Teaching guide - Constant acceleration

Contains **0 items** • Worth **0 points**

# Teaching guide - Constant acceleration

## Timing

This lab should take 1 hour and 45 minutes.

## The goal of the lab

Don't be taken in by the name of the lab. This lab is as much about forces as it is about constant acceleration. The lab is about students tying together their understanding of forces with their knowledge of constant acceleration.

## Slides to use before the lab

We have a very nice slide set (3 slides? 4 slides?) that goes through the derivation of the equations for acceleration, in these scenarios:

- the zero friction case

- including friction, cart moving away from the pulley

- including friction, cart moving toward the pulley

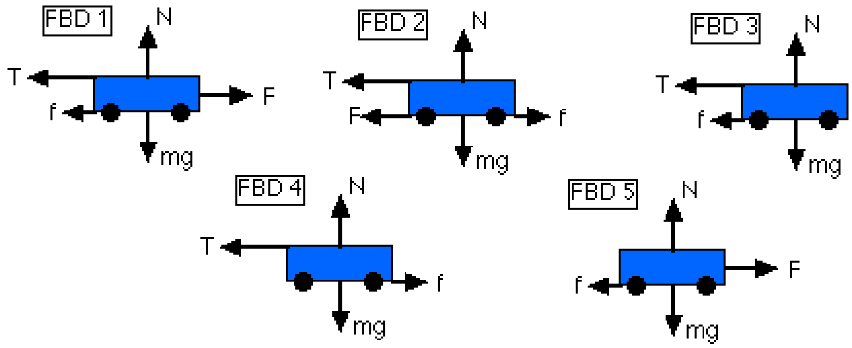
It takes a few minutes to go through these before the lab.

## Pre-lab

In the lab experiment, a cart on a horizontal track is connected via a string to a mass hanging from a pulley. The cart's acceleration is determined from graphs of the cart's position, velocity, and acceleration as a function of time.

In part of the experiment, you push the cart away from the pulley and release it. The cart moves along the track, stops for an instant, and then returns toward the pulley. This is shown in the simulation.

On the pre-lab, the students have to pick two correct free-body diagrams for the situation **after** you have stopped pushing the cart, one for when the cart is moving away from the pulley (FBD 3) and one for when it is moving back toward the pulley (FBD 4).




N = normal force; mg = force of gravity; T = tension in the string; f = friction; F = another force

## The lab

### Deriving the acceleration equation (assume no friction)

**Step 1:** Examining Newton's second law for the cart, begin with sum of the forces with the positive direction being in the direction of the system's acceleration, and with no friction tension T is the only horizontal force on the cart:

