2.1 Brush Up on Ohms and Watts Law

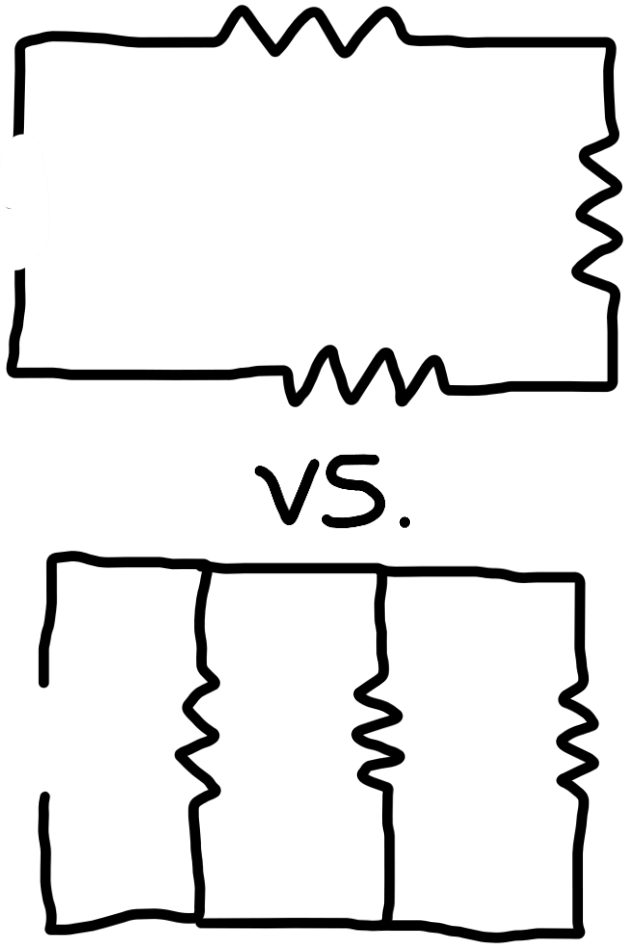
Part 2

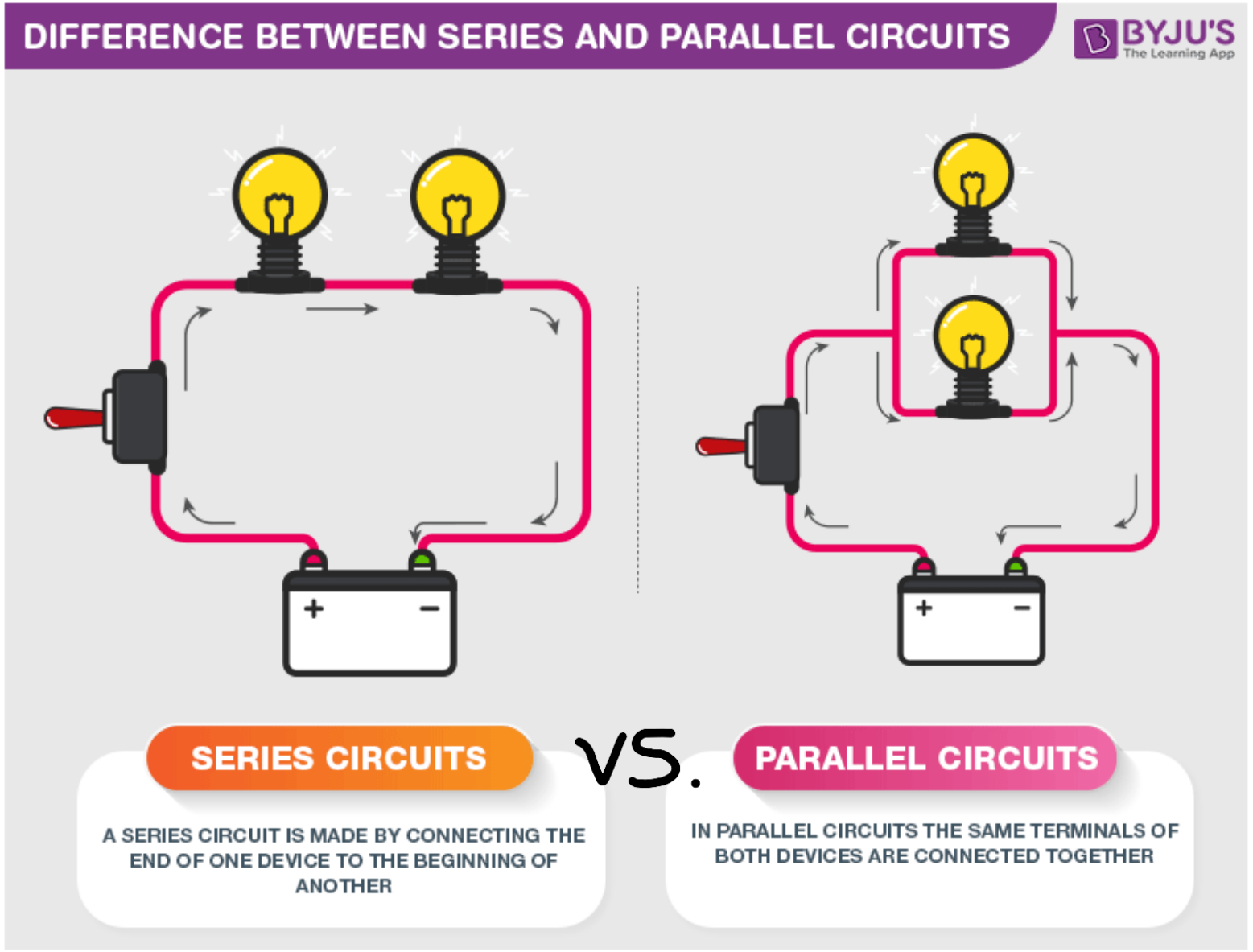
Series Circuits

Series Circuits

Identify and solve for electrical quantities within a series circuit

Series vs. parallel.

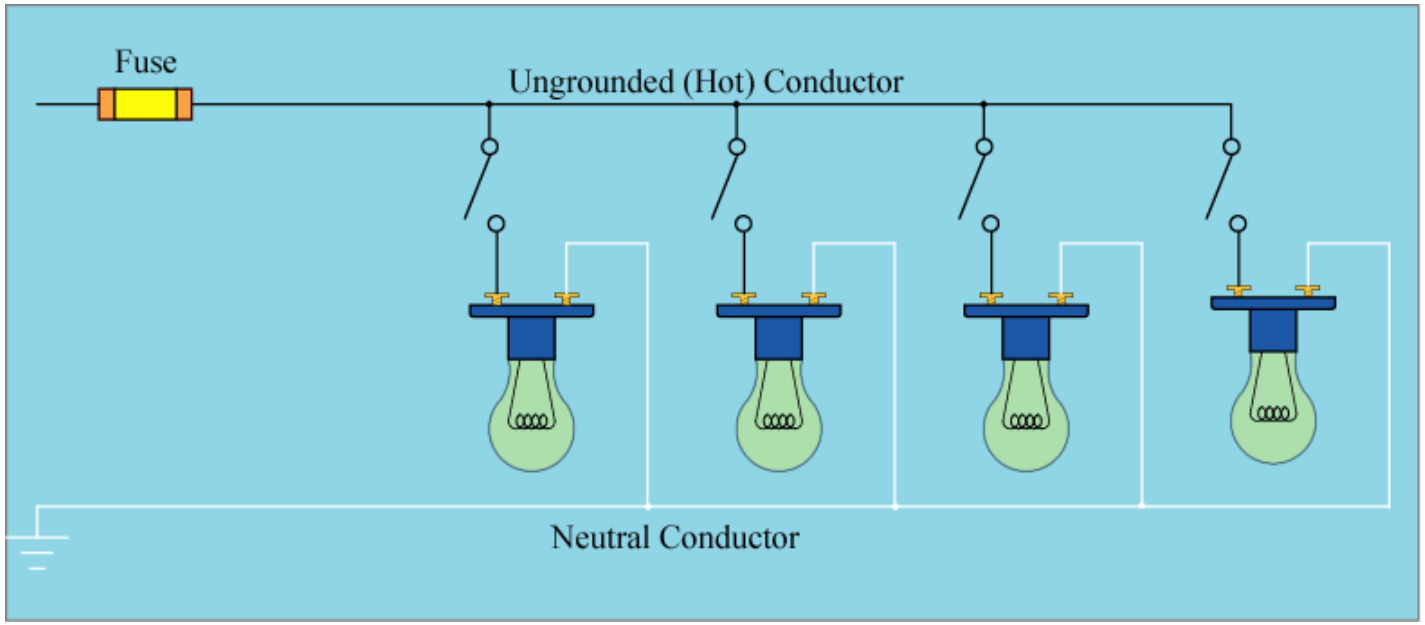




Applications of series.

Loads are not normally wired in series but…

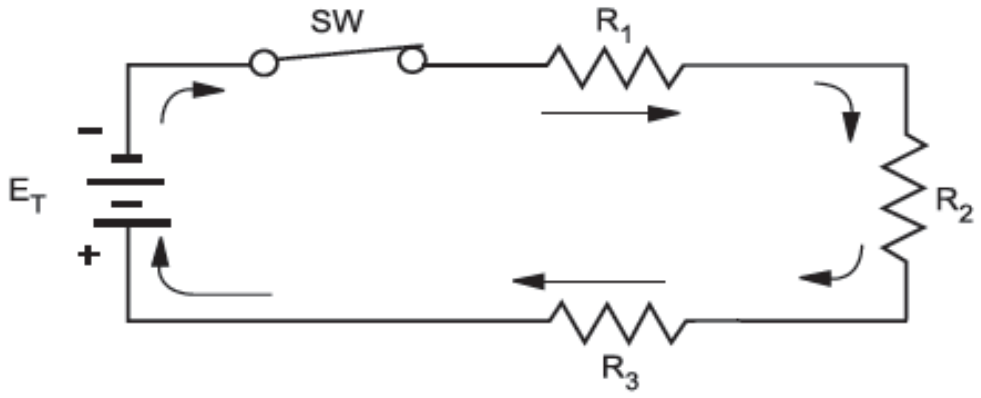
We connect switches and circuit breakers in series with loads to control them.



Construction of a series circuit.

All components are in line with one another.

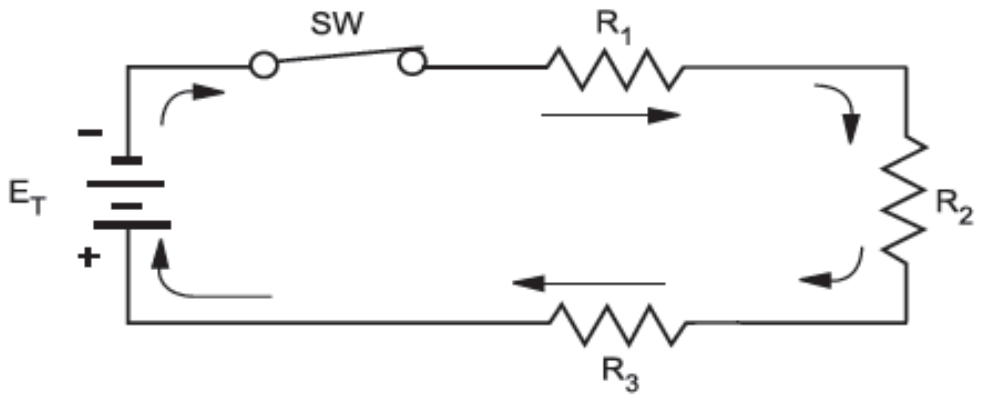
Only one path for current to flow.



Construction of a series circuit.

