Overhauled Bicep Lab

See outline and future work at end of document

Introduction

This lab will be different from the others you've done so far. Rather than giving you explicit steps to follow, we're providing you with a problem to investigate and some hints on how to proceed. It will be something of a challenge to figure out how exactly to accomplish each step, but this will be much more like doing science in the real world.

Warm up

Warm up – comments

- Assume students don't know anything about torque (it's very likely they won't know anything)
- Give activity which guides them through torque
- Possibly just take from open source tutorial
- Ok, open source tutorial requires them to do experiment that we don't have resources set up for (though we could relatively easily set them up)

Warm up problems

A lot of these problems can be taken with minimal modification from the UMD open source tutorial on torque (and the corresponding HW assignment) [click colored text for links], which focus on static torque , especially on things like levers

Note: These questions would probably work better if the students could actually perform some of these mini-experiments. I'm planning to talk to those in charge (not Marty, but others) to ask whether we have the materials needed to investigate the balance of torques on a simple lever-fulcrum system (like the one in the open source tutorial activity). **Such an apparatus will not be available this quarter, but it may work for next quarter** – depending on the resources already in place.

1. Balancing weights on a ruler atop a fulcrum
    a. Two equidistant weights on opposite side of pivot
    b. Double one weight's distance; ask how much weight needs to be added and to which side
2. Replace one of the weights with an arbitrary force pointing downward
3. Replace arbitrary force with a cable at an angle (positioned like bicep)

**Need to figure out how to introduce quantitative relations

- $\tau \sim rF$ (for orthogonal force)
- $\tau \sim rF \sin\theta$

Ideally, we'd have a simple experiment for them to figure out. This is almost certainly possible for a future quarter. **

Procedure

Do we want them to measure upper arm force at all? In the interests of time, likely not.

We wish to investigate some of the forces involved with weight lifting. Specifically, we'll examine the situation where you're holding a weight in your hand, with your forearm being held horizontal. We'll measure the forces experienced by both the biceps muscle and the upper arm.

If you'd like, imagine yourself as a physical therapist or prostetic limb designer, who wishes to combine physics with some general experimental design skills to determine some of the forces involved in lifting objects.

** Common sense warning about using reasonable values, making sure to keep everything but the thing you're measuring constant, etc.**

** Discussion about which variables are relevant. Answer – forces, distances, angles. **

** Make sure to emphasize that we'll keep the forearm horizontal, to simplify things. **

1. Start by measuring the biceps force B and the upper arm force A for some fixed weight H being held in the hand.

Then devise and carry out a procedure for measuring the forces B and A for different weights H. Make sure to explicitly write out the steps of the procedure. If you find you need to modify the procedure as you carry it out, that's okay – but be sure to change the written version to correctly reflect the steps you really carried out.

After taking several measurements (you can choose a number which seems reasonable), use your data to extrapolate a relationship between the biceps force B and the weight H in the hand. Write a explicit formula for B as a function of H. *Hint: In case this terminology is a bit unfamiliar, it might help to know that* $y(t) = \left(10\,\mathrm{m}\right) + \left(4.9\,\mathrm{m/s^2}\right)t^2$ *is an example of an explicit formula for y as a function of t (for a certain physical situation).* Make sure you specify the units of the quantities.

2. Choose a new value for H – one that you haven't measured yet, but that you are able to measure. Before you measure B, use your model to predict the biceps force B for this new value of H.

** Ideally, first make a rough prediction of B based only on neighboring data points, but I probably won't add this due to time. **

Now use the apparatus to measure B for this value of H. How does it compare to the prediction from your model? (Calculate the percent deviation.) If the two values don't precisely agree, do you think this is okay? Do you think it tells us our model is wrong? Why or why not?

Varying model parameters

TODO: Expand this prompt

How does the bicep force change when we increase each of the following parameters: Fill in your own copy of the chart below, answering with "increases", "decreases", "stays constant", or "it depends".

Parameter change	Effect on B	Effect of slope of graph	Effect on y-intercept of graph
$\uparrow R$			
$\uparrow r$			
$\uparrow W$			
$\uparrow \alpha$			

It will probably be difficult to describe what we mean by α, and why it's important.

Consider having students come up with their own ideas of what parameters to vary. Maybe only provide 3 lines. Note that they might have trouble coming up with parameters other than r. (Hopefully r will be easy.)

Understanding model parameters

Ideally we'd have enough time to guide the students in deriving this formula, but this isn't out main goal for the lab. Hopefully we'll still give them some intuition for the formula.

In a previous step above, you experimentally determined a formula for the biceps force B as a function of the weight H in the hand. Now we'll compare this model to the one the theory predicts.

It turns out that we can analyze the torques acting on the forearm to determine a formula for B vs H. You actually have all the tools needed to do this from the warm up exercises at the beginning of this lab, and we encourage you to give it a try! But in the interest of time, we'll just provide you with the formula, which is as follows:

$$B = \left(H + \frac{W}{2}\right)\frac{R}{r\cos\alpha}$$

Given this theoretical model, can you determine what the theory predicts the coefficients appearing in your formula for B vs H should be? First write your answer in terms of symbols (i.e., variables) only; then, plug in the values for those variables from your apparatus, to determine the theoretical model coefficients. How do these theoretical coefficients compare to your experimental model coefficients? (Calculate the percent difference and comment on how well they agree .)

You just used a theoretical model to predict the values of your experimental model coefficients. Now, we'll look at the predictions the theoretical model makes on your data itself. (This may seem similar to the previous step, but there's actually a subtle difference.) Hopefully, you noticed your data plot of B vs H was linear. It turns out, we can use the theoretical model to predict what the slope and y-intercept of that graph should be. First, use the theoretical model to predict the slope and y-intercept of your graph in terms of symbols only. Next, plug in the actual parameter values from your experimental apparatus to get a numerical value for these parameters (with units!). How does this prediction compare with your actual slope and y-intercept?

Probably want to avoid making them do the same steps twice...

Do the theoretical predictions above agree with the predictions you recorded in the chart above, regarding how the bicep force and linear equation parameters change when increasing certain apparatus parameters?

You probably noticed some similarities between the previous steps. Why do they seem so similar? Is there a relationship between the model parameters and the slope and y-intercept of your graph? Since this is a linear model, the model parameters are precisely the slope and the y-intercept of the graph.

Outline

Outline of steps up to this point so far

- Warm up problems, introducing torque to the students for the first time
- (?) Warm up problems directly involving this apparatus

  Matching parts of apparatus to parts of body

  Short exercise with torque? Maybe intuitive 'if we increase r, what happens to bicep force?' TODO
- Measure bicep force (and upper arm force) as a function of weight in hand. Extrapolate equation from graph.
- Use the model for B vs H to make a prediction for a new value, and test the prediction.
- Try to understand coefficients in formula as functions of physical parameters (e.g., lengths and weights) of the apparatus.

- TODO

Remaining steps

- Reason physically how coefficients should change if each parameter is increased or decreased.
- Give them the full formala for $B(H; W, R, r, \alpha)$
- Perform some checks (both experimental and mathematical) to verify that this formula makes sense

    Understand that it is linear in certain variables

Note: It's difficult to tell how much time this will take students, but it's likely this is far too much content already.