GENERAL

answers to lab 3 force motion

Published: September 19, 2026 | Index ID: #-

Introduction

Lab 3 in most introductory physics courses focuses on the relationship between force and motion. It is a cornerstone experiment that helps students connect Newton's laws to real world scenarios, develop data collection skills, and learn how to interpret results. Whether you're a high school senior or a college freshman, mastering the concepts and procedures in this laboratory will strengthen your foundation in mechanics. In this article we provide a thorough walkthrough of Lab 3, answer common questions, and present sample solutions that illustrate how to apply the theory to the data you collect.

Overview of Lab 3: Force and Motion

In Lab 3, students typically investigate how a constant force produces acceleration on a known mass and how friction alters that relationship. The experiment usually involves a cart on a low friction track, a pulley system to apply a known pulling force, a motion sensor or high speed camera to record velocity, and a set of weights to vary mass. By systematically changing the force and mass, you generate a data set that should follow the linear relationship predicted by Newton's second law: **F = m·a**. The lab's goal is to confirm this law experimentally, quantify uncertainties, and explore deviations caused by non ideal factors.

Key Concepts Covered in Lab 3

Newton's Laws of Motion

Lab 3 relies on the three foundational laws. The first law introduces inertia, the second law defines force as the product of mass and acceleration, and the third law describes action reaction pairs. While the experiment primarily tests the second law, understanding all three laws provides context for interpreting anomalies, such as unexpected forces from the pulley or air resistance.

Force, Mass, Acceleration Relationship

The core equation **F = m·a** links the applied force **F**, the mass of the system **m**, and the resulting acceleration **a**. In the lab, you typically measure **a** by recording the cart's velocity over time, while **F**is known from the weight attached to the pulley. By plotting force versus acceleration, you should obtain a straight line whose slope equals the mass.

Friction and Its Effects

Real world experiments are never perfectly frictionless. Kinetic friction opposes motion and reduces the net force available to accelerate the cart. The frictional force can be expressed as **f_k = ;Åö»t**, where **;Åö** is the coefficient of kinetic friction and **N**is the normal force. In many setups, friction is small enough that it can be treated as a constant offset in the force acceleration plot, allowing you to isolate the true mass from the slope.

Data Collection and Analysis

Accurate data collection is essential. You'll use a motion sensor or video analysis software to capture the cart's position versus time, from which you calculate velocity and acceleration. After collecting multiple trials for each mass, you compute averages and standard deviations to quantify experimental uncertainty. Finally, you fit the data

to a linear model and compare the slope with the theoretical mass to evaluate the lab's success.

Step by Step Guide to Completing Lab 3

Preparing the Apparatus

1. Set up the track: Place the track on a level surface and secure it to prevent movement.
2. Attach the cart: Ensure the cart's wheels run smoothly and that the pulley system is properly aligned.
3. Calibrate the motion sensor: Follow the manufacturer's instructions to establish a baseline and confirm accurate distance measurements.
4. Prepare masses: Weigh each added mass accurately using a digital scale.

Conducting the Experiments

1. Choose a mass: Start with the smallest mass to verify the apparatus works.
2. Apply a known force: Attach the predetermined weight to the pulley system and release the cart.
3. Record motion: Capture the cart's motion until it comes to a stop or reaches the end of the track.
4. Repeat: Perform at least three trials for each mass to ensure reproducibility.
5. Vary the mass: Incrementally increase the cart's mass and repeat the above steps.

Recording Data

During each trial, record the following:

- Initial and final positions (in meters).
- Time stamps for key positions.
- Calculated velocity and acceleration values.
- Environmental notes (e.g., track tilt, air currents).

Analyzing Results

After data collection, follow these steps:

1. Calculate acceleration: Use a = (v_f - v_i) / t or fit velocity versus time data to a linear trend and take the slope.
2. Determine net force: Subtract frictional force from the applied force: F_net = F_applied - f_k.
3. Plot F_net versus a: Use a graphing tool to generate a scatter plot and fit a straight line.
4. Extract mass: The slope of the line equals the mass; compare this with the known cart mass.
5. Evaluate uncertainty: Compute standard errors for the slope and intercept to assess the reliability of your results.

Common Questions and Answers

What is the purpose of Lab 3?

Lab 3 aims to provide hands on experience with Newton's second law, demonstrate the linear relationship between force and acceleration, and highlight the role of friction and measurement errors in experimental physics.

How do I calculate acceleration from the data?

Acceleration can be derived in two ways:

- Direct calculation: a = (v_f - v_i) / t, where v_f and v_i are final and initial velocities.
- Graphical method: Plot velocity versus time, fit a straight line, and take the slope as the acceleration.

What if my data doesn't fit the expected line?

Several factors can cause deviations:

- Unequal friction across the track.
- Misalignment of the pulley system.
- Timing errors or sensor lag.
- Unaccounted forces, such as air resistance.

Review your setup, re measure, and consider adding a friction correction to your analysis.

How do I account for friction in my calculations?

Measure the static friction by slowly pulling the cart with a known force until it just starts moving. That force equals the maximum static friction. For kinetic friction, use the average force needed to maintain constant velocity. Subtract this value from the applied force to obtain the net force driving acceleration.

Why is the slope of the force acceleration plot equal to the mass?

According to Newton's second law, **F_net = m·a**. Rearranging gives **a = (1/m)·F_net**, which is a linear equation with slope **1/m**. When plotted as force versus acceleration, the slope becomes **m**, allowing you to determine mass directly from the graph.

Sample Problems and Their Solutions

Problem 1: Calculating Net Force

Given a cart mass of 0.5 /kg and a frictional force of 0.2 /N, what net force is required to accelerate the cart at 2 /m/s²?

Solution: Using **F_net = m·a = 0.5 /kg × 2 /m/s² = 1.0 /N**. To overcome friction, the applied force must be **F_applied = F_net + f_k = 1.0 /N + 0.2 /N = 1.2 /N**

Problem 2: Determining Mass from Acceleration

During an experiment, you apply a 4 /N force and measure an acceleration of 1.6 /m/s². What is the mass of the cart?

Solution: Rearranging Newton's second law: **m = F / a = 4 /N / 1.6 /m/s² = 2.5 /kg**

Problem 3: Accounting for Friction

A cart with a mass of 1.2 kg experiences a kinetic friction coefficient of 0.05 on a horizontal track. What is the frictional force, and how does it affect the net acceleration when a 5 /N force is applied?

Solution: Normal force equals **m·g = 1.2 /kg × 9.81 /m/s² = 11.77 /N**. Frictional force: **f_k = ;Åö»tâ Ò ã R r ãsr ôâ Ò 0.5885 /N**. Net force: **F_net = 5 /N - 0.5885 /N = 4.4115 /N**. Net acceleration: **a = F_net / m = 4.4115 /N / 1.2 /kg "H 3.676 /m/s²**.

Problem 4: Linear Regression and Uncertainty

Suppose you collected the following data pairs (F_net, a): (1.0 /N, 0.5 /m/s²), (2.0 /N, 1.0 /m/s²), (3.0 /N, 1.5 /m/s²). Perform a linear regression to determine the mass and its uncertainty.

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