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Introduction to Quantum Harmonic Oscillator Material Using Discussion Method for Students of SMAN 5 Bengkulu City

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Abstract

The knowledge of the student about harmonic oscillators is quite limited. The purpose of this PPM is to 1) increase the knowledge of Bengkulu City 5 SMAN students about Quantum Harmonic Oscillators and their application in everyday life 2) improve the skills of Bengkulu City 5 High School students in calculating Quantum Harmonic Oscillators using the fast-forward method to accelerate quantum dynamics adiabatic. PPM was carried out at SMAN 5 Bengkulu City, especially in class 12 IPA 5 on October 24, 2022. The research method was carried out in three stages. The firststage is preparation. The second stage is the presentation of quantum harmonic oscillator material using research instruments in the form of power points, the third stage is research evaluation.

Keywords: *adiabatic quantum dynamics, fast-forward, quantum harmonic oscillator, student knowledge*

A. Introduction

Physics is one part from the field science done by process discoveries that are mostly learned from natural events [1]. In physics material, harmonic oscillators are often used as a model approach in many physics cases. If in classical mechanics, harmonic oscillators can be solved by using the relationship of Hooke's Law and Newton's Second Law, but in quantum terms a system of harmonic oscillations can be solved by transforming the time-independent Schrödinger equation in one dimension [2].

In quantum mechanics, the Schrödinger equation has an important role in that it can describe the behavior of waves as particles that cannot be explained in classical mechanics [3]. The harmonic oscillating particle system can be solved by transforming the one-dimensional time-independent Schrödinger equation into the Hermite differential equation for the asymptotic boundary taking into account the normalized condition of the wave function [2] . We can state that the solution to the Schrödinger equation using the Hamiltonian is a momentum space solution while the solution to theSchrödinger equation using the Hamiltonian is called a coordinate space solution. The wave function in the coordinate space is written as $\psi\ (\vec{x}, t)$ and the wave function in the momentum space is written as $\psi(x,t)$. Harmonic moving quantum particles can also be used via the one-dimensional Schrödinger equation.

There are several studies that review the Harmonic Oscillator system that have also been carried out, one of which is an attempt to accelerate the quantum dynamics of microscopic particles that move in oscillations. There are two methods for accelerating quantum dynamics, namely Shortcut to Adiabaticity (STA) [4]-[8] and Fast Forward (FF). The STA method was developed by Gonzalo Muga and the FF method was developed by Nakamura. Masuda and Nakamura have developed an adiabatic process scaling technique (*fast-forward*) to accelerate state dynamics [9] with examples of its application, namely for the transport of particles or time depending on potential harmonics, and charged particles in an electro-magnetic field. The *fast-forward method is* also applied to systems in motion, to quantum orbital systems by applying the method of obtaining additional potential terms. This method aims to accelerate known quantum evolution and to obtain desired target states on shorter time scales, by accelerating adiabatic quantum dynamics [10]. An adiabatic process occurs when the external Hamiltonian parameters of the system are changed adiabatically [11]. Applications of *fast-forward theory* can be found in accelerating Dirac particle

dynamics, classical adiabatic invariant dynamic construction and quasi- adiabatic spin dynamics from stochastic dynamics [12]. In this study, researchers tried to introduce a quantum harmonic oscillator using the Fast Forward method which is linked to quantum physics to 12th grade students at SMAN 5 Bengkulu City. Quantum physics is a micro-sized particle and is a microscopic phenomenon. Microscopic phenomena are phenomena that cannot be seen directly by the eye, for example atomic protons, electrons, neutrons and so on [13].

Previous studies have stated that the harmonic oscillator energy is determined from its Schrodinger wave function. The method used to solve the Schrodinger wave equation of the harmonic oscillator is to use the generator function from the Hermit function [14].

Based on the explanation above, the researcher intends to hold a service which is formulated under the title "Adiabatic Phases and Driving Potential to Accelerate Adiabatic Dynamics in Harmonic Oscillator Systems and Complex Wave Functions". Research to accelerate adiabatic quantum dynamics has also been carried out using general adiabatic parameters using additional potentials. In previous studies, the adiabatic phase of the Harmonic Oscillator wave function was obtained for the *ground state* and *first excited state* with the same value, namely $\theta = -\frac{m}{4\hbar\omega}x^2$.

Additional potential is also found in the Harmonic Oscillator

$$\tilde{\mathrm{V}} = -mB\int_0^x x^2 \exp\left[\frac{m\omega}{\hbar}x^2\right]dx + \frac{\hbar}{2\omega}\dot{\omega}Bx\ \exp\left[\frac{m\omega}{\hbar}x^2\right]dx + \left[\frac{1}{h} - \frac{1}{2\omega}\right]\frac{x^2 m\omega^2}{4\dot{\omega}^2}$$

By introducing quantum physics material to students, it is hoped that students will be able to understand more broadly about physics so that they are more interested in researching everything that happens in this universe. The success of a study not only influenced by only the teacher, but the material and examples of the application of the teaching materials teacher used.
But apart from all that, there is something more important for us to think about, which is about what are the advantages of studying physics, and what are the disadvantages if we do not want to study physics. In fact, whether we realize it or not, essentially every human being needs knowledge and follows technological developments in order to live this life in harmony. Where the development of technology is certainly an implication of the physical sciences that have been studied by experts who are experts in their fields [15] .

