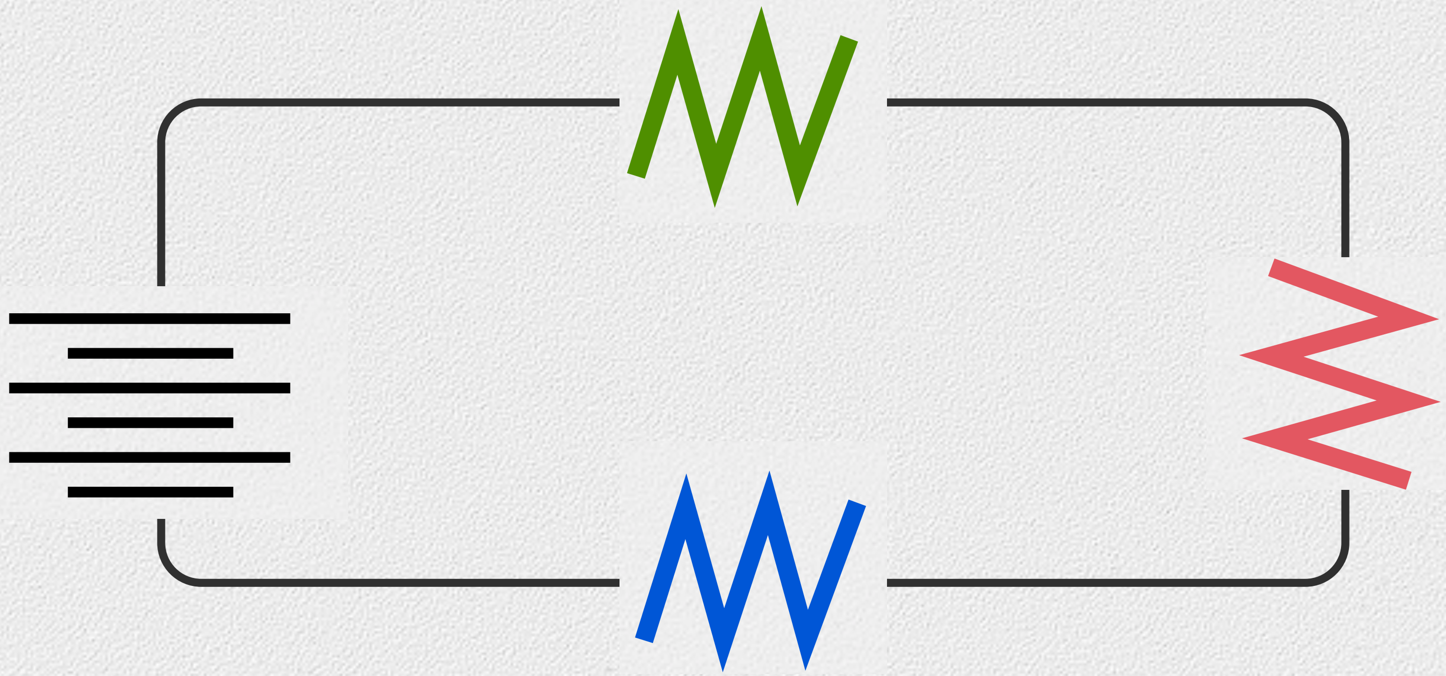
Series



The current starts at the top of the battery and follows a single path, clockwise, around the circuit.

	V (V)	**I** (A)	**R** (Ω)	**P** (W)
R_1			2	
R_2			4	
R_3			6	
TOTAL	24			

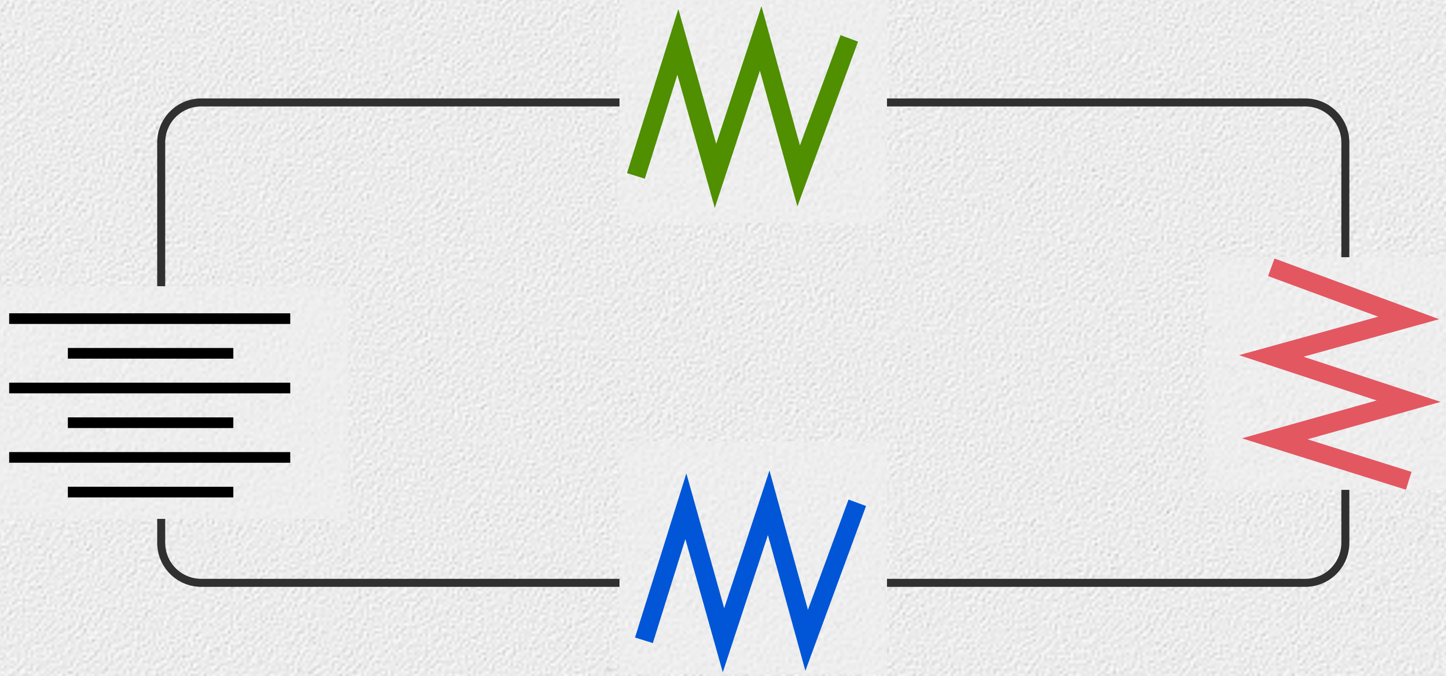
Series



Start with the total resistance, a simple sum of the individual values

	V (V)	**I** (A)	**R** (Ω)	**P** (W)
R_1			2	
R_2			4	
R_3			6	
TOTAL	24		12	

Series



Use the total resistance to find the total current.

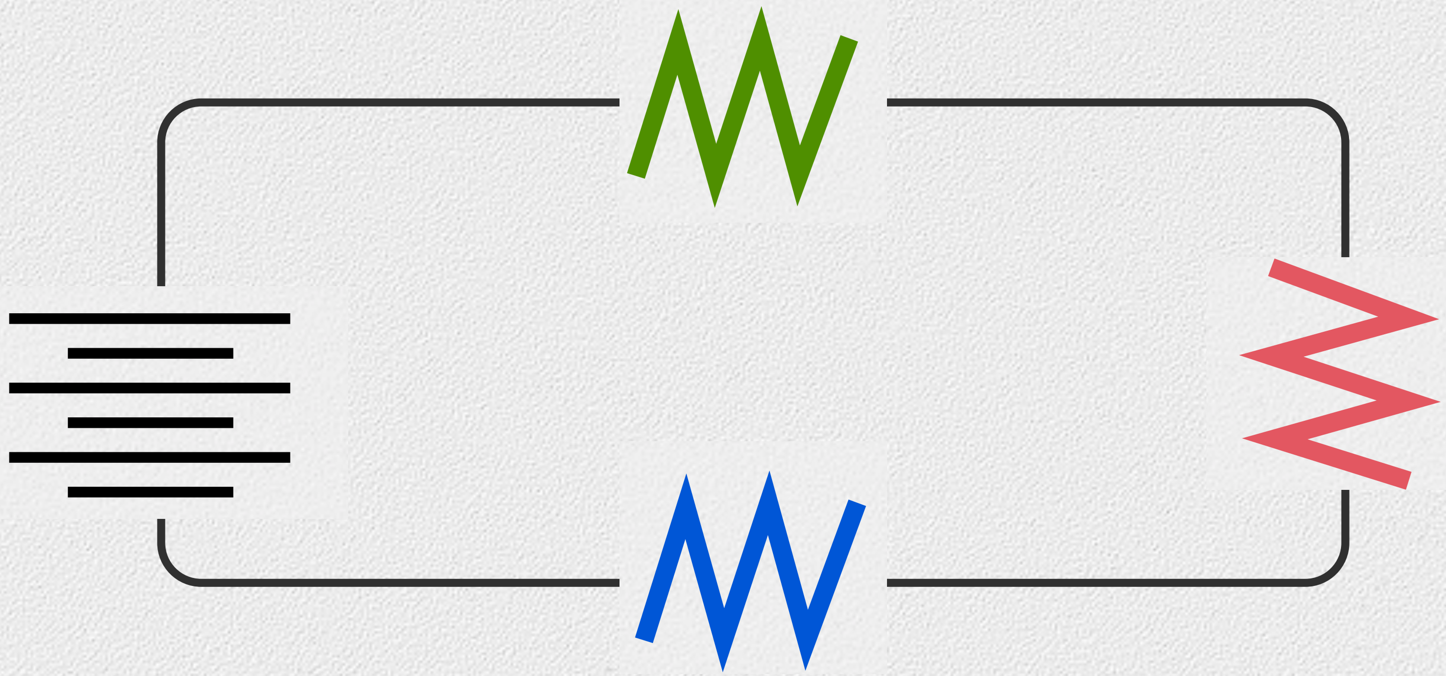
$I = V / R$

$= 24 / 12$

$= 2$ Amperes

	V (V)	I (A)	R (Ω)	P (W)
R_1			2	
R_2			4	
R_3			6	
TOTAL	24	2	12	

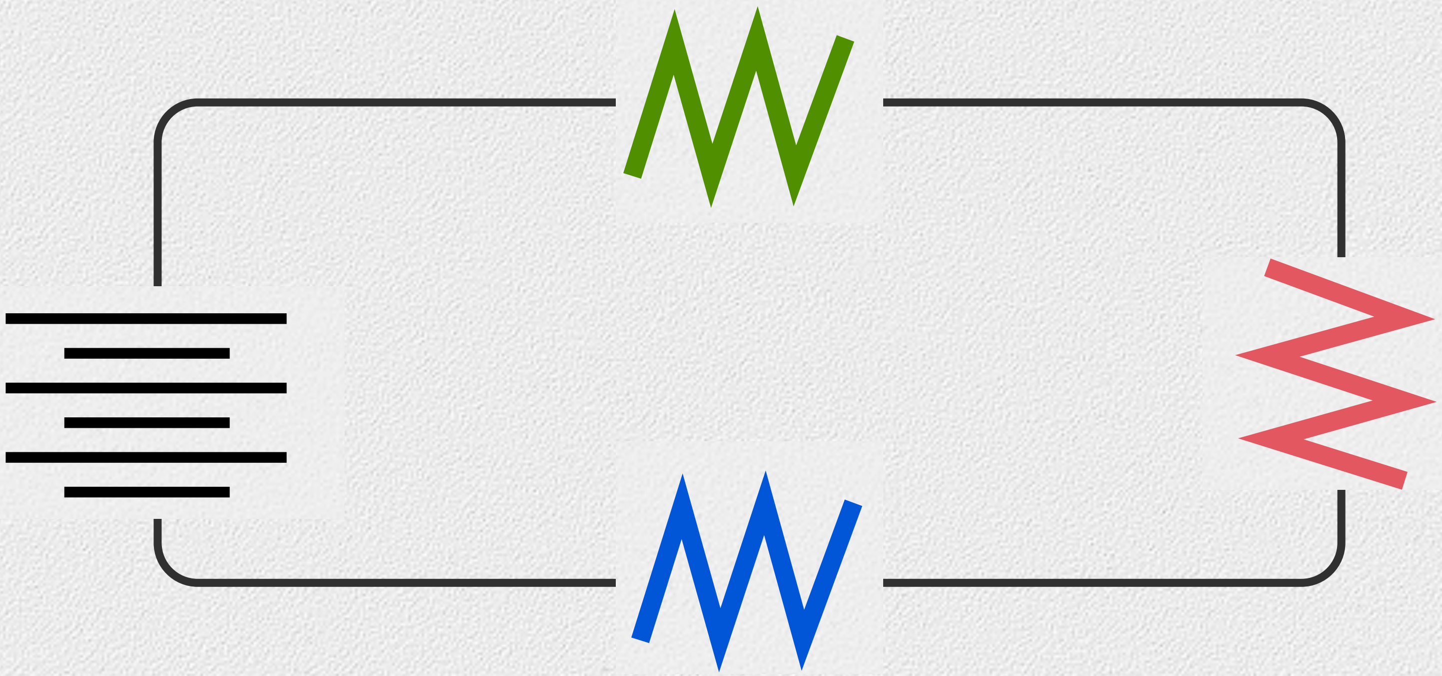
Series



In a series circuit, there is only one current, so that value can be applied to each resistor.

	V (V)	**I** (A)	**R** (Ω)	**P** (W)
R_1		2	2	
R_2		2	4	
R_3		2	6	
TOTAL	24	2	12	

Series



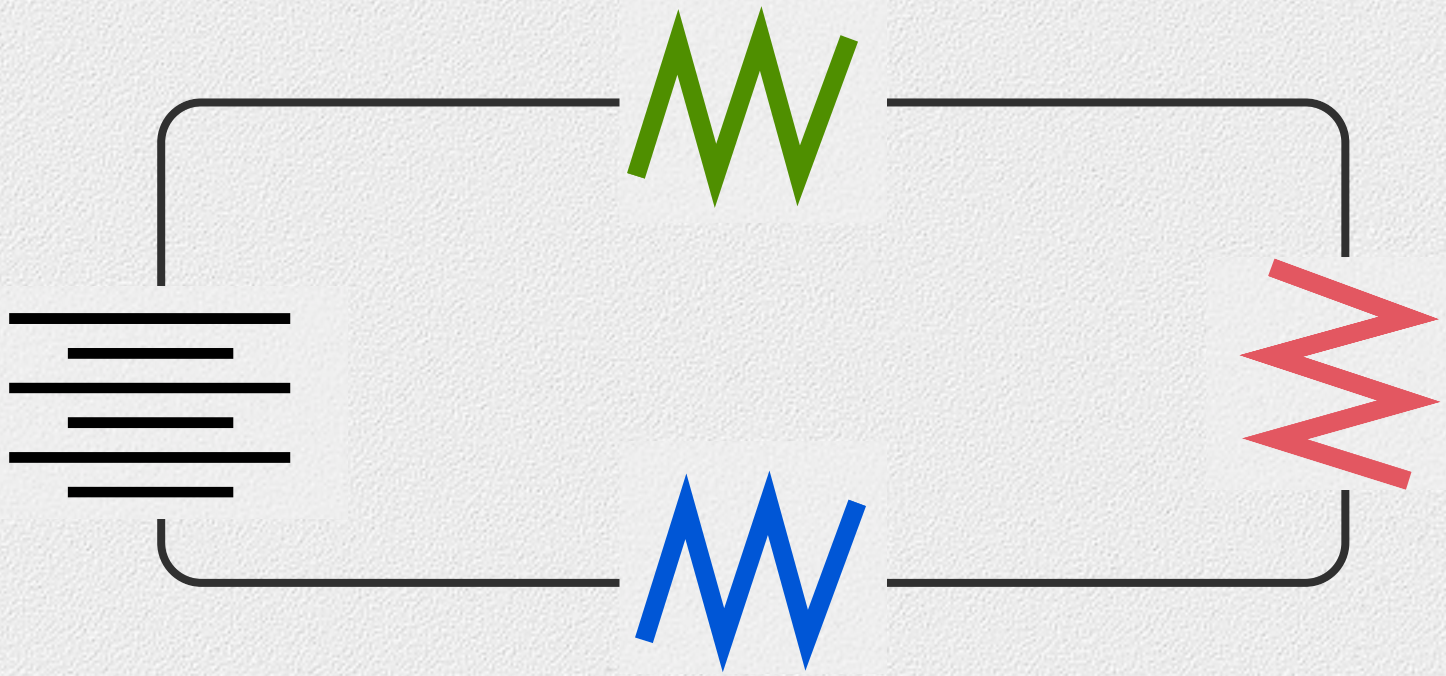
When you have two values for a resistor, equations will get you the other numbers.

