E-6016: Electronics You Might Not Have Learned in College: Lesson 4 – Introduction to Inductors, Coils, Electromagnets, and DC Motors

An Online Continuing Education Course for Engineers

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Credit: 6 Hours / 6 PDH / 6 CPD

Electronics You Might Not Have Learned in College: Lesson 4 – Introduction to Inductors, Coils, Electromagnets, and DC Motors

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INTRODUCTION FOR THOSE WHO HAVEN'T DONE OTHER LESSONS IN THIS COURSE

"ELECTRONICS YOU MIGHT NOT HAVE LEARNED IN COLLEGE" is a course that is divided into several lessons that are each "stand-alone" with their own quizzes and credit units. Normally, lessons 1, 2, and 3 are taken before this lesson. However, those who are mainly interested in inductors and have some basic knowledge of electricity can take this as a stand-alone lesson.

If this is your first lesson in this course, there is some introductory information included here that might be useful. **If you have taken other lessons in this course, part 1 is basically repeated in each lesson and may be skipped or skimmed over as a memory refresher.**

INTRODUCTION TO THE COURSE

During this course, the author will be sharing as much of his 50 years of Electrical Engineering experience as he can. Therefore, there will be many asides that may be of interest to the student as background and general knowledge, even though they may not be essential to the basic course and won't be in the course test. Some of the information contained herein is purely to help students who have not been exposed to the electrical world understand a little better how electricity works. After all, very little of our technology and industry would even exist if it wasn't for the many miracles electricity has brought to us in the short 150 years since Tesla, Edison, Westinghouse, and Faraday first took the novel magic of electricity and put it to work. It now does everything from activating tiny computer microcircuits to powering huge cities. Living in our world without at least some familiarity with electricity is like cooking without knowing how to use a stove. It can be done, but you totally have to rely on others to do the work and know what is going on. I can't imagine any engineer who would be comfortable with that. Hopefully, the factoids picked up in this course will pique the curiosity of the student enough to take other lessons in this course or search the myriad sources of information on the internet and in the media. There are many videos and lessons of various detail and complexity. This course will provide the student with sufficient background knowledge to build upon by using our amazing information networks that were not available only 40 years ago.

A little knowledge of molecular physics is important to nearly all engineering professions. Civil engineers need some understanding of atomic structure to understand how concrete works and the strength of materials. Mechanical engineers must understand the atomic structures of metals, alloys, lubricants, and the effects of friction. From the beginning, advances in the electrical world relied on experiments in physics and chemistry done by curious scientists who slowly gained understanding of the atomic world. Eventually, they learned a lot about how electricity works and can be manipulated to allow humans to do things they never did before.

THE WATER ANALOGY

Since the discovery of electricity, water flow has been used to try to help students understand the invisible world of electrons, charges, and magnetism. Water is observable, and its effects are easily explained, while much of the electrical world remains magical and confusing.

The water analogies seemed intuitive because there are many similarities and even similar terminologies used when describing water or electrical systems. In a water system, we have liquid flowing through pipes, while in an electrical system, we have electrons flowing through wires.

The similarities notwithstanding, there are some differences between such dissimilar worlds that require a little imagination to compensate. However, to many who find many of the terms and the workings of electric systems to be confusing, a comparison to a more comfortable and familiar water analogy can be helpful.

Instructors, time and again, sketch water systems on chalkboards when trying to explain electrical circuitry in beginning electronics courses. It always proved to be instructive and an aid to understanding despite its flaws. Hopefully, this course that heavily makes use of water analogies will further your understanding of the seemingly magical world of electronics.

FIRST LESSONS STUDY DIRECT CURRENT CIRCUITS

The first part of this course concentrates on DIRECT CURRENT (DC) components and circuitry, which are much easier to understand than the more complex world of ALTERNATING CURRENT (AC) circuits. Nearly all electronic circuits used in everything from flashlights to computers and electric cars are powered by DC. Even most devices that are plugged into AC outlets contain AC to AC-to-DC converters to provide DC power to internal components. A basic understanding of the main components used in DC circuits and the way the power that drives them is measured is extremely useful to anyone working in any engineering profession. Electronics is essential in instrumentation, measurement, and control for any design or construction project.

