Electronics

Radio

Television

Radar

UNITED ELECTRONICS LABORATORIES

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MAKING YOUR OWN EQUATIONS **ASSIGNMENT 20**

MAKING YOUR OWN EQUATIONS

Before starting on the discussion on how to "make your own equations," or in other words, how to set up or develop equations, it will be helpful to explain the relationship between mathematics and your study of electronics.

If you hope to be more than a "soldering iron and screwdriver" electronics technician you will certainly want to know how to use arithmetic, powers of ten, etc. covered in the assignments dealing with arithmetic. There will be many occasions when you will find a practical use for the algebra you studied in the two previous algebra assignments. You will often want to solve an electronics formula for different unknowns. The "math" you have had so far in the training program is **practical.** You are going to apply it directly to your electronics work.

In this assignment we have some exercises in "math" that are not practical in the true sense of the word. Why then, should we take up our time and yours with the study of mathematical operations you may never use again?

The answer is simple. When you study algebra you are **training your mind.** Algebra requires imagination. Surely you recognize by now that intelligent work with electronics circuits will require imagination. Any time you explore new subjects, or refresh your memory on almost forgotten subjects, you have thereby increased your mental powers so that you can approach any other new problem in a more intelligent manner.

There is another important reason for studying mathematics. Electronics is a **technical** field, and a qualified electronics technician is expected to know at least the fundamental operations of arithmetic and algebra. Thus the math is included in the training in order **to thoroughly qualify you for the industry.**

We can sum up with these words: Algebra will help you understand the electronics information in this training program, and it will be a tremendous aid in years to come as you endeavor to keep abreast of new circuit developments in the broad field of electronics.

Setting up Equations

You should be able to solve most "circuit" problems in this assignment without "setting up" any equations. It would be well for you to work out each of these problems using the methods you studied in previous assignments. Notice that the "equations" will give the correct answers also.

In this assignment we shall use the same method of denoting the operations being performed on an equation as in the preceding algebra assignment. Thus, **D** : 4 means **divide both sides of the equation** by 4, **S** : 4 means subtract 4 **from both sides, etc.**

Example 1. Let us find out how much current is flowing in the simple series circuit in Figure 1. In order to set up an equation we might think of the circuit in this way:

The sum of the voltage drops across the three resistors equals the battery voltage or $E_{1\,\Omega} + E_{3\,\Omega} + E_{4\,\Omega} = 16$ volts. (Note: $E_{1\,\Omega}$ stands for the voltage drop across the $1\,\Omega$ resistor.)

This is a **series** circuit, so the same current, which we shall call I, flows through each of the three resistors. The voltage drop across each resistor is equal to this current, I, multiplied by the ohmic value of that resistor ($E = I \times R$).

Thus: $E_{1\Omega} = I \times 1$

$E_{3\Omega} = I \times 3$

$E_{4\Omega} = I \times 4.$

We have learned in a previous assignment, that one quantity may be substituted for an equal quantity in an algebraic equation. It is then permissible for us to substitute $(I \times 1)$ for $E_{1\Omega}$, $(I \times 3)$ for $E_{3\Omega}$, and $(I \times 4)$ for $E_{4\Omega}$ in the equation $E_{1\Omega} + E_{3\Omega} + E_{4\Omega} = 16$.

Thus we obtain:

$$(I \times 1) + (I \times 3) + (I \times 4) = 16$$

Remove parenthesis: $I + 3I + 4I = 16$

Combining terms: $8I = 16$

D : 8 $\frac{\not{8}I}{\not{8}} = \frac{16}{8}$

$$I = 2 \text{ amperes.}$$

Do you see where we obtained each and every letter and number in every bit of the work? Go over this example again if necessary. Are you satisfied that 2 amperes is the correct answer?

Let us solve this problem by Ohm's Law and check the answer.

$$I = \frac{E}{R_t}$$

$$R_t = R_{1\Omega} + R_{3\Omega} + R_{4\Omega}$$
$$R_t = 1 + 3 + 4$$
$$R_t = 8\Omega$$

$$I = \frac{E}{R_t} = \frac{16}{8} = 2 \text{ amperes.}$$

This check proves that the original method of finding the current was satisfactory.

Before proceeding with electrical circuits, we will show that an equation can be written when a problem is stated in simple English. As we write the problem, the equation will be written beneath it. Notice that certain key words in the sentence give us letters, number and signs of operation.

Example 2: How many six-volt batteries must be added in series with
N ×6 +

a forty-five volt battery to obtain a voltage equal to sixty-nine volts?
45 = 69

Thus: $6N + 45 = 69$

S : 45 $6N = 24$

D : 6 $N = 4.$ Answer: 4 six-volt batteries.

