

GIFTS: Introducing First Year Students to The Running Track Analogy of an Electric Circuit

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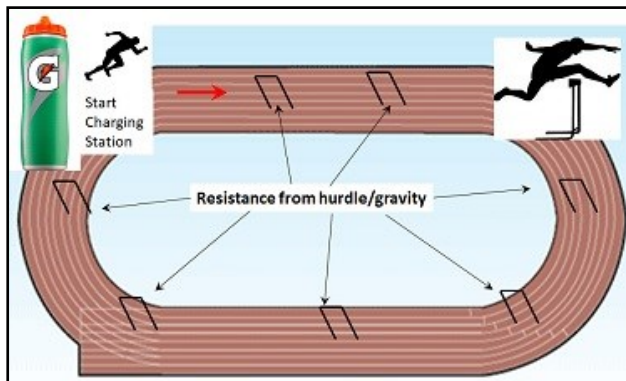
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Introduction

This Great Idea for Teaching Students (GIFTS) describes a teaching method used for introducing the series electric circuit to under-represented minority engineering students. It is unique because of its teaching method for mathematics, and historically, is not used in FYEE programs [1]. Too often a struggling first semester student has limited knowledge of how a simple series electric circuit relates to a real-world event or physical concept. Student-centered active learning, in which students are asked to “do” something beyond listening and note taking, as this teaching idea suggests, should be used in STEM courses.

Introduction and Description

Freshmen students often do not make the ‘link’ between an equation and a physical system. Despite attempts to explain an equation with diagrams, many students still fail to fully grasp the math, for example, the water flow analogy for electric circuits. One such equation that is pervasive in many branches of the engineering profession is Ohm’s Law which states the current through a conductor between two points is directly proportional (by the resistance) to the voltage across the two points. The ability to understand and apply this equation is useful in electrical, computer, biological and even mechanical engineering courses and industry projects. The teaching method used for explaining the series circuit is a running track analogy followed by a low cost electric circuit kit that the students build and test. They also learn how to model the circuit using MATLAB Simulink. Students engage in discussions and surveys on the running event called the hurdles and its physical relationship to circuit experiments. The running track analogy is first presented with an actual video of an Olympic hurdle event in the Problem Solving for Engineers course for freshman. Students are tested on the analogy and each student builds their kit. Most of the students are considered underrepresented and most all engineering majors are included. The series electric circuit was conceptualized in terms of a hurdle event where runners are analogous to electric charges, hurdles represent electrical resistance and the Gatorade station is explained in terms of the source voltage. The idea goes like this: a runner receives her energy from a Gatorade drinking station which the instructor referred to as the voltage source (or battery). When the track and field runner starts moving he is referred to as the electron (or charge) who runs fast (electrical current). He then has to exert and lose energy to cross over a hurdle referred to as a voltage drop. The voltage drop concept is emphasized with a photo of runners before and after jumping over a hurdle with their facial expressions of pain (or sweat) which is loss of energy. Additional concepts in the simple



series circuit including the voltage and resistance are explained and compared to this real-world event. Students are surveyed on their understanding of the running hurdles event in terms of analogies and Ohm’s Law.

Student Perception Data Analysis

Discussion board responses, test responses and student surveys were used to measure student perception of their understanding of the running track analogy and Ohm’s Law.

In a discussion forum, students were asked “What is a circuit and what is an application of a circuit? By application, something in the real world, not a textbook example.” Several students responded: “A circuit is a continuous flow of voltage through a power source.” However, the term power was never used in the running track analogy and to be correct, current flows, voltage does not flow. The students were asked to answer survey questions shown below.

Table 1: Student Perception of Running Track Analogy and Ohm’s Law

Survey Question	Student Response Before Teaching Method	Student Response After Teaching Method
Have you heard of the Running Track Analogy?	No (35/37)	
In high school, I used the formula called Ohm's Law	Yes (12/37)	
When I think of electric charges flowing I think of	water flowing in a pipe (20/37)	
	I don't think of that on a daily basis (7/37)	
	an invisible force (7/37)	
	an atom (3/37)	
The running track analogy helped me understand voltage		Strongly agree (30/37)
		Agree (7/37)
The running track analogy helped me understand electrical current		Strongly agree (3/37)
		Agree (34/37)
The photos of the running track hurdle runners helped me understand voltage drop and energy loss		Somewhat disagree (1/37)
		Agree (36/37)
The running track analogy helped me understand a new math formula $V=I \cdot R$		Strongly agree (1/37)
		Agree (36/37)
My race/ethnicity is	African American (36); Asian (1)	

Conclusion and Lessons Learned

Based on course surveys this method increases student’s awareness and appreciation for simple one-dimensional energy as the relationship between the physics of a sporting event and electron motion in a series electrical circuit. Through practical lecture material on hurdle running and hands-on experimentation, freshmen student learning is enhanced. However, mathematical competence, for example, algebra to solve Ohm’s Law was lacking in some students (30-40%). The author plans to teach the parallel circuit to prepare students for more rigorous circuit problems in their sophomore year. Finally, the author will use a skills-based assessment of solving Ohm’s law problems after learning this method.

References:

[1] <https://prezi.com/xoqif52iw1fj/electrical-circuit-analogy/>