Physics 1050
Experiment 4

Conservation of Energy and Projectile Motion

Prelab Questions

These questions need to be completed before entering the lab.

Show all workings.

Prelab 1:

A $500\ kg$ car is at rest at the top of a $50.0\ m$ high hill.

a) Calculate the energy of the car at the top of the hill.

The car rolls to the bottom of the hill. At the bottom of the hill, the car has a speed of $27.8\ m/s$.

b) Calculate the energy of the car at the bottom of the hill. (Assume the bottom of the hill has a height of $0\ m$.)

c) Calculate the work done by friction on the car as it rolled down the hill.

Prelab 2:

Write, in a sentence or two, the objective of this experiment.

Introduction

In this lab, you will launch a pointed mass through a tube track. It will leave the track with an initial velocity and land on a piece of paper. We'll mark and measure the impact points and use this information in our analysis using kinematics and energy considerations.

For the analysis, we'll use the horizontal distance travelled and the **kinematic equations** to determine the *actual* speed with which the projectile emerged. In conjunction with this information, we can apply the **conservation of energy** to determine an estimate for the **work done by friction** on the projectile, as well as make some comparisons with the kinematics calculations.

Introduction

The **mechanical energy** (E) of an object consists of two types of energy, potential (U) and kinetic (K)

$$E = U + K\ .$$

For an object at a height H, $U = mgH$ where m is the mass and g is the acceleration due to gravity $(9.81\ m/s^2)$. $K = ½\, mv^2$ where v is the speed of the object.

If a non-conservative force e.g. friction, acts on the system, then the final energy is different from the initial energy and the difference is equal to the **work** done by that force (W_{NC}).

$$E_f - E_i = W_{NC}$$

$$\left(K_f + U_f\right) - \left(K_i + U_i\right) = W_{NC}\ .$$

Introduction

Work done by a force is the scalar product of force and displacement. Work may be positive, negative, or zero.

$$W = \vec{F} \cdot \vec{d} = Fd\cos\theta$$

where θ is the angle between the force $\vec{F}$ and the displacement $\vec{d}$.

Generally speaking, the work done by friction has an angle of $\theta = 180°$, meaning,

$$W_f = -f_k d$$

where f_k is the force of friction.

Introduction

Projectile motion is the special case of two-dimensional motion experienced by objects only under the influence of gravity. Such objects, termed projectiles, are under constant acceleration where

$$a_x = 0\, m/s^2 \text{ and } a_y = -g = -9.81\, m/s^2.$$

In this case, the kinematics equations give the results for the horizontal component of the motion:

$$v_{xf} = v_{xi} = constant$$
$$x_f = x_i + v_{xi}t\,,$$

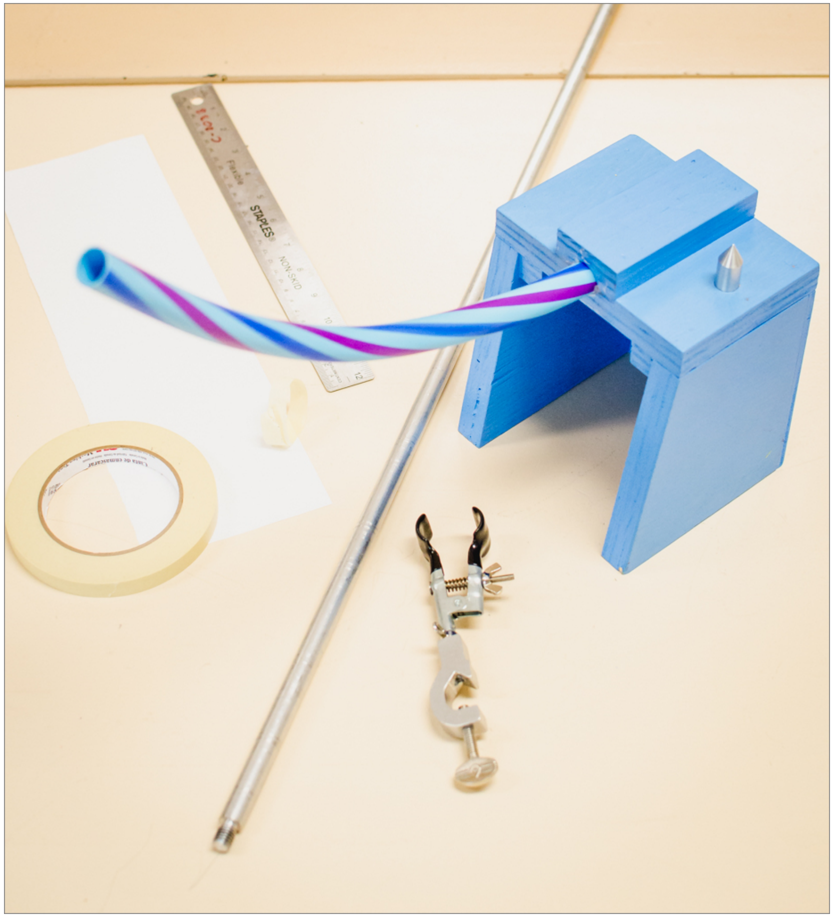
and for the vertical component of the motion:

