Tech Tip # 65

HEATING, AIRCONDITIONING & REFRIGERATION DISTRIBUTORS INTERNATIONAL

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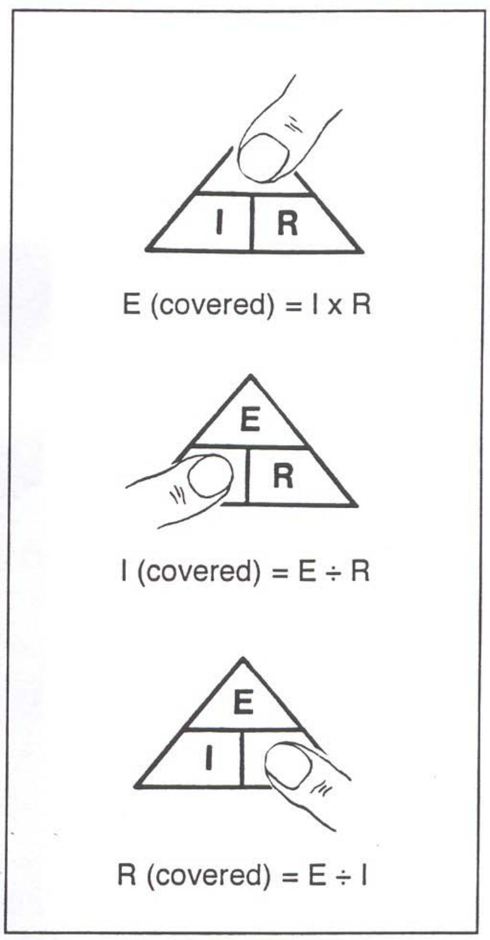
Using an "E R I P" Chart to Solve Electrical Circuits

Solving electrical circuits can be frustrating and confusing. As with any job, using the correct "tool" can make the job a lot easier. Shown below is one such tool to help you solve and have a better understanding of electrical circuits. We call this tool an "E R I P" chart. It is used to analyze the relationship between voltage (E), resistance (R), current (I) and power (P). We will use it to unlock the mystery of ***any*** direct current circuit or an alternating current circuit having only pure resistance. First – we must remember the electrical laws that pertain to electrical circuits.



One of the first things to remember is the relationship between the three major players – voltage, current and resistance.

Using the reference on the left, unknown factors maybe determined.

Cover the unknown factor to determine the correct formula. To determine the unknown factor of voltage, use your finger or thumb to cover the E and the formula would become E = I x R

For current it would be I = E divided by R and to determine R it would be E divided by I.

Series circuit electrical laws:

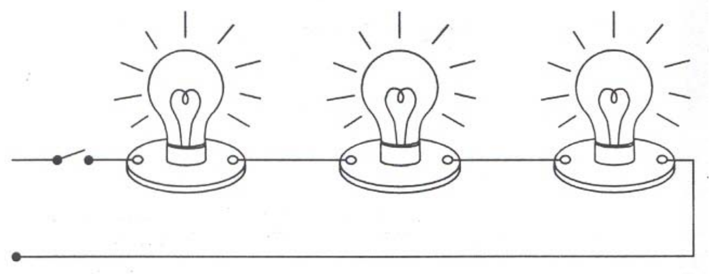
1. ***Resistance total*** is the ***sum*** of the individual resistance values. $R_T = R_1 + R_2 + R_3$ ….

2. **Current** flow is the ***same*** everywhere in the circuit.

3. A series circuit is considered to be a ***voltage*** **divider** circuit.

4. The voltage drop of each load equals the total voltage applied.

The "key" to using the chart below is to fill in any two boxes vertically in a column. Having these two answers will allow us to complete the rest of the puzzle. Here is an example.



Items that you know or can obtain. Applied circuit voltage is 100 volts. Light bulb #1 (R_1) is 40 ohms resistance, light bulb #2 (R_2) is 50 ohms resistance and light bulb #3 (R_3) is 60 ohms resistance.

Step #1: Put all known information into chart below. 100 volts goes in the box below total and resistance values goes into their respective boxes.

Step #2: Remember, we must fill two boxes vertically to start the process. Looking at the chart below, we don't know any of the voltage values yet. We don't know any of the current or wattage values either. But we can find the total resistance value by using electrical law #1 on first page. We can add up the individual resistance values and put the answer into the total resistance box. Resistance total = 40 + 50 + 60 = 150 ohms.

E R I P Chart

	Total	**R_1**	**R_2**	**R_3**
Electromotive Force Voltage (E)	**100** Step #1			
Resistance Ohms (R)	**150** Step #2	**40** Step #1	**50** Step #1	**60** Step #1
Current Amps (I)				
Power Watts (P)				

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	**100**	**26.664** Step #5	**33.33** Step #5	**39.996** Step #5
Resistance (Ohms) (R)	**150**	**40**	**50**	**60**
Current (Amps) (I)	**0.6666** Step #3	**0.6666** Step #4	**0.6666** Step #4	**0.6666** Step #4
Power (Watts) (P)				

Step #3. Now that we have two boxes vertically, we can solve for the unknown values in the total column. Using Ohm's Law we can now determine the unknown current values. The formula for finding current is current equals voltage divided by resistance (I = E/R) or 100/150 = 0.666.

