Simulink as Multidisciplinary approach in Teaching Engineering Mathematics

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Abstract: It is better to get rid of the classical method of teaching (The Board) from time to time and go to a teamwork plan in a problem solving or understanding the mathematical concepts. The most attractive way is, STEM, which is an approach to learning and development that integrates the areas of science, technology, engineering and mathematics. Using Simulink that is a visual programming interface designed to make modelling systems intuitive. It offers a way to solve equations numerically using a graphical user interface, rather than requiring code. In addition, a physical simulation save time and equipment. Rather than that, a theoretical solution or numerical solution needed which must be coincide with the graphical results. Some examples are given to show how the Mathematics instructor could achieve an interactive way of teaching Mathematical concepts and student's self-study and problem solving using different ideas that leading to the same answer that coincide with the theoretical mathematical solution.

Index Terms— Multidisciplinary, The future Mathematics Instructor, Teaching Mathematics, Computer Algebra System, STEM Education System, Mathematical Modelling, Simulink, Simscape, Ordinary Differential Equations.

1 INTRODUCTION

Given the rapid growth and accumulation of the scientific information, a student, to succeed in the future professional career, needs not only the solid background in fundamental disciplines, but an essential mental flexibility in terms of the development of a combined inductive-deductive vision together with a freedom of inter-, multidisciplinary receptivity. To this end, the ideas, methodological approaches, diversity and universality of the subjects involved that lie behind the concepts of nanotechnologies, biomedical engineering and mathematical education may be adapted as a ready-to-use model tool, "ideological fulcra", for the educational curricula of today. From the other side, it is obvious, that preserving the nomination of a highly qualified professional today is synonymous to the permanent self-education as never before. Therefore, the capacity of seeing no interdisciplinary borders, thus optimizing the learning effort distribution, understanding a close relation and formal analogy of different physical phenomena multiplied by the strongest unifying and all-pervading elegance of mathematics are those "shoulders of giants" that would help next generation to see further. Simulink requires describing the problem by a mathematical model that is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. Mathematical models are used in the natural sciences (such as Physics, Biology, Earth Science, Meteorology) and Engineering disciplines (such as Computer Science, Artificial Intelligence), as well as in the Social Sciences (such as Economics, Psychology, Sociology, Political Science).

Simulink is a visual programming interface designed to make modelling systems intuitive. It offers a way to solve equations numerically using a graphical user interface, rather than requiring code. Models contain Blocks, Signals and Annotation on a background. Blocks are mathematical functions; they can have varying numbers of inputs and outputs. Signals are lines connecting blocks, transferring values between them. Signals are different data types, for example numbers, vectors or matrices. Annotations of text or images can be added to the model, and while not used in the calculations they can make it easier for others to understand design decisions in the model.

Simscape enable us rapidly to create models of physical systems within the Simulink environment. With Simscape, you build physical component models based on physical connections without need to a mathematical modelling. STEM is an approach to learning and development that integrates the areas of Science, Technology, Engineering and Mathematics. Through STEM, students develop key skills including Problem Solving, Creativity, Critical Analysis, Teamwork, Independent thinking, Initiative, Communication, Digital literacy. The continual advances in technology are changing the way students learn, connect and interact every day. Skills developed by students through STEM provide them with the foundation to succeed at school and beyond. STEM empowers individuals with the skills to succeed and adapt to this changing world. Some examples are given to show how the Mathematics Instructor could achieve an interactive way of teaching Mathematical concepts and student's self-study and problem solving using different ideas that leading to the same answer. In [2] and [3], the Computer Algebra System (CAS) was the approach of the impact in Teaching Mathematics. Recently [1], enhance me to study the impact of Simulink in Teaching Engineering Mathematics [4]. In schools, STEM education system is adopted and students could continue to join the advance level of STEM at University Level.