If there is an open anywhere in the circuit no current will flow, and nothing will work.

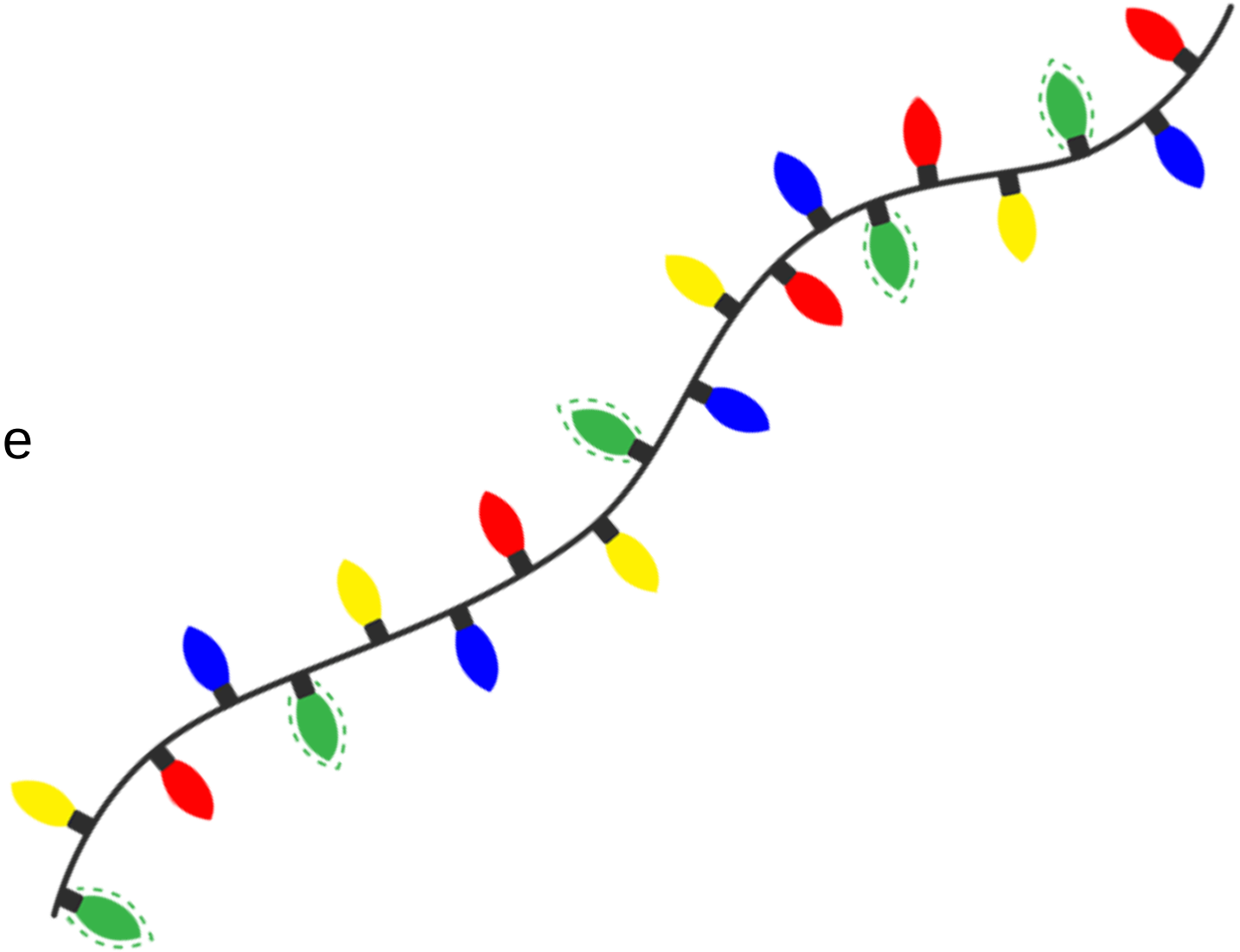
An open could mean an open switch, loose connection, cut wire, burned open resistor, burnt out light bulb…



Construction of a series circuit.

Some strings of Christmas lights are wired in series.

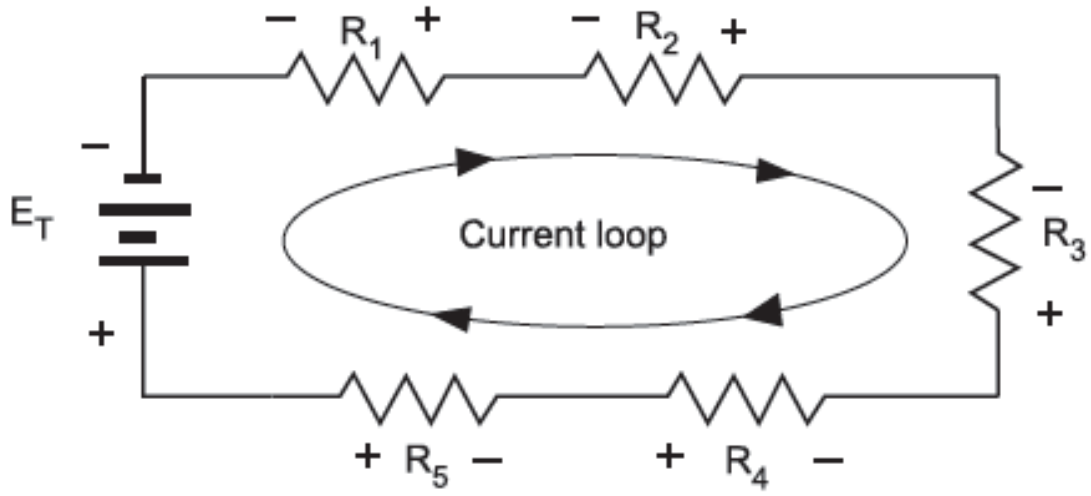
This means that if one bulb burns out, the whole string is out.



Polarity throughout a series circuit.

Current leaves the negative of the supply and flows through the circuit back to the positive of the supply.

Current flows through each resistor from negative to positive.



Resistance in a series circuit.

$$R_T = R_1 + R_2 + R_3 \ldots$$ *

The total resistance in a series circuit is equal to all the resistances added up.

Resistance in a series circuit.

$$R_T = R_1 + R_2 + R_3 \ldots$$

Example.

$R_T = 15\,\Omega + 5\,\Omega + 20\,\Omega = 40\,\Omega$

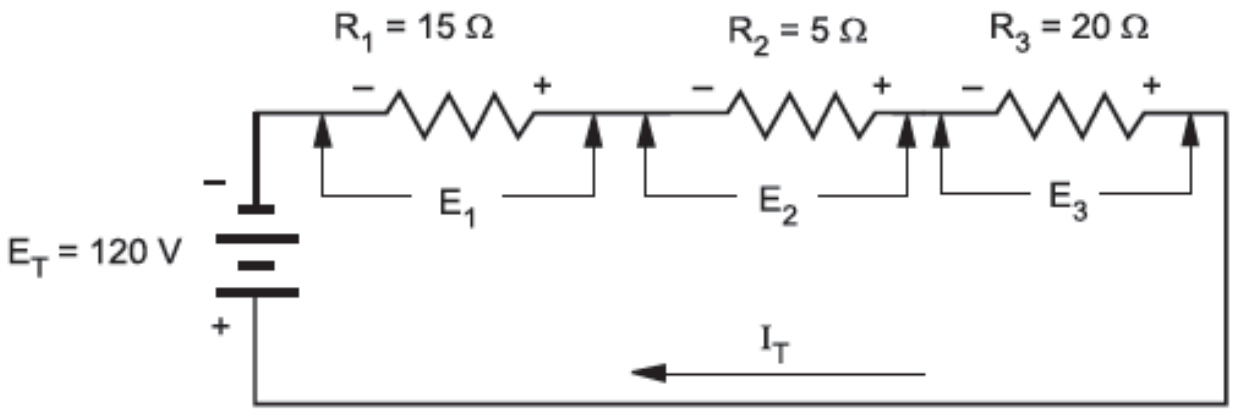


Figure 3—A series circuit

Current in a series circuit.

$$I_T = I_1 = I_2 = I_3 \ldots$$ *

The current is the same throughout a series circuit. Always.

Current in a series circuit.

$$I_T = I_1 = I_2 = I_3 \ldots$$

Example.

Not that we know the total resistance of the circuit is 40Ω, We can just use ohm's law to figure out the total current.

$$I_T = \frac{120V}{40\Omega} = 3A$$

$R_T = 15\,\Omega + 5\,\Omega + 20\,\Omega = 40\,\Omega$

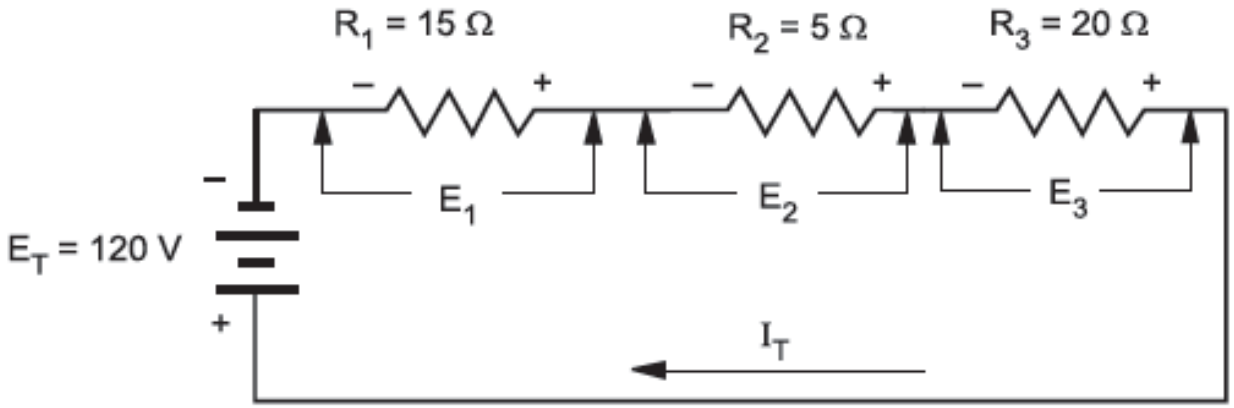


Figure 3—A series circuit

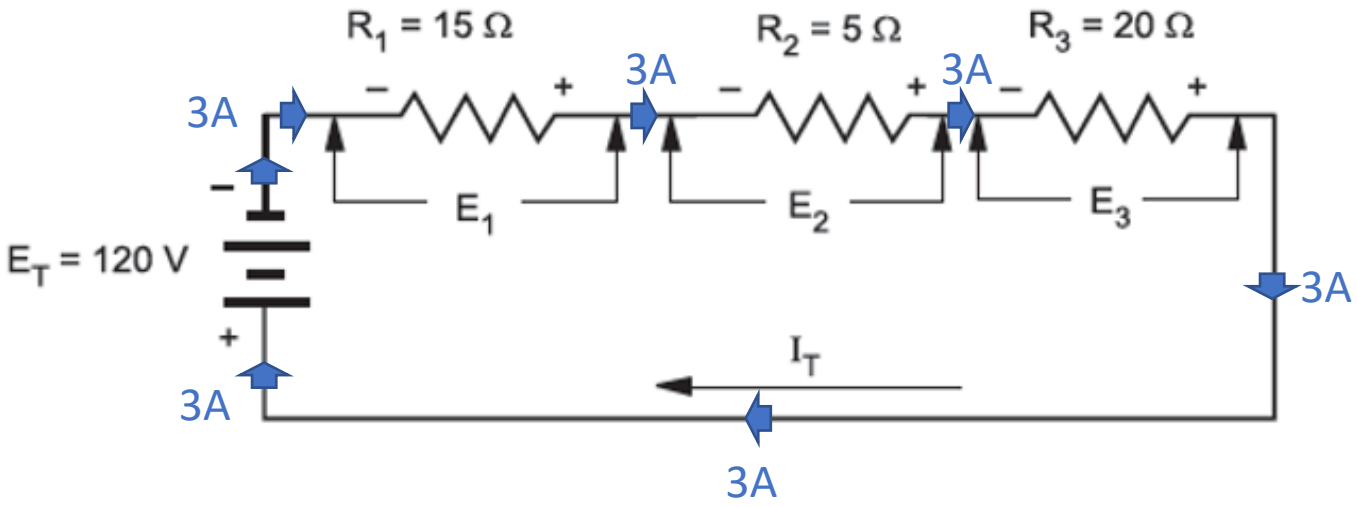
Current in a series circuit.

