Lesson 3 Kirchhoff's Laws

May 2, 2020 2:52 PM

Physics 12 Unit 7 Lesson 3 Kirchhoff's Laws Name: ____________

Lesson 3: Kirchhoff's Laws

Σ = sigma "sum of"

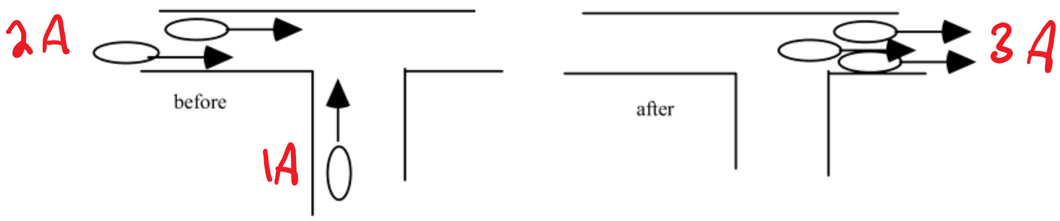
•Kirchhoff's Current Law (KCL) is basically conservation of charge:

KCL states that at a junction between wires, current flow splits or combines and continues to flow 'downhill'. When the current splits or combines, no charge is lost, so that the total flow into the junction equals the total flow out of the junction.

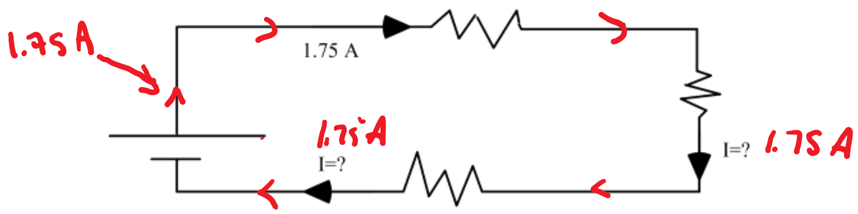
$$\sum I_{in} = \sum I_{out}$$

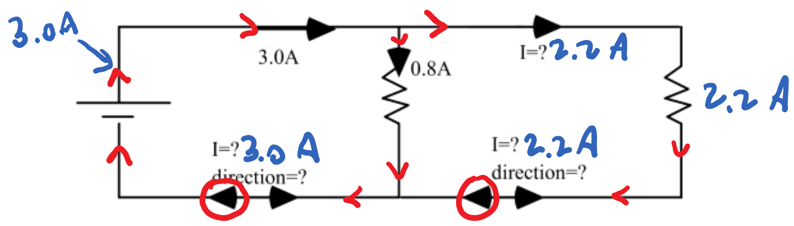
I_{in}=current into/towards junction = Amp
I_{out}=current out of/away from junction=Amp

•In terms if the ski hill analogy, KCL simply means that if three skiers (amps) converge on an intersection from two different paths, then three skiers must leave the intersection still going downhill.

