I. Washers

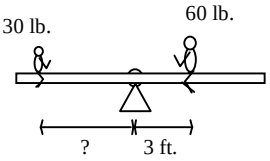
A. Suppose you had an object that you suspected had a mass of one half of one of the washer+paperclip units you used in tutorial. (In the rest of this problem we'll call that a "washerclip.") Describe how you could use the balance you used in tutorial and a single washerclip to check this.

B. How could you use the balance to check that an object had a mass of one-fifth of one of your washerclips?

C. Suppose you had a single washerclip and an object that you suspected had a mass of 5 washerclips. How could you use your balance to check this?

II. See-saw

A. A 60-pound girl sits on a see-saw, 3 feet to the right of the pivot. How far to the left of the pivot should her 30-pound little brother sit in order to balance the see-saw? Answer using any kind of reasoning you want.



B. Now a 54-pound boy sits 2.7 feet to the right of the pivot. Where should his 45-pound friend sit in order to balance the see-saw? Answer using any kind of reasoning you want.

C. Here's how two different students approached part A.

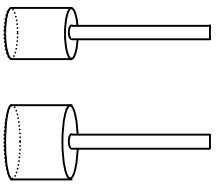
Elizabeth: Since the little brother is half as heavy as her sister, he must sit twice as far from the pivot in order to "compensate" for his lower weight—6 feet instead of 3 feet.

Jill: I used the formula for torque, $\tau = Fr$, where F is force and r is distance from the pivot. Here, the relevant forces acting on the see-saw are gravitational, the weights of the children: F_1 = 60 pounds and F_2 = 30 pounds. The big sister sits r_1 = 3 feet from the pivot, and we're solving for r_2. The torques must balance: $F_1 r_1 = F_2 r_2$. I plugged in the numbers to get (60 pounds)×(3 feet) = (30 pounds)×r_2, and solved for r_2 to get 6 feet.

1. The two students got the same answer. Did one (or both) of them get lucky, or are both kinds of reasoning valid? Explain.

2. Are Jill and Elizabeth's reasoning fundamentally the same, fundamentally different, or a mix of those two extremes? Explain.

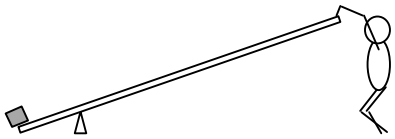
III. Screwdriver



You need to loosen a really stuck screw. You have a choice between two screwdrivers, both of which you can grip very well. The only difference is that one of them, the bottom one of these drawings, has a thicker handle than the other. Which screwdriver, if either, will be more effective at loosening the stuck screw (or will they be the same)? Why?

IV. Lever

A *lever* enables you to lift objects that are too heavy to lift by hand. The lever pictured here consists of a long board placed on a pivot. To lift the concrete slab on the left end of the board, the person pushes downward on the right end.



A. Using the concept of torque, explain why a lever makes it easier to lift the heavy slab. Hint: In order for board to "swing" clockwise, thereby lifting the slab, how must the torque exerted by the person on the board compare to the torque exerted by the slab on the board?

B. The slab weighs 1000 newtons. The segment of the board to the right of the pivot is 5 times longer than the segment of the board to the left of the pivot. Assuming the board is very light, how hard must the person push down on the right end of board to lift the slab?

C. A student from last year gave the following explanation for why this lever works:

> *If you take the slab off the board, and if the student lets go of the board, the board naturally swings clockwise; it ends up with its right end on the ground. That's because the weight of the board to the right of the pivot is greater than the weight of the board to the left of the pivot. My point is, even with the slab in place, the weight of the board "helps" the student make the board swing clockwise. That's why the student's force on the board can be less than the slab's weight.*

In what ways do you agree and/or disagree with this explanation? Hint: It'll help to check for coherence between your answer here and your answers to parts A and B above.

