CHAPTER FOUR
Series and Parallel Circuits

In Chapter Three you learned Ohm's Law, which is fundamental in electricity. You became familiar with some basic circuit components (battery, lamp, resistor, switch, fuse) and their schematic symbols, and you learned to solve problems involving voltage, current, resistance, power, and energy.

When you finish this chapter you will know how to:

- apply Kirchhoff's Law of Voltages to series circuits;
- apply Ohm's Law to solve for values in parallel circuits;
- apply Kirchhoff's Current Law to solve for current flow in parallel circuits;
- distinguish between series and parallel circuits;
- solve for total resistance in parallel circuits; and
- trace a circuit to establish the polarities of voltages.

Series Circuits

1. In the circuits listed in Chapter Three, you probably noticed that the same current in the circuit flowed through each component, such as a resistor, lamp, or fuse, in that circuit. Those circuits were series circuits. Thus, you could define a series circuit as a circuit in which the current has

   (only one/more than one) ____________________ path.

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2. You also learned that current cannot flow in an open circuit, since there is no complete path for the current. If a light bulb burns out, its filament breaks, and interrupts the circuit. In strings of old-fashioned Christmas tree lights (and some of the less-expensive lights available today), if one bulb burns out, all lights on the string go out. The lights in such a string

   are part of a ____________________ circuit.

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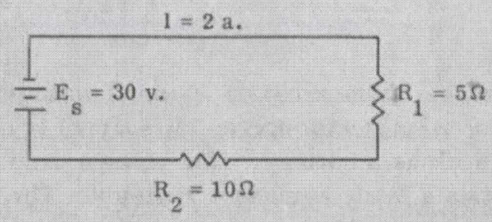
3. So far you have solved problems involving source voltage only. But when current flows through any device (sometimes called "load") that has resistance, we say that a voltage is "dropped" across the device. (The term "drop" is used because, when voltage is developed in one location, there is a drop in the voltage available at other locations.) In each case, you can calculate the amount of voltage that is dropped across a device if you know its resistance and the current flowing through it, using the formula E = IR that you already know. In the circuit below, solve for the voltage drops across the two resistors.



V_{R_1} = E_{R_1} = I x R_1 = 2 a. x 5Ω = 10 v.

E_{R_2} = ____________

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Solution: E_{R_2} = I x R_2 = 2 a. x 10Ω = 20 v.

4. The source voltage (E_s) in the circuit is 30 v.

E_{R_1} + E_{R_2} = ____________

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5. From Frame 4 we can deduce (though we won't prove it here) that the total of all voltage drops in a series circuit is equal to the ______________.

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6. Kirchhoff's Law of Voltages states this truth in different words: The algebraic sum of all the voltages in any complete electric circuit is equal to zero. In a circuit that includes three resistors, there will be a source voltage (E_s) and three voltage drops in the circuit.

To demonstrate:

$V_s = E_s = E_1 + E_2 + E_3$

Transposing everything to the left side of the equation:

$E_s - E_1 - E_2 - E_3 = 0.$

This is called the algebraic sum of the terms. In other words, the sum of all positive voltages must be equal to the sum of all ___________ voltages.

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7. For any voltage rise there must be an equal voltage drop somewhere in the circuit. The voltage rise (potential source) is usually regarded as the power supply, such as a battery. The voltage drop is usually regarded as the voltage across a load, such as a resistor. The voltage drop may be distributed across a number of resistive elements, such as a string of lamps or several resistors. However, according to Kirchhoff's Law, the sum of their individual voltage drops must always equal the voltage rise supplied by the power source. In the circuit diagram in Frame 3, the source voltage is 30 v. The voltage drop across R_1 is 10 v., and the voltage drop across R_2 is 20 v. The total voltage drop across the two resistors is 30 v., which is the same as ______________________________.

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8. If R_1 is taken out of the circuit (and its connecting wires joined), the current will increase because the circuit resistance is lower. You could apply Ohm's Law ($I = \frac{E}{R}$) to find the current, then apply another Ohm's Law equation ($E = IR$) to find out the voltage drop across R_2, or E_{R_2}. In this case, however, we don't need to do that, because there is only one resistor in the circuit. Applying Kirchhoff's Law of Voltages instead, we know immediately that E_{R_2} is 30 v. Why? ____________________________

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9. In your own words, state the relationship between all the voltage drops in a series circuit and the source voltage. ________________________

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10. In a circuit whose source voltage is 12 v. and in which there are only two resistors, there is a voltage drop of 10 v. across one resistor. How much voltage is dropped across the other resistor? __________

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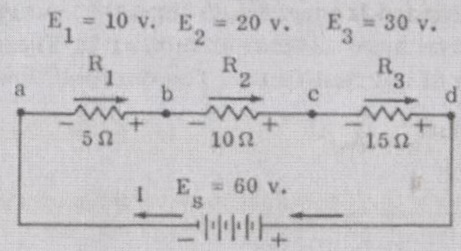

Figure 4-1. Series circuit for demonstrating Kirchhoff's Law of Voltages.

