Conservation of Energy

In-Person | Two Weeks | Draft & Report Submissions

Introduction

The goal of this lab is to explore one of the most foundational laws in physics: conservation of energy. Conservation of energy is the law that states energy is always conserved in any system. Sometimes this is seen as "energy is neither created nor destroyed, it is only transformed." This lab will offer students the opportunity to verify the Law of Conservation of Energy by observing two systems: (a) a cart rolling down a hill, and (b) a simple pendulum. Students will also get practice identifying and quantifying possible sources of error in both systems.

Theory

The Law of Conservation of Energy states that for any system, the <u>total amount of energy is conserved</u>. There are many different types of energy that you will have discussed in lecture, and this lab is meant to give you the opportunity to investigate how those types of energy can be observed in real systems. This law can be expressed in a simple equation as:

$$E_{initial} = E_{final} \tag{1}$$

The total amount of energy in any system (at least those we will study in this course) can be given as:

$$E_{total} = E_{mechanical} + E_{internal}, \tag{2}$$

where $E_{mechanical}$ is sum of the kinetic energy and the potential energy (either gravitational or elastic). This is the generic formulation, but as we know, forces can do *work* on a system. If a force adds or removes energy from a system, it is called a by *non-conservative force*, with the work done by these forces denoted as W_{NCF}. Because these forces are non-conservative, they change the amount of energy in our system, allowing us to find how much work is done by these forces by examining the change in energy of a system. In equation form, this looks like:

$$-\Delta E_{mechanical} = W_{NCF} = \Delta E_{internal} \tag{3}$$

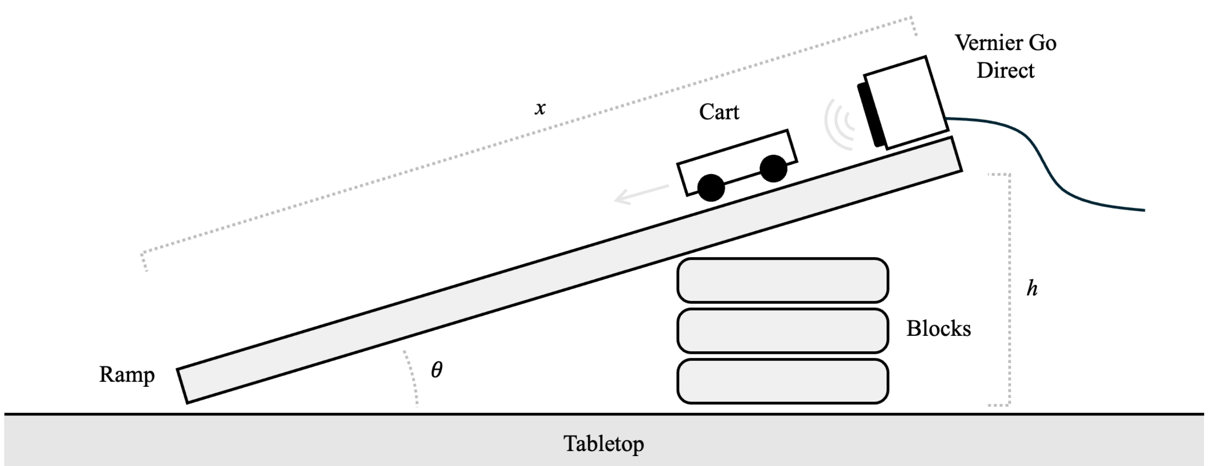
The lab's purpose today is to determine the work due to non-conservative forces (WNCF) by utilizing the Law of Conservation of Energy in two distinct systems: a cart rolling down an incline and a simple pendulum.

Procedure

For this lab, we will utilize the following equipment:

- Vernier Go Direct Motion Detector to measure velocity and position of a cart traveling down an incline
- Vernier Graphical Analysis Software Package
- A dynamics cart
- A smooth ramp made of a track and blocks
- A meter stick
- A computer to obtain data from the motion detector
- A simple pendulum made of a pendulum bob and a lightweight string
- A protractor to measure the angle
- A photogate (or stopwatch)
- A metal rod and clamp
- Excel (or equivalent) for data analysis and making graphs.
- Word (or equivalent) for writing up your report.

