2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #38859

Introducing Circuit Analysis in an Introduction to Engineering and Technology Course

Dr. Kelly Korzeniowski,

Dr. Kelly Korzeniowski is member of the Department of Physics and Engineering at the Community College of Rhode Island. She was an Associate Professor at the United States Naval Academy. Her research interests include robotics and sensor integration. She holds a PhD and ScM in Electrical Engineering from Brown University and a BS in Computer Engineering from the University of Rhode Island.

Introducing Circuit Analysis in an Introduction to Engineering and Technology Course

Abstract

This work describes the introduction of circuit analysis in an introductory engineering course taken by first-year community college students. The students are following diverse career paths majoring in engineering, engineering technology, as well as students deciding on a major course of study or pre-college students earning college credit. This one semester course gives a broad introduction to the field of engineering as well as the engineering design process. Because students come to the course with disparate prior academic experience, this can present a challenge when balancing the accessibility of the topic while at the same time introducing the theoretical background necessary to provide a meaningful opportunity for students to perform analysis in the laboratory portion of the class. The purpose of this activity is to bring students to a common level of proficiency so that they can perform an iterative engineering design experiment investigating the performance of a small vertical axis wind turbine, VAWT.

Background

Being mindful of how students acquire knowledge, Turns and Van Meter [1] discuss teaching methods to improve problem solving, informed by cognitive science. Part of the objective of this introduction to engineering and technology course is to show students that engineers work to solve concrete problems and improve solutions. For many of the students, they are embarking on the first step in developing their problem-solving skills. The fact is that these skills are hard won through experience. This type of struggle makes the individual aware of the underlying scope of the problem. Learning new skills can be an uncomfortable experience. Students need to understand that this type of labor is productive, and it is worth their time. Acknowledging to students that the task is a struggle but a necessary one, and then rewarding students for their efforts goes a long way. The concept of desirable difficulties is described in Bjork and Bjork. [2]

When faced with difficult, unfamiliar problems, confidence can be a barrier to student practice. Practice and struggle are effective ways to improve analytical skills. To overcome this barrier, low risk, rewarded activities can build student confidence and provide the necessary practice that builds the foundation to make it possible for students to participate in more challenging open-ended analyses as well as improving long-term memory retrieval. Preparing students for this challenge means giving them the opportunity to experience different types of problems while at the same time scaffolding skills. Brown, Roediger, and McDaniel explain how switching contexts and interleaving can be an effective way to improve long-term recall and analytical skills. [3]

One pitfall to be aware of is that students often misconceive studying to be simply diligently reading material and reliving lecture presentations. There is some value to this, students need to be familiar with the subject matter, but to be effective, it can’t end there. Roediger and Butler [4] show that this passive activity doesn’t lend itself to long-term retrieval and skill mastery the same way that actively engaging with the material by practicing and problem solving does. This isn’t a new idea as shown by the adage, “learn by doing” and courses with laboratory components present an opportunity to contextualize and reinforce theoretical course material. In the context of effective learning, it makes the connection between testing and long-term memory retrieval. Part of the seeming contradiction for students is they tend to feel they know the material better after reading and reviewing and less after problem solving, but research shows that this self-assessment is not accurate.

Taking these considerations into account, the goal is to prepare first-year community college students taking an introduction to engineering and technology course, to analyze a simple series circuit for the purpose of understanding the operation of a vertical axis wind turbine, VAWT. As with other introductory STEM courses, students' disparate prior academic experience can present a challenge. The prerequisite for this course is listed as elementary algebra and students following the course come from different academic backgrounds with different declared degree paths.

This course provides students with a broad overview of engineering problem solving strategies. The multiweek activity described here is a component of the problem-solving work in the course and it concentrates on circuit analysis. Some students have experience with circuit analysis, but the majority do not and for them, this activity can be difficult and entirely foreign. The importance and challenge of engaging students while introducing them to the field of engineering and technology is highlighted by Lin and Morton [5]. In this course, the laboratory experience revolves around the construction and testing of a small VAWT, so a basic level of understanding in circuit analysis is essential. The purpose of this activity is to bring everyone to a common level of proficiency to perform an iterative engineering design experiment investigating the performance of the VAWT under different conditions.

The introduction to engineering and technology course as a whole does not focus on circuit analysis. The challenge therefore is to balance theory and practice, using elementary algebra to give students enough background to solve problems while at the same time developing an appreciation of the dependencies. Students are taken through the analysis of a simple series circuit consisting of three components connected in series, a voltage source, V_G, the resistance of the generator coils, R_G, and the resistance of the load, R_L. This circuit provides a model that is used to predict the performance of the VAWT. Low risk, scaffolded activities are introduced to provide the practice that builds the foundation to make it possible for students to participate in more challenging open-ended analyses. Students begin by applying Ohm's law to the series circuit, then learn to make power calculations, and eventually draw conclusions related to impedance matching. This activity remains relevant because the calculations are reflected in laboratory measurements with the VAWT.

Assignments

The activity spans five weeks. A problem set is completed once a week in class and part of that problem set is a simple series circuit, the model for the VAWT. The lab component meets once a week, and this is where concepts are reinforced. It is not unusual for some students, usually those with no prior experience, to find the circuit analysis problem so different that they react by disengaging and deciding it is not worth their time to attempt to solve the problem. To address this hesitancy, the first problem set is completed together and graded for participation.