2 METHODOLOGY

A multidisciplinary approach involves drawing appropriately from multiple disciplines to redefine problems outside of normal boundaries and reach solutions based on a new understanding of complex situations. Skill-centered specialists often see multidisciplinary working, as revolutionary but it is simply a fundamental expression of being guided by holism rather than reductionism, as described by Jan Smuts in his 1926 book Holism and Evolution. One of the major barriers to the multidisciplinary approach is the long established tradition of highly focused professional practitioners cultivating a protective boundary around their area of expertise. This tradition has sometimes been found not to work to the benefit of the wider public interest, and the multidisciplinary approach has recently become of interest to government agencies and some enlightened professional bodies who recognize the advantages of systems thinking for complex problem solving. The use of the term 'multidisciplinary' has in recent

years been overtaken by the term 'interdisciplinary' for what is essentially holistic working by another name. The former term tends to relate to practitioner led working while the latter term tends to carry a more academic overtone. Using a trial version of Matlab 2019a, Some examples are given to show how the Mathematics Instructor could achieve an interactive way of teaching Mathematical concepts and Student's self-study and Problem Solving using different ideas that leading to the same answer.

Let us start with a pure Mathematics concept and properties with an interface window

Example 2.1 (Taylor Series) The Taylor Series (Expansion) for
a function goes to be close to the original value of the function when more terms taking N, as it is shown for $f(x) = \cos(x)$ in Fig (1)
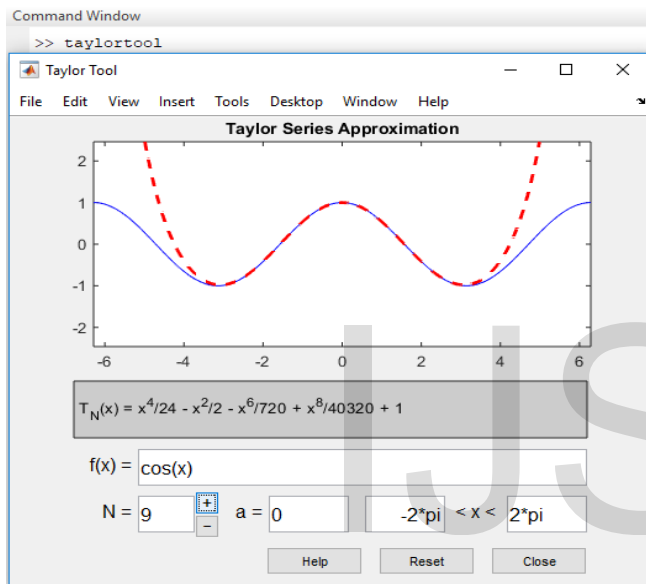
Fig (1)

Now, using a Simulink for Mathematics concept and its properties

Example 2.2 (Introduction to Matrix Algebra)

Consider a Mathematics concept, say the Identity Matrix, $\mathbf{I_{3x3}}$ and its properties in a matrix multiplication as in in Fig (1)
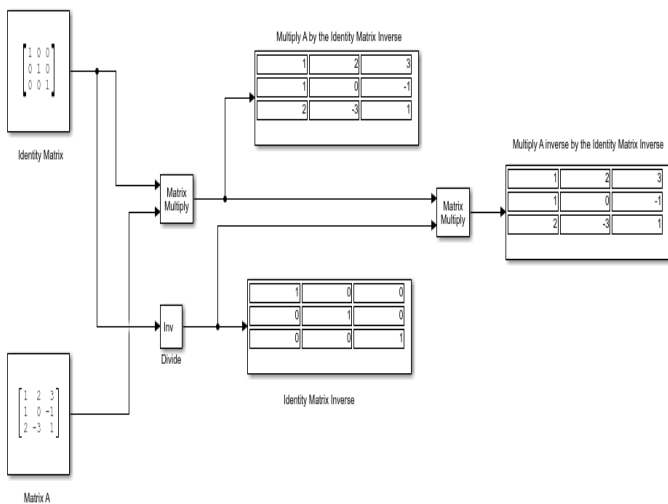

