Article

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Analysis of Undamped Free Vibration Parameters using GeoGebra

Análisis de parámetros de la vibración libre no amortiguada utilizando Geo Gebra

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Abstract

Through this article, a teaching methodology will be designed using a simulation in Geo Gebra, arose due to the need to contribute to the achievement of significant learning in the field of Mechanical Predictive Maintenance of the Industrial Maintenance Career at the Technological University of Xicotepec de Juárez, In this research, a teaching methodology was designed using a simulation in Geo Gebra since the university students could not understand the concepts about simple harmonic motion (MAS) as it is also known as undamped free vibration. Vibrations occur in systems that try to return to their state of rest or equilibrium when they are disturbed, or move away from their equilibrium state. It is about presenting how a simple harmonic motion problem was solved, highlighting the physical characteristics of the phenomenon. The current educational format has led teachers to use GeoGebra to analyze the behavior of some physical variables, proposing to students to interact with a simulation. With this it can be verified that, in relation to a simulation, it helps to facilitate the understanding of the concepts.

Methodology, Geo Gebra, Vibrations, Predictive, Technological, Variables, System, Significant, Simulation

Resumen

Mediante este artículo se diseñara una metodología de enseñanza utilizando una simulación en Geo Gebra, surgió debido a la necesidad de contribuir al logro de aprendizaje significativo en la materia de Mantenimiento Predictivo Mecánico de la Carrera de Mantenimiento Industrial en la Universidad Tecnológica de Xicotepec de Juárez, en esta investigación se diseñó una metodología de enseñanza utilizando una simulación en Geo Gebra ya que los alumnos universitarios no lograban comprender los conceptos acerca del movimiento armónico simple (MAS) como también se le conoce a la vibración libre no amortiguada. Las vibraciones ocurren en sistemas que intentan regresar a su estado de reposo o equilibrio cuando se perturban, o se alejan de su estado de equilibrio. Se trata de presentar como se resolvió un problema de movimiento armónico simple, que resalten las características físicas del fenómeno. El formato educativo actual ha llevado a los docentes a usar GeoGebra para analizar el comportamiento de algunas variables físicas, proponiendo a los estudiantes interactuar con una simulación. Con esto se puede comprobar que, en relación con una simulación, ayuda a facilitar la comprensión de los conceptos.

Metodología, Geo Gebra, Vibraciones, Predictivo, Tecnológica, Variables, Sistema, Significativo, Simulación

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Introduction

The teaching of the exact sciences with emphasis on mechanical predictive maintenance, as in the case of other areas of knowledge, continues to be a task for the transmission of knowledge in the use of new technologies and novel didactics in the school.

The pedagogical work of teachers is confronted with the search for tools to improve the learning motivation of students (Díez, 2015), who are observed with less commitment to learning through traditional teaching methods. According to the above and taking into account the current position after the pandemic of new technologies in society and particularly in the lives of young people, it is necessary to incorporate them into the educational system, in order to achieve a transformation of the current teaching approach (Huapaya et al., 2005) towards a system that is easily assimilated by any student, regardless of their characteristics. Generally, teaching is based on traditional systems where the student is only a passive receiver of knowledge (Zuluaga, 2016).

The objective of this paper is to present a theoretical analysis and simulation in Geo Gebra to understand the behavior of simple harmonic motion.

Our purpose is to support the training of engineering students, in particular for those who are pursuing the educational experience called mechanical predictive maintenance. The underlying philosophy guiding our efforts is problem-based learning.

Mechanical vibrations are usually addressed as an example of the application of higher order linear differential equations in a university differential equations course.

Therefore, we wanted to present a practice performed in the computer laboratory, which is part of the performance criteria of the educational experience of differential equations, which in turn serves as a basis for further studies in the study of mechanical vibrations.

The instructional objective of this practice is that the student builds his learning from the experience of this practice, which solves the problem of quantifying the effect on a mass-spring system.

The authors discuss the activity proposed here, taking into account that traditional education can be complemented by the didactic strategy of project-based learning, which contributes to consolidate significant learning that in turn translates into the desired skills, such as: analysis of the solution of the case, mathematical analysis and analysis of the experiment.