$$v_{yf} = v_{yi} - gt$$
$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2\,.$$

Apparatus

For this experiment, you have been provided with:

- Launch apparatus
- Long rod
- Burette clamp
- Aluminum projectile



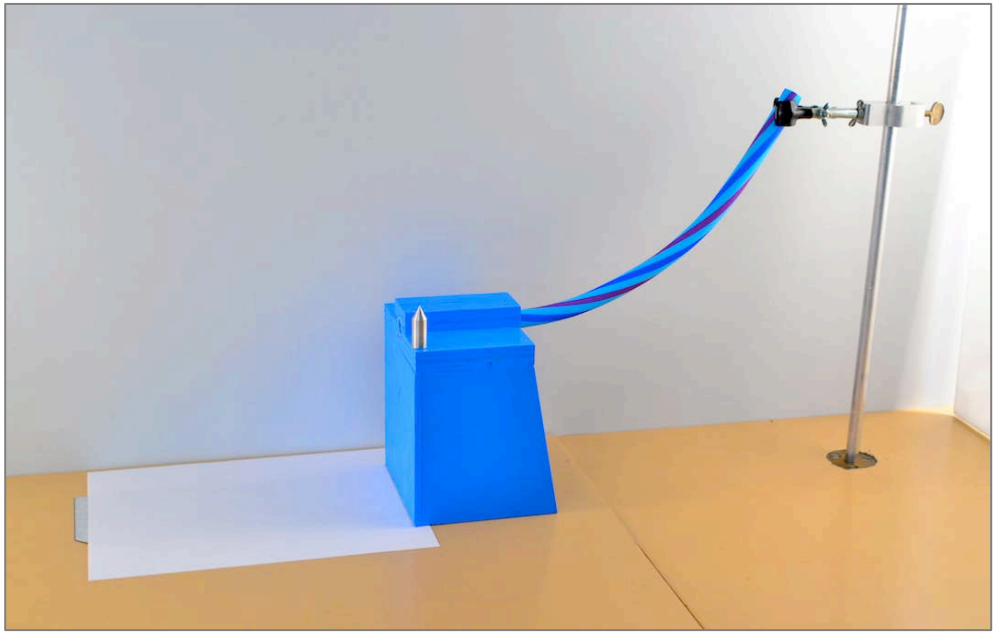
Pick up:

- Paper
- Piece of masking tape
- Ruler (if preferred)

Apparatus

Assemble your apparatus as shown.

The clamp is used to hold the launch tube at a constant height and angle while releasing the mass.



Secure your paper to the desktop with some tape and mark the position of the edge of the stand.

The track is assumed to be horizontal at the launch point.

Apparatus

Measure the height **H** of the top of the track relative to the table.

Measure the height **h** of the bottom of the track relative to the table.