Fig (2)

Next examples are more practical and deeper that comes in the advance Mathematics courses:

Example 2.3 (Separable-First Order Ordinary Differential Equation)

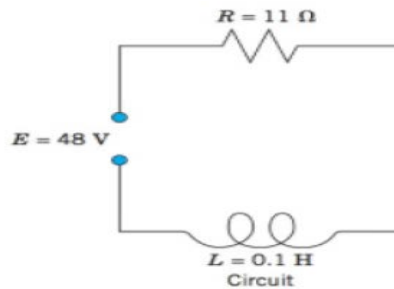RL-Circuit with Constant Voltage Source (Consider the current I at the time t=0 is zero) as given in Fig (3)

Fig (3)

Let the student to write the Mathematical Modeling of the given circuit in equation (1)

$$0.1\frac{dI}{dt} + 11I = 48 \text{T(1)}$$

Which is a first order separable differential equation. Then ask them to solve in different methods the Mathematical Modeling equation and plot the result by using any Mathematical software, such as Matlab and compare the result done theoretically.

First one, use the Matlab command for equation (1) and get the answer as follows:

```
>> syms t I;I=dsolve('0.1*DI+11*I=48','I(0)=0','t')

I =

48/11 - (48*exp(-110*t))/11

>> t=0:0.1:2;I=48/11-(48*exp(-110*t))/11;plot(t,I)
```

Next one, one said because it is Initial Value Problem, solve the problem, by taking the Laplace Transform and have

$$I(s) = \frac{480}{s^2 + 110s}\text{T(2)}$$

Then plot the inverse Laplace Transform for equation (2) by the Matlab command

```
>> syms s t; I=ilaplace(480/(s^2+110*s),s,t);ezplot(I,[0 2])
```

Other one, use Matlab Simulink to construct the Mathematical modelling of the circuit after reorder it by putting the highest order of differentiation in a side of the equation and the rest of the mathematical modelling in the other side. Then represent it as Blocks and Signals in Fig (4)
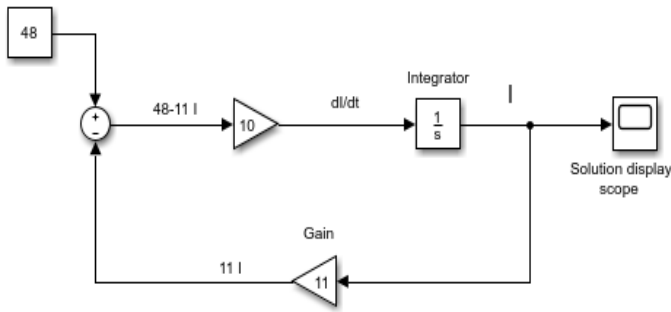
Fig (4)

Double click in Scope, the current as a function of time displayed.

Finally, one use Matlab Simscape to construct the physical electrical RL-circuit in Fig (5)
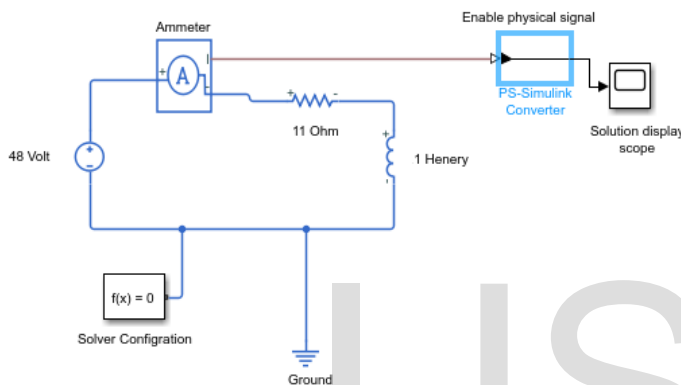

Fig (5)

Double click in the Scope, the current as a function of time displayed.