To check the answer let us substitute 4 for N in the original equation.

$$(N \times 6) + 45 = 69$$
$$(4 \times 6) + 45 = 69$$
$$24 + 45 = 69$$
$$69 = 69.$$

Example 3: What size resistor added in series with a 6842 ohm resistor
R + 6842

will give the same total resistance as three 2500Ω resistors in series?
= 3 × 2500

Thus: $R + 6842 = 3 \times 2500$

$R + 6842 = 7500$

S : 6842 $R = 7500 - 6842$

$R = 658$ ohms.

Check: $658 + 6842 = 3 \times 2500$

$7500 = 7500.$

Example 4: A resistor added in series with another resistor seven times
R + 7 × R

as large gives a total resistance of 32,000 ohms. How large is the resistor?
= 32,000

$R + 7R = 32{,}000$

$8R = 32{,}000$

D : 8 $R = 4{,}000$ ohms.

Check: $R + 7R = 32{,}000$

$4000 + 7(4000) = 32{,}000$

$4000 + 28{,}000 = 32{,}000$

$32{,}000 = 32{,}000.$

Example 5: Three resistors are in series and have a total resistance of 3300 ohms. The second resistor is 300 ohms larger than the first resistor.

The third resistor is four times as large as the first. What are the sizes of the three resistors?

Let: R be the size of the first resistor.
R + 300 equal the size of the second resistor.
4R the size of the third resistor.

Then: $R + (R + 300) + 4R = 3300$

Collect terms: $6R + 300 = 3300$

S : 300 $6R = 3300 - 300$

$6R = 3000$

D : 6 $R = 500$ (first resistor)

$R + 300 = 800$ (second resistor)

$4R = 2000$ (third resistor).

Check: $500 + (500 + 300) + 4(500) = 3300$

$500 + 800 + 2000 = 3300$

$3300 = 3300.$

Example 6: Suppose we have a 45 volt battery. What size battery
45

should be connected so as to "buck" or oppose the 45 volt battery, so that
—B

the resultant of these two battery voltages is equal to four 6 volt storage
= 4 × 6

batteries connected in series?

$45 - B = 4 \times 6$

$45 - B = 24$

S : 45 $- B = 24 - 45$

Collect terms: $- B = - 21$

Change signs: $B = 21$ volts.

Check: $45 - B = 4 \times 6$

$45 - 21 = 24$

$24 = 24.$

If, by any chance, you do not thoroughly understand just what was done in these six examples, read them over until you are satisfied about the origin of every letter, number and sign of operation.

Why were the three resistor sizes **added together** in example 5? The resistors were said to be connected in **series.** You know from your theory that the total resistance of resistors in series is the **sum** of the individual resistances.

Why was the 21 volt battery subtracted from the 45 volt battery in example 6? The problem stated that the battery was to be connected to "buck" or oppose the 45 volt battery. Electrical theory tells us that the resultant voltage will be the difference of the two battery voltages.

You will find that your knowledge of Ohms Law, electrical circuits, electronics theory, etc., will have a great deal to do with your ability to set up equations using algebra.

It is not possible to write out a set of rules to be followed in setting up all equations, due to the wide variety of problems which may be encountered. The following general outline will be found useful in setting-up equations.

1. **Read the problem several times** until you are sure you understand every fact given.

2. **Decide what is to be found,** and then let some letter stand for the unknown. For example, N for number, R for resistance, etc. If there is more than one unknown quantity, try to state each one in terms of the first unknown.

3. **Find the expressions which,** as stated in the problem, **equal another group of expressions.** Let these two groups of expressions equal each other in an equation, and solve the equation for the unknown.

Ratio and Proportion

Before proceeding with the process of setting-up equations, let us study a type of algebraic equation called a proportion. We have used this type of equation, but let us study it in more detail at the present time.

Calculations that would ordinarily require two steps can often be performed in one operation by means of proportions. Proportion, therefore, is merely a short-cut of **thinking.** Proportions themselves are very easy to solve. In order to set up a proportion, however, you must clearly understand the underlying principles involved in each particular case.

A proportion is merely an equation containing two **ratios,** so let us see what a ratio is.

Ratio is the comparison of two **like numbers.** It is always expressed by the answer obtained by dividing the first number by the second. For example, if we wish to state the relationship between 16 and 8, we can say that the ratio of 16 to 8 is 2; that is, $16/8 = 2$. There are four ways of writing a ratio: The ratio of 16 to 8, or $16 \div 8$, or $16 : 8$, or $\frac{16}{8}$. In each case we would read the expression as "the ratio of 16 to 8", and in each case the value of the ratio can be found by dividing 16 by 8, giving 2. The two numbers in a ratio are called the terms of a ratio.