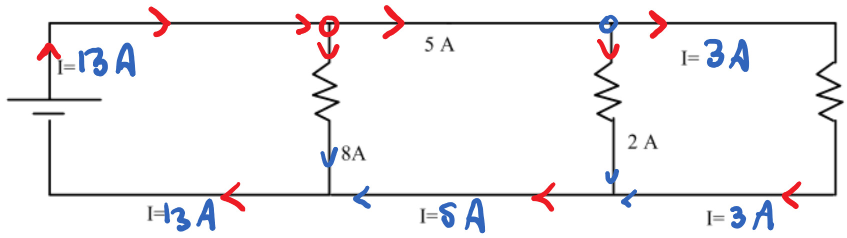


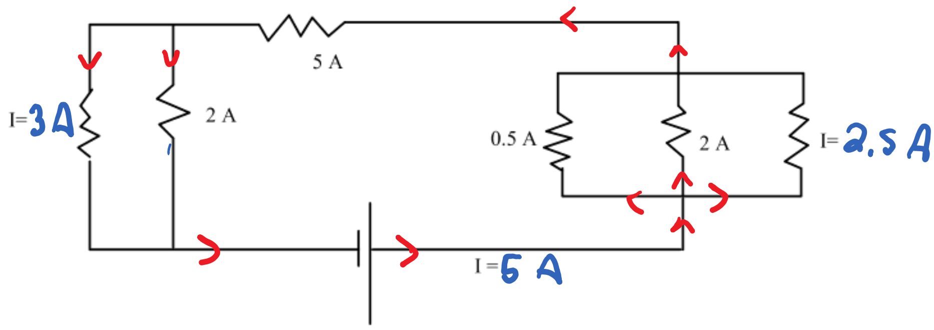
•example 1: Find the unknown currents

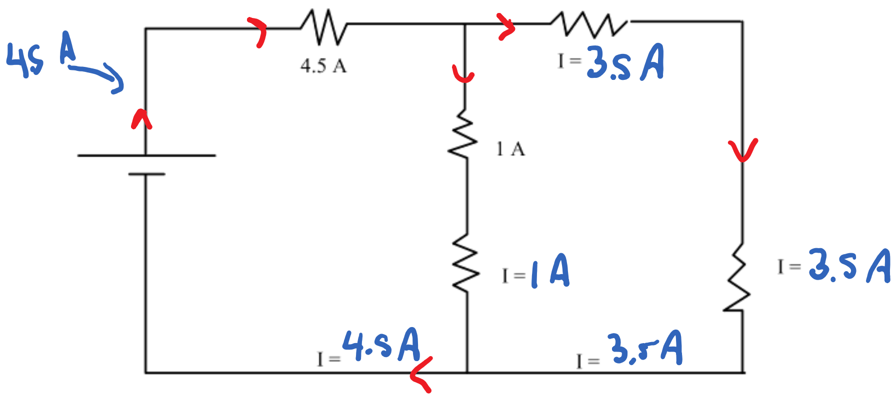




•example 2: Show the direction of each current, and find unknown currents







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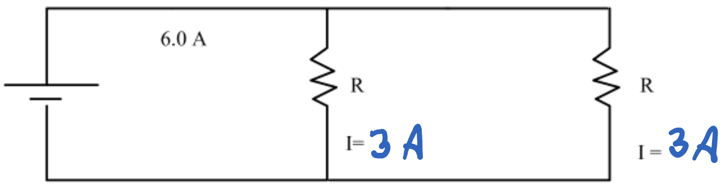
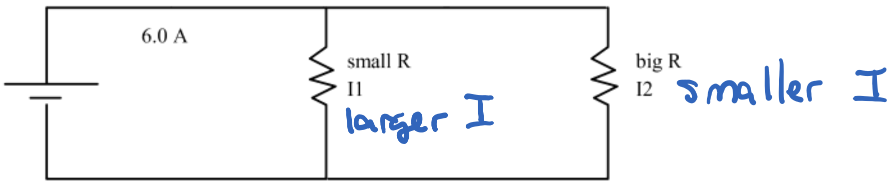
•The amount of flow along a particular path from a junction depends on the resistance of that path.

•example 3: a) If the resistance of each path leading away from a junction is the same, what can be said about the splitting of the current? For instance, find the unknown currents below.

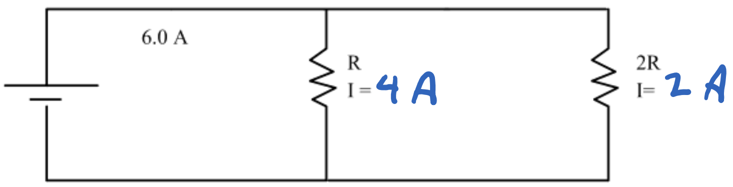


b) if one path has more resistance then what can we say about the splitting of the current? For instance compare the unknown currents I_1 and I_2 below below



$I_1 > I_2$

c) if the resistors are simple ratios of each other, we can relate the currents via the same ratios. For instance, find the unknown currents below. (note the second resistor is twice the first)



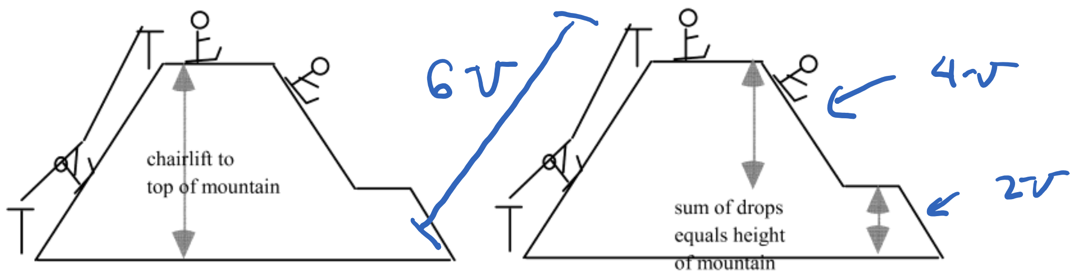
•Kirchhoff's Voltage Law (KVL) is basically conservation of energy:

KVL states that as charges flow around the circuit, they experience voltage gains in the cell and voltage drops across the resistors. For every path through the circuit the voltage gains equal the voltage losses.

$$\sum V_{gain} = \sum V_{loss}$$

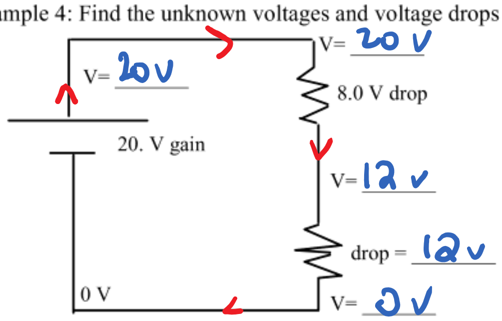
V_{gains}=gains on voltage in a loop=volt
V_{losses} = losses of votlage in a loop=volt

