UNIVERSITI TEKNOLOGI MARA

JOHOR INTERNATIONAL INNOVATION, INVENTION COMPETITION AND SYMPOSIUM

PROCEEDINGS OF JOHOR INTERNATIONAL INNOVATION INVENTION COMPETITION AND SYMPOSIUM 2024 (JIIICaS 2024)

"Flourish and Nurturing Sustainable Innovation for a Prosperous Nation"

JOHOR INTERNATIONAL INNOVATION, INVENTION COMPETITION AND SYMPOSIUM

Editorial Board

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Preface

In the name of Allah, the Almighty who gives us the enlightenment, the truth, the knowledge and with regards to Prophet Muhammad (peace be upon him) for guiding us to the straight path. We thank to Allah for giving us guidance and strength to write this e-book.

This e-book compiles the extended abstracts that submitted to Johor International Innovation Invention Competition and Symposium 2024 (JIIICaS2024), where JIIICaS2024 is a virtual platform for all creative minds to share and present their invention and innovation. Each abstract gives a brief background on the innovation or project.

We hope that this e-book will help the readers to get to know the innovation done by the students and get some ideas to develop future innovation products.

Foreword Rector

Assalamualaikum warahmatullahi Wabarakatuh, Salam Sejahtera, Salam Malaysia MADANI and Salam UiTM Dihatiku.

In the name of Allah, the Most Gracious, the Most Merciful.

It is a great honor to welcome you to the Johor International Innovation, Invention, Competition, and Symposium 2024 (JIIICaS 2024). This event connects various disciplines, focusing on education and engaging educators, students, researchers, and innovators from all walks of life.

Innovation is not just about ideas; it demands perseverance, creativity, and determination to turn those ideas into reality. The remarkable projects showcased today highlight the dedication and spirit of all participants. Initiatives like this not only explore new technologies but also cultivate skills and leadership among our youth. At Universiti Teknologi MARA (UiTM) Johor Branch, we are fully committed to fostering a dynamic culture of innovation, promoting the commercialization of new products, and encouraging meaningful collaborations with industry and society.

As we celebrate this event, I would like to extend my heartfelt gratitude to all sponsors, judges, the College of Computing, Informatics and Mathematics, UiTM Pasir Gudang Campus as the event organizer, as well as to the researchers and participants for their hard work in making this event a success. Let us continue striving for innovation and excellence. May the ideas presented today inspire us and lay the groundwork for future achievements.

Thank you.

Associate Professor Dr. Saunah Zainon
Rector
Universiti Teknologi MARA (UiTM)
Johor Branch

(A-PP028) ANALYSIS OF HARMONIC MOTION IN MASS-SPRING SYSTEMS: INSIGHTS FROM SECOND-ORDER DIFFERENTIAL EQUATIONS

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ABSTRACT

This study focuses on analyzing the dynamics of a mass-spring system, a fundamental concept in physics and engineering. The system's behavior is modeled using a second-order differential equation derived from Newton's Second Law of Motion. Specifically, the study examines the oscillatory motion of a mass attached to a spring with a spring constant k, exploring key parameters such as natural frequency, amplitude, and phase angle. The solution of the differential equation provides insights into harmonic motion and its implications for mechanical vibrations and resonance phenomena. It also considers the effects of damping on the system's behavior, enhancing the understanding of real-world applications. The findings from this study are expected to contribute to a deeper comprehension of mass-spring systems, offering valuable knowledge for applications in fields such as mechanical engineering, materials science, and structural analysis.

Keywords: Harmonic motion, Mass-spring, Newton’s Second Law

1.0 INTRODUCTION

Harmonic motion is a fundamental concept in the study of oscillatory systems, particularly those involving mass-spring configurations. These systems are characterized by their periodic motion, where the mass oscillates around an equilibrium position due to the restoring force of the spring. The behavior of such systems can be accurately described using second-order differential equations derived from Newton’s Second Law of Motion. This mathematical modeling is crucial for understanding the natural frequency, amplitude, and phase of oscillations, which are essential parameters in various applications, from mechanical systems to electronic circuits. Moreover, the study of damping effects provides insights into how real-world factors influence system stability and performance.

1.1 PROBLEM STATEMENT

Mass-spring systems are fundamental in various engineering and physics applications, yet there is a need for a deeper understanding of how system parameters such as mass, spring constant, and damping affect their dynamic behavior. While the basic principles of harmonic motion are well-known, the impact of these parameters on the natural frequency, amplitude, and overall stability of the system under different conditions is not fully explored. Additionally, understanding the effects of damping on mechanical vibrations and resonance is crucial for optimizing the design and performance of systems that rely on these principles.

