Department of Physics, SNS

Applied Physics

(PHY-113) Lab

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Submission Date: December 22,2025

School:	**SNS**	**Lab Date:**	
Semester/Year:	**1st / 2025**	**Section:**	A

Lab Report 4

Fiction Cofficient & Faraday's Law of Induction

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Experiment # 03

Newton's Second Law (Predicting Accelerations)

Purpose:

In this lab, a small mass **m** will be connected to the PAScar by a string as shown in Figure 3.1. The string will pass over a pulley at the table's edge so that as the mass falls the car will accelerate over the table's surface. If the string is not too elastic and there is no slack in it, both the falling mass and the PAScar will have the same acceleration. The resulting acceleration of this system will be experimentally determined, and this value will be compared to the acceleration predicted by Newton's Second Law.

Theory:

The car will be released from rest and allowed to accelerate over a distance **d**. Using a stopwatch, you will determine how long it takes on average, for the car to move through the distance **d**. An experimental value for the car's acceleration **a** can be determined from:

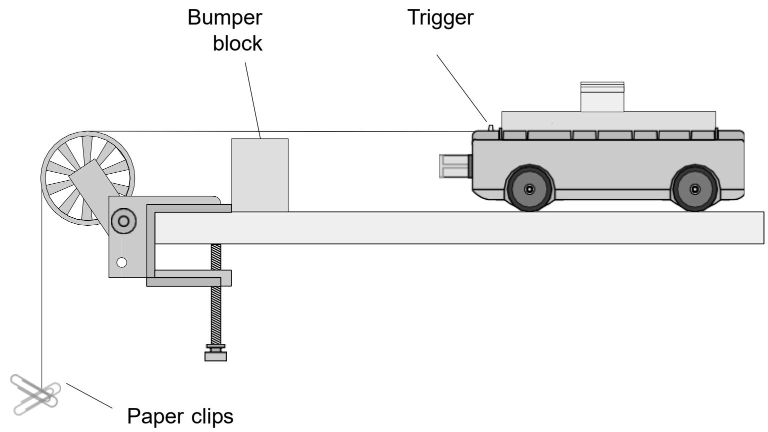
$d = \frac{1}{2}at^2$ which leads to $a = \frac{2d}{t^2}$ (Experimental Value)

Assuming that the tabletop is truly horizontal (i.e. level), Newton's Second Law (F = ma) predicts that the acceleration of this system will be:

$a = \frac{F_{net}}{M_{Total}}$ or $a = \left(\frac{m}{M_{Total}}\right) g$ (Theoretical Value)

Apparatus:

- PAScar (ME-6950)
- Pulley and pulley clamp (ME-9448)
- Mass set (SE-8704)
- Stopwatch (SE-8702)
- String
- Paper clips
- Block (to act as bumper)
- Balance (SE-8723 or equiv.)



Procedure:

1. Set up the pulley system with the car and place something at the end to stop the car from crashing into the pulley. Put weights on the car (10 g, 50 g, 500 g, and two 20 g pieces).
2. Make sure the table is perfectly level, so the car doesn't roll on its own.
3. Tie one end of the string to the car's spring-release trigger, then pass it over the pulley. Adjust the pulley so the string stays straight.
4. Adjust the string's length so the weights don't touch the floor before the car reaches the bumper. Tie a loop at the end of the string.

   (Note: The system's total mass stays the same during the experiment.)
5. Hang paper clips on the end of the string until the car barely keeps moving when pushed lightly. This cancels out friction, and these clips stay in place for the whole experiment.
6. Take 10 g weight from the car and attach it to the hanging side of the string. Pull the car back to a marked starting point. Measure the distance from the start to the bumper and note it.
7. Practice releasing the car without pushing it. The best way is to block it with your finger, then quickly move your finger away and start timing as soon as the car begins to move. Stop the timer when it hits the bumper. The same person should release and time to avoid reaction delays.
8. Do several trials to measure the time it takes for the car to travel the distance. Record the average of your most accurate four trials. Repeat for each set of weights.
9. Find the total mass of the system (car, weights, string – but not the pulley) and record it.
10. Use your data and the given formulas to complete the results table.