B. Methods

The method used in this research is through three stages, namely:

a. Preparation
   D done by preparing and make a *power-point* according to the quantum harmonic oscillator materialthat will be introduced
b. Explanation
   Practice explains _ quantum harmonic oscillator material.
c. Evaluation
   At this stage is to conduct a question and answer session and summarize the quantum harmonicoscillator material that has been explained.

PPM was carried out at SMAN 5 Bengkulu City, especially in class 12 IPA 5 on October 24, 2022.

C. Result and Discussion

Implementation of community service followed by students SMAN 5 Bengkulu City . First, providing material on harmonic and quantum oscillators , evaluation of the delivery of harmonic and quantum oscillator material . Students are motivated to understand the importance of studying material about quantum physics to find out the benefits of quantum physics in today's sophisticated technological world even though it has not been studied in school . Second, evaluation of the delivered kateri . Students are given the opportunity to ask questions about the explanation of the material that has been delivered and also answer the questions given to close the material that has been delivered.
Based on the method that has been implemented, the preparatory stage is to make a Power Point which is submitted including the following:

1. Introduction to Quantum Physics material
2. Explanation of Quantum Harmonic Oscillator material
3. Use of Harmonic Oscillator in everyday life

4. Application of Quantum Harmonic Oscillator technology

At the Explanation stage, the activity begins with:

1. Preliminary questions about whether students know quantum physics and harmonic oscillators.
2. Furthermore, examples of the phenomenon of harmonic oscillators in everyday life are carried out to make students more familiar with and interested in quantum physics.
3. Then explain the material through PPT

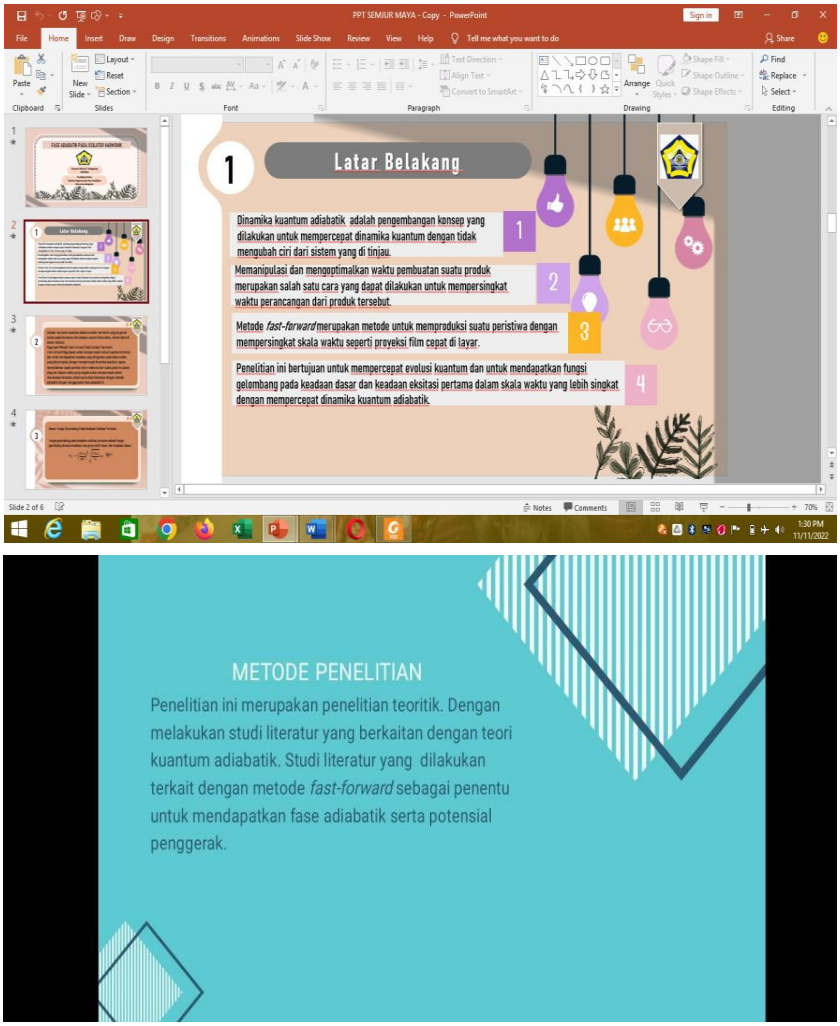
At the Evaluation stage, activities are carried out:

1. After the presentation of the material through PPT, a question and answer session was held about the material that had been explained.