$$I_T = I_1 = I_2 = I_3 \ldots$$

Example.

$$I_T = \frac{120V}{40\Omega} = 3A$$

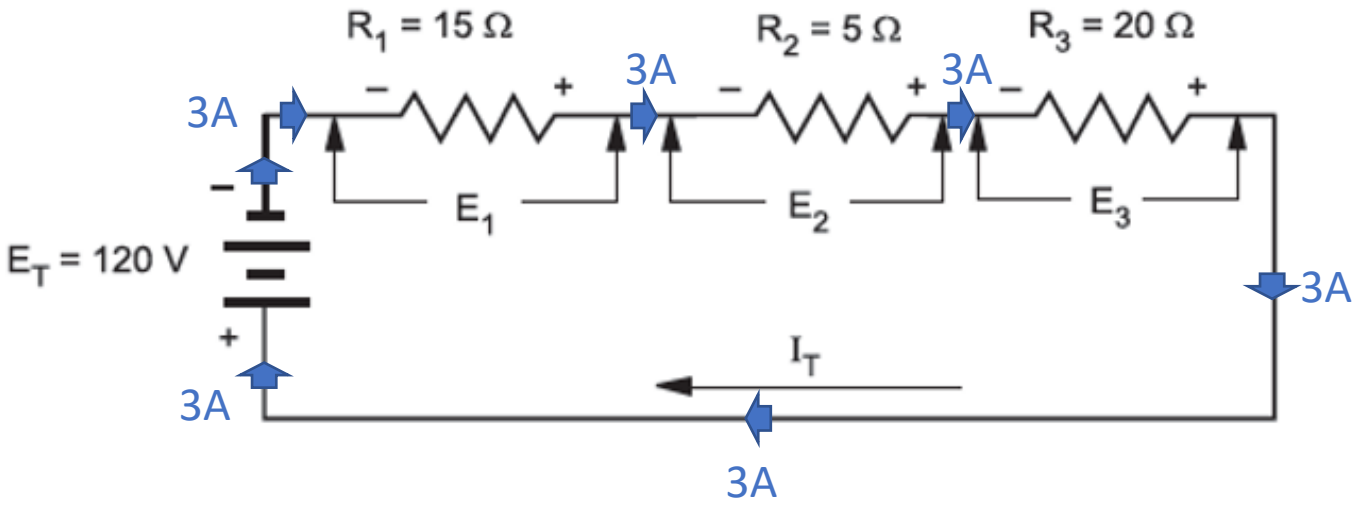
That 3A leaves the negative of the supply and flows through every resistor and back to the positive of the supply.



Voltage in a series circuit.

$$E_T = E_1 + E_2 + E_3 \ldots$$ *

The total voltage in a series circuit is equal to the total of all of the voltages throughout the circuit added up.

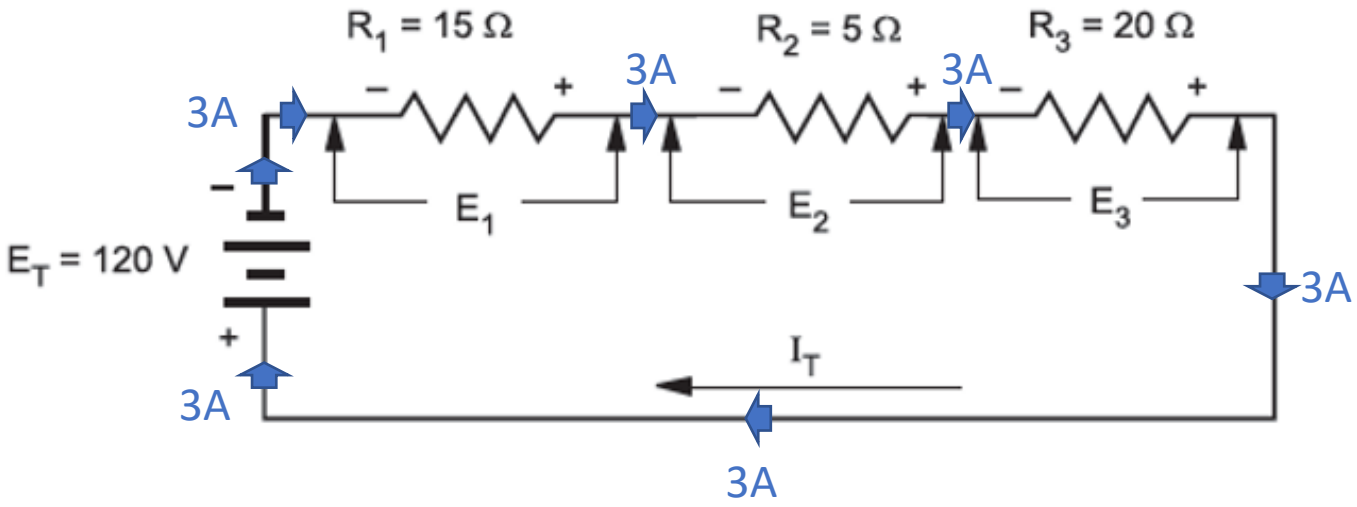


Voltage in a series circuit.

$$E_T = E_1 + E_2 + E_3 \ldots$$

Example.

Now that we know the current throughout the circuit, we can just use ohm's law to find the individual resistor voltages.



Voltage in a series circuit.

$$E_T = E_1 + E_2 + E_3 \ldots$$

Example.

The voltage drop across resistor R_1 is:

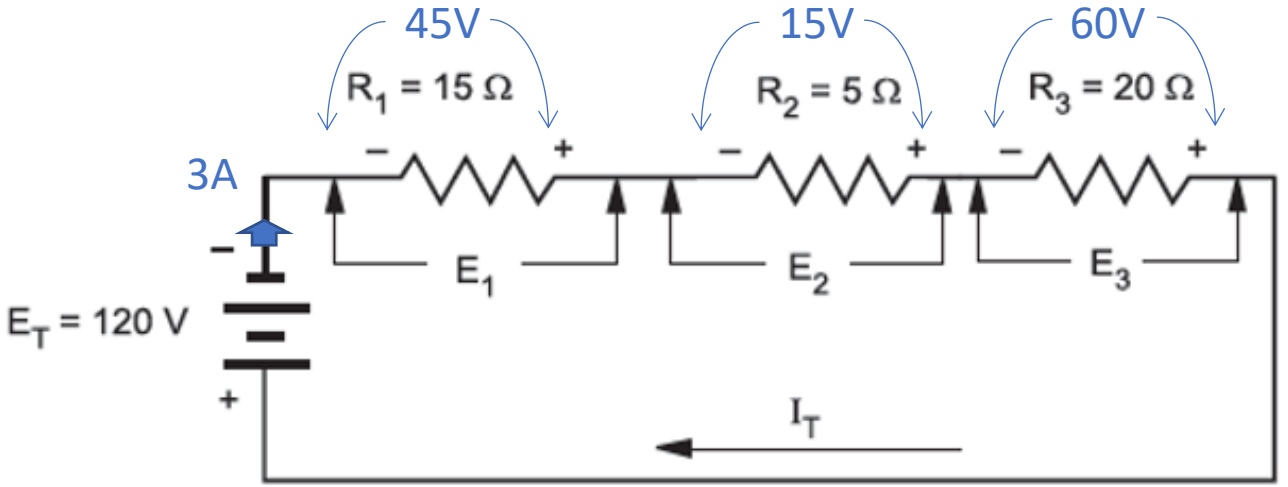
$$E_1 = I_1 \times R_1 = 3\ A \times 15\ \Omega = 45\ volts$$

The voltage drop across resistor R_2 is:

$$E_2 = I_2 \times R_2 = 3\ A \times 5\ \Omega = 15\ volts$$

The voltage drop across resistor R_3 is:

$$E_3 = I_3 \times R_3 = 3\ A \times 20\ \Omega = 60\ volts$$



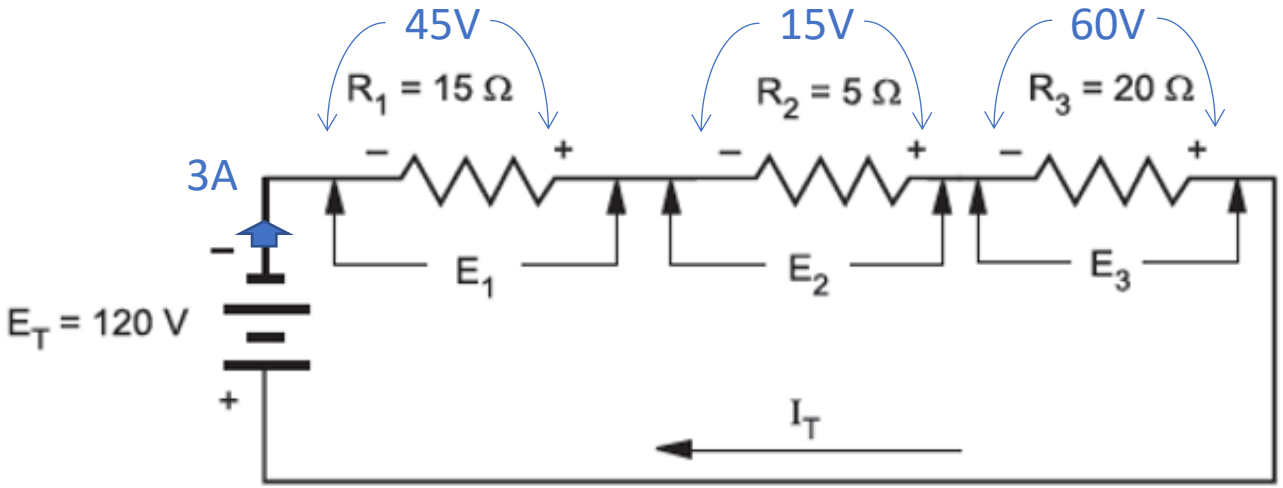
Voltage in a series circuit.

$$E_T = E_1 + E_2 + E_3 \ldots$$

Example.

Now check to make sure the voltage rule works.