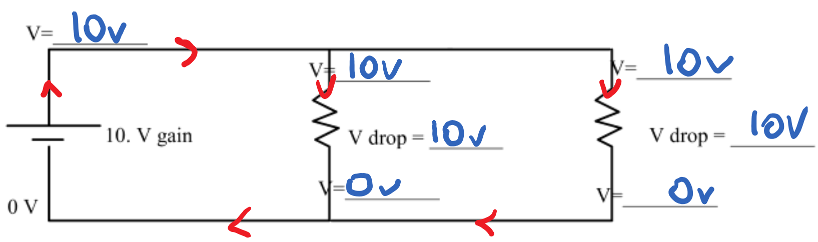
•In terms of the ski hill analogy, KVL simply says that the chairlift takes you to the top of the mountain. From there, as you ski down to the bottom along any path the sum of the drops must equal the height of the mountain.



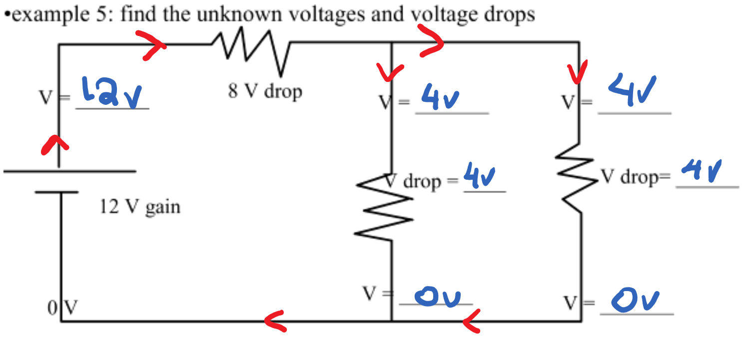
ski hill analogy

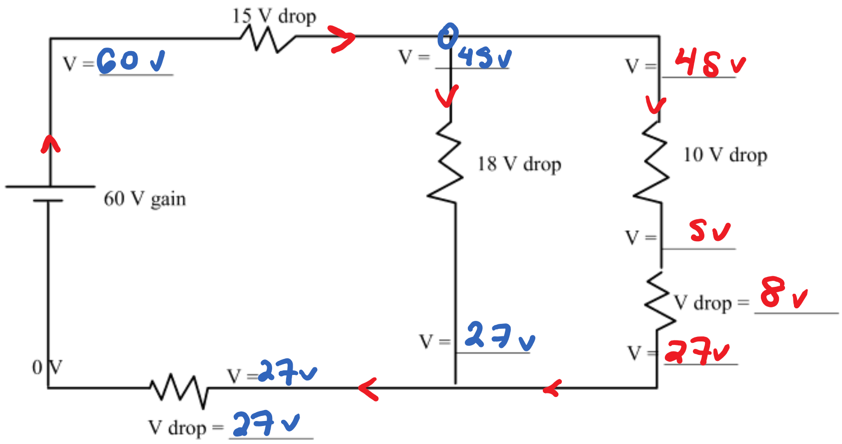
•example 4: Find the unknown voltages and voltage drops



