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WEB BASED VIRTUAL LABORATORY FOR EXPERIMENTAL PHYSICS (SIMULATOR AND SOLVER) FOR YOBE STATE UNIVERSITY

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Abstract

This study aims to design, develop, and evaluate a web-based Experimental Physics Simulator and Solver to improve the practical learning experience of 100-level science students at Yobe State University (YSU), Damaturu. The research was motivated by persistent challenges including inadequate laboratory facilities, overcrowded classrooms, and limited hands-on experimentation opportunities, which collectively hinder students' mastery of essential practical skills. The system was developed using the Waterfall Software Development Life Cycle model, employing HTML5, CSS, JavaScript for the front-end, and MySQL for data management.

The study contributes by providing a scalable, cost-effective virtual laboratory tailored to a resource-constrained educational environment. Unlike many existing systems, it integrates multiple experiments within a single web-based platform accessible across devices, thereby enhancing flexibility, engagement, and independent learning. The web-based platform ensures cross-platform accessibility on both computers and mobile devices, providing a cost-effective, scalable solution that enables self-paced, repeatable experimentation.

This virtual laboratory represents a significant pedagogical innovation for resource-constrained educational settings, offering a sustainable alternative to supplement traditional laboratory sessions while enhancing conceptual understanding through interactive visualization and real-time feedback mechanisms. To evaluate the effectiveness and usability of the system, preliminary validation was conducted by comparing simulation outputs with established theoretical physics models, while usability testing involved university physics laboratory instructors and students interacting with the system. The results indicated that the simulator produced accurate outputs consistent with theoretical expectations and was user-friendly for learners. The simple pendulum with length of 1.0m gives a Period (T) = 2.0 s. for acceptability test, 20 staff and 100 students used the system and reported its acceptability result. According to the test result both the staff and the students recommended the system for virtual experiment. The result reveals that simplicity got 88%, accurate results 75%, clarity 80% and acceptable 90%. The system demonstrates potentials to bridge the practical skills gap, improve academic performance, and foster greater engagement in physics education among introductory science students.

Keywords: Experimentation Opportunities, Interactive Learning, Simulation, Virtual Laboratory, Web-Based Application

Introduction

Hands-on physics experiments are fundamental to science learning, allowing students to develop critical thinking, problem-solving skills, and a deeper understanding of scientific principles, practical physics activities are essential in science curricula because they allow students to apply theoretical knowledge, develop problem-solving abilities, and strengthen their grasp of core scientific ideas. By engaging in experiments, learners take part in hypothesis formulation, data collection, analysis, and the process of drawing conclusions that build deeper conceptual understanding and increase interest in physics. These experiential learning opportunities allow students to bridge theoretical concepts with real-world applications, cultivating essential skills such as logical reasoning, data interpretation, and collaborative inquiry. Globally, there has been a significant shift in science education towards inquiry-based learning (IBL), which emphasizes student-centered exploration and discovery over traditional lecture-based instruction. IBL encourages students to pose questions, design investigations, and construct knowledge through active engagement, aligning with constructivist theories of learning. Studies have demonstrated that IBL approaches, when integrated into physics curricula, significantly improve students' critical thinking abilities and conceptual understanding, particularly in complex topics like mechanics and electromagnetism. For instance, research on the implementation of IBL in physics classrooms has shown positive effects on student outcomes, with effect sizes indicating substantial gains in higher-order thinking skills. The integration of technology, particularly virtual simulations, has further transformed physics education by providing accessible and interactive learning environments. Virtual laboratories allow students to conduct experiments in a simulated setting, manipulating variables and observing outcomes without the constraints of physical resources or safety concerns.

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Recent studies highlight the efficacy of interactive simulations in enhancing conceptual understanding in introductory physics courses at the university level. HTML5-based simulations have been shown to effectively illustrate abstract concepts, such as projectile motion and oscillatory systems, making them particularly valuable for first-year undergraduates. Moreover, during the COVID-19 pandemic, virtual labs bridged the gap between traditional and online learning, maintaining student engagement and performance in physics.

In the Nigerian context, physics education faces unique challenges that underscore the need for innovative approaches like virtual simulations. Despite the country's emphasis on science and technology education, student performance in physics remains suboptimal, often attributed to inadequate laboratory facilities, overcrowded classrooms, and limited access to modern teaching tools. Yobe State University, faculty of science serves a diverse student body, primarily from northeastern Nigeria, where educational infrastructure is often underdeveloped due to socioeconomic and security. The 100-level science students at the University encounter difficulties in mastering experimental skills, as evidenced by internal assessment data showing average CGPA below 2.5 in practical-oriented courses for the 2020/2021 academic session. Common problems include limited access to functional laboratory equipment, insufficient hands-on practice, and challenges in data analysis and interpretation, which hinder students' ability to connect theoretical knowledge with experimental outcomes. These issues are compounded by larger class sizes and varying levels of preparedness among incoming students, many of whom come from secondary schools with inadequate science facilities. The motivation for this study arises from the observed low performance and engagement of 100-level science students at Yobe State University in practical experiments. These challenges are part of a broader national issue where science education in Nigeria faces significant barriers, including inadequate laboratory facilities and overcrowded classrooms.

