Honors Physics

Newton's Laws of Motion Lab

Introduction

If you try to slide a heavy box resting on the floor, you may find it difficult to get the box moving. *Static friction* is the force that counters your force on the box. If you apply a light horizontal push that does not move the box, the static friction force is also small and directly opposite to your push. If you push harder, the friction force increases to match the magnitude of your push. There is a limit to the magnitude of static friction, so eventually you may be able to apply a force larger than the maximum static force, and the box will move. The maximum static friction force is sometimes referred to as *starting friction*. We model static friction, F_{static}, with the inequality $F_{\text{static}} \leq \mu_s N$ where μ_s is the coefficient of static friction and N is the *normal* force exerted by a surface on the object. The normal force is defined as the perpendicular component of the force exerted by the surface. In this case, the normal force is equal to the weight of the object.

Once the box starts to slide, you must continue to exert a force to keep the object moving, or friction will slow it to a stop. The friction acting on the box while it is moving is called *kinetic friction*. In order to slide the box with a constant velocity, a force equivalent to the force of kinetic friction must be applied. Kinetic friction is sometimes referred to as *sliding friction*. Both static and kinetic friction depend on the surfaces of the box and the floor, and on how hard the box and floor are pressed together. We model kinetic friction with $F_{\text{kinetic}} = \mu_k N$, where μ_k is the coefficient of kinetic friction. (Source: Vernier)

In this experiment, you will calculate the coefficient of kinetic friction between a rolling skateboard and the gym floor.

Materials

Skateboard or Cart
Vernier Graphical Analysis 4
Motion Detector
iPhone with Measure App

Procedure

1. Connect the Go Direct Motion Detector to your laptop.
2. Open Vernier Graphical Analysis 4 on your laptop.
3. Place the Go Direct Motion Detector on the box.
4. Place the skateboard/cart perpendicular to the box/Go Direct Motion Detector.
5. Click **Collect** and push the skateboard in a relatively straight line. Note: You may have to extend the data collection time to collect more of the skateboard slowing down.
6. Your graph should look something like this.

Note 1: The skateboard does three things: it accelerates, moves at constant velocity and decelerates. You only want the part where the skateboard decelerates.

Note 2: Your graph will not be perfect. If you are happy with your graph, save it as **Trial 1**.

