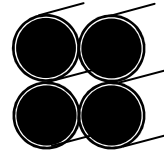


1. Series or parallel?

- A. ___ Only one path for the electricity to flow.
- B. ___ * Paths are dependent on each other (*one affects the other*).
- C. ___ How your house is wired.
- D. ___ Paths are independent of each other.
- E. ___ If one light turns off, the others stay on.
- F. ___ If you turn off one light, all the lights turn off.
- G. ___ Has more than one path for the electricity to flow.
- H. ___ * Two devices have the same current.
- I. ___ * Two devices have the same voltage.

2. The holes at the right show four pipes.

- A. * Are the four holes in parallel or series, as shown?
 - B. Together is there a bigger hole or a smaller hole for water to flow thru?
 - C. Each pipe can allow 2 gal/sec, how much can flow thru them together?
 - D. So, is the combined resistance greater or less than one pipe?
- This is why 4 equal resistors in parallel are the same as a single resistor that is 1/4th as big.*



3. Five 100Ω resistors are placed in a circuit. What is the total resistance if they are:

- A. * place in series?
- B. * place in parallel?



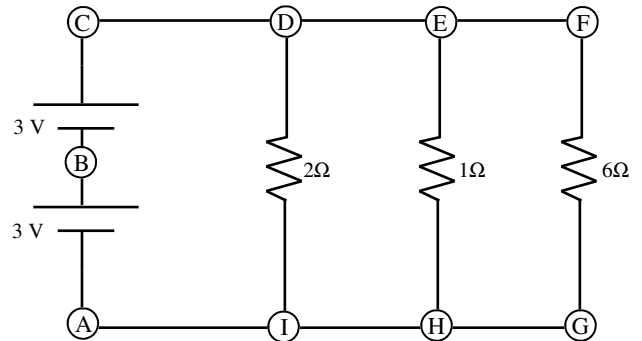
But what about a large and small resistor together in parallel? It is true that electricity (like water) takes the path of least resistance. Compare the two pipes at the left. MOST of the water goes thru the larger pipe (the smaller resistor), but some still flows thru the smaller pipe (the larger resistor). Together the two pipe still are equivalent to a smaller resistor. This is why resistors in parallel decrease the total resistance.

4. The circuit at the right will help us understand the relationship between resistors and current in parallel resistors. Remember to label the diagram (including units) as you go.

- A. What is the voltage at C, relative to A?
- B. * What is the change of voltage across a wire?
- C. * So, what is the voltage at D, E, and F?
- D. * And what is the voltage at I, H, and G?

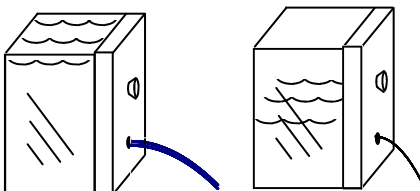
So, the voltage at the top of the circuit is 6V and the voltage at the bottom of the circuit is 0V. Which means that each resistor has the same voltage across it: 6V. So, you have the resistance and voltage for each branch.

- E. * Calculate the current flowing thru each resistor.
- F. Which resistor has the most current flowing thru it?
- G. Why?
- H. * How does the current flowing thru the 2Ω compare with the 6Ω resistor?
- I. * Is the current directly or inversely proportional to resistance?
- J. * What is the total current (I_{total}) flowing thru the circuit (and provided by the battery)?
- K. * So, now that you have V_{total} and I_{total} , use $V = IR$ to calculate R_{total} .



And, just as we said before, notice that when resistors are placed in parallel, the total current goes up and the total resistance goes down. If the car and roadway analogy works better for you, think of the 1Ω as a freeway and the 6Ω like a small road. Most cars will take the freeway, but a few cars will take the little road.

So, what is this voltage thing, anyway? A Volt = Joules/Coulomb, or energy per charge. 2V give 2 J for every coulomb. 12V gives 12J to every coulomb. More voltage = more energy per electron.



For water, voltage is like pressure from a water tank. For the left tank, the water height and pressure (voltage) is greater, so the water flow is greater and goes farther. For the right side, the water height and pressure (voltage) is lower, so the water flow is less and goes a shorter distance. Notice the corks in holes that are higher up than the open holes. The left corked hole has less voltage, since it is closer to the top of the water. The right cork has no voltage, since it is above the water level. If you were to put the two tanks together, water would flow from right to left: from high to low voltage.