Refer to Figure 4-1 for frames 11 through 20.

11. The "positiveness" or "negativeness" of a value in electricity is called polarity. Whenever there is a difference in potential between two points, such as the two terminals of a battery or the two ends of a resistor, one point is always positive (+) with respect to the other point, which is negative (–). Polarity cannot be assigned to a single point unless that point is compared with some other point. For convenience in understanding the schematic in Figure 4-1, certain points are labeled a, b, c, and d. Look at point b; it is positive with respect to point a but negative with respect to point c. In electricity, we are often interested in the polarity of a difference in potential. Certain devices are designed to be placed in a circuit in a specific way and will not work properly if the polarity is reversed. In troubleshooting electric circuits, the technician often needs to know whether a given difference in potential is positive or negative. E_1, the voltage drop across R_1, is 10 v. This represents a difference in potential of 10 v. between which two points labeled in the circuit? ____________

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12. We have not yet assigned a polarity to the difference in potential. We will learn how to do this in a little while, but first let us review voltage drops and current flow. Remember that a voltage drop is a difference in potential. What is the voltage drop between points c and d? __________

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13. What is the voltage drop between points a and c? (Hint: Add E_1 and E_2.)

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14. You have been reminded from time to time that current flows from negative to positive. You have another reminder in Figure 4-1, since arrows show the direction of current flow. The current flow through R_1 is from point ______ to point ______.

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15. To establish the polarity of a difference in potential, a convention has been established that neatly fits the algebraic terms of Kirchhoff's Law of Voltages. Start at any point in a complete circuit and, following the direction of the current flow, label the ends of all loads as positive or negative. (A load is any device outside the power supply, such as a resistor or lamp, across which there is a difference in potential.) There is also a difference in potential across a power supply, and its terminals are labeled (+) and (–). Go around the circuit only once and be sure to trace the circuit in the direction of current flow. The first point of a load, such as R_1, encountered by the current is labeled (–). The other side of that load is labeled (+). The end of R_1 in Figure 4-1 encountered second as you trace the circuit is labeled (–/+) _______.

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16. The end of R_2 first encountered as you trace the circuit in the direction of current flow is labeled (–/+) _______.

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17. A question may have occurred to you at this point: Since the right end of R_1 and the left end of R_2 in Figure 4-1 are electrically the same, why is one point labeled (+) and the other (–)? It is because we are interested in the polarity of the voltage across a load, not in the polarity (positive or negative) of a single point. By labeling the polarity of the first point encountered when a load is reached, the polarity of the voltage drop across the load can be established. Since the first point encountered when you

reach R_1 is negative, E_1 is –10 v. E_2 is (–20/+20) __________ v.

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18. In all work with direct-current electricity, you should label each voltage as either (+) or (–). What is the voltage drop across R_3? ________

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19. What is the voltage drop across E_s? __________

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20. You can see that the labeling of loads described above is consistent with Kirchhoff's Law of Voltages:

$$E_s + E_1 + E_2 + E_3 = 0$$

$$(+60) + (-10) + (-20) + (-30) =$$

$$+60 - 10 - 20 - 30 = 0$$

The algebraic sum of all the voltages in any complete electric circuit is equal to ______.

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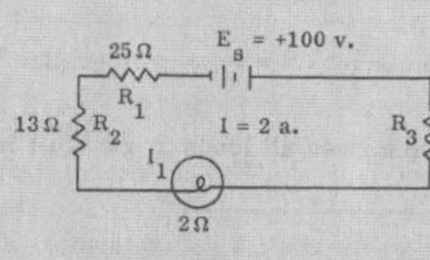

Figure 4-2. A simple DC circuit.

Refer to Figure 4-2 for Frames 21 through 25.

21. A resistor is designated R. What letter designates a lamp? ______

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22. Current flow is from E_S toward __________. (Hint: Remember that the short side of the battery symbol indicates the negative terminal.)

