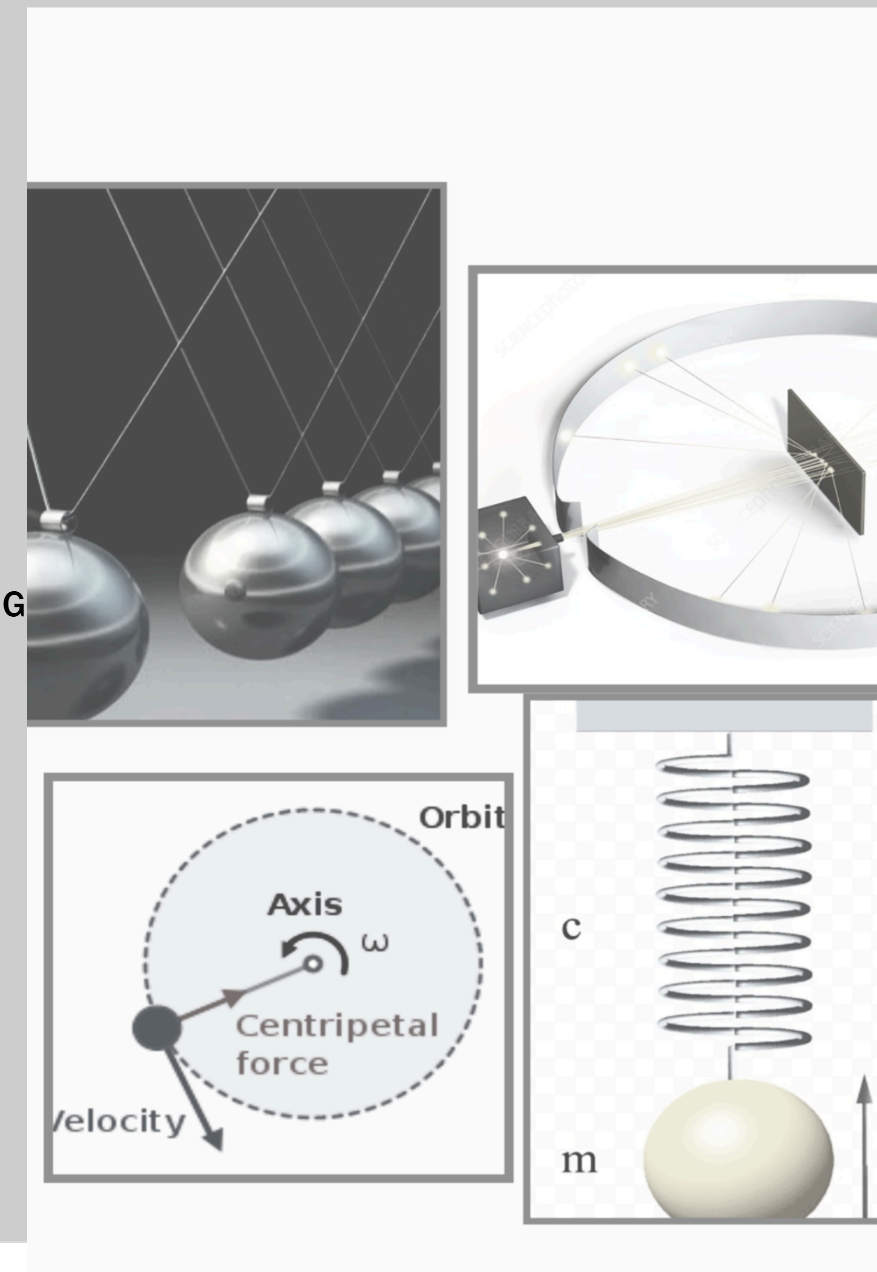
FOSSEE Winter Internship Report

on

Fundamental Concepts in Classical and Modern Physics

Submitted By

RAKSHA A DAVE
3 YEAR B.SC PHYSICS
ATMIYA UNIVERSITY
(GUJARAT)



UNDER THE GUIDANCE OF
PROF. KANNAN MOUDGALYA
DEPT OF CHEMICAL ENGINEERING
IIT BOMBAY

MENTORS
MADHURI GANAPATHI
DR. SNEHALATHA KALIAPPAN

MARCH 4, 2025

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to everyone who supported and guided me throughout the course of this project. Their encouragement and assistance have been invaluable in helping me achieve my objectives and complete this work successfully.