Step #4. Since current is the same everywhere in the circuit (according to electrical law # 2 on first page), we can also put these values into the other boxes in the chart.

We're really cookin' now. We have two boxes vertical in every column so let's fill in the rest of the chart.

Step #5: We can now solve for the unknown voltage values. The formula for voltage is E = I x R. So…for R_1 = 0.6666 x 40 is 26.664 volts; R_2 = 0.6666 x 50 is 33.33 volts and finally for R_3 = 0.6666 x 60 is 39.996 volts.

Electrical law #3 states that a series circuit is a voltage divider circuit. In this case the total voltage is divided between the three resistors. If the resistors were of the same value, then the voltage would also have been equally divided (100 volts/3 = 33.33 volts each). Since in our case the resistors have different ohmic values, the voltage drop across each resistor would be different. As you can see from the chart, as the resistance increases the voltage value also increases to maintain the same current value.

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	100 Step #7	26.664 Step #7	33.33 Step #7	39.996 Step #7
Resistance (Ohms) (R)	150	40	50	60
Current (Amps) (I)	0.6666	0.6666	0.6666	0.6666
Power (Watts) (P)	66.66 Step #6	17.774 Step #6	22.218 Step #6	26.661 Step #6

Step #6: One last row to fill up and that's for the power boxes. The formula for power is as easy as PIE. P = I x E.

Remember ….. total power is additive of all individual loads.

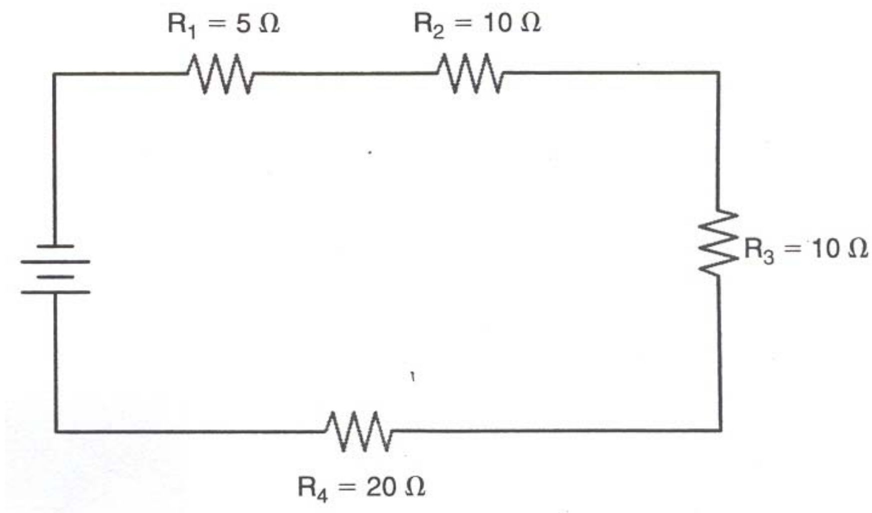
For the total power column: 100 x 0.6666 = 66.66 watts
For R1 power: 26.664 x 0.6666 = 17.774 watts
For R2 power: 33.33 x 0.6666 = 22.218 watts
For R3 power: 39.996 x 0.6666 = 26.661 watts

So …. 17.774 + 22.218 + 26.661 = 66.653. Checked and verified.

Step #7: Let's verify our work. Electrical law #4 states that the individual voltages equal the total voltage applied. Let's see how close we are.

26.664 + 33.33 + 39.996 = 99.99. Every bit of voltage can be accounted for. We didn't come up with 100 volts exactly because we rounded off the current value to four places (0.6666). If we would have kept all of the places it would have come out to 100 volts exactly.

Now let’s see if you can do one on your own. Voltage applied to this circuit is 120 volts.



	Total	**R_1**	**R_2**	**R_3**	**R_4**
Electromotive Force (Voltage) (E)					
Resistance (Ohms) (R)					
Current (Amps) (I)					
Power (Watts) (P)					

Now let's deal with parallel circuits.

We still apply the same rules of the "electrical" road to our circuit. The rules for parallel circuits are:

1. **Voltage** is the ***same*** across connected parallel circuits.
2. Parallel circuits are considered to be a ***current divider*** circuit.
3. Resistance total ***will always be lower*** than the lowest ***individual*** resistor.
4. To determine ***resistance total*** use one of the following formulas:

Formula #1 -- A parallel circuit having ***only two*** resistors of different values:

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

Example: $R_1 = 40$ ohms and $R_2 = 50$ ohms

$$R_T = \frac{40 \times 50 = 2000}{40 + 50 = 90} = 22.22 \text{ ohms}$$

Remember the answer must always be lower than the lowest ohmic value resistor. In our case 22.22 ohms is lower than the 40 ohm resistor. Therefore it passed one test.

Note: If you have two resistances of the same resistance value, then the equivalent resistance would be exactly half of one of them. Example: (2) 40 ohm resistors wired in parallel would equal (1) 20 ohm resistor.