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23. Label both ends of each load with the proper symbol of polarity (+ or −); then calculate the following voltage drops. (Remember that the current is the same throughout the circuit.)

$E_{R_1} = ?$ $E_{R_3} = ?$

$E_{R_2} = ?$ $E_{I_1} = ?$

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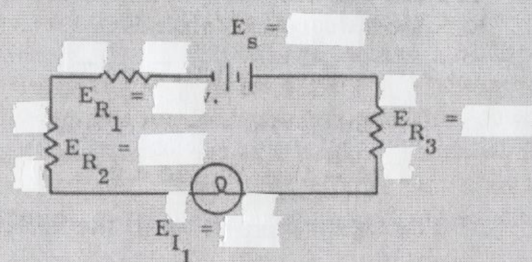

24. What is the sum of the voltage drops across all loads in the circuit outside the battery? __________

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25. The total voltage drop across all loads in a circuit is the same as the

______________________________.

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26. From now on, we're going to simplify things a bit. Ignore polarity for this series of frames. Polarities of voltage drops are usually omitted in this book unless they are needed to demonstrate Kirchhoff's Law of Voltages. In many applications in general practice, however, it is necess-

ary to assign polarities. Unlike the practice in algebra, the absence of a sign does <u>not</u> mean (+). Note that we are also simplifying the designations of voltage drops. E_1 is the same as E_{R_1}, E_2 is E_{R_2}, etc. The more complicated subscript is useful, however, when different types of components, such as resistors and lamps, are used as loads. Study Figure 4-3 below and then solve for the voltage drops.

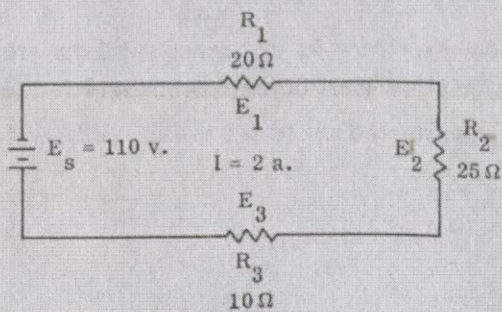

Figure 4-3. Series circuit with three resistors.

Refer to Figure 4-3 for Frames 26 through 39.

$V_1 = E_1 =$ ________

$V_2 = E_2 =$ ________

$V_3 = E_3 =$ ________

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27. What is the total voltage drop across all three resistors? ________

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28. You can establish an equation for the source voltage and all the individual voltage drops in the circuit:

$V_s = E_s =$ ______ + ______ + ______

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29. To find each voltage drop, you had to apply Ohm's Law, $E = IR$. You knew the total circuit current, which was the same at all points in the series circuit, and you knew each value of resistance. You could have written a variation of the equation in Frame 28:

$V_s = E_s = IR_1 + \_\_\_\_ + \_\_\_\_$

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30. R_t is the designation for total circuit resistance. Applying Ohm's Law,

$V_s = E_s = I\_\_\_\_.$

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31. Substituting IR_t for E_s, you can write an equation for the source voltage and all the voltage drops in the circuit in terms of I and R:

$IR_t = \_\_\_\_ + \_\_\_\_ + \_\_\_\_$

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32. Thus, you see that E_s can be expressed in terms of circuit current and total circuit resistance: $IR_t = IR_1 + IR_2 + IR_3$. Since there is only one path for current in a series circuit, the total current is the same in all parts of the circuit. Dividing both sides of the voltage equation by the common factor, I, an expression is derived for the total resistance of the circuit:

$IR_t = IR_1 + IR_2 + IR_3$

Divide through by I.

$R_t = \_\_\_\_ + \_\_\_\_ + \_\_\_\_$

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33. To find the total resistance, R_t, substitute the resistance values in Figure 4-3 and solve for R_t. ________________

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34. State in your own words the relationship between total circuit resistance and the individual resistances in a series circuit. ____________

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35. In Figure 4-3, the total resistance is 20 + 25 + 10 = 55 Ω. You can prove this by applying Ohm's Law. E_t designates the total of all voltage drops in the circuit. I_t is 2 a. Using the basic resistance equation ($R = \frac{E}{I}$), solve for R_t. ________

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36. Now let's solve some power problems using known values from Figure 4-3. The power equation to be used when resistance and current are known is $P = I^2R$. Applying this equation to R_1 in Figure 4-3, we have $P = 2^2 \times 20 = 4 \times 20 = 80$ w., the power absorbed by R_1. How much power is absorbed by R_2? ________

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37. How much power is absorbed by R_3? ________

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38. What is the total power absorbed by the three resistors in Figure 4-3?