Data Analysis:

D = 0.29m

M = 0.75kg

Serial #	**M** (kg)	**Average Time** (s)	a_{exp} (m/s^2)	a_{theo} (m/s^2)	**%Error**
1.	0.015	2.71	0.17	0.19	10.5
2.	0.02	1.63	0.285	0.261	8.4
3.	0.035	1.26	0.476	0.457	4
4.	0.040	1.18	0.54	0.52	4.1

Conclusion:

In this experiment, we studied Newton's Second Law by measuring the acceleration of a PAScar pulled by a hanging mass. The experimental acceleration values were found by timing how long the car took to travel a known distance, while the theoretical values were calculated using Newton's Second Law. The results showed that the experimental accelerations were generally close to the predicted values, with small differences likely caused by friction, human reaction time, or slight misalignment in the setup. Overall, the experiment confirmed that the acceleration of a system depends on the net force applied and the total mass, which supports Newton's Second Law.

<u>Q/n:</u>

1) How did the experimental data support Newton's Second Law (F = ma)?

The experimental data showed a clear linear relationship between the net force applied to the system and the resulting acceleration when mass was kept constant. Similarly, when the mass of the system was increased while keeping the force constant, the acceleration decreased, demonstrating an inverse relationship. These trends are consistent with Newton's Second Law, which states that acceleration is directly proportional to net force and inversely proportional to mass ($F = ma$). The results aligned closely with theoretical predictions, confirming the law's validity under control conditions.

2) Why is it important to minimize friction in Newton's Second Law experiment, and how was this achieved in the setup?

Friction adds an opposing force, which can distort the results by reducing the net force acting on the system, making acceleration lower than predicted. To reduce friction, equipment like low-friction carts, air tracks, or pulley systems were used. Additionally, ensuring smooth track and well-lubricated wheels helped isolate the effect of applied force on acceleration, aligning results more closely with theoretical predictions.

3) What sources of error may have affected the accuracy of the results, and how could they be reduced?

Sources of error included **friction between the cart and track, pulley resistance, air resistance, and timing inaccuracies**. This could have caused the measured acceleration to be slightly lower than predicted. To reduce these errors, improvements such as using an air track or a frictionless pulley system, ensuring proper calibration of motion sensors or timing devices, and minimizing human error through automated data collection could be implemented.

Experiment # 04

Cart Calibration (Measuring the Spring Constant)

Purpose:

The PAScar has a spring plunger, which can be used for producing relatively elastic collisions and providing a reproducible launch velocity.

Theory:

For this and the following experiments, it will be necessary to find the spring constant **k** of the car's spring plunger. As compressional forces **F** are applied to the spring, the spring will compress a distance **x,** which is measured with respect to its uncompressed equilibrium position. If **F** is plotted versus **x** on graph paper, the spring constant is given by the slope of the graph as:

(EQN-1): $$k = \frac{\Delta F}{\Delta x}$$

Once **k** is known, it is possible to predict the launch velocity $v_0$by using conservation of energy, since the elastic potential energy stored in the spring is converted into kinetic energy at the time of launch. The launch velocity can be found from:

(EQN-2): $$\frac{1}{2}mv_o^2 = \frac{1}{2}kv_o^2$$

which leads to:

(EQN-3): $$v_o = x_o\sqrt{\frac{k}{m}}$$

This predicted launch velocity can be experimentally checked by measuring the total rolling distance **d** on a horizontal surface and the corresponding time **t** for given launch conditions. This leads to:

(EQN-4): $$v_0 = 2\frac{d}{t}$$

It is assumed that the acceleration of the car is constant, so that the initial velocity of the car at the moment of launch is twice the average velocity of the car over its whole run.

Apparatus:

- PAScar (ME-6950)
- 250g mass
- Mass set (SE-8704)
- Stopwatch (SE-8702)
- Pan for holding masses
- Balance (SE-8723 or equiv.)