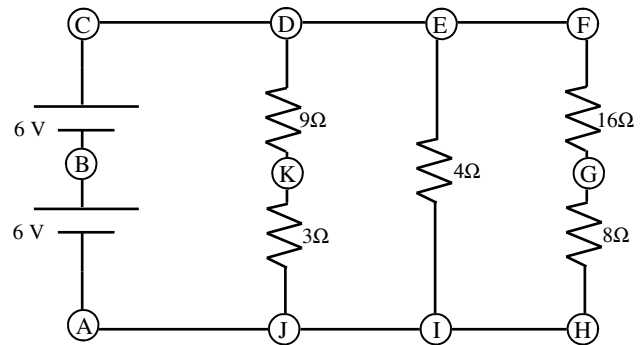
Now that I have walked you thru both series circuits, it is time to walk you thru a slightly more advanced combination circuit. Follow along and it will be relatively painless. **MAKE SURE TO LABEL THE DIAGRAM AS YOU GO, INCLUDING UNITS (and you might start using J/C and V interchangeably)!**

5. First step is to lay the ground work by totaling up voltages and easy resistor combinations.

- A. Since we like to work with all positive numbers we call the voltage at letter A:
- B. What is the voltage at letter C relative to letter A?
- C. Since wires don't change voltage (called "equipotential surfaces"), what is the voltage at letters D, E and F?
- D. Then what must be the voltage at letters J, I, and H?

Notice that the 9Ω and 3Ω are in series with each other. If you change one of them the current changes in the other, so you have to add them together.

- E. What is the equivalent resistance from D to J?
- F. What is the equivalent resistance from F to H?



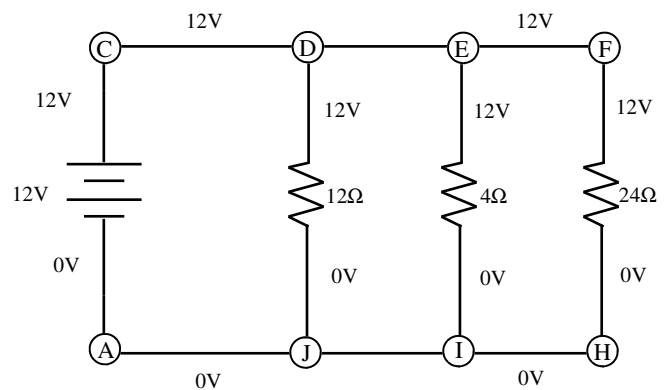
Now comes the new step, which simplifies things. We are going to redraw the circuit, including the simplifications we just figured out. (In the future you will do this mentally for circuits this easy.) And because you have never done this before, I will redraw it for you. Notice the new symbol for the combined battery. Again, this is the symbol for a multi-cell battery like a 9-volt battery or a 12-volt car battery, which have multiple batteries connected in series inside.

6. Since you have the voltages across each resistor, calculate and label the current flowing thru each resistor (each branch).

7. Using arrows, show the flow of current throughout the circuit, making sure to add currents at junctions that join (like I) and subtract current at junctions that split (like D).

8. You should now be able to answer the following questions.

- A. What is the current flowing from I to J?
- B. What is the total current flowing thru the batteries?
- C. Using the total voltage and total current, calculate the total resistance of the circuit.



Then we go back to our original circuit and include all of our new found knowledge about the circuit. Notice the equivalent voltages and resistances. You will put this on a combo diagram automatically in the future. Answer the following.

9. Calculate the voltage used by the 9Ω resistor.

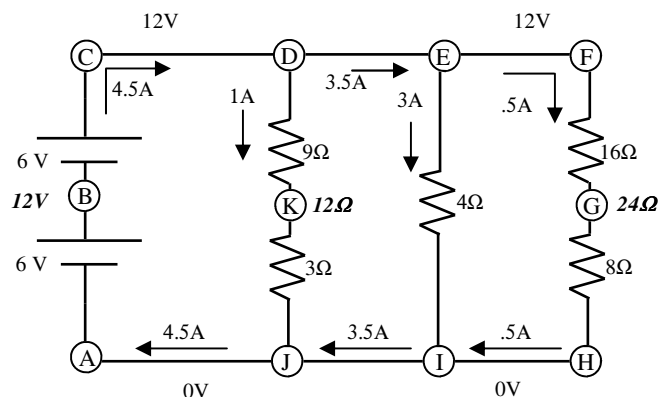
10. Calculate the voltage left at point K.

11. Using $P = VI$, calculate the power used by the 9Ω resistor.

12. How would the total current change if the 4Ω resistor was removed completely?

13. How would the current flowing thru the 16Ω resistor change if the 9Ω resistor was replaced by a wire?

14. Calculate the total power produced by the batteries.



And there you have it: your first combination circuit.

1B: Series 1H: S 1I: P
2A: parallel 3A: 500Ω 3B: $100/5 = 20\Omega$
4B: 0 volts (no change over a wire) 4C: 6V
4D: 0V 4E: $I_{2\Omega} = 6V/2\Omega = 3A$. $I_{1\Omega} = 6A$ Do the other yourself.
4H: 3 times as much
4I: Inversely
4J: 10A