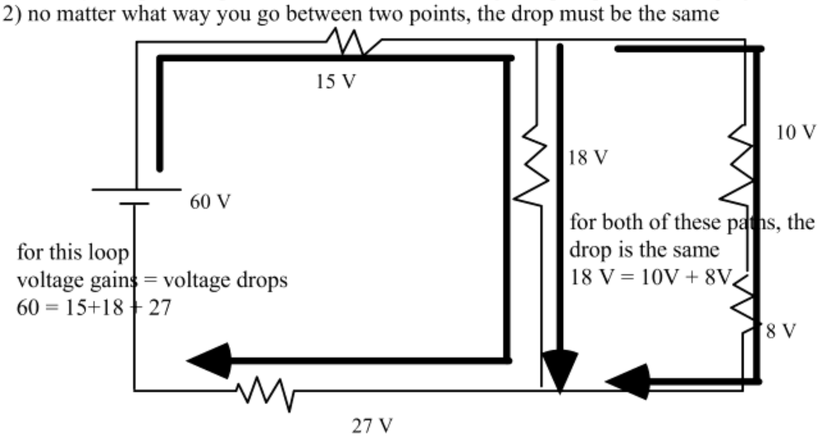


•example 5: find the unknown voltages and voltage drops

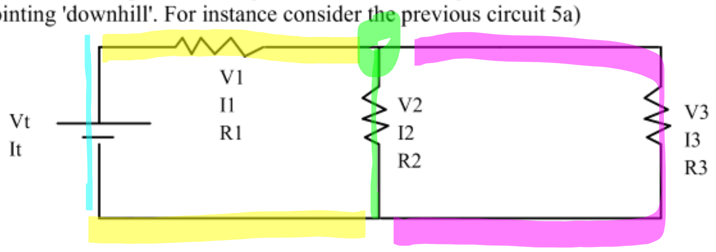




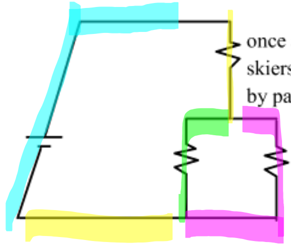
•note that there are really two useful conclusions to draw from KVL:
1) for any complete loop around the circuit, the voltage drops equal the voltage gains
2) no matter what way you go between two points, the drop must be the same



•to see the voltage relationships, it is sometimes helpful (at first) to redraw the circuit so that all resistors are pointing 'downhill'. For instance consider the previous circuit 5a)



this circuit can be re-drawn in the following manner:

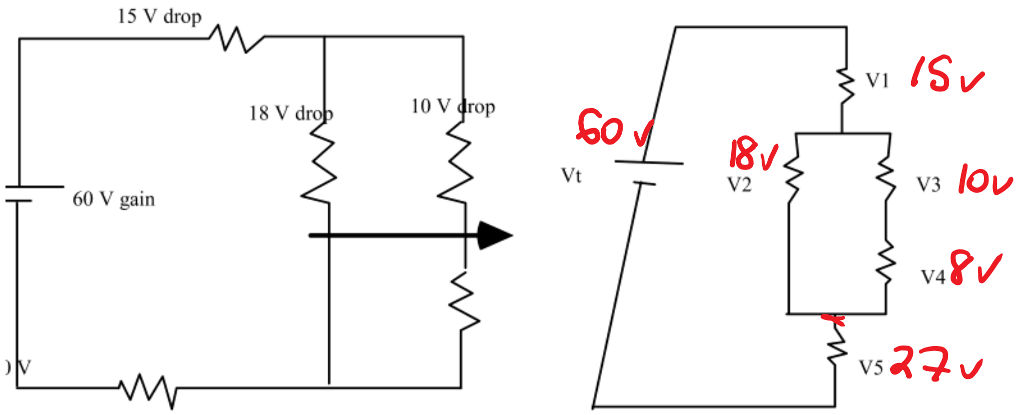


the cell (chairlift) leads to the top of the mountain

once at the top, all skiers must descend by path R1

skiers then have a choice of path R2 or R3 both of which end at the bottom of the hill

and 5b) can be redrawn as follows:



•example 6: write equations relating the voltage drops Vt, V1 V2 V3 V4, V5 in the above circuits

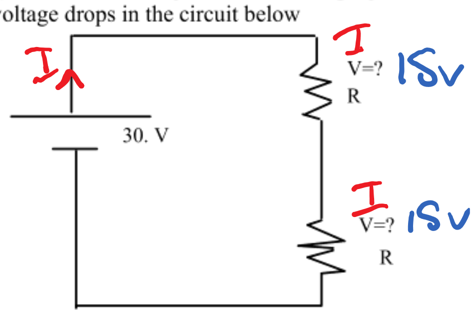
a)

b)

•If there are several resistors along a path, the charges will lose a fraction of their voltage (ie. energy) in each.

•example 7:

a) if we have two equal resistors along a path, what can be said about the voltage drops? For instance find the voltage drops in the circuit below



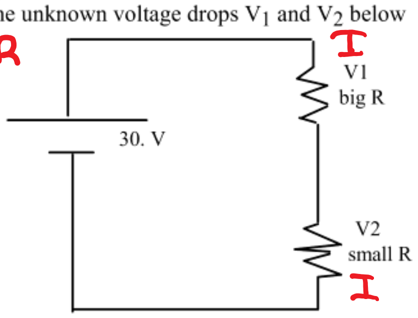
$V = IR$

same I, R

∴ same V

b) if the resistances are not the same then what can we say about the division of the voltage? For instance compare the unknown voltage drops V_1 and V_2 below

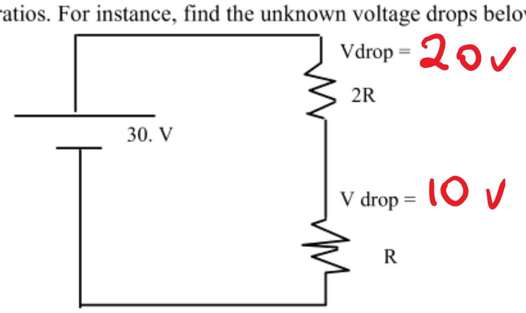
$V = IR$



IR vs I_R

$V_1 > V_2$

c) if the resistors are simple ratios of each other, we can relate the voltage drops via the same ratios. For instance, find the unknown voltage drops below. (note the first resistor is twice the second)



