intro to electric circuits

• electric Charge

- electric Charge is what causes objects to Feel Force From electric and magnatic Field

$$U = qV$$

- u: Potential electric energy
- q: the electric Charge
- V: electric Potential

• the eletric Potential

- the Field "V" is termed the electric Potential it describes Potential energy Per unit Charge of all Points Space

- the absolute Value of V has No Physical meaning it may be set to Zero this is Called Choice of gauge

- thus we talk Primarily about ΔV, Not V

• Setting V=0 (or to ground "gnd") think of this as a change in Positive (like Final minus inital) the reference Point is mostly set to ground which is zero think of this as the Change From ground to whatever Point you are Calculating

• Current

- an electric current through an area is defined to be the amount of Charge Flowing through that area Per unit time

$$I = \frac{dq}{dt} \quad \frac{(\text{Change in charge})}{(\text{Change in time})}$$

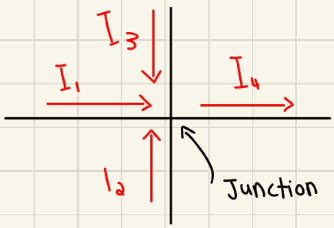
units of Amps (A)

Made with Goodnotes

- the Junction rule

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

- this is Kirchoff First rule



- the Junction law is about current Conservation
- the sum of current into a Junction must equal the sum of current out the Junction

- ohms law

- For most objects that carry a current (I) we can model the electric Potential change (ΔV) by ohms law

$$\Delta V = I R$$

ΔV = repersents difference in voltage also called Potential differnce
I = is the current Flowing through the conducter
R = the resistor

the ΔV Voltage difference between two Points, and one of those Points can be ground

☆ resistance has units of ohms or Ω

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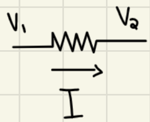

$V_1 > V_2$

- Current always Flows From higher Potential to lower Potential looking at the drawing V_1 must be higher than V_2

- Current Flows in the direction Positive Charges move
  - For example: If you have a battery. The Current Flows From the Positive terminal (higher Potential) to Negitive terminal (lower Potential) OF the battery

- Positive Charges move in the direction of decreasing Potential
  - Positive charges Naturany move From higher Potential to lower Potential

- ΔV is negitive in the direction of current Flow
  - ΔV refers to Change in Voltage between two Points
  - if current is Flowing in the direction that Positive Charges would move, that Means the Voltage is decreasing along the Path of current
  - in other words moving along the Path of current results in negitive Change in Potential because you are moving From region of higher Potential to lower Potential
  - Voltage drop: a current Flows through Components like resistors, energy is lost

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- the Positive terminal of the battery is at higher Potential (Say +V)
- the negitive terminal of the battery is at lower Potential (Say 0V)

- Current Flows From the Positive terminal of the battery (higher Potential) to negitive terminal (lower Potential) and this movement of charge (current) corresponds to a decrease in Voltage

- **electro motive Force (EMF)**

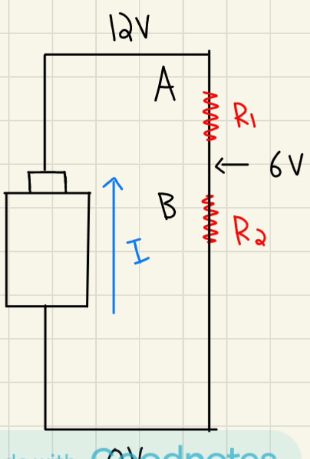
☆ this is Not an actual Force

- in order exist a steady state current, the Path of the current must Form a complete loop

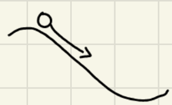
- Sources of emf include battries solar cells, and thermo couples

- inside the battery the emf moves electrons From the negitive terminal to the Positive terminal

- outside the battery (current) ∴ the Current Flows From the Positive to the negitive terminal



- Current Flows From high Potential to low Potential
- think of it like this



- as a ball Flows From high Potential to low Potential

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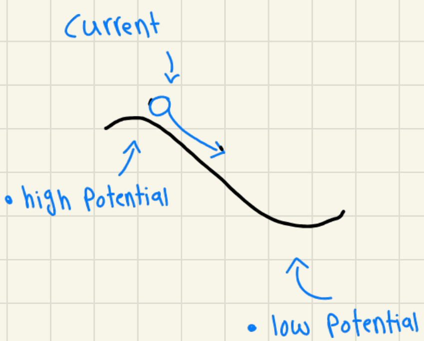
- as current Flows From A to B its electric Potential energy (ΔV) decreases, a resistor consumes energy as a current Flows through the resistor ΔV losses energy

