Dragster Forces

This week, your goal will be to accurately determine the forces at work on a small CO2 dragster race car. You should show up to lab having designed experiments to measure a variety of factors, making use of all the physics you've learned so far. You have already talked about forces, but if you've covered momentum and/or energy, you are welcome to approach the problem from those angles as well. In the last 15-20 minutes of the lab, you'll test your calculations with the following measurements:

How long will it take for your car to travel 0.5 m, 1.0 m, and 2.5 m?

In this lab, you'll want to work through the activities in the order listed, but you do you. Make sure to ration your time so that you have a chance to test your prediction!

Step #1: Prep

First things first, we'll want to outline the problem at hand. You'll be making several measurements today, and will need to design an experiment to do so

- As always, draw a force-body diagram for each of your methods.
  - Identify the forces involved in each method.
  - Do a back-of-the-envelope calculation or estimation of the magnitude of the variables involved.
  - Discuss how reasonable your methods are for estimating the forces involved.
- Compare your estimate to your measured results, and discuss how significant the forces involved are.

Force #1: Friction Force

We'll start easy (though you are welcome to jump around if desired). Your cart will be rolling across the floor, and so will encounter friction. In particular rolling friction. Design a set of tests to measure the frictional coefficient. Hint: You've measured frictional forces in a previous lab, how might you do so again here? After recording the info listed in Step 1, answer the following:

- What is your cart's rolling frictional coefficient?
  - Is your number reasonable?

Force #2: Thrust

Each cart will be propelled by a single CO2 canister, which will be popped open by the launcher. When the seal is pierced, a jet of pressurized gas will exit the back of your vehicle, propelling your cart forwards - thanks to Newton's Third Law! You'll be provided with a measurement of a typical canister's force (an average from several runs) as a function of time, given this data in a table.

- Look at the provided data and graph it out on a graphing program of your choice (we encourage you to use LoggerPro, which you can download from the links on the Canvas assignment).
  - You've got a force vs time graph, what calculations do you need to be able to determine your vehicle's velocities and distances?
    - If you need it, how might you turn a forces graph into a graph of acceleration vs time?
  - Describe: How can you determine how fast your vehicle will go after a bit of time?
  - You will need to do this calculation for sections of this force graph, not just the entire thing. How will you get the software to do the hard work for you?

Through the browser on your iPad, you can access google sheets, or you might have Excel or such on your laptop, and are likely familiar with using formulas and manipulating columns of data. You are also welcome to download LoggerPro form the main Labs Page on Canvas to your computer, wherein you can create calculated columns.

- In LoggerPro, You'l want to go to "Data" in the menu bar, then "New Calculated Column". You might check out https://www.youtube.com/watch?v=TnrKxbvhYA0 at the 1 minute mark to see this in action.

Force #3: Drag Force

The last force is a real drag. Well, it *is* drag, anyway. As you can tell, the cart is not super aerodynamic. The drag force should be considered as part of your analysis today, if you've the time for it. Topics to consider:

- The drag force will vary with velocity. How?
- How can you measure the drag force acting on your cart?
  - How might you measure/estimate wind-speed?
- What is your vehicle's coefficient of drag?
  - Is this reasonable, based on numbers you've seen in your text?

Calculations

Now it is your turn. Collect all your data, and combine it to determine how long it will take your vehicle to travel 0.5m, 1.0m, and then 2.5m . Your considerations:

- What kind of model are you applying for each distance? Constant acceleration? Constant velocity? A mix of the two? Non-constant acceleration? Are you considering all the forces, or are you ignoring some? Discuss your choice, and how appropriate they are.
- How close do you expect your results to be?

Once your calculations are done, talk to your TA and run your test! Make sure that you run your test before the lab ends regardless!

Race Setup

You'll need to do some setup in order to race your Dragster. Make sure you start this (or will be ready to start this) in the last 20 minutes of lab. If your calculations are not done, it is still important that you run the test - it's the extra fun part of the lab!

