Using Analogy to Enhance Understanding of Electrical Circuits

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Abstract

When teaching has both a visual dimension and auditory one, the information is easily delivered to students. Students, who can not imagine the behavior of electrical circuits, have difficulty, understanding electrical circuits behavior. These difficulties stem from the strain in visualizing the actual behavior of electrical circuits. Visualization constitutes an important part of learning process when instructors try helping students understand what is happening inside electrical circuits and explaining its concepts.. In this paper, we introduce multimedia-based analogy as a remedy approach for this difficulty. Multimedia based analogy aims to visualize how electric circuits operate, and thus help the student in understanding electrical circuit principles. By the aid of multimedia, we explore the analogy concepts between the electrical system and other systems such as mechanical and hydraulic systems to help students gain a good understanding of the dynamic and static behaviors of electrical circuit. A computer-based Instruction (CBI) has been developed with analogies. Every module in the curriculum has analogies to help students understanding the curriculum concepts.

Introduction

Educators have come to realize that learners come in different learning styles, backgrounds, and motivation. Some students learn by seeing and hearing; second group learns by reflecting and acting, third group learns by memorizing and visualizing, and the last group learns by building mathematical models and drawing [1-3]. Moreover, instructors have different teaching styles. Also, Some instructors emphasize understanding and others emphasize memorization. In a traditional classroom, the lecturer views students as empty minds that need to be filled with knowledge and facts [4]. However, an essential factor in student's academic success is student desire to learn. This desire can be strengthened if the student's interest can be motivated by presenting the course material in an attractive manner which encourage students to like the material and learn more. To achieve this goal, we offer to students a material as an integrated scheme of text and animation enforced by animated analogy. We introduce, analyze and visualize the electrical circuits concepts based on other system which are easily visualized, to enhance the understanding of the material and train the student to link the behaviors of different systems.

To achieve these goals (visualizing the concepts, presenting the material in an attractive manner, and enhancing student's understanding of course material), a Computer-based Instruction (CBI) curriculum have been developed along with analogies between electrical and mechanical systems. Analogous systems represent systems for which the mathematical representations of them have the same form. The corresponding variables and parameters of the two systems used in the mathematical representations are called analogy. The analogies are selected such that both systems have similar behavior and easy to visualize. Analogy between electrical circuit and mechanical system

Well-implemented multimedia curriculum is proven effective tool in education, especially technical education. Such curriculum capable of holding student's attention, encouraging their involvement, and animating technical concepts with impressive results [5].

A Computer-based Instruction (CBI) instructor's and learner's dream comes true. Combining text, sound, graphics and motion in creating instructional materials, educational applications, classroom training and job aids help students to understands the main concepts and enable learners to do far more than read or listen [6]. The Computer-based Instruction (CBI) modules are developed using Macromedia's Authorware. The Macromedia's Authorware software allows the ability to include full-motion video, animations, audio, hypertext, and active user instruction.

Analogies

Analogies are normally introduced during CBI modules and animation is used to show analogous components. The analogies are developed based on the following approach:

1. Select a system that is analogous to an electrical system such that it can be visualized easily, for example the mechanical and hydraulic systems.

2. The behavior of this system and its equivalent circuit are animated using Multimedia.
3. A simple mathematical analysis of this system is developed to derive the system equations.
4. Similarly, the electrical system is analyzed to derive system equations.
5. The equations from steps 4 and 5 are compared to element and variable equivalency between for both systems.
6. Based on this analogy, the behavior of the electrical system is animated using Authorware.
7. Finally, both systems are animated concurrently to show the analogous relationship.

Electrical and Mechanical Systems Analogy

A mechanical system shown in Figure (1) can be represented by an equivalent electrical circuit. Both systems have the same mathematical representation (model). Moreover, nodes in mechanical system are analogous to nodes in electrical network

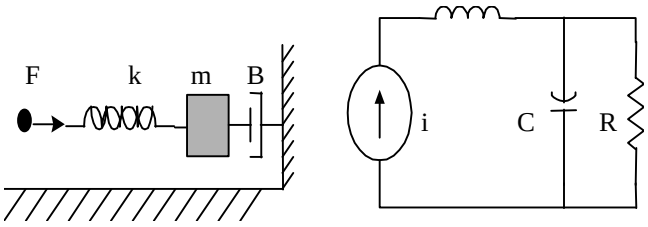


Fig. (1) mechanical and equivalent electrical systems

The Electro-mechanical analogy can be classified into two categories:
1. Analogy by quantity
2. Analogy by elements.

Analogy by Quantity:

The force (f) in a mechanical system is analogous to the current (i) in an electrical system as shown in Figure (2).

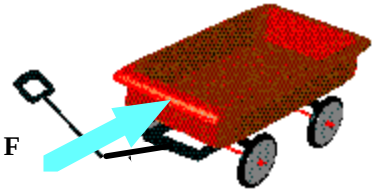
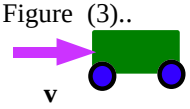


Fig. (2) force current analogy.

The velocity (v) across a mechanical element is analogous to a voltage (v) across an electrical element as shown in Figure (3)..



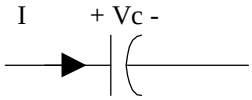


Fig. (3) velocity voltage analogy.