After the presentation of the material, it turned out that many students still did not understand. This was evident when the question-and-answer session was conducted, students were less enthusiastic about asking questions. So it can be concluded that in the presentation of the material, real additional props are needed so that students more easily understand the material.

Figure 1. Practice explains harmonic and quantum oscillator material

Figure 2. Material evaluation of harmonic and quantum osscilators



The implementation of community service carried out at SMAN 5 Bengkulu City can improve students' knowledge and thinking skills well in understanding the introduced quantum harmonic oscillator material. It is said to have worked well because from the results of the evaluation to students , all stages have been carried out and can be categorized well.

D. Conclusion

Submission of material on quantum physics and quantum harmonic oscillators at SMAN 5 Bengkulu City has been completed. The material is delivered through PPT with the method of preparation, explanation and evaluation. Based on the introduction that has been done, students are still less enthusiastic because the material is difficult. Therefore, physics material which is quite difficult requires visual aids so that students more easily understand the material.

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References

[1] AP Ningrum, AD Lesmono, and RW Bacthtiar, "Development of Teaching Materials in the Form of Quantum Teaching-Based Modules in Physics Learning in High School," *J. Physical Learning. Univ. Jember* , vol. 5, no. 4, pp. 315–320, 2017.

[2] Y. Setianingsih, H. Akhsan, and N. Andriani, "Recursion relations and orthogonality of hermite

polynomials in the quantum harmonic oscillator wave function in a case study of Heisenberg uncertainty," *Pros. Monday. Nas. Educator. IPA* , vol. 1(1), pp. 163–170, 2017.

[3] N. Wahdah, Y. Arman, and BP Lapanporo, "Determination of the Ground State Energy of Anharmonic Quantum Oscillators Using the Monte Carlo Diffusion Quantum Method," *Positron* , vol. 6, no. 2, pp. 317–323, 2016, doi: 10.26418/positron.v6i2.16837.

[4] Demirplak M and Rice S A 2003 Adiabatic population transfer with control fields J. Phys. Chem. A 89 9937 [2] Demirplak M and Rice S A 2005 Assisted adiabatic passage revisited J. Phys. Chem. B 109 6838 [3] Berry M V 2009 Transitionless quantum driving J. Phys. A 42 365303

[5] Lewis H R and Riesenfeld W B 1969 An exact quantum theory of the time-dDependent harmonic oscillator and of a charged particle in a time-dependent electromagnetic field J. Math. Phys. A 10 1458

[6] Chen X, Ruschhaupt A, del Campo A, GuLery-Odelin A and Muga J G 2010 Fast optimal frictionless atom cooling in harmonic traps Phys. Rev. Lett. 104 063002

[7] Torrontegui E, Ibanez M, Martinez-Garaot M, Modugmo M, del Campo A, Guery-Odelin D, Ruschhaupt A, Chen X and Muga J G 2012 Shortcuts to adiabaticity Adv. At. Mol. Opt. Phys. 62 117

[8] Masuda S, Nakamura K and del Campo A 2014 High-fidelity rapid ground-state loading of an ultracold gas into an optical lattice Phys. Rev. Lett 113 063003

[9] X. Chen and JG Muga, "Transient energy excitation in shortcuts to adiabaticity for the time-dependent harmonic oscillator," *Phys. Rev. A-At. Mol. Opt. Phys.* , vol. 82, no. 5, pp. 1–7, 2010, doi: 10.1103/PhysRevA.82.053403.

[10] I. Setiawan, B. Eka Gunara, S. Masuda, and K. Nakamura, "Fast forward of the adiabatic spin dynamics of entangled states," *Phys. Rev. A* , vol. 96, no. 5, pp. 1–13, 2017, doi: 10.1103/PhysRevA.96.052106.

[11] S. Masuda, KN-P. of the Royal, and undefined 2010, "Fast-forward of adiabatic dynamics in quantum mechanics," *royalsocietypublishing.org* , Accessed: Jun. 19, 2022. [Online]. Available: https://royalsocietypublishing.org/doi/abs/10.1098/rspa.2009.0446

[12] G. Babajanova, J. Matrasulov, and K. Nakamura, "Quantum gas in the fast forward scheme of adiabatically expanding cavities: Force and equation of state," *Phys. Rev. E* , vol. 97, no. 4, pp. 1–13, 2018, doi: 10.1103/PhysRevE.97.042104.

[13] NR Aini, "The History of the Development of Physics (Quantum) from Classical to Modern," vol.4, no. 3, pp. 57–71, 2020, doi: 10.13140/RG.2.2.17085.08160.

[14] FM Sholihah, S. S, and VI Variani, "Energy Analysis of the Harmonic Oscillator Using Path Integral Hypergeometry and Operator Methods," *Indones. J. Appl. Phys.* , vol. 2, no. 02, pp. 6–15, 2016, doi: 10.13057/ijap.v2i02.1280.

[15] AR Harefa, "The role of physics in everyday life," *J. War.* , vol. 60, no. April, pp. 1–10, 2019