Electronic Trainer

Kirchoff’s Laws

The best thing about Kirchoff’s Laws is that there are only two of them!

Kirchoff’s loop rule says that the sum of the voltage gains and drops around any closed loop will be zero.

Kirchoff’s junction rule says that the sum of the currents going into a single junction equals the sum of the currents exiting the junction. This is also called “conservation of charge.”

Equipment:
Electronics Trainer
Multimeter
Resistors: 1000, 2200 & 4700Ω

Cautions:
This equipment is delicate. Avoid bending the components if you don’t have to. Do not apply power until you are instructed to do so!!

Never Never Never short-circuit the power supply! Doing so will (if you are lucky) blow the fuse. If you’re not lucky, it will blow the whole $200 trainer unit! Don’t plug a wire into the trainer unless you are told to do so!

Be very cautious when using the meter to read current! While in the amperage mode, if you put the meter across a voltage source without a series resistance you will blow a fuse in the meter. The meter will have to be disassembled to replace this fuse, which will not please your teacher in the least! As a rule of thumb, never leave the red lead plugged into the “µAmA” socket. Always move the red lead to the “VΩ” socket when done taking a current measurement.

How to read resistor color codes:
Since resistors are so small, they are marked with colored bands to give the resistance value. Knowing how to read the resistor color code is required if you want to do this lab correctly. You can also use this knowledge to impress your friends at parties!

Each number is represented by a color thus
Black  0
Brown  1
Red    2
Orange 3
Yellow 4
Green  5
Blue   6
Violet 7
Grey   8
White  9

The precision (how accurate the resistor is guaranteed to be) is represented by:
Silver  10%
Gold   5%
None   20%
OK, so let’s read a resistor! First you have to figure out which end to start from. If the resistor has a gold or silver band, then you start from the other end. If it doesn’t, you start from the band that is closest to the end of the resistor. Let’s say that the resistor you are reading is marked Yellow-Violet-Orange-Gold. The tolerance band (Gold, Silver, or none) comes last.

Yellow stands for “4”, Violet stands for “7”, Orange stands for “3” and Gold stands for “5%”

Now let’s start putting these together. You simply write the first two digits “47” down as is. The third digit, called a “multiplier” is the number of zeros that follow the first two digits. In this case, Orange translates to “000”, so this resistor has a value of 47,000Ω and a tolerance of 5%. Many resistors have large values, so they are listed in kΩ (thousand of ohms) or MΩ (millions of ohms). 47,000Ω is equal to 47kΩ.

Let’s try one of your own, Brown, Black, Yellow, and Gold.

What is Brown? Write it here:
What is Black? Write it here:
What is Yellow? Write it here:
What is Gold? Write it here:

Now, write the first two numbers:

Behind those, write the number of zeros specified by the third number.

And, you’ve already written the tolerance! You’re now a color code expert!

**Procedure to verify Kirchoff’s laws:**
The breadboard is set up with three rows of power sockets marked with blue (-) and red (+) lines called a “power bus”. The rest of the breadboard consists of four banks of sockets in a grid marked vertically with letters and horizontally with numbers. Each vertical set of five sockets are connected together within the breadboard. For example, socket 5a is connected to 5b, 5c, 5d, and 5e, but not to 5f. In addition, the upper breadboard is not connected to the lower breadboard. You will plug components directly into the breadboard sockets and use jumper wires to connect them together.

You will be setting up a simple series-parallel circuit to verify Kirchoff’s laws. This circuit will have two resistors in parallel connected in series to another resistor and a power source. Let’s get to it!

1. Open the trainer, make sure that the rocker switch is toward “OFF” and plug the line cord into a wall outlet.

Note: This circuit will be constructed entirely on the upper breadboard and upper power bus. In other words, looking at the top of the white section inside the Trainer there is a red and blue line with a section just under it vertically labeled a-e and f-j and columns
numbered horizontally 1-63, this is the UPPER breadboard. Do not put any components on the lower breadboard or the middle or lower power buses.

