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Laboratory Report

Experimental Verification of Mechanical Energy Conservation Using an Air Track

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ABSTRACT

This experiment aimed to verify **the Law of Conservation of Mechanical Energy** using an **air track and a glider system** (Fig.1). The mechanical energy of the system, defined as the **sum of potential energy (PE) and kinetic energy (KE)**, was measured at two points along the track using photogates. Six trials were conducted, varying the distance between the photogates to measure changes in velocity and height. The results showed that the total mechanical energy (PE+KE) remained nearly constant within experimental error, supporting the conservation principle.

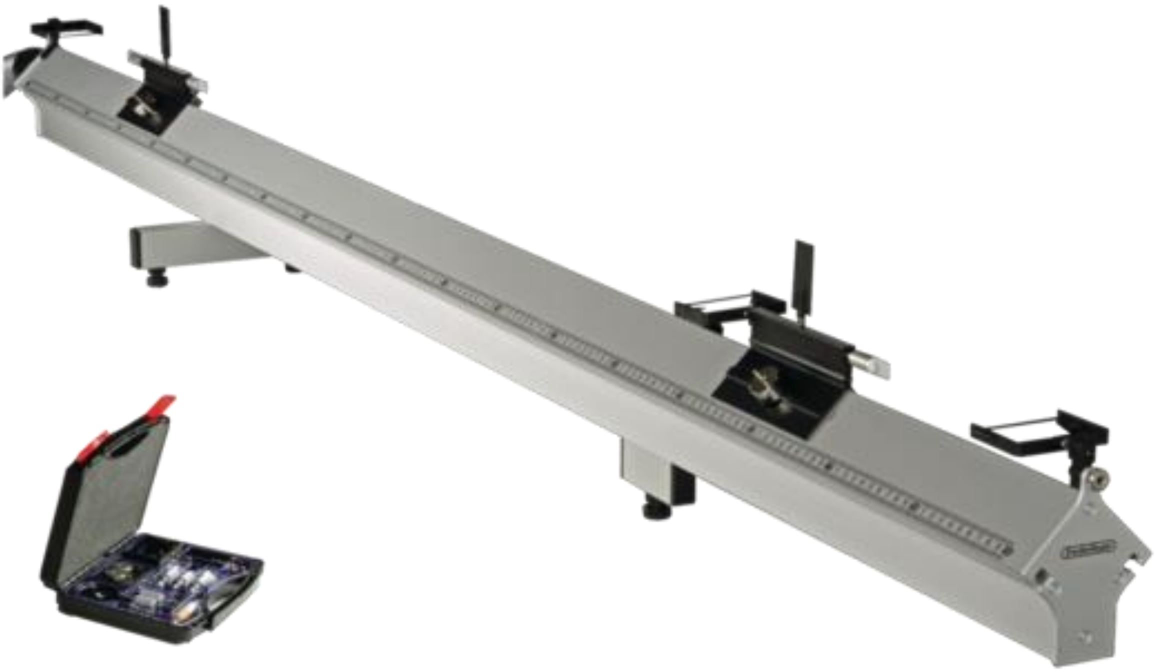

Fig. 1. *Experimental apparatus featuring an inclined air track with photogates to measure the motion of the glider.*

THEORETICAL BACKGROUND

The principle of conservation of mechanical energy is one of the most fundamental laws of physics. It states that in an isolated system, where only conservative forces are acting, the total mechanical energy of the system remains constant. This experiment focuses on verifying this principle using an air track to minimize friction and study the conversion between potential energy (PE) and kinetic energy (KE).

WHAT IS MECHANICAL ENERGY?

Mechanical energy is the energy associated with the motion and position of an object. It is the sum of two components:

1. **Potential Energy (PE):**
   This is the energy an object possesses due to its position or configuration. For gravitational potential energy, it is given by:
   $$PE = mgh$$
   where:
   - m is the mass of the object,
   - g is the acceleration due to gravity (9.81 m/s^2),
   - h is the height of the object above a reference point.

   Gravitational potential energy is always associated with conservative forces like gravity, where the work done depends only on the initial and final positions, not the path taken.

2. **Kinetic Energy (KE):**
   This is the energy an object possesses due to its motion. It is expressed as:
   $$KE = \frac{1}{2}mv^2$$
   where:
   - m is the mass of the object,
   - v is its velocity.