PURPOSE OF THIS COURSE

Electronics are ubiquitous in the modern world, especially in engineering. Most engineers in all specialties have taken at least some basic electronics courses, but might need a refresher course. Even engineers working in Information Technologies and with computers and measurement instruments could use more understanding of the basic electronic components used in their equipment.

This course is designed for engineers in professions that don't require a lot of electronics knowledge, but who would still like to round out their technical understanding. So many electronic tools and instruments are used in all professions that even a basic knowledge of the components that make them function is very useful to engineers. We don't have to know how current, resistance, and voltage work to use meters for troubleshooting problems with power supplies or instrumentation wiring, but it often makes the difference between being able to set up equipment properly or having to call in help.

Even electrical and electronics engineers who have been many years in the profession could use a quick electronics refresher. This course is designed to teach electronics in a little different way that might help those who had a hard time understanding the concepts as they were taught in school. Those who already know most of this information should be able to breeze through the course, but still can increase their understanding of many concepts they have forgotten, never learned, or misunderstood because of the way they were taught.

Those who have had little or no electronics training should be able to pick up an understanding of how electricity is measured and how it is used. They will also learn about electronic components, how they work, and what they do. The water analogy is designed for those who have a hard time understanding how things work that they cannot see or feel. It is also helpful to those who misunderstood what they thought they already knew.

SUMMARIES OF OTHER LESSONS IN THIS COURSE

This is LESSON 4 in the "ELECTRONICS YOU MIGHT NOT HAVE LEARNED IN COLLEGE" COURSE, which is an ongoing series of individual "stand-alone" lessons that are best taken in order to build on progressively advanced information. However, **no lesson is necessarily a prerequisite for the next lesson in the course.** If students already have a sufficient background to comprehend any lesson that piques their interest, any lesson can be taken in any order.

LESSON 1 – "THE ELECTRICAL TOOLBOX"

Lesson 1, "THE ELECTRICAL TOOLBOX", is the first lesson of the "ELECTRONICS YOU MIGHT NOT HAVE LEARNED IN COLLEGE" COURSE. It introduces basic knowledge that will help engineers trained in non-electrical disciplines be able to comprehend later lessons in the course.

The first part of lesson 1 focuses on basic electronics, which must be learned before trying to understand specifications for hardware and tools used for low-voltage DC circuits installed in electronic equipment such as audio amplifiers and computers, and also higher-voltage (over 90 volts) AC hardware used for RESIDENTIAL and INDUSTRIAL wiring.

- Basic concepts of VOLTAGE, RESISTANCE, AMPERAGE, AND POWER are introduced because knowledge of these is necessary when learning about conductors and electrical hardware. The specifications for even a simple wire cannot be understood without knowing the basics of Ohm's LAW.
- The WATER ANALOGY for a simple series resistance circuit is provided to help understand the basics of electrical measurements and terminology
- CONDUCTORS are discussed in detail because they are the most essential item in the electrical world.
- INSULATORS are reviewed because they are an important item that is often skimmed over in engineering courses
- RESISTANCE, CURRENT, AND VOLTAGE specifications for wire are examined and explained.
- Ohm's Law, which determines the relationship of VOLTS, AMPS, AND OHMS to each other, is introduced

The main body of lesson 1 provides an OVERVIEW OF MANY OF THE TOOLS OF THE ELECTRICAL TRADE that technicians take for granted after years of experience, but are commonly not introduced in engineering courses, even for Electrical Engineers. It discusses:

- different types of wire
- how wire is specified and measured
- how wire is insulated
- soldering, types of solder, and soldering tools
- wire connection hardware and methods
- crimped terminals, connectors, and crimping tools
- plug connectors for low-voltage equipment
- and, finally, conduits

LESSON 2: RESISTORS, BATTERIES, OHM'S LAW, FUSES, AND MULTIMETERS

The focus of this lesson is mainly BATTERIES, RESISTORS, terminology, and measurement used in low voltage DC (DIRECT CURRENT) circuits that are common in electronic equipment such as toys, video games, entertainment systems, measuring and monitoring equipment, and computers.