1. Analysis of the case solution

In the field of physics, simple harmonic motion (S.H.M.) is a periodic back-and-forth motion in which a body oscillates back and forth from its equilibrium position at equal time intervals. Examples of this motion are the motion of a simple pendulum or the motion of an oscillating particle attached to a spring that has been compressed.

This exercise was applied to the subject of mechanical predictive maintenance of the Industrial Maintenance Engineering course in the ninth quarter of the Technological University of Xicotepec de Juárez during the pandemic, these strategies were adapted to improve the performance of the subject and are oriented according to the curricular guidelines of the technological universities and the internal instructional design.

For this research Geo Gebra was selected, a free software used to teach and learn mathematics, it allows its users to create models and interact with them, Geo Gebra accepts commands related to geometry, algebra and calculus; it enables the interactive application of different topics, presenting them in the form of animations and allowing a visual and dynamic exploration (Caligaris et al., 2015). This tool allows the familiarization of the student with the subject of study, through the visualization of the results of measurements performed (León, 2017). The simulations were designed and are described in Fig. 1 through basic programming used for their construction.

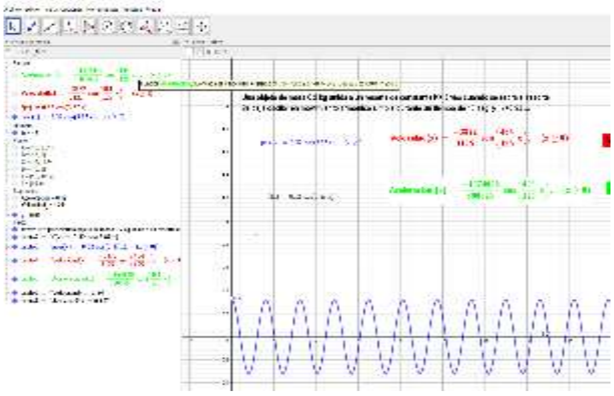

Figure 1 Programming used to build the simulations in Geo Gebra
Own Elaboration

Most of the research oriented to the implementation of software in classrooms focuses on the use of simulations, little use is given to computational modeling activities, probably because it implies apart from the knowledge of mathematical models knowledge in the use of a specific programming language (López et al., 2016). In this sense, the research presented in this article contains modeling elements since the scenarios of the phenomena studied were built from scratch from their mathematical models; however, the product of these computational models is presented to the student as a series of simulations, in which he/she must manipulate variables and observe the behavior presented.

2. Mathematical analysis

The following is how the analysis is incorporated: To perform the exercise it is necessary to understand that the elements of a simple harmonic motion (MAS): which focuses on the free vibrations that occur when the motion is maintained due to gravitational or elastic restoring forces in the exercise presented are calculated undamped vibrations that exclude the analysis the effects of friction on the system.

In very simple terms a vibration is an oscillatory motion of small amplitude. It is represented by an object attached to a spring, the system oscillates vertically and its motion moves horizontally.

A particle has an oscillatory motion when it moves periodically around an equilibrium position. Its study is essential to understand the simple harmonic motion.

As we can observe it is periodic back-and-forth motion in which a body oscillates back and forth from its equilibrium position and at equal time intervals.

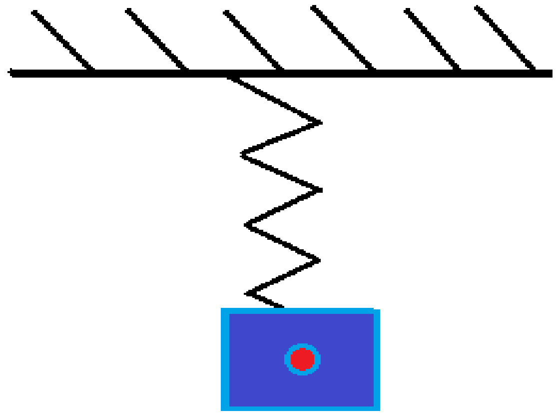

Figure 2 Periodic movement of shock absorber
Own Elaboration

This is produced by an elastic restoring force that originates when the body separates from its equilibrium position, we will explain the formulas applied to perform the simulation.

3. Characteristic vibration parameters

Displacement: Indicates the amount of motion that the mass experiences with respect to its rest position.