The sum of these two energies gives **total mechanical energy (E):**

$$E = PE + KE = mgh + \frac{1}{2}mv^2$$

LAW OF CONSERVATION OF MECHANICAL ENERGY

The law states that in an **isolated system** (where non-conservative forces like friction and air resistance are negligible), the **total mechanical energy remains constant**. Mathematically:

$$E_{initial} = E_{final}$$

or

$$mgh_1 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}mv_2^2$$

where:

- v_1 is the initial velocity of the object,
- v_2 is its final velocity.

Rearranging this equation allows us to relate the changes in potential and kinetic energy:

$$-\Delta PE = \Delta KE$$

This means that a loss in potential energy corresponds to an equal gain in kinetic energy and vice versa.

ENERGY TRANSFORMATION IN THIS EXPERIMENT

In this experiment, an air track with negligible friction provides an ideal environment to observe the transformation of gravitational potential energy into kinetic energy. As the **glider** (Fig. 2) moves along the track:

- At the **initial position**, the glider has potential energy due to its height and minimal kinetic energy.
- At the **final position**, the potential energy decreases, and the kinetic energy increases as the glider speeds up.

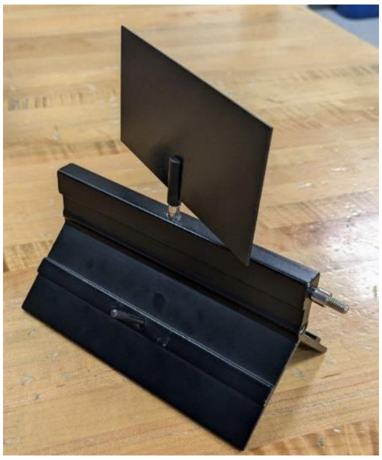

Fig.2. *Experimental glider with a flag for photogate detection during motion on the air track.*

The experiment involves measuring the velocity of the glider at two points using **photogates** and calculating the corresponding kinetic and potential energies to verify the conservation of mechanical energy.

By using an air track, we create a near-ideal isolated system where friction and air resistance are negligible. This simplifies the study of energy transformation and makes it easier to observe the conservation of mechanical energy.

PROCEDURE

MATERIALS:

- An air track with an adjustable incline
- A glider with a flag
- Two photogates to measure the glider's speed
- A meter stick for precise distance measurement
- A scale for measuring the glider's mass
- A computer with data acquisition software to record and calculate the glider's initial and final time as it passes through the photogates

SETUP:

