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CIRCUIT LAB

LEARNING

Build and test Direct Current electrical circuits (ages 14 and up)

by Mark Dovids and Sheldon Leemon

Requires: ATARI BASIC Language Cartridge
One ATARI Joystick Controller

Diskette version (1): (APX–20215)	ATARI 810 Disk Drive 32K RAM

Edition B

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Introduction

OVERVIEW

With CIRCUIT LAB, you learn about Direct Current (D.C.) electrical circuits by building and testing your own circuits. While a high school physics teacher designed it for the classroom, its "hands-on" approach makes it suitable for individual experimentation as well.

Choose from four basic circuit layouts: series, parallel, and combination series/parallel circuits. Once you've chosen a layout, place light bulbs, ammeters, resistors, switches, and voltmeters at various points in the circuit. Select individual resistance values for the resistors and light bulbs, and select the voltage of the battery that powers the circuit. After you've finished constructing the circuit, activate it by manipulating the switches, and read the meter values to see the relationship among the factors of voltage, current, and resistance. The circuit you build is so realistic that the lightbulbs even light up!

Once you've built your circuit and seen the results, you can go back and modify it by substituting components, and see what changes occur. After a few experiments, you should have a better understanding of the fundamentals of D.C. electrical circuits.

REQUIRED ACCESSORIES

ATARI BASIC Language Cartridge
One ATARI Joystick Controller
32K RAM
ATARI 810 Disk Drive

CONTACTING THE AUTHORS

Users wishing to contact the authors may write to:

Mark Davids
21825 O'Connor
St. Clair Shores
Michigan 48080

LOADING CIRCUIT LAB INTO COMPUTER MEMORY

1. Insert the ATARI BASIC Language Cartridge in the cartridge slot of your computer.

2. Plug your Joystick Controller into the first controller jack of your computer console.

3. Have your computer turned OFF.

4. Turn on your disk drive.

5. When the BUSY light goes out, open the disk drive door and insert the CIRCUIT LAB diskette with the label in the lower right-hand corner nearest to you. Close the door. (Use disk drive one if you have more than one drive.)

6. Turn on your computer and your TV set. The program will load into computer memory and start automatically.

THE FIRST DISPLAY SCREEN

When the program has loaded into computer memory, this title screen appears:

CIRCUIT LAB
BY
M. DAVIDS & S. LEEMON
C. 1982
PUSH FIRE TO BEGIN

Figure 1 First display screen

Using CIRCUIT LAB

SAMPLE SESSION

It's a good idea to read the manual and try out a sample session to get started. If you choose the suggested values, the circuit performs as it should, and a successful result is assured. After you see how the process works, you can experiment with different values. Instructions for the sample session appear in bold-face print below.

SETTING UP A CIRCUIT

When you push the red joystick button, this screen appears:

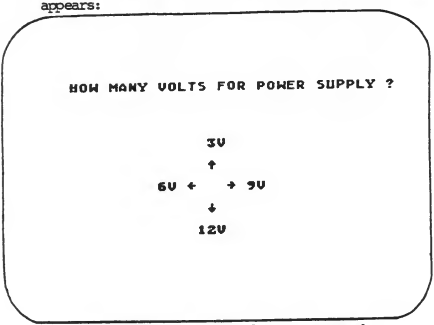


Figure 2 Volts for power supply

Now choose the voltage of your battery. Simply push the joystick up for 3 volts, left for 6 volts, and so on.

Choose 12 volts. Move the joystick down.

Now choose the resistance of the light bulbs.

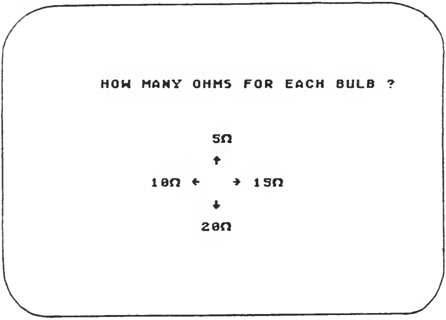


Figure 3 Resistance for light bulbs

Push the joystick up for 5 ohms, to the right for 15 ohms, and so on.

Move the joystick to the left to choose 10 ohms.