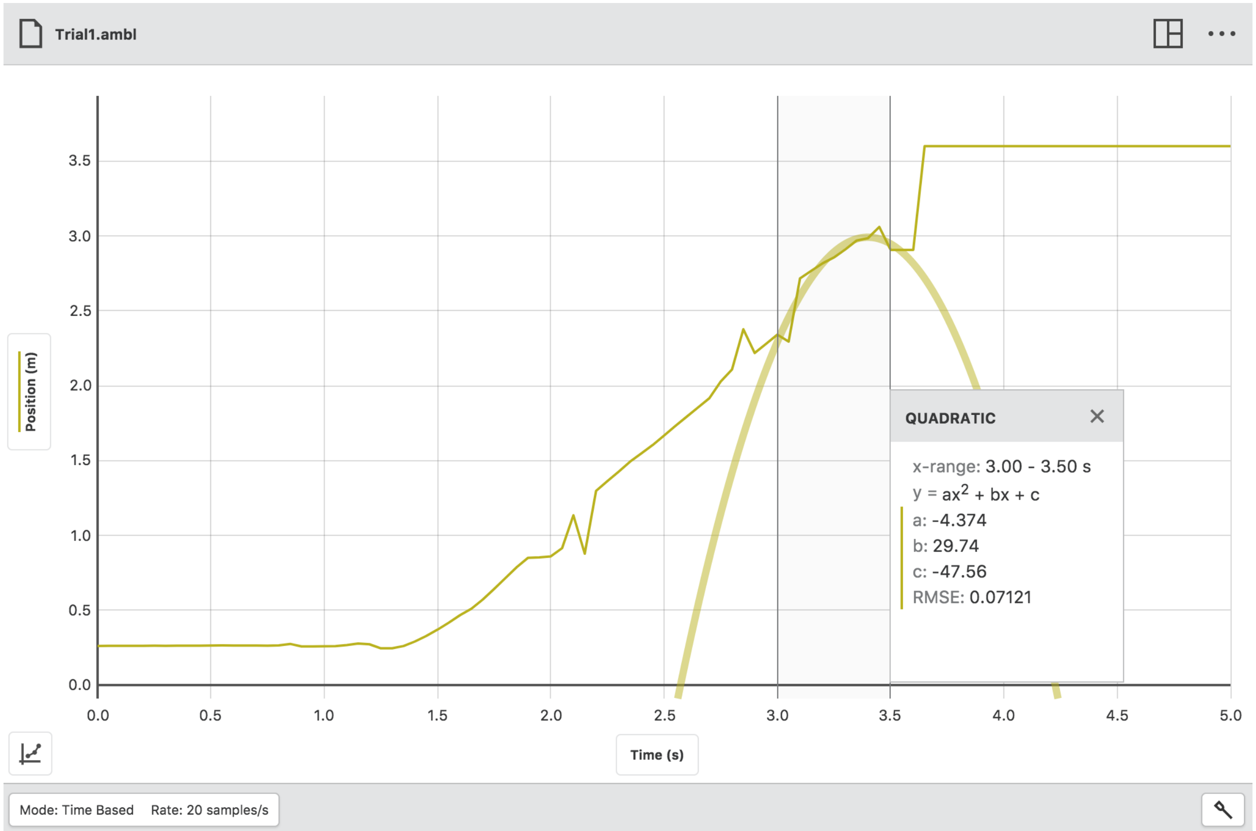
7. Repeat for two additional trials. Save these trials as **Trial 2** and **Trial 3**.

Data Analysis

1. For each graph, highlight the segment where the skateboard has a negative acceleration by clicking and dragging on the graph.

2. Click on the little graph in the lower left corner. Edit the graph options so that the graph has an appropriate title and appropriately labeled axes.

3. Click **Apply Curve Fit** and select **Quadratic.** Adjust your blue window so you do not include any part of the curve where it is "going down." Click **Apply**.



4. Recall the kinematic equation $x = x_o + v_o t + 1/2at^2$. You can match the values a, b, and c to a, v_o and x_o. Therefore, the coefficient a in the best fit quadratic is equivalent to ½(acceleration). Record the value of the acceleration in the data table.

Data

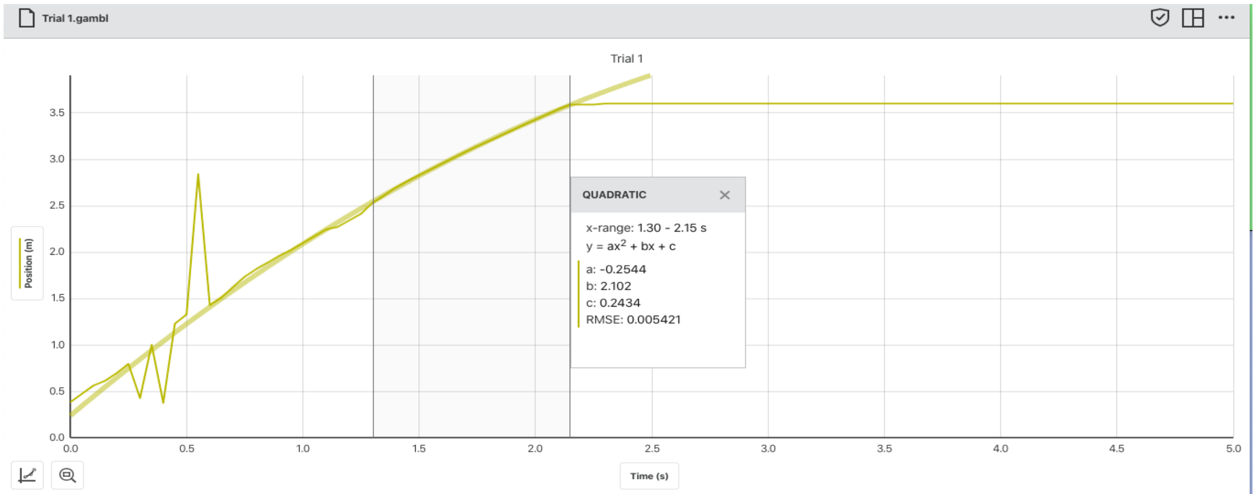
Insert images of your analyzed graphs below. Make sure they are appropriately sized.