Now, all approaches lead to a unique answer, in both all the display solutions (scopes) and the answer plot for the Matlab Differential equation command as in Fig(6)
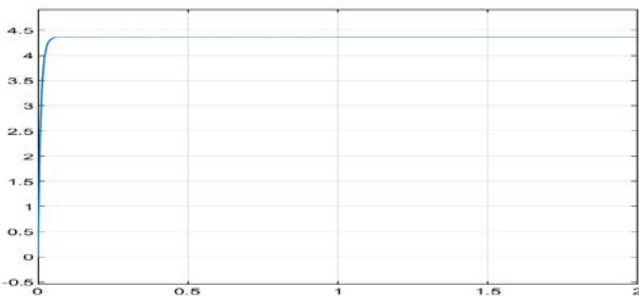

Fig (6)

Example 2.4 (Linear-First Order Ordinary Differential Equation)

Let us change in Example 2.3, the DC into AC voltage source E=48 Sin (3t) Volt, the Mathematical Modeling of the given circuit such that the current I at the time t=0 is zero by equation (3)

$$0.1\frac{dI}{dt} + 11I = 48 \text{ Sin(3t)} \text{T}(3)$$

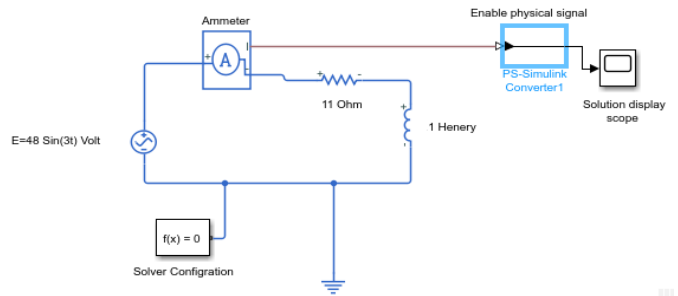The Simscape for equation (3), in Fig (7)

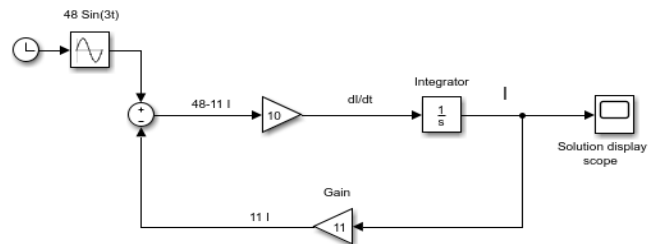Fig (7)

Also the Simulink for equation (3), in Fig (8)

Fig (8)

Finally, the Matlab command that solve and plot the Mathematical modelling in equation (3)

```
>> syms t I;I=dsolve('DI+11*I=48*sin(3*t)','I(0)=0','t');ezplot(I,[0,10])
```

Now, all approaches lead to a unique answer, in both all the display solutions (scopes) and the answer plot for the Matlab Differential equation command as in Fig(9)

Fig (9)

The idea of Example 2.4 can be adopted to any similar modeling but with different variables, such as position and velocity or extended to a position and acceleration but in this case, two integrator needed as we have a second order differentiation. Going further, let the two sets of data and ask students to sketch the circuit for each set. Discuss the difference between the two circuits and letting the initial condition as time t=0, both I=0 and $\frac{dI}{dt} = 0$ in a Physical and Mathematical Modeling point of view:

Example 2.5 (Homogeneous and Non-Homogeneous Linear Second Order Ordinary Differential Equation with Constant Coefficient)

5.1 Let R=1 Ohm, L=0.25 H, C=0.00005 F, and E=110 Volt

5.2 Let R=2 Ohm, L=1.0 H, C=0.05 F and E=157/9 Sin (3t) Volt

such that the current I and $\frac{dI}{dt}$ at the time t=0 are both zero. Simulink and Matlab solving command require a Mathematical modelling.