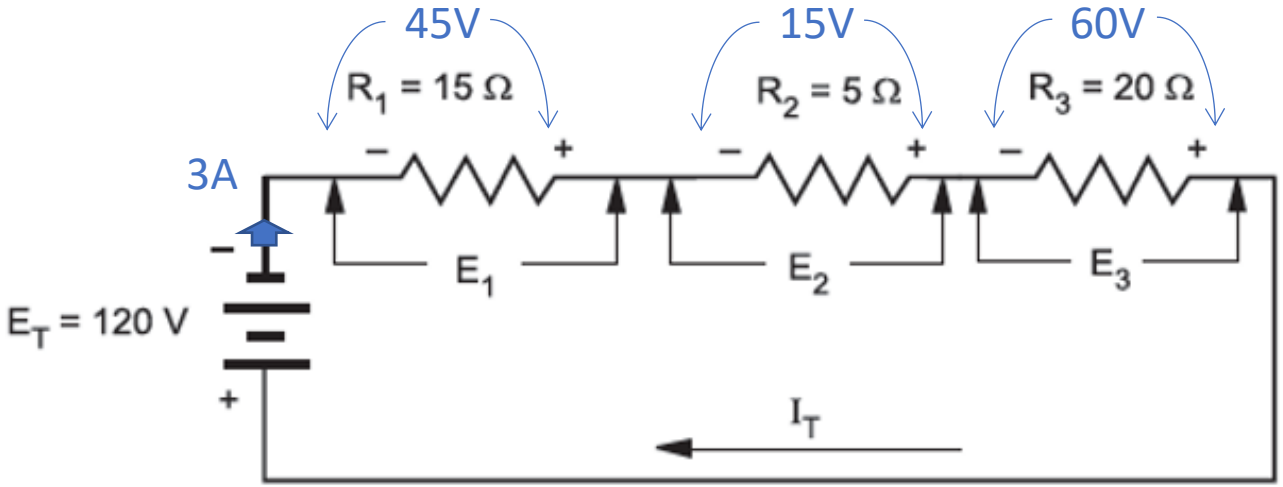
The three individual voltages must add up to the total voltage.



Power in a series circuit.

$$P_T = P_1 + P_2 + P_3 \ldots$$ *

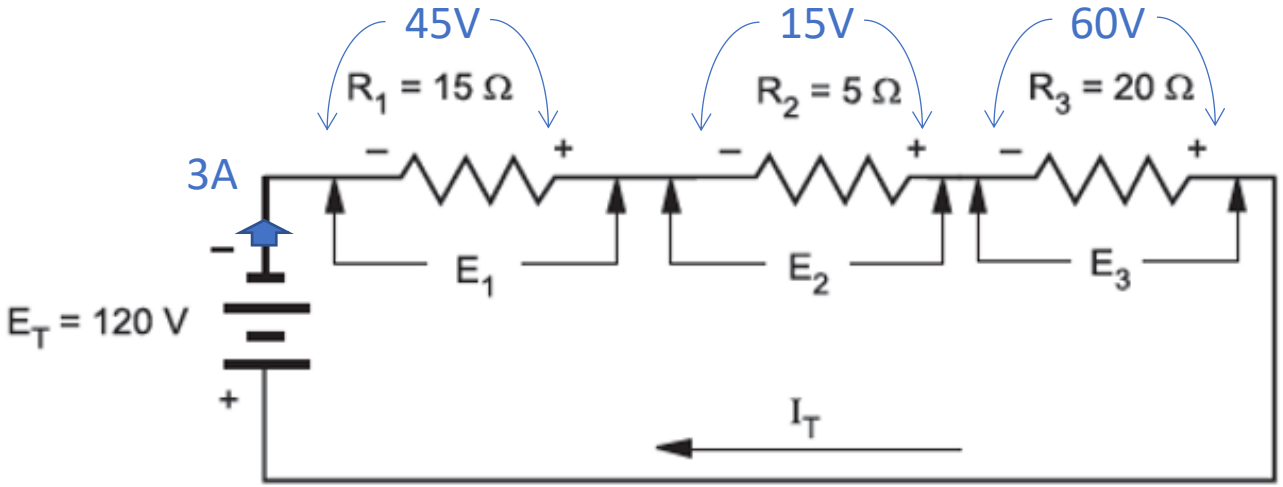
The total power in a series circuit is equal to the total of all of the power throughout the circuit added up.



Power in a series circuit.

$$P_T = P_1 + P_2 + P_3 \ldots$$

Now that we know the voltage and the current at each resistor we can just use Watt's law to solve for each individual power.



Power in a series circuit.

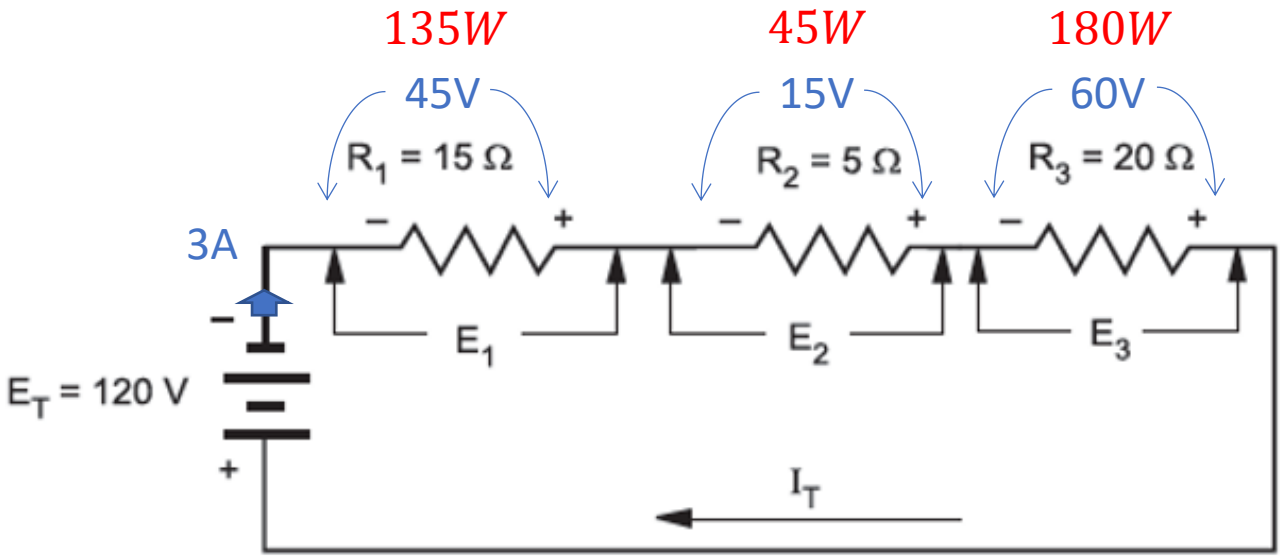
$$\boldsymbol{P_T = P_1 + P_2 + P_3 \ldots}$$

$$P_1 = 45Vx3A = 135W$$

$$P_2 = 15Vx3A = 45W$$

$$P_3 = 60Vx3A = 180W$$

$$P_T = 120Vx3A = 360W$$



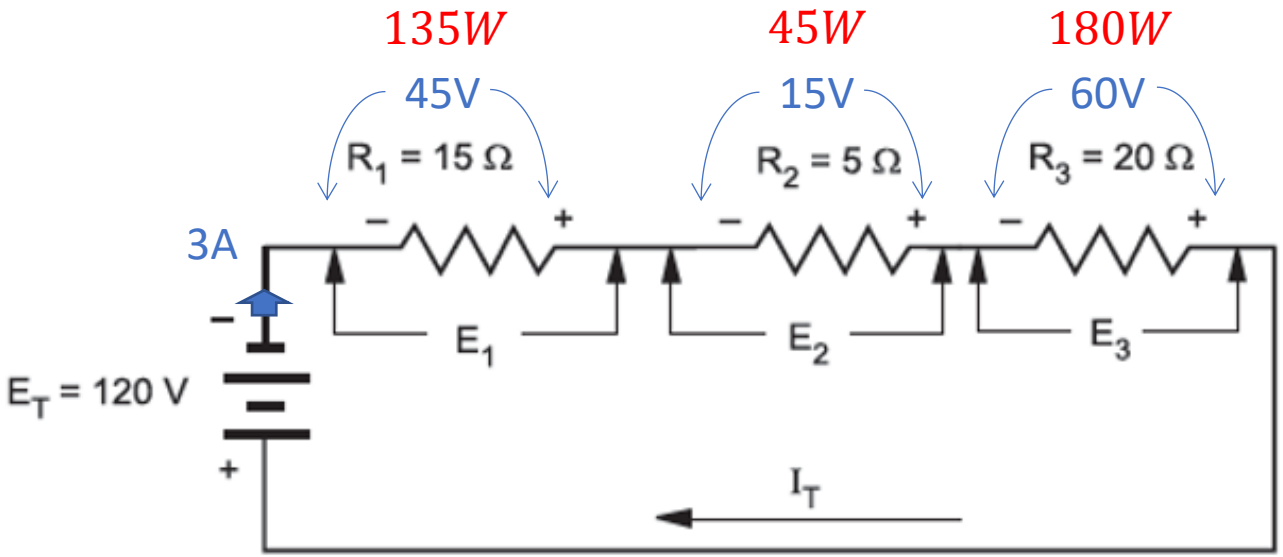
Power in a series circuit.

$$\boldsymbol{P_T = P_1 + P_2 + P_3 \ldots}$$

$P_T = 120Vx3A = 360W$

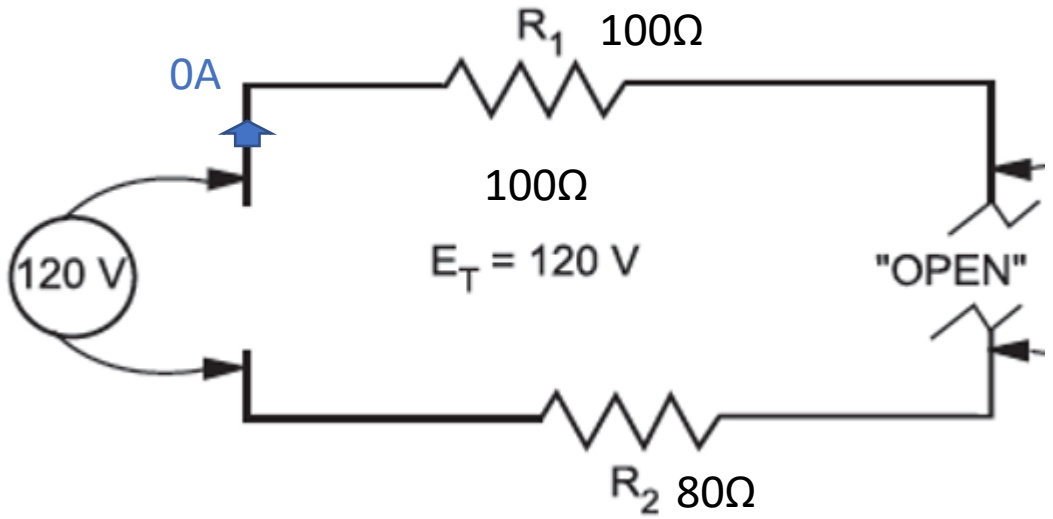
Double check to make sure the individual Watts add up to the total Watts.

$135W + 45W + 180W = 360W$



An open in a series circuit.