Now decide whether all the resistors should have the same value. The following screen appears:

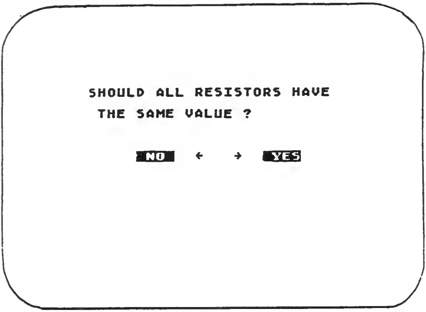


Figure 4 Value of resistors

A NO answer will allow more variety later. To answer, move the joystick to the right for YES, and to the left for NO.

Choose NO by moving the joystick to the left.

The following screen appears only if you answer NO to the last question (Figure 4):

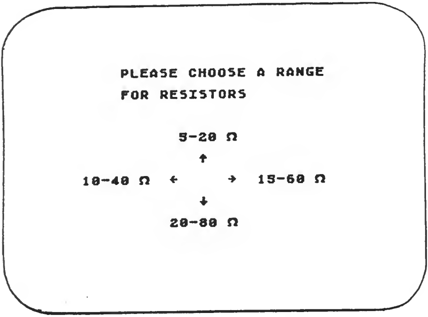


Figure 5 Range for resistors

Again, push the joystick in the direction of your choice.

Push UP for a value of 5 to 20 ohms.

Now you see CIRCUIT 1.

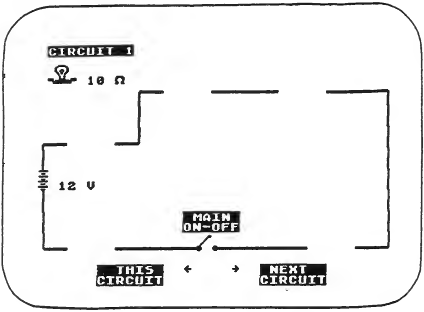


Figure 6 Circuit 1

Notice that the light bulb in the upper left corner has the resistance you selected.

The message at the bottom of the screen shows that you may choose this circuit (by moving the joystick to the left) or a different circuit (to the right). Circuits 2,3, and 4 are increasingly complex.

Move the joystick to the left to follow the circuit on the screen.

Begin filling in the circuit when the following screen appears:

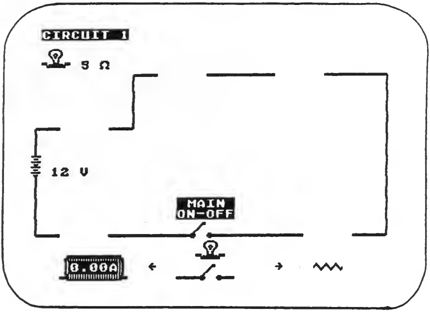


Figure 7 Circuit choices

On the TV screen, you see a set of brackets. The brackets show your present position in the circuit. The message at the bottom of the screen shows the choices you have for each open space in the circuit. Move the joystick to the left to position an ammeter in the open space. Move it up for a light bulb, to the right for a resistor, and down for a switch.

If you change your mind, move the joystick again, and your new choice replaces the previous one. When you've made your decision, press the red joystick button.

Move the joystick to the left to place an ammeter in the first space. Push the red joystick button. The brackets move to the next open position in the circuit.

Push the joystick UP. A light bulb appears in the second position. Take a moment to admire your work.

If you select a light bulb, you can choose to display a voltmeter above it. The following screen appears for your choice:

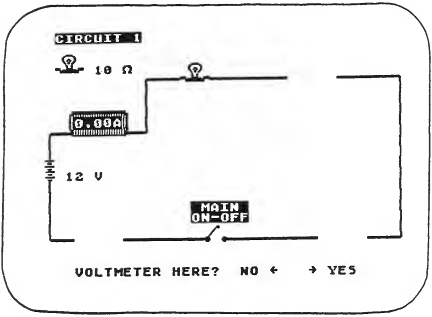


Figure 8 Voltmeter choice

Notice that the message at the bottom has changed again. You may draw a voltmeter whenever there's a bulb or a resistor.

Push the joystick to the right
to request a voltmeter.
Then press the red joystick button
to move the brackets to the next position.

Figure 9 shows Circuit 1 with an ammeter in the first place, and a light bulb with a voltmeter in the second position.