- a battery generates a EMF and as a result the EMF increases the electric Potential energy

- you can think of it like this you can see the ball is on the ground to get it up to Point D you would need to give it a Push or something because that cannot happen by it self thats how you can imagine EMF

So as current goes down the hill as show here it reaches the bottom and stops you do not want that so you use EMF (battrey) to get it back to where it was at a higher Potential and you keep doing this until the battery dies



- as soon it drops to Floor EmF get it back to high Potential

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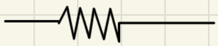
• Circuit diagram

• ideal source of Emf
battery (the long side is positive terminal)



• resistor

• ideal wire ($r=0$)

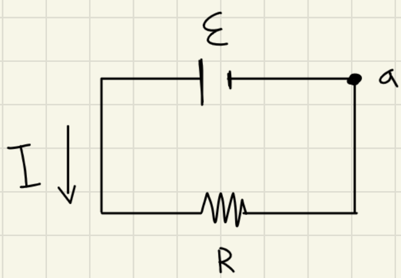
• Kirchoffs loop rule

- the total in potential around any closed loop for steady state current must be zero

- mathmatically

$$\Delta V_{a \to a} = 0$$

- as long as you move around a completely closed circut (starting and ending at the same point) the total sum of voltage change must be zero



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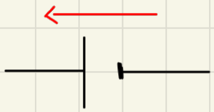
$$\Delta V_{a \to a} = 0 \Rightarrow \mathcal{E} - IR$$

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



- electron going From negitive to Positive

$$\Delta V = \mathcal{E}$$

- electrons going From Positive to negitive

$$\Delta V = -\mathcal{E}$$

- if you are moving in the direction of current Flow, the Potential drops so the voltage drop will be negitive

$$\Delta V = -IR$$

- in this case the voltage drop becomes Positive because you are opposing the Flow of current which means your going aganist the natural drop in Potential

$$\Delta V = IR$$

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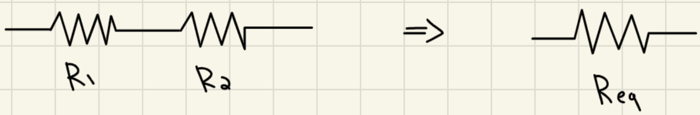
Voltage rise: occurs when you move from negitive to the positive terminal of the battery

Voltage drop: occurs when you move with the direction of current through resistors

- Kirchoff loop rule says the sum of all voltages in a closed loop is zero writen as:

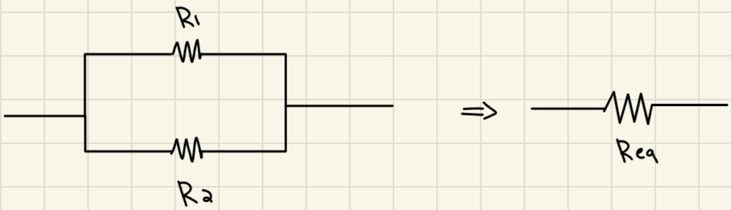
$$0 = \sum \varepsilon - \sum IR$$

- **resistors in series**



$$R_1 + R_2 = R_{eq}$$

- **resistors in parallel**



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

☆ remember to flip the answer you get

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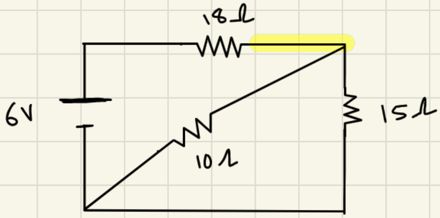
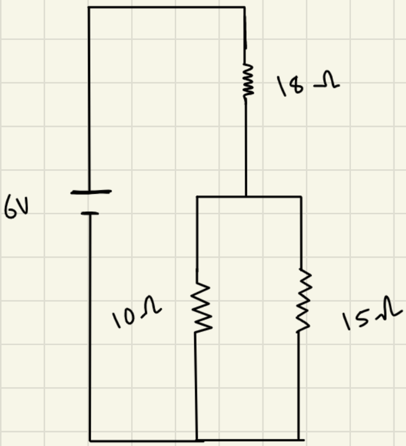