Formula #2 -- Circuits containing two or more and all having ***the same*** resistance value:

$$R_T = \frac{R_{value} \text{ of one resistor}}{\text{Number of resistances}}$$

Example: (5) 40 ohm resistors wired in parallel.

$$R_T = \frac{40}{5} = 8 \text{ ohms}$$

Formula #3 -- Circuits having ***more than two*** resistors having ***different values***:

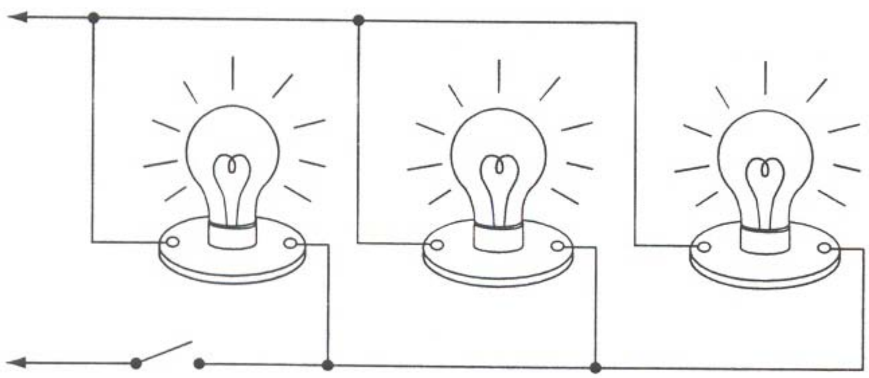
$$R_T \frac{1}{1/R_1 + 1/R_2 + 1/R_3 \ldots..}$$

Example: You have a circuit containing a 40 ohm resistor, a 50 ohm resistor and a 60 ohm resistor.

$$R_T \frac{1}{1/40 + 1/50 + 1/60}$$

$$R_T = \frac{1}{.025 + .02 + .016667} = \frac{1}{.061667} = 16.216 \text{ ohms (total resistance)}$$

Let's do a practical exercise using 3 light bulbs as pictured below. The first light bulb has a resistance value of 40 ohms, the second one 50 ohms and the last one 80 ohms. Applied voltage of 120 volts.



	Total	**R_1**	**R_2**	**R_3**
Electromotive Force (Voltage) (E)	120			
Resistance (Ohms) (R)		40	50	80
Current (Amps) (I)				
Power (Watts) (P)				

Looking at the individual resistances we should know the total resistance should be less than the 40 ohm resistance. Let's figure it out.

First of all we look at the circuit. We can't use formula #1 because we have three resistances. We can't use formula #2 because we do not have equal resistances. So it looks like we are stuck with using formula #3. Let's get started by putting the known values into the formula.

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	120	120	120	120
Resistance (Ohms) (R)	17.391	40	50	80
Current (Amps) (I)	6.90	3	2.4	1.50
Power (Watts) (P)				

$$R_T \frac{1}{1/40 + 1/50 + 1/80}$$

$$R_T \frac{1}{.025 + .02 + .0125} = \frac{1}{.0575} = 17.391 \text{ ohms (total resistance)}$$

This again satisfies the rule that says the total resistance has to be less than the lowest individual resistance.

Secondly --- we also know that the voltage applied to a parallel circuit is the same across all loads. Therefore we can fill in the voltage boxes.

Next, we can determine the current value for the total as well as the individual resistances. Remember the formula for I is E/R.

So for:
R_T ---I = 120/17.391 = 6.90 amps
R_1 --- I = 120/40 = 3 amps
R_2 --- I = 120/50 = 2.4 amps
R_3 --- I = 120/80 = 1.50 amps

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	120	120	120	120
Resistance (Ohms) (R)	17.391	40	50	80
Current (Amps) (I)	6.90	3	2.4	1.50
Power (Watts) (P)	828	360	288	180

Now it's finish by calculating the power. Remember power is as easy as pie. Power is I x E.

P_T ---P = 120 x 6.90 = 828 watts
P_1 --- P = 120 x 3 = 360 watts
P_2 --- P = 120 x 2.4 = 288 watts
P_3 --- P = 120 x 1.50 = 180 watts

Let's practice what we just learned.

Parallel practical problem

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	24			
Resistance (Ohms) (R)		20	25	80
Current (Amps) (I)				
Power (Watts) (P)				

Series circuit answer key.

	Total	R_1	R_2	R_3	R_4
Electromotive Force (Voltage) (E)	120	13.335	26.67	26.67	53.34
Resistance (Ohms) (R)	45	5	10	10	20
Current (Amps) (I)	2.667	2.667	2.667	2.667	2.667
Power (Watts) (P)	320.04	35.564	71.129	71.129	142.258

Parallel circuit answer key.

	Total	R_1	R_2	R_3
Electromotive Force (Voltage) (E)	24	24	24	24
Resistance (Ohms) (R)	9.756	20	25	80
Current (Amps) (I)	2.46	1.2	0.96	0.3
Power (Watts) (P)	59.04	28.8	23.04	7.2

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