Enhancing Lectures with Calculations, Simulations, and Experiments.

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Technology is widely used today in all places of human endeavors. Both academia and industry use various technological tools to perform calculations and simulations before the experimentation. These powerful tools effectively assist the professional to curry on calculations is short time, and simulate virtual prototypes avoiding the expensive and long manufacturing and testing times. Both approaches allow investigations using the "What if" approach. These tools supplement and complement the Lecture and the laboratory. In this work, an integrated approach of all four aspects, lecture, calculations, simulations and experimentation, is presented, as they fit in academic and industrial environments.

Lecture is a convenient way to introduce new ideas in short time using mathematical modeling. Calculations allow for symbolic and numerical results. Computer simulation of a system is represented as the running of the system's model. Experimentation allows for the realization and verification of the results obtained earlier by the previous three methods, for a real system.

In this work we propose the integration of the lecture with calculations, simulations, and experimentation in order to ensure that the subject matter under consideration is fully comprehended, investigated, and understood. This approach uses active participation of the student to avoid decline of students' attention during long sessions.

As an example we consider a second order system that is driven by a step function. We realize the system using an electrical application, a resistor, capacitor, and inductor connected in series and driven by a constant voltage source. An RLC is described, using Kirchhoff's voltage law, by a second order differential equation of the form

$$u_L + u_R + u_C = V_S$$

$$i = C\frac{du}{dt}$$

$$\therefore \frac{d^2u}{dt^2} + \frac{R}{L}\frac{du}{dt} + \frac{1}{LC}u = \frac{1}{LC}V_S$$

The solution is examined for three cases: an over damped, a critically damped, and an under damped case by changing the value of the resistor R.

Over damped solution $\alpha > \omega_0$:

$$u_C = U_S + \left(U_1 e^{-s_1 t} + U_2 e^{-s_2 t}\right)$$

Critically damped solution $\alpha = \omega_0$:

$$u_C = U_S + \left(U_1 + U_2 t\right)e^{-st}$$

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Under damped solution $a < \omega_0$:

$$u = U_S + \left[U_1 \cos(\omega t) + U_2 \sin(\omega t)\right] e^{-\alpha t}$$

Figure 1: Lecture - Mathematical Modeling

Step Responce of a Second Order System
(RLC Series system with initial conditions)

Overdamped System

$u_1(t) := 24 + \frac{4}{3}\cdot(-16\cdot\exp(-t)+\exp(-4\cdot t))$

Cricaly Damped System

$u_2(t) := 24 - 19.2\cdot(1+t)\cdot e^{-2\cdot t}$

Underdamped System

$u_3(t) := 24+(21.694\cdot\sin(1.936\cdot t)-12\cdot\cos(1.936\cdot t))\cdot e^{-0.5\cdot t}$

$t := x$

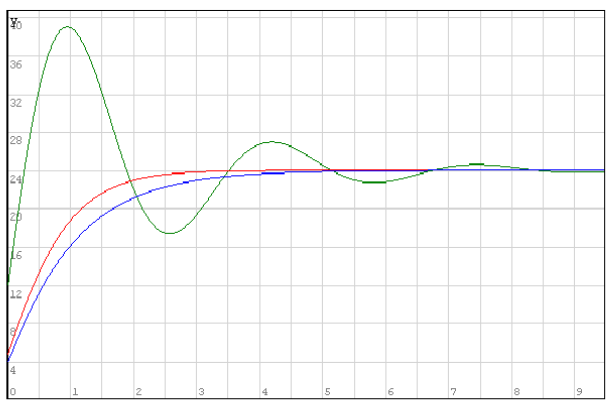

Figure 2: Calculations - Mathematical Notepad calculations

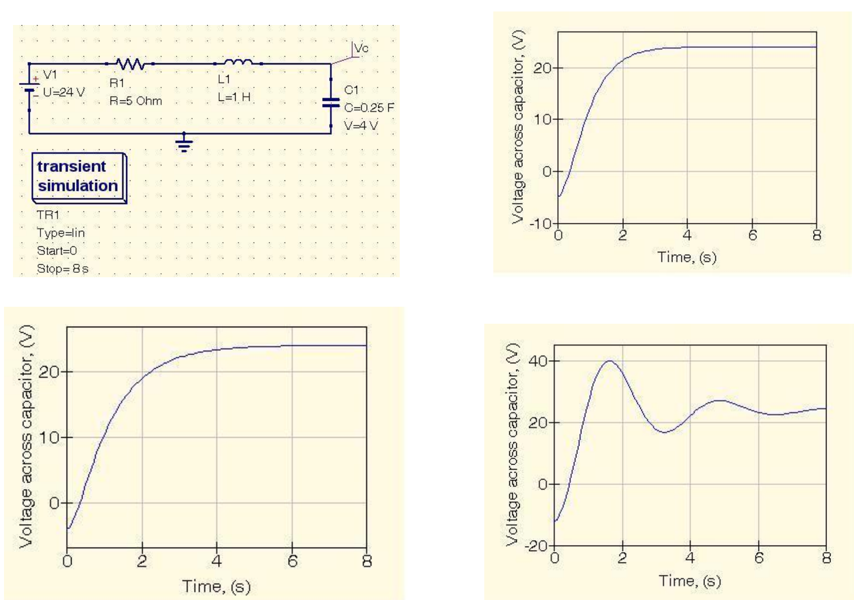

Figure 3: Simulation – Computer Simulation

Keywords: Lecture, Calculation, Simulation, Experimentation.