In Week 1, the simple series circuit shown in Figure 1 is introduced. The circuit is a model for the VAWT. The main components of the VAWT are the magnets attached to a rotor and the wire coils in the stationary base. As wind is caught in the blades, the rotor spins the magnets thereby applying a changing magnetic field to the coils. The circuit is a simplification showing how the peak generator voltage and therefore, the peak load voltage and dissipated power, can be predicted.

The problem is solved in steps, beginning with the dimensions and units for resistance, current, voltage, and power. Prior knowledge of elementary algebra is used to rearrange variables in formulas, also discussing how changing the value of the variables affects the final calculation. The first calculation is the current that is shared by all elements, using Ohm’s Law. This leads to calculating the voltage across each element individual element. Stressing the balance in this system, students apply Kirchoff’s voltage law. This also gives students an opportunity to check their calculations. Lastly, the current and voltage are used to show that the power generated equals power dissipated.

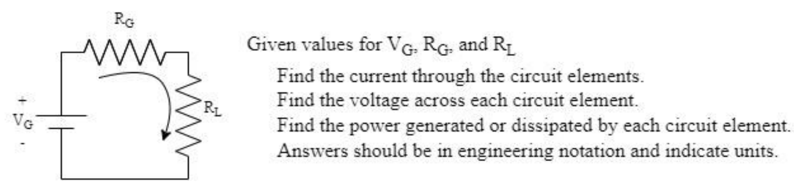

Figure 1: Circuit Analysis Assignment

In Week 2, a second problem is completed independently, using the first problem as a guide. To encourage participation and to highlight the fact that errors provide valuable learning opportunities, this is again graded for participation. Students are encouraged to solve the problems by following the same steps as in Week 1.

In Week 3, students are required to complete the problem on their own from memory. Instructor feedback is vital to reinforce good habits and correct mistakes.

In Week 4, students complete the problem on their own and what is observed is that some students notice variations that they can apply to the solution. If the purpose is to calculate the power dissipated by the load, there is no reason to calculate the voltage dropped across each resistor when you can move directly to using the current to calculate the power dissipated.

In Week 5, for the last problem, students are asked to make a comparison of dissipated power in the resistors and decide how to set the value for the load resistor to maximize the load power, making this no longer a simple analysis problem. Students begin to see the interaction of the variables in this open-ended problem. Figure 2 shows the circuit analysis problem.

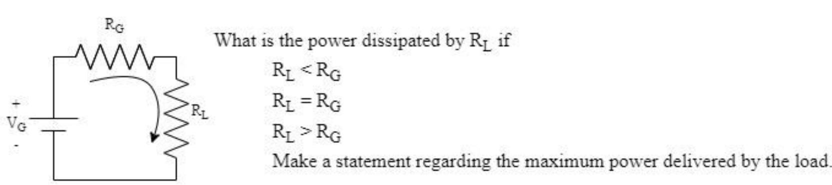

Figure 2: Assignment Extension, Maximum Power Delivered to the Load

Conclusion

Engineering and technology students gain experience with problem solving as they move through each step of their undergraduate education. It is a challenge to make this experience meaningful in a first-year course when students bring limited prior academic experience and mathematical skill. Recognizing how students learn can impact the way that this material is presented and how it is received by students. It can also inform the balance between theory and practice in a first-year course. Often, the first step is to overcome hesitancy and engage students. This can be done using low risk activities with repetition and scaffolding. Reinforcement in the laboratory presents the perfect opportunity to add context to the theoretical nature of the problems.

The purpose of this activity is not to train students to solve one type of problem but rather to leverage prior algebraic knowledge to illustrate how to analyze the interaction of variables in simple formulas, thus improving their problem-solving skills and at the same time making open-ended design problems accessible. In this introductory engineering and technology course, students apply these skills to a simple series circuit that is the model of a small VAWT. This circuit is used to predict the peak performance of the VAWT. Students are asked to make a comparison of the dissipated power in the resistors in order to decide how to set the value of the load resistor to maximize the load power when the VAWT is tested in the laboratory.

References

[1] S. Turns and P. Van Meter, "Applying Knowledge from Educational Psychology and Cognitive Science to a First Course in Thermodynamics," in *2011 ASEE Annual Conference & Exposition, Vancouver, BC, June 2011.*

[2] E. Bjork and R. Bjork, "Making things hard on yourself, but in a good way: Creating desirable difficulties to enhance learning," in *Psychology and the Real World: Essays Illustrating Fundamental Contributions to Society*. New York, NY: Worth, 2011, pp. 56-64.

[3] P. Brown, H. Roediger III, and M. McDaniel (2014). *Make It Stick: The Science of Successful Learning.* Cambridge, MA: Belknap Press of Harvard University Press, 2014.

[4] H. Roediger III and A. Butler, "The critical role of retrieval practice in long-term retention," *Trends in Cognitive Sciences*, vol. 15(1), pp. 20–27, 2011.

[5] Y. Lin and T. Morton, "Novel practices in teaching circuit analysis" in *EET Program Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia, USA, June 2013*.