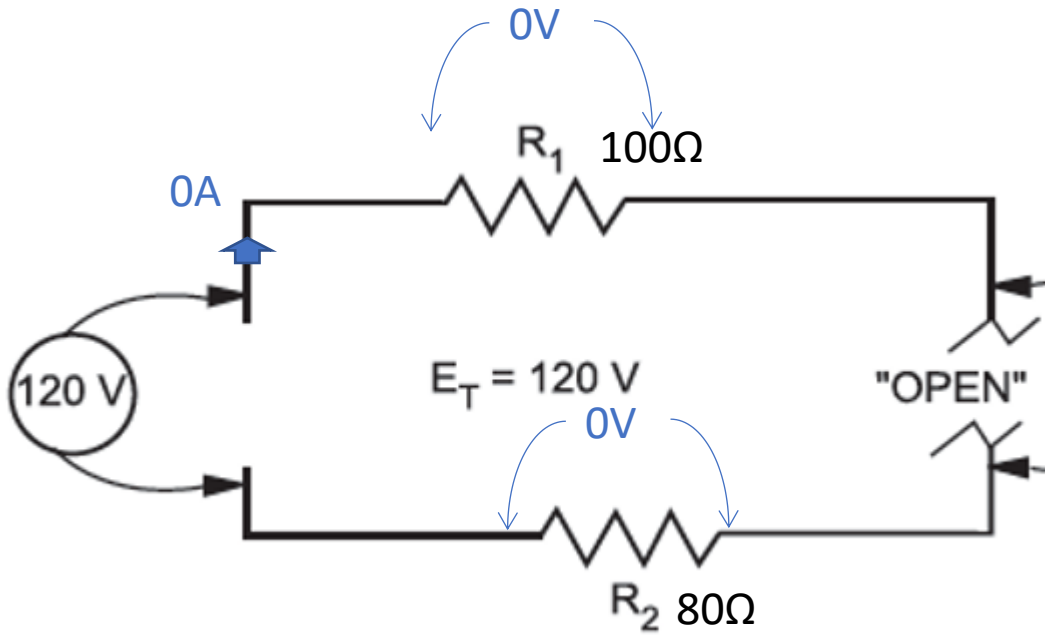
An open anywhere in a series circuit results in no current.



An open in a series circuit.

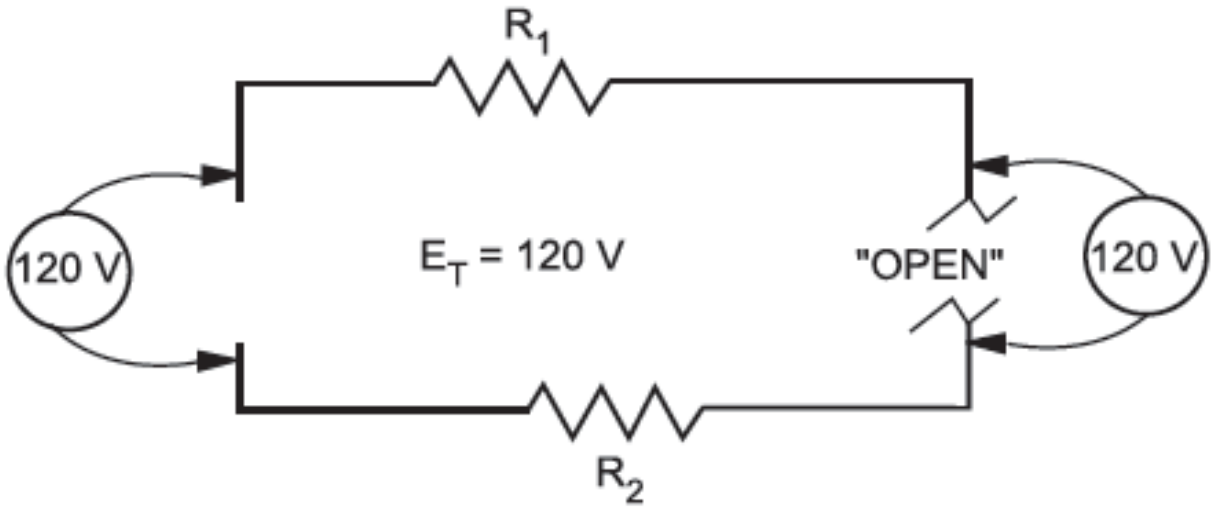
With no current flowing the voltage at each individual resistor will also be 0.

(0A x 100Ω = 0V)
(0A x 80Ω = 0V)



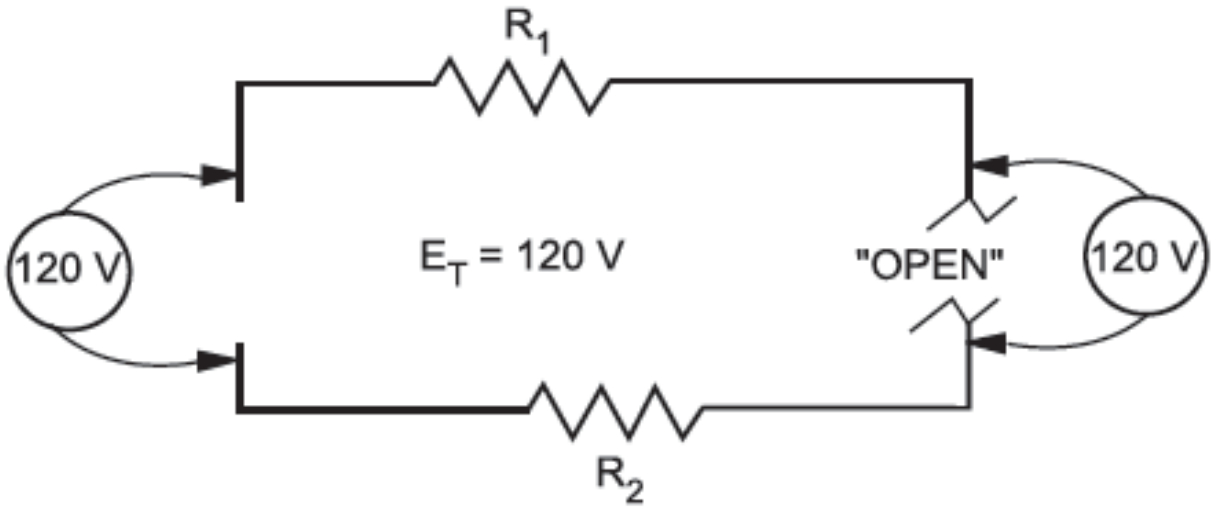
An open in a series circuit.

Since the voltage drops around the series loop must add up to the supply voltage the 120V must be seen across the open.



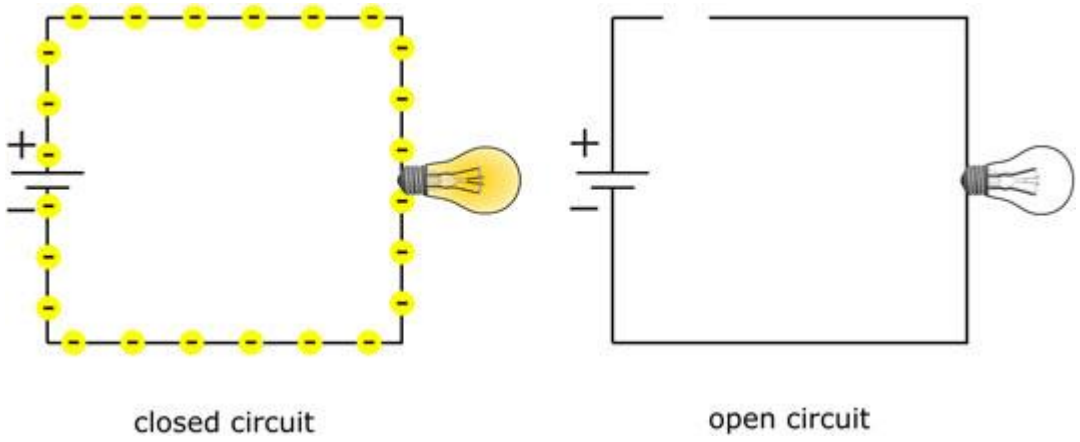
Kirchhoff's voltage law.

The voltage drops around any closed loop must add up to the voltage supply of that loop.



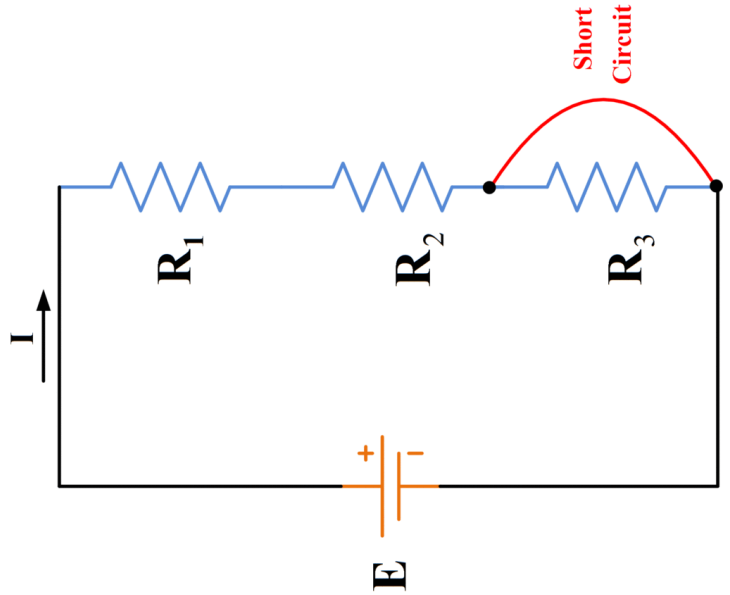
Disadvantages of series.

An open in one part of the circuit shuts down the entire circuit.



A short over one part of the circuit will cause the total resistance to decrease, and the current to increase.

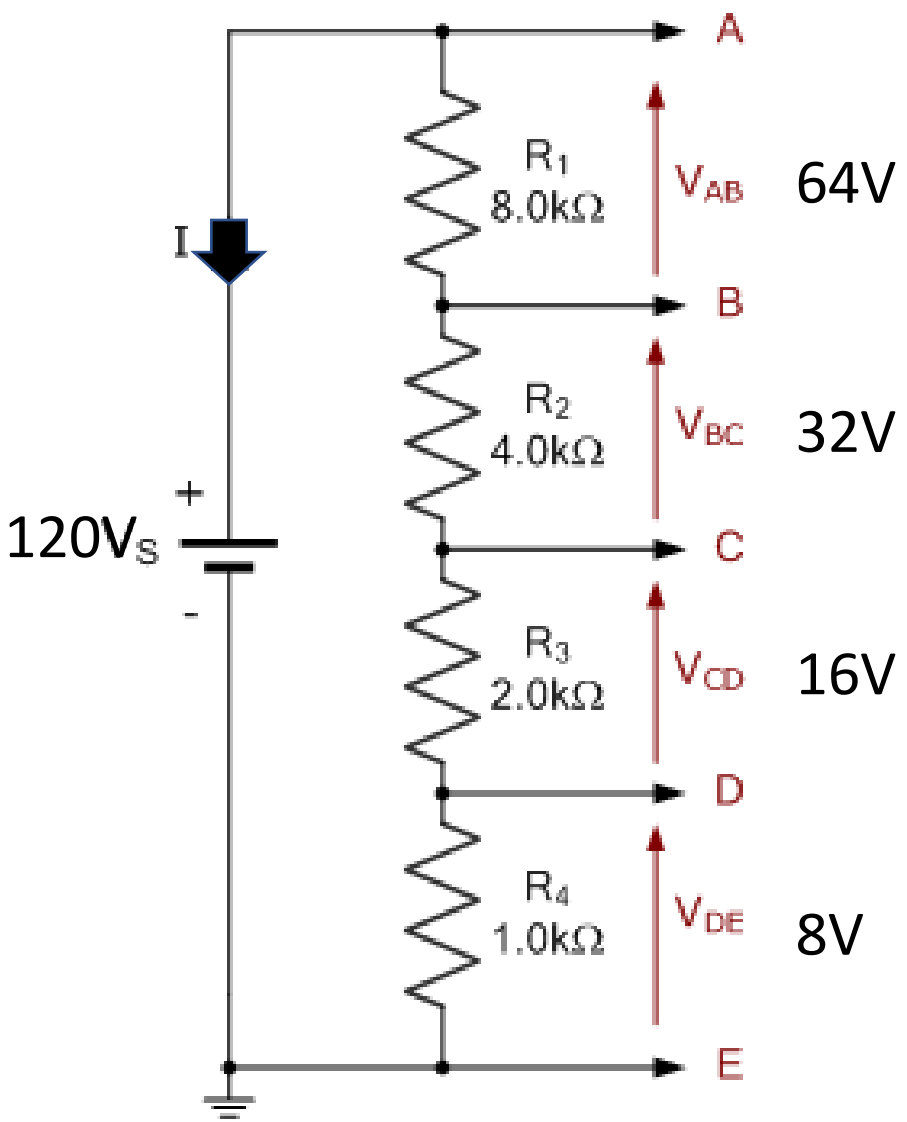
Adding resistors will cause current to decrease.