The COVID-19 pandemic severely exacerbated this situation, halting all physical laboratory sessions and exposing the critical lack of alternatives for practical science education, a problem documented across Nigerian universities. Furthermore, these challenges are particularly acute in Northern Nigerian educational institutions, where socioeconomic and infrastructural constraints are more pronounced. Following insurgent attacks in 2010, schools across the Damaturu (the state's headquarters) education zone were shut down. This prolonged closure has made it challenging to complete the academic syllabus. Teachers, fearing for their safety, are often reluctant to report to schools in regions with high and recurring insurgent activity and abductions. This shows an urgent need to provide a resilient, accessible platform inform of a web-based virtual simulation tool that supplements traditional laboratories to foster inquiry-based learning, and equips students

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with essential practical skills, thereby helping to bridge this critical educational gap.

The Need for Virtual Laboratory for Experimental Physics in YSU

Yobe State University, 100-level science students exhibit persistent challenges in practical coursework, with internal evaluations indicating that over 50% of students score below average in experimental assessments between 2020 and 2023. Key issues include difficulties in conducting accurate measurements, interpreting data plots, and understanding concepts such as simple harmonic motion and Faraday's law, often due to inadequate laboratory resources and limited practice opportunities. National reports echo these problems, noting that resource constraints in Nigerian universities lead to poor student outcomes in physics. Furthermore, existing solutions are often designed for general use without considering the specific curriculum requirements and device accessibility limitations prevalent in the institution.

This study addresses the gaps by developing a virtual simulator tailored to the local context that enables virtual experimentation at student's convenience. To remedy the problems a web based virtual Experimental Physics Simulator and Solver was developed for YSU. The system utilizes interactive animations to simulate key experiments, enabling students to use computer input devices to manipulate virtual instruments. This approach not only overcomes logistical barriers but also promotes self-paced learning, repeated experimentation, and immediate feedback, ultimately enhancing students' practical proficiency and academic performance in introductory physics.

Objectives of the Study

The aim of this research is to develop a web-based virtual laboratory for simulating physics experiments of YSU to improve the practical skills of 100-level science students. The research has the following objectives:

- To review existing literature on virtual physics laboratories and their application in higher education.
- To design a computer-based system that assists students in performing and analyzing physics experiments.
- To develop and test simulations for experiments.
- To evaluate the system's usability and effectiveness in enhancing students' practical skills and conceptual understanding.

Significance of the Research

This research holds significant value for physics education at Yobe State University and beyond. It provides an affordable, scalable solution to laboratory constraints, enhancing students' practical skills and conceptual understanding. By enabling repeated, risk-free experimentation, the simulator increases student interest and performance in physics, potentially reducing failure rates. Furthermore, it bridges

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educational disparities in under-resourced regions like Yobe State, empowering students to compete nationally and contribute to sustainable technological development in Nigeria. This This research is limited to simulating key introductory physics experiments for 100-level science students at Yobe State University, including forced and damped motion, data fitting, simple pendulum, Faraday's law, Hooke's law, Simple Harmonic Motion, Kepler's Second law, and Falling and Wiggling Slinky. The web-based system is accessible via computers and mobile devices, emphasizing interactive animations and data analysis tools. Access requires internet enabled devices, which could limit usability in areas with poor connectivity in Yobe State.

Theoretical Review

Section establishes the theoretical foundation for the study, drawing on established educational theories and philosophies of science. It anchors the development of the Experimental Physics Simulator and Solver in constructivist and social constructivist learning theories, which posit that knowledge is actively built by learners through experience and social interaction. The review confirms that practical experimentation is not merely an add-on but the very essence of physics as an empirical science, where conceptual understanding is grounded in observational evidence. Furthermore, the research is aligns with Inquiry-Based Learning (IBL) methodologies, which shift the focus from passive reception to active, student-centered exploration. This theoretical framework justifies the use of a virtual laboratory as a valid and necessary pedagogical tool, especially in contexts where traditional labs are inaccessible, by demonstrating its capacity to facilitate the core processes of hypothesis testing, investigation, and knowledge construction.

Conceptual Review

This focuses on the key concepts central to this project: virtual laboratories, simulations, and technology-enhanced learning. It differentiates a virtual lab a comprehensive online environment for conducting experiments from a simple simulation, which models a specific phenomenon. The concept is positioned within the broader domain of e-learning, emphasizing its role in providing accessible, scalable, and safe practical experiences. For the context of Yobe State University, the critical conceptual benefits include accessibility (overcoming spatial and temporal constraints), scalability (accommodating large student numbers), and cost-effectiveness (reducing reliance on physical hardware). The review conceptualizes the proposed system not as a replacement for hands-on labs, but as a crucial complementary tool that can effectively bridge the practical experience gap in resource-constrained environments, thereby supporting the core learning objectives of introductory physics.

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An Overview of Computer Simulation

Computer simulation is a comprehensive method for studying systems. In this broader sense of the term, it refers to an entire process. This process includes choosing a model finding a way of implementing that model in a form that can be run on a computer, calculating the output of the algorithm, and visualizing and studying the resultant data. The method includes this entire process used to make inferences about the target system that one tries to model as well as the procedures used to sanction those inferences. Simulations make creative use of calculational techniques that can only be motivated extra-mathematically and extra-theoretically.

As such, unlike simple computations that can be carried out on a computer, the results of simulations are not automatically reliable. Much effort and experts go into deciding which simulation results are reliable and which are not. When philosophers of science write about computer simulation, and make claims about what epistemological or methodological properties "computer simulations" have, they usually mean the term to be understood in this broad sense of a computer simulation study. Computer simulations are now widely accessible across various scientific disciplines, including physics. Studies exploring the simulation of physics concepts such as projectile and circular motion—have been conducted. Research generally supports the effectiveness of simulations, with most comparisons between simulation-based and traditional instruction showing favorable outcomes. Simulations can either supplement or replace conventional teaching methods. Today, a vast number of simulations available online can be integrated into teaching. However, it is essential to evaluate each simulation before use first to confirm its scientific accuracy, and second to ensure it aligns with instructional goals. Language can also pose a barrier; for instance, simulations are rarely available in Slovak, which complicates their classroom application.