V= I R

V_1 = 2 x 2 = 4 Volts

	V (V)	**I** (A)	**R** (Ω)	**P** (W)
R_1	4	2	2	
R_2	8	2	4	
R_3	12	2	6	
TOTAL	24	2	12	

Series



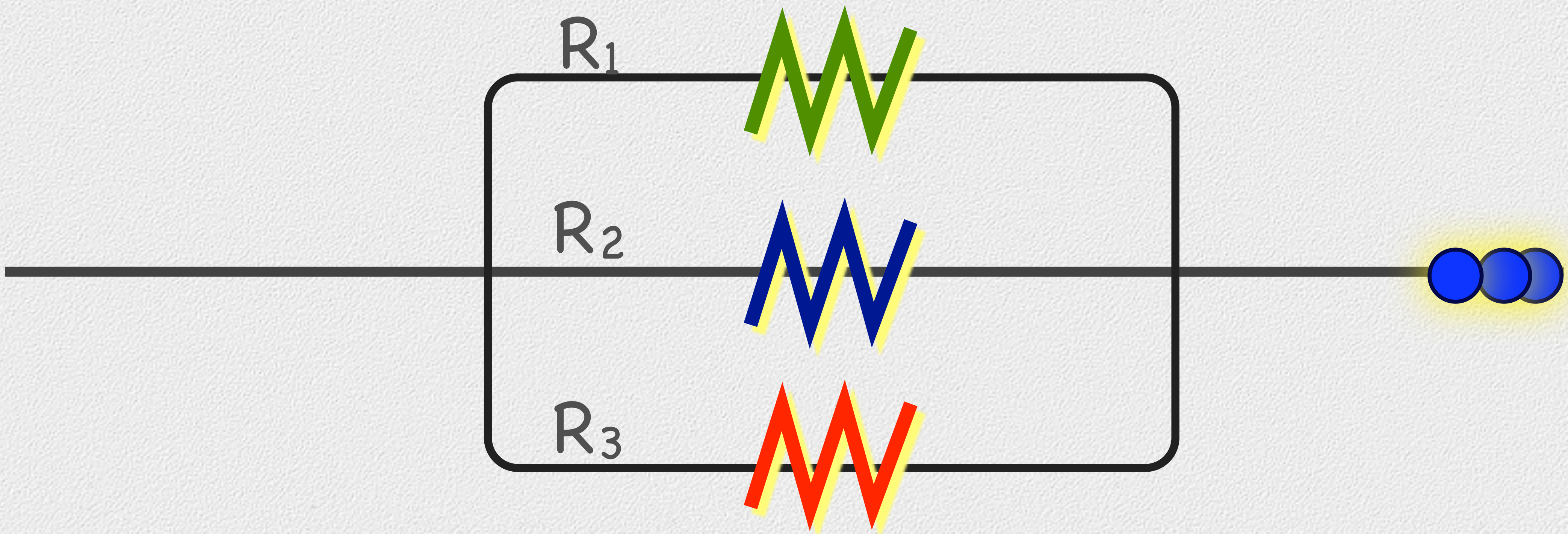
Save Power for last.
The sum should always equal the product.

$P = I\ V$

$P_{Total} = 24 \times 2 = 48$ Watts

	V (V)	I (A)	R (Ω)	P (W)
R_1	4	2	2	8
R_2	8	2	4	16
R_3	12	2	6	24
TOTAL	24	2	12	48

Resistors in Parallel



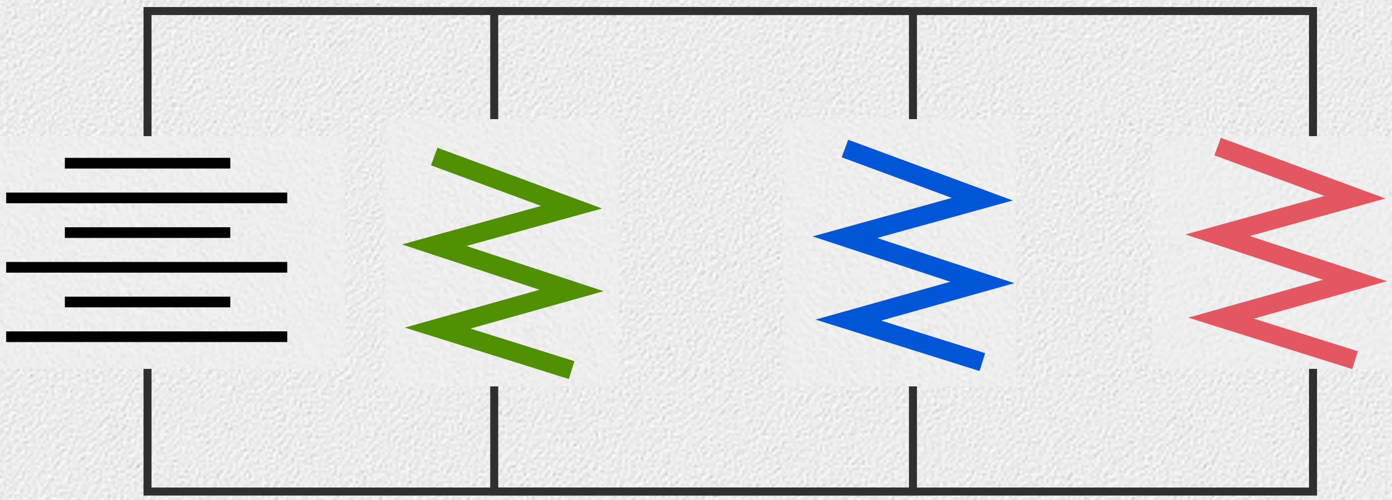
- The Charges have a choice of paths to follow.
- This decreases the total resistance.

Voltage: $V_T = V_1 = V_2 = V_3$

Current: $I_T = I_1 + I_2 + I_3$

Resistance: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$

Parallel



Add the resistors inversely.

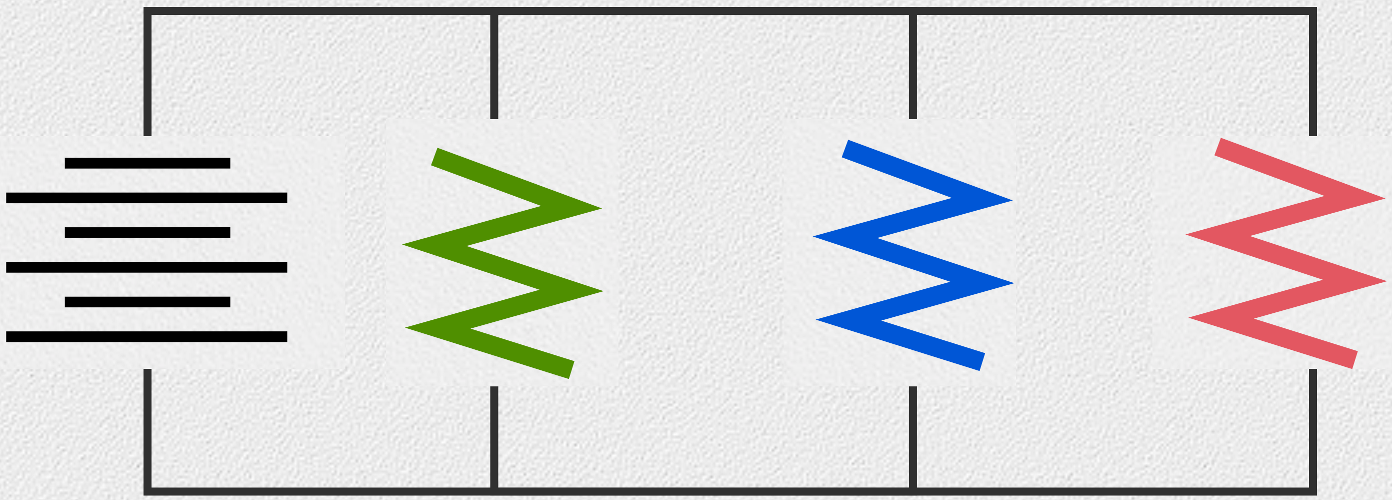
$1/R_T = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_T = 1/120 + 1/60 + 1/10$

$R_T = 8\ \Omega$

	V (V)	I (A)	R (Ω)	P (W)
R_1			120	
R_2			60	
R_3			10	
TOTAL	12		8	

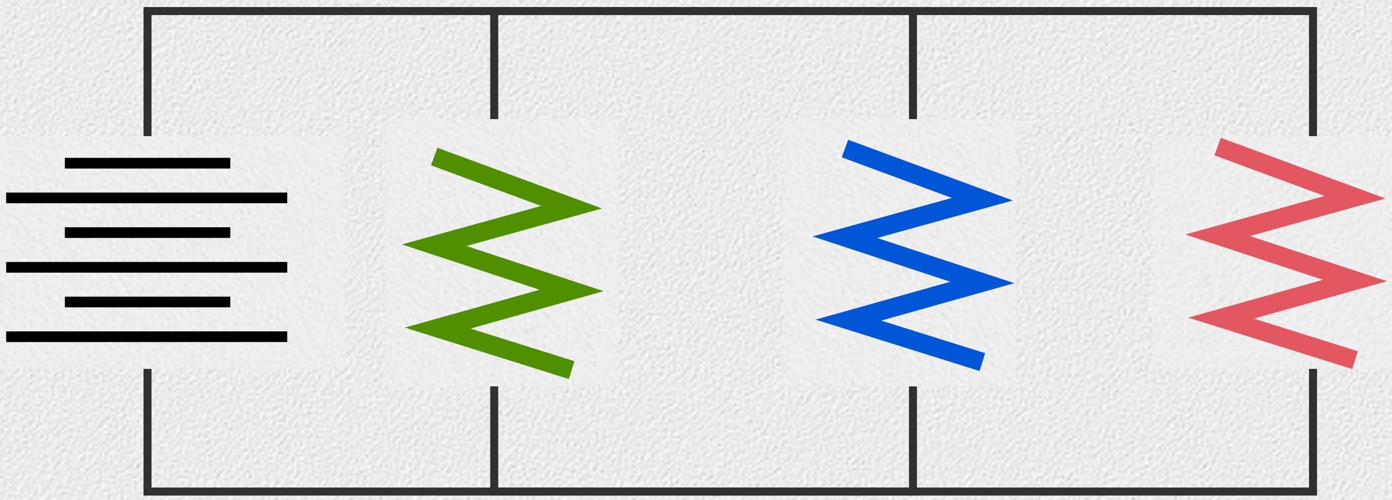
Parallel



If you are given the total Voltage [EMF], resistors in parallel all have the same Voltage.

	V (**V**)	I (**A**)	R (Ω)	P (**W**)
R_1	12		120	
R_2	12		60	
R_3	12		10	
TOTAL	12		8	

Parallel



Use Ohm's Law to find the currents

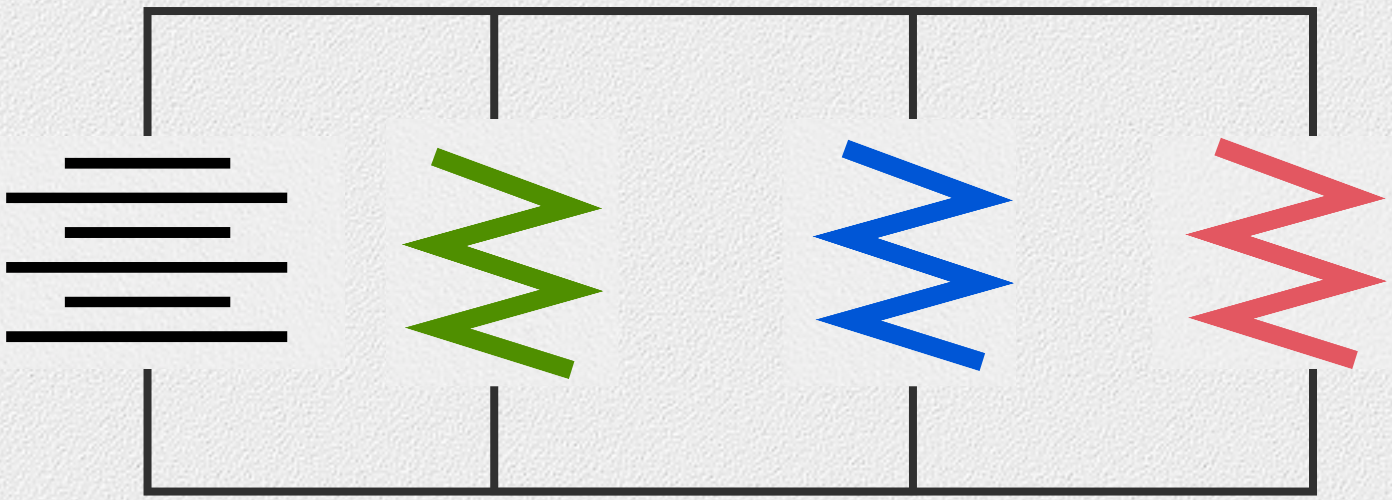
$V = I R$

$12 = I_1 \times 120$

$I_1 = 0.1$ Amperes

	V (V)	I (A)	R (Ω)	P (W)
R_1	12	0.1	120	
R_2	12	0.2	60	
R_3	12	1.2	10	
TOTAL	12	1.5	8	

Parallel

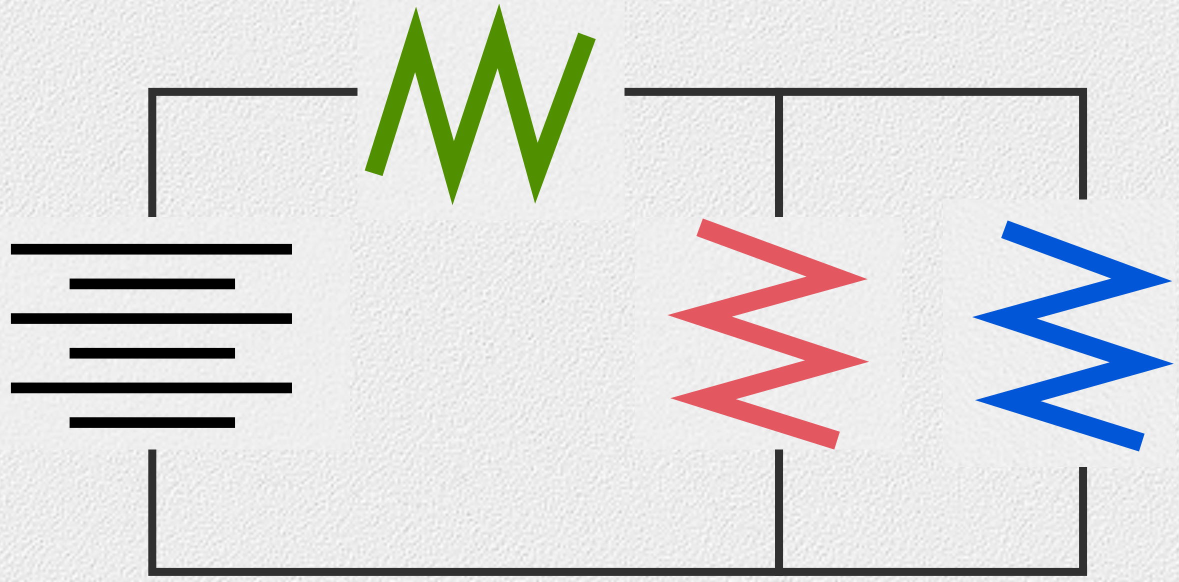


Multiply V and I to find Power.