First and foremost, I extend my sincere thanks to the SOUL project team.
I would also like to acknowledge the invaluable support and guidance of Prof. Kanan M. Moudgalya, Principal Investigator of the FOSSEE Project, Department of Chemical Engineering, IIT Bombay. His passion for fostering open-source initiatives has been a source of inspiration for me. Their dedication and guidance have greatly enriched my learning experience.

My heartfelt thanks go to SOUL team Dr. Snehalatha Kaliappan and Ms Madhuri Ganapathi and FOSSEE Managers Usha Viswanathan and Vineeta Parmar for their constant support.

I am immensely thankful for the support provided by the National Mission on Education through Information and Communication Technology (ICT), Ministry.

SOUL Project

SOUL (*Science OpensoUrce Software for Teaching Learning*) attempts to put together the popular ICT software used for teaching/learning tools by the community of educators and the learners in basic concepts as well as advanced learning of Science subjects. These software can be used as ICT tools in classroom teaching and learning for topics in science subjects.

Introduction

- Internships play a crucial role in bridging the gap between academic learning and practical application, offering invaluable exposure to real-world research and problem-solving. My internship at FOSSEE(IITB), provided an opportunity to apply theoretical concepts in Physics of atoms, Oscillations & waves, Mechanics through a series of projects.
- The primary objective of this internship was to bridge the gap between theoretical knowledge and practical implementation, and to contribute to the FOSSEE community by creating and improving educational content, such as documentation, tutorials. I had the opportunity to work on **four diverse projects**, each contributing to my understanding of physics and strengthening my ability to approach scientific problems systematically.
- This report presents a detailed account encompassing an overview of the projects undertaken, methodologies employed, resources utilized, challenges encountered, and key takeaways.

Projects Undertaken:

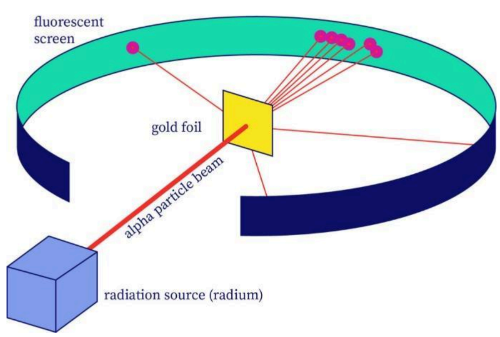
I worked on four distinct projects that are:

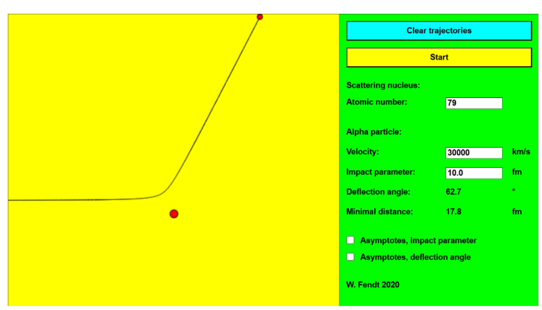
1. **Rutherford scattering**
2. **Spring pendulum**
3. **Elastic & Inelastic collision**
4. **Model of a looping coaster (centripetal force)**

The following sections provide a brief overview of each project, outlining their objectives, methodologies, and key outcomes.