Knowledge Gap

The literature reveals a strong foundation in the theoretical and practical roles of experiments and simulations in physics education. Strengths include enhanced conceptual understanding, cost-effectiveness and accessibility. However, weakness such as device-specific applications, limited experiment coverage, and lack of context-specific solutions are evident. Limitations include outdated technology, language barriers and restricted scalability. The knowledge gap identified in this review is threefold.

First, while comprehensive simulation platforms like PhET exist, they are designed for global audience and do not account for the specific curriculum requirements, infrastructural constraints and connectivity challenges of institutions like Yobe State University. Second, existing solutions are predominantly platform-dependent (Android-only) or focus on single experiments, limiting their utility for comprehensive introductory

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physics instruction. Third, there is a notable absence of web-based multi-experiment virtual laboratories specifically developed for resource-constrained Nigerian university contexts that can be accessed across both computers and mobile devices without requiring high-end hardware or consistent high-speed internet. The proposed Experimental Physics Simulator and Solver addresses this gap by offering a web-based platform that is accessible on both computers and mobile devices, include multiple experiments of Yobe state university 100-level physics curriculum, tailored to the specific needs of students at Yobe State University.

Methodology

System development life cycle adopted was a waterfall model also referred to as linear sequential life cycle model, each phase must be completed before proceeding to the next phase and there is no overlapping in the phases. The existing system at Yobe State University relies on physical laboratories where 100-level science students conduct experiments under lecturer supervision. The flow begins with lesson planning, followed by equipment allocation, student group assignments, and hands-on experiments. Data from experiments (e.g., measurements, observations) are manually recorded, analyzed using basic tools like graph paper or calculators, and submitted for grading. Feedback is provided by lecturers, with results stored in physical records or basic spreadsheets. The existing system suffers from inadequate laboratory equipment, leading to limited hands-on practice. Overcrowded classes hinder individual attention, and manual data analysis is time-consuming and prone to errors. Poor maintenance of equipment and inconsistent power supply further disrupt practical sessions. Additionally, the lack of scalability and accessibility outside scheduled times restricts student learning opportunities.

Advantages of the Proposed System

The proposed Experimental Physics Simulator and Solver offers a web-based platform accessible on multiple devices, overcoming physical resource limitations. It provides interactive simulations for repeated practice, immediate feedback, and self-paced learning. The system enhances data analysis with automated tools, reduces costs associated with physical labs, and is scalable to accommodate large student numbers, particularly benefiting under-resourced settings like Yobe State University.

High Level Model of the Proposed System

The high-level model includes a web interface for student interaction, a backend server hosting simulation engine, and a database for storing experiment data and user progress. The system features modules for experiments (e.g., simple pendulum, Hooke's law), a data analysis tool, and a feedback mechanism. It is designed to integrate with existing curricula, ensuring alignment with 100-level science requirements. Figure 1 presents the system flowchart which is simply a graphical representation of steps. It shows

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steps in sequential order and is widely used in presenting the flow of algorithm, workflow or processes.

Database Development Tool

MySQL is used as the database development tool to manage user data, experiment results, and progress tracking, ensuring efficient data retrieval and storage. The database includes tables for Users (student ID, name, login details), Experiments (experiment ID, name, parameters), and Results (student ID, experiment ID, data, timestamp), linked via primary and foreign keys for relational integrity.

Math Specification

Mathematical models include the following equations for simple harmonic motion (1), Hooke's law (2) and Faraday's law (3) respectively, implemented in the simulation engine to calculate dynamic responses.

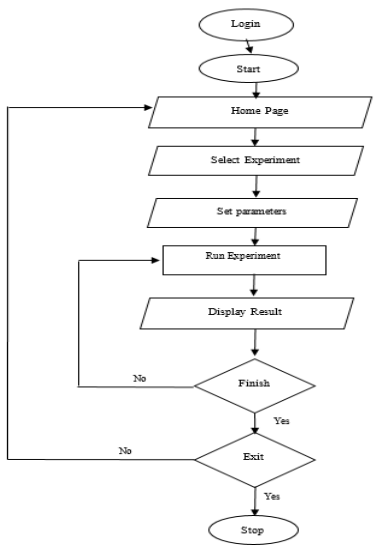

Figure 1: Flow chart of the proposed System

$$x = a\sin(wt) \quad (1)$$

$$F = -kx \quad (2)$$

$$\epsilon = -d\Phi/dt \quad (3)$$

Program Module Specification

Various modules are used to implement the Simulation Engine (handles physics calculations), User Interface (HTML5/CSS/JavaScript), and Data Processor (analyzes and visualizes results), each with defined input-output specifications.

Input: User selections (experiment type, parameters) via dropdowns and sliders.

Output: Graphs, numerical results, and feedback displayed in real-time on the web interface.