- notice that this is **Not** in Series with 15Ω the electrons Flow to both 10Ω and 15Ω

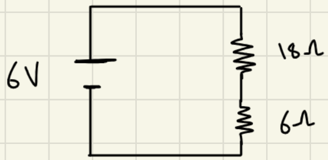
- You can redraw it



- those two circuts are the Same, 18Ω is still Flowing to 10Ω and 15Ω

$$\frac{1}{10} + \frac{1}{15} = \frac{1}{6} = 6\Omega$$

- redraw it again



$$R_1 + R_2 = R_{eq}$$

$$18 + 6 = 24\Omega$$

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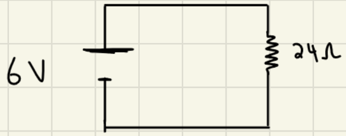
• redraw it again

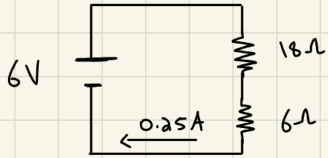


apply loop rule

$$\Delta V_{a \to a} = 0 \quad \mathcal{E} - IR = 0$$

$$I = \frac{\mathcal{E}}{R} \quad \frac{6}{24} = 0.25\,A$$ (whole circut)

• We must undo our Combinations, Since your last Combination was in Series the the current is Perserved meaning the Current at all Points that were in Series are Perserved



• thus the Voltage drop accross 18Ω is equivient by ohms law

$$\Delta V = IR \Rightarrow (0.25)(18) = 4.5V$$

• we thus conclude that the 18Ω has a Voltage drop of 4.5V and a Current of 0.25 A

• the Voltage drop by the 6Ω resistor can be done by ohms law:

$$\Delta V = IR = (0.25)(6) = 1.5V$$

or by loop law

$$\sum \mathcal{E} - \sum IR = 0$$

$$\mathcal{E} - (\Delta V_{18\Omega} + \Delta V_{6\Omega}) = 0$$

$$6 - 4.5 = \Delta V_{6\Omega}$$

$$\Delta V_{6\Omega} = 1.5V$$

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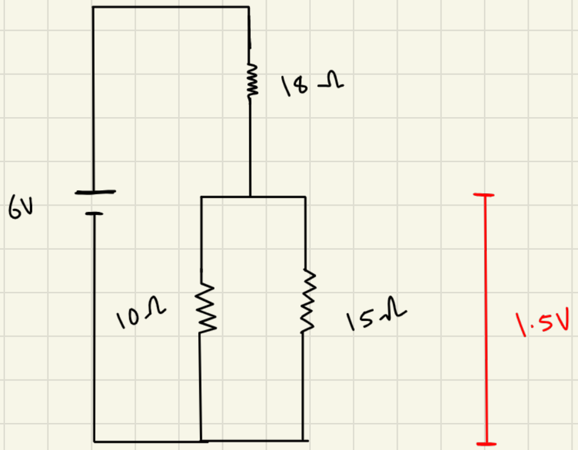
• Since our Next was in Parallel this 1.5V must be across our 15 Ω and 10Ω as Well



• You Can undo the Combinations of the 6 Ω resistor which will give you a Parallel combo consisting of a 10Ω and a 15 Ω resistor

When resistors are Parallel to one another the Voltage drops (ΔV) are equivelent While in Series the current is equivalent

• in simple words

Parallel = ΔV is the Same

Series = I is the Same

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Power in Circuts

- Power in electric circuts

$$P = \Delta V I$$

- where I is the current through the resistor and ΔV the voltage across the resistor

- Substiting $\Delta V = IR$

We can rewrite our previous result in two additional equiavalent way by using algebra and substitution

$$P = \Delta V I \Rightarrow (IR) I$$

$$\Rightarrow \boxed{P = I^2 R}$$

- You can use any any equation depending on what is given to you

$$P = \Delta V I \Rightarrow \Delta V\left(\frac{\Delta V}{R}\right)$$

$$\boxed{P = \frac{(\Delta V)^2}{R}}$$

Method #1: Use eqivalent resistance to sytemically simlify the resistor Network

Method #2: Use Kirchoffs laws directely to find a system of n linearly independent