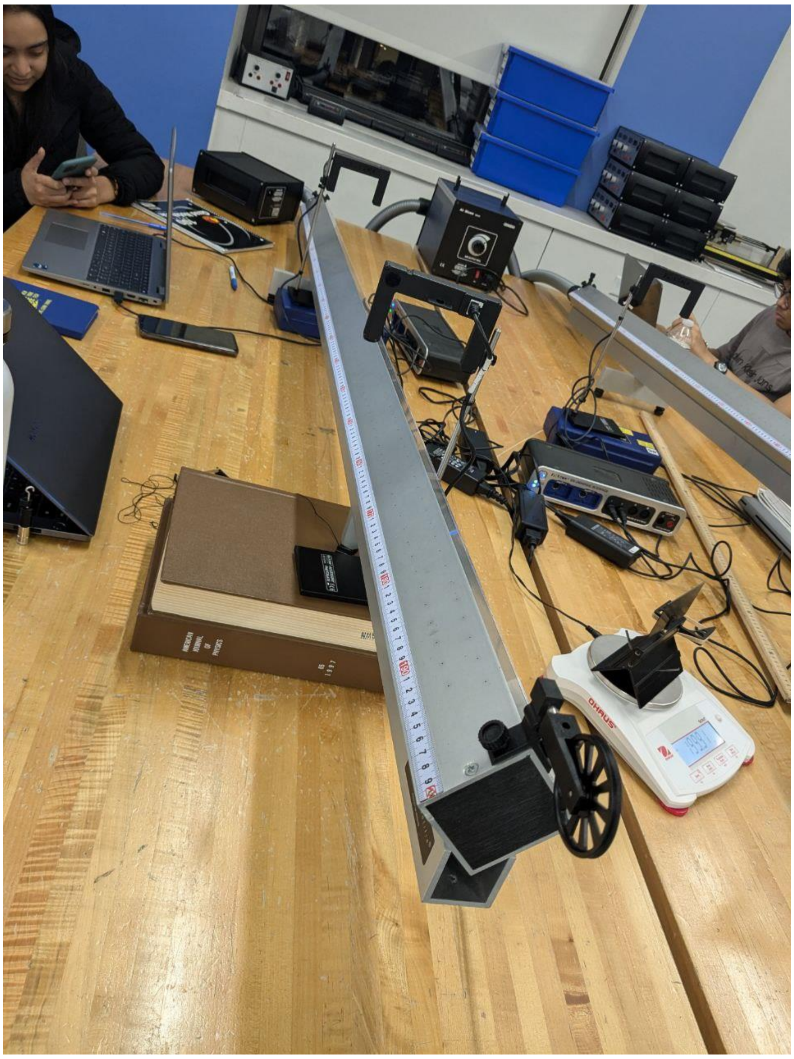

Fig.3. *The air track was set up horizontally with two photogates placed at measured distances along the track. A flag was attached to the glider to trigger the photogates. The glider was released from a fixed starting point, and its velocity was measured at the photogates. The height of the track was adjusted slightly to introduce a vertical component.*

EXPERIMENT:

1. Measure the mass of the glider and flag.
2. Attach a flag to the glider and set the photogates at the desired distance.
3. Measure the vertical height from the table to the glider's position at the photogates (h_1 and h_2).
4. Release the glider and record the time at each photogate.
5. Calculate the initial (v_1) and final (v_2) velocities using the recorded times and the flag length.
6. Compute the potential and kinetic energies at the initial and final points.
7. Repeat for six runs, increasing the distance between photogates in each trial.

DATA & ANALYSIS

Run	Height (h_1) (m)	Height (h_2) (m)	Velocity (v_1) (m/s)	Velocity (v_2) (m/s)	PE_i (J)	KE_i (J)	PE_f (J)	KE_f (J)	PE_i+KE_i (J)	PE_f+KE_f (J)	Error (%)
1	0.32	0.2460	0.7046	1.1837	0.6053	0.0479	0.4653	0.1351	0.65	0.60	8%
2	0.32	0.2360	0.7080	1.2534	0.6053	0.0483	0.4464	0.1515	0.65	0.60	9%
3	0.32	0.2290	0.7094	1.3944	0.6053	0.0485	0.4332	0.1874	0.65	0.62	5%
4	0.32	0.2180	0.7066	1.3964	0.6053	0.0481	0.4124	0.1880	0.65	0.60	8%
5	0.32	0.2090	0.7023	1.4559	0.6053	0.0476	0.3953	0.2043	0.65	0.60	8%
6	0.32	0.2000	0.7081	1.5172	0.6053	0.0483	0.3783	0.2219	0.65	0.60	9%

The total mechanical energy (PE+KE) remained nearly constant across all trials, with an average error of ~7%. This small variation can be attributed to experimental uncertainties such as minor friction in the air track or inaccuracies in height and velocity measurements.

CONCLUSION

The results of this experiment successfully demonstrated the Law of Conservation of Mechanical Energy in a nearly idealized system. By using an air track to minimize friction and a photogate setup to precisely measure velocities, we observed that the total mechanical energy (sum of potential and kinetic energy) remained nearly constant across different trials.

Despite small variations in total energy caused by experimental uncertainties, such as air resistance, slight imperfections in the air track, or calibration errors in the equipment, the observed error margins (5–9%) were reasonably low and well within acceptable limits for experimental verification. These deviations highlight the challenges of perfectly isolating a system from external forces but also underscore the robustness of the conservation law, even under less-than-perfect conditions.

This experiment not only reinforces the fundamental principle of energy conservation but also demonstrates the importance of reducing external influences and carefully measuring data for accurate experimental results. Future refinements, such as improving the air track alignment, further calibrating the photogates, or conducting additional trials, could reduce errors and provide even stronger confirmation of the law.

In conclusion, this lab effectively illustrates how energy transforms within an isolated system and provides compelling evidence that the total mechanical energy of a system remains conserved, aligning closely with theoretical predictions.

ACKNOWLEDGMENTS

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Fig. 1. Air track setup image. Retrieved from https://cdn2.webdamdb.com/md_wmxnFi0nkxo1.png?1565279260

Fig. 2. Tuiachieva, Z. (2024, November 11). Close-up of the glider passing through photogate . [Zhasmin Tuiachieva]. Personal collection.

Fig.3. Tuiachieva, Z. (2024, November 11). Inclined air track with the experimental setup. [Zhasmin Tuiachieva]. Personal collection.