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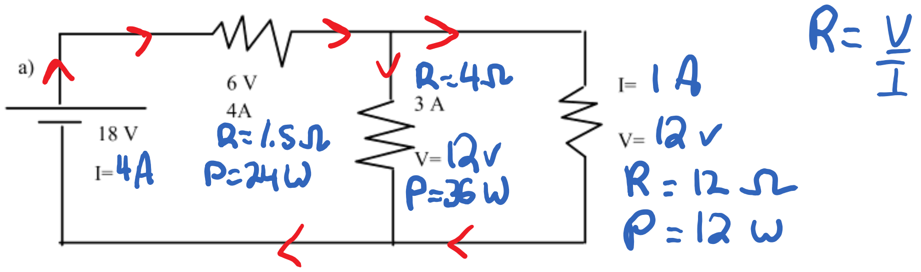
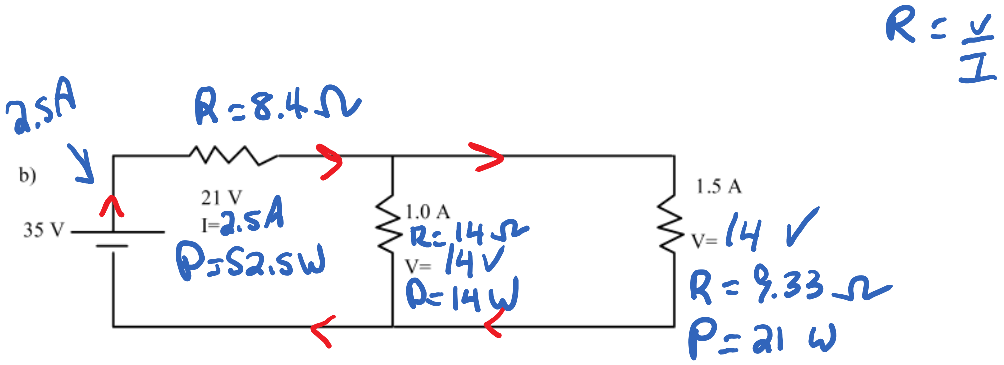
$V = IR$ $R = V/I$ $I = V/R$ $P = VI$

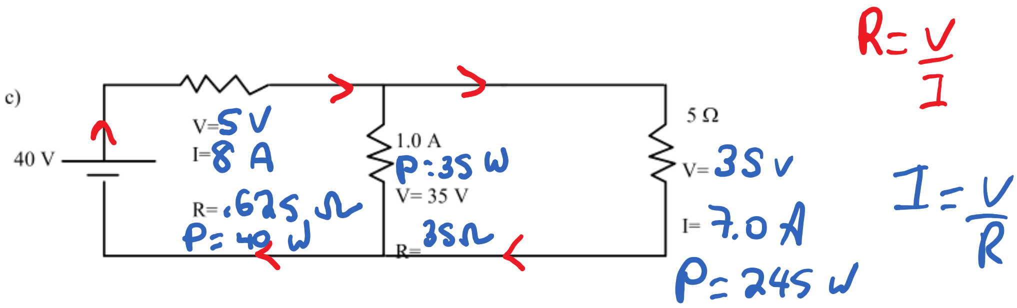
•Although it is helpful at first to label voltages at each point in the circuit, it is desirable at this point to label only the gains and drops. In all of the following examples, the voltages written next to resistors are understood to be the voltage drops. Likewise the voltage numbers written next to cells are the voltage gains.

•example 8: find the unknown voltage drops, currents, resistances, and the power lost in each resistor (V=IR)



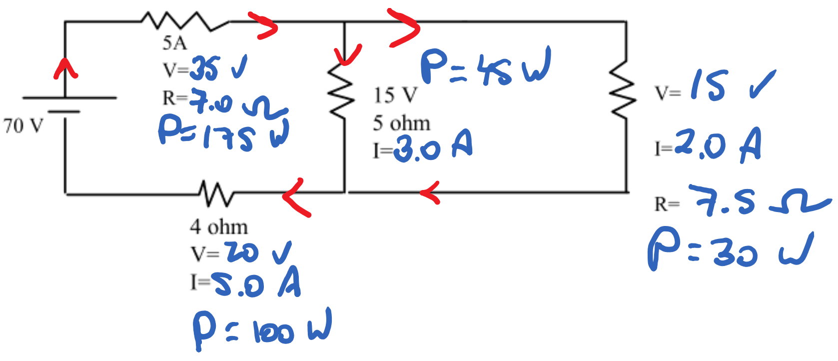
Note: you can build these in the PHET DC Circuit Construction Kit to check your answers!