Now the Mathematical modelling for the RLC-Circuit in general:

If E = constant as in 5.1 , $\quad 0 = \frac{1}{0.00005} I + \frac{dI}{dt} + 0.25 \frac{d^2 I}{dt^2}$ T(4)

If E = E(t) as in 5.2, $\quad \frac{157}{3} \sin(3t) = \frac{1}{0.05} I + 2 \frac{dI}{dt} + \frac{d^2 I}{dt^2}$ T(5)

Start with equation (4), Simcape in Fig (10), which does not require any Mathematics, to motivate students to look at the physical and mathematical consideration beyond the solution
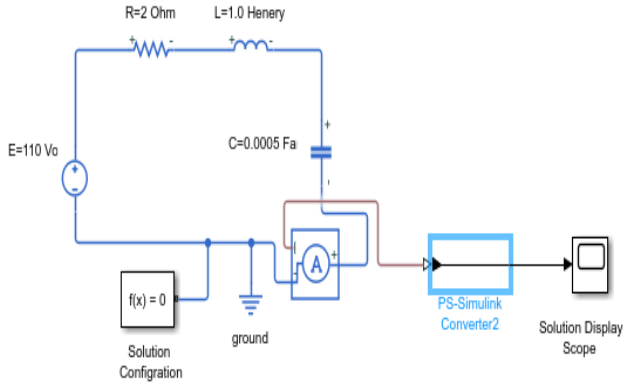

Fig (10)

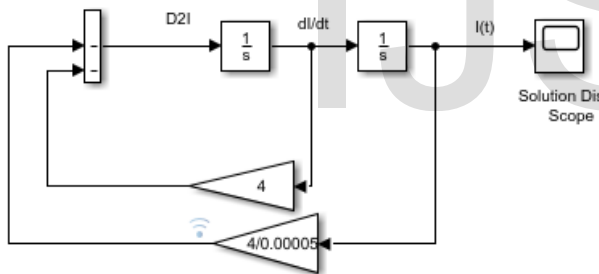Next, using the Matlab Simulink of equation (4) as in Fig (11)

Fig (11)

The theoretical solution requires two initial condition because the mathematical modelling is a second order differential equation. These two conditions come from the physical understanding of the damping of the current due to both the inductive and capacitance resistance. So the current I = 110 at the time t=0 and the current is constant at t =0, and so is mathematically, the slope of the current function. The Matlab command that solve and plot equation (4) is

```
>> syms t I;I=dsolve('0.25*D2I+DI+(1/0.00005)*I=0','I(0)=110','DI(0)=0','t');pretty(I)
                         sqrt(19999) exp(-2 t) sin(2 sqrt(19999) t) 110
exp(-2 t) cos(2 sqrt(19999) t) 110 + -------------------------------------------
                                                   19999
```

```
>> ezplot(I,[0,2])
```

Now, all approaches lead to a unique answer, in both all the display solutions (scopes) and the answer plot for the Matlab Differential equation command as in Fig (12)
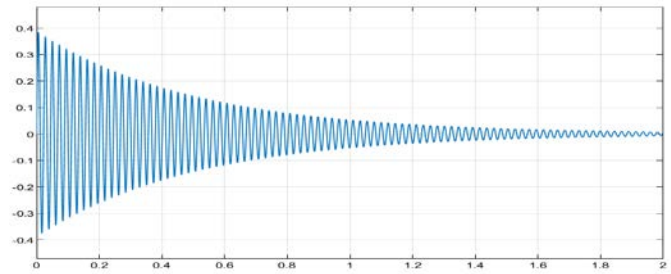

Fig (12)