$P = I\ V$
$P_1 = 0.1 \times 12$
$P_1 = 1.2$ Watts

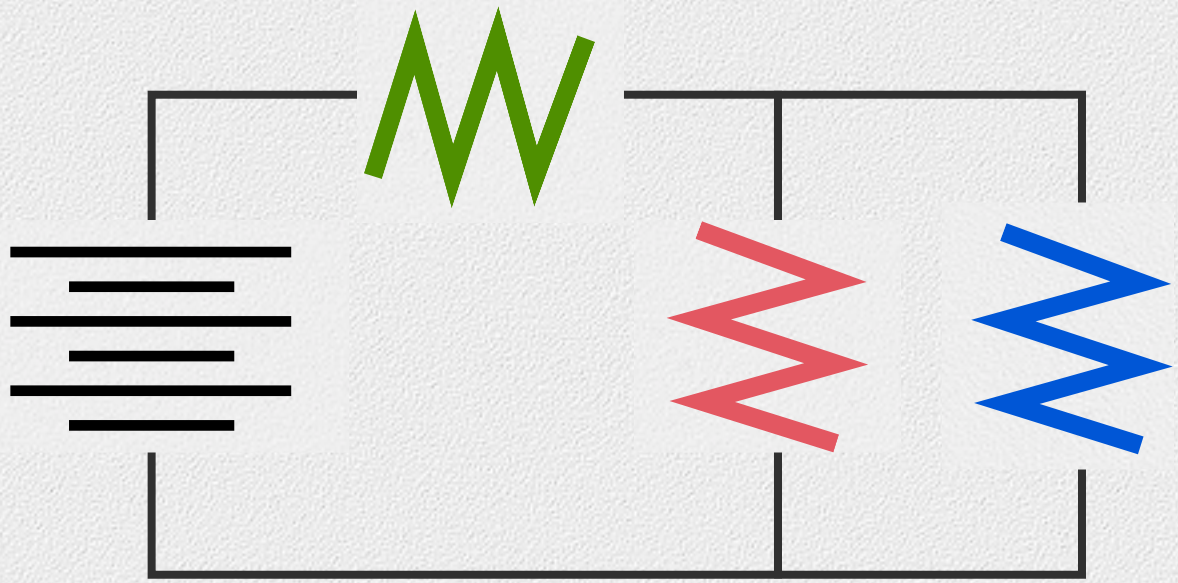
	V (V)	I (A)	R (Ω)	P (W)
R_1	12	0.1	120	1.2
R_2	12	0.2	60	2.4
R_3	12	1.2	10	14.4
TOTAL	12	1.5	8	18

Combinations



- Some in Series, some in Parallel
- Look for parts that are only one or the other
- Find an Equivalent Resistance

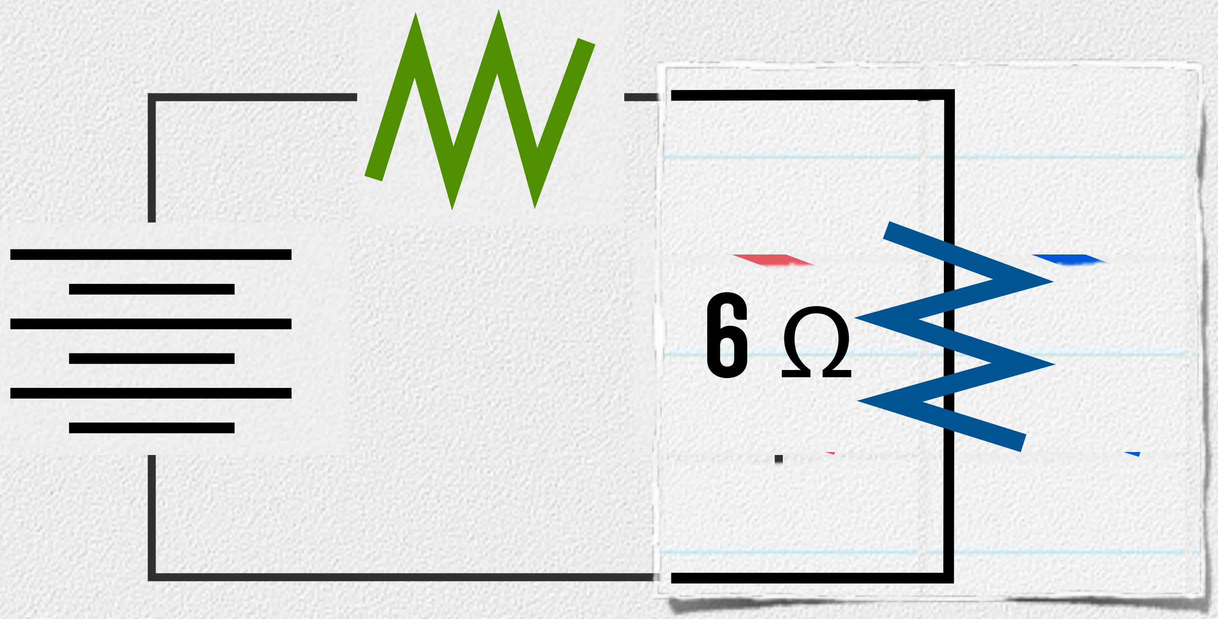
Combinations



This one starts with the parallel component. Rip a piece of paper large enough to cover R_2 and R_3.

	V (V)	**I** (A)	**R** (Ω)	**P** (W)
R_1			4	
R_2			18	
R_3			9	
TOTAL	60			

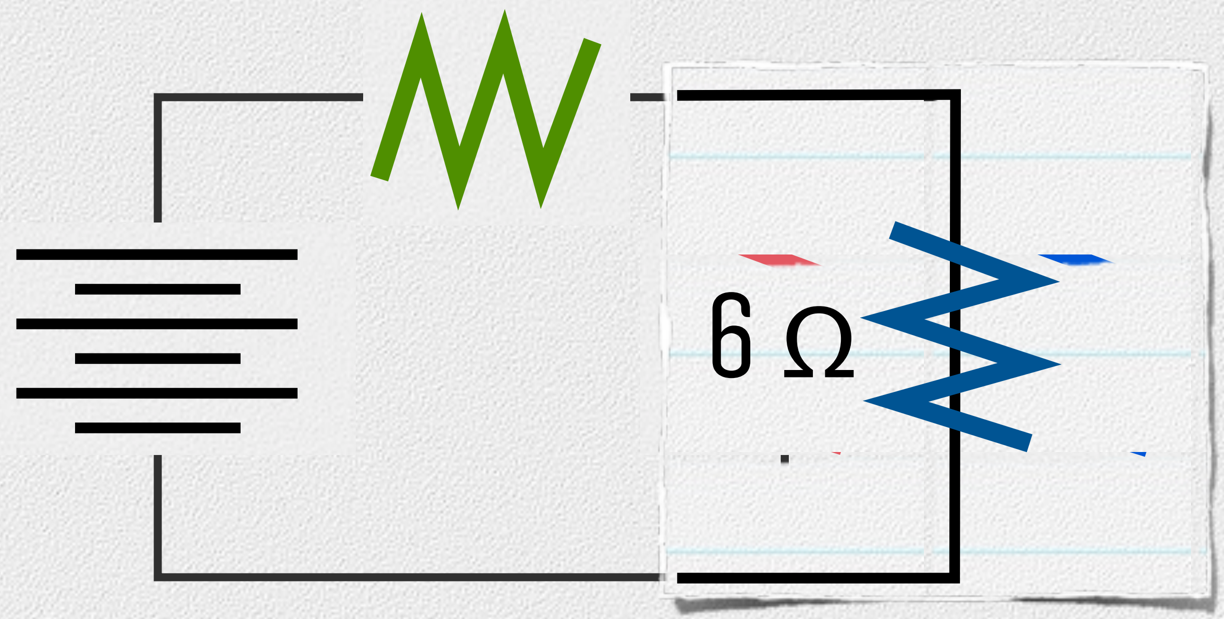
Combinations



A parallel combination of 18 and 9 can be replaced by a 6 ohm resistor

	V (**V**)	I (**A**)	R (**Ω**)	P (**W**)
R_1			4	
R_2			**18**	
R_3			**9**	
TOTAL	60			

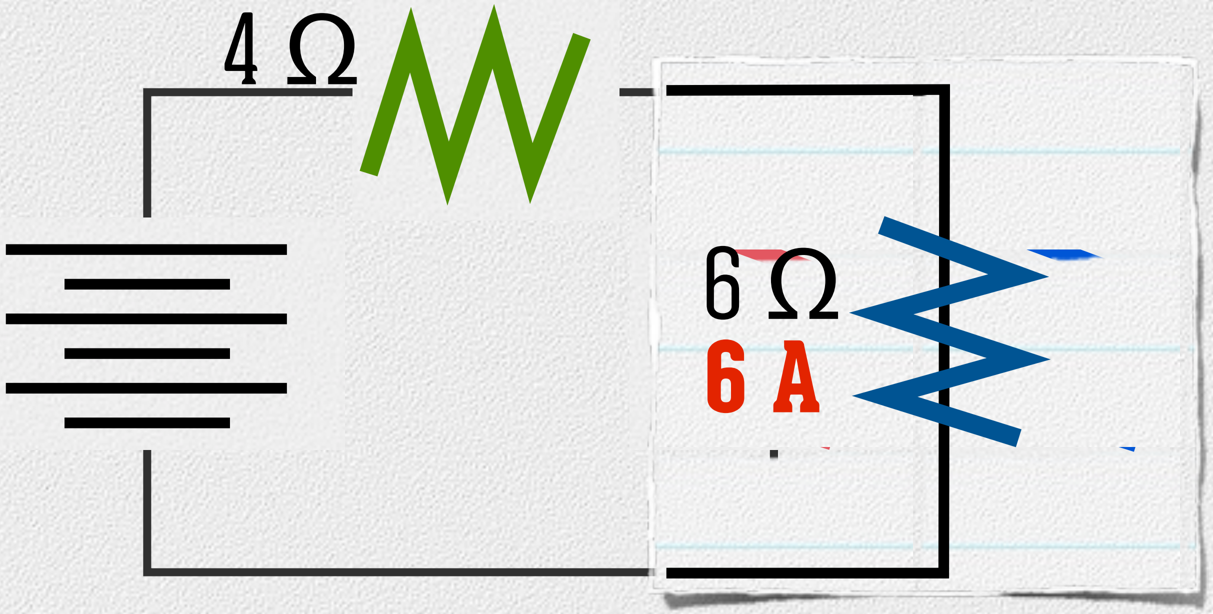
Combinations



the new series of 6 and 4 creates a total resistance of 10 ohms.

	V (V)	I (A)	R (Ω)	P (W)
R_1			**4**	
R_2			18	
R_3			9	
TOTAL	60		**10**	

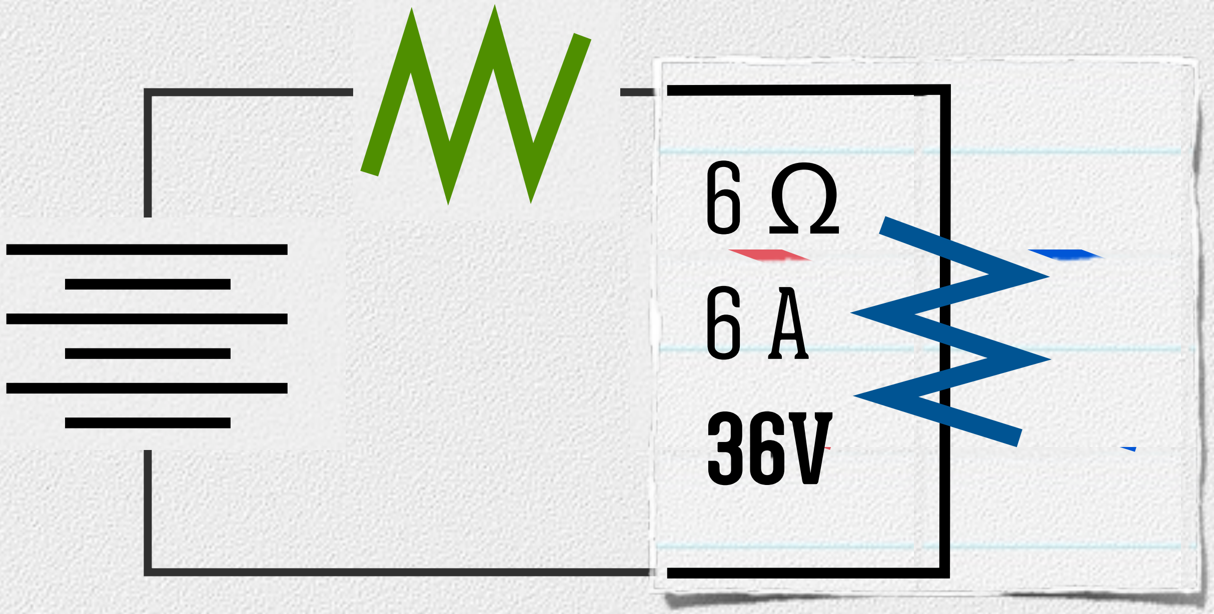
Combinations



Use Ohm's Law to find a total current of 6 amperes.
This is the current throughout the SERIES.

	V (**V**)	I (**A**)	R (**Ω**)	P (**W**)
R_1		**6**	4	
R_2			18	
R_3			9	
TOTAL	60	**6**	10	

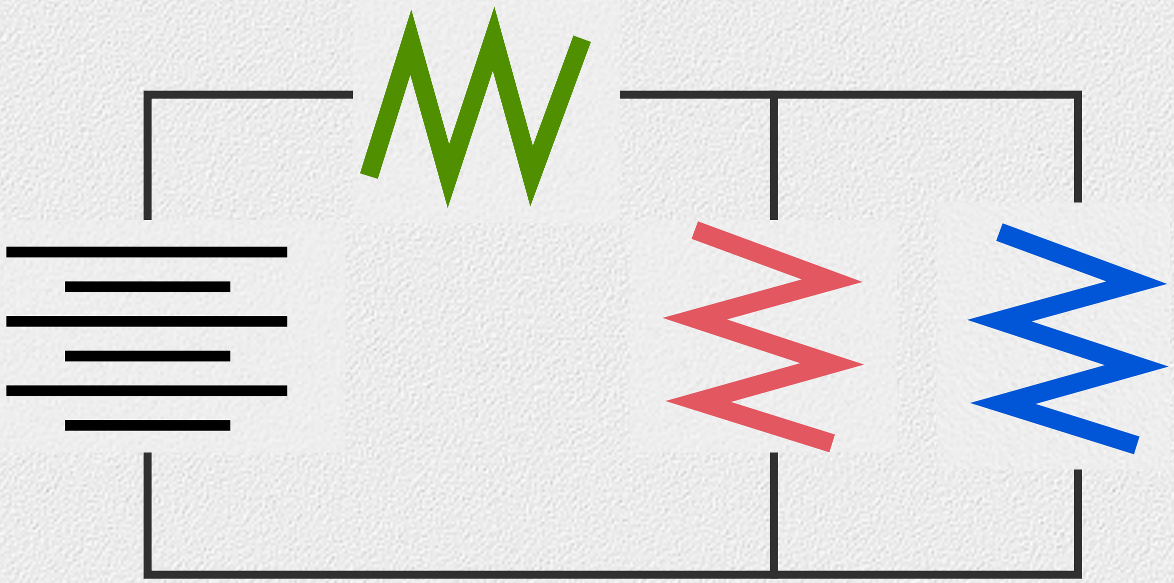
Combinations



Now find the voltage for R_1 and for the paper.