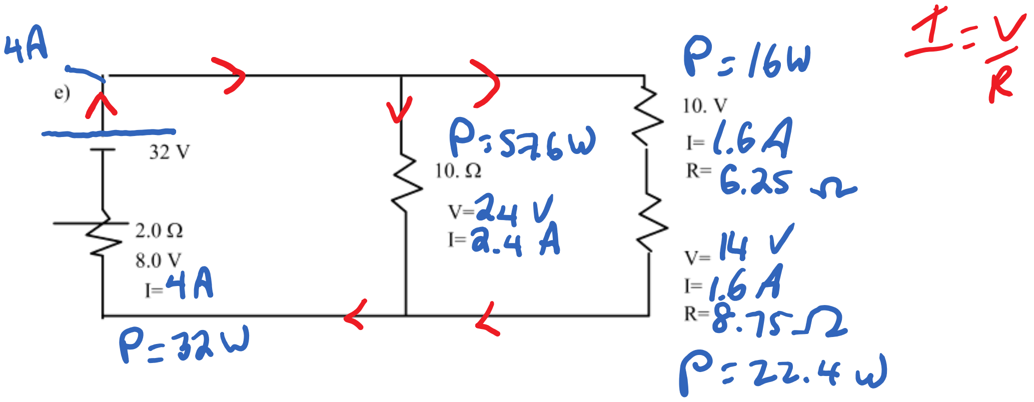


$V = IR \quad I = \frac{V}{R}$

d)



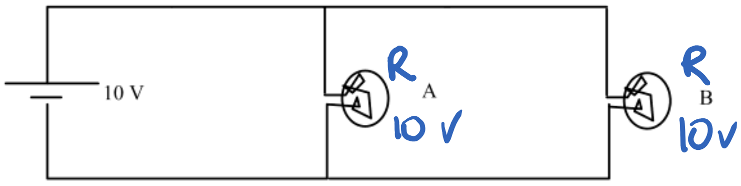
e)



•Lightbulb questions are a good test of student understanding of Kirchhoff's Laws. The brightness of a light bulb is related to the power use (J/s), and therefore depends on the current through a resistor and the voltage drop across the resistor (P=VI)

$P = \frac{V^2}{R}$

•example 9: the bulbs below are identical(same R)- which bulb is brighter?

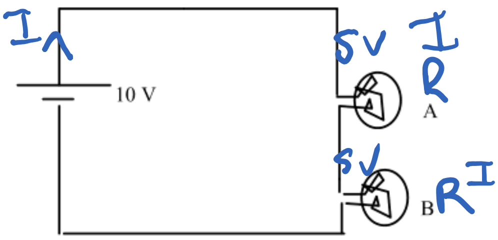


explain your answer using relevant concepts of physics

same R, same V

since $P = \frac{V^2}{R}$, same P = same brightness

•example 10: the two bulbs below are identical- which bulb is brighter?



$P = I^2 R$

explain your answer using relevant concepts of physics

same R, same I,

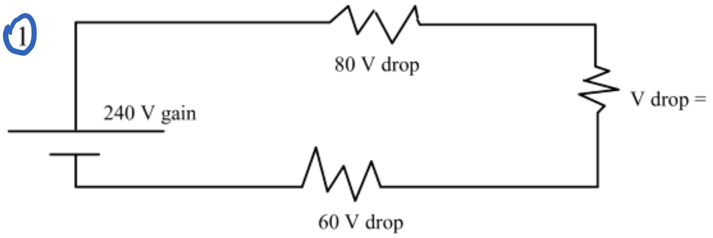
∴ same P, same brightness

Steps for Solving Circuits

1. Label downhill
2. Try to find the total current leaving the battery
   - -- if you find this, the question is going to fall apart
3. Look for any place in the circuit where you know 2 things
   - -- "if we know 2 things, we know 4 things"
4. Ski (use Kirchhoff's Laws)
   - -- anytime you find something, go to step 2 and 3

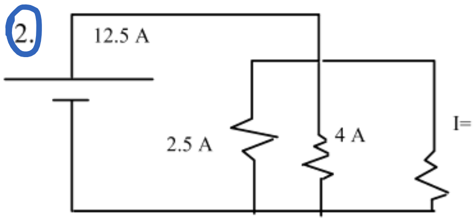
exercises: find unknown voltages and currents

1



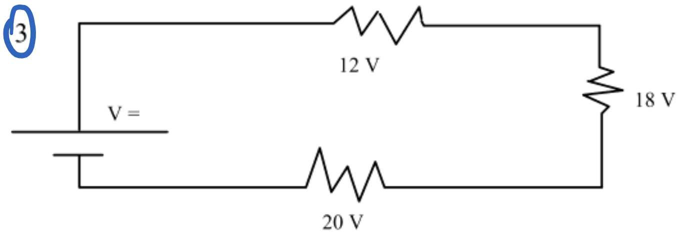
(100V)

2.