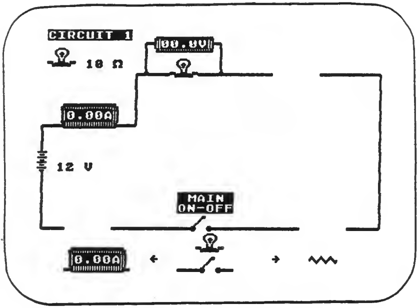


Figure 9 Circuit with ammeter, light bulb, and voltmeter

Move the joystick to the right for a resistor.

When you choose a resistor, you can decide on the values within the range you selected at the beginning of the program (see Figure 5). The message at the bottom of the screen shows your choices, as follows:

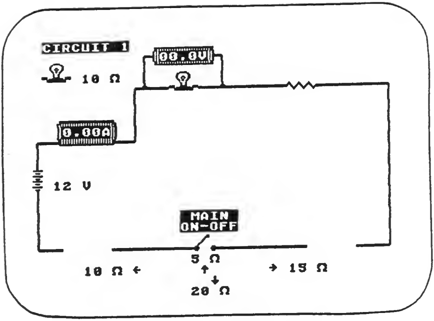


Figure 10 Value for specific resistor

Move the joystick down for 20 ohms.

When you select a resistor, you have the option of adding a voltmeter, as you did in Figure 8.

Draw a voltmeter by moving the joystick to the right and press the red joystick button. The brackets move to the next open position.

Figure 11 shows Circuit 1 with three positions filled.

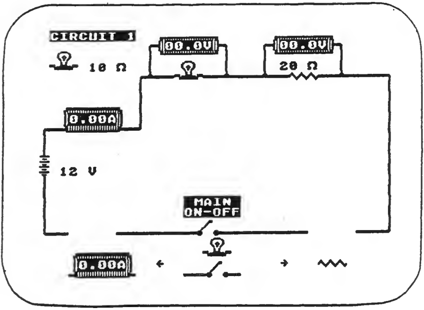


Figure 11 Partially completed circuit

Move the joystick up to draw a bulb.
Now draw a voltmeter.
Press the red joystick button
to move the brackets to the last opening.

Figure 12 shows Circuit 1 with only the last position remaining open.

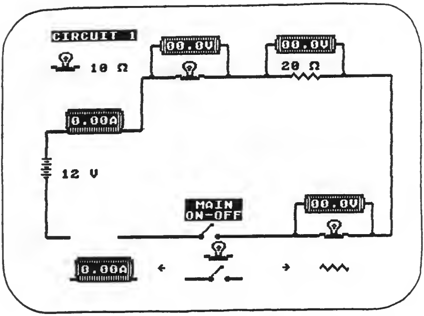


Figure 12 Circuit 1 with one position open

Move the joystick down to draw a switch in this last position and push the red joystick button to complete the circuit.

When all the spaces on the circuit are filled, a message flashes at the bottom of the screen, as in Figure 13.

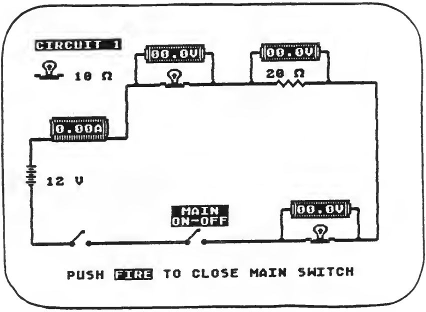


Figure 13 Instructions to close main switch

Hold the red joystick button down to close the main switch.

After a short sound, the MAIN SWITCH closes. If any other switches remain open, the instructions at the bottom of the screen look like this:

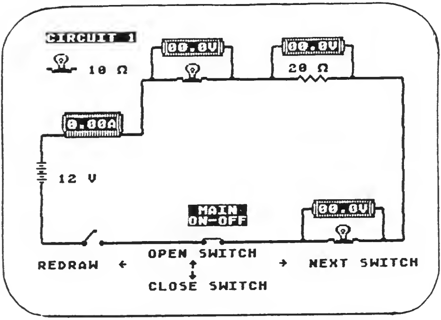


Figure 14 Options for open switches

Close the switch by pushing down on the joystick.

When all the switches are closed, and if you've selected options that work, the light bulbs light up. Figure 15 shows a successfully completed circuit.