Activity 1: Conservation of Energy for a Cart Rolling Down an Incline



1. Spend a little time designing your experimental setup. Measure the total height and total length of the ramp. Record these values in an Excel (or equivalent) spreadsheet.

2. Place the motion detector at the top of the ramp (see diagram). Make sure the motion detector is hooked up to the Vernier Graphical Analysis™ (VGA) software package. You should hear the motion detector "clicking" when it is properly setup.

3. Measure the mass of the car, record this value. Place the car at the top of the ramp ~15cm from the motion detector.

4. Do some practice runs. Export a run to Excel and ensure you are getting time, position, and velocity data. Make sure to determine the sections of your graph where the cart is in motion with *constant* acceleration. Check with your TA if you are unsure.

5. Take your first run of data and export the data to Excel. It might be helpful to begin by isolating the part of the data where the car is in motion with constant acceleration.

6. Make columns in your spreadsheet for the cart height, potential energy, kinetic energy, and total mechanical energy (KE +PE).

7. To find the potential energy of the cart, you will need to first find the height of the cart as it travels along the path. Think about how you can find the height using the total distance the car travels (the last position data point), the position of the cart at each point, and the angle of the ramp. Note: you will not need to find the actual angle, in fact, just finding $\sin(\theta)$ is sufficient (hint: you found the total length and height of the ramp in step 1). As a check, consider where the height would be equal to 0m and verify that this is the value you get before moving on.

8. Find the kinetic, potential, and total mechanical energy at each point in the cart's path.

9. Make a single graph with kinetic, potential, and total mechanical energy at each point vs time.

10. From your data, determine the work done by non-conservative forces (NCF).

11. Assuming friction dominates the work done by NCF, please find the frictional force.

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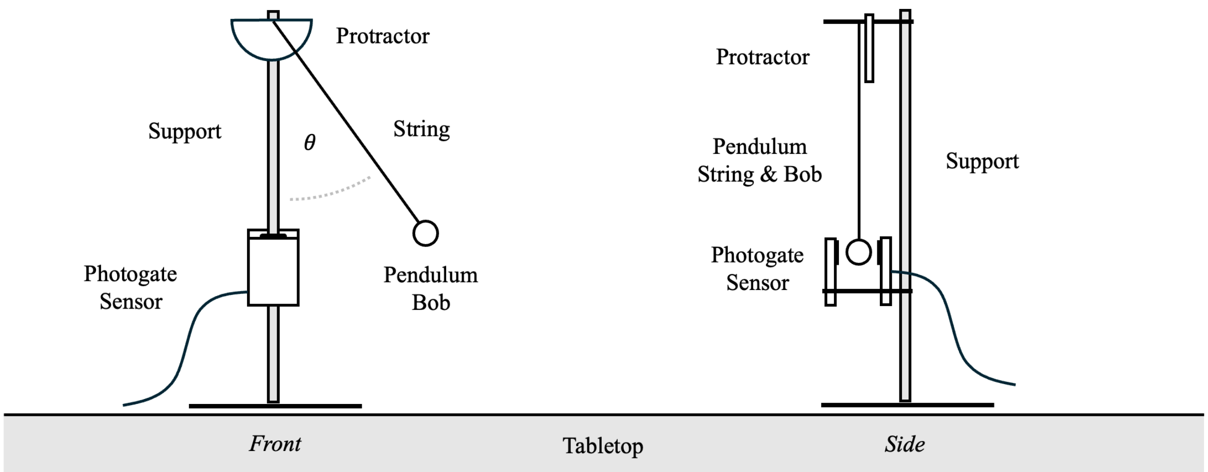
Activity 2: Conservation of Energy for a Simple Pendulum



***Note:** you will need this data for a later lab, so make sure to save all pendulum data.*

1. Measure the mass of the pendulum bob. Record this value.

2. Prepare your setup. Suspend a pendulum bob and string from the ring stand. Attach the photogate such that the bob travels straight through the photogate. It might be helpful to take a few practice runs to ensure a correct setup.

3. Measure and record the total length of the pendulum (note: length is from the top to the *center of mass* for the bob.