Algorithm: The algorithm follows the sequence; Initialize simulation parameters → Compute physics equations iteratively → Update visual output → Store results → Provide feedback. Implemented using a loop with time-step control as shown in figure 2 below:

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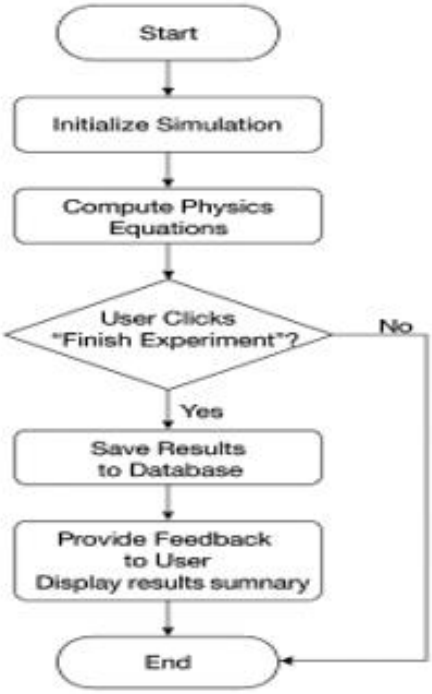

Figure 2: Algorithm for the Proposed System

Data Dictionary

User: ID (int), Name (varchar), Password (varchar), Role (enum: student/lecturer)

Experiment: ID (int), Name (varchar), Parameters (json), Description (text)

Result: ID (int), UserID (int), ExperimentID (int), Data (json), Timestamp (datetime)

Use case diagram of the proposed system

The use case diagram shown in figure 3 describes what the systems does from the perspective of the user. It shows the high-level map of interactions between the users and the system. It also provided the functional requirements of the system by showing the relationship between actors and the use cases.

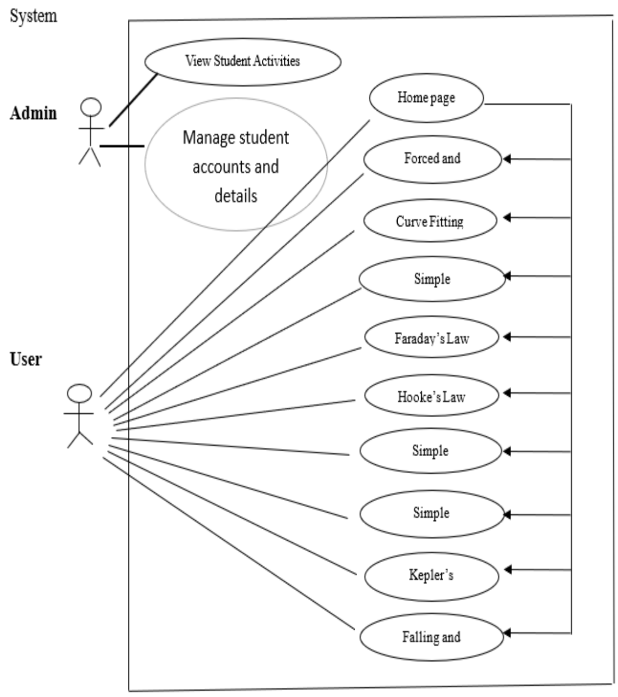

Figure 3: Use case Diagram of the proposed System

Proposed System Requirements

The system has two basic requirements; hardware and software requirements.

Hardware Requirement

1. Laptop or PC

- Core i3 Processor Based Computer
- 2GB RAM
- 5 GB Hard Disk

2. Android Phone or Tablet

- Quad core Processor or higher.
- 1 GB RAM

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Software Requirement

1. Laptop or PC

- Windows 8 or higher.
- Updated Browser

2. Android Phone or Tablet

- Android v5.0 or Higher

Result and Discussion

The results are presented based on the successful implementation of the system's core components as outlined in the methodology.

System Architecture

The interaction occurs as follows: user inputs are captured via the front-end, processed by the simulation engine, and results are displayed dynamically while optionally being stored in the database. The selection of HTML, CSS, JavaScript, and MySQL were based on specific technical requirements. HTML was chosen for its semantic structure, native support for multimedia elements, and cross-browser compatibility. CSS; enables responsive design through media queries, allowing interface to adapt seamlessly to different screen sizes from desktop monitors to mobile phones.

The JavaScript; provides the computational engine for physics simulations, enabling real-time calculations and manipulation. MySQL; was selected for its lightweight footprint, reliability and compatibility with standard web hosting environments, making it suitable for deployment in resource-constrained settings. The system architecture follows a three-tier model:

- Presentation Tier (Front-end): Built with HTML and CSS, delivered via responsive web experiment selection menus, parameter input controls (sliders, numeric fields and visualization panels for graphs and animations.
- Application Tier (Simulation Engine): JavaScript handles all physics calculations, user interactions and real-time updates. The engine implements differential equation solvers for oscillatory systems and mathematical models.
- Data Tier (Backend): MySQL manages user profiles, experiment configurations and result storage. Php serves as middleware to handle database queries and session management.

Functional Simulation Results

The core objective of developing simulations for specific physics experiments was achieved. The system currently includes operational modules for the following experiments:

1. Simple Pendulum:

Users can adjust parameters such as string length, mass of the bob, and gravitational field strength. The simulation visually displays the oscillation and dynamically displacement versus time.

2. Hooke's Law:

This module allows students to vary the applied force and observe the corresponding extension of a spring.

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The simulation automatically generates a force vs. extension graph, demonstrating the linear relationship and allowing for the determination of the spring constant (k).

3. Faraday's Law of Electromagnetic Induction:

This simulation allows students to adjust either the speed at which a magnet passes through a coil or the number of wires turns in the coil. The system visually demonstrates the resulting induced electromotive force (EMF) and provides a real-time graph showing how EMF changes over time.