1. Rutherford Scattering(Physics of atom)

1. **Aim**: To investigate atomic structure and confirm the existence of the nucleus.
2. **Working Principle Of The Experiment:**





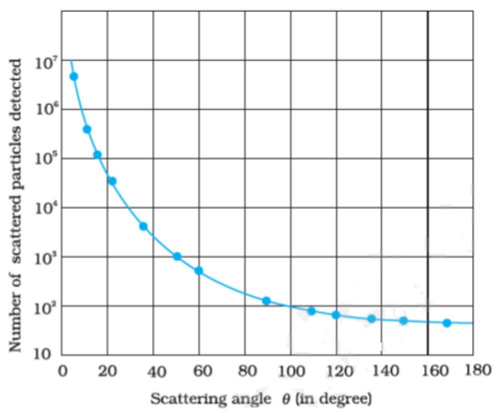
(Image-experiment: available on apps on physics, www.walter-fendt.de/html5/phen)

- Alpha particles are bombarded onto a thin gold foil, and their scattering is observed.
- Most particles pass through, while some deflect at various angles due to electrostatic repulsion from the nucleus.

- The deflection patterns confirm that atoms have a dense, positively charged nucleus surrounded by an empty space.

3. **Key Findings:**

   - **Higher atomic number (z)** increases deflection due to stronger coulombic force.
   - **Higher velocity (v)** decreases deflection and minimal distance.
   - **Larger impact parameter (b)** decreases deflection but increases minimal distance.



   Here is the graph showing **incident particles vs. Reflected particles at different angles**. It illustrates how most particles continue forward (low reflection at small angles), while a few get strongly deflected at larger angles.

4. **Conclusion:** the experiment confirms that atoms are mostly empty space with a small, dense, positively charged nucleus.

5. **Tools & Resources Used:**

   - Simulation app: **www.walter-fendt.de/html5/phen**
   - Online resources: https://phet.colorado.edu/en/simulations/rutherford-scattering
   - Book: **Modern physics** by S.CHAND & COMPANY PVT.LTD