Period: The time it takes for a complete oscillation to be completed. Its unit of measurement in the International System is the second (s). It is the time it takes for the mass to make a complete cycle.

Frequency: It is the number of cycles that occur in a unit of time. It is the number of times an oscillation is repeated in one second. Its unit of measurement in the International System is the hertz (Hz).

Velocity: Refers to the ratio of change of position to time.

Acceleration: Provides the measure of the change in velocity with respect to time.

4. Equations of motion

Applying Newton's second law, simple harmonic motion is then defined in one dimension by the differential equation:

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$$m\frac{d^2 x}{dt^2} = -kx \quad (1)$$

$F = ma$

Equation of the elastic constant

x= elongation or displacement with respect to equilibrium point
t = time
K = elastic constant N/m
m = masd
a = aceleration

Being m, the mass of the body in displacement. Writing $\omega^2 = k/m$ we obtain the following equation where ω is the angular frequency of the motion:

$$\frac{d^2 x}{dt^2} = -\omega^2 x \quad (2)$$

Angular frequency equation

Equations of a MAS: the same mass-spring system of the simulation is used.

The instantaneous oscillation of a material point executing a simple harmonic motion is obtained therefore by deriving the position with respect to time we obtain the velocity equation:

$$v = \frac{dx}{dt} = -\omega Asen\ (wt + \varphi) \quad (3)$$

Velocity equation

Acceleration is the variation of the velocity of motion with respect to the waiting time and is therefore obtained by deriving the equation of the velocity with respect to the time of as shown in the following figure:

$$a(t) = \frac{dv(t)}{dt} = -\omega^2 Acos(wt + \varphi) \quad (4)$$

Acceleration equation

5. Solution of the exercise

This section describes the exercise performed for the analysis. An object of mass 0.2 kg attached to a spring of constant K= 3N/m when the spring is stretched. It is allowed to oscillate in simple harmonic motion for a time of 15 sec. and A=0. 32m.

It is important to identify the following parameters:

– The equation predicting the motion of the particle
– The period
– The equation of position
– Velocity
– Acceleration

The equation that predicts the motion of the particle.

As a first step we must obtain the angular frequency in order to determine the period:

$$\omega = \sqrt{\frac{K}{m}} = \sqrt{\frac{3\frac{N}{m}}{0.2kg}} = 3.872\frac{rad}{seg}$$

Period

Once we know the value of the angular frequency we can calculate the period and frequency as a complement.

$$f = \frac{\omega}{2\pi} = \frac{3.87\ rad/seg}{2\pi\ rad/ciclo} = .616\ Hz$$

$$T = \frac{1}{f} = \frac{1}{.616\ ciclos/s} = 1.623\ seg$$

The position equation

$x = A\cos(wt + \varphi)$
x= 0.32 m cos ((3.872 rad/seg)(15seg)) =0.01m

Velocity

We can also look up the value of the velocity, which is given by the following equation:

$$\boldsymbol{v}(t) = -A\omega * Sen(\omega t + \varphi) \quad (3)$$

$\boldsymbol{v}(t) = -0.32m$ (3.872 rad/seg) $*$
Sen (3.872 x 15)

$v(t)$ = -1.24 m/s

Acceleration

Substituting the values

$$a(t) = -A\omega^2 * Cos(\omega t + \varphi) \quad (4)$$

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$a(t) = -0.32m\ (3.872\text{rad/seg})^2 *$
$\cos(3.872\text{rad/seg} * 15seg)$

$\text{a}(t) =\ -.1892\ m/s^2$

6. Simulation in Geo Gebra

This section describes how the Geo Gebra simulation was performed.

Add the following function in the program:

f(x) = 0.32cos (3.872 x) as shown in the figure.