Applications of series.

By connecting resistors in series with each other we can get a variety of voltage from a single supply (voltage divider).

That's also how Christmas lights in series work. Each bulb only gets a small portion of 120V.



The laws of series circuits.

$$R_T = R_1 + R_2 + R_3 \ldots$$ *

$$E_T = E_1 + E_2 + E_3 \ldots$$ *

* $$I_T = I_1 = I_2 = I_3 \ldots$$ I_T is the key for a series circuit! *

$$P_T = P_1 + P_2 + P_3 \ldots$$ *

VIDEO

Engineering Mindset. (October 30, 2019)

DC series circuits explained – The basic working principle. YouTube.

https://www.youtube.com/watch?v=VV6tZ3Aqfuc&t=331s

The laws of series circuits.

$$R_T = R_1 + R_2 + R_3 \ldots$$ *

$$E_T = E_1 + E_2 + E_3 \ldots$$ *

* $$I_T = I_1 = I_2 = I_3 \ldots$$ I_T is the key for a series circuit! *

$$P_T = P_1 + P_2 + P_3 \ldots$$ *

More series examples.

Find:

P_1, P_2, P_3, P_T

E_1, E_2, E_3

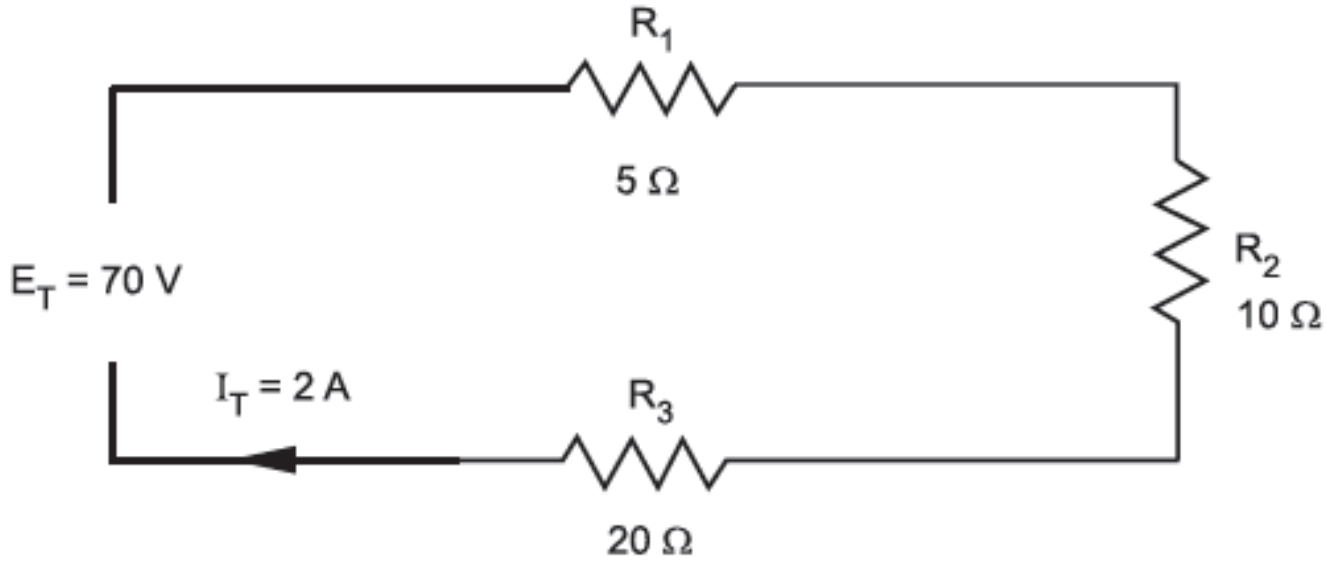


Figure 1—Simple series circuit

More series examples.

Find:

$R_T \; and \; R_3$

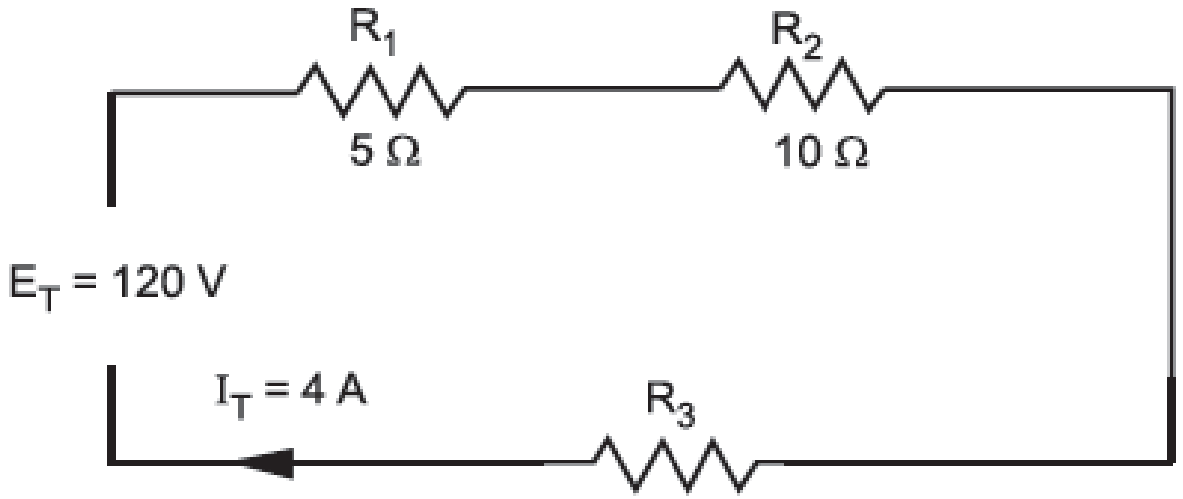


Figure 2—Series circuit for Example 1

More series examples.

Find:

$I_{1,}\, I_2, I_3, I_T$

E_2, E_T

P_1, P_2, P_3, P_T

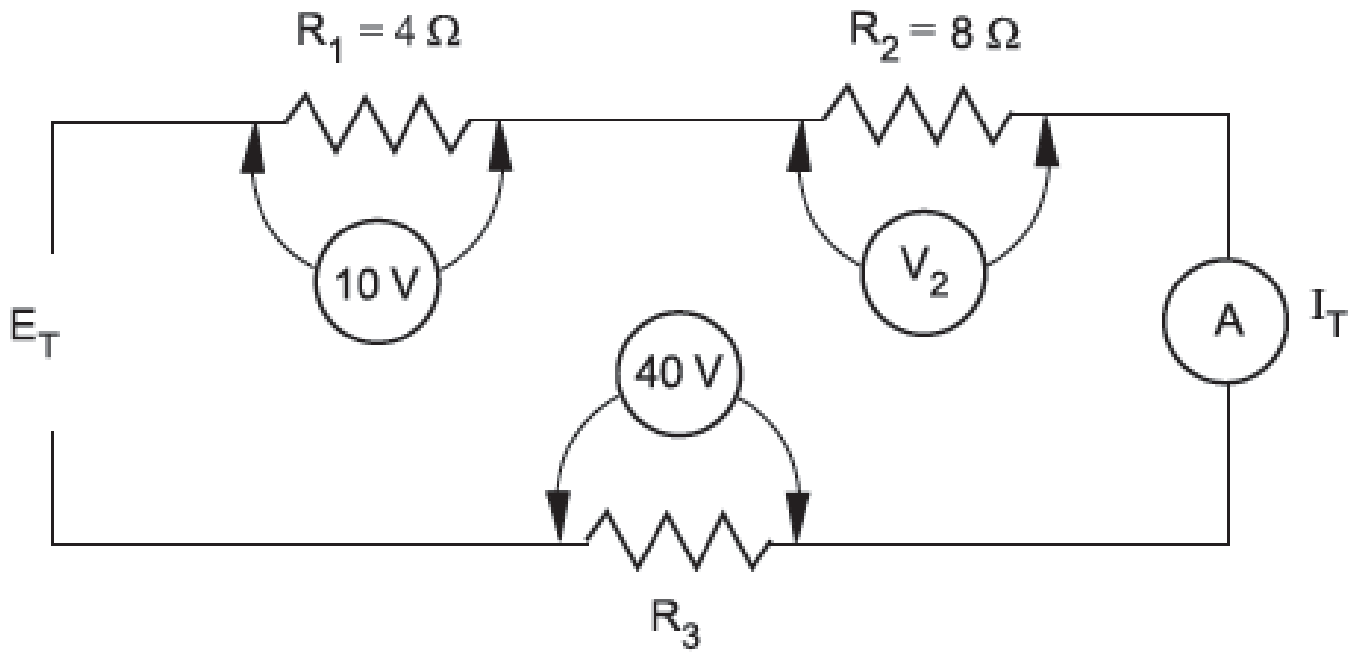


Figure 3—Series circuit for Example 2

More series examples.

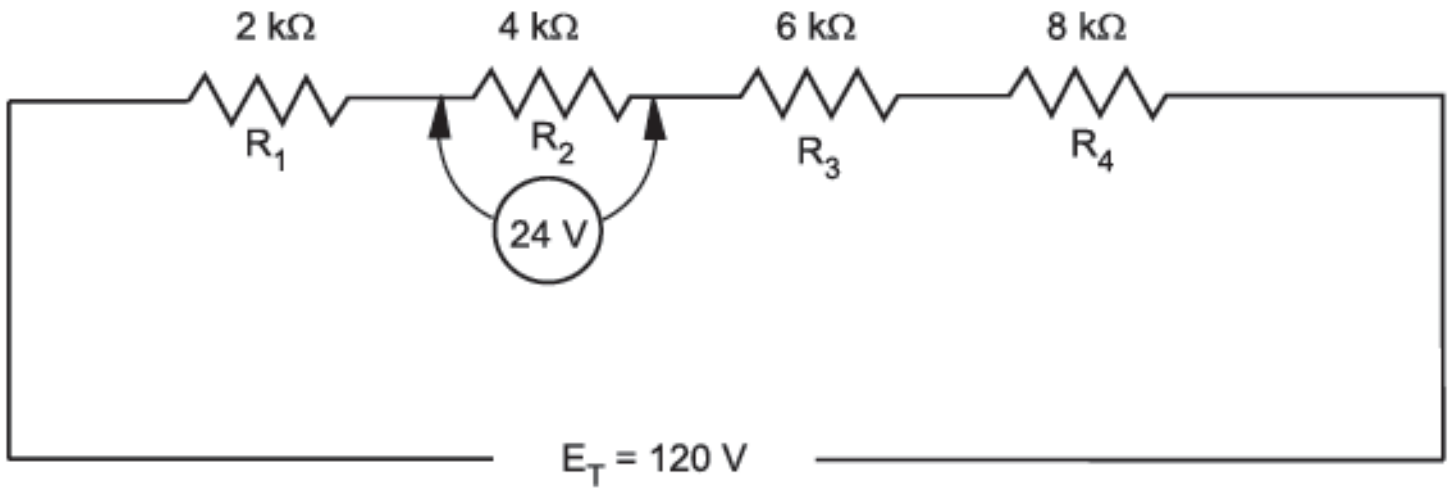
Find:

R_T

I_T

E_1, E_3, E_4

P_1, P_2, P_3, P_T



More series examples.

