Overhauled Bicep Lab

LEGEND:
* [Black text] – Regular text
* Question or action the students need to take
* Tip for TAs. Will be removed from student verstion of the lab.
* [These green or orange boxes] – comments on what needs to be done, etc. Not part of the lab for students.

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

Comments on warm up:
* 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, especially in a future quarter)

Warm up I: Torque

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)

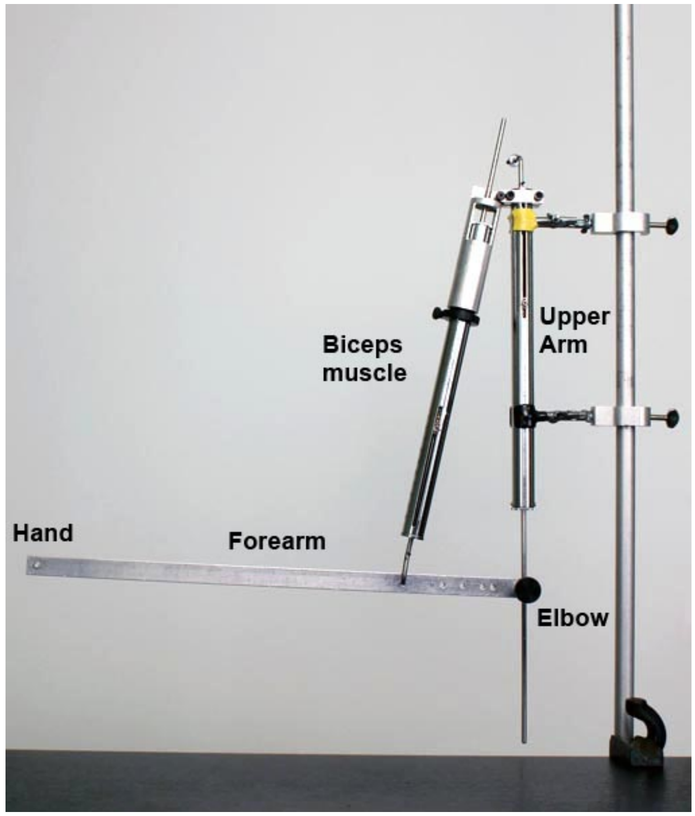
Need to figure out how to introduce quantitative relations
* $\tau \sim rF$ (for orthogonal force)
* $\tau \sim rF \sin\theta$

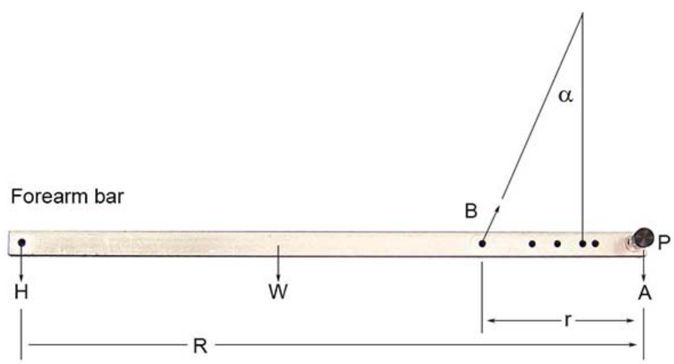
Ideally, we'd have a simple mini-experiment for them to play with, to help this introduction to torque. This is almost certainly possible for a future quarter.

Warm up II: The apparatus

Before we get into equations, take a moment to understand the equipment. Fill in the blanks on the diagram below, from among the following choices: upper arm (humerus), elbow, forearm, hand, and biceps muscle.

TODO – Block out the labels in the picture of the apparatus, and replace with blanks – similar to a diagram one might fill in for a biology course. Blanks include upper arm (humerus), elbow, forearm, hand, and biceps muscle. Do something similar for extended free body diagram (?)





Procedure

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 the biceps muscle.

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.

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

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

Start by measuring the biceps force B for some fixed weight H being held in the hand.

Then devise and carry out a procedure for measuring the forces B 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. The idea is that they need to realize to make a graph to do this. Then they need to notice that the graph is linear, so the 'formula' is just the equation of a line.

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.

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 exactly 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

Using a combination of your intuition for how your own arm works, and the knowledge of torque you developed in the warm up exercises, predict how 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 "something else". (If you choose something else, explain why you chose that.)

Parameter change	Effect on B	Effect of slope of graph	Effect on vertical intercept of graph
$\uparrow R$			
$\uparrow r$			
$\uparrow W$			

We're implicitly telling the students here that the data should be linear. This is perhaps not ideal, but it makes questions like this one much less awkward and much more straightforward.

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.)

The way our apparatus is set up, it's easy to change one of the parameter values in the left hand column of the table above. Which value is this? Once you've determined what it is, devise an experiment to determine the effect that increasing that parameter has on the biceps force B as well as on the slope and the vertical intercept of the graph. They should choose a new value for r, then re-enact their procedure to determine $B(H)$ for this new r value. It might be difficult for them to realize that they don't want to find $B(r)$ – doing so does answer the first question, but it doesn't tell them anything about the slope or the vertical intercept .

We might want to just tell them to vary r.

Subtlety: Changing r changes α as well. This might be worth a footnote (or mills), but I won't lose any sleep over it, and it won't much affect the data.

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:

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

Hopefully, you noticed your data plot of B vs H was linear. Now that we have this theoretical model, we can use it to predict what the slope and vertical intercept of your graph should be. First, use the theoretical model to predict the slope and vertical intercept of your graph in terms of symbols (i.e., variables) only. Next, plug in the actual parameter values that correspond to your experimental apparatus to get a numerical value for these theoretical coefficients (with units!). How does this prediction compare with your actual slope and vertical intercept ?

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?