Every common fraction may be regarded as a ratio. Thus the fraction ¾ is the ratio of 3 to 4.

If we **invert** (turn upside down) the terms of a ratio, we get an **inverse ratio.** Thus, 4 : 3 is the inverse of 3 : 4.

Ratios must be expressed by numbers meaning the same physical things. For example, we **cannot** compare 8 automobiles with 4 railroad bridges, or 9 volts with 4 amperes. We can compare 8 automobiles with 4 automobiles, or 9 volts with 4 volts.

If we write an equation so that one ratio is equal to another ratio, this equation is called a **proportion.** For example, if we write a formula stating that the ratio of 16 to 8 is equal to the ratio of 6 to 3, we form the proportion 16 : 8 = 6 : 3. A proportion can also be written in the following ways:

16 : 8 : : 6 : 3, or $\frac{16}{8} = \frac{6}{3}$.

Solving Proportion Problems

Suppose you have 2000 square feet of lawn to sow with grass seed and you know that 3 lbs. of seed will cover 400 square feet of lawn. You can tell immediately that you will need 15 lbs. of seed for 2000 square feet.

You probably worked it out this way: 2000 is five times as large as 400.
Five times as much seed, or $5 \times 3 = 15$ lbs., will be needed.
As a proportion it could be stated:
400 square feet is to 2000 square feet as 3 lbs. is to X lbs.,
or in mathematical symbols:
400 : 2000 = 3 : X.

Notice that we put the areas (square feet) on one side of the equal sign and the lbs. of seed on the other side.

DEFINITIONS. The 400 and the X (the two numbers at either end of our proportions) are called the **extremes.** The 2000 and the 3 (the two "inside" numbers) are called the **means.**

In the problem, X (the quantity or number we wish to determine) is one of the extremes. Proportions of this type can be solved by the following method:

$$X \text{ (extreme)} = \frac{\text{mean} \times \text{mean}}{\text{other extreme}} = \frac{3 \times 2000}{400} = 15.$$

If we have a proportion in which we do not know one of the means, we have an equally simple rule for finding the value of the mean.

$$X \text{ (mean)} = \frac{\text{extreme} \times \text{extreme}}{\text{other mean}}$$

Thus, if we have the proportion, 5 : 7 = X : 28, $X = \frac{5 \times 28}{7} = 20$.

If we **increase** the area of our lawn, we will need **more** seed.

If we **increase** the voltage across the resistor, we will have **more** current flow through the resistor.

If we **increase** the current through a resistor, we will have a larger voltage drop across the resistor.

For a given amount of current, more voltage will be produced across a larger resistor.

These are examples of **direct proportion.** In a direct proportion, the first term on the left side of the equal sign corresponds to the first term on the right side of the equal sign. For example, in the grass seed problem, the 400 sq. ft. corresponds to the 3 lbs. of seed, and the 2000 sq. ft. corresponds to the unknown value of seed.

To illustrate the use of direct proportion, suppose a 3 ohm and an 8 ohm resistor are in series. The 3 ohms resistor has 5 volts drop. What is the voltage across the 8 ohm resistor?

Solution: $3 : 8 = 5 : X$

$$X = \frac{8(5)}{3} = \frac{40}{3} = 13\frac{1}{3} \text{ volts.}$$

This shows the voltage drop across the 8 ohm resistor to be $13\frac{1}{3}$ volts. In working out this problem we had to understand from our **theory** work that, since the resistors are in series, the same current will flow through each, and therefore the voltage drop is **directly** proportional to the size of the resistor. Work this problem by Ohm's Law, and see if you obtain the same voltage drop.

To further illustrate this principle, look again at Figure 1. Assume that it is known there is a voltage drop of 8 volts across the 4 ohm resistor, and we wish to know the voltage drop across the 3 ohm and the 1 ohm resistor. The resistors are in series, so the same current flows through each of them. The voltage drop will be **directly** proportional to the resistance.

To find the voltage drop across the 3 ohm resistor we set-up the proportion: $4 : 3 = 8 : X$ (the 4 ohm resistor is to the 3 ohm resistor as the voltage drop across the 4 ohm resistor is to the voltage drop across the 3 ohm resistor.)

$$X = \frac{3(8)}{4} = \frac{24}{4}$$

$X = 6$ volts.

To find the voltage drop across the 1 ohm resistor we proceed as follows:

$4 : 1 = 8 : X$

$$X = \frac{1(8)}{4} = 2 \text{ volts.}$$

Check these results by using Ohm's Law.