Preliminary Testing and Validation Result

A preliminary validation was conducted to ensure the system's functional correctness. The output from the simulations (e.g., the period of a pendulum, the spring constant from Hooke's law plot) was compared against theoretical calculations. The results from the simulator were consistent with the expected physical principles and mathematical models is shown in table 1(for the Equations 1, 2, and 3), confirming the accuracy of the underlying algorithms

Table 1: Output from Simple Pendulum Simulation

Parameter	Value Set by User	Simulated Result	Theoretical Calculation
Length (L)	1.0 m	Period (T) = 2.01 s	T = 2π√(L/g) ≈ 2.01 s
Gravity (g)	9.8 m/s²		

Key physics:

- Motion under gravity for small angles (θ<10∘θ<10∘)
- Equation: d2θdt2+gLθ=0$dt2d2\theta+Lg\theta$=0
- Period: T=2πLgT=2πgL (for small angles)

What to simulate:

- Slider for length LL, mass mm (period independent of mass)
- Show graph of **θ vs time** (sinusoidal)
- Show energy transfer between kinetic and potential
- Include option for large angles to show anharmonicity

In this experiment the length of the thread can be adjust, also the value of the can be changed to any desired number. Once the simulation starts running, the time T will begin reading automatically. The picture below shows the result of a simple pendulum after five complete oscillation, the time (T) happens to be 7.4 sec when length of the thread was set to 1 Cm and damping coefficient D was 0.

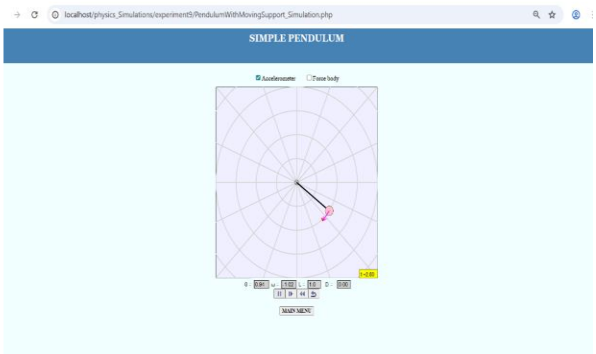

Figure 4: Output from Simple Pendulum Simulation

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Home Screen

Figure 5 shows the home page of the system which contains links on the left-hand side from which other pages of the system can be visited. . Each page in the system contains exactly one experiment. The following experiments are contained in the system;

1. Forced and Damped motion
2. Curve fitting or Data Fitting
3. Simple pendulum
4. Faraday's Law
5. Hook's Law
6. Simple Harmonic Oscillation
7. Pendulum and Spring Motion
8. Kepler's Second Law
9. Falling and Wiggling Slinky

Forced and Damped Motion Simulation

In this experiment, you can drag the ball to set your preferred starting position. By default, the ball begins at its equilibrium point. Once you have adjusted the settings as desired, press the **Play** button to begin the simulation. You can explore three different types of damped motion by selecting the corresponding radio buttons at the top of the screen as shown in figure 6.

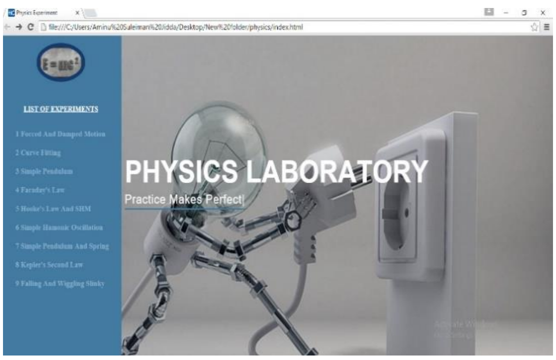

Figure 5: Home Screen

1. Underdamped: Damping is very slight, allowing the system to oscillate many times before coming to rest.

2. Overdamped: Damping is strong, causing the system to return slowly to equilibrium without oscillating.

3. Critically damped: A specific condition where the system returns to equilibrium as quickly as possible without oscillating.

Figure 7 show how to run Forced and Damped Motion Simulation.

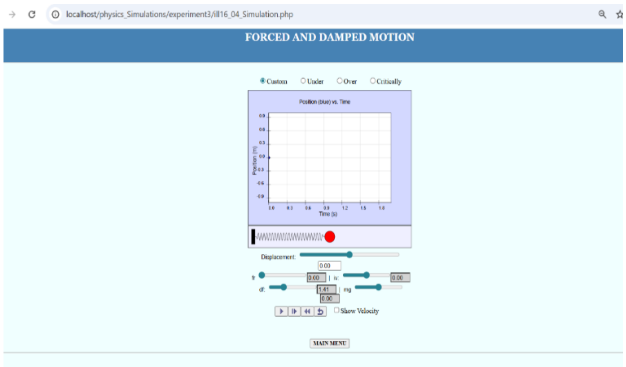

Figure 6: Forced and Damped Motion Simulation

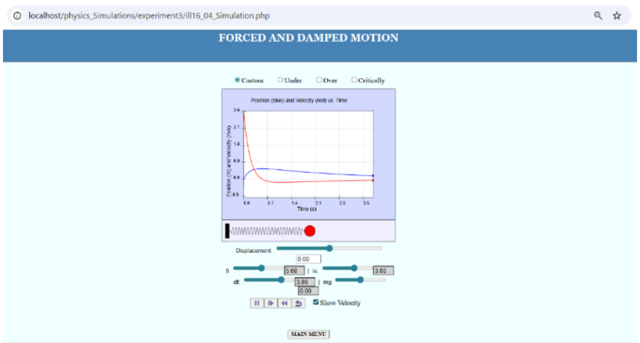

Figure 7: Running Forced and Damped Motion Simulation

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Data Fitting Simulation

This simulation fits a polynomial curve to a data set. Users can add points (up to a limit) by clicking within the plotting panel. Add data to the panel and then adjust the parameters of the polynomial y = f(x), in order to obtain a good fit using the a, *b*, *c*, *d*, and *e* parameters. Use the best-fit button to compare your fit to the best possible polynomial fit. Figure 8 shows data fitting simulation.