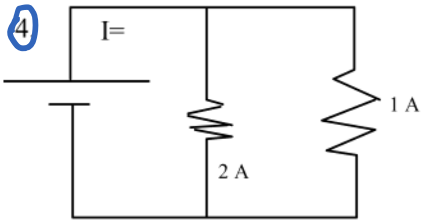
(6 A)

3



(50V)

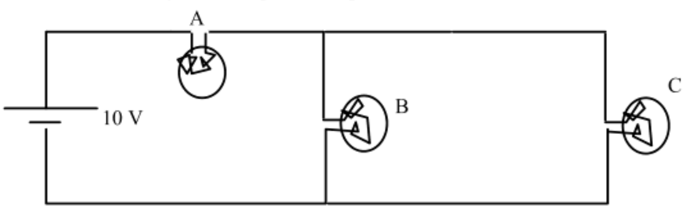
4



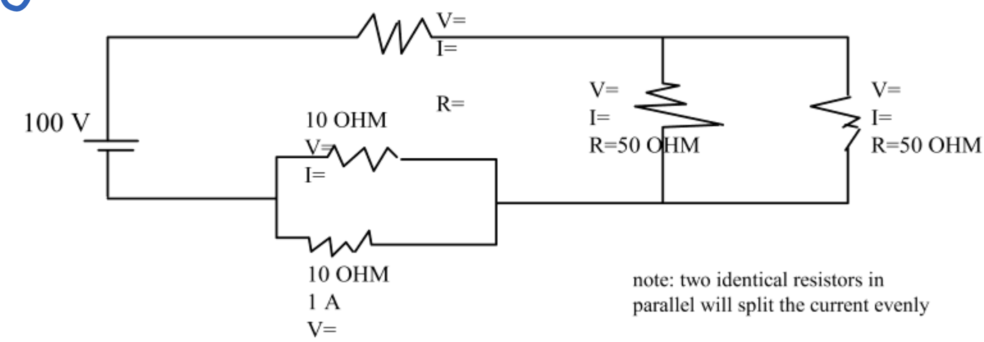
(3A)

5. The three bulbs below are identical- which bulb is brightest? Explain your answer. i) bulb A ii) bulb B iii) bulb C iv) equally bright

Note that bulb brightness depends on power, and therefore on both current and voltage drop



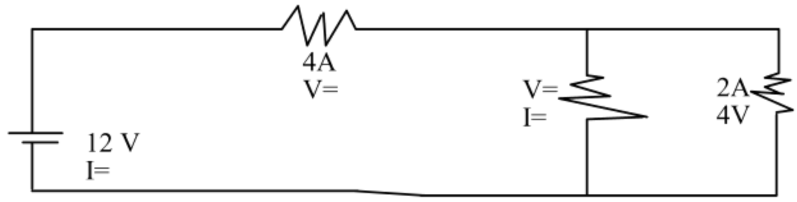
6. Find unknown voltages and currents



note: two identical resistors in parallel will split the current evenly

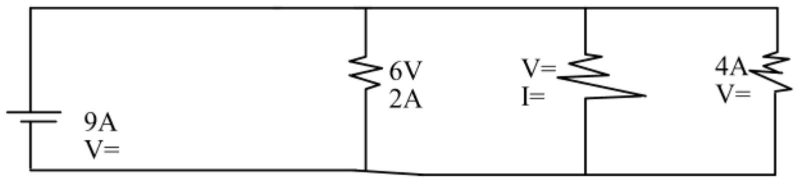
(40V 2A 20 OHM; 50V 1A; 50V 1A; 10V 1A; 10V)

7. Find unknown voltages and currents



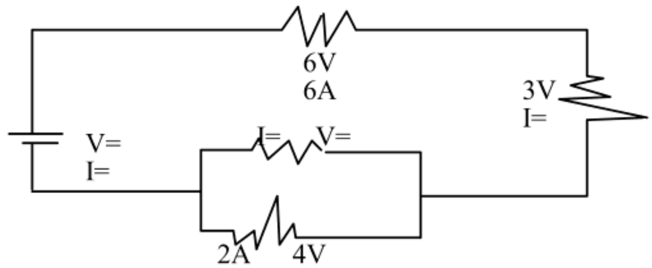
(4A; 8V; 4V 2A)

