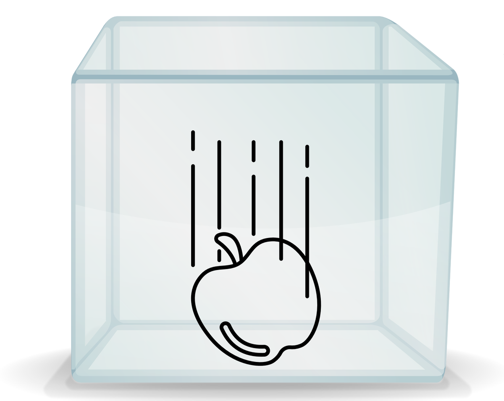
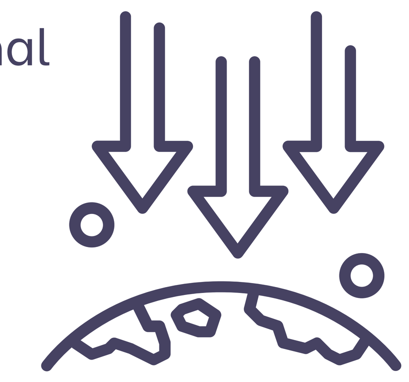
Microgravity Experiments



With an Inexpensive and Portable Educational Drop Tower

$$\vec{F} = m\vec{a}$$



First Cycle Integrative Project in Electrical and Computer Engineering - ElectroCap

Group 2

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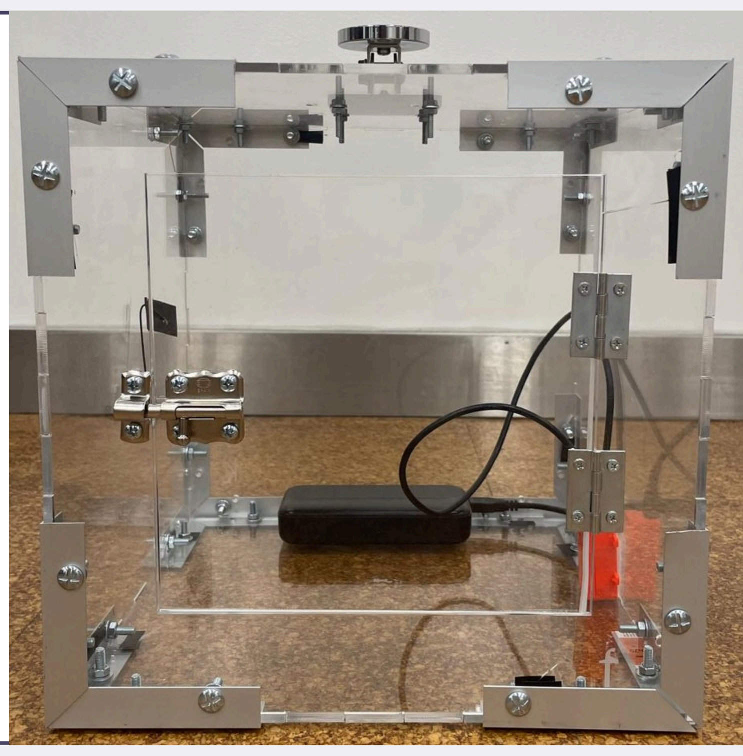
Motivation and Objectives

Microgravity effects spark scientific curiosity across all ages. Currently, these experiments are conducted using expensive drop towers and outdated models, limiting public engagement. This restricted accessibility highlights the need for affordable, user-friendly drop towers, in order to make microgravity experiments more accessible and scalable. Naturally, our solution and its results cater mostly to high school students newly introduced to physics. However, our results are interesting to anyone, as most schools don't own an experimental drop tower, increasing the likelihood that someone has never seen microgravity effects firsthand but has likely studied them in high school physics textbooks.



The Group Solution

- We built a reinforced acrylic box with metal profiles (to increase its robustness) inside which an object/experiment will be placed.
- The box features a camera, to observe the object's behavior in free fall, and an IMU, responsible for measuring parameters like acceleration, enabling us to create graphs for result analysis.
- The resulting graphics and videos of the experiences are shown and saved automatically on a database website.
- The activation of the camera, solenoid, and IMU is done at the same time, with a push of a button, on the website.
- The support structure stands at approximately two meters, a height we concluded to be sufficient for obtaining satisfactory data for educational demonstrations and/or brief observations.

