The Physics of Phucking Up

(Why the Top of a Ladder Is No Place To Be)

by Chris Dichtel

Installers have odd jobs. Odd hours, odd tasks, odd environments, and a gaggle of odd personalities. It's odd never knowing when you're going to have time off, and it's an odd assortment of skills that we practice in the course of a work day. Oddly enough, we keep doing it.

But if you've been doing this work for any length of time, odds are you've seen someone get hurt on the job. It's an easy-enough thing to have happen. We work in an environment not far removed from a beehive in overdrive, so it pays to be aware of what's going on around you. A miscalculated step, poor exchange of communications, or not paying attention to your partner can result in a serious injury.

Last year, Industrial Hygienist Eileen Lloyd of Cal-OSHA spent several days testing air quality at Moscone, in response to numerous complaints. She reported to the union that, although the air quality was below standard and needed correcting, the biggest threat to Installers' health she witnessed was people standing on the top two steps of of ladders. She then proceeded to notify us that they would begin handing out $500 fines to the employer of anyone caught doing so.

I have witnessed fellow 510-ers come tumbling down off of ladders, and will admit to having come close to that once or twice myself. When you're in the middle of putting something together twelve feet up in the air, and all you need to do is just get that last, top wingnut on, it's all-too-tempting to climb up there on those top two steps (you know, the ones that say "Do Not Stand Here"), and reach out to get the job done. "Well hell," as someone recently asked me, "if they don't want you standing on those steps, why do they even put them there?"

So why *do* they have those stickers saying "Do Not Stand on the Top Two Rungs of this Ladder"? I realized that I couldn't really explain it. I knew it had something to do with your center of gravity, but what exactly does that mean? Never having taken physics in high school, I needed help. I turned to two sources: a book called "Physics Can Be Fun," and the Internet.

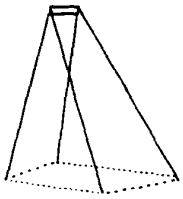
In "Physics Can Be Fun," the popular Soviet science writer, Yakov Perelman, gives a nice example to illustrate the concept of center of gravity: "Sit down in a chair. Sit upright and *don't shove your feet under the chair*. Now try to get up without moving your feet or bending forward. You can't, however hard you try. You'll never stand up until you push your feet under the chair or lean forward." This is because your center of gravity is over the chair, not your feet: if someone were to pull the chair away, you'd fall on your ass.

Perelman adds, "A thing will not topple only when the perpendicular (line) from its centre of gravity goes through its base." When you are standing, your "base" is the area bounded by the soles of your feet. "You won't fall only when the perpendicular (line) from your centre of gravity lies within the area bound by the outer edge of your feet. That is why it is so hard to stand on one leg."

Alright, so if your center of gravity gets outside of the base, you are likely to fall over. But why does a ladder become more unstable at the top, and why in particular at the top two rungs?

Now here is where I remembered reading about a service on the Internet, where journalists could post questions of a scientific nature to the scientific community around the world. And any interested professional could choose to respond to a particular question. I posted an inquiry regarding the physics of ladder stability, and lo-and-behold, ten days later I received an e-mail response from Carl S. Brandon, professor of physics at the Vermont Technical College.

Professor Brandon pointed out that on a ladder, the base is represented by the area bounded by the four legs of the ladder. "The weight of a person climbing a ladder will make the ladder unstable if the climber's center of gravity gets outside of the ladder's base."



Dotted line represents the "base" of stability of the ladder. If your center of gravity falls outside of this base, the ladder is going to topple sideways, taking you with it. A ladder cannot easily topple forwards or backwards, but it can easily be knocked over sideways, since its base is more narrow in that direction.

But what about those top two rungs? Why are they so particularly unstable? Professor Brandon said that there are several reasons:

- Near the bottom of a ladder, a climber would have to lean out pretty far before his center of gravity would fall outside the ladder's legs. But up high, where the ladder is more narrow, climbers have a tendency to start leaning out even further.
- This is frequently due to the improper placement of the ladder in the first place. As you reach out further to compensate for not having put your ladder in the right place, you are further jeopardizing your stability by placing your center of gravity further away from the ladder's base.
- "When you are near the top, leaning out beyond the base causes your weight to be lifted only a small amount (because of the distance from the leg of the ladder around which the tipping occurs), compared to when you are near the base. Therefore the force necessary to cause the ladder to start tipping is much less." I had trouble grasping this one, so Carl elaborated:

"If you tip the ladder (try this with a chair), as the one leg comes off the

floor, the center of gravity (try center of the seat of the chair) lifts a small amount. If you watch the center of the seat, you will see that if you tip the chair enough to get the center of the seat over the leg still on the floor, and compare it to the amount the center of the seat lifts when you put the top of the chair's back over the leg, the seat will have lifted more to get the seat's center over the leg than the seat lifted to get the chair back over the leg, since the angle is smaller as you go higher from the leg.

"The same is true for ladders. The higher you go, the less of an angle you have to tip the ladder to get that point (the climber's center of gravity) over the leg you are pivoting on as you tip the ladder." (see illustration below)

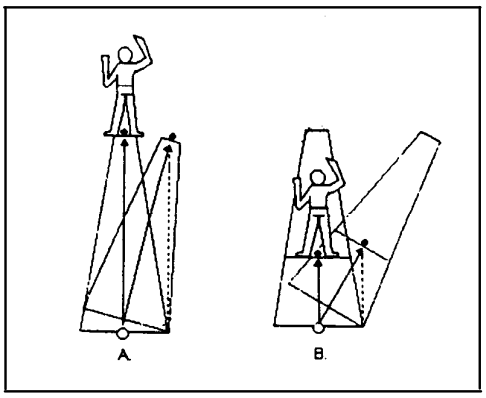


Figure A shows the angle of tilt (arrowed lines) required to move your center of gravity outside the ladder's base when you are standing on the top rung.

Figure B shows the angle at a lower rung on the ladder.

But the main reason you are warned not to stand on the top two rungs of a ladder is that once your waist is higher than the top of the ladder, it is very easy to lose your balance. And when you start to lose your balance, you have nothing to hold onto, since your hands—like your waist—are well above the top of the ladder. And as you start flailing your arms about trying to stabilize yourself or grab hold of something, that movement will more likely simply throw your center of gravity beyond the base of the ladder.

And once you've done *that*, what you'll notice is that it's as if you've actually kicked the ladder away from you; and the next thing you'll notice is that time has suddenly slowed down, and you're watching the cement floor come up at you in slow motion. The ultimate ground-rush.

So is that "concrete" enough for you? People joke about all the mandated warning stickers one sees plastered on ladders nowadays, until they start looking like some globe-trotting tourist's suitcase. But this is not merely some bureaucrat's demented plaything: we're talking about the laws of nature here, against which there are no appeals. Gravity: it's not just a neat idea: it's the law.

And as for why ladder designers *put* those top two rungs there, it's so that you can *hold on to them.*

So before you pull a ladder into place and scramble up it, think about what you're going to be doing up there, and just how you're going to do it. Run through the scenario in your head, and make sure it makes sense before you go up with some heavy booth part in your hands. *Visualize* what you're going to be doing, and place your ladder in the right place *before* you climb. Use your head, and you might well save your neck.

Have a Happy New Year. And—since it would be unnecessarily morose—I'll refrain from employing the traditional 510 salutation of "I'll see you on the floor."

Wing Nut