Physics Lecture 2 - Friction 101

In **Figure 1 - A** we see a lead-weighted block of wood being pulled by a flexible spring until it slides to the right. In picture B we see the same block turned over so there is only about 1/2 as much surface sliding on the table top. How far the spring stretches is a measure of the force applied to pull it. Ask people the question: "which will take more applied force in order to slide, the large surface at the top or the smaller surface at the bottom." Most folks think like this. "Well, the more friction the harder it's going to be to slide the block, and I know the more surface area you have sliding the more friction you'll have, so I say its harder to pull the block at the top."

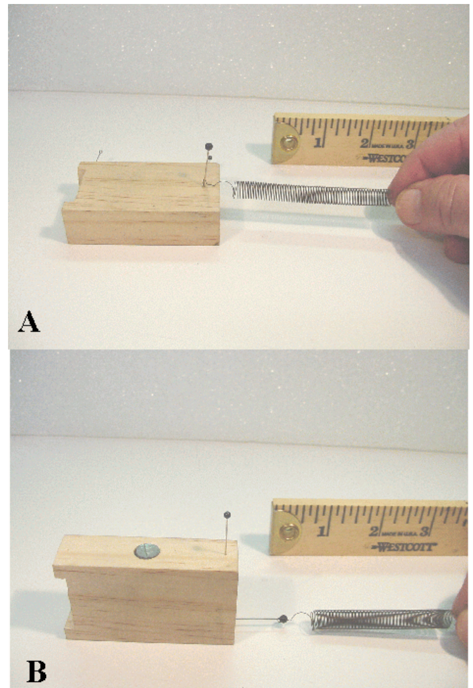

Figure 1. **A -** *pulling a block with a large area sliding.* **B -** *pulling same block with a smaller area sliding.*

But you must tell them, "Sorry, that's not quite correct."

"You mean its going to take more force to slide the block turned on its smaller side like in the bottom picture?"

"Nope, that's not quite correct either."

"It couldn't be the same, could it?"

"Yep, it sure could. And you have to stretch the spring by precisely 3 inches to move the block in both cases"

"Could you please explain that?"

What happens is that people get their areas mixed up. What you see ain't what you get in this case. The block surface is not really flat on a microscopic scale. Say the block is resting on a glass table top and you look up underneath with a powerful magnifying glass and see these tiny "footprints", areas where the atoms of the block really touch the atoms of the table top. These areas are shown as the small dark circles in **Figure 2**. Really they are randomly sized and spaced in most cases but the point is that only a small fraction of the *Apparent* Area A_A is really touching. So the real contact area in our example is 32*a* where *a* are the real (but invisible) individual contact areas. And the real contact area stays constant as long as the weight *W* stays constant no matter what the apparent contact area is. Here's how this works.

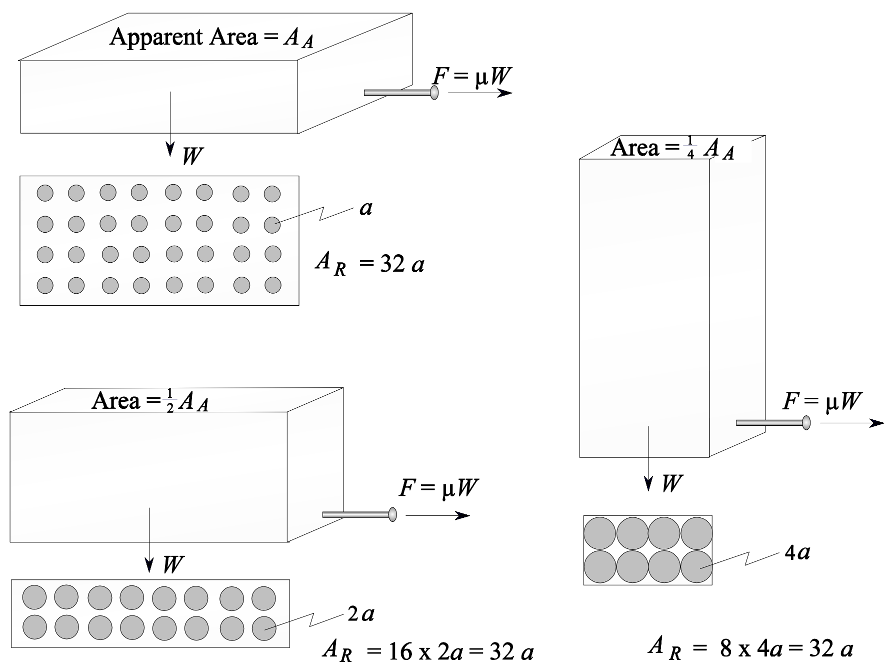

Figure 2. *Sliding a block on 3 of its sides of different apparent areas.*

Figure 3 gives a side view of **Figure 1**. Imagine the bottom of the block is covered with rubber bumps like tiny tennis balls sticking out. So when you reduce the amount of apparent contact area but keep the same weight you have only half as many “tennis balls” to support *W*. Thus the remaining balls are squished more and spread out to accomodate. In this case doubling the force per unit apparent area causes the individual contact areas to each double themselves leading to no real change in net real contact area $A_R = 32a$.