These examples illustrate a very useful point in finding the voltage in a series circuit. **In a series circuit, the voltage drop across resistors is directly proportional to the size of the resistors.**

Things do not always vary directly, either in real life or in electrical circuits.

If we **increase** the number of men on a labor crew, it will take **less** time to do a job.

If we **increase** the size of a resistor, we will have **less** current flow in the circuit (voltage being held constant).

These last two are examples of **indirect** proportion (sometimes called **inverse** proportions).

It takes 12 days for 3 men to perform a certain task. How long will it take 8 men to do the same job?

If we put down $3 : 8 = 12 : X$ as in a direct proportion we would have $X = \frac{8 \times 12}{3} = 32$ days! A very **unreasonable** answer.

All we have to do for an **indirect** proportion is to reverse the position of the two right hand terms.

Thus, $3 : 8 = X : 12$, $X = \frac{3 \times 12}{8} = \frac{9}{2} = 4\frac{1}{2}$ days. Notice again that we kept **men** on one side and **days** on the other side, but that in the indirect proportion, the first term on the left side of the equation corresponds to the last term on the right side. Thus, the 3 men corresponds to the 12 days, and 8 men to the unknown number of days.

Suppose that a 3 ohm and a 11 ohm resistor are connected in parallel. The 3 ohm resistor has 7 amperes of current flowing through it. How much current flows through the 11 ohm resistor?

Here again, we must apply our **knowledge** of electrical circuits before writing the equation. We know that when two resistors are connected in parallel, that the voltages across the two resistors are equal. We also know that for a given voltage **less** current will flow if the resistance is larger. This problem will then be an indirect proportion.

We would write it thus:

$3 : 11 = X : 7$ (The 3 ohm resistor is to the 11 ohm resistor as the current through the 11 ohm resistor is to the current through the 3 ohm resistor.)

$$X = \frac{3(7)}{11} = \frac{21}{11} = 1\frac{10}{11} \text{ or } 1.91 \text{ amperes.}$$

This solution tells us that $1\frac{10}{11}$ or 1.91 amperes would flow through the 11 ohm resistor. Let us check this by Ohm's Law.

The voltage across the 11 ohm resistor is equal to that across the 3 ohm resistor. The voltage across the 3 ohm resistor can be found by Ohm's Law.

$E = IR$

$E = 7 \times 3 = 21$ volts.

There is a voltage of 21 volts across a 11 ohm resistor. The current through the resistor would be:

$$I = \frac{E}{R} = \frac{21}{11} = 1\frac{10}{11} \text{ or } 1.91 \text{ amp.}$$

This problem illustrates a useful point when dealing with parallel circuits. **In a parallel circuit, the current is inversely proportional to the resistance of the individual resistor.**

Solving Circuit Problems

We will now proceed with the solution of electronics circuits. We have already said that you should be able to solve most of these circuits by the methods you studied in previous assignments. In a future assignment we will work with circuits that cannot be easily solved without the use of algebraic equations.

Look at the circuit in Figure 2. We want to know the voltage drop across the 200 ohm resistor.

The drop ($E_{200\Omega}$) across the 200 ohm resistor will be found by the equation, $E_{200\Omega} = I \times R = I \times 200$. The current I through the resistor will equal $\frac{E}{R_t}$ where E is the battery voltage, and R_t is the sum of all the series-connected resistors in the circuit. Stated in the form of an equation, this is:

$$I = \frac{E}{R_t}$$

Since I is equal to $\frac{E}{R_t}$ we may substitute $\frac{E}{R_t}$ for I in the original formula.

$$E_{200\Omega} = I \times R = I \times 200 = \frac{E}{R_t} \times 200$$

Substituting the known values in the equation we have:

$$E_{200\Omega} = \frac{45}{100 + 200 + 600} \times 200$$

$$= \frac{\overset{1}{45}}{\underset{20}{900}} \times 200$$

$$= 10 \text{ volts.}$$

Work the problem in the usual two steps using Ohm's Law. Do you get 10 volts for an answer? Notice that we performed these same two routine steps in our equation. We found the current $\frac{E}{R_t}$ and multiplied by the resistance (200Ω) to obtain the drop across the resistor ($E_{200}\,\Omega$). We certainly did nothing unusual. We merely put all the Ohm's Law **arithmetic in one step.**

Pay close attention to the following examples. You may find one or two problems that you could not work without algebra!

In Figure 3 we have a simple series-parallel circuit. How many ohms should we use for R_L in order that the current through the 104Ω resistor be 2 amperes? Be careful not to fall into a trap! You can work this very easily step by step from your present knowledge of Ohm's Law.

The voltage drop across the 104 ohm resistor equals $I \times R = 2 \times 104 = 208$ volts.