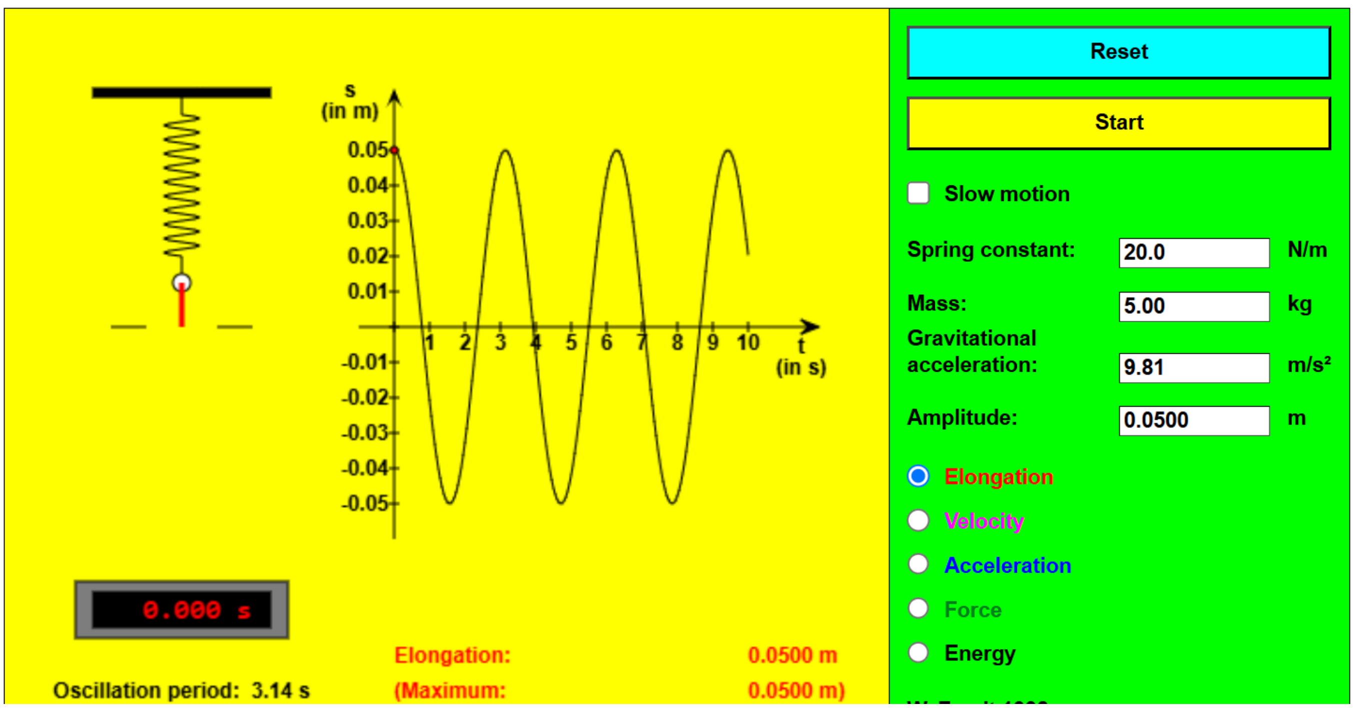
6. **Challenge Faced:**

- **Fixed velocity input:** the simulation did not allow to setting a completely random velocity value, restricting flexibility in experimenting with different initial conditions.

2.Spring pendulum(Oscillation & Waves)

1. **Aim**:: to study the **oscillatory motion** of a spring pendulum, determine its **time period**, and verify the relationship between **time period, mass, and spring constant** (hooke's law).

2. **Working Principle Of The Experiment:**



(Image-experiment: available on apps on physics, www.walter-fendt.de/html5/phen)

In the simulation, a mass is attached to a spring, and when we start, it undergoes oscillatory and periodic motion due to the restoring force of the spring (Hooke's Law). We can observe and measure various parameters as the system evolves.

3. **Key Findings:**

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where:

- T = Time period of oscillation
- m = Mass attached to the spring
- k = Spring constant (stiffness of the spring)

4. **Conclusion:**

- **Effect of spring constant (k)**: a stiffer spring increases velocity, acceleration, force, and energy while decreasing the time period.
- **Effect of mass (m)**: a heavier mass decreases velocity and acceleration but increases the time period, with force and total energy remaining unchanged.
- **Effect of amplitude (a)**: a higher amplitude increases velocity, acceleration, force, and energy, but the time period remains constant.

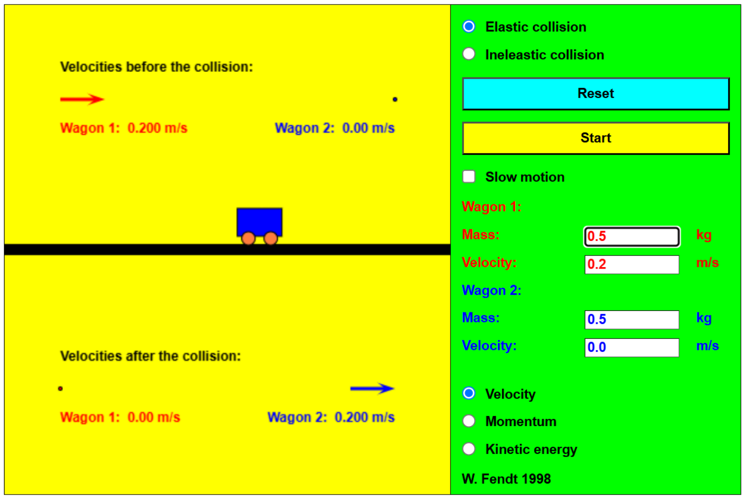
5. **Tools & Resources Used:**

- Simulation app: **www.walter-fendt.de/html5/phen**
- Online resources: https://en.wikipedia.org/wiki/Elastic_pendulum

3.Elastic & Inelastic collision(Mechanics)

1. **Aim**:To study and analyse **elastic and inelastic collisions**, verify **momentum conservation**, and examine the **kinetic energy transformation** during collisions.

2. Working Principle Of The Experiment:



(Image-experiment: available on apps on physics, www.walter-fendt.de/html5/phen)

- As we start the simulation in the App, we can observe the motion of colliding objects. The simulation displays key parameters such as initial and final velocities, mass, momentum, kinetic energy, and coefficient of restitution, allowing us to analyze whether the collision is elastic or inelastic.