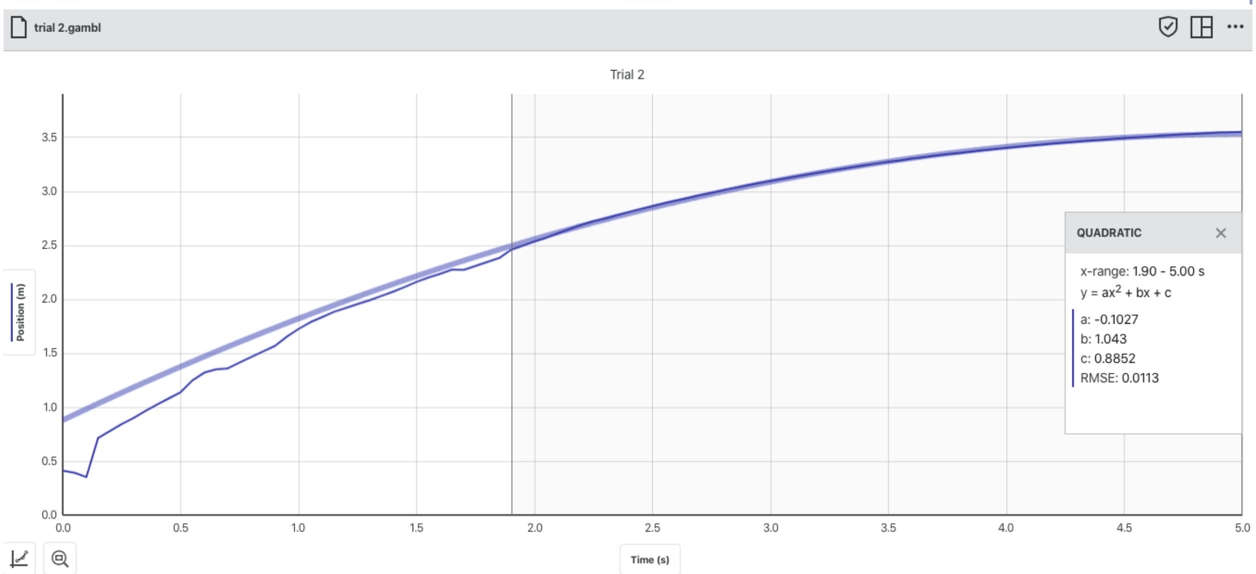
Data Table

Mass of the Skateboard: _____________ kg

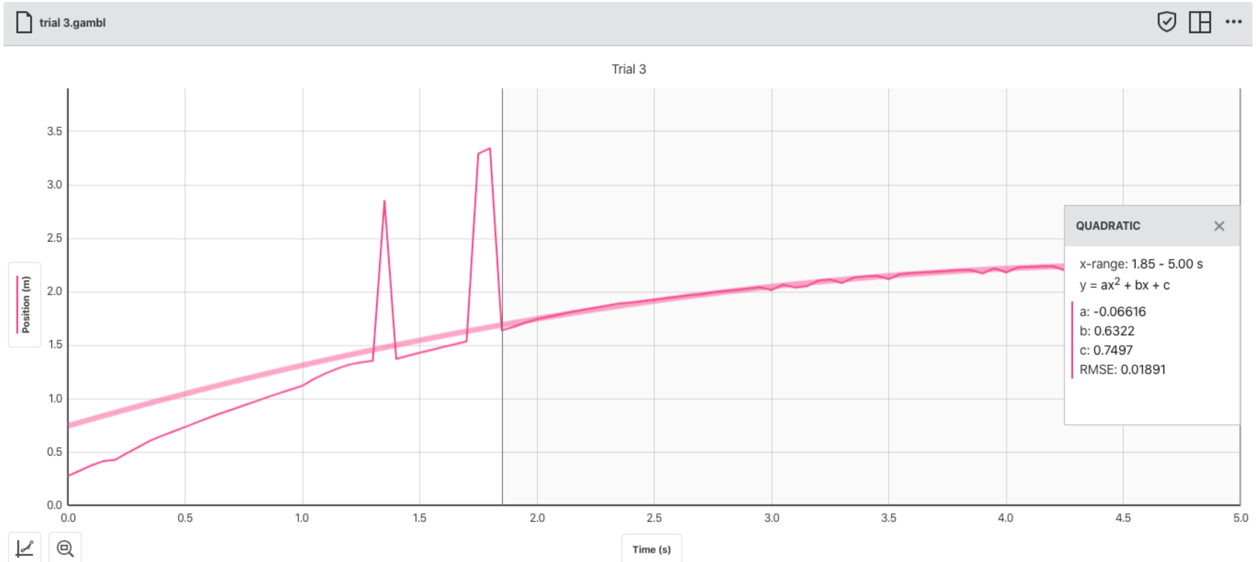
a = $_k g \rightarrow {}_k = a/g$

Trial	a (m/sec^2)	$_k$
1	2(-0.2544) = -0.5088	0.0519
2	2(-0.1027) = -0.2054	0.0210
3	2(-0.06616) = -0.13232	0.0135


Trial 1.gambl
Trial 1
Position (m)
Time (s)
QUADRATIC
x-range: 1.30 - 2.15 s
y = ax2 + bx + c
a: -0.2544
b: 2.102
c: 0.2434
RMSE: 0.005421

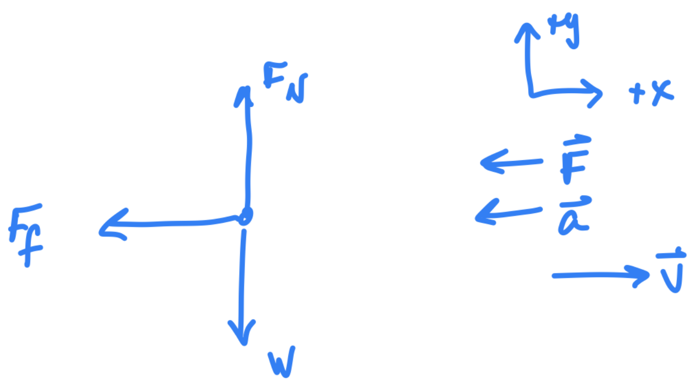

trial 2.gambl
Trial 2
Position (m)
Time (s)
QUADRATIC
x-range: 1.90 - 5.00 s
y = ax2 + bx + c
a: -0.1027
b: 1.043
c: 0.8852
RMSE: 0.0113

we



Calculations

1. The free body diagram for the skateboard is below.



2. We then write the Newton II Equations. We can solve the equation in the x-direction for k .

$$\Sigma F_y: \quad N - W = 0$$

$$\Sigma F_x \quad -f_k = ma_x \qquad f_k = \mu_k N$$

3. Use this equation to calculate the value for k. Enter your calculated value in the data table.

Analysis

1. Recall that the coefficients of kinetic and static friction are less than one. Are your values for the coefficient of kinetic friction less than one?
2. If you have few sources of error in your experiment, your values for the coefficient of kinetic friction should be similar. Are they? Or is there substantial variability in your values?
3. There is a lot of room for error in this lab. It shouldn't make a difference how hard you push the skateboard, but the skateboard does tend to wobble as well as not move in a straight line. List two things you might do, that are both reasonable and realistic, to reduce any errors in this lab.
4. If the coefficient of friction is changed, how does that affect frictional force?
5. If the mass of an object changes, how does that affect the frictional force?