The remaining voltage ($240 - 208 = 32$) is the voltage across the parallel branch.

The sum of the current through the 80 ohm resistor and through R_L must equal 2 amperes. $I = \frac{E}{R}$, and the current through the 80 ohm resistor is $I = \frac{32}{80}$. The current through R_L is $\frac{32}{R_L}$. The sum of these two currents is 2 amperes.

$$\frac{32}{80} + \frac{32}{R_L} = 2$$

$$.4 + \frac{32}{R_L} = 2$$

$$S : .4 \qquad \frac{32}{R_L} = 1.6$$

Invert both sides: $\frac{R_L}{32} = \frac{1}{1.6}$

M : 32 $\quad R_L = \frac{32}{1.6}$

$R_L = 20$ ohms.

Did you get an answer of 20 ohms using simple Ohm's Law as a check for this work? Your work might have been as follows:

The drop across the 104 ohm resistor equals 208 volts.

This leaves 240 — 208 or 32 volts across the parallel branch.

The current through the 80 ohm resistor will be $I = \frac{E}{R} = \frac{32}{80}$ or .4 amperes.

The remaining current (2 — .4) 1.6 amperes must pass through R_L which is also operating at 32 volts. Therefore, $R_L = \frac{E}{I} = \frac{32}{1.6} = 20$ ohms.

Check the equation and you will see that we used this same reasoning in applying algebra to the circuit.

In Figure 4 we have two resistors in series. What size should we use for R_L in order that we have a power of .25 watts in the 400 ohm resistor?

We could solve this problem algebraically in one step by using "quadratics", a branch of algebra slightly more advanced than the algebra of this training program. However, by logical **reasoning** we can quickly obtain our answer. Here is a case then, where we will not set up an equation. If you have been following the previous examples closely you probably already know just what has to be done to solve the problem.

We want a power of .25 watts in the 400Ω resistor.

$P = I^2R$, solving this for I^2 we have:

$I^2 = \frac{P}{R}$, taking the square root of **both** sides:

$I = \sqrt{\frac{P}{R}}$

The current through the 400Ω resistor must be:

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{.25}{400}} = \sqrt{.000625} = .025 \text{ amperes.}$$

How much resistance do we need in the simple series circuit in order that .025 amperes will flow? $R_t = \frac{E}{I} = \frac{22.5}{.025} = 900$ ohms.

R_L **must equal 500 ohms** if the total resistance is to equal 900 ohms.

In the last problem we have a clear cut example of the type of thinking necessary in electronics work. The problem was quite simple. The arithmetic was not complicated. It was necessary to "think the problem through" before any work was started. We wanted to determine the size of a **resistor,** yet in thinking and reasoning we decided that we would first have to know the amount of **current** through the resistor.

Here is a problem we should be able to work out without writing anything down on paper. Look at the circuit in Figure 5. The current through the three arms of the parallel branch is 1, 2 and 3 amperes respectively. We do not know the sizes of the three resistors in the parallel branch. What is the voltage across the parallel branch? This voltage across the parallel branch will equal the battery voltage minus the voltage drop in the 2 and 3 ohm resistors. The current in the 2 and 3 ohm resistors is 1 + 2 + 3, or 6 amperes. The total voltage drop in the 2 and 3 ohm resistors is equal to $I \times R$ or $6 \times (2 + 3) = 6 \times 5 = 30$ volts. This leaves 48 — 30 or 18 volts across the parallel branch. If we wished to know the resistance of each branch, we would easily find it since we know the applied voltage (18V) and the current in each.

Did you follow very easily and quickly in the last paragraph? If not, go back over enough of the previous examples until you feel a little more at ease with the work that is being done.

Here is an easy problem. Try to set up the formula for it before reading the solution.

One third of a certain voltage, plus one half of that voltage, equals 125 volts. What is the original voltage?

Look the problem over carefully to determine every fact given. Decide what letter to use for the unknown. (It really makes no difference. You could call it A, or X or any other letter, but since you are dealing with voltage it would be a good idea to use E.) Now set up the equation. Is your equation and solution the same as the following?

$$\frac{1}{3}E + \frac{1}{2}E = 125$$

Change the fractions to a common denominator of 6:

$$\frac{2}{6}E + \frac{3}{6}E = 125$$

$$\frac{5}{6}E = 125$$

$$\frac{5E}{6} = 125$$

M : 6 $\quad 5E = 125 \times 6$

D : 5 $\quad E = \frac{125 \times 6}{5}$

Cancel: $\quad E = \frac{\overset{25}{\cancel{125}} \times 6}{\cancel{5}}$

$$E = 150 \text{ volts}$$

Check $\quad \frac{1}{3}E + \frac{1}{2}E = 125$

$$\frac{1}{3}(150) + \frac{1}{2}(150) = 125$$

$$50 + 75 = 125$$

$$125 = 125.$$

Here is another easy one. Set up an equation for it and find the unknown.

