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Laboratory Manual

For

DC Electrical Circuit Analysis

(Part one)

Laboratory Staff

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The Electrical Laboratory

Objective

The laboratory emphasizes the practical, hands-on component of this course. It complements the theoretical material presented in lecture, and as such, is integral and indispensible to the mastery of the subject. There are several items of importance here including proper safety procedures, required tools, and laboratory reports. This exercise will finish with an examination of scientific and engineering notation, the standard form of representing and manipulating values.

Lab Safety and Tools

If proper procedures are followed, the electrical lab is a perfectly safe place in which to work. There are some basic rules: No food or drink is allowed in lab at any time. Liquids are of particular danger as they are ordinarily conductive. While the circuitry used in lab is normally of no shock hazard, some of the test equipment may have very high internal voltages that could be lethal (in excess of 10,000 volts). Spilling a bottle of water or soda onto such equipment could leave the experimenter in the receiving end of a severe shock. Similarly, items such as books and jackets should not be left on top of the test equipment as it could cause overheating.

Each lab bench is self contained. All test equipment is arrayed along the top shelf. Beneath this shelf at the back of the work area is a power strip. All test equipment for this bench should be plugged into this strip. None of this equipment should be plugged into any other strip. This strip is controlled by a single circuit breaker which also controls the bench light. In the event of an emergency, all test equipment may be powered off through this one switch. Further, the benches are controlled by dedicated circuit breakers in the front of the lab. Next to this main power panel is an A/B/C class fire extinguisher suitable for electrical fires. Located at the rear of the lab is a safety kit. This contains bandages, cleaning swaps and the like for small cuts and the like. For serious injury, the Security Office will be contacted.

A lab bench should always be left in a secure mode. This means that the power to each piece of test equipment should be turned off, the bench itself should be turned off, all AC and DC power and signal sources should be turned down to zero, and all other equipment and components properly stowed with lab stools pushed under the bench.

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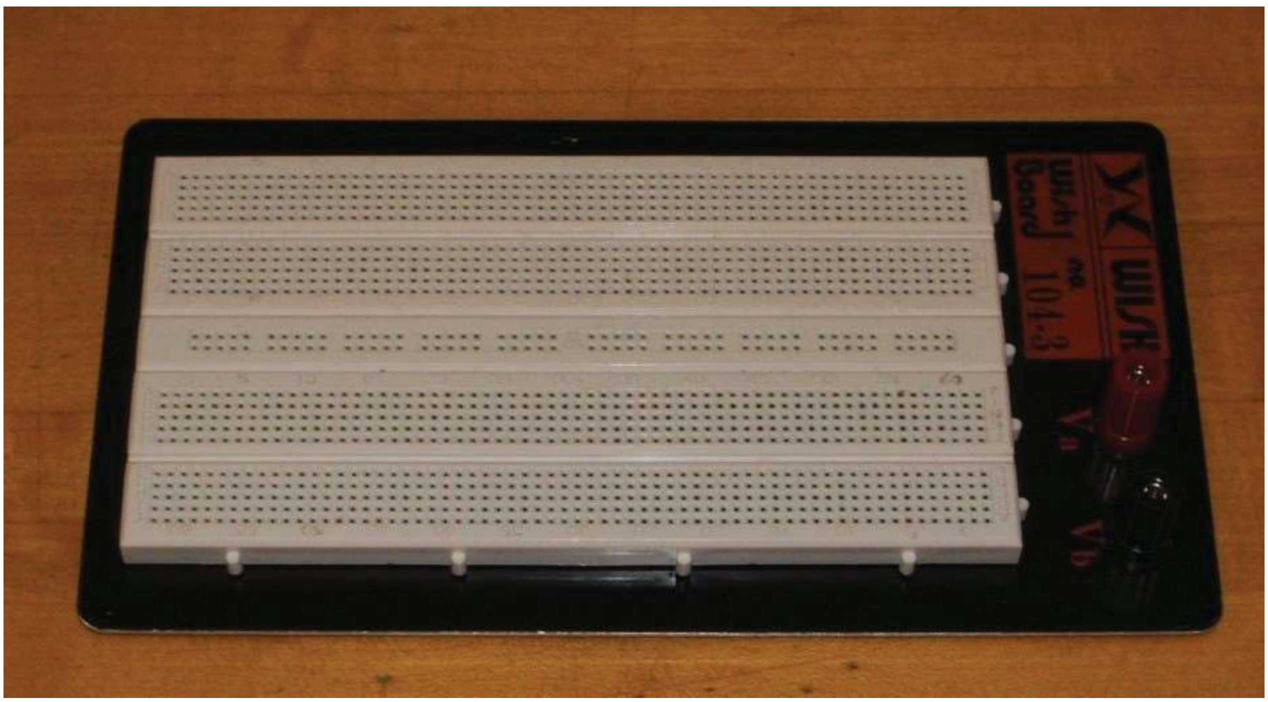
It is important to come prepared to lab. This includes the class text, the lab exercise for that day, class notebook, calculator, and hand tools. The tools include an electronic breadboard, test leads, wire strippers, and needle-nose pliers or hemostats. A small pencil soldering iron may also be useful. A basic DMM (digital multimeter) rounds out the list.