2. Using a medium black jumper, connect one of the “GND” sockets (found just to the left of the breadboard) on the power supply with the leftmost socket just below the blue line on the upper edge of the upper breadboard. *This will be your negative power bus.*

3. Using a medium red jumper, connect one of the “+5” sockets to the leftmost socket just above the red line on the upper breadboard. *This will be your positive power bus.*

4. Locate a 1000Ω resistor and use it to connect socket 5f to socket 15f.

5. Locate a 2200Ω resistor and use it to connect socket 25j to socket 35j.

6. Locate a 4700Ω resistor and use it to connect socket 25a to socket 35a.

One of the basic realities of life is that resistors seldom have exactly the values they say. That’s why they have a tolerance band! Now you will use the meter to measure the actual resistances of the three resistors:

7. Plug the socket end (90° bend) of the black test lead into the “COM” terminal of the meter and the socket end of the red test lead into the “VΩ” terminal of the meter.

8. Turn the meter’s dial to “20K” on the “Ω” scale.”

9. Make sure that the power switch on the trainer is in the “OFF” position. *Taking resistance readings from a powered circuit will ruin the meter! Even though these resistors aren’t hooked to anything yet, it is good practice to make sure that there is no chance of accidentally measuring a powered circuit.*

10. Touch each of the meter leads to opposite metal leads of the 1000Ω resistor. The meter is reading in thousands of ohms, so multiply the meter reading by 1000 and record the true value here under the nominal value:

<table>
<thead>
<tr>
<th>Nominal Value</th>
<th>1000Ω</th>
<th>2200Ω</th>
<th>4700Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Value</td>
<td>Ω</td>
<td>Ω</td>
<td>Ω</td>
</tr>
</tbody>
</table>

11. Repeat the same process for the other two resistors and add their true values to the table.

12. Turn the meter knob to the “0” (off) position

Now you’ll finish the circuit by adding jumpers.

13. Use a short red jumper to connect socket 5j to the socket on the positive power bus directly above it. *This is the socket just above the red line.*

14. Use a medium white jumper to connect socket 15h with socket 25h

15. Use a short white jumper to connect socket 25f with socket 25e.

16. Use a short white jumper to connect socket 35f with socket 35e.
17. Use a short blue jumper to connect socket 35g with the negative power bus above it. *This is the socket just below the blue line.*

18. Go back and check all connections made to this point. It is best if the group member who didn’t make the connections does the checking!

19. Once you’ve made sure your circuit is correct, draw a schematic of it.

Next, you will take some voltage measurements across each resistor.

20. Make sure that the black test lead is still plugged into the “COM” terminal of the meter and the red test lead is in the “VΩ” terminal of the meter.

21. Turn the meter’s dial to “20” on the “V” scale.”

22. Turn the power switch on the trainer to the “ON” position. *The circuit is now “hot”!* *The voltages are low, however, so there’s no concern about shocks.*

23. Touch the meter probes to both sides of the 1000Ω resistor, the red probe to the lead going into socket 5f and the black probe to the lead going into socket 15f. Record the meter reading in the table below (Do not divide by 1000):

<table>
<thead>
<tr>
<th>Resistor</th>
<th>1000Ω</th>
<th>2200Ω</th>
<th>4700Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
</tbody>
</table>

24. In a similar way, measure and record the voltages across the 2200Ω (red probe to 25j, black to 35j) and 4700Ω (red to 25a, black to 35a) resistors. *Is it any surprise that these voltages are the same?*

Next, you will need to find the supply voltage. This is nominally 5V, but the real world may be different.

25. Measure from the resistor lead going into socket 5f (red probe) to the resistor lead going into socket 35a (black probe). *These leads are connected directly to the voltage supply bus bar through the red and blue jumpers.* Write the supply voltage here:

Kirchhoff’s law states that the voltage around any closed loop (“round trip”) will add up to zero. The supply voltage is a voltage gain, while the voltages across the resistors are voltage losses, which are negative. If you refer to the schematic or the circuit you built, you will see that one loop consists of the voltage supply, the 1000Ω resistor, and the 4700Ω resistor.

Add up the values and see what the result is:

\[
V_{\text{supply (pos.)}} + V_{1000 \text{ (neg.)}} + V_{4700 \text{ (neg.)}} = V_{\text{net}}
\]
Did you get zero or close to zero? If you did, Kirchhoff’s loop rule worked! If not, either
you’ve discovered a new law of physics (do not pass Go, fly directly to Stockholm to
collect your Nobel prize) or something was awry in your data or calculations. Like all
good experimenters, you should go back and double-check your results!