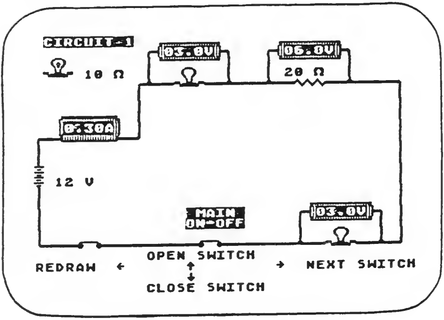


Figure 15 Successful circuit

IT WORKS!
Take a moment to admire your creation.

When you're finished with one circuit, move the joystick up to open the switch. The meter values go back to zero and the lights go off.

Circuit theory

CLOSED CIRCUITS AND OPEN CIRCUITS

All the circuits in this lab include a battery. The battery provides the potential energy to move the electrons through the circuit. The electrons flow whenever the two sides of the battery are connected by a conductive material. This is called a CLOSED CIRCUIT.

You may build the circuit with one or more switches. Opening a switch may break the path of the electron flow. A circuit that doesn't have at least one closed path is called an OPEN CIRCUIT.

SERIES AND PARALLEL CIRCUITS

Look carefully at Circuit 1. The electrons must pass through every element in the circuit to travel from one side of the battery to the other side. This type of circuit is called a SERIES circuit.

Look at Circuit 2. In this circuit the electrons might travel through the top path or the bottom path. Any circuit that provides more than one path for the electrons to flow is called a PARALLEL Circuit. Circuit 3 and Circuit 4 are also Parallel circuits.

CURRENT

The rate of the electron flow is called the current. The current is measured by building an ammeter in the circuit. In a Series circuit, the current is always the same at all points in the circuit. In a parallel circuit, the currents in parallel branches will add up to equal the current in the main branch.

The value of the current depends on two factors: the battery voltage and the total resistance in the circuit. This relationship is called Ohm's Law.

OHM'S LAW

The mathematical relation among current, voltage, and resistance is:

$$I = \frac{V}{R}$$ where I is current (in amps)
V is voltage (in volts)
R is resistance (in Ω)

This equation is valid for each element in the circuit and for the circuit as a whole.

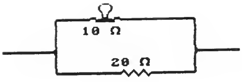
ADDING RESISTORS

There are two methods of adding resistors. If the resistors are in series, the effective resistance is the simple sum.

$$R = R1 + R2 = 10+20 = 30\ \Omega$$

Figure 16 Adding resistors in series

In the case below, the resistors are in parallel. (The electrical flow will split into two branches.) The resistors add as follows:



$$\frac{1}{R3,8} = \frac{1}{10} + \frac{1}{20} = \frac{3}{20} \qquad R3,8 = \frac{20}{3} = 6.7\,\Omega$$

Figure 17 Adding resistors in parallel

Note that the effective resistance is ALWAYS SMALLER than the resistance in either branch!

KIRCHOFF'S LAWS

A. Series circuits share the current and split the voltage. This rule implies that: 1. The current must always be the same at all points in a series circuit, and 2. The voltage drops across the resistors must add up to equal the voltage of the battery. See the circuit below.

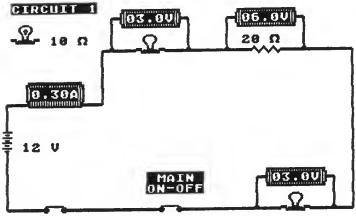


Figure 18 Kirchoff's Law - series circuit

B. Parallel circuits share the voltage and split the current. (See the example below.) Note that voltage across each branch is the same. Also note that the current in the parallel branches adds up to equal the current in the main branch.