A typical breadboard or protoboard is shown below:



This particular unit features two main wiring sections with a common strip section down the center. Boards can be larger or smaller than this and may or may not have the mounting plate as shown. The connections are spaced 0.1 inch apart which is the standard spacing for many semiconductor chips. These are clustered in groups of five common terminals to allow multiple connections. The exception is the common strip which may have dozens of connection points. These are called *buses* and are designed for power and ground connections. Interconnections are normally made using small diameter solid hookup wire, usually AWG 22 or 24. Larger gauges may damage the board while smaller gauges do not always make good connections and are easy to break.

In the picture below, the color highlighted sections indicate common connection points. Note the long blue section which is a bus. This unit has four discrete buses available. When building circuits on a breadboard, it is important to keep the interconnecting wires short and the layout as neat as possible. This will aid both circuit functioning and ease of troubleshooting.

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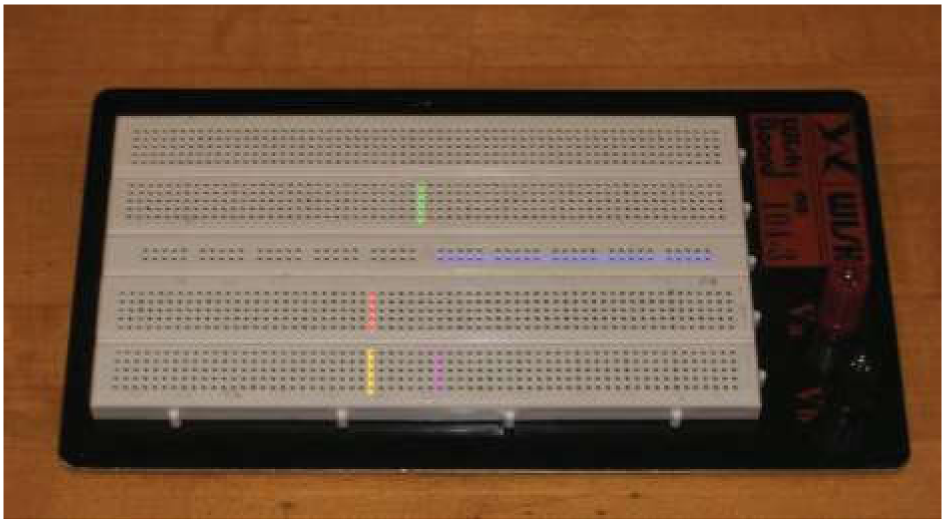

Laboratory Reports

Unless specified otherwise, all lab exercises require a non-formal laboratory report. Lab reports are individual endeavors not group work. The deadline for reports is one week after the exercise is performed. A letter grade is subtracted for the first half-week late and two letter grades are subtracted for the second half-week late. Reports are not acceptable beyond one week late. A basic report should include a statement of the Objective (i.e., those items under investigation), a Conclusion (what was found or verified), a Discussion (an explanation and analysis of the lab data which links the Objective to the Conclusion), Data Tables and Graphs, and finally, answers to any problems or questions posed in the exercise.