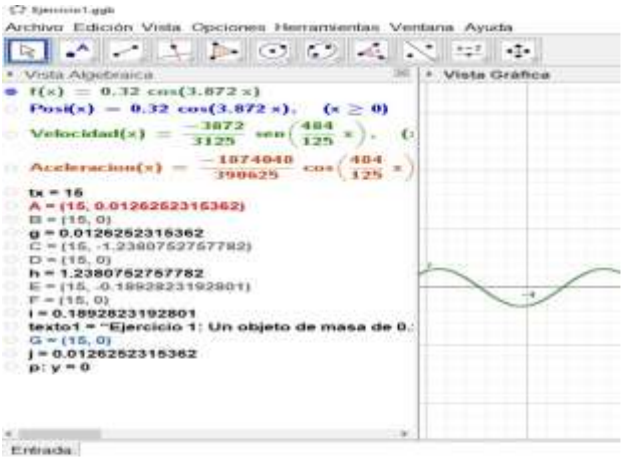

Figure 3 Geo Gebra simulation of the function
Own Elaboration

The previously added function must be conditioned in a new one so that it can start from zero, since there is no negative time. So a new constraint function must be added that has a condition with the following code: If(x ≥ 0, f(x)), we will name this function as "Posi Function" as shown in Figure 4. We can observe that the graph starts from the straight line x=0 so that real values can be read.

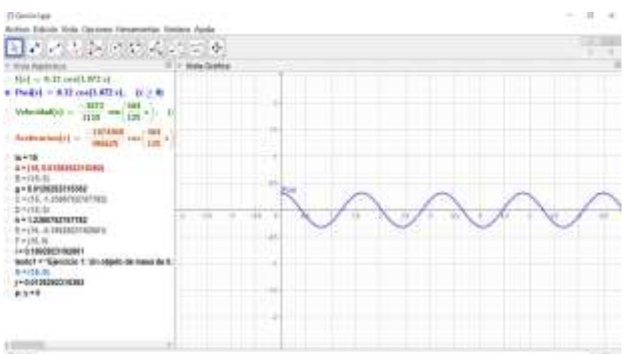

Figure 4 Geo Gebra simulation of the condition function
Own Elaboration

The next step is to add the function that will be used to obtain the velocity: this will be posed as the derivative of the "Posi Function" which will be the following, Derivative(Posi(x)) which in turn will be called "Velocity Function" as shown in the figure.

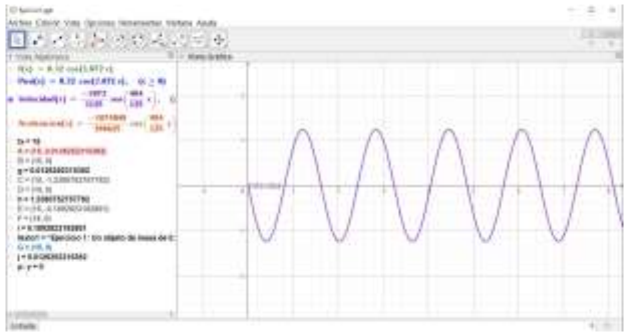

Figure 5 Simulation in Geo Gebra position function
Own Elaboration

To continue with the simulation we will use a slider that will represent the time units, where it will be modified to take the values from 0 to 15 in increments of 1 unit, it will be called "tx" shown in the figure.

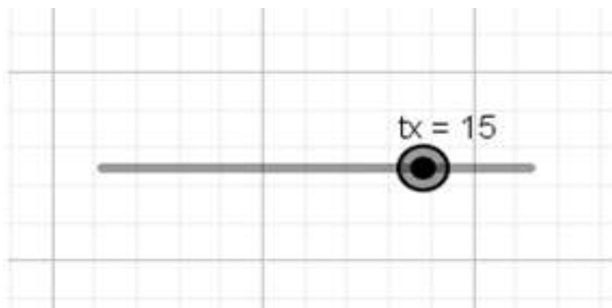

Figure 6 Simulation in Geo Gebra of the slider representing time
Own Elaboration

To find the distances in the different graphs you must choose each one, for example: to calculate the distance from the x-axis to a point of the position function, so we must add a point so that it moves on the "Posi Function".