- advantage: will always work to reduce problems to algebra
- disadvantage: the resulting algebra might be tedious (without matrices)

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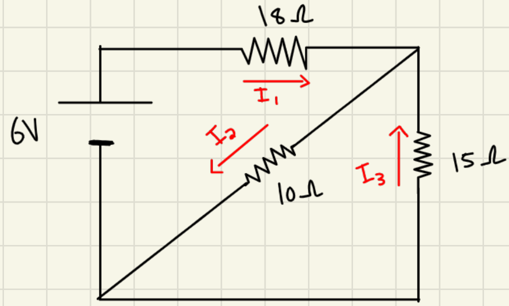

- We will resolve this by using Kirchoff law we can began began by labeling these I_1, I_2, and I_3, it does not matter what you label each resistor and what direction its going

- if you walk the current direction → it a drop $(-IR)$

- if you walk aganist the current direction → its a rise $(+IR)$

- We can began by applying the Junction rule or loop rule but I with Junction rule

$$I_1 + I_3 = I_2$$

$$6V - I_1(18\Omega) - I_2(10\Omega) = 0$$

☆ We are using IR + IR but remember $IR = \Delta V$ so you can replace IR with ΔV

$$-I_2(10\Omega) - I_3(15\Omega) = 0$$

- We have made around 3 equation but we can create as much as much as we want

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- if they they told you $I_1 = 10\Omega$ and solve for I_3

$$I_1 + I_3 = I_2 \Rightarrow 10 + I_3 = I_2$$

$$-(10 + I_3)(10\Omega) - I_3(15\Omega) = 0$$

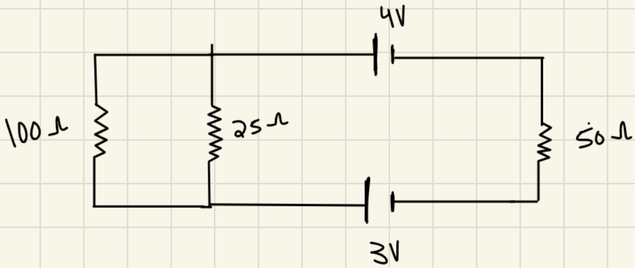
$$-100 - 10I_3 - 15I_3 = 0$$

$$-100 = 25I_3$$

$$\boxed{I_3 = 4A}$$

- we only used two equations out of the the three

- Circuts with 2 EMF's

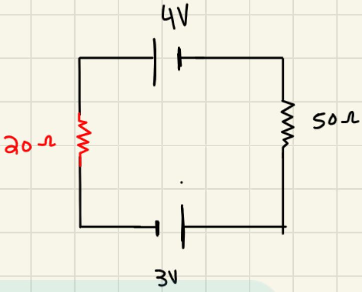


- Notice the 100Ω and the 25 Ω are Parallel

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

$$\frac{1}{25} + \frac{1}{100} = \frac{1}{20}$$

$$R_{eq} = 20$$



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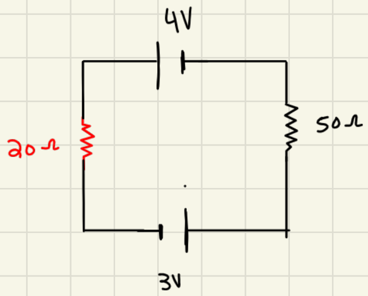

$$4V - I_1(20\Omega) + 3V - I_1(50\Omega) = 0$$

- notice there No Junctions so the current current is the same everywhere

if there are No Junctions in a circut (meaning the circut is a simple series loop) the current is going to be the same in that loop

$$4V - I_1(20\Omega) + 3V - I_1(50\Omega) = 0$$

$$7 - 70 I_1 = 0$$

$$-70 I_1 = -7$$

$$\boxed{I_1 = 0.1 A}$$

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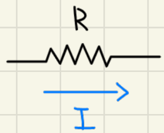
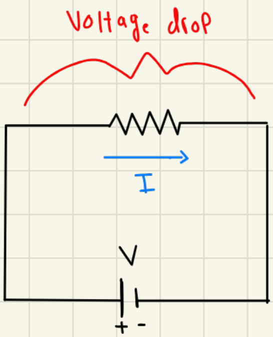
- summary