Two resistors are in series. There is one milliampere of current flowing through them. One resistor has a value of 10,000 ohms. What should the ohmic value of the other resistor be in order that the voltage drop across the two resistors will be 15 volts?

The correct answer is 5,000 ohms. Is that what you obtained? Be sure to try to solve this problem before looking at the solution given below.

$I \times R = E$

$.001 \times (10{,}000 + R) = 15$ (remember, 1 mA = .001 A.)

Removing parenthesis: $\quad 10 + .001R = 15$

S : 10 $\quad .001R = 5$

M : 1000 $\quad R = 5{,}000$ ohms

Check: $\quad .001 \times (10{,}000 + 5{,}000) = 15$

$$10 + 5 = 15.$$

Figure 6 illustrates another problem which you should have no difficulty in solving. The supply voltage is 250 volts. There is a current of 2 mA flowing in the circuit. What value must R be, so that the voltage drop from A to B will be 150 volts, as indicated. This problem can be worked very simply by Ohm's Law, but try to set-up an algebraic equation to solve it, for practice.

In setting up the equation, you should use reasoning something like this: The voltage drop across the resistor R, must be equal to the difference between the supply voltage and the voltage from A to B.

$$E_R = 250 - 150 = 100 \text{ V}$$

$$R = \frac{E}{I}, \text{ or in this case } \frac{E_R}{.002}$$

The equation would be:

$$R = \frac{100}{.002}$$

$R = 50{,}000$ ohms.

Check: $E_R = I \times R = .002 \times 50{,}000 = 100$ volts

$100 + 150 = 250$

$250 = 250.$

Don't let the next example discourage you. You should at least be able to follow what is being done. If you feel that you could work a similar problem, so much the better. Remember that the primary purpose of this assignment is to improve your method of thinking about electronics circuits.

Take a look at the circuit in Figure 7. We want to make R_X of such a value as to have a current of 3 amperes through the right hand branch of the parallel circuit. All we have given to start with is the battery voltage and the sizes of the other three resistors. Study the circuit. Can you think of any **series of steps** that will lead us to the correct value for R_X?

There is only one resistor in the circuit about which we know two things. We know the size of the 3Ω resistor and we know the current through it (3 amperes).

The voltage drop in the 3Ω resistor will be; $E_{3\Omega} = I \times R = 3 \times 3 = 9$ volts.

The voltage drop in R_X will be; $E_{RX} = I \times R_X = 3R_X$.

The entire voltage in the right hand branch then $= 9 + 3R_X$.

This voltage $(9 + 3R_X)$ is also the voltage across the 12Ω resistor, since the 3Ω resistor and R_X in series, are connected in parallel with the 12Ω resistor.

The current through the 12Ω resistor equals $\frac{E}{R} = \frac{9 + 3R_X}{12}$ amperes.

The total current in the main line to the parallel branch is the sum of the currents in the two arms of the parallel branch. Current in the right hand branch equals 3 amperes. Current in the left hand branch $= \frac{9 + 3R_X}{12}$ amperes.

Total current $= 3 + \frac{9 + 3R_X}{12}$

All of this current flows through the 5 ohm resistor in the main line. The voltage drop across the 5 ohm resistor equals $I \times R = \left(3 + \frac{9 + 3R_X}{12}\right) 5$

The voltage drop across the 5 ohm resistor $\left[\left(3 + \frac{9 + 3R_X}{12}\right)5\right]$ plus the voltage drop across the parallel branch $(9 + 3R_X)$ must **equal** the battery voltage (49).

Now we have an **equal** sign. We have an equation. Solve the equation for R_X and you will have the value of R_X. The equation is:

$$\left(3 + \frac{9 + 3R_X}{12}\right) 5 + 9 + 3R_X = 49$$

$$\left(3 + \frac{9}{12} + \frac{3R_X}{12}\right) 5 + 9 + 3R_X = 49$$

Changing the fraction to decimals: $(3 + .75 + .25R_X)\ 5 + 9 + 3R_X = 49$

Collecting terms inside parenthesis: $(3.75 + .25R_X)\ 5 + 9 + 3R_X = 49$

Removing parenthesis: $18.75 + 1.25R_X + 9 + 3R_X = 49$

Collecting terms: $4.25R_X + 27.75 = 49$

S : 27.75 $4.25R_X = 49 - 27.75 = 21.25$

D : 4.25 $R_X = \frac{21.25}{4.25} = 5$ ohms.