Cost, Benefits and Other Solutions

- Existing solutions for conducting experiments in microgravity include conventional drop towers, parabolic flight services, stratospheric balloons, and the ISU's Drop Tower. However, these options are often expensive, restricted to specialized facilities, require significant human intervention, and sophisticated setups.
- Our solution utilizes easy-to-find and relatively cheap construction materials, is reliable (if proper protection for the acrylic box is used), and versatile (you can easily change experiments).
- The electrical components are minimal, simple, and quick to operate via a computer, rendering an effortlessness factor to the realization of experimental trials, since each one requires minimal human intervention.
- The structure can be disassembled and reassembled as needed, making it neat to store and transport.
- The tubes and junctions used offer a satisfactory reuse factor, which adds to the cost-effectiveness of the product.

What is Microgravity?

- Microgravity is due to a free-fall condition.
- Gravitational effects are due to restraining forces which stop an item from falling - the floor stops us from falling with a normal force on our feet - this force is what we perceive as weight.
- In free-fall, restraining forces are drastically reduced.
- Everything is falling with the same accelaration - 9.8 m/s^2 close to the earth's surface.
- As a result, everything in a microgravity environment falls or moves in a way that appears weightless or floating, such as inside orbiting spacecraft, and while in free fall we feel the same way.

Understanding the Physics Behind Microgravity

- In a free-falling elevator, you float relative to the elevator because both you and the elevator accelerate downward at the same rate, eliminating the support (normal) force that you usually feel as weight.
- Since you and your surroundings are accelerating together, and at the same rate, you do not experience any relative motion between yourself and the surroundings. This creates a sensation of floating or weightlessness.
- According to Einstein's equivalence principle, locally, the effects of gravity are indistinguishable from those of acceleration.
- This principle, part of general relativity, describes gravity as the curvature of spacetime. Thus, in free fall, you experience weightlessness, float, and encounter microgravity, all interrelated through the **absence of relative forces**.

Experiments

In Experiment 1, the candle flame changes shape because there's no gravity pulling the gases upward. This lack of upward movement of air also affects how the flame behaves compared to normal conditions. While in microgravity, the flame can expand equally in all directions, leading to a rounded or spherical appearance. Additionally, the absence of vertical air movement means there's no typical convection flux to maintain the flame's usual shape. The flame of a candle extinguishes after terminating free fall due to the disrupted air flow and oxygen supply needed for combustion.

In Experiment 2, a scale with a weight is placed inside the falling box. The scale reads lower than the actual weight due to free fall. Both the scale and the weight are in free fall, resulting in a reading affected solely by the fall's inertia (the tendency of an object to maintain its motion unless acted upon by an external force, as there are no external forces apart from gravity acting on the scale and weight during free fall), not reflecting the true weight. At times, depending on the weight of the object placed on top of the scale (preferably lightweight), the scale may briefly read zero when its normal force is canceled by the fall's acceleration.

In Experiment 3, the pendulum behaves differently because both the pendulum and its support accelerate downward equally due to gravity. This removes the force that usually pulls the pendulum back and forth. As a result, the pendulum seems weightless and doesn't swing like it normally would. If it was still before the fall, it remains still. If it was moving, it continues in that motion without swinging back and forth, stopping its motion at the equilibrium point.

The graphic shows the acceleration of the box with its contents (the variation in the mass of the box from experiment to experiment is not significant). The box starts falling with the expected acceleration of 9.8 m/s^2, represented by the initial straight line that indicates the normalized value of acceleration on the y-axis. In the following moments, the IMU shows a null value for acceleration because it is experiencing weightlessness (the absolute acceleration remains 9.8 m/s^2 nonetheless). The squiggly lines in the final moments are due to the impact of the landing.