3. Key Findings:

1. Coefficient of Restitution (e):

$$e = \frac{v_2' - v_1'}{v_1 - v_2}$$

where:

- v_1, v_2 = Initial velocities of objects
- v_1', v_2' = Final velocities after collision

2. Conservation of Momentum:

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$

3. Final Velocities in Elastic Collision:

$$v_1' = \frac{(m_1 - m_2)v_1 + 2m_2 v_2}{m_1 + m_2}$$

$$v_2' = \frac{(m_2 - m_1)v_2 + 2m_1 v_1}{m_1 + m_2}$$

4. Final Velocity in Perfectly Inelastic Collision:

$$v' = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

4. Conclusion:

- **Effect of mass**: as mass increases, **momentum increases linearly**, but **kinetic energy increases with the square of velocity**.

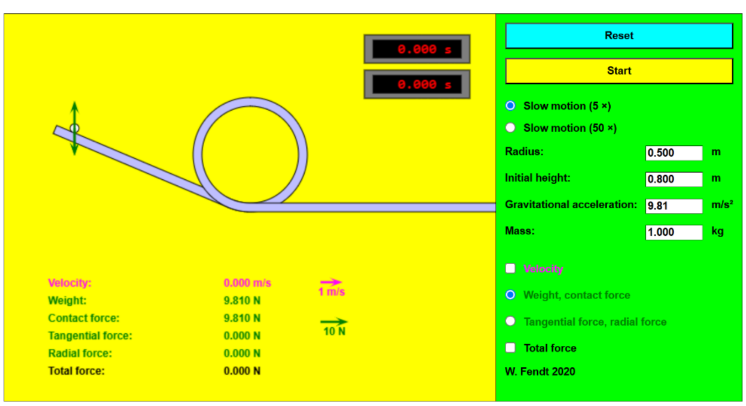
- **Effect of velocity**: increasing velocity (keeping mass constant) leads to **higher momentum and kinetic energy**.
- **Elastic collision**: e=1→ no kinetic energy loss. It means both **momentum** and **kinetic energy** are conserved.
- **Inelastic collision**: 0<e<1→ some kinetic energy lost, but objects separate. only **momentum** is conserved, but **some kinetic energy is lost**.
- **Perfectly inelastic collision**: e=0→ maximum kinetic energy lost, objects stick together.

5. **Tools & Resources Used:**

- Simulation app: **www.walter-fendt.de/html5/phen**
- Online resources: https://en.wikipedia.org/wiki/Elastic_collision

4. Model of a looping coaster (centripetal force) (Mechanics)

1. **Aim:** To analyse the forces and motion of a rolling ball on a looping coaster and determine the minimum height required for complete circular motion.
2. **Working Principle Of The Experiment:**



(Image-experiment: available on apps on physics, www.walter-fendt.de/html5/phen)

- We can observe the trajectories of the rolling ball and how its motion changes based on the initial height and loop radius. The simulation visually represents key forces such as centripetal, gravitational, and contact forces, allowing us to analyze the conditions required for the ball to complete the loop.

3. Key Findings:

The motion of the ball depends on its **initial height relative to the loop's radius (r):**

1. **h≤r** → the ball oscillates like a pendulum.
2. **r<h<2.5r**→ the ball rolls part way up before falling.
3. **h≥2.5r**→ the ball successfully completes the loop.

4. Conclusion:

- **Increasing the loop radius (r)** reduces top velocity, lowers bottom contact force, and has minimal effect on tangential forces.
- **Increasing the initial height (h)** increases velocity and forces at both the top and bottom, with higher contact force at the bottom due to greater centripetal force requirements.
- **To complete the loop**, **the initial height must be at least 2.5 times the loop's radius (h≥2.5r),** ensuring the ball maintains sufficient velocity at the top.

5. Tools & Resources Used:

- Simulation app: **www.walter-fendt.de/html5/phen**

6. Challenge Faced:

- Difficulty in accurately measuring values at the top and bottom or at any instant due to rapid motion, leading to minor practical inaccuracies.

Overall Reflection:

- This study helps in understanding the fundamental principles of physics by analyzing key factors and their effects. It reinforces theoretical concepts and improves practical knowledge, making complex ideas easier to grasp.

- This pie chart provides a graphical analysis of the entire report, categorizing the key physics learning approaches explored through simulations.