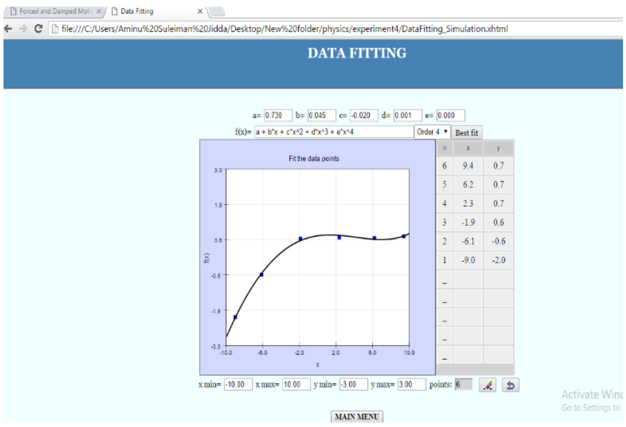

Figure 8: Running Data Fitting Simulation

Simple pendulum

In this experiment the length of the thread can be adjust, also the value of the can be changed to any desired number. Once the simulation starts running, the time T will begin reading automatically. The picture below shows the result of a simple pendulum after five complete oscillation, the time (T) happens to be 7.4 sec when length of the thread was set to 1 Cm and damping coefficient D was 0. Figure 9 shows running simple pendulum simulation.

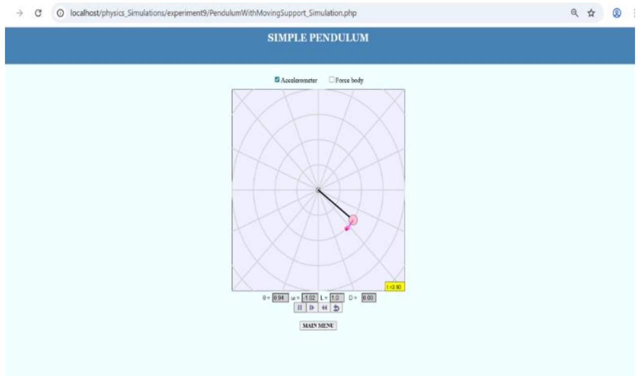

Figure 9: Running Simple Pendulum Simulation

Faraday's Law Simulation

This simulation visualizes a magnetic field oriented straight through your screen, with its strength defined by a function B(x,t). A color map helps you see both the direction and intensity of the field: blue means the field points into the screen, while red means it points out. The deeper the color, the stronger the field. Measurements in the simulation use meters for distance, milliTesla for magnetic field strength, millivolts for electromotive force (emf), and seconds for animation time. Keep in mind the animation plays faster than real time. You can explore a uniform magnetic field by setting B(x,t) = 1. The readout labeled Φ shows the magnetic flux through the loop formed by the wires. The top and bottom wires are spaced 6 meters apart. Try moving the slider for the wire—you'll see the emf stays at zero while the simulation clock is paused. To see induction in action, press the Play button to start the clock, then slide the wire. As you move it, an emf is generated.

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An arrow beneath the loop indicates the direction of the induced current. Figure 10 shows Faraday law simulation.

Hooke's Law and Simple Harmonic Motion Simulation

When a mass is connected to a spring and allowed to move without friction, it behaves as a basic harmonic oscillator. If you pull or push it away from its rest position, the mass will oscillate back and forth. This back-and-forth motion has a maximum distance from the center called the amplitude (X) and repeats in a regular time known as the period (T).

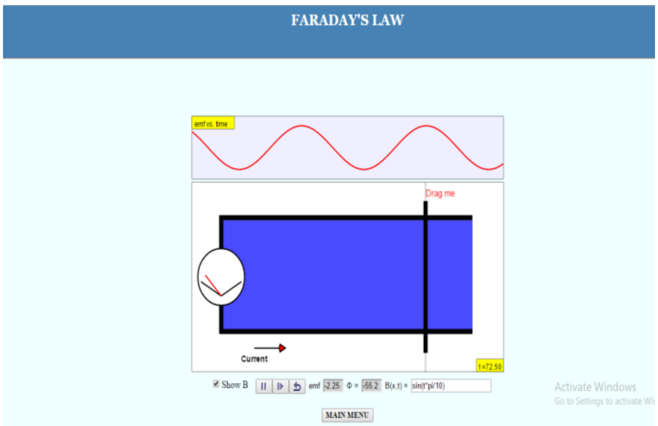

Figure 10: Running Faraday's Law Simulation

The object reaches its top speed right at the moment it passes through the center, or equilibrium, point. How often it oscillates depends on two things: how stiff the spring is and how heavy the object is. A stiffer spring means a shorter period—it vibrates faster. A heavier mass means a longer period—it vibrates more slowly. Figure 11 shows running Hooke's Law and Simple Harmonic Motion Simulation