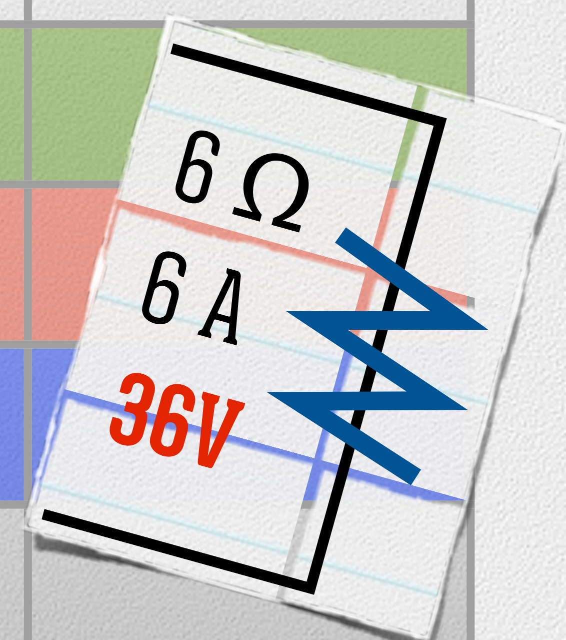
	V (V)	I (A)	R (Ω)	P (W)
R_1	24	6	4	
R_2			18	
R_3			9	
TOTAL	60	6	10	

Combinations

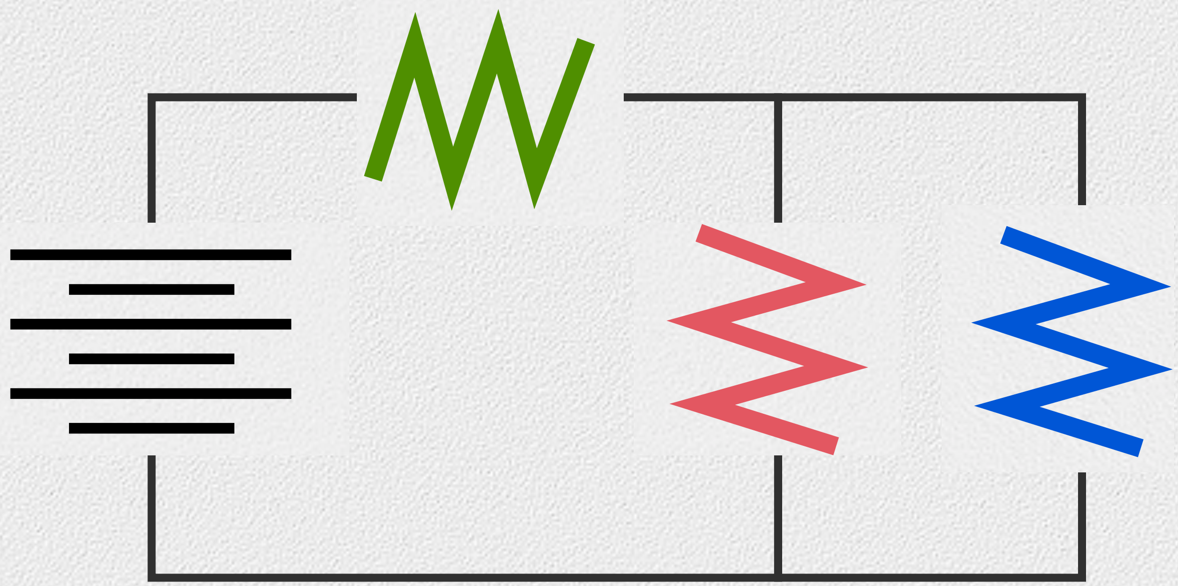


Uncover the original circuit, keep the voltage for parallel components. [if the original is a series, keep the current]

	V (**V**)	I (**A**)	R (**Ω**)	P (**W**)
R_1	24	6	4	
R_2	**36**		18	
R_3	**36**		9	
TOTAL	60	6	10	



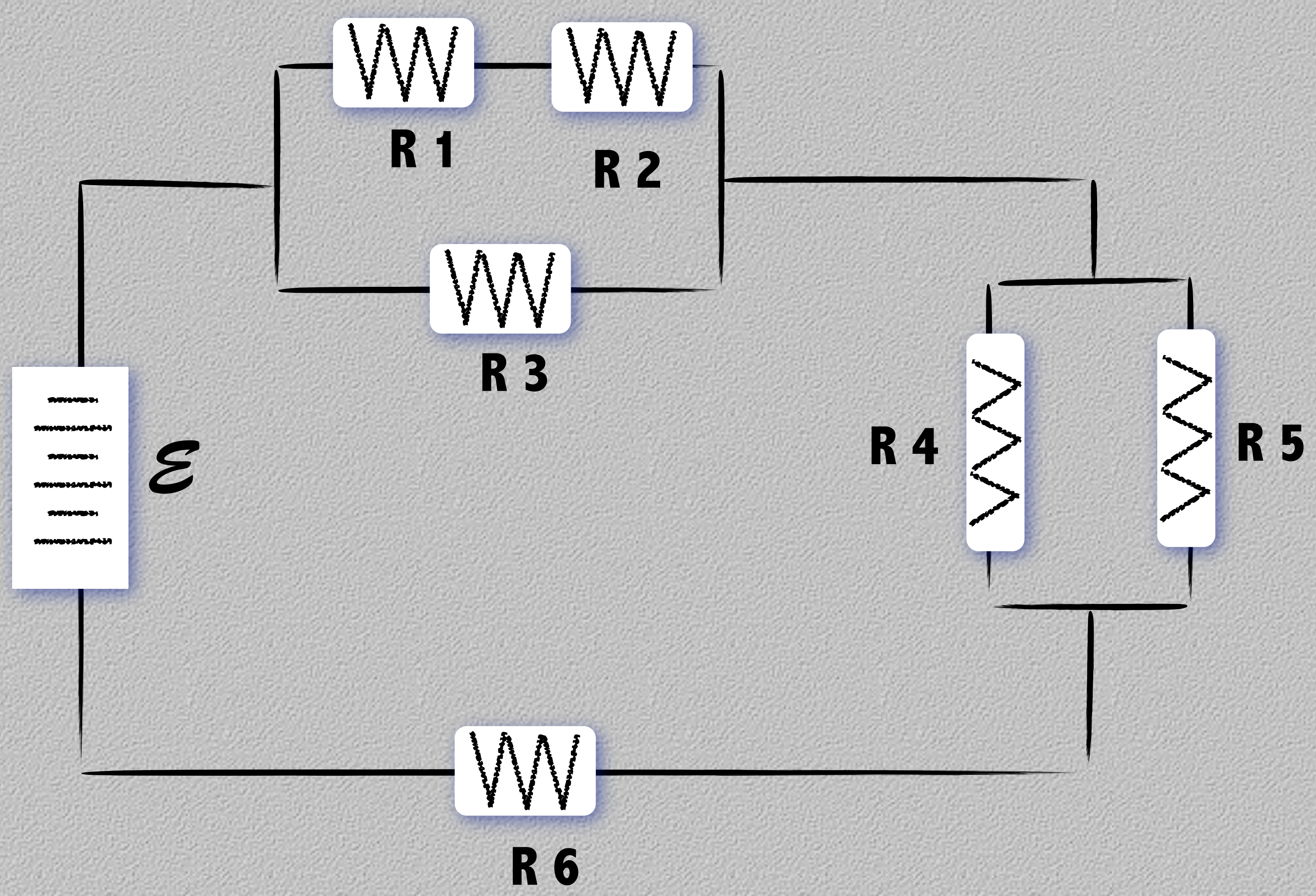
Combinations



Finish the table with Ohm's Law and Power equations.

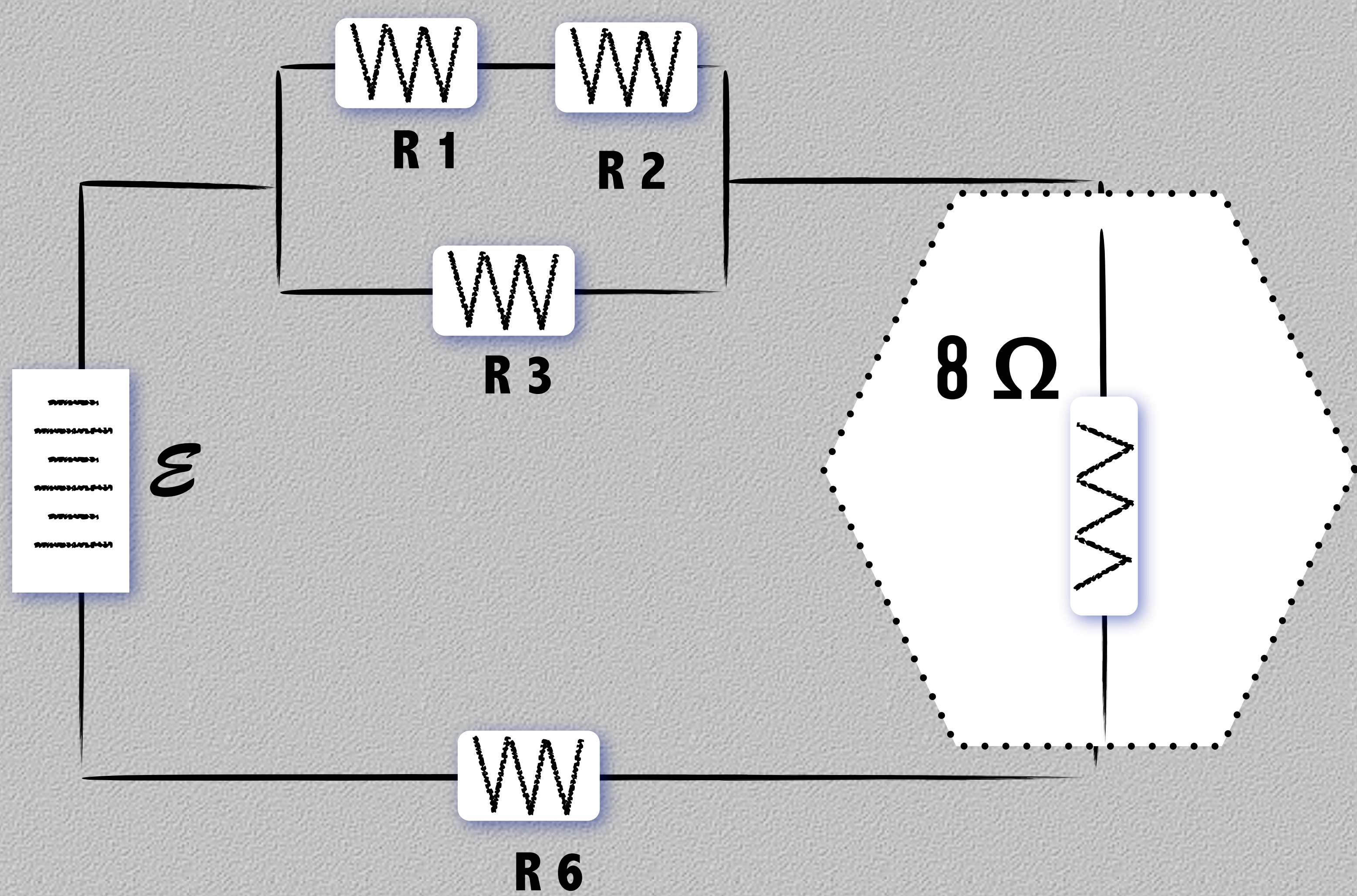
	V (**V**)	I (**A**)	R (**Ω**)	P (**W**)
R_1	24	6	4	**144**
R_2	36	**2**	18	**72**
R_3	36	**4**	9	**144**
TOTAL	60	6	10	**360**

Practice



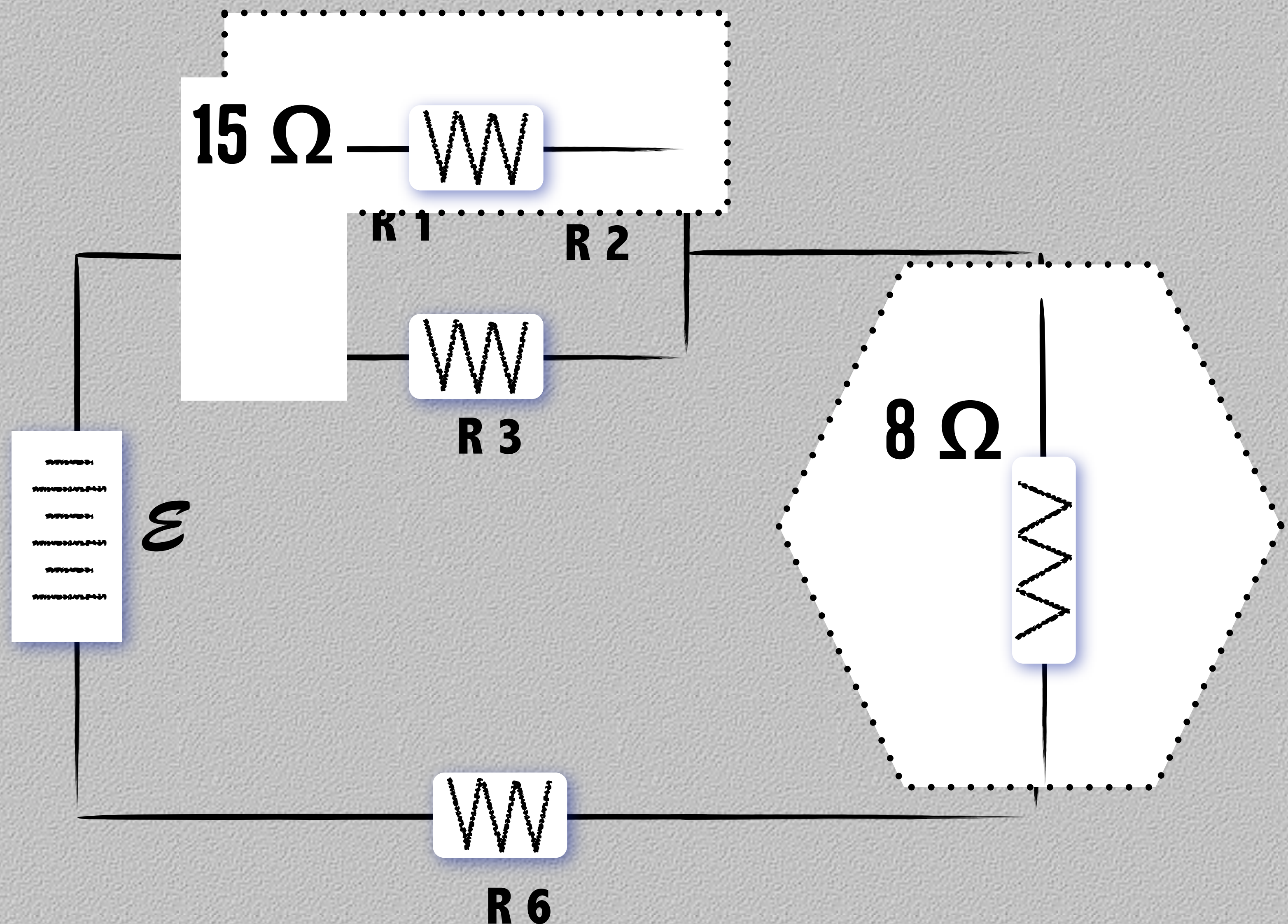
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6			12	
T	180			