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(You may either add separate power values, or add the resistances and use the equation $P = I^2R$.)

39. Since you know the circuit current and the total of the voltage drops in the circuit, you could have applied another power equation, $P = EI$, or in this case, $P_t = E_t I_t$.

P_t = ______ x ______ = ______ w.

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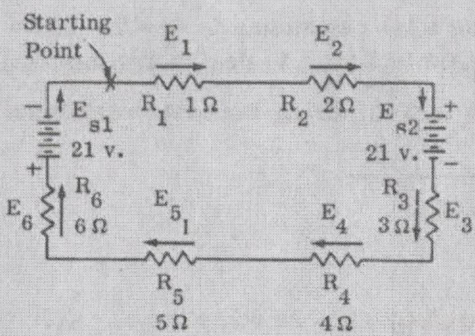

Figure 4-4. Series source with aiding voltage sources

Refer to Figure 4-4 for Frames 40 through 58.

40. So far the source voltage has been given. Let's look at a case in which two voltage sources are used in the same series circuit. Now we have to work out an effective source voltage to use in solving other problems. If the polarities are such that they aid each other (each causes current to flow in the same direction), the sources are simply added and treated as a single source in solving circuit problems. In Figure 4-4, there are two batteries. Examine the circuit carefully. Is the current flow caused by E_{s1} in the same direction as the current flow caused by E_{s2}? ________

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41. E_{s1} = ______ E_{s2} = ______

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42. What value of source voltage should you use in solving circuit problems? (Hint: Add E_{s1} and E_{s2}.) ________

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43. From Figure 4-4, R_t = ______, I_t = ______.

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44. E_4 = ________

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45. E_6 = ________

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46. E_t = ________

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47. The power absorbed by R_3 is ________. (Hint: $P = I^2R$.)

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48. P_t = ________

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49. In Figure 4-4, the two batteries were aiding. Sometimes when a series circuit has more than one voltage source, they might be connected opposing each other to achieve a specific net voltage. If the voltage sources are connected so that each would cause current to flow in a different direction (as they are in Figure 4-5, on the following page), the voltage sources are opposing. Of course, current in a series circuit cannot flow in two directions at once, so the larger source voltage determines the direction of current flow.

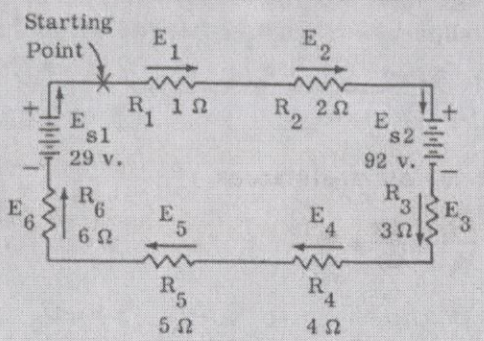

Figure 4-5. Series circuit with opposing voltage sources.

Refer to Figure 4-5 for Frames 49 through 57.

In Figure 4-5, which is the larger voltage source, E_{s1} or E_{s2}? ____

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50. In Figure 4-5, current flow is (clockwise/counterclockwise) __________ __________________.

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51. In solving circuit problems involving opposing voltage sources, we have to work out an <u>effective</u> source voltage. To do this, we must trace the circuit to find out the polarity of each voltage source. E_{s1} is (+29/−29) ________ v.

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52. E_{s2} is (+92/−92) _______ v.

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53. The effective source voltage in Figure 4-5 is the algebraic sum of E_{s1} and E_{s2}. The effective source voltage is ________ v.

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54. Once the effective, or net, source voltage is found, circuit problems are solved in the same way as for a single voltage source. We merely regard the effective voltage as the only source voltage. Refer to Figure 4-5 to find the following values.

R_t = ________

I_t = ________

E_5 = ________

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55. The total of all voltage drops across the six resistors is ______ v.

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56. $E_{s1} + E_{s2} + E_1 + E_2 + E_3 + E_4 + E_5 + E_6 =$ ________. (Hint: Remember to assign polarities to all voltages.)