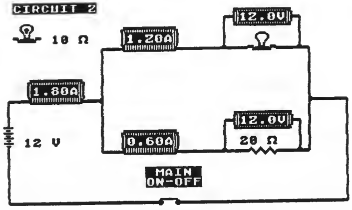


Figure 19 Kirchoff's Law - parallel circuit

Calculations for Circuit 1

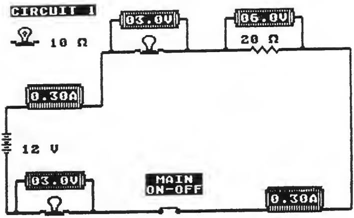


Figure 20 Calculations for Circuit 1

The first step is to calculate the total resistance in the circuit. The total resistance is the simple sum of the resistors.

$$
\begin{aligned}
Rt &= R1 + R2 + R3 + R4 + R5 \\
&= 0 + 10 + 20 + 0 + 10 \\
&= 40\ \Omega
\end{aligned}
$$

The next step is to apply Ohm's law to find the current in the circuit.

$$I = \frac{Vbattery}{Rt} = \frac{12}{40} = 0.30 \text{ amps}$$

The current must be the same through all points of a SERIES circuit. The voltage can be calculated by applying Ohm's law to each element in the circuit .

V2 = R2 * I	V3 = R3 * I	V5 = R5*I
= 10 * 0.3	= 20 * 0.3	= 10*0.3
V2 = 3.0 volts	V3 = 6.0 volts	V5 = 3.0 volts

Calculations for Circuit 2

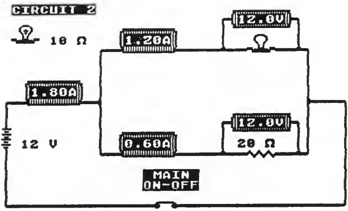


Figure 21 Calculations for Circuit 2

The first step is to calculate the resistance of the parallel branches. The resistance of the branches is :

$$\frac{1}{Rloop} = \frac{1}{Rtop} + \frac{1}{Rbot}$$

$$\frac{1}{Rloop} = \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{Rloop} = \frac{2}{20} + \frac{1}{20} = \frac{3}{20}$$

$$Rloop = 6.7\,\Omega$$

The next step is to calculate the total resistance of the circuit. The total resistance is :

$$Rt = Rloop + R1 + R4 + R5$$

$$= 6.7 + 0 + 0 + 0$$

$$Rt = 6.7\ \Omega$$

Next, find the current in the main branch. Apply Ohm's law to the circuit as a whole :

$$I = \frac{Vbattery}{Rt} = \frac{12}{6.7} = 1.80 \text{ amps}$$

Ohm's law can now be used to determine the voltage across the resistors in the main branch.

$V1 = R1*I$ $\quad$ $V4 = R4*I$ $\quad$ $V5 = R5*I$

$= 0*1.80$ $\quad$ $= 0*1.80$ $\quad$ $= 0*1.80$

$V1 = 0$ volts $\quad$ $V4 = 0$ volts $\quad$ $V5 = 0$ volts

The next step gives the current through each of the parallel branches. The current in the top branch is:

$$Itop = \frac{I * Rloop}{Rtop} = \frac{1.8 * 6.7}{10} = 1.2 \text{ amps}$$

The current through the bottom parallel branch is:

$$Ibot = \frac{I * Rloop}{Rbot} = \frac{1.8 * 6.7}{20} = 0.6 \text{ amps}$$

Again apply Ohm's Law to find the voltage across the components in the parallel branches.

For the top branch :

V2 = Itop * R2 and V3 = Itop * R3

= 1.2 * 0 = 1.2 * 10

V2 = 0 volts V3 = 12 volts

For the bottom branch :

V6 = Ibot * R6 and V7 = Ibot * R7

= 0.6 * 0 = 0.6 * 20

V6 = 0 volts V7 = 12 volts

Calculations for Circuit 3

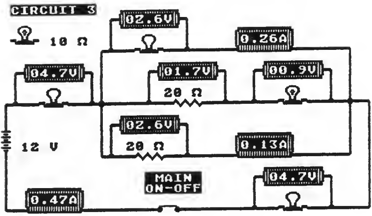


Figure 22 Calculations for Circuit 3

The first step is to calculate the resistance of each parallel branch.