Practice



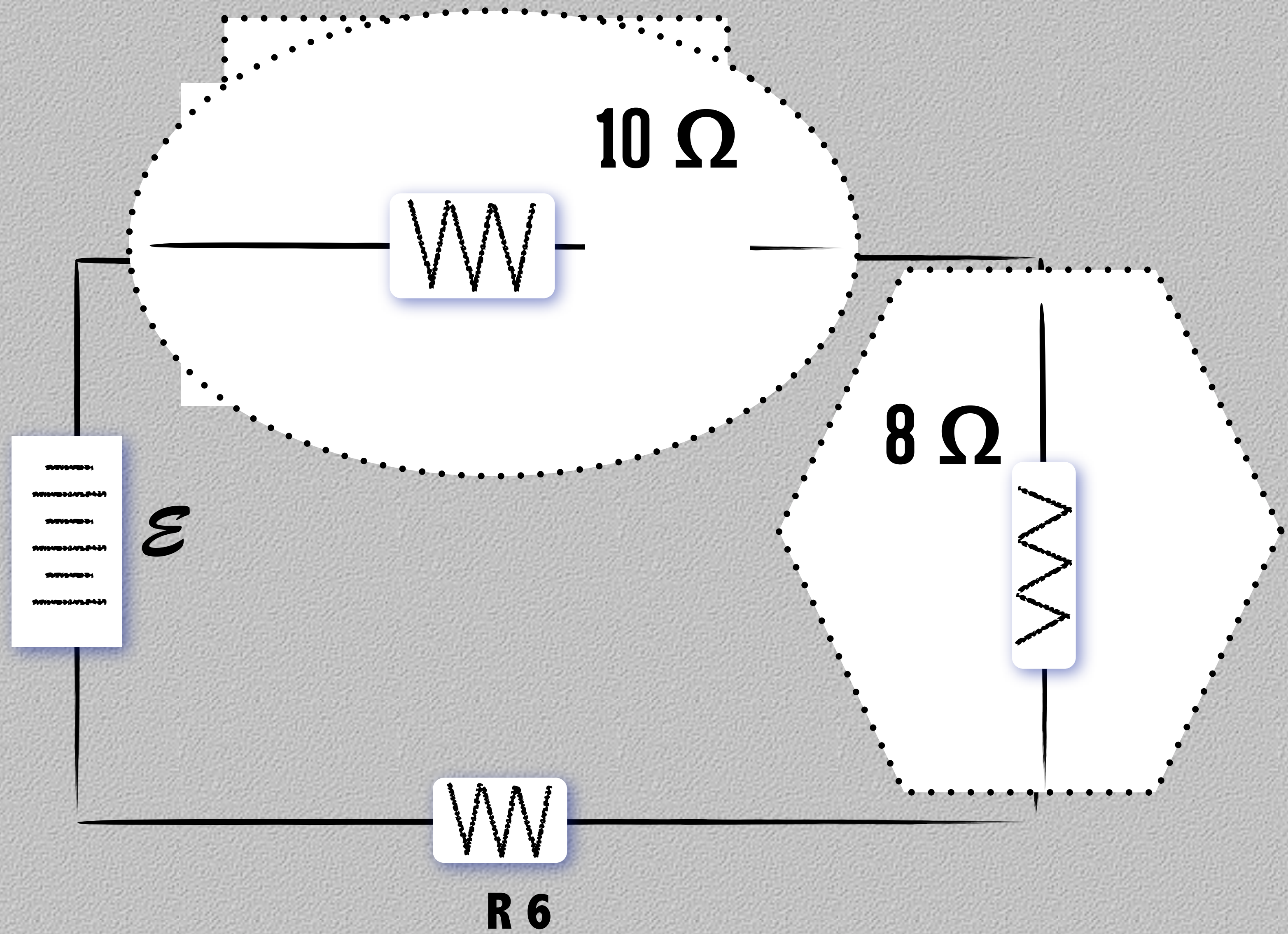
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6			12	
T	180			

Practice



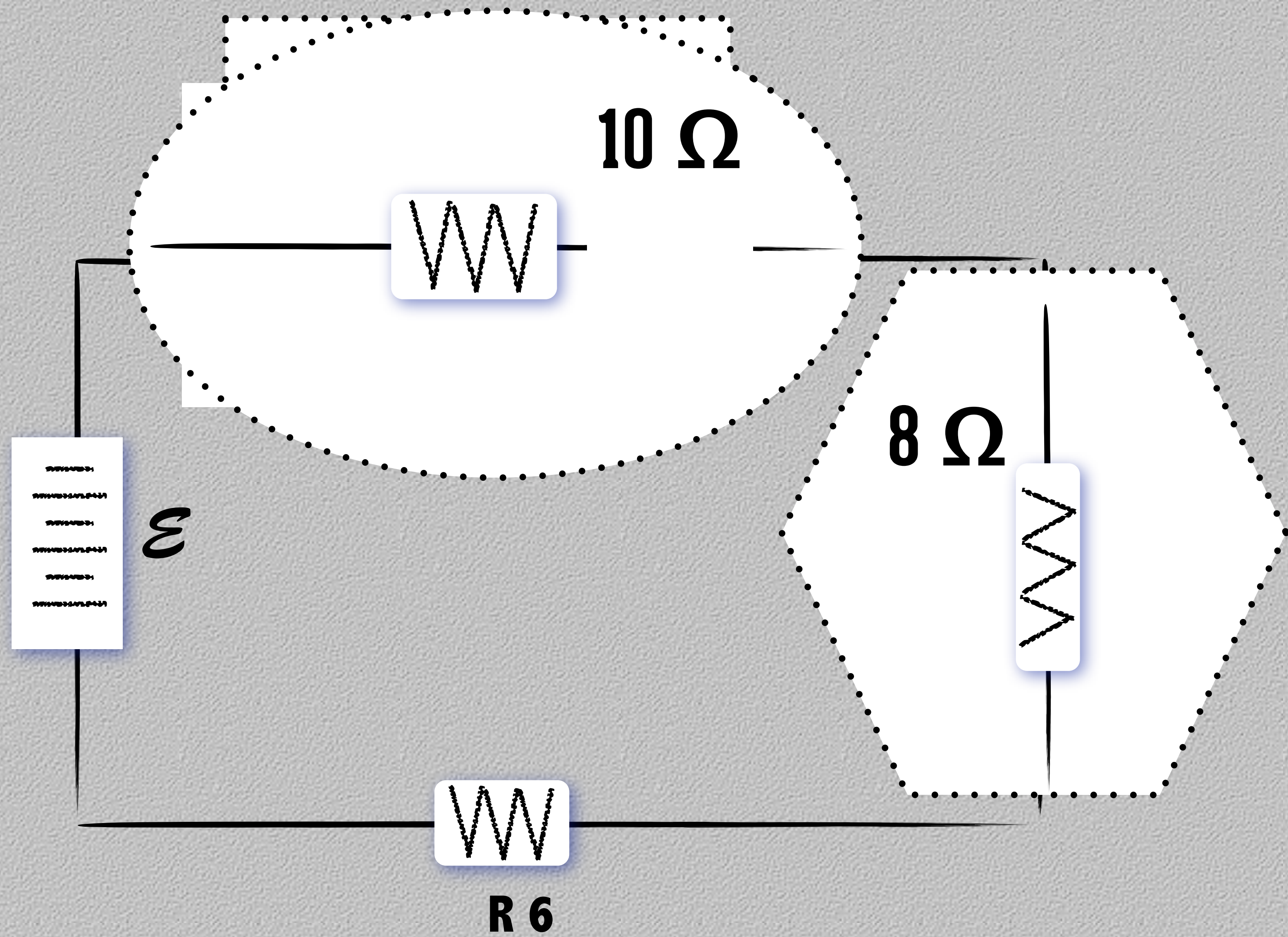
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6			12	
T	180			

Practice



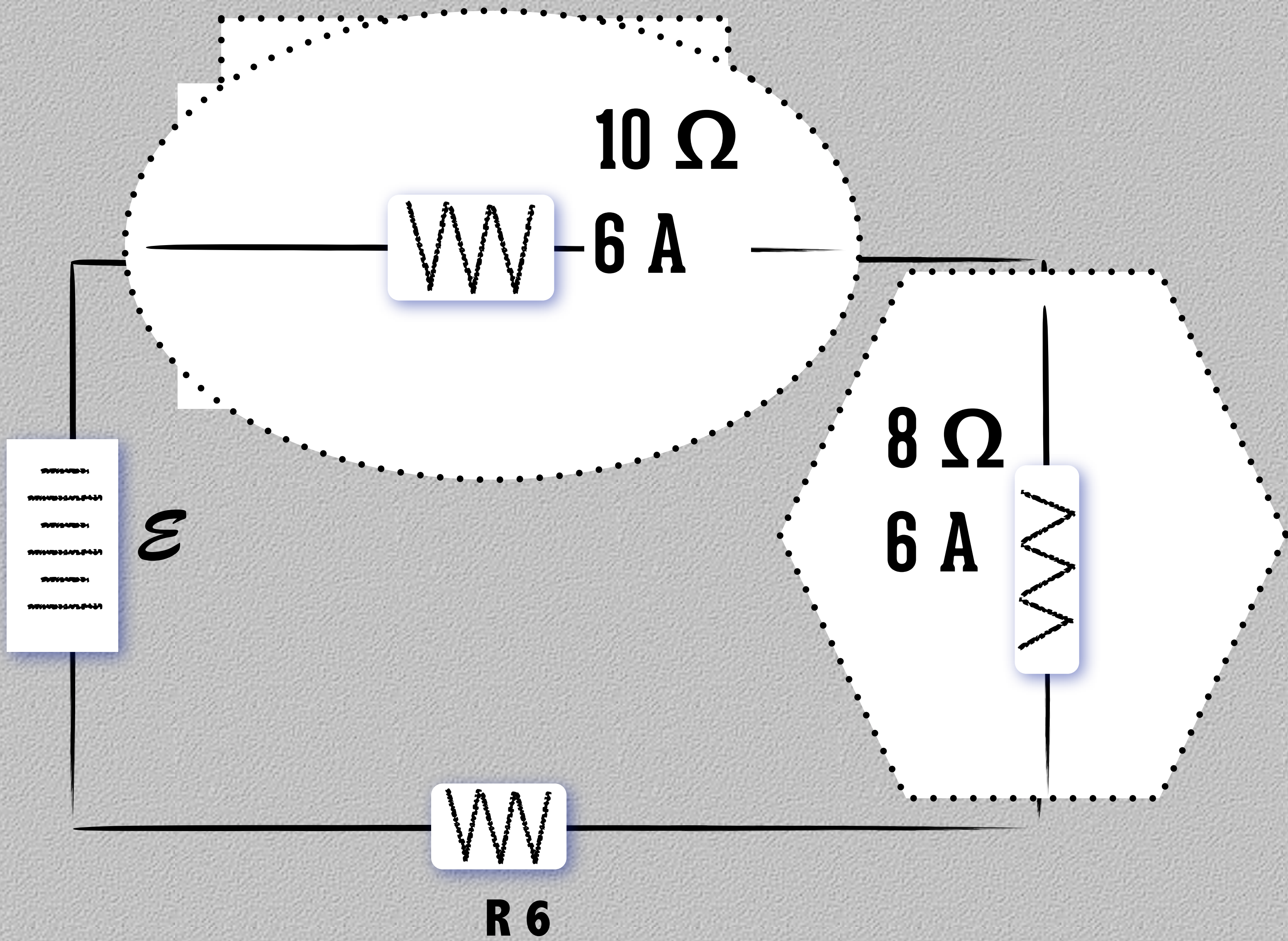
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6			12	
T	180		30	

Practice



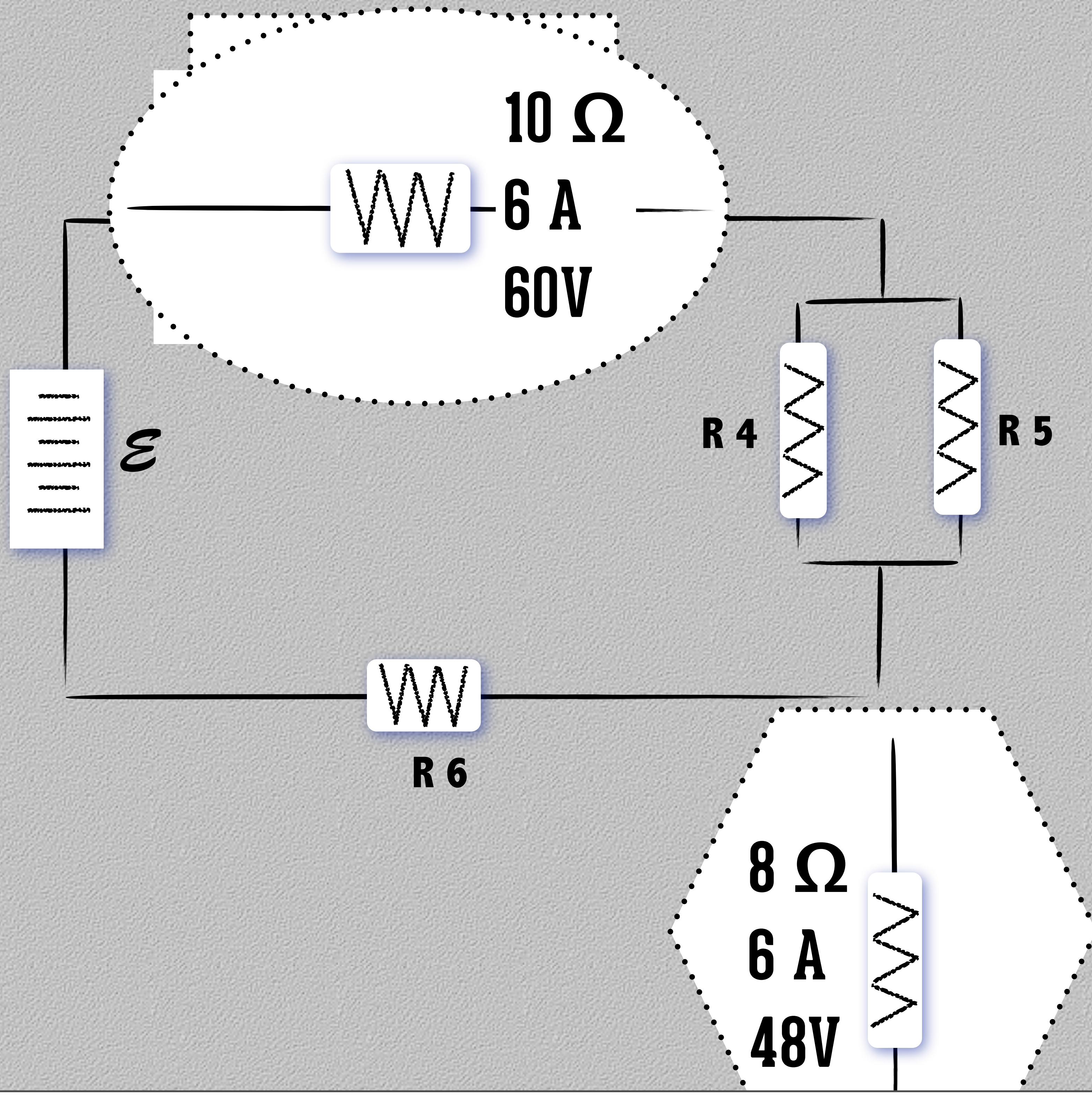
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6			12	
T	180	6	30	

Practice



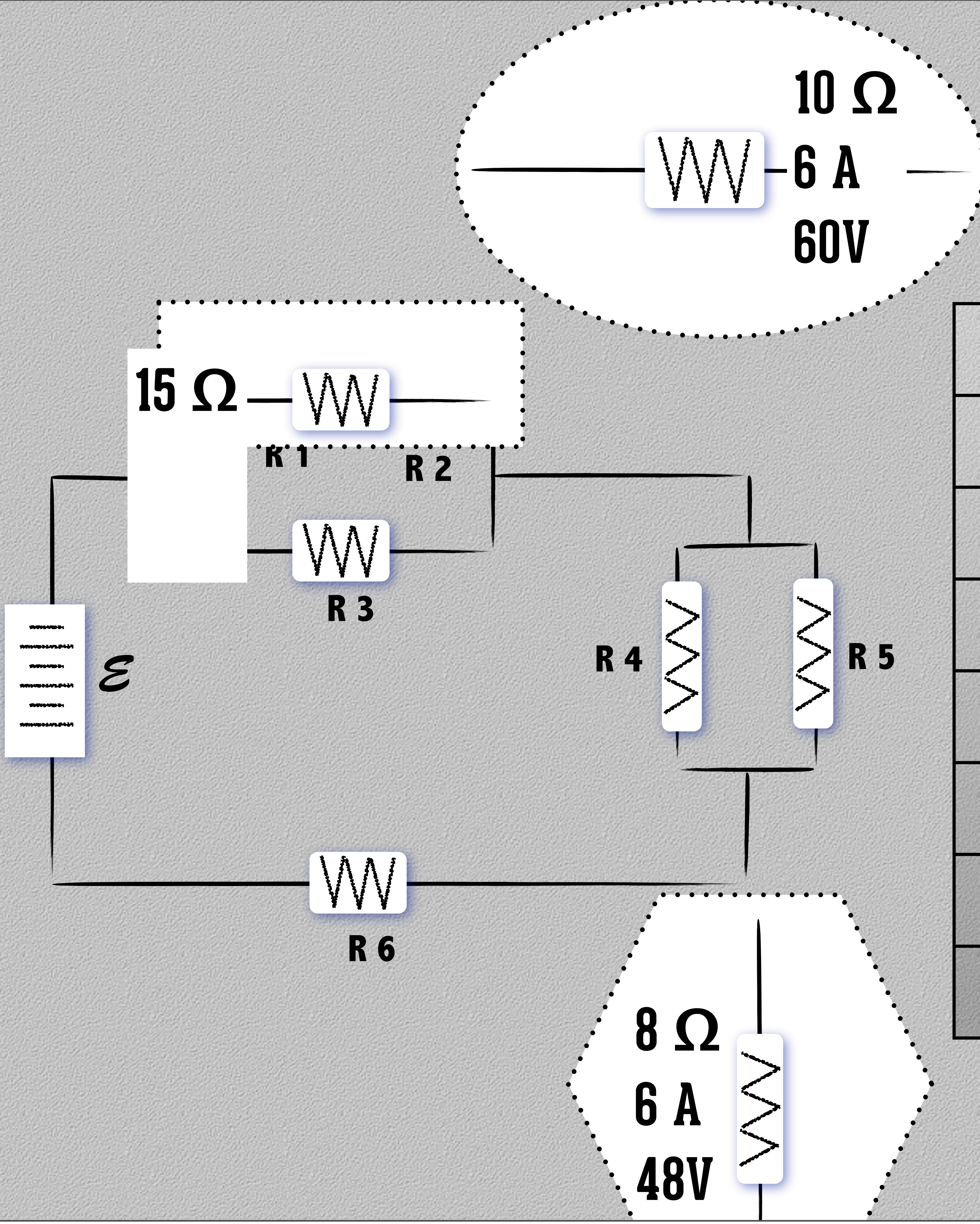
	V	I	R	P
1			10	
2			5	
3			30	
4			40	
5			10	
6		6A	12	
T	180	6	30	