The best way to check the answer of 5 ohms is to let R_X equal 5 ohms in the circuit of Figure 7. How much current will flow through the right hand branch of the parallel circuit? Check our answer by using Ohm's Law to solve the circuit.

In the circuit of Figure 8, how large should we make the second battery in order to have point B 35 volts above point A in potential? (Point B, 35 volts positive in respect to point A.)

We will not set up an equation at first to obtain the answer. See if you can determine the proper size for the second battery E. Take time to try this one before you read the solution that follows.

Between points A and B we have 14 ohms of resistance. If we are to have 35 volts between points A and B, the current must be $I = \frac{E}{R} = \frac{35}{14} =$ 2.5 amperes. If point B is to be positive (above) with respect to point A, the added battery E must be the larger of the two (current will have to flow counter-clockwise in the circuit to have a — to + drop from A to B).

The total resistance in the circuit is 23 ohms. The total voltage must be $E = I \times R = 2.5 \times 23 = 57\frac{1}{2}$ volts. The added battery will have to be strong enough to cancel out the original $67\frac{1}{2}$ volts and produce an extra $57\frac{1}{2}$ volts. $E = 67\frac{1}{2} + 57\frac{1}{2} = 125$ volts.

Now, for practice, we will set-up an equation. The voltage E of the second battery will equal the sum of the voltage drops around the circuit.

$$E = I\,R + 67\tfrac{1}{2} = 2.5(3 + 2 + 1 + 8 + 5 + 4) + 67\tfrac{1}{2}$$
$$= 2.5(23) + 67\tfrac{1}{2}$$
$$57\tfrac{1}{2} + 67\tfrac{1}{2} = 125 \text{ volts.}$$

Why did we **add** the $67\frac{1}{2}$ volts of the original battery along with the IR voltage drops? Tracing the path of current around the circuit (counter-clockwise in this case) we find — to + voltages for the resistors **and** the $67\frac{1}{2}$ volt battery.

Summary

You should have learned something from this assignment. Do you think of electronics circuits any differently than before? The answer should be yes. You should have the feeling, that with experience, you could tackle any circuit.

In solving any electronics circuit proceed on a step by step basis. Be careful with plus and minus signs. Set up algebraic equations in practical problems only when you can find no other simple solution.

Test Questions

Be sure to number your Answer Sheet, **Assignment 20.**
Place your Name and Associate Number on **every** Answer Sheet.

Submit your Answers for this assignment immediately after you finish them. This will give you the greatest possible benefit from our personal grading service.

In answering these algebra problems, **show all of your work. Draw a circle around your answer.** Do your work neatly and legibly.

1. How many 1000 ohm resistors must be connected in series with a 2500 ohm resistor to obtain a total resistance equal to 9500 ohms?
2. (a) Write a simple **algebraic** equation for the voltage drop that results when a current of 2 amperes flow through a resistance of 3 ohms.
   (b) Solve this equation to find the voltage drop.
3. How many 1.5 volt batteries must be connected in series with a 15 volt battery, to make a total of 45 volts?
4. A **parallel** circuit has three branches. One branch current is 2 amperes, another branch current is 3 amperes, and the third branch current is 4 amperes.
   (a) Set up an equation to find the total current.
   (b) What is the value of the total current?
5. A 100, a 200, and a 600 ohm resistor are connected in series. How many 50 ohm resistors must be connected in series with them to obtain a total of 1250 ohms?
6. A 2000 ohm resistor and a 6000 ohm resistor are connected in series. If the voltage drop across the 2000 ohm resistor is 12 volts, what will the voltage drop across the 6000 ohm resistor be?
7. A 200 ohm resistor and a 600 ohm resistor are connected in parallel. If the current through the 200 ohm resistor is 6 amperes, what will the current through the 600 ohm resistor be?
8. (a) In the circuit of Figure 9, set up an **equation** for the voltage drop across the 1000 ohm resistor.
   (b) What is the value of this voltage drop?
9. (a) In the circuit of Figure 9, set up an **equation** to find the voltage drop from point A to point B. (Remember that this voltage will be equal to the battery voltage minus the voltage drop across the 1000 ohm resistor and the voltage drop across the 3000 ohm resistor.)
   (b) What is the value of the voltage drop from point A to point B?
10. How many 1.5 volt cells must be connected in series with a 45 volt battery to obtain a total of 67½ volts?