8. Find unknown voltages and currents



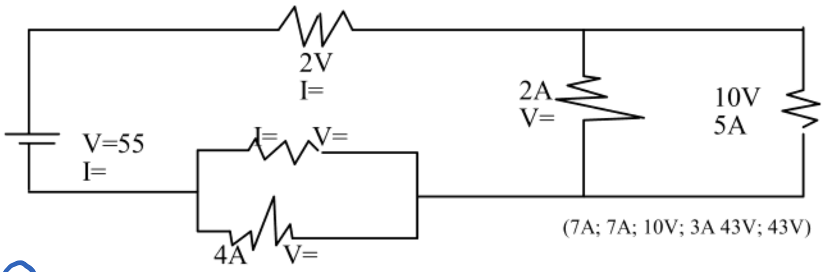
(6V;
6V 3A;
6V)

9. Find unknown voltages and currents



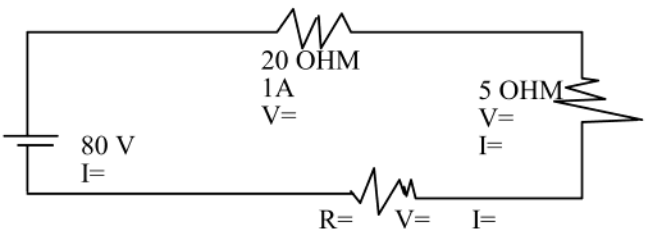
(13V 6A;
6A;
4A 4V)

10. Find unknown voltages and currents



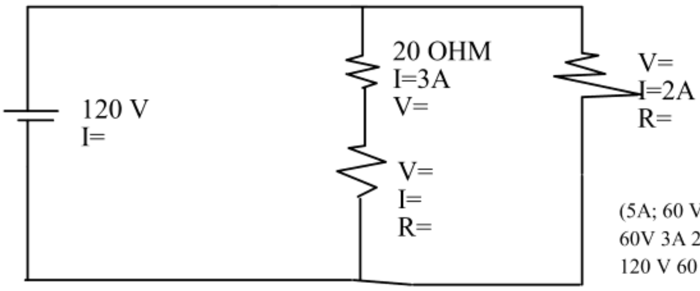
(7A; 7A; 10V; 3A 43V; 43V)

11. Find unknown voltages and currents



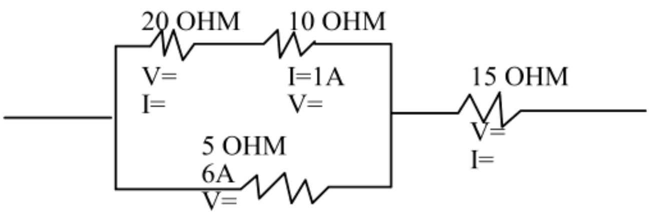
(1A; 20V; 5V 1A; 1A 55 OHM 55V)

12. Find unknown voltages and currents

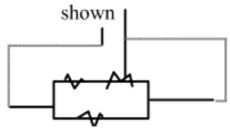


(5A; 60 V; 60V 3A 20 OHM; 120 V 60 OHM)

13. Find unknown voltages and currents



note: in problesm such as these, assume that the two end wires are connected to a cell. that has not been shown



(20V 1A; 10V; 30V; 105V 7A)

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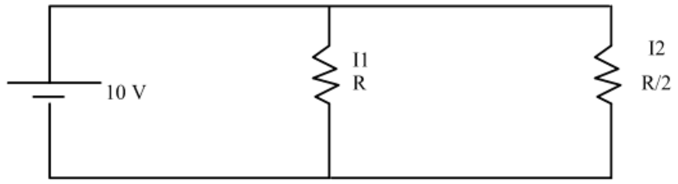
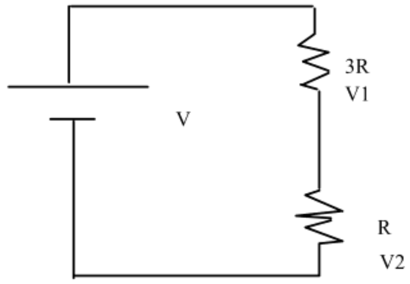
~~14.~~ What can be said about the currents I_1 and I_2 if the resistance of R_2 is half the resistance of R_1?



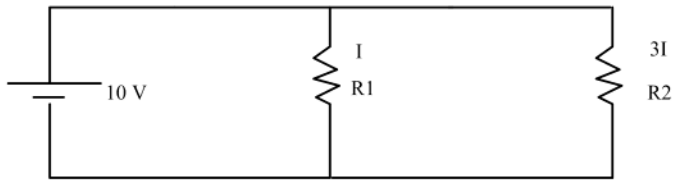
explain your answer using appropriate physics principles

~~15.~~ What can be said about the voltage drops V_1 and V_2 if the resistance of R_1 is three times the resistance of R_2?



explain your answer using appropriate physics principles

~~16.~~ What can be said about the resistances R_1 and R_2 if the current through R_2 is three times the current through R_1?



explain your answer using appropriate physics principles

I will email out a solution key on Wednesday.