Practice



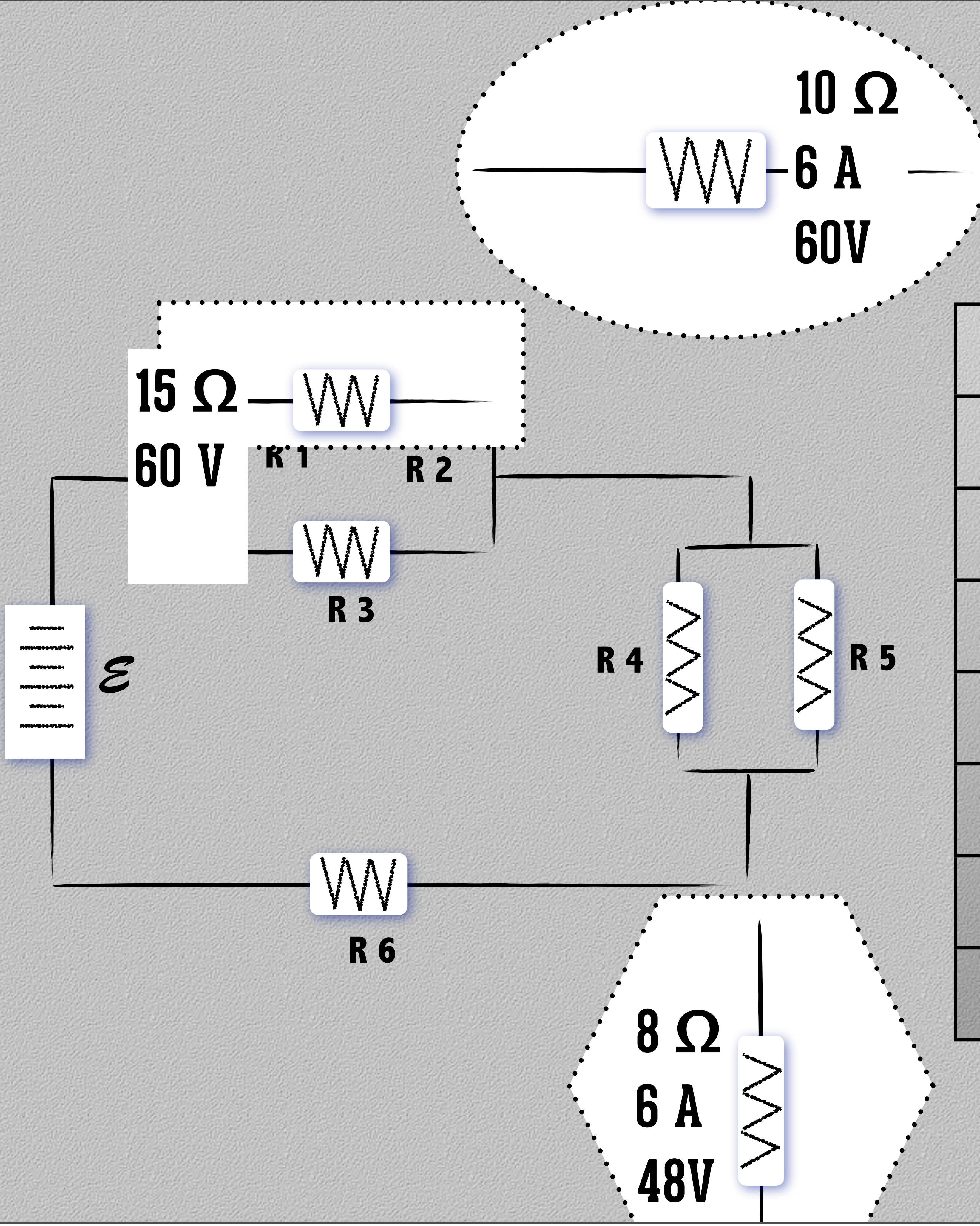
	V	I	R	P
1			10	
2			5	
3			30	
4	48V		40	
5	48V		10	
6	72V	6A	12	
T	180	6	30	

Practice



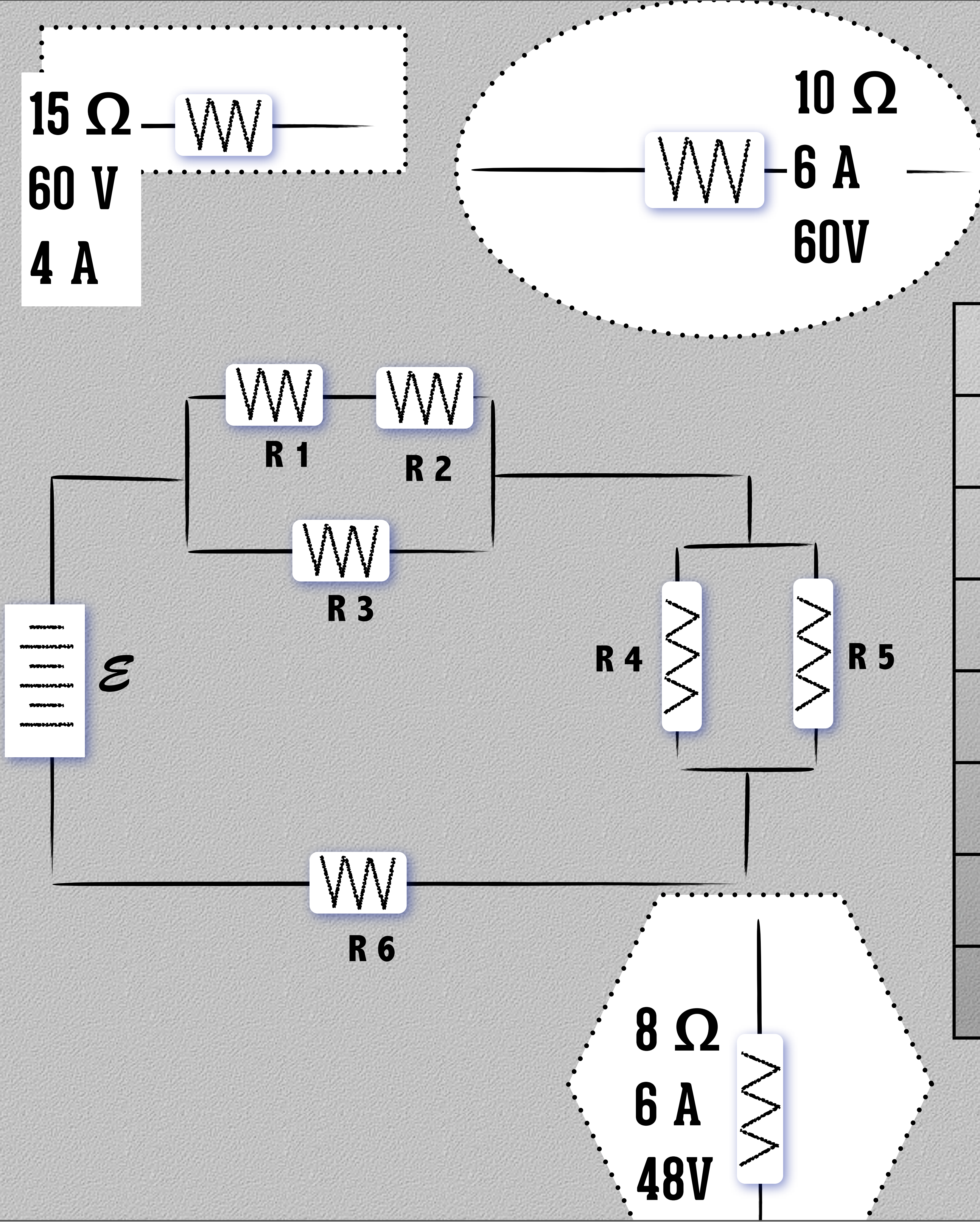
	V	I	R	P
1			10	
2			5	
3			30	
4	48V		40	
5	48V		10	
6	72V	6A	12	
T	180	6	30	

Practice

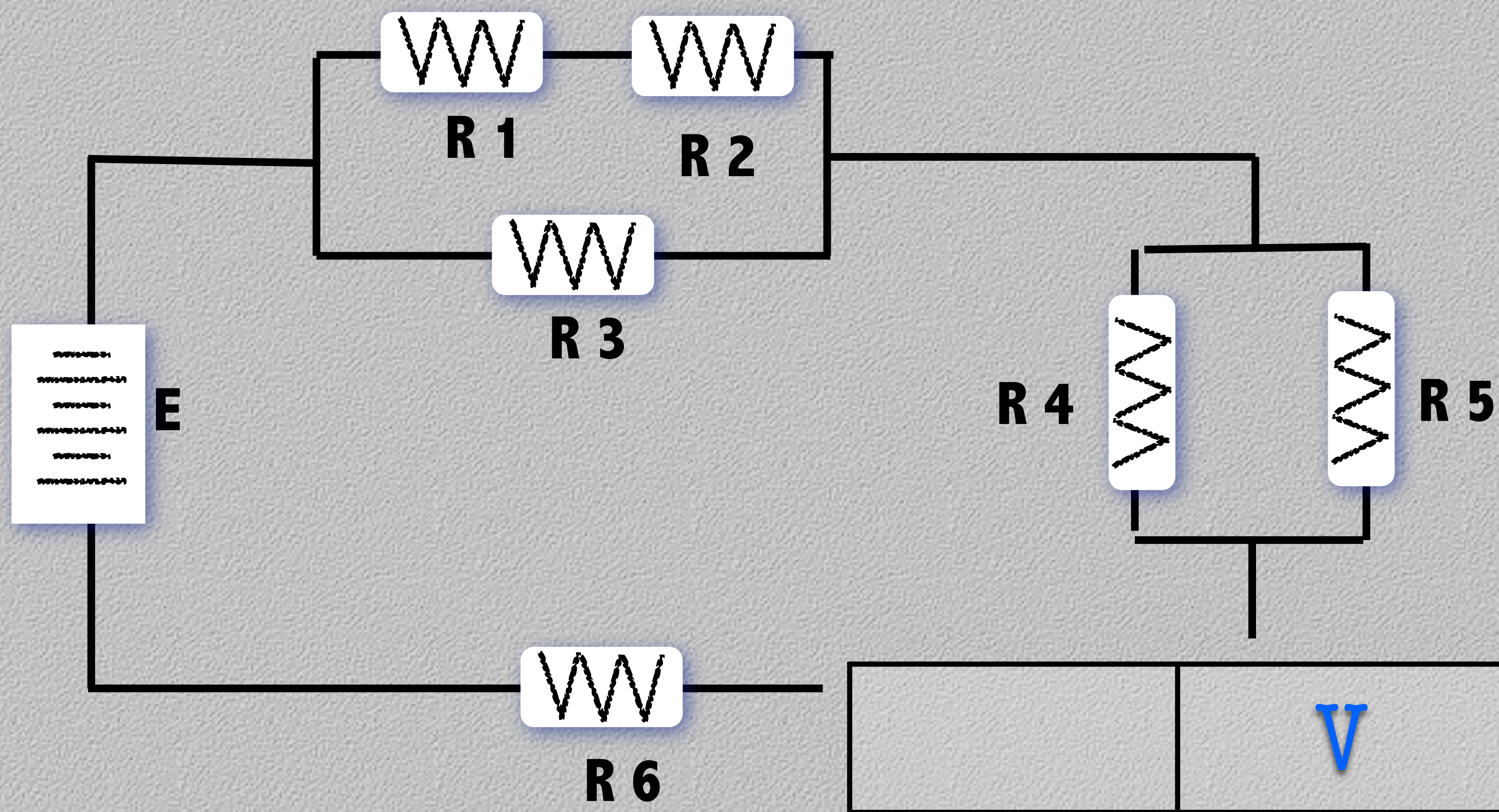


	V	I	R	P
1			10	
2			5	
3	60V		30	
4	48V		40	
5	48V		10	
6	72V	6A	12	
T	180	6	30	

Practice



	V	I	R	P
1		4A	10	
2		4A	5	
3	60V		30	
4	48V		40	
5	48V		10	
6	72V	6A	12	
T	180	6	30	

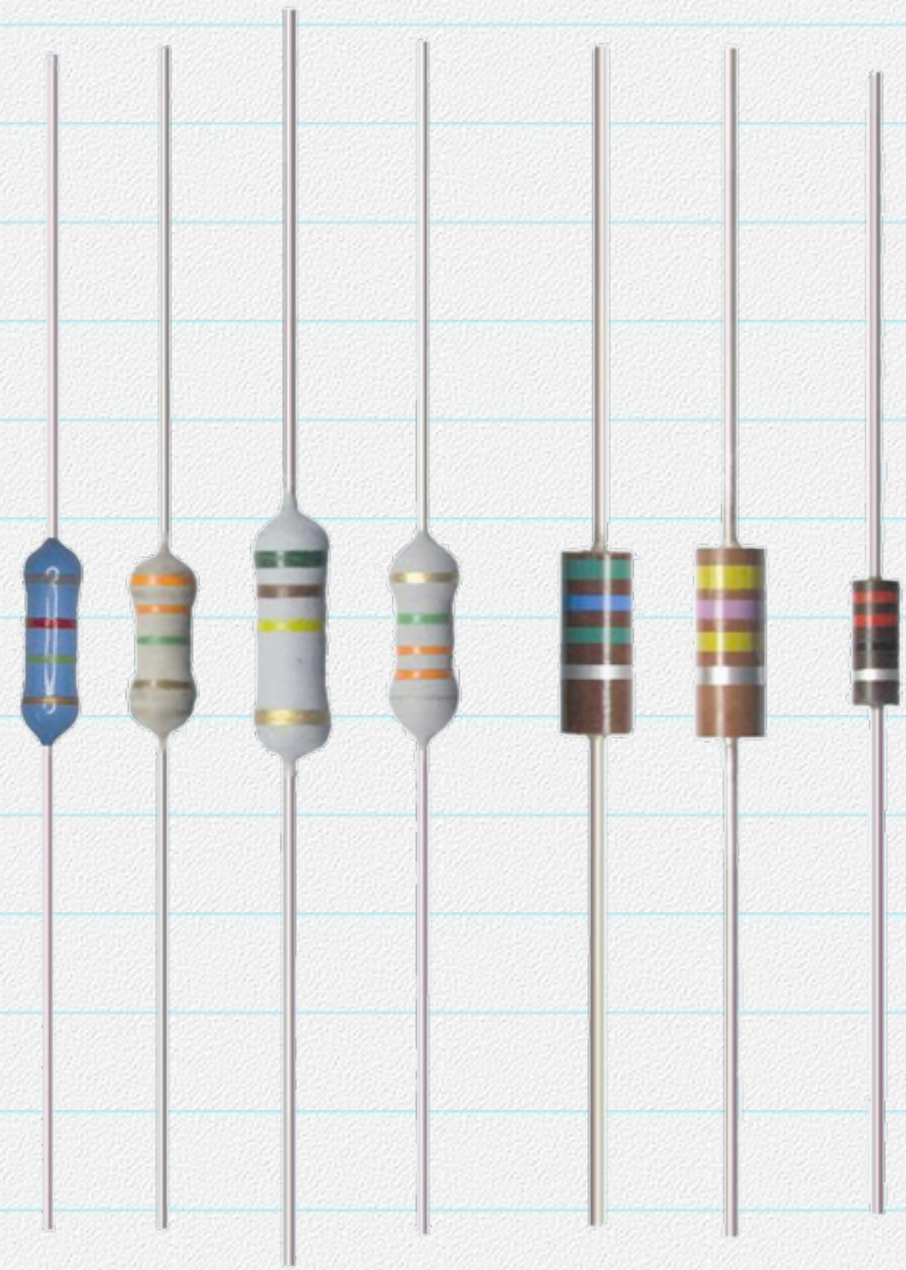


Practice

	V	I	R	P
1	40	4	10	160
2	20	4	5	80
3	60	2	30	120
4	48	1.2	40	57.6
5	48	4.8	10	230.4
6	72	6	12	432
T	180	6	30	1080

Resistor Codes

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9



Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Orange, Orange, Green, Gold

orange 3
orange 3
green 00,000

3,300,000 Ω ± 5%

3.3 MΩ

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Gold, Yellow, Brown, Green ?