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57. P_t = ________

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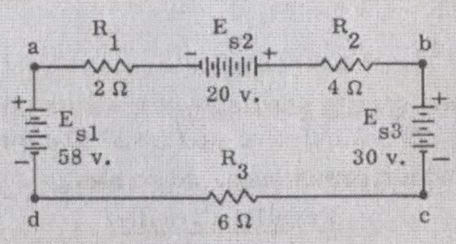

Figure 4-6. Series circuit with three batteries.

Refer to Figure 4-6 for Frames 58 through 61.

58. Even in a more complex problem the principles are the same. In Figure 4-6, the three voltage sources (E_{s1}, E_{s2}, and E_{s3}) are connected so that two are aiding and the third is opposing. Which two voltage sources are aiding? ____________________

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59. What is the direction of current flow? (Hint: Are the combined voltages E_{s1} and E_{s2} larger or smaller than E_{s3}?) ____________________________

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60. What is the effective source voltage? __________

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61. Study Figure 4-6 and answer the following questions.

   (a) What is the current in the circuit? ______________

   (b) What is the voltage drop between point c and point d? _______

   (c) How much power is absorbed by R_2? __________

   (d) What is the total power consumption in the circuit? ________

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$(I_t = \frac{E_s}{R_t} =$

$(E = IR =$

$(P = I^2R =$)

$(P_t = E_sI_t =$)

Parallel Circuits

62. In a series circuit there is only one path for current flow. As additional loads (such as resistors) are added to the circuit, the total resistance increases and the total current decreases. This is not true in a parallel circuit, as we shall see. In a parallel circuit, each load (or branch) is connected directly across the voltage source. In Figure 4-7, on the next page, the total current flows from the negative terminal of the voltage

source E_s, splits into separate paths at point a, and comes together again at point b.

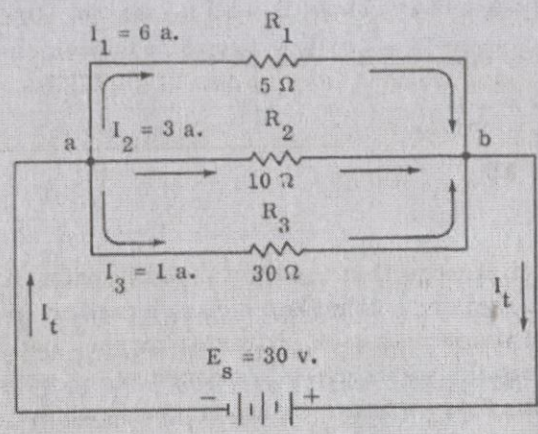

Figure 4-7. Resistors in parallel.

Refer to Figure 4-7 for Frames 62 through 70.

Starting at the negative terminal of the battery in Figure 4-7, how many separate paths for current flow can you trace? __________ (Remember to go along any path only <u>once</u>.)

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63. A parallel circuit is one in which there is (only one/more than one) _____ ________________________ path for current flow.

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64. The total current (I_t) is the sum of all the separate currents in the three branches. Later we will learn how to solve for the branch currents. In this case, they are given for simplicity. What is I_t? __________

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65. Examine Figure 4-7. What is the value of E_s? __________

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66. The total resistance (R_t) in this parallel circuit is not the sum of R_1, R_2, and R_3! Since we already know E_s and I_t, we can apply Ohm's Law to find R_t. Use the equation $R = \frac{E}{I}$. R_t = __________.

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67. You may think it strange that the total circuit resistance is less than that of the smallest resistor. It makes sense, however, if you will consider an analogy with water pressure and water pipes. Let's assume there is some way to keep the water pressure constant. A small pipe offers more resistance to the flow of water than a larger pipe; but if you add another pipe in parallel, even one of very small diameter, the total resistance to water flow is decreased. In an electrical circuit, even a larger resistor in another parallel branch provides an additional path for current flow, so the total resistance is less. (We proved this in Frame 66.) It is probably more accurate to call this total resistance something like "equivalent resistance," but by convention R_t, or total resistance, is used. If we add one more branch to a parallel circuit, the total resistance (increases/decreases) ____________________ and the total current (increases/decreases) ____________________.

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68. The voltage across all branches of a parallel circuit is the same, because all branches are connected directly to the voltage source. Consequently, the current through each branch is independent of the others and depends only on the resistance of that branch, as long as the source voltage remains the same. The currents are already indicated in Figure 4-7. However, you can compute them yourself, since the source voltage (the same for all branches) and the resistance of each branch are both known:

$$I_1 = \frac{E_s}{R_1} = 30 \div 5 = 6 \text{ a.}$$

$$I_2 = \frac{E_s}{R_2} = 30 \div 10 = 3 \text{ a.}$$

I_3 = ______ = ______ = ______ a.

