Formulas HW 2: Postholing (i.e., 'why skis work")

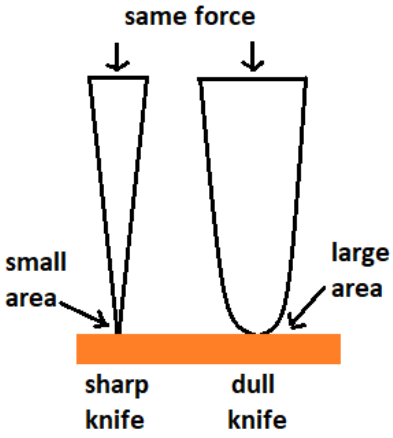
"Postholing" is a wonderful little term that describes what can happen when you try to walk on powdery snow (like that guy at right). Post holing is a fact of life in the snow – but it's also a pain to move around that way: your hips and legs are pushing against the snow that they're buried in, and sometimes your upper torso gets ahead of you and you fall forward.

In fact, it was to avoid post holing that people first invented skis! They figured out that a pair of skis (or snowshoes) could "hold them up" on the snow.

But how can that be? If someone sinks ***without*** skis, why wouldn't they sink ***with*** them? The person weighs the same, right? With the skis, they even weigh *more*! So why don't they sink? We'll look at all of that here. ☺

A slight detour, first…have you ever tried to cut with a very dull knife, and no matter how hard you try, it just doesn't ***work***? And then, finally, you give up and get a sharp knife, and it works great? Ever wonder why?

It's because the force you apply to the knife is spread out along its blade, and a dull blade has ***more area to spread the force out***. So, if you apply the same force to two knives, one dull and one sharp, it looks like the diagram at right.



So, let's say the area of the sharp knife is **10** (I'm leaving units off for now – we'll bring them back in momentarily), and the area of the dull knife is **30** (a "larger" area). If a chef applies the same force to both knives (say it's **300** "somethings"), the resulting **average force** on the sharp knife will be 3 times stronger! Why? (Note: This average force is also known as "pressure".)

$$\text{Average Force} = \frac{\text{force applied}}{\text{area force is applied over}}$$

Here are the average forces for both knives.

Sharp Knife	Dull Knife
$\frac{300}{10} = 30$	$\frac{300}{30} = 10$

So the sharp knife generates 3 times the force per unit area that the dull knife does[1]. Another way to think of it is that it would only take 1/3 of the effort to make the same cut with the sharp knife as it would with the dull knife.

Now, we're going to calculate something similar – for our skier with and without skis. We'll do the same average force calculation, but with the proper units of "pounds per square inch" (PSI) – in other words, we'll take her weight (without skis and boots on) and figure out how her weight is "spread out" over the ground when she's standing on it.

Let's assume that our skier weighs 144 pounds, and her skis (plus bindings) weigh about 14 pounds and her boots weigh about 5 pounds.

Let's do her average force in PSI ***without*** skis and boots first. Her shoes are approximately rectangles, measuring 12 inches long by 3 inches wide.

1. **(1 point)** The area of a rectangle is found by multiplying its **length times width**. So what is the area of one of these shoes? Make sure to give the correct unit!

2. **(1 point)** Now double that, and that's the area that her body stands on each day. ☺

3. **(3 points) (w)** Now, remembering that she weighs 144 pounds, calculate her average force in pounds per square inch (PSI) across the bottom of her shoes. Make sure that the unit PSI shows up in your calculation.

Now, let's do the same thing, but ***with*** her skis and boots on. Her skis are about 100 millimeters wide and 180 centimeters long (you don't need to worry about the bottom of her boots, as they clip into the skis, and the skis are what touches the ground).

4. **(2 points)** Start by converting both of those metric units to inches (use Google, fo sho!). Round to the nearest inch in each.

5. **(1 point) (w)** Calculate the ***total*** area of those skis in square inches. Remember that there are ***two*** of them – and don't forget to give the unit on your answer!

6. **(2 points) (w)** Calculate her average force in pounds per square inch (PSI) across the bottom of her ***skis***. Remember to add in the weight of her skis and boots! Round to the nearest tenth of a PSI.

See how much ***less*** that is? That's why skis work: they're like the "dull knife" (which you want, when you're skiing). They "fool" the snow into thinking you're lighter than you actually are, so you float more on top. Rad!

[1] You've likely experienced this with a dull razor when you're shaving; know when you have to press harder as the razor gets duller? That's because, as the blades dull, their area increases – and ***you*** have to supply the extra force!