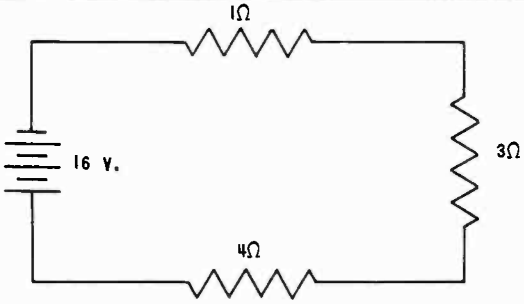

FIGURE 1

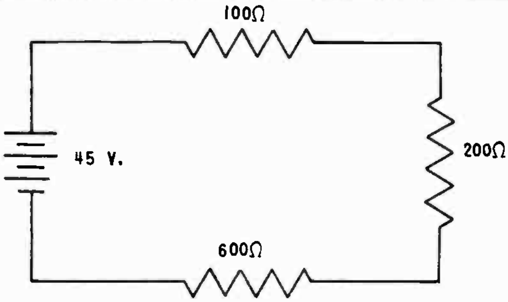

FIGURE 2

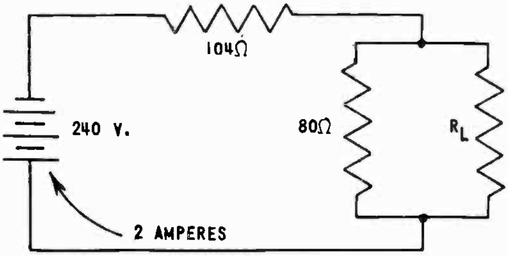

FIGURE 3

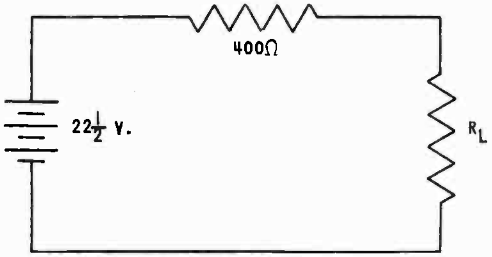

FIGURE 4

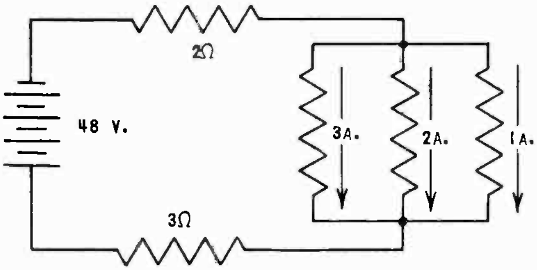

FIGURE 5

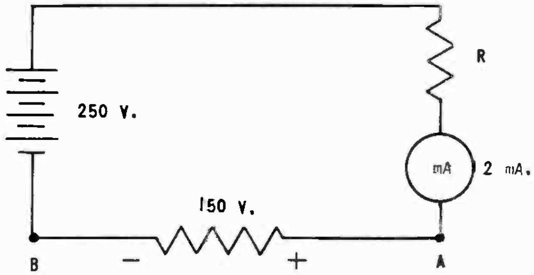

FIGURE 6

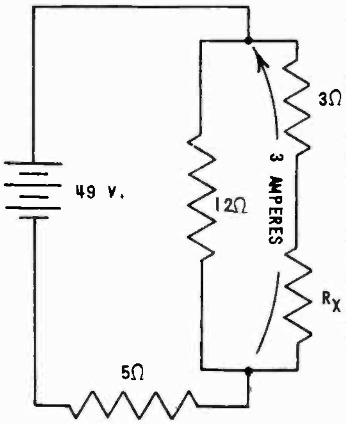

FIGURE 7

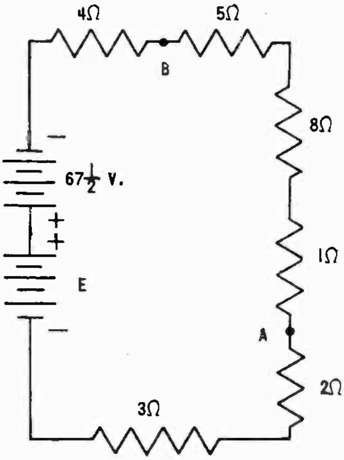

FIGURE 8

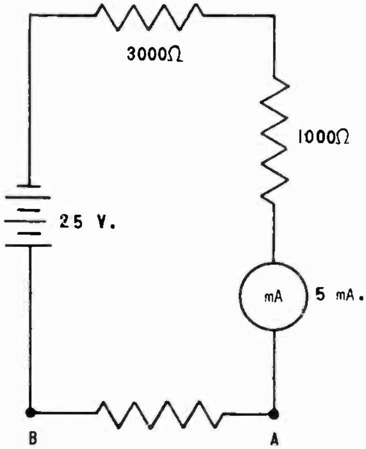

FIGURE 9