Rtop = R2+R3 Rmid = R8+R9 Rbot = R6+R7

= 10+0 = 10+20 = 20+0

Rtop = 10Ω Rmid = 30Ω Rbot = 20Ω

Now find the effective resistance of all parallel branches. Study this example carefully. This is the most difficult of all the calculations.

$$\frac{1}{Rloop} = \frac{1}{Rtop} + \frac{1}{Rmid} + \frac{1}{Rbot}$$

$$\frac{1}{Rloop} = \frac{1}{10} + \frac{1}{30} + \frac{1}{20}$$

$$\frac{1}{Rloop} = \frac{6}{60} + \frac{2}{60} + \frac{3}{60} = \frac{60}{11}$$

$$Rloop = 5.45\Omega$$

The total resistance of the circuit is equal to the effective resistance of the parallel branches plus the resistors in the main branch.

$$Rt = Rloop + R1 + R4 + R5$$

$$= 5.45 + 10 + 10 + 0$$

$$Rt = 25.45\Omega$$

The current in the main branch IS ALWAYS:

$$I = \frac{Vbattery}{Rt} = \frac{12}{25.45} = 0.47 \text{ amps}$$

Now you can determine the voltages across each resistor in the main branch.

V1 = I * R1	V4 = I * R4	5 = I * R5
= 0.47*10	= 0.47*10	= 0.47*0
V1 =4.7 volts	V4 =4.7 volts	V5 =0 volts

The current in the parallel branches must add up to the value in the main branch. The current in the top parallel branch is:

$$Itop = \frac{I * Rloop}{Rtop}$$

$$= \frac{0.47 * 5.45}{10}$$

$$Itop = 0.26 \text{ amps}$$

The current in the middle parallel branch is:

$$Imid = \frac{I * Rloop}{Rmid}$$

$$= \frac{0.47 * 5.45}{30}$$

$$Imid = 0.09 \text{ amps}$$

The current in the bottom parallel branch is:

$$Ibot = \frac{I * Rloop}{Rbot}$$

$$= \frac{0.47 * 5.45}{20}$$

$$Ibot = 0.13 \text{ amps}$$

The voltage across each resistor in the parallel branches can be found by Ohm's law. For the top branch:

V2 = Itop * R2 and V3 = Itop * R3

= 0.26 * 10 = 0.26 * 0

V2 = 2.6 volts V3 = 0 volts

For the middle parallel branch:

V8 = Imid * R8 and V9 = Imid * R9

= 0.085*20 = 0.085*10

V8 = 1.7 volts V9 = 0.9 volts

For the bottom parallel branch:

V6 = Ibot * R6 and V7 = Ibot * R7

= 0.13*20 = 0.13*0

V6 = 2.6 volts V7 = 0 volts

Calculations for Circuit 4

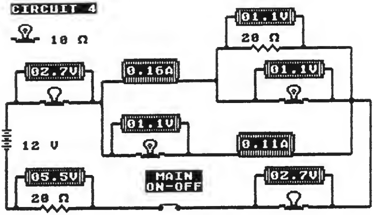


Figure 23 Calculations for Circuit 4

To solve this circuit, carefully apply the rules for series and parallel circuit. First find the effective resistance of resistor R3 and R8. These resistors are in parallel (with each other) so that the effective resistance is:

$$\frac{1}{Rloop} = \frac{1}{R3} + \frac{1}{R8} = \frac{1}{20} + \frac{2}{20} = \frac{3}{20}$$

$$Rloop = \frac{20}{3} = 6.7\,\Omega$$

These resistors are in series with the resistor in position 2. The effective resistance of all 3 is:

$$Rtop = R2 + R3,8 = 0 + 6.7$$

$$Rtop = 6.7\,\Omega$$

Next, find the effective resistance of the bottom parallel branch. Since these resistors are in series, the effective resistance is the simple sum.

Rbot = R6 + R7 = 10 + 0 = 10

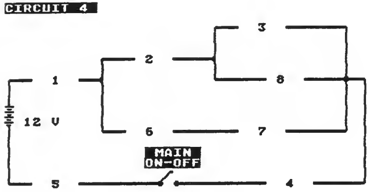


Figure 24 Numbered positions in the circuit

The circuit may now be compared to Circuit 2. The effective resistance of the parallel branches is:

$$\frac{1}{Rloop} = \frac{1}{Rtop} + \frac{1}{Rbot}$$

$$\frac{1}{Rloop} = \frac{1}{6.7} + \frac{1}{10}$$

$$Rloop = 4.0\,\Omega$$

The total resistance in the circuit is equal to the effective resistance of the parallel branches plus the resistors in the main branch.

$$Rt = Rloop + R1 + R4 + R5$$

$$= 4.0 + 10 + 10 + 20$$

$$Rt = 44.0\,\Omega$$

The total resistance in the circuit can be used to find the current in the main branch. Use Ohm's law.

$$I = \frac{Vbattery}{Rt} = \frac{12}{44} = 0.27 \text{ amps}$$

The resistors in positions 1,4, and 5 are in the main branch. The current through these positions has just been calculated. Now find the voltage across each position using Ohm's law.