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69. The total current, I_t, is the sum of all the currents in the parallel branches. This, in somewhat different words, is Kirchhoff's Current Law, which is discussed later in this chapter. Total current is equal to the sum of the ____________________.

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70. You could work out R_t of a parallel circuit by Ohm's Law, but this would be time-consuming, because you would first have to work out each branch current to arrive at I_t. To arrive at the formula for R_t, you must manipulate equations. As you have seen, I_t is the sum of I_1, I_2, and I_3. $I_1 = \frac{E_s}{R_1}$, etc. Here is the equation for total current I_t (the sum of the branch currents) expressed in terms of E and R:

$$\frac{E_s}{R_t} = \frac{E_s}{R_1} + \frac{E_s}{R_2} + \frac{E_s}{R_3}$$

This introduces R_t, the quantity you are trying to determine, into the equation. Since E_s appears as the numerator in all four factors, it is divided out, and the equation then contains only the desired factor R_t:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_t} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30}$$

$$\frac{1}{R_t} = 0.2 + 0.1 + 0.033$$

$$\frac{1}{R_t} = 0.333 \text{ (approximately)}$$

$$R_t = \frac{1}{0.333}$$

R_t = ______

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(Note: It is more convenient to work with decimals rather than fractions. The difference is insignificant.)

71. Note that you must work with <u>reciprocals</u> in solving for R_t in parallel circuits. A reciprocal is an inverted fraction; the reciprocal of the fraction $\frac{4}{5}$, for example, is $\frac{5}{4}$. We consider a whole number to be a fraction with 1 as the denominator, so the reciprocal of a whole number is that number

divided into 1. For example, the reciprocal of R_t is $\frac{1}{R_t}$. What is the reciprocal of 20? __________

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72. A parallel circuit has three branches whose resistances are 2Ω, 4Ω, and 10Ω. Solve for R_t. (Give your answer in decimals.)

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73. You can see that R_t is always less than the smallest resistance of any branch. A parallel circuit has two branches whose resistances are 1Ω and 1,000,000Ω. R_t is (less/more) ______________ than 1Ω.

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74. Solving for R_t of a parallel circuit can be sheer drudgery, with many opportunities for arithmetical errors. Fortunately, two shortcuts may be used in certain cases. The first applies only when the parallel resistors (any number of them) all have the same value of resistance. In this case, R_t is found simply by dividing the resistance of one branch by the number of equal branches. Here is the solution for R_t of a parallel circuit that has five branches, each consisting of a 10-ohm resistor:

$$R_t = 10 \div 5 = 2\Omega$$

What is R_t of a parallel circuit that has four branches of 20Ω each?

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75. What is R_t of a parallel circuit consisting of four branches of 16 Ω each?

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76. The second shortcut may be used when two and only two branches are connected in parallel. This is called the "product over sum" shortcut, because the product of the two resistances is divided by their sum. Here is the solution of R_t when two branches have resistances of 3Ω and 6Ω:

$$R_t = \frac{R_1 R_2}{R_1 + R_2} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2\,\Omega$$

Solve for R_t in a parallel circuit where two branches have resistances of 4Ω and 12Ω. R_t = __________

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77. Two parallel branches have resistances of 5Ω and 20Ω. R_t = __________.

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Kirchhoff's Current Law Applied to Parallel Circuits

78. Kirchhoff's Current Law states that: At any junction of conductors the algebraic sum of the currents is zero. This is another way of saying that as many electrons leave a junction as enter it. Refer once more to Figure 4-7, appearing in Frame 62. Assume that the current flowing toward junction a (I_t) is positive and the currents flowing away from junction a (I_1, I_2, and I_3) are negative. (You could assume opposite polarities; it is only important that the polarity assigned to current flowing toward a point is opposite to the polarity of any current flowing away from that point.) Kirchhoff's Current Law is then expressed mathematically:

$$+ I_t - I_1 - I_2 - I_3 = 0$$

$$+ 10 - 6 - 3 - 1 = 0$$

I_t in a parallel circuit with three branches is 12 a. The currents in the three branches are 7 a., 3 a., and 2 a. Express mathematically this situation, applying Kirchhoff's Current Law. ____________________

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79. In a three-branch parallel circuit, $I_t = 10$ a., $I_1 = 2$ a., and $I_2 = 3$ a. What is the value of I_3? __________

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80. As in the series circuit, the total power consumed in a parallel circuit is equal to the sum of the power consumed in the individual resistors. All the power equations may be applied exactly as they were in the series circuit. For example, the current through R_1 in Figure 4-7 is 6 a., and the voltage drop across R_1 is 30 v. (Remember that the voltage drop across each branch of a parallel circuit is the same as the source voltage.) Here is the solution for power consumed by R_1, using both $P = EI$ and $P = I^2R$:

(1) $P = EI = 30$ v. x 6 a. = 180 w.