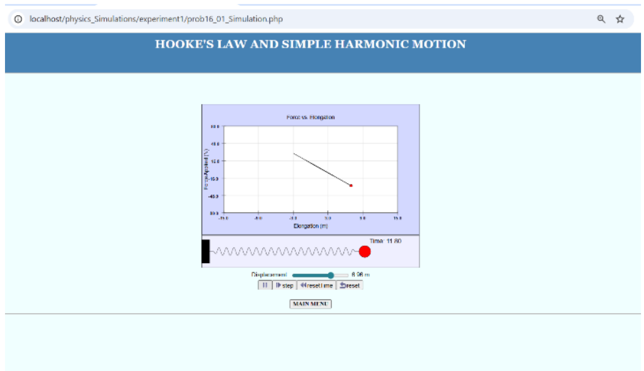

Figure 11: Running Hooke's Law and Simple Harmonic Motion Simulation

Simple Pendulum and Spring Motion

The concept of simple pendulum is often illustrated using a mass attached to a spring, a classic model where the spring constant \(k \) defines the proportional relationship between force and displacement. However, another common and observable example of simple harmonic motion is the pendulum. Essentially, a pendulum consists of a weight (the bob) suspended from a light string. If the string's own mass is significant, the system is treated as a compound pendulum.

In the accompanying simulation (Animation 1), the string length is set to 15 m and the bob's mass is 1 kg. Position is measured in meters, angle in radians, and time in seconds.

When users interact with the simulation—dragging the bob from equilibrium using the slider and pressing "play"—two primary forces come into play:

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gravity and string tension. To analyze these forces, it is helpful to resolve them into radial and tangential components relative to the pendulum's circular arc.

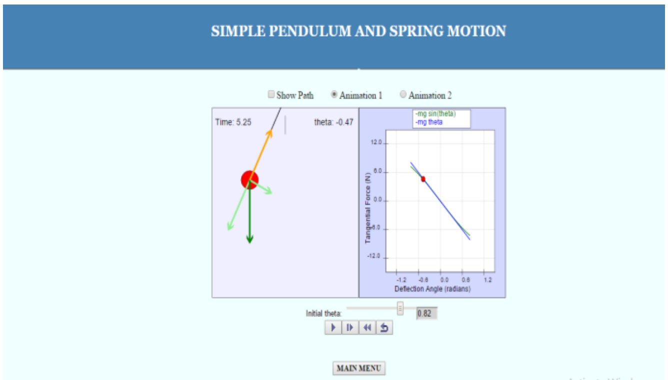

Figure 12: Running Simple Pendulum and Spring Motion

System Validation

System validation in this context is the process of confirming that a developed system meets its intended requirement and performed reliably in real world environment. It ensures that the entire system delivers the expected outcome for the end users. In this case the system was evaluated across four key performance metrics. The system was exposed to a usability test in two folds. Twenty (20) Laboratory technicians and one hundred (100) students used the system. Their feedbacks are tabulated to draw a histogram to visualize the result. Figures 13 shows the result.

The result confirmed that the system can be adopted for virtual practical of experimental physics of YSU. Both the laboratory technicians and the student wholeheartedly accepted the system as indicated in the figure. According to the test result both the staff and the students recommended the system for virtual experiment. The result reveals that simplicity got 88%, which indicates that users could navigate and complete core tasks without extensive training or technical skills. This high simplicity score indicates lower barrier to adoption, especially for non-technical users. Accurate of 75% measures how closely the system's output matched the expected true results under standard test condition. Clarity of 80% indicates how well the system presents information and feedback to the user. And acceptable 90% reflects how the overall willingness to adopt and continue using the system. This shows there is strong confidence and satisfaction among the stakeholders who are lecturers, technical staff and students. The validation result shows that the system is largely effective and well received. This confirmed that the system can be adopted for virtual practical of experimental physics of YSU.

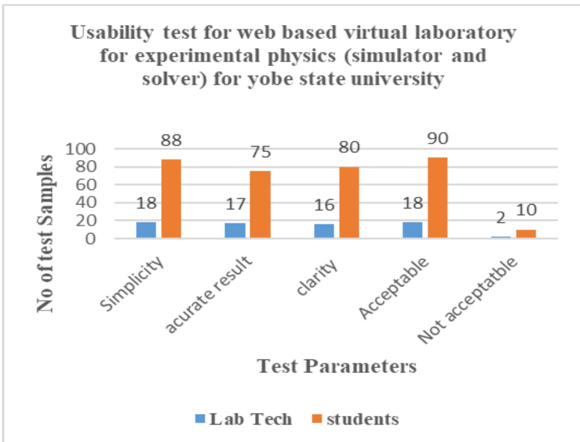

Figure 13: Acceptability test of the proposed system

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Conclusion

This research was undertaken to design and implement an *Experimental Physics Simulator and Solver* to address the critical challenges in practical physics education faced by 100-level science students at Yobe State University, Damaturu. The study began by identifying the problems of inadequate laboratory resources, overcrowded classes, and limited hands-on practice, which lead to poor performance in experimental assessments. The research work adopted the waterfall model of the System Development Life Cycle (SDLC) for its structured approach. A comprehensive literature review established the theoretical foundation in constructivism and inquiry-based learning and highlighted a gap in existing solutions, which are often device-specific or limited in scope.

The developed system is a web-based virtual laboratory that simulates key introductory physics experiments, including the simple pendulum, Hooke's law, and Faraday's law. It features an interactive interface, real-time graph plotting, and is accessible on both computers and mobile devices. The results from the development and preliminary testing confirm that the system is functional, accurate, and ready for deployment and further user evaluation. The findings confirm that the developed simulator aligns with constructivist learning theory by promoting interactive and self-directed learning. However, limitations such as lack of full sensory experience and dependence on internet connectivity were observed during testing.