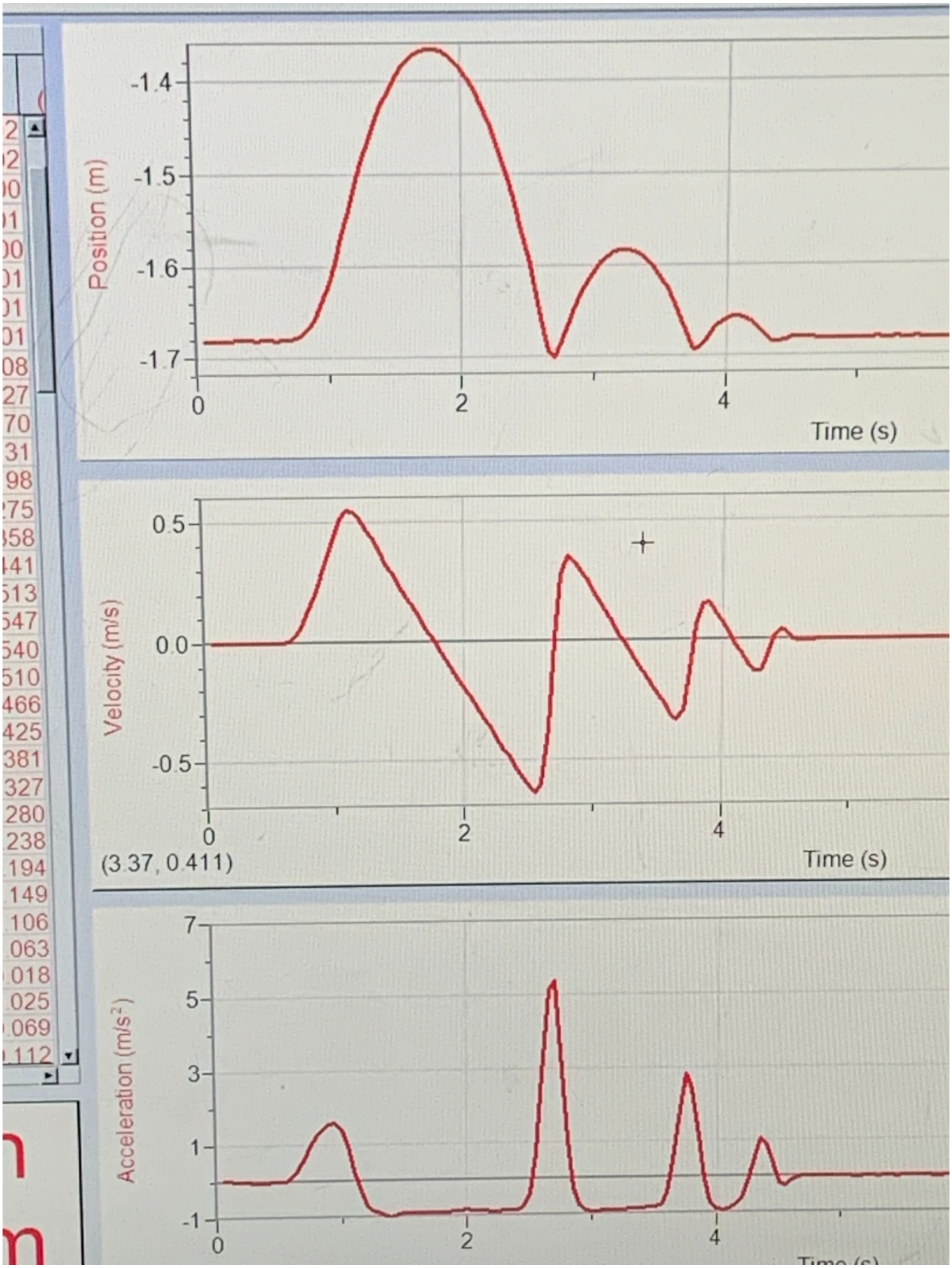
$\sum F = T = Ma_{sys}$

**Step 2:** Look at Newton's second law for the hanging mass (remember, positive direction is in the direction of acceleration, which will be *down* in this scenario!):

$\sum F = F_g - T = mg - T = ma_{sys}$

**Step 3:** Now solve for Tension T, and insert it into the equation from Step 1 (this is Newton's third law in action): $mg - ma_{sys} = T = Ma_{sys}$ ---> $mg - ma_{sys} = Ma_{sys}$ ---> $mg = Ma_{sys} - ma_{sys} = a_{sys}(M + m)$ ---> $a_{sys} = mg/(M + m)$

### Typical student data




There's a lot going on here, but this is what the students get. The data we really want is between around t = 1.2 s and t = 2.5 s. There are some bounces after that (and an initial push at the beginning), and we're not interested in any of that. The velocity graph really is the best guide to the useful part of the data - for this data we want the first downward sloping part, but we want to fit that in two pieces! Do a linear fit to the positive part of that section to find the acceleration for when the cart is moving away from the pulley, and another linear fit to the negative part to find the acceleration for when the cart is moving toward the pulley. These will be a little different because friction is in the same direction at the tension initially, but then it's in the opposite direction.

The students can find the acceleration by doing a quadratic fit (remember the factor of 2) to each half of the peak, or just averaging the acceleration, in each case using the velocity graph as a guide to the end-points.

Here is a sample set of tables - the students will have their own values, but this is something to compare to, at least:

**Table Title**

Constant acceleration data

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|
| Cart mass (g) | Hanging mass | a_1 (m/s/s) | a_2 (m/s/s) | average a | Theoretical a |
| 500 | 50 | 0.879 | 0.813 | 0.846 | 0.891 |
| 750 | 200 | 2.005 | 1.951 | 1.978 | 2.063 |
| 1000 | 50 | 0.447 | 0.382 | 0.415 | 0.467 |
| 1000 | 200 | 1.619 | 1.561 | 1.590 | 1.633 |
| 1250 | 200 | 1.320 | 1.264 | 1.292 | 1.352 |
| 1250 | 500 | 2.646 | 2.586 | 2.616 | 2.800 |

B i X₂ X² Ω Undo Start Over Column Row

**Table Title**

Finding the coefficient of friction

| Trial | Coefficient of friction |
|---|---|
| 1 | 0.005 |
| 2 | 0.011 |
| 3 | 0.006 |
| 4 | 0.005 |
| 5 | 0.007 |
| 6 | 0.026 |
| AVERAGE VALUE | 0.010 |

**Wrap-up:** Although the experimental results did a pretty decent job matching the theory (most of them within 0.1 m/s^2), there could be some improvements to the experiment. The experimental results are always under the theoretical results! It is likely, then, that there is something else in the system that the theory we used isn't quite capturing - something that will cause a slightly lower acceleration than originally predicted. Friction is one suspect, but air resistance, for example, would be be another source of error. It could be possible that the track is not perfectly level, or that the masses were not measured accurately enough, but to the best of our ability we made sure these would not significantly contribute error.

**Question 1:** *C) The maximum is g and the minimum is zero.*
This should make sense because being at *g* implies free-fall, which of course just the Earth pulling on you. The minimum being *zero* (n.b. we're specifically talking about acceleration magnitude) makes sense as well, because then the system just exhibits no motion whatsoever, which is clearly the minimal case.

**Question 2:** *B) When the cart is at rest.*
When holding the cart, the tension in the string has to equal the weight of the hanging mass, because there is no acceleration. When the cart is let go, the hanging mass has a downward acceleration, so

the two forces on the hanging mass do not balance. The force of gravity is unchanged, so the tension in the string has to be less than before.

## Lab grading

The pre-lab is automatically graded. The lab is mostly automatically graded, except for these three items. Each of these is graded out of 1 point, but in each case 0.5 points is given for completion. So, graders are only awarding up to 0.5 points each on:

- the Data table

- the table for the coefficient of friction

- the wrap-up, where the students comment about what they learned and about sources of error

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