V1 = I * R1   V4 = I * R4   5 = I * R5

= 0.27*10   = 0.27*10   = 0.27*20

V1 = 2.7 volts V4 = 2.7 volts 5 = 5.5 volts

The current through position 1 will split when it reaches the parallel branches. The current through the bottom parallel branch is:

$$Ibot = \frac{I * Rloop}{Rbot} = \frac{0.27*4.0}{10} = 0.11 \text{ amps}$$

The voltage across these resistors is given by Ohm's law.

$$V6 = Ibot * R6 \quad \text{and} \quad V7 = Ibot * R7$$

$$= 0.11 * 10 \qquad = 0.11 * 0$$

$$V6 = 1.1 \text{ volts} \qquad v7 = 0 \text{ volts}$$

The current through the top parallel branch (position 2) is :

$$I2 = \frac{I * Rloop}{Rtop} = \frac{0.27 * 4.0}{0.67} = 0.16 \text{ amps}$$

The current through position 2 will split again. Some current will go through position 3. The rest will go through position 8. The current through position 3 is:

$$I3 = \frac{I2 * R3,8}{R3} = \frac{0.16 * 6.7}{20} = 0.055 \text{ amps}$$

The current through position 8 is:

$$I8 = \frac{I2 * R3,8}{R8} = \frac{0.16 * 6.7}{10} = 0.11 \text{ amps}$$

Last, use Ohm's Law to find the voltage across these resistors.

$$V3 = I3 * R3 \quad \text{and} \quad V8 = I8 * R8$$

$$= 0.055*20 \qquad = 0.11*10$$

$$V3 = 1.1 \text{ volts} \quad V8 = 1.1 \text{ volts}$$

Questions and extra circuits for practice

Now, let's find out what you've learned. The next four pages have sample circuits. Try to answer these questions before actually building them:

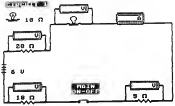
1. Will all bulbs have the same brightness? If not,which bulb(s) will be the brightest?

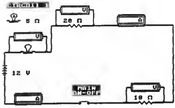
2. Will the values of the current (on the ammeters) be the same? If not, then where will the current be the greatest? Explain your answer.

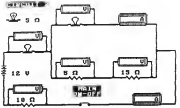
3. Will the values on the voltmeters be the same? If not, then which will have the highest value? Explain your answer.

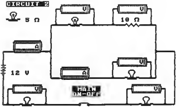
After answering these questions, follow the steps in the sample calculations. See if you can calculate the correct values on the meters. DON'T BUILD THE CIRCUITS until you've calculated all the values for the meters!

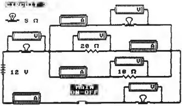
If your values are correct then pat yourself on the back. If your values are different, then try again and be careful with the math.


CIRCUIT 1
10 Ω
V
A
V
20 Ω
6 V
V
MAIN
ON-OFF
V
10 Ω
5 Ω

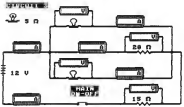

CIRCUIT 1
5 Ω
V
20 Ω
A
V
12 V
MAIN
ON-OFF
V
A
10 Ω


CIRCUIT
5 Ω
V
V
A
12 V
V
5 Ω
V
15 Ω
V
10 Ω
MAIN
ON-OFF
A

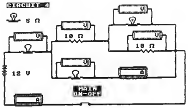

CIRCUIT 2
5 Ω
V
V
10 Ω
A
12 V
A
V
V
MAIN
ON-OFF
V



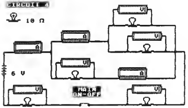
5 Ω
V
A
20 Ω
12 V
10 Ω
MAIN
ON-OFF



CIRCUIT 3
5 Ω
V
A
20 Ω
12 V
MAIN
ON-OFF
15 Ω



CIRCUIT 4
5 Ω
10 Ω
10 Ω
12 V
MAIN
ON-OFF



CIRCUIT 4
10 Ω
6 V
MAIN
ON-OFF