- if we have a resistor and current flows through it in this direction

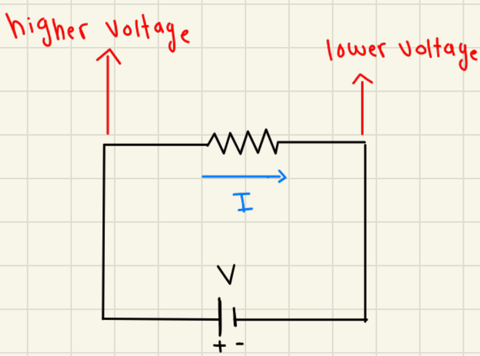


- the resistor acts like a voltage eater it take way from the energy from the battery



- the voltage drops in the direction of the current

- if the current goes from left to right the left side of the resistor is a a higher voltage and the right side is at a lower voltage



- this is given or explained by $V = IR$ (ohms law)

  ex: if a 2 A current flows through a $5\,\Omega$ resistor the resistor will eat 10 volts $V = (5\,\Omega)(2\,A)$

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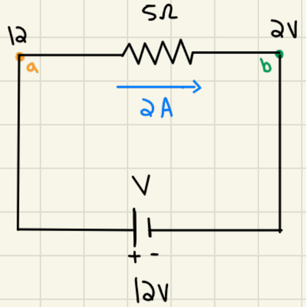
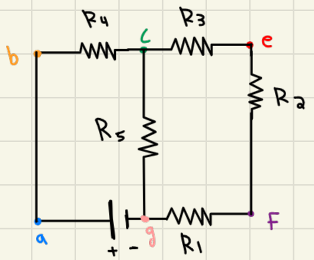
this means if the left side (a) has 12V the right side (b) will have 2V as
12 − 10 = 2V

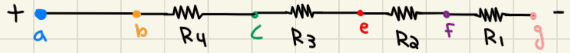


Practice problem

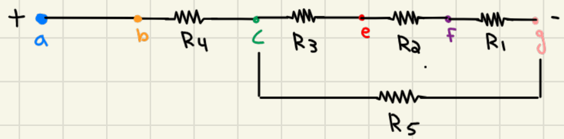
Consider the circuit depecited below. Each resistor has resistance R (all resistance is the same) what power is being put into the circut by the ideal battery?



• began by labeling a, b, c this will help you break down and see which one is parallel and which ones are series



☆ notice how we went through the whole circut and its resistors except R_5 because it goes from c to g



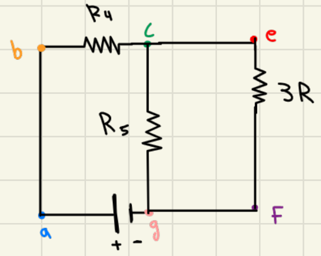
☆ R_5 is parallel to R_3, R_2 and, R_1

• we can use seriesquation on R_3, R_2 and, R_1 also they have the same resistance

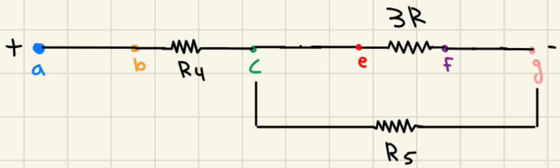
$$(R + R + R) = 3R$$

Made with Goodnotes

- redraw



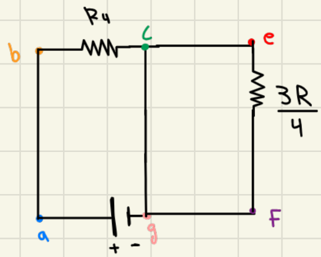
- We combined R_1, R_2 and, R_3 now we have 3R Parallel to R_5

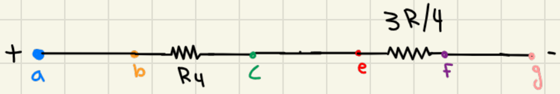


$$\frac{1}{R_5} + \frac{1}{3R} = \frac{3+1}{3R} = \frac{4}{3R} = \frac{3R}{4}$$

- Flip this around

- redraw





$$\frac{3R}{4} + R_4 = \frac{3R + 4R}{4} = \frac{7R}{4}$$

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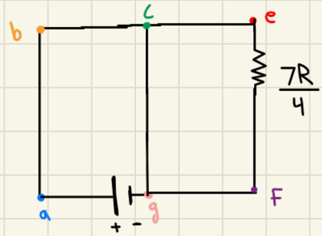