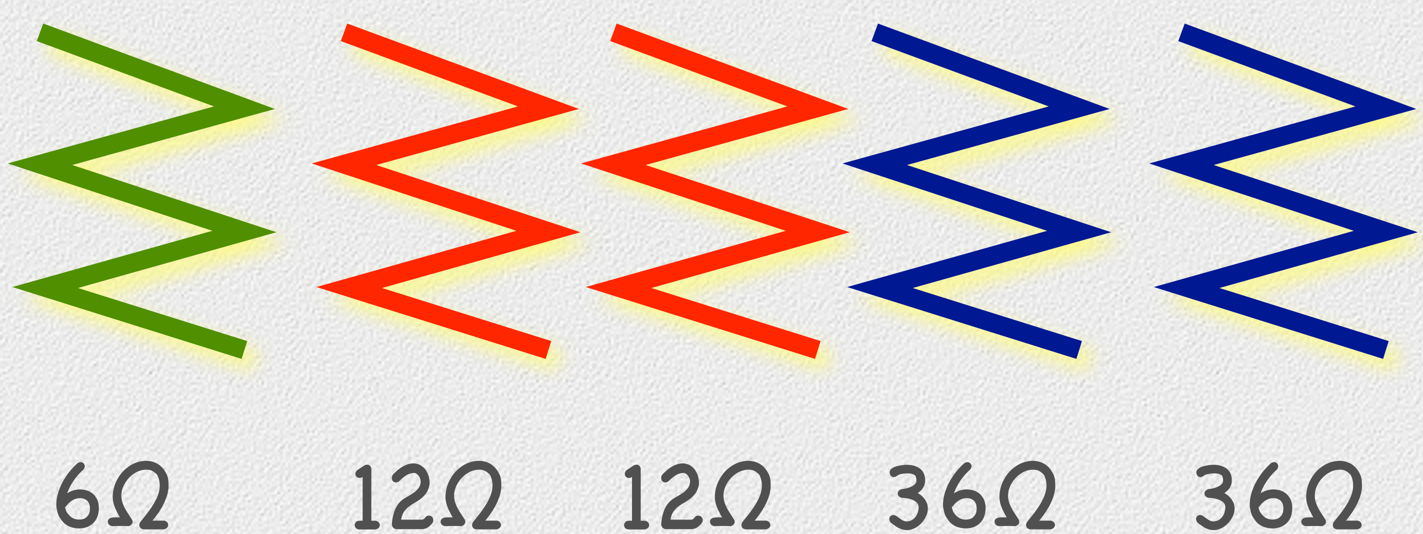
green	5
brown	1
yellow	0,000

510,000 Ω ± 5%

510 kΩ

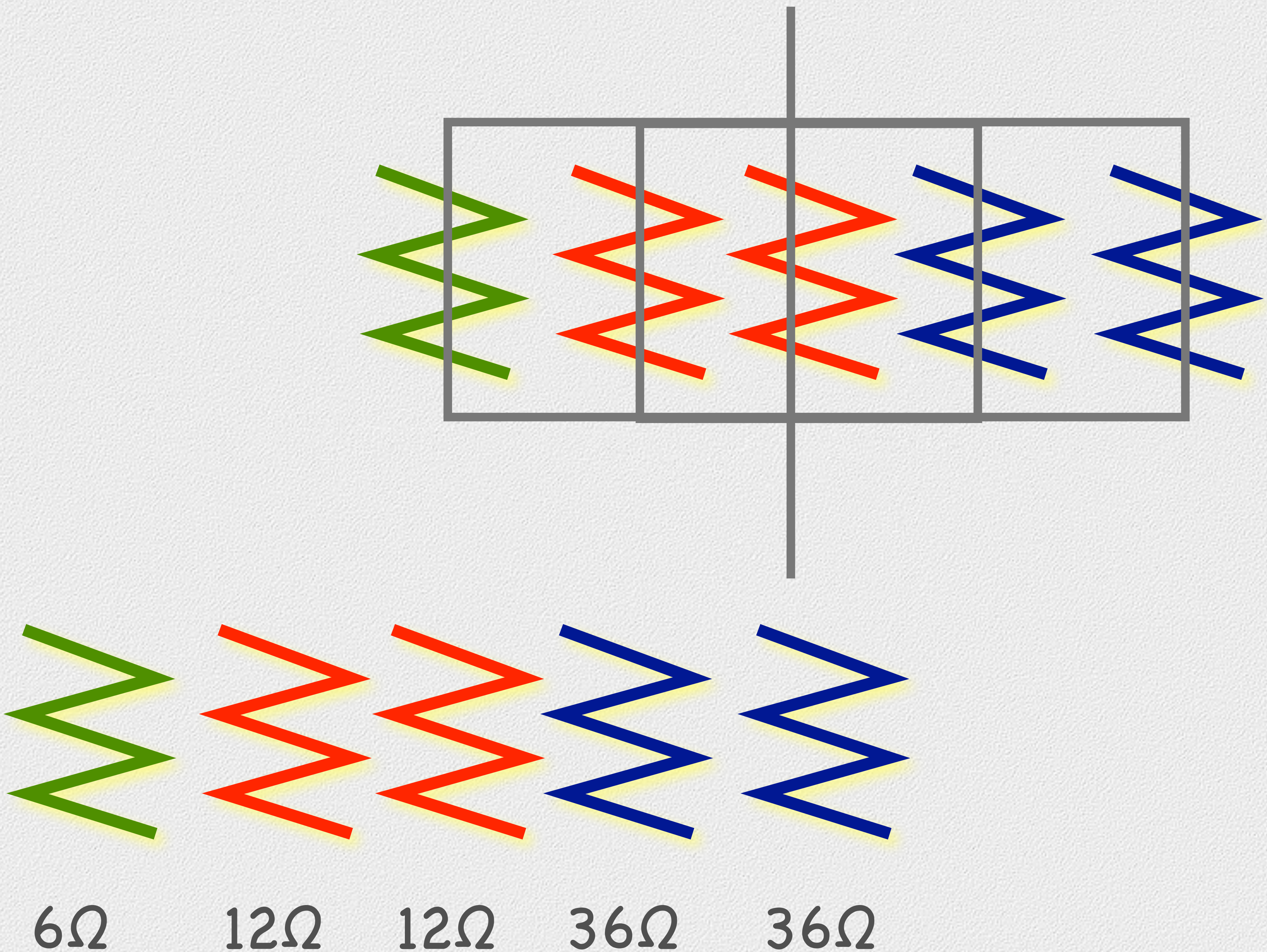
Biggest Possible Total?

102 Ω



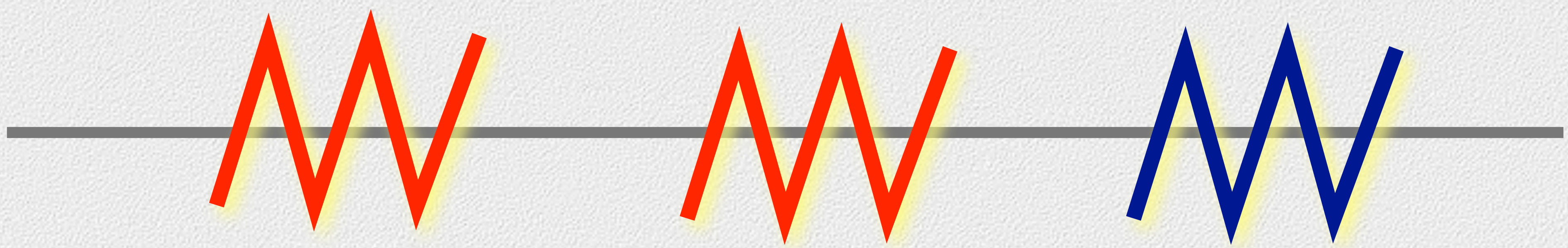
Smallest Possible Total?

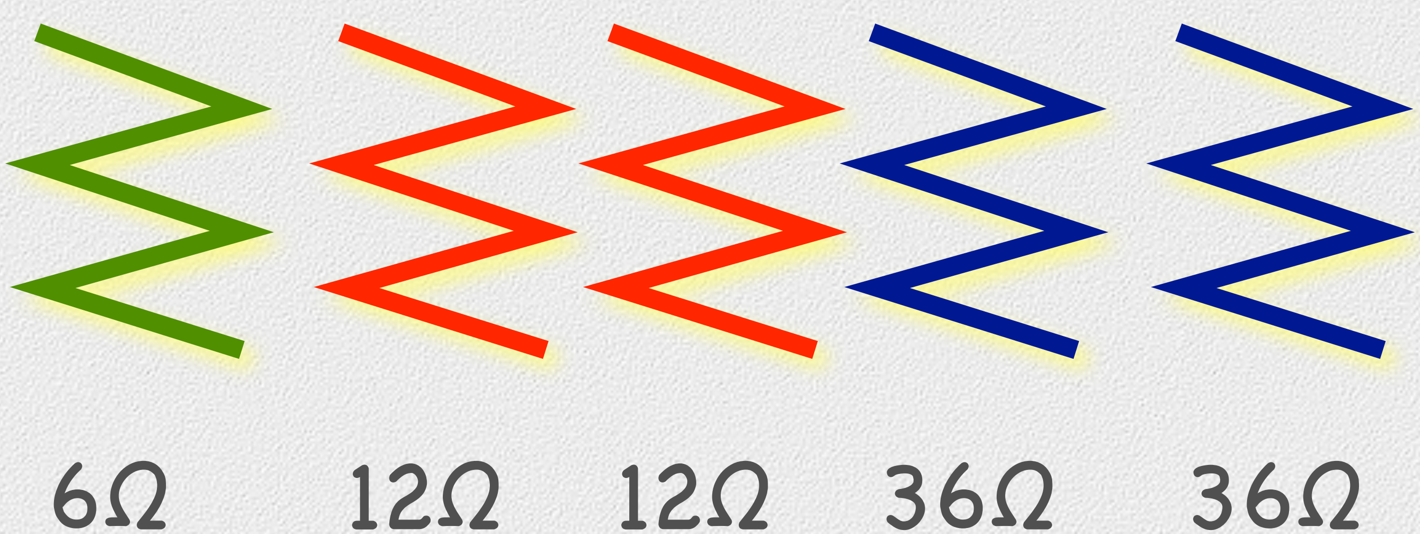
2.57 Ω



How could you get...

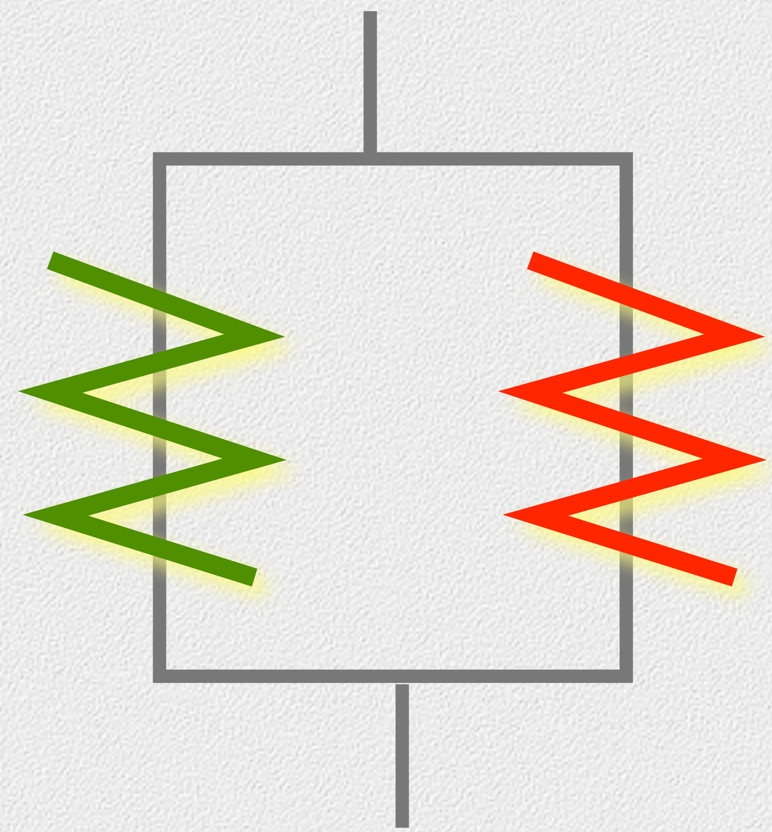
60 Ω

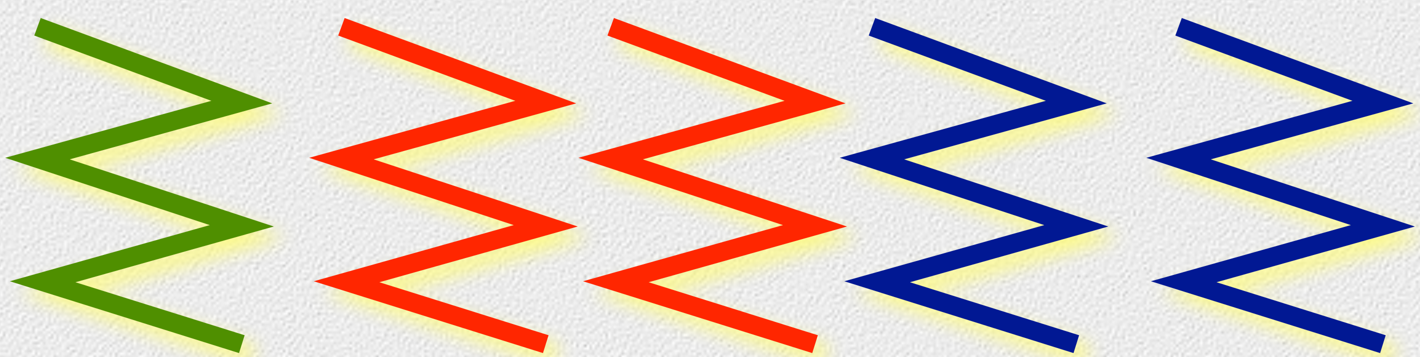




How could you get...