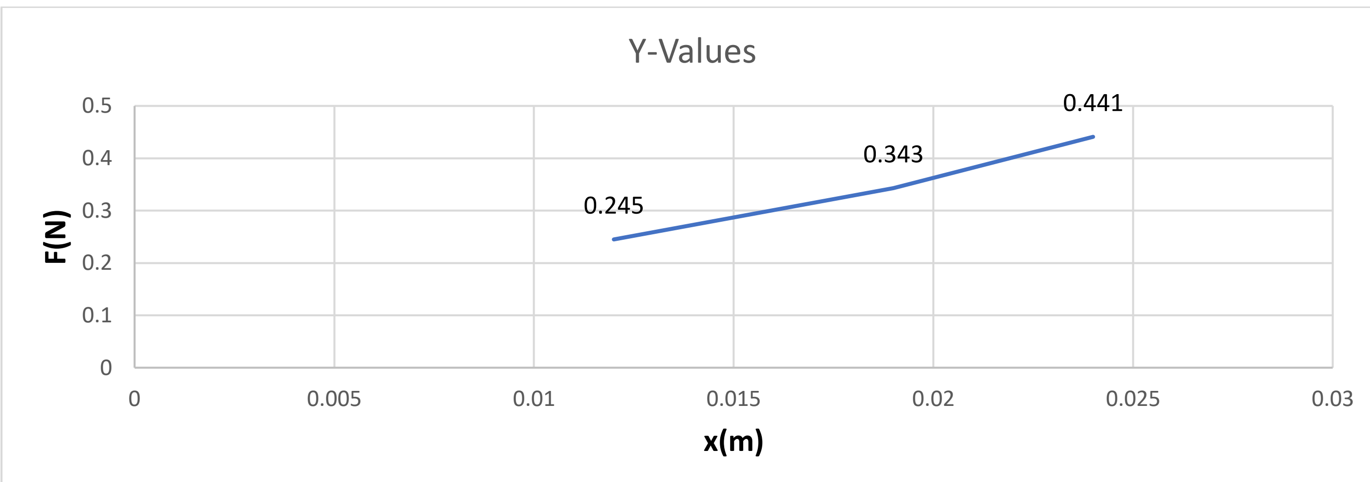
Procedure:

1. Stand the PAScar upright with the spring plunger pointing up. Attach a ruler so its zero-mark lines up with the top of the plunger. Make sure to read it correctly (no parallax error).
2. Put enough weight on the plunger to almost fully push it down. Note the weight and how much the spring is compressed (x).
3. Remove about one-quarter of that weight. Record the new weight and compression.
4. Keep repeating step 3 until there's no weight left.
5. Draw a graph of force (F) versus compression (x). Find the slope of the best-fit line. That slope is your spring constant (k). Write it down.
6. Weigh the car on a balance and record its mass (m).
7. Use the formula (EQN-3) with m, k, and your chosen compression (x_0) to predict the car's launch velocity.
8. Push the plunger to x_0, place the car at the start, and release it. Use a stopwatch and meter stick to measure how far it travels (d) and the total rolling time (t). Take averages.
9. Use EQN-4 to calculate the actual starting velocity (vo) and compare it with your predicted value.

Data Analysis:

Serial #	m (kg)	x (m)	F= mg (N)	$k = \frac{F}{x}$
1.	0.035	0.019	0.343	18.05
2.	0.045	0.024	0.441	18.37
3.	0.025	0.012	0,245	20.41

Straight line graph



$k = \frac{y_2 - y_1}{x_2 - x_1} = \frac{F_2 - F_1}{x_2 - x_1}$

With mass: $\boxed{T_{theo} = 1.299s}$

Without mass: $\boxed{T_{theo} = 0.7096s}$

$k = 19.06$ $T = 2\pi\sqrt{\frac{m}{k}}$

With mass: $\boxed{T_{exp} = 1.233s}$

Without mass: $\boxed{T_{exp} = 0.704s}$

Conclusion:

In this experiment, the spring constant of the PAScar's plunger was determined by measuring the relationship between applied force and compression. Using this value of k, the predicted launch velocity of the car was calculated through conservation of energy. The experimental velocity was then measured by timing the car's motion over a known distance. The comparison of predicted and observed velocities showed that the spring constant method provides a reliable way to estimate the launch speed, with small differences likely due to friction, reaction time, and measurement errors.

Q/n:

1) Why is it important for the force vs. displacement graph to be linear in this experiment?

A linear force vs. displacement graph confirms that the spring obeys **Hooke's Law**, which is valid only within the **elastic limit** of the spring. This linearity is essential because the spring constant k is defined only in the linear region. If the graph becomes nonlinear (e.g., due to spring deformation or plastic behavior), then the measured value of k would not be accurate or consistent.

2) What are potential sources of error in determining the spring constant using this method?

Possible sources of error include:

Friction in the cart's wheels or track, which resists motion and affects the measured displacement.

Inaccurate measurement of displacement, especially if the ruler or scale is not aligned correctly.

Parallax error when reading values by eye.

Non-uniform mass distribution on the cart, causing uneven force application.

Spring may have **internal damping** or wear, altering its true behavior.

Human reaction time if displacement is recorded manually during oscillations instead of at rest.