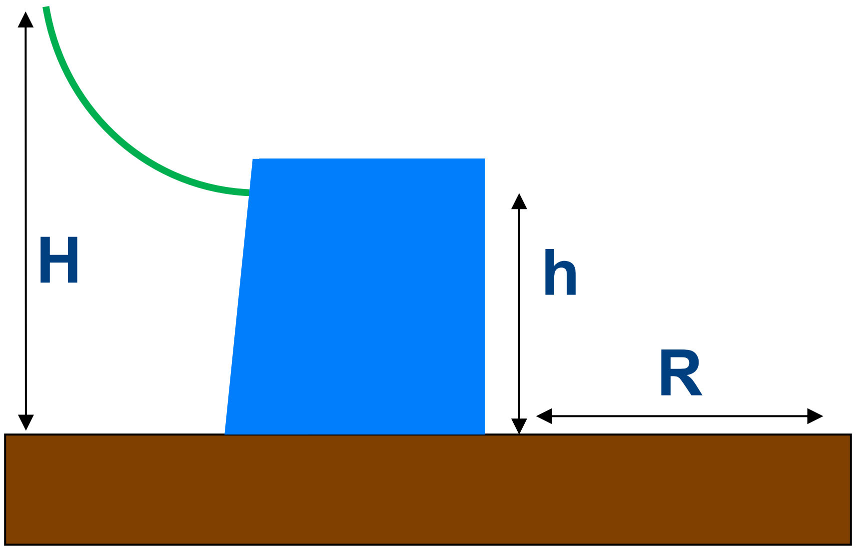
Weigh the mass **m** using a triple beam balance.

Include uncertainty estimates.

Use this naming when writing expressions based on these terms.

LW

Enter these results in **Table 1.**



Conservation of Energy

QUESTION 1: Draw and label the forces for free body diagram for the mass while it is on the middle of the track.

QUESTION 2:

a) Write down the equation for the mechanical energy when the mass is at the top of the track (just before it is released).

Be careful to use the symbols from the diagram on the previous slide.

b) Write down the equation for the energy of the mass as it emerges from the bottom of the track.

c) Do you expect these energies to be the same or different? Explain.

Have an instructor check your answers and initial your lab report.

Data Collection

Holding the mass at the top of the track, release it from rest. Pay close attention to release it without applying an force to the projectile.

Mark the landing position on the paper.

Repeat your procedure 8 times, marking the position on the paper each time.

Be sure to release the mass in the same way each time.

LW

Measure the distance from the base of the stand to each landing point. Record these values in **Table 2**.

Data Collection

Click the icon to open Graphical Analysis.

Enter your range values in Graphical Analysis.

Click **Analyze** then **Statistics**.

LW Write the mean, standard deviation, and number of samples in **Table 2.**

LW Calculate the standard error and record your result in **Table 2**.

Data Analysis

QUESTION 3: With $\overline{R}$ and the height h, determine the velocity of the mass as it emerged from the bottom of the track. You may assume air resistance is negligible. Include direction and uncertainty.

Hint: Use kinematics and treat this like an assignment question!

Calculate the uncertainty with the expression

$$\frac{\delta v}{v} = \frac{\delta \bar{R}}{\bar{R}} + \frac{1}{2}\frac{(\delta h)}{h}$$

QUESTION 4: Determine the initial mechanical energy of the mass at the top of the track (just before it is released).

Use your results from Question 2.

Data Analysis

Q **QUESTION 5:** Determine the mechanical energy of the mass as it emerges from the bottom of the track.

Q **QUESTION 6:** Using these results, determine the work due to friction.

Q **QUESTION 7:** If we assume that the track has a length of 0.438 m, estimate the average frictional force between the track and the mass.

Summary

Q

QUESTION 8:

a) Using conservation of energy from your expressions in Question 2, determine the velocity with which the mass would emerge from the bottom of the track if there were no friction between the mass and the track. Include **uncertainty** and **direction** in your answer.

b) Is this value equal to the velocity calculated in Question 3 within the uncertainty? Is this an expected result? Explain.

c) Considering your results, is it reasonable to neglect friction when determining the velocity of the mass emerging from the track? Explain.

Part III: Summary

Q **QUESTION 9:** List at least three sources of the experimental uncertainties. Classify them as random or systematic.

Q **QUESTION 10:** Write a brief paragraph summarizing the experiment and your findings.

Ensure that you have completed all **Tables** and answered all **Questions** completely.

Submit your workbook to the appropriate shelf/box as directed.