Now you will analyze your data and predict the current through each resistor. Just to
keep everything straight, transfer your existing data to the following table:

<table>
<thead>
<tr>
<th>Resistor</th>
<th>1000Ω</th>
<th>2200Ω</th>
<th>4700Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>True Resistance</td>
<td>Ω</td>
<td>Ω</td>
<td>Ω</td>
</tr>
<tr>
<td>Calculated Current</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Actual Current</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

26. Using Ohm’s law (I=V/R) calculate the current for each resistor using the voltage
and true resistance data you found in #22 & #24. Remember: “I” represents
current in Amperes; “V” represents voltage in Volts; and “R” represents
resistance in Ohms. Fill in the appropriate spaces in the table.

Now that you have calculated the currents through the resistors, you will now measure
them directly. In order to measure current, you must put an ammeter (configured
multimeter) in series with the resistor. You must be careful
doing this, since excessive
currents will damage the meter. If you put the
ammeter directly across a voltage supply
it will be damaged, probably by a fuse blowing. This is very easy to do, so be sure to
follow the next few instructions carefully and exactly!

27. Plug the black test lead into the “COM” terminal of the meter and the red test
lead into the “µAmA” terminal of the meter.

28. Turn the meter’s dial to “20m/10A” on the “A” scale.

29. Pull the end of the 1000Ω resistor out of socket 5f. Do not allow the end of this
resistor to fall into any other hole in the breadboard. You can safely allow it to
rest in the groove between rows e and f.

30. Insert a yellow jumper into socket 5f.

31. Touch the black test probe to the free end of the resistor and the red test probe
to the free end of the yellow jumper. Divide the meter reading by 1000 (to
convert mA to A) and record the meter reading in the table above.

32. Remove the yellow jumper and return the 1000Ω resistor lead to socket 5f

33. Pull the end of the 2200Ω resistor out of socket 25j. Do not allow the end of this
resistor to fall into any other hole in the breadboard. You can safely allow it to
rest in the groove between row j and the power bus.
34. Insert a yellow jumper into socket 25j.

35. Touch the black test probe to the free end of the resistor and the red probe to the free end of the yellow jumper. Divide the meter reading by 1000 (to convert mA to A) and record the meter reading in the table above.

36. Remove the yellow jumper and return the 2200Ω resistor lead to socket 25j.

37. Pull the end of the 4700Ω resistor out of socket 25a. Do not allow the end of this resistor to fall into any other hole in the breadboard. You can safely allow it to rest in the groove below row a.

38. Insert a yellow jumper into socket 25a.

39. Touch the red test probe to the free end of the resistor and the black test probe to the free end of the yellow jumper. Divide the meter reading by 1000 (to convert mA to A) and record the meter reading in the table above.

40. Move the red test lead from the “µAmA” socket to the “VΩ” socket on the meter. This protects the meter from being accidentally subjected to high currents.

41. Turn the meter knob to the “0” position. (Off!)

42. Turn the power switch on the trainer to the “OFF” position.

43. Remove the yellow jumper and return the 4700Ω resistor lead to socket 25a.

44. Now you will analyze your data to see if your circuit conforms to Kirchoff’s loop rule. The 1000Ω resistor feeds into a junction that in turn feeds the 2200Ω and 4700Ω resistors. The current through the 1000Ω resistor, therefore, should be divided between the 2200Ω and 4700Ω resistors. Let’s check that out!

45. On the chart below, fill in your values for $I_{2200}$, $I_{4700}$, and $I_{1000}$. Then, calculate the value for $I_{junction}$. Is this value close to or equal to $I_{1000}$? If not, read note above about Nobel Prize and checking your work!

\[
\begin{array}{c}
I_{2200} \\
+ \\
I_{4700} \\
+ \\
I_{junction} \\
= \\
= \\
= \\
I_{1000}
\end{array}
\]

46. Return all jumpers and components to their original containers.

47. Disconnect the trainer and stow the line cord.

48. Close the trainer and return the lab station to the condition in which you found it.
Answer the following questions:

How did your experiment verify Kirchoff’s Loop Rule?

How did your experiment verify Kirchoff’s Junction Rule?

What possible sources of error were there in this experiment? List at least two and state ways that these errors could be minimized.