Analogy by Parts:

The analogy between mechanical system and electrical system shown in Figure (4) can be described by writing the equations for both systems:

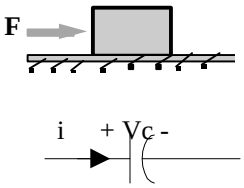


Fig. (4) mechanical and electrical systems

The current (i) through a capacitor (C) is

$$i_c = c\frac{dv_c}{dt}$$

Similarly, the force acting on a mass (m) is

$$f = m\frac{dv}{dt}$$

v is the speed of the mass m, which is analogous to the voltage across C (Vc). Hence, the mass (m) is analogous to the capacitance of the capacitor (c).

An applied force (f) to a spring shown in Figure (5) can be described by:

$$f = kx$$

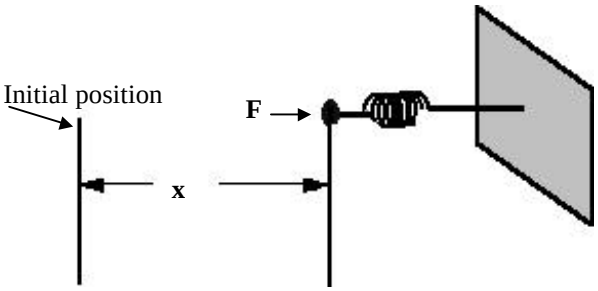


Fig. (5) spring mechanics

Where k is the stiffness coefficient of the spring and x is the displacement. Also, the speed of the coil is

$$v = \frac{dx}{dt} = \frac{d}{dt}\left(\frac{f}{k}\right) = \frac{1}{k}\frac{df}{dt}$$

Similarly, the voltage across the inductor L is

$$V_L = L\frac{di}{dt}$$

Since the speed, (v) of the spring is analogous to the voltage (V_L) across the inductor,

$$V = \frac{1}{k}\frac{df}{dt} \longleftrightarrow V_L = L\frac{di}{dt}$$

Therefore, the inductance (L) is analogous to the reciprocal of the stiffness (1/k) as shown in Figure (6).

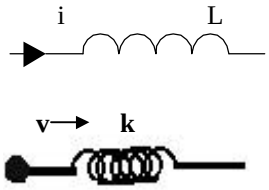


Fig. (6) stiffness and inductor analogy

Similarly, the damping coefficient (B) in a mechanical system is analogous to the resistance (R) in an electrical circuit by comparing the following equation:.

$$F = BV = B\frac{dx}{dt} \longleftrightarrow i = \frac{V}{R} = \frac{1}{R}V$$

Since speed (v) is analogous to voltage (V); therefore; resistance (R) is analogous to 1/B as shown in Fig. (7).

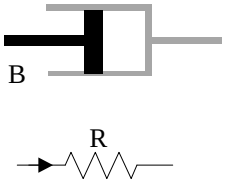


Fig. (7) Damping coefficient resistance

Conclusion

Analogies between mechanical and electrical systems have been introduced. Multimedia modules based on this analogy have been developed and will be presented in the conference. The developed analogy based on quantity and elements. Summary of the electrical and mechanical analogy is shown in figure (8).

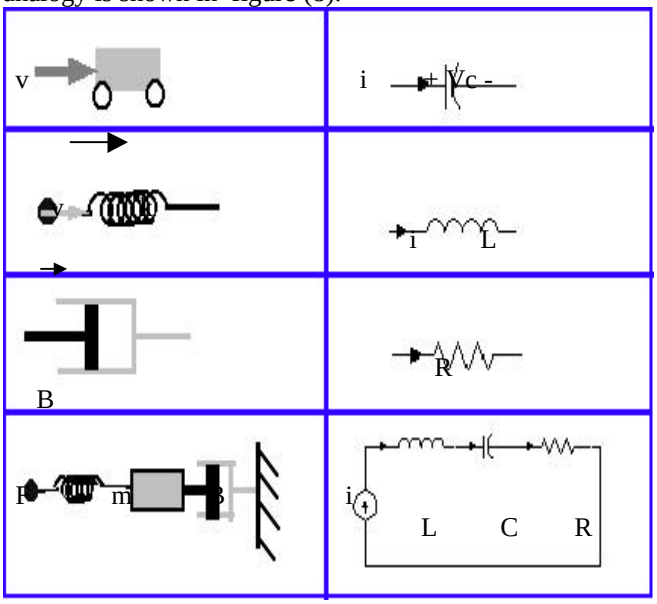


Fig. (8) summary of the Electro-mechanical analogy.

References:

1. Bonwell, C.C., Eison, J.A. *Active learning (Creating Excitement in the Classroom), report one.* ASHE-ERIC Higher Education Reports 1991.
2. Silberman, M. *Active learning 101 Strategies to Teach Any Subject*. Allyn and Bacon, 1996.
3. Felder, R.M., and L.K. Silverman, "Learning and Teaching Styles In Engineering Education," *Journal of Engineering Education*, April 1988, pp. 574-581.
4. Ametrano, D., and T.M. Harkin, "Making the Transition from Traditional Classroom Instructor to Coach In Computer-Based Instruction," *Proceedings, 1999 ASEE-NCS Conference*, ASEE-NCS, 1998, p. 248-251.
5. *Niz*ar Al-Holou, and Timothy W. Savage, Selecting an Authoring Program for Undergraduate Engineering Computer-based Instruction, the IEEE FIE '95 Proceedings, pp. 4d1.13-17.
6. Edward R. Doering, "Supplement to "CircuitViz: A New Method for Visualizing the Dynamic behavior of Electric Circuits," IEEE Transaction on Education on CD, Aug. 1996.