4. Beginning with a small angle (less than 10°), pull the pendulum bob back. Measure and record the starting angle.

5. Begin data collection and release the bob. Allow it to travel 5-10 *complete* cycles before stopping data collection. Export this data to Excel and remember to save it.

6. Using your data, find the average velocity of the bob as it passes through the lowest point. Record this value.

7. Using your angle and length measurements, find the starting height of the pendulum bob. Record this value.

8. Find the total mechanical energy before the bob's release and at its point of maximum velocity. Record these values.

9. Determine the work due to non-conservative forces.

10. Repeat steps 4-9 for various angles from ~5° up to no more than ~45°. How many trials is up to you, but you should get enough to be able to see a trend in the data.

11. Make a graph of the work due to non-conservative forces vs θ.

Analysis

In your submission, you will need to include:

- All data tables made in Excel.

- All graphs made in Excel.

- Activity 1: A summary data table that includes the ramp measurements (length, height, sin(θ)), work due to NCF, frictional force, and a comparison between total initial mechanical energy and total final mechanical energy (% difference).

- Activity 2: A summary data table that includes the work due to NCF and comparison between initial and final mechanical energy (% difference) for each angle, θ.

Discussion

As *parts* of your discussion, please make sure to include:

- A discussion of Activity 1. Consider thinking through things such as: Does the graph make physical sense? What is happening to each energy (PE, KE, ME) as the cart moves down the ramp? Is this expected? What do you think would happen to the % energy "lost" due to NCF if the ramp was changed (lowered or raised)?

- A discussion of Activity 2. Consider thinking through things such as: What happens to the potential and kinetic energy as the angle is changed? Is this expected? What happens to the % energy lost due to NCF as the angle is increased? Is this expected (why or why not)?

For each activity, please discuss potential sources of error in the data collection. Consider systematic vs random errors and how each could apply to the data collection process. For your analysis, consider the assumptions that were made. For example, in Activity 1, we assume friction is the dominant NCF, but should we? Why is this likely the most dominant NCF? What are the other possible sources that could be responsible for energy loss? In Activity 2, what would the dominant NCF be? Could we measure it like we did friction in Activity 1? What other sources could be responsible for energy loss?

FAQ's & Recommendations

How should I prepare for lab time?

You only have so much time in lab each week, so proper preparation makes a huge difference in what you're able to accomplish! Read the handout ahead of time so that you can ask clarifying questions immediately and get started as soon as you arrive!

What goes in my lab notes?

The purpose of lab notes is to enable your or a colleague to reconstruct what was done and why after you've left the lab and are performing analysis or writing a submission.

- You can use any form you like to record experiment information: notebook, spreadsheet, etc.
- They don't have to be neat, in complete sentences, etc., but they do have to be useful!
- Make sure to take detailed notes about your setup, how to use the equipment, what results you found, measurements related to the environment you may need, etc. You may not be able to get back into the lab later in the week if you miss something, so record as much detail as possible!
- When storing multiple data files while in lab, make sure to name the files clearly so they're easy to find later.

When should I work on the experiment and analysis?

We strongly recommend doing the lab as early in the week as possible, rather than waiting until it is almost due. This is just so that, if you run into trouble and need help, you'll have plenty of time to talk to your TA and get issues resolved before the deadline.

How do I turn in my results?

After leaving lab, performing your analysis, and completing your submission, you're ready to turn in your work!

- Every lab session requires submission of either an assignment, summary, draft report, or report.
- Collaborate with your partners on data collection, analysis, and writing.
- Turn in a single group submission and make sure the names of all group members are included.
- Upload your submission to Canvas/Brightspace as a .pdf by the deadline in the course calendar.
- Other than the spreadsheet assignment, you will not upload any spreadsheets. Just copy and paste figures and other elements from your spreadsheet into your formal submission as needed.

Where can I get help?

Your lab TA can answer questions during the lab, by email, or by setting up a time to meet. You can also ask advice from lab partners and/or other students.

General DO's and DON'T's

- *DON'T* break the equipment – always be careful when using lab supplies!
- *DO* consult with your lab TA before leaving a lab session about your experimental method, the validity of your results, and any confusion you have about the analysis process.
- *DON'T* forget to record all the parameters and measurements for your experiment, including saving files.
- *DO* be creative in your experimental design and enjoy!