4 Ω





6Ω 12Ω 12Ω 36Ω 36Ω

Kirchhoff's Rules

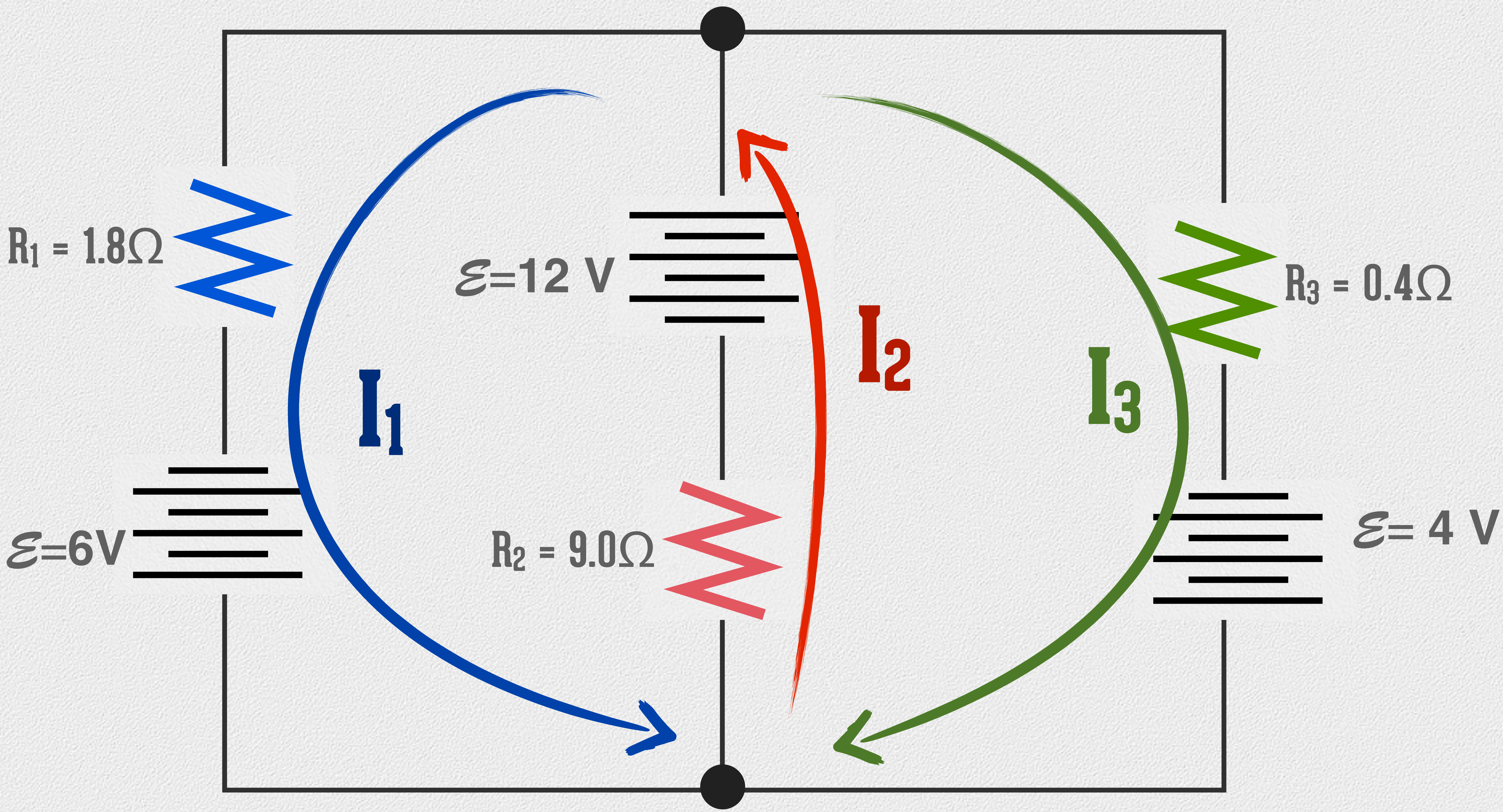
The Point Rule-
The sum of current going in to a point must equal the sum of current coming out.

$$\Sigma I_{in} = \Sigma I_{out} \qquad \Sigma I = 0$$

The Loop Rule-
A closed path that begins and ends at the same point will have no net change in potential.

$$\Sigma V = 0$$

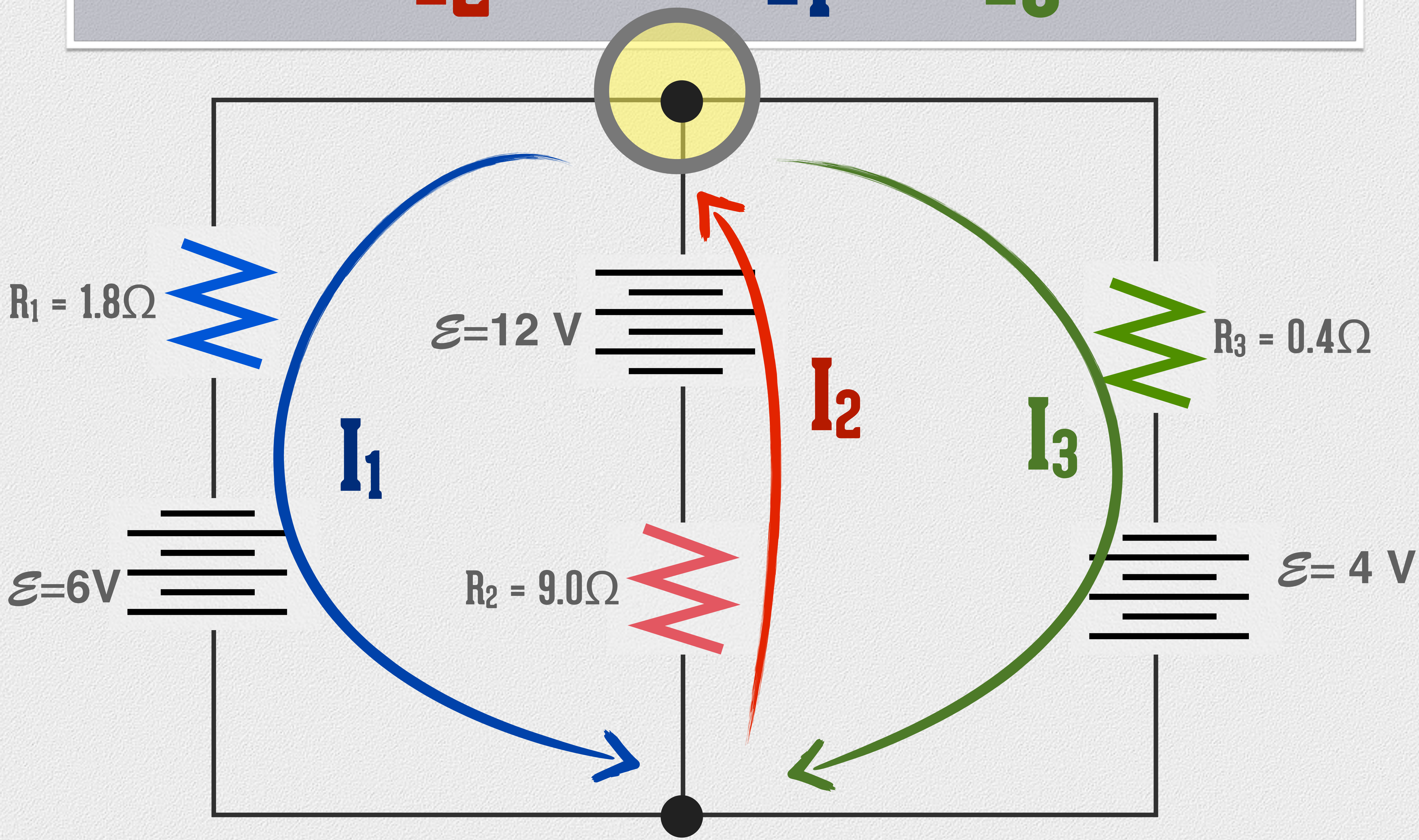
Kirchhoff's Rules



Point Rule

$$\Sigma I_{in} = \Sigma I_{out}$$

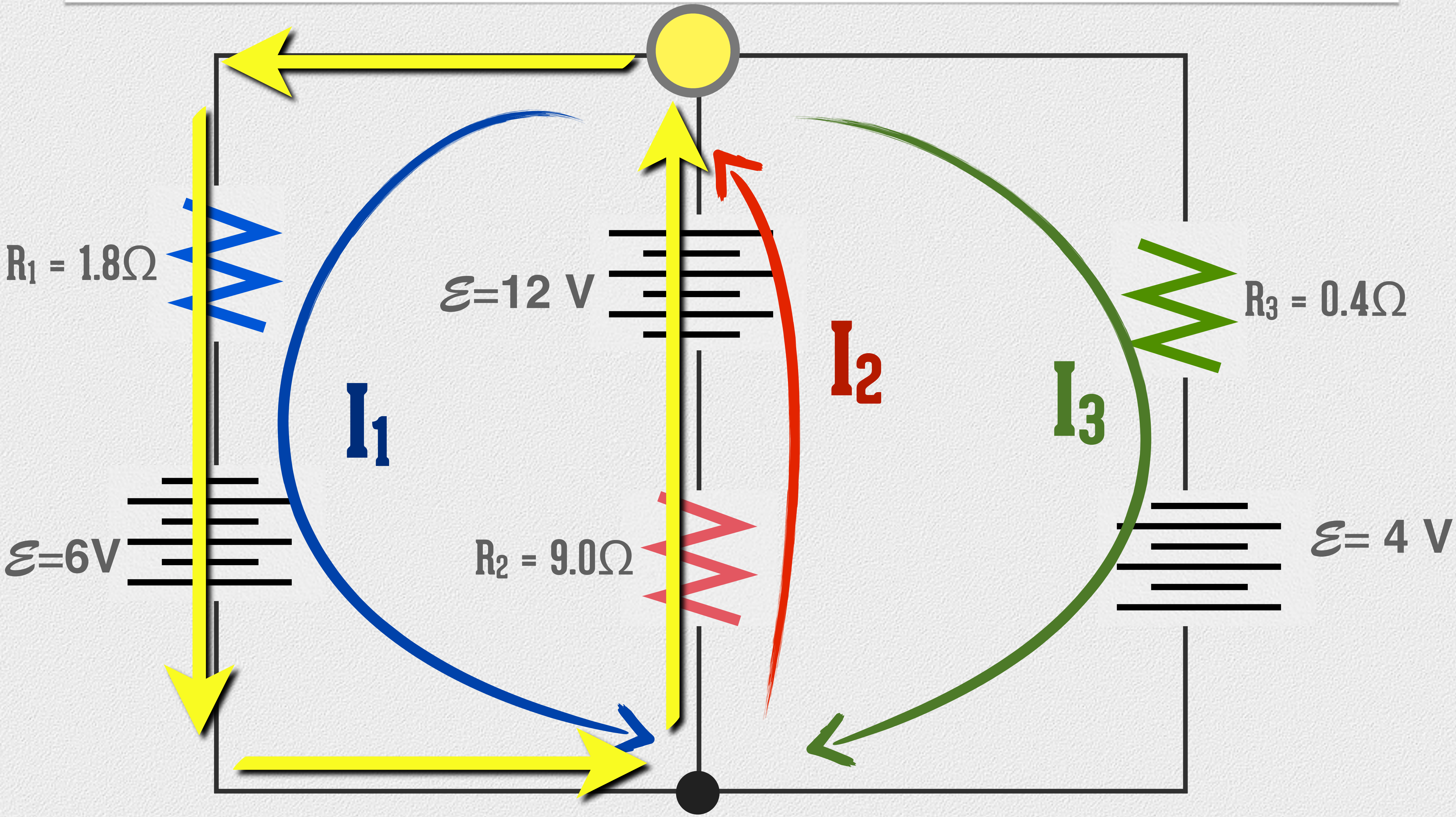
$$I_2 = I_1 + I_3$$



Loop Rule

$$\Sigma V = 0$$

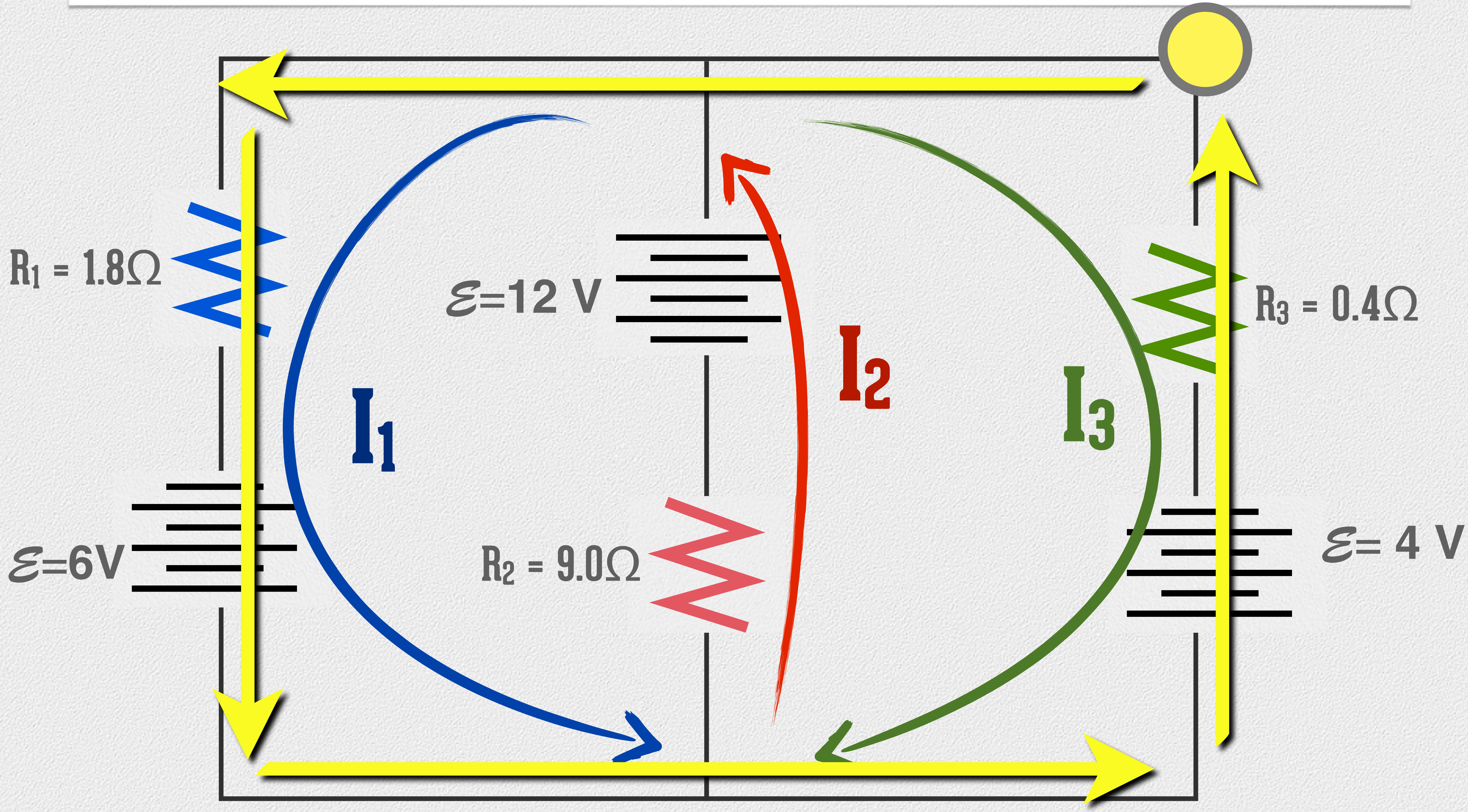
$$-1.8I_1 + 6 - 9I_2 + 12 = 0$$



Loop Rule

$$\Sigma V = 0$$

$$-1.8I_1 + 6 - 4 + 0.4I_3 = 0$$



Loop Rule $-1.8I_1 + 6 - 9I_2 + 12 = 0$

Boring Algebra

simplify to: $18 - 1.8I_1 = 9I_2$

divide by 9 to get: $2 - 0.2I_1 = I_2$

$1.23\ A = I_1$

Loop Rule $-1.8I_1 + 6 - 4 + 0.4I_3 = 0$

simplify to: $2 - 1.8I_1 = -0.4I_3$

divide by -0.4 to get: $-5 + 4.5I_1 = I_3$

Point Rule $I_2 = I_1 + I_3$

substitute I_2: $2 - 0.2I_1 = I_1 - 5 + 4.5I_1$ substitute I_3:

$7 = 5.7\ I_1$