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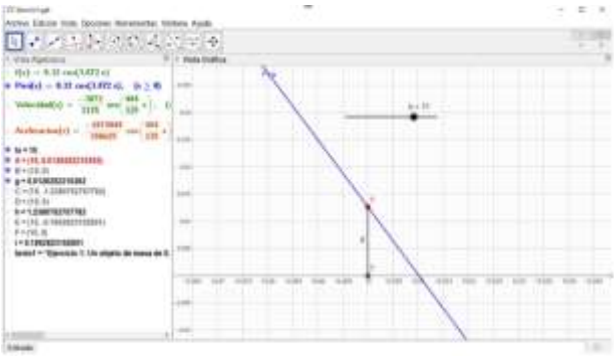

Figure 7 Simulation in Geo Gebra of the length 1 of the position function at 15 seconds
Own Elaboration

If you want to obtain the result of velocity and acceleration you must put the derivative of the position function and then the derivative of the velocity.

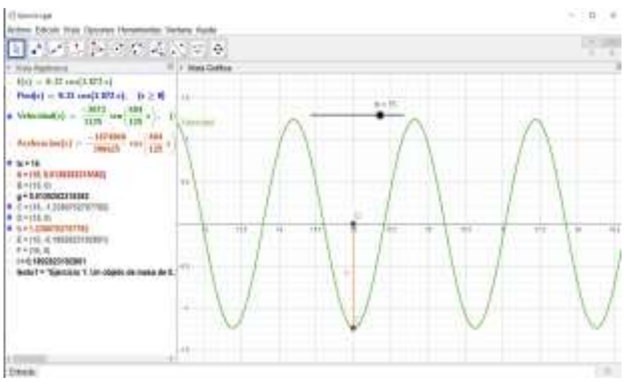

Figure 8 Simulation in Geo Gebra of maximum length of the Velocity function at 15 seconds
Own Elaboration

It is important to add the problem written with the text tool of the same system, to indicate which exercise we are performing.

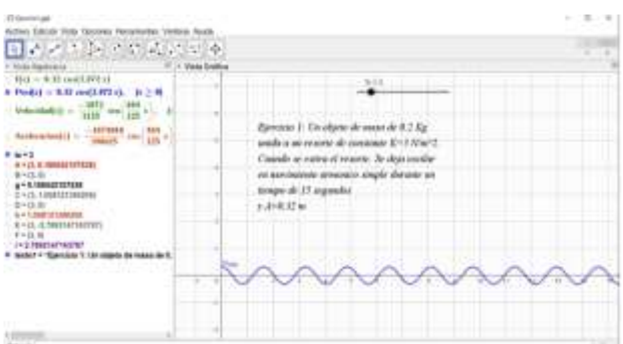

Figura 9 Writing the problem in a text box
Own Elaboration

With this simulation we were able to compare and check that the results did indeed coincide with the analytical procedure.

Finally, the following questions were posed to complement the learning 1. What is the displacement in f(x) in 15 sec, 2.When is the velocity at maximum or minimum acceleration, and 3.When is the acceleration at maximum or minimum velocity?

With the simulation of this exercise, they were adequately answered since they had the graphic support.

In the figures it was possible to observe the reading of the time elapsed from the beginning of the start-up and at 15 seconds after the start-up. The result for the first question is 0.01 m. which coincides with the result of the problem that was performed analytically for the answers of the following questions the behavior of the speed is maximum or minimum when the acceleration is zero and when the acceleration is at the ends of the trajectory the speed is in equilibrium position.

Conclusion

An oscillating system has an undamped free vibration only if the restoring force is directly proportional to the displacement. To solve an exercise, it is necessary to make sure that this is true in the problem scenario by identifying the unknowns.

In this article we rely on Geo Gebra to explain the behavior of an object in the exercise, thus, a simulation was made to support the teaching process. It is noticeable that, in the simulations, the motion described by the mass-spring system corresponds to the graphs that are described when an object moves following the pattern of simple harmonic motion.

This allows the student to design hypotheses and exchange data and to be able to verify or discard them, through the complete analysis of the results that can be obtained by manipulating the parameters relevant to the study being carried out. With this, we can conclude that Geo Gebra allows them to visualize in a simple way the graphical results obtained by solving the different exercises of damping systems, velocity and mass of the system.

The methodology is simple and provides a sense of satisfaction among the students, which allows them to better understand the fundamental concepts of mechanical vibrations, which can be checked at any time analytically.

Finally, it is important to mention that the process of vibration analysis in industry is indispensable to monitor and control machines and thus effectively plan maintenance activities without interrupting the operation of the production plant or compromising the service life of the machines.

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