Find:

$I_{1,}\, I_2, I_3, I_T$

R_T, R_2, R_3

P_1, P_2, P_3, P_T

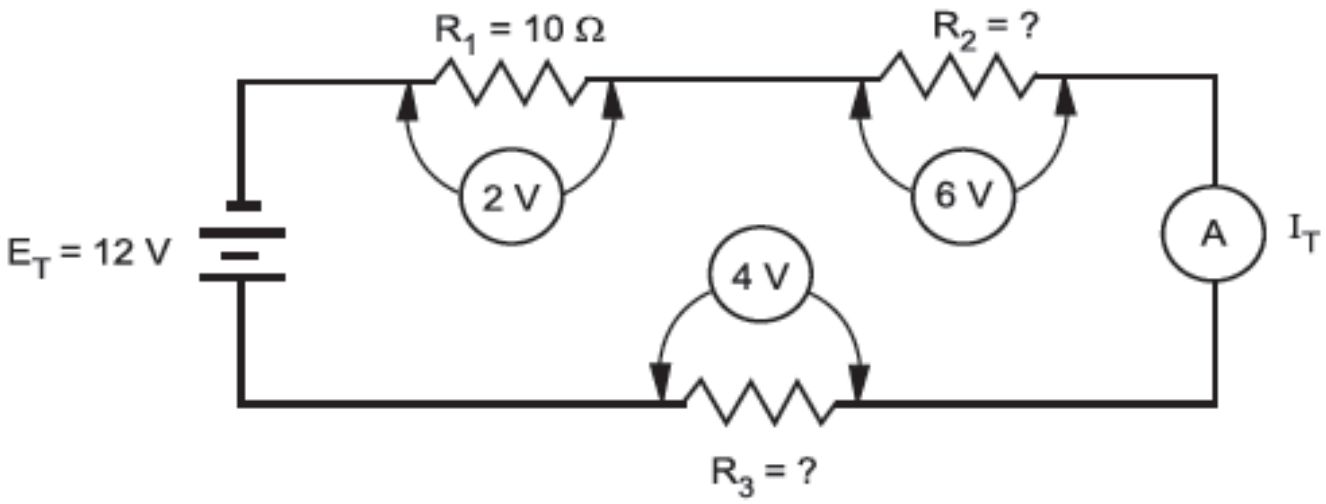


Figure 6—Schematic for solving Example 4

Kirchhoff's voltage law.

The voltage drops around any closed loop must add up to the voltage supply of that loop.

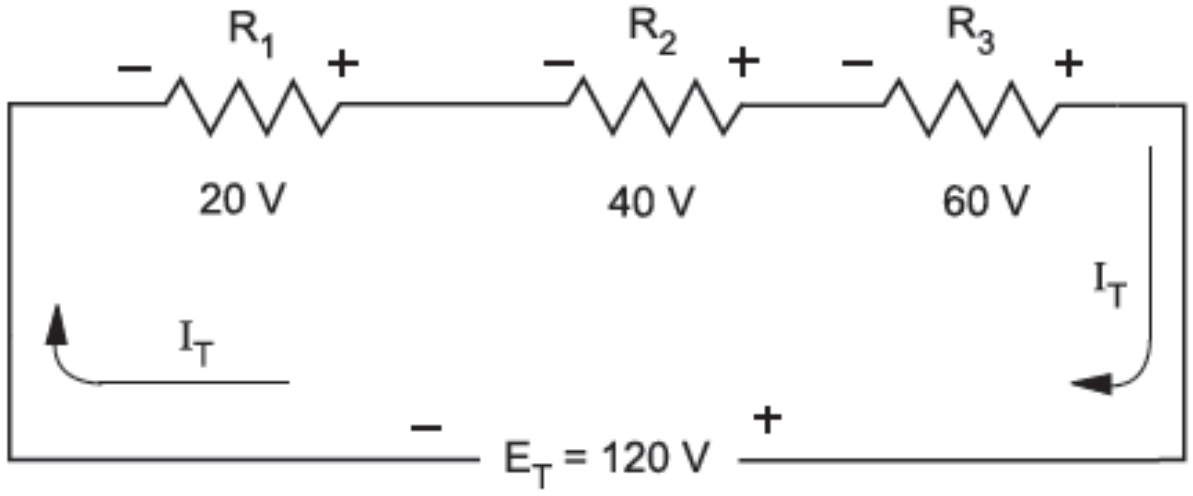


Figure 7—Kirchhoff's voltage law

2.2 Series Circuits

Series Circuits

How to take measurements using a digital multi meter (DMM)

Skip video from 4:50 min to 8:07
It gets into capacitance and diodes

Then end the video at 9:55

VIDEO

James Gatlin. (January 21, 2024)

How to use a multimeter like a pro – The ultimate guide. YouTube.

https://www.youtube.com/watch?v=0loXukB302Q&t=610s

Digital Multi Meter (DMM)

As electricians we will want to not only calculate values for volts, amps, and ohms but also measure those values.

You need a meter to do that.

A multimeter will do a variety of those things for us depending on what you buy.

Voltmeters

Must set your meter to measure DC if it's a DC circuit, AC if it's an AC circuit.

The circuit need to be live to get some volts.

*Draw an example of a voltmeter in parallel

Ammeters

Must set your meter to measure DC if it's a DC circuit, AC if it's an AC circuit.

You'll need a live circuit, and a load connected to get any amps.

An ammeter **must be connected in series** with the circuit. More on that later.

*Draw an example of an ammeter in series

Ammeters

You might end up buying what's called a clamp-on ammeter.

It's easier to use than an inline meter.

Ohmmeters

Never use an ohmmeter on a live circuit!!!!!!!!!!!!!!!!!!

The power must be turned off before ever using an ohmmeter.

*Draw an example of a ohmmeter in parallel

Kirchhoff's voltage law.

The voltage drops around any closed loop must add up to the voltage supply of that loop.

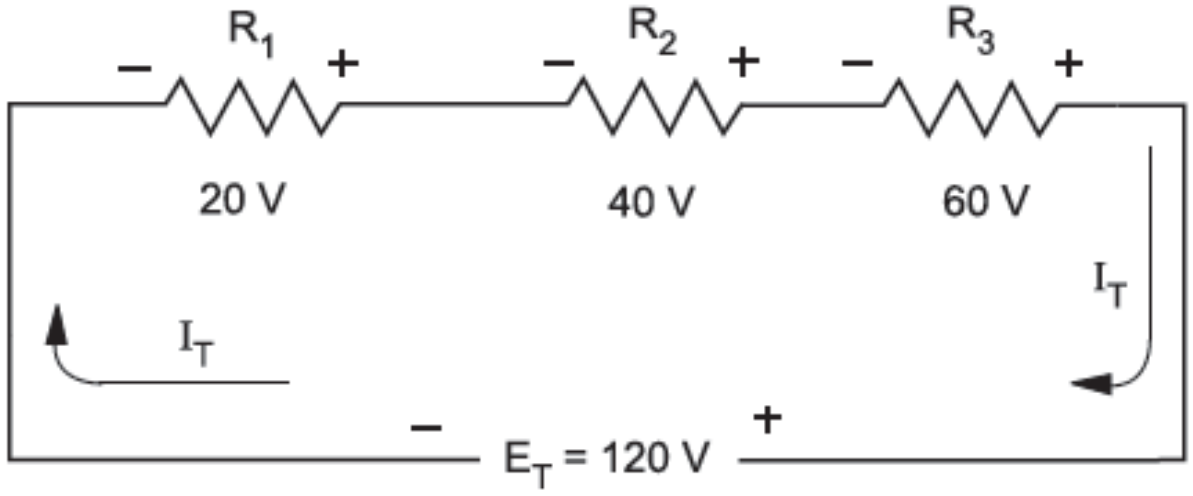
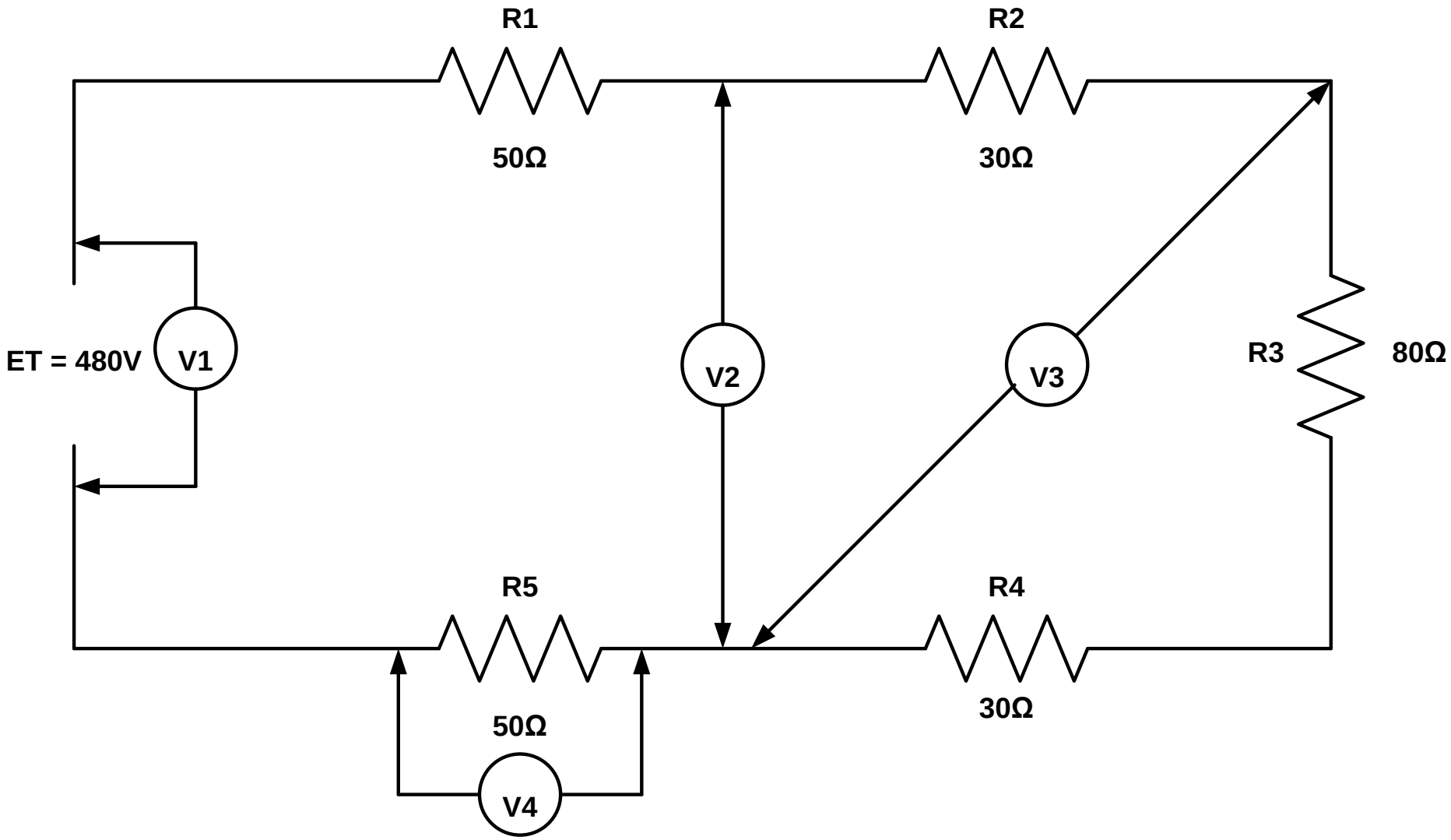
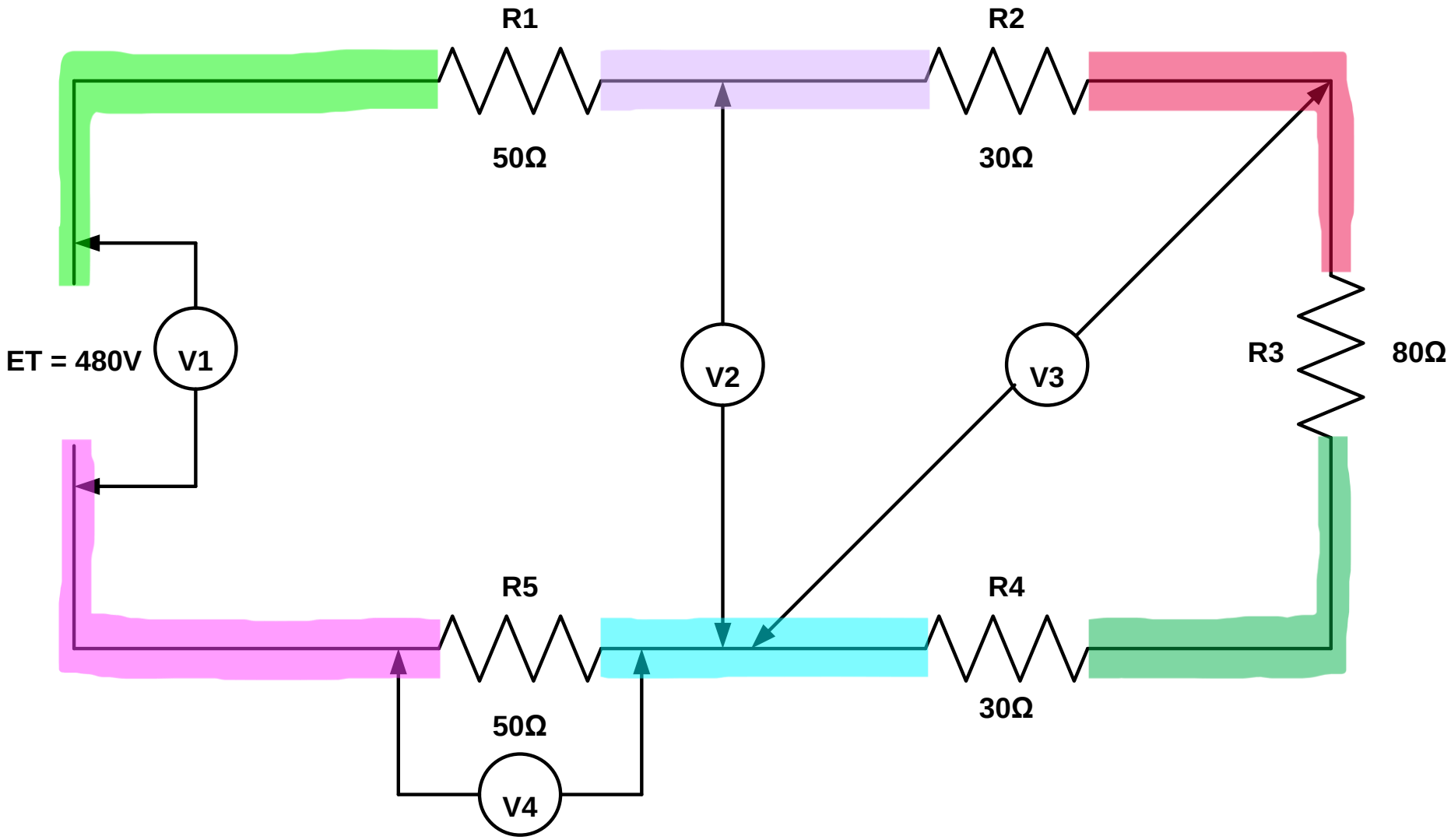