2.0 OBJECTIVE

The main objectives of this studies are:

a) To develop a comprehensive understanding of harmonic motion in mass-spring systems.
b) To determine the system's natural frequency, amplitude, and phase angle, and explore their dependence on key parameters

3.0 METHODOLOGY

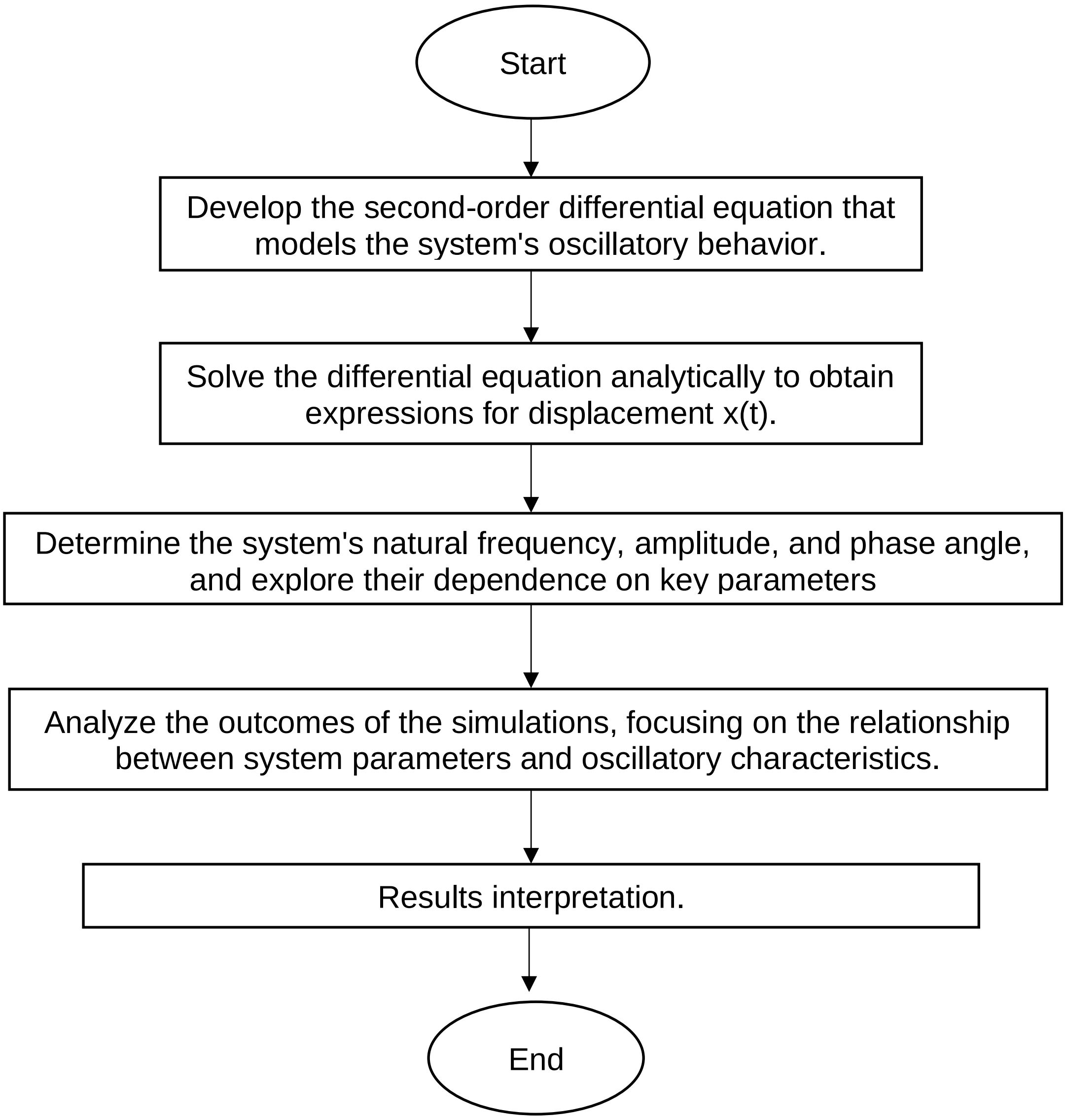

Figure 1: The methodology framework of study.

Figure 1 shows this study begins with the formulation of the mass-spring system, using Newton's Second Law to derive the governing second-order differential equation that models the system's oscillatory behavior. Analytical solutions are then obtained to determine key parameters like displacement, natural frequency, amplitude, and phase angle. Numerical simulations are conducted to validate the analytical results and to explore how variations in system parameters such as mass, spring constant, and damping coefficient affect the system's dynamics. The results are analyzed to understand the relationship between these parameters and the system's oscillatory characteristics, with particular attention to the impact of damping on stability. Finally, the findings are interpreted in the context of practical applications, demonstrating how the insights can be applied to optimize the design and performance of systems relying on mass-spring dynamics.