(2) $P = I^2R = 36$ a. x 5Ω = 180 w.

Solve for the power consumed by R_2 using both equations.

(1) $P = EI$ ____________________

(2) $P = I^2R$ ____________________

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81. You found that R_t in Figure 4-7 is 3Ω and I_t is 10 a. Solve for P_t using the equation $P = I^2R$. P_t = __________

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82. Solve for P_t using the equation $P = EI$. P_t = __________

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83. Problems involving resistance, voltage, current, and power are no more difficult for parallel circuits than for series circuits, although some of the computations take longer. However, it is more difficult to picture the electrical situation in a parallel circuit. If you are given circuit values for a series circuit, you can usually solve any problem associated with that circuit without trouble, simply because there is only one path for current flow. But in solving problems in parallel circuits, you should

always draw a schematic diagram of the circuit, label components, and assign known circuit values. Most people become hopelessly lost without a schematic to help them keep track of known values as well as the unknowns.

Here is a procedure that will help you to visualize what is known and what you need to do to solve for unknowns:

1. Draw a circuit diagram.
2. Write the given values on the diagram.
3. Write down the values to be found.
4. Write the applicable equations.
5. Substitute the given values and solve for the unknown in each equation.

A circuit consists of a 15-ohm and a 35-ohm resistor connected in parallel across a 100-volt battery. Draw the circuit diagram and label the components. Use a separate sheet of paper.

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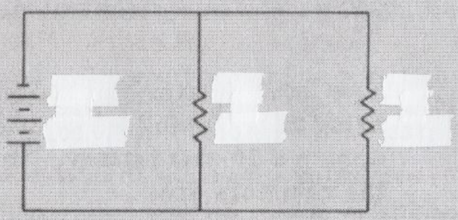
Your circuit diagram should look something like this, although your labeling of components might be different. The physical location of components does not matter as long as the electrical connections are correct.



84. Refer to your diagram for the next few frames. It is helpful to write each new value on the diagram as you solve it. R_t = __________. (Hint: You can use the "product over sum" shortcut.)

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85. I_t = __________. (Round off your answer to two decimal places.)

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86. The current through R_1 = __________

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87. The current through R_2 = __________

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88. The power consumed by R_1 = ________.

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89. The power consumed by R_2 = ________.

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90. P_t = ________

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91. Now let's put everything together. Draw your own schematic diagram, using the following information. Three resistors are connected in parallel across a 50-volt battery, labeled E_s for "source voltage." The values of the resistors are:

$R_1 = 25\Omega$
$R_2 = 10\Omega$
$R_3 = 50\Omega$

When you have drawn your schematic and have labeled all circuit components with their values, answer the following questions.

1. What is the total resistance (R_t) of the circuit? ________
2. What is the total current (I_t)? ________
3. What are the three branch currents, I_1, I_2, and I_3? ________
4. What is the total power (P_t) consumed by the circuit? ________

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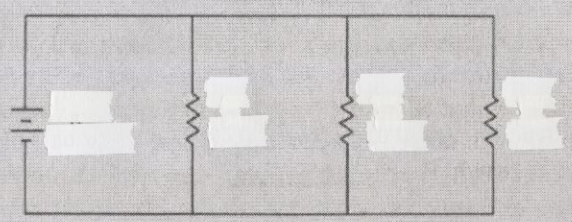
Your schematic should look something like this, although the components need not be in the order shown.



1. $R_t = 6.25\Omega$ $\left(\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$
2. $I_t = 8$ a. $\left(I_t = \frac{E_s}{R_t}\right)$ You could have solved for the branch currents first and then added the three.
3. $I_1 = 2$ a.; $I_2 = 5$ a.; $I_3 = 1$ a. $(I = \frac{E_s}{R}$ for each branch.)
4. P = 400 w. ($P_t = E_s I_t$.) You could have found the power of each branch ($P = I^2R$) and then added the three branch powers.