Figure 7—Kirchhoff's voltage law

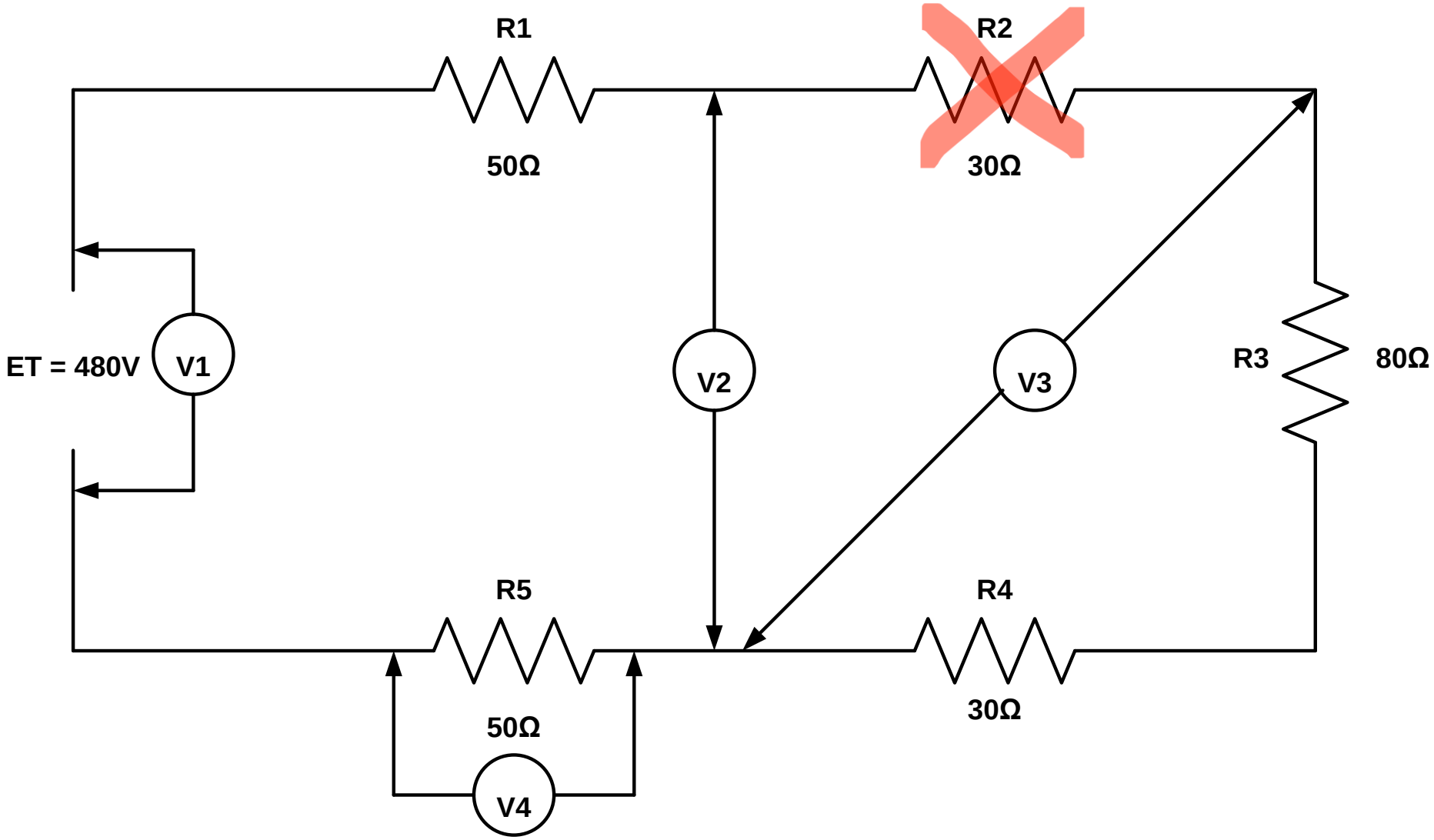
Voltmeters in a closed series circuit



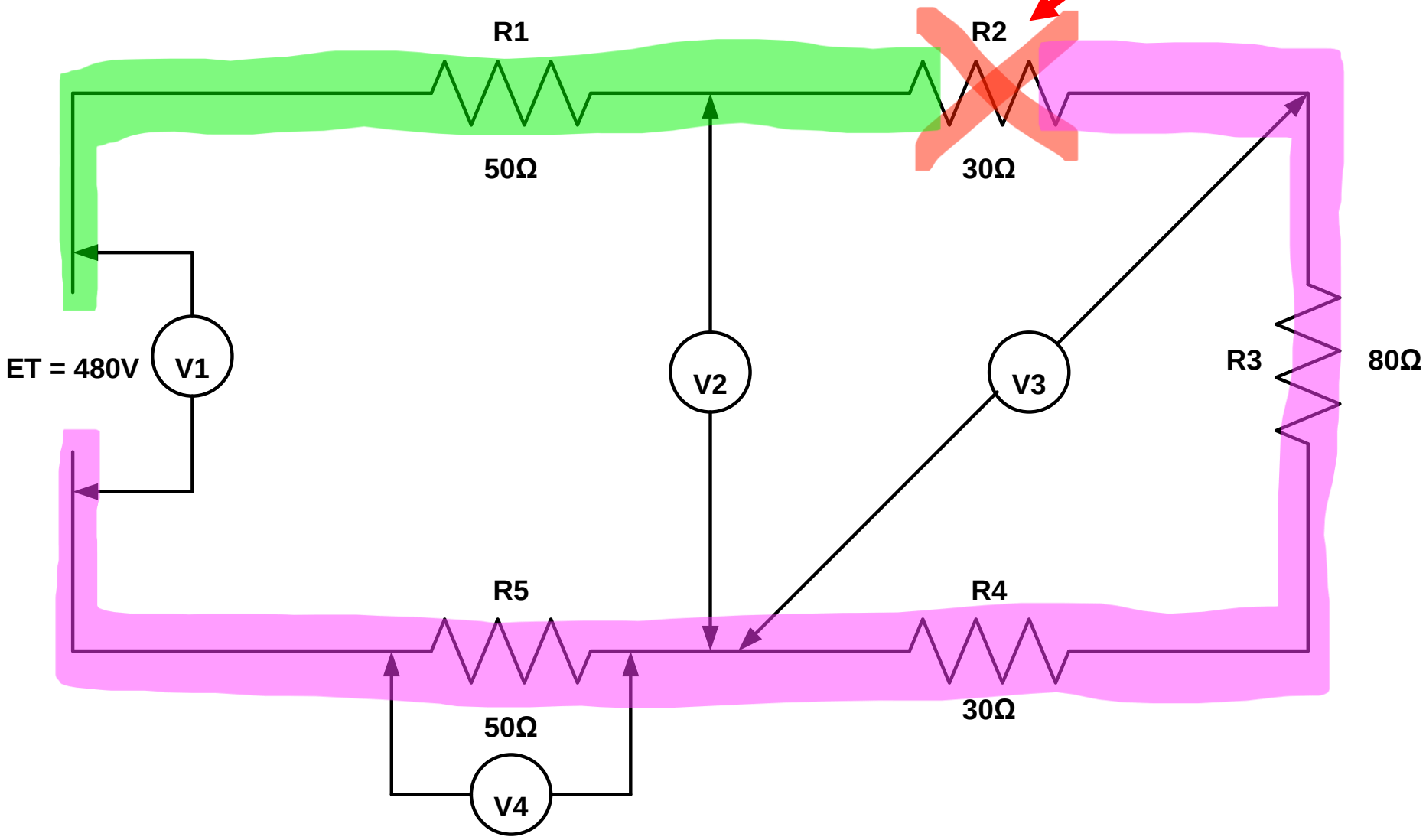
Voltmeters in a closed series circuit



Voltmeters in an open series circuit



Voltmeters in an open series circuit



2.3 Voltmeter Readings in a Series Circuit

KAHOOT!

QUIZ 2