Scientific and Engineering Notation

Scientists and engineers often work with very large and very small numbers. The ordinary practice of using commas and leading zeroes proves to be very cumbersome in this situation. Scientific notation is more compact and less error prone method of representation. The number is split into two portions: a precision part (the mantissa) and a magnitude part (the exponent, being a power of ten). For example, the value 23,000 could be written as 23 times 10 to the 3rd power (that is, times one thousand). The exponent may be thought of in terms of how places the decimal point is moved to the left. Spelling this out is awkward, so a shorthand method is used where “times 10 to the X power” is replaced by the letter E (which stands for exponent). Thus, 23,000 could be written as 23E3. The value 45,000,000,000 would be written as 45E9. Note that it would also be possible to write this number as 4.5E10 or even 0.45E11. The

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only difference between scientific notation and engineering notation is that for engineering notation the exponent is always a multiple of three. Thus, 45E9 is proper engineering notation but 4.5E10 isn't. On most scientific calculators E is represented by either an "EE" or "EXP" button. The process of entering the value 45E9 would be depressing the keys 4 5 EE 9.

For fractional values, the exponent is negative and may be thought of in terms how many places the decimal point must be moved to the right. Thus, 0.00067 may be written as 0.67E−3 or 6.7E−4 or even 670E−6. Note that only the first and last of these three are acceptable as engineering notation.

Engineering notation goes one step further by using a set of prefixes to replace the multiples of three for the exponent. The prefixes are:

E12 = Tera (T)	E9 = Giga (G)	E6 = Mega (M)	E3 = kilo (k)
E–3 = milli (m)	E–6 = micro (μ)	E–9 = nano (n)	E–12 = pico (p)

Thus, 23,000 volts could be written as 23E3 volts or simply 23 kilovolts.
Besides being more compact, this notation is much simpler than the ordinary form when manipulating wide ranging values. When multiplying, simply multiply the precision portions and add the exponents. Similarly, when dividing, divide the precision portions and subtract the exponents. For example, 23,000 times 0.000003 may appear to be a complicated task. In engineering notation this is 23E3 times 3E−6. The result is 69E−3 (that is, 0.069). Given enough practice it will become second nature that kilo (E3) times micro (E−6) yields milli (E−3). This will facilitate lab estimates a great deal. Continuing, 42,000,000 divided by 0.002 is 42E6 divided by 2E−3, or 21E9 (the exponent is 6 minus a negative 3, or 9).
When adding or subtracting, first make sure that the exponents are the same (scaling if required) and then add or subtract the precision portions. For example, 2E3 plus 5E3 is 7E3. By comparison, 2E3 plus 5E6 is the same as 2E3 plus 5000E3, or 5002E3 (or 5.002E6).
Perform the following operations. Convert the following into scientific and engineering notation.

1. 1,500
2. 63,200,000
3. 0.0234
4. 0.000059
5. 170

Convert the following into normal longhand notation:

6. 1.23E3
7. 54.7E6
8. 2E–3
9. 27E–9
10. 4.39E7

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Use the appropriate prefix for the following:

11. 4E6 volts
12. 5.1E3 feet
13. 3.3E–6 grams

Perform the following operations:

14. 5.2E6 + 1.7E6
15. 12E3 – 900
16. 1.7E3 • 2E6
17. 48E3 / 4E6
18. 20 / 4E3
19. 10 M • 2 k
20. 8 n / 2 m