- Attach your dragster to the racing line:
  - There is a 3m length of fishing line running between the start and finish - you need to thread this through the screw eyes under your cart. It is firmly attached to the circular weight, and so use the "starting" end with a paperclip to thread it through the holes, and then hook the paperclip onto the back of the launcher.
  - The string should be taut, but not overly-stretched. Think a tension of 5ish newtons.
- Your TA will give you a fresh CO_2 cartridge - insert it into your vehicle.
- Place the first photogate at 0m - just barely in front of the top post. Then, measure and place the other three gates at 0.5m, 1m, and 2.5m.
- Plug the 0m gate into your LabQuest, and make sure the *Gate State* is **Unblocked**. If the gate state is "blocked", you need to make sure none of the photogates have their shutter closed (their light would be on). You can wave your hand through the gates to verify their operation, blocking and unblocking the Infrared beam.
  - Click on the Grey box, and set the *Photogate Mode* to **None** then press OK. You will want the raw time data on your LabQuest! Start your data collection and then...
- Your TA will prime the launcher, insert your vehicle - and then set it off!
  - Your graph should end up with four blips - when the vehicle passed the 0.0m photogate, the 0.5m, 1m, and 2.5m gates!

Discussion

Spend some time discussing your results:

- What were your vehicle's actual times?
- How close were your calculations?
  - Your predictions were likely not perfect. Can you deduce why they might have been off?
- Is it reasonable to say you "got it right", or not?
- How might you improve upon the experiments you performed today, if you were asked to do it again?

Hotwheels

If there is still time remaining, kudos to you! We've got some simpler experiments to work on. You can revisit your earlier measurements if you like, or pick one of the two following activities and give them your best shot!

Ramping It Up: At the center we have a selection of hotwheels cars and tracks. The track pieces connect to each other using a set of plastic wafers - don't lose these! Your first task: before you send a car down the ramp from a height of at least half a meter so that it will roll off the edge of your table, make a prediction of where it will land.

- There are two phases to this motion, what models will you apply to the situation?
- Record your methods, and results, and then test it out.
  - What are you doing to make sure your models fit the motion as well as they can?
- Discuss how things went.
  - Were your models a good fit for the action, or how might they need to be improved upon?

Round Again: Instead of predicting a landing distance, you might grab one of the Loop-the-Loop tracks and attach that to the end of your ramp. The question here for the second activity is: given the height of the loop, how far up the starting track must your car begin in order to just barely make it around the circle?

- There are two (or more) phases to this motion, what models will you apply to the situation?
- Record your methods, and results, and then test it out.
    - What are you doing to make sure your models fit the motion as well as they can?
- Discuss how things went.
    - Were your models a good fit for the action, or how might they need to be improved upon?

Report

You'll be recording your work on the whiteboard tables as you go, and so be clear when summing up your process and your conclusions. Keep your discussions short, sweet, and to the point, please. Be sure to indicate what work you did on the report (as opposed to what your lab partners did).

Remember: The point of the report is to show your TA how well each of you understand the material, how well you designed and performed experiments, and how much of a scientist you were - not to show them you can parrot the textbook, always get the "right" answer, or do everything. You might include a photo or sketch (or few) of your setups. The process, your reasoning, and your improvement are the key to earning full credit.

Be sure that each of your group members submit this assignment as soon as possible (ideally at the end o your lab), and take some time to consider how lab went for you and your peers, and how you can improve the experience next week.

Looking Ahead: Starting a race

This isn't something to calculate today, but something to think about: To fill the endless void with television programming, several years back a few shows had humans racing different animals. Running, swimming, pulling, etc... - it was all on the table (but the challenges were not always "even-steven", and sometimes ethically dubious - how do you convince ostriches they are in a race?). Humans tend to have a pretty ok acceleration (certainly compared to animals with larger masses), but our top speed isn't something to brag about in the animal kingdom. Given that: if you wanted the human to win would you design the race course to be a short one, or something fairly long? Humans are particularly good at endurance running, after all... At what distance(s) would that need to be factored in to ensure the Human's success?