The system has been successfully developed a functional and relevant web-based virtual physics laboratory.

Recommendation

Based on the successful completion of this project, the following recommendations are made on two categories; application area and research area:

1. **Distance Learning:**
   The web-based nature of the application makes it an ideal tool for supporting distance-learning programs offered by the university.
2. **Secondary School Outreach:**
   The university could adapt this platform for outreach programs to improve physics education in secondary schools across Yobe State.

Further Research

Ensuring the simulations ran smoothly on low-end mobile devices with **poor internet connectivity** required optimized code and lightweight assets. Furthermore, while the simulations accurately represent the mathematical relationships, replicating the full tactile and sensory experience of a physical laboratory, such as the friction in a pendulum pivot or the precise feel of handling lab equipment, remains an inherent limitation of the virtual environment. Future iterations should focused refining the algorithms and data handling to bring accuracy closer to the clarity and acceptance levels, while maintaining the simplicity and users value.

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1. **Enhanced Interactivity:**
   Research could explore the integration of more advanced features, such as collaborative tools that allow student groups to conduct experiments together in the virtual lab.
2. **Offline Functionality:**
   To mitigate the limitation of internet dependency, further development could create a Progressive Web App (PWA) version that allows for limited offline functionality.
3. **For future improvement of the system:**
   I recommended that more experiments should be added to the system, and the system should be able to store the result of an experiment for future retrieval.

Reference

1. Putra, R. S. (2023). The role of hands-on experiments in developing scientific thinking skills. Journal of Physics: Conference Series, 1234(1), 012034.
2. Wieman, C. E., Perkins, K. K., & Adams, W. K. (2022). PhET interactive simulations: Transformative tools for teaching physics. Physics Today, 75(1), 42–48.
3. Kurniawan, D. A., & Redjeki, S. (2020). Student-centered learning in science: A systematic review of inquiry-based approaches. International Journal of Instruction, 13(2), 535–550.
4. Batlolona, J. R. (2011). Inquiry-based learning in physics: A meta-analysis. International Journal of Science Education, 33(3), 321–341.
5. Erdemir, N., & Bakırcı, H. (2017). The effect of inquiry-based learning on critical thinking skills in physics education. Journal of Baltic Science Education, 16(6), 903–917.
6. Gupta, A., & Singh, S. (2021). Virtual laboratories in physics education: A review of trends and efficacy. Journal of Educational Technology Systems, 50(1), 5–23.
7. Kumar, V., Sharma, D., & Garg, R. (2022). Effectiveness of interactive simulations in introductory university physics: An empirical study. Journal of Computer Assisted Learning, 38(4), 1123–1137.
8. Šorgo, A., Heričko, M., & Horvat, D. (2021). Transition to online physics labs during the COVID-19 pandemic: Student perceptions and learning outcomes. Journal of Science Education and Technology, 30(5), 692–704.
9. Okebukola, P. A. (2015). The state of science and technology education in Nigeria: Policies and practices. Science Education International, 26(4), 385–401.
10. Muhammad, A., & Ibrahim, B. (2023). Infrastructural deficits and academic performance in science: A case study of Yobe State University. Nigerian Journal of Educational Studies, 28(1), 33–49.
11. Ogunode, N. J., & Ahaotu, G. N. (2021). Impact of COVID-19 on science laboratory education in Nigerian Universities. International Journal of Higher Education Management, 8(1), 77–92.

INTERNATIONAL JOURNAL OF COMPUTER SCIENCE
Scholorly Peer Reviewed Research Journal - PRESS - OPEN ACCESS
ISSN: 2348-6600
Since 2012
www.ijcsjournal.com Volume 14, Issue 1, No 27 2026 ISSN: 2348-6600
REFERENCE ID: IJCS-707 PAGE NO: 031-048

12. Adegoke, B. A. (2013). Improving students' learning outcomes in practical physics: Which is better? Computer simulated experiment or hands-on experiment? Journal of Educational Technology & Society, 16(4), 284–293.
13. Kapilan, N., Vidhya, P., & Gao, X. Z. (2021). Virtual laboratory: A boon to the mechanical engineering education during COVID-19 pandemic. Higher Education for the Future, 8(1), 31–46.
14. Ajadi, T. O., & Adebakin, A. B. (2013). Educational security and academic performance in insurgency-affected areas of Nigeria. Journal of Education and Practice, (2), 37–45.
15. Akpan, J. P. (2020). Resource constraints and student performance in Nigerian physics education. African Journal of Educational Research, 24(1), 88–102.
16. Winsberg, E. (2018). Philosophy and climate science. Cambridge University Press.
17. Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. International Journal of Science Education, 36(15), 2534–2553.
18. Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 393–441). Routledge.
19. De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. Science, 340(6130), 305–308.
20. Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. ACM Computing Surveys, 38(3), 7-es.
21. Kumar, V., Sharma, D., & Garg, R. (2022). Effectiveness of interactive simulations in introductory university physics: An empirical study. Journal of Computer Assisted Learning, 38(4), 1123–1137.
22. Holec, S., & Pfefferova, M. (2004). Computer simulations in mechanics at secondary schools. Journal of Physics: Conference Series, 12(1), 45–52.
23. Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. Computers & Education, 58(1), 136–153.
24. Miriam, S. (2014). Computer simulations and their influence on students' understanding of oscillatory motion. Journal of Science Education and Technology, 23(5), 702–713.

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