Going back to the spring lets put the block on a sensitive scale and then pull up on it with the spring. With no pulling the block weighs *W* = 45 grams. For each inch the spring is stretched while pulling up the scale reads 5 grams less. Therefore the spring constant is 5 g/in. Thus you can make a calibration graph as shown in **Figure 4.** Now when the blocks are pulled with the spring as shown in **Figure 1** you will get a stretch of 3 inches in both **A** and **B** before the blocks start sliding. From the graph you can see this is a force of 15 g. So the coefficient of friction μ, which is the ratio of horizontal sliding force to vertical weight force, is:

$$\mu = \frac{F}{W} = \frac{15g}{45g} = 0.33$$

Thus, the frictional drag force *F* on a sliding object is simply $F = \mu W$ and has nothing to do with the apparent area. It depends only on the characteristics of the surfaces down to the molecular level. That is why, when you reduce the apparent contact area of a pinewood derby axle by reducing the diameter of the center of the axle, you see no change in frictional drag. <u>*F* depends only on μ and *W*.</u>

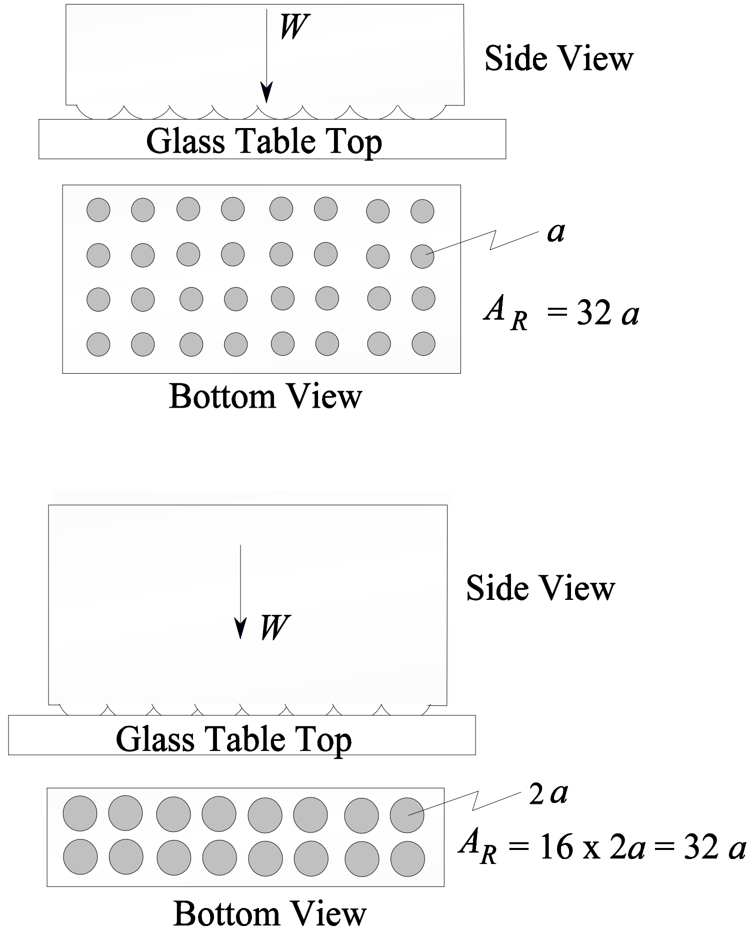

Figure 3. *What’s really happening in* Figure 1.

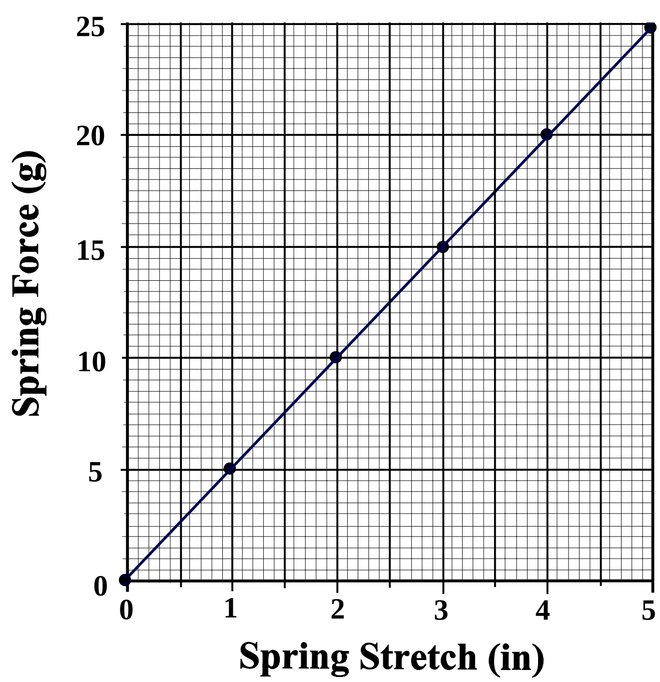

Figure 4. *Calibrating the spring of* Figure 1

It should be noted that normal sliding does not mean deforming or subtantial material loss (like skidding car tires in emergency stop) or mechanically digging in (like pulling a plow through a field). And it should also be noted that in pure rolling of a hard wheel tread over a hard track there is no friction between the wheel and the track because there is no sliding, deforming, or digging in. But if you have some toe-in or toe-out in your wheel alignments, you cannot get pure rolling because some sliding will occur and then you have frictional energy losses. An automobile tire, even with perfect alignment, can have rolling friction because the rubber/pneumatic tire is built to deform as it rolls for shock absorbing purposes.