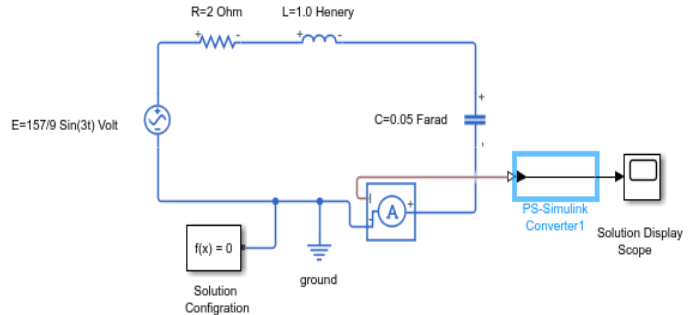Here is equation (5) Simscape method in Fig (13)

Fig (13)

The Matlab Simulink in Fig (14) that solve and plot equation (5)
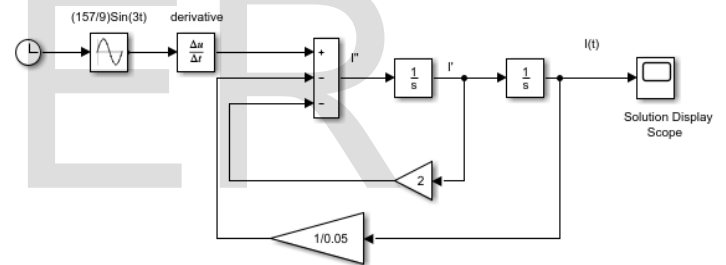

Fig (14)

Finally, the Matlab command that solve and plot equation (5) is

```
>> syms t I;I=dsolve('D2I+2*DI+(1/0.05)*I=(157/3)*cos(3*t)','I(0)=0','DI(0)=0','t');ezplot(I,[0,10])
```

Now, all approaches lead to a unique answer, in both all the display solutions (scopes) and the answer plot for the Matlab Differential equation command as in Fig (15)
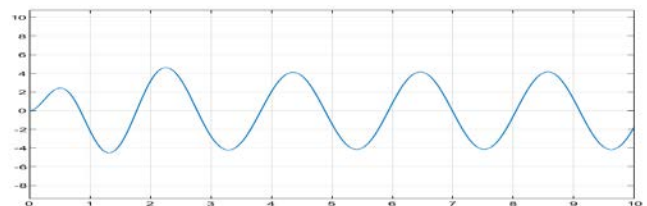

Fig (15)

Note that the Homogeneous Second Order Linear Differential equation is not only a mathematical modelling for the RLC-circuit with DC-voltage source, but also for and LC-circuit with DC-voltage source, the Mass Spring and for many things else.

Now time for a creative discussion and innovative Exercise:

Example 2.6 (Mathematical Modelling Discussion)
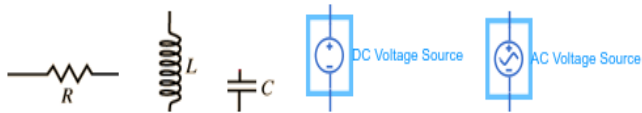
Here assume the components in Fig (16)

Fig (16)

given. Construct your own Circuit, such as RC-circuit, LC-Circuit, RL-circuit, as well as RLC-circuit using either Direct Voltage Source or Alternating Voltage Source and find the current using different approach with your own Initial Condition.

3 CONCLUSION

Learning by doing and clarify the ambiguity in some students of the importance of Mathematics. Learning. Linking the physical interpretation to the Initial condition in the initial value problem (IVP) involve Physics in the Mathematics problem solving as well as the Technology. The future Mathematics Instructor need more qualification and integration of knowledge in other areas rather than the mathematical knowledge. Solution by a physical simulation save time and equipment and make a creative method of teaching Mathematics. The Mathematics Tutorial will be enjoyable as a working lab with innovative discussion. The board replaced by a smart shape by using Simulink. Research and Education using STEM-based approaches for Modeling, Analysis and Simulation of social or scientific problem solving.

4 ACKNOWLEDGMENT

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