• Find Current

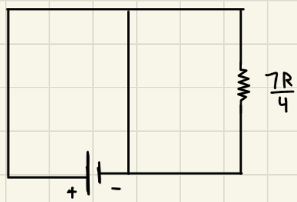
$$P = \frac{(\Delta V)^2}{R} \Rightarrow \frac{(\mathcal{E})^2}{R} \Rightarrow \frac{\mathcal{E}^2}{\left(\frac{7R}{4}\right)} \Rightarrow \boxed{\frac{4\mathcal{E}^2}{7R}}$$

Find the Power disapated by resistor R_3

$R_{total} = \frac{7R}{4}$

• We can use this to Find the total current

$$I = \frac{\mathcal{E}}{R_{tot}} = \frac{\mathcal{E}}{\left(\frac{7R}{4}\right)} = \frac{4\mathcal{E}}{7R}$$



• if we go back we will have a circut in series which means that both resistors have the same current Flowing through them

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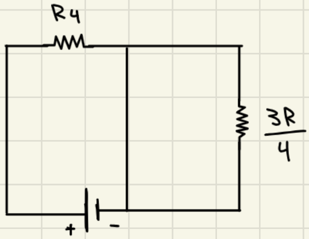
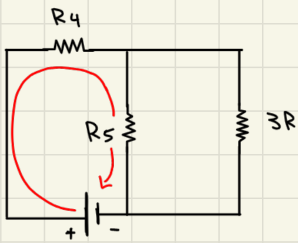


- these two resistors both have the same current flowing through them, again this is happening because they are in series

  - we can find the drop in voltage in R4

$$\Delta V_{R_4} = IR \Rightarrow \left(\frac{4\varepsilon}{7\cancel{R}}\right)(\cancel{R}4) = \frac{4\varepsilon}{7}$$

- if we take a step back further



- we can now use loop law to figure what R5 is

$$\sum \varepsilon - \sum IR = 0$$

$$\sum \varepsilon - \sum \Delta V = 0$$

$$\varepsilon - (\Delta V_{R_4} + \Delta V_{R_5}) = 0$$

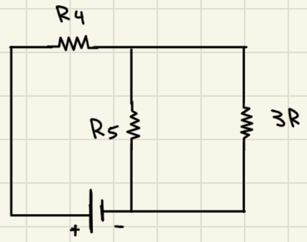
$$\varepsilon - \Delta V_{R_4} = \Delta V_{R_5}$$

$$\varepsilon - \frac{4\varepsilon}{7} = \Delta V_{R_5}$$

$$\Delta V_{R_5} = \frac{3\varepsilon}{R}$$

Made with Goodnotes

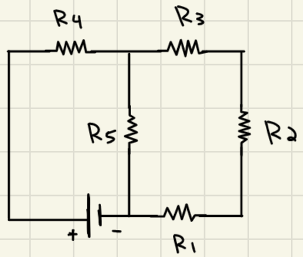
- We got ΔV_{R5} now R_5 and $3R$ are parallel to one another which means they have the same ΔV so the ΔV for $3R$ is $\frac{3\varepsilon}{7}$



We will find the current for $3R$

$$\Delta V = IR \Rightarrow I = \frac{\Delta V}{R} \Rightarrow \frac{\left(\frac{3\varepsilon}{7}\right)}{3R}$$

$$I = \left(\frac{\cancel{3}\varepsilon}{7}\right)\frac{1}{\cancel{3}R} = \frac{\varepsilon}{7R}$$



- after breaking down $3R$ even further we get three resistors all in series which means they all have the same current

☆ all resistance is the same

$$P = I^2R \Rightarrow \left(\frac{\varepsilon}{7R}\right)^2 \cdot (R_2)$$

$$\left(\frac{\varepsilon^2}{49R^{\cancel{2}}}\right)(\cancel{R_2})$$

$$= \boxed{\frac{\varepsilon^2}{49R}}$$

Made with Goodnotes