In this chapter you have learned that all the voltage drops in a series circuit must have a total value that is equal to the value of the source voltage although opposite in polarity (Kirchhoff's Law of Voltages). Since there is only one path for current flow, however, the value of current is the same in any part of a series circuit.

In a parallel circuit, the total current splits into the various branch currents, whose sum must equal the total current (Kirchhoff's Current Law). However, the source voltage is impressed across each branch, so all branch voltage drops have the same value as the source voltage.

In other words, current is constant and voltage drops vary in a series circuit, while in a parallel circuit, voltage is constant and current values vary.

You have learned to trace a series circuit to establish the polarities of voltage drops in the circuit, in accordance with Kirchhoff's Law of Voltages.

When a series circuit has more than one voltage source, the voltages either aid or oppose, depending on how they are placed in the circuit, and you must work out a net voltage to represent E_s. (The same principle applies in parallel circuits. We did not deal with multiple voltage sources in those circuits because the solution of such problems is too difficult for this stage of study.)

You have learned that total resistance (R_t) in a parallel circuit requires a special equation (although two shortcuts may be derived from it for certain cases).

Finally, you have learned to solve for values of current, resistance, voltage, and power in both series and parallel circuits.

In this chapter, you have encountered circuits that were purely series or purely parallel. In "real life," of course, circuits usually have portions that are series and other portions that are parallel. We shall examine these circuits in the next chapter.

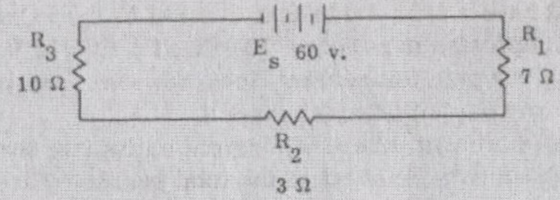
Now, go on to the Self-Test.

Self-Test

These questions will test your understanding of Chapter Four. Write your answers on a separate sheet of paper and check them with the answers provided following the Self-Test.

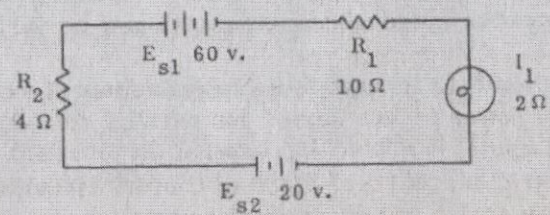
1. What is the difference between a series and a parallel circuit?
2. The sum of all voltage drops in a series circuit is equal to ________.
3. In a series circuit with three resistors, E_s = _____ + _____ + _____.
4. Assuming a series circuit with a battery and two resistors, express Kirchhoff's Law of Voltages mathematically in terms of the circuit voltages.
5. For any total voltage rise in a circuit, there must be an equal total ____.

Refer to the diagram below for questions 6 through 11.



6. Is the direction of current flow clockwise or counterclockwise?
7. Is the voltage drop across R_1 positive or negative?
8. I_t = ?
9. E dropped across R_1 = ?
10. What is the power absorbed by R_2?
11. P_t = ?

Refer to the diagram below for questions 12 through 18.

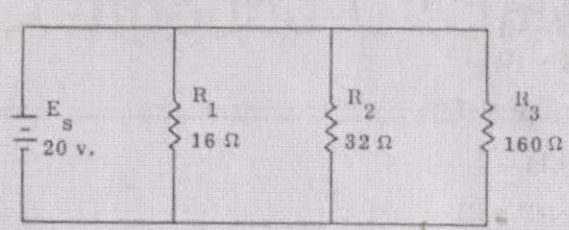


12. Is the direction of current flow clockwise or counterclockwise?
13. What is the effective source voltage?
14. I_t = ?
15. What is the voltage drop across the lamp?
16. What power is consumed by the lamp?
17. What is the current through R_2?

18. $P_t = ?$

19. As more parallel resistances are added to a circuit, does total resistance increase or decrease?

Refer to the diagram below for questions 20 through 24.



20. $R_t = ?$

21. $I_t = ?$

22. How much current flows through R_2?

23. What is the power consumed by R_3?

24. $P_t = ?$

25. Four 5-ohm resistors are connected in parallel across a battery. What is R_t?

26. Two resistors, whose values are 15 Ω and 30 Ω, are connected in parallel across a battery. What is R_t?