4.0 RESULTS

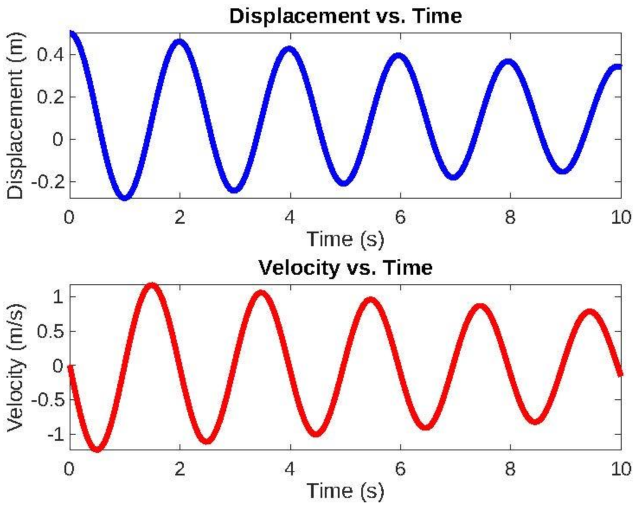

Figure 2: Simulation Displacement vs Time

Figure 2 shows the simulation results for the mass-spring system reveal the effects of oscillatory behavior over time, modeled by the differential equation $m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = 0$. In the undamped case (when $c = 0$), the displacement $x(t)$ exhibits harmonic motion with constant amplitude and frequency, determined by the mass and spring constant. The natural frequency of oscillation is given by $\omega = \sqrt{\frac{k}{m}}$, with the period T. and frequency f showing regular oscillations. In contrast, when damping is present (with $c > 0$), the amplitude of oscillation decreases exponentially over time, reflecting the energy loss due to damping. The results illustrate how damping alters the system's response by reducing oscillation amplitude and affecting stability, providing practical insights into the system's behavior in real-world applications.

5.0 CONCLUSION

The study successfully models and simulates the dynamics of a mass-spring system using a second-order differential equation, providing a comprehensive understanding of harmonic motion and the effects of damping. The analytical and numerical results demonstrate that, in an undamped system, oscillations occur with constant amplitude and frequency, while damping introduces a gradual reduction in amplitude, highlighting the impact of energy dissipation. This detailed analysis not only confirms theoretical predictions but also illustrates practical implications for engineering and physics applications. The findings underscore the significance of these dynamics in designing and optimizing systems involving oscillatory motion.

6.0 BENEFIT OF STUDY

a) The study aids in optimizing the design of mechanical systems like shock absorbers and vibration isolators by considering the effects of damping and resonance.

b) It provides valuable insights for developing effective vibration control strategies to reduce unwanted vibrations in engineering applications.

c) The findings improve understanding of mechanical vibrations and resonance, benefiting fields like structural engineering and automotive design.

REFERENCES

Turab, A., Montoyo, A. & Nescolarde-Selva, J.A. (2024). Stability and numerical solutions for second-order ordinary differential equations with application in mechanical systems. *Journal of Applied Mathematics and Computing*. https://doi.org/10.1007/s12190-024-02175-4

Mazzone, G., & Mohebbi, M. (2024). On periodic motions of a harmonic oscillator interacting with incompressible fluids. *Physica. D, Nonlinear Phenomena*, 134259. https://doi.org/10.1016/j.physd.2024.134259

Sangeetha, S.V., Mrithula, R., Priya S. H, & Preetha, V.G. (2019). Application Of Differential Equation in Simple Harmonic Motion. *Sri Krishna Arts & Science College, Coimbatore*, *4*(2), 2455–2631. https://www.ijsdr.org/papers/IJSDR1902058.pdf

Mohammed, O & Al-Nuaimi, A. (2023) Mathematical Modeling and Simulation of Spring Constant on the Behavior of Damping in a Mass-spring Damped Harmonic Oscillator. *Alq J Med App Sci. 2023;6(2):433-440*. https://doi.org/10.5281/zenodo.8219514

Al-Nuaimi, A.S. & Mohammed, O.A. (2021). Study the Effects of Mass in a Simple Damped Harmonic Motion of a Mass-spring System Using Simulation. *Libyan Journal of Basic Sciences (LJBS)*, *14*(1), eISSN 6261-2707. https://doi.org/10.36811/ljbs.2021.110069