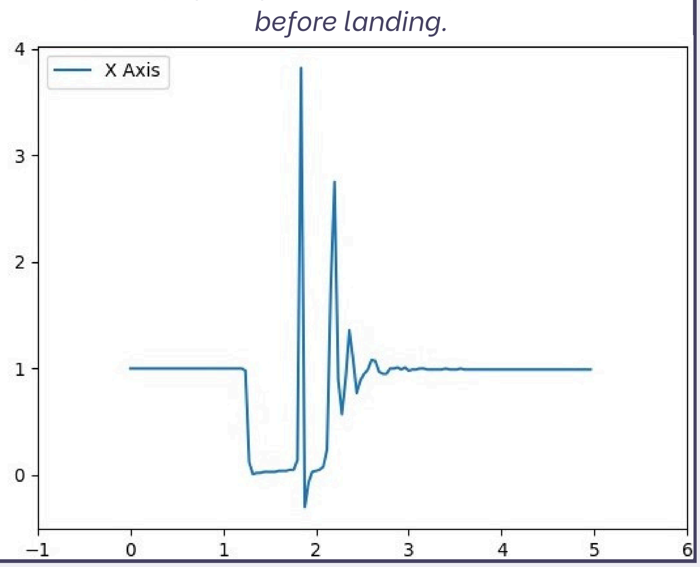
Experiment 1 - Normal Flame

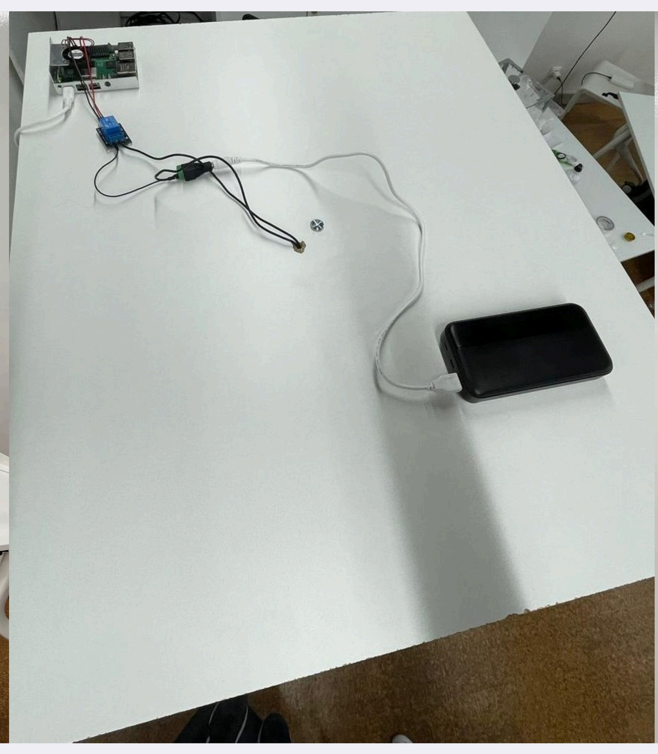
Experiment 1 - Round Flame due to microgravity

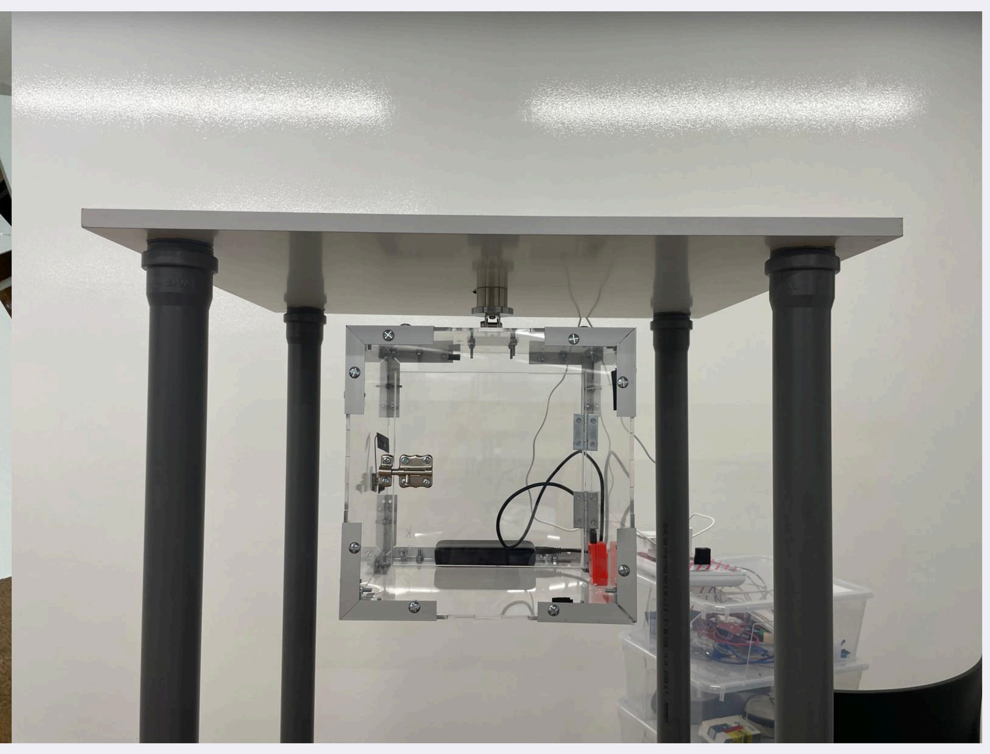
Experiment 2 - The scale read 78.94 grams at the beginning of the fall and 73.54 grams moments before landing.

Experiment 3 - The pendulum continues its initial swinging motion started before the fall.

Experiment 3 - The pendulum is almost in it's equilibrium position, just moments before the box lands on the damper net







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