Basic concepts of VOLTAGE, RESISTANCE, AMPERAGE, and POWER are introduced because knowledge of these is necessary when learning about electronic components and how they work.

- OHM'S LAW, which defines the relationship between VOLTS, RESISTANCE, and AMPS, is presented
- The WATER ANALOGY for a simple series resistance circuit is introduced to help understand the basics of electrical measurements and terminology
- CONDUCTORS are discussed in detail because they are the most essential item in the electrical world
- BATTERIES are introduced because they are the most common low-voltage DC power source
- RESISTORS are the simplest but also the most useful component used in electronic circuitry. Understanding of resistors is essential to understanding electronic circuits
- VARIABLE RESISTORS are important for adjusting and controlling electronic circuitry, INPUTS, and OUTPUTS
- PROTECTIVE DEVICES, such as fuses and circuit breakers, are vital for the protection of all electronic circuitry
- MULTIMETERS are the most useful measuring tool for anyone working with electrical circuits. They can be used to measure POTENTIAL (VOLTAGE), CURRENT (AMPERES), and RESISTANCE (OHMS)
- WORST-CASE ANALYSIS and TOLERANCE SPECIFICATIONS for components because these topics are especially important considerations in circuit design and repair

LESSON 3 - INTRODUCTION TO CAPACITORS

CAPACITORS are extremely versatile and are supplied in a wide variety of types to handle the myriad applications to which they are put. This lesson provides information on the many types of capacitors, how they are made, where they might be used, and why one type should be chosen over another. Lesson 3 is designed to provide critical information on capacitors, their terminology, and measurement as they are applied to low-voltage DC (DIRECT CURRENT) circuits. Capacitors are nearly as crucial as resistors in usefulness and abundance in electronic circuits. The basic operation of capacitors is described in this lesson, although details of their uses in AC circuits are left for later courses.

As with resistors, it is important to understand the basic functions of capacitors and the meaning of their ratings when they are applied in circuits. While most uses of capacitors are in AC circuits, studying their operation in DC circuits allows an understanding of their basic operation using simple mathematics and analogies. Further operation of capacitors will be discovered in future lessons that delve into the far more complex world of AC analysis.

The similarity of capacitors to batteries is analyzed. Also, similarities and differences in the calculation of resistor series and parallel values are compared to those of capacitors. While a previous study of "LESSON 2: RESISTORS, BATTERIES, OHM'S LAW, FUSES, AND MULTIMETERS" would be helpful to understanding of this section, it is explained in sufficient detail to stand alone.

Water analogies are used to demonstrate how capacitors work when connected in parallel and series. Water analogies are also helpful to explain the charge and discharge actions of capacitors and their step response.

The step response of resistor-capacitor (RC) networks is covered in detail because it is important to understand the charge and discharge characteristics of capacitors for many of their uses, including timing circuits and determining ripple in power supplies. The log rhythmic formulas for plotting the charge and discharge curves are also discussed in detail.

Even though this lesson concentrates on DC circuits, A waves are intr with the simplest semiconductors – diodes. This is the most filtering half-wave and full-wave AC to DC ull understanding.

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- Resistor–capac
- Water analogie
- Calculation of ch
- An example of us rk
- How to shop for c
- Basic operation of
- Half-wave and full-
- The important use of capacitors for smoothing the outputs of AC to DC converters

LESSON 4: INTRODUCTION TO INDUCTORS, COILS, ELECTROMAGNETS, AND DC MOTORS

It is assumed that anyone taking this course is familiar with most technical terminology, even if their area of engineering expertise is outside the world of electronics. **Even though lessons 1, 2, and 3 of this course are not needed to understand this lesson, the student should have some knowledge of basic electronics, which provides the confidence to do this session.**