Air Pressure

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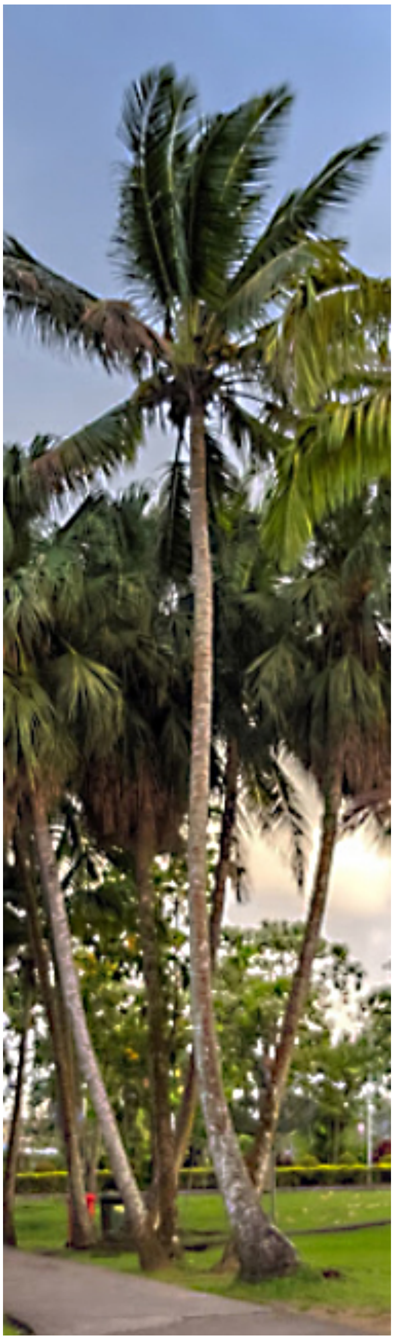
Once upon a time Dad lectured freshmen in a WW2 aircraft hanger by the sea, at the USP in Suva. Coconut trees lined the shore and his class included Solomon Islanders. Coconut trees are more than 10 m tall and Solomon Islanders can climb them.

He asked a student to climb a 12 m tree and hang a string through the coconuts at the top. The class then pulled up a clear plastic hose (closed at the top) that was full of water and had been coiled in a bucket of water on the ground. As expected the man up the tree reported that the water rose in the hose no more than 10 m above the level in the bucket. Air pressure supported around 10 m of water with a vacuum above. We say "about" because air pressure is not constant. It varies from around 9.6 m of water in a low-pressure zone at the centre of a storm, and around 10.4 m in a high-pressure zone in fine weather.



Torricelli in Italy invented a mercury barometer to measure air pressure in 1644. He understood that there was a vacuum above the 76 cm of mercury in his closed tube, that air pressure was due to the weight of air above, and that air pressure dropping may signal a coming storm.

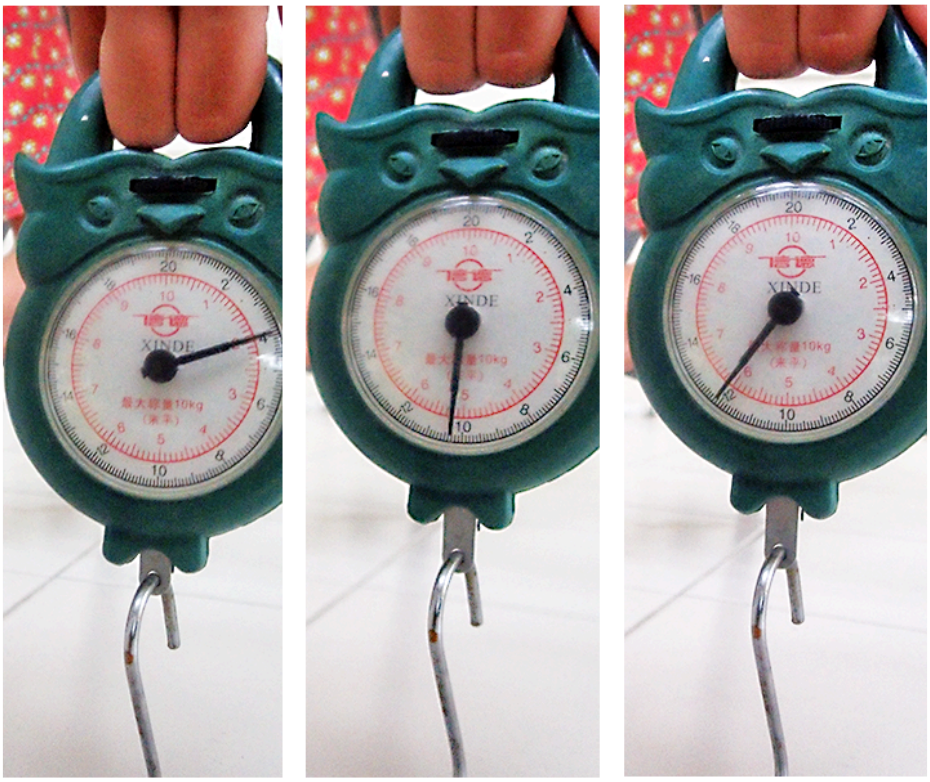
We have a long hose and a bucket. I’m not going to climb a tree but my school has a fourth floor balcony. I could measure air pressure by myself in meters of water …

… but I’m at home and I just want to show that air pressure is very large. I can find an accurate value for the day by “asking google” if I want to know that.

I have a small set of scales that read up to 100 newtons (the weight of 10 kg) and I have a “suction” cup used for hanging a towel or something like that from a tiled wall or a window.

Pushing the cup down firmly on a smooth flat surface pushes most of the air out from underneath. Pulling it off creates a near vacuum under the cup and air pressure on the top of the cup makes it difficult to lift.

This wouldn’t work on the moon. There would be no air pressure to hold the cup down on the tile.



Three frames from a 30 fps video as I pulled the cup off the tile.

The cup let go suddenly when the force was about 60 newtons. The radius of the cup just before it let go was about 1.8 cm.

The area of the cup was … $\pi r^2 = 3.14 \text{ x } 1.8 \text{ x } 1.8$

$$= 10 \text{ cm}^2$$

Pressure is defined as F/A with force in newtons area in m^2.

Noting that the area is 10 cm^2, which is 0.001 m^2 …

$$F/A = 60/0.001$$

$$= 60{,}000 \text{ N/m}^2 \text{ (pascals)}$$

We know from Dad's lecture demonstration in Suva that air pressure at sea level is close to 100,000 pascals.

The value found here is low for two reasons. Most, but not all of the air, was pushed out from under the cup so there was a small pressure in the cup, and the seal between the cup and the tile was not perfect. Because of these two large errors, that both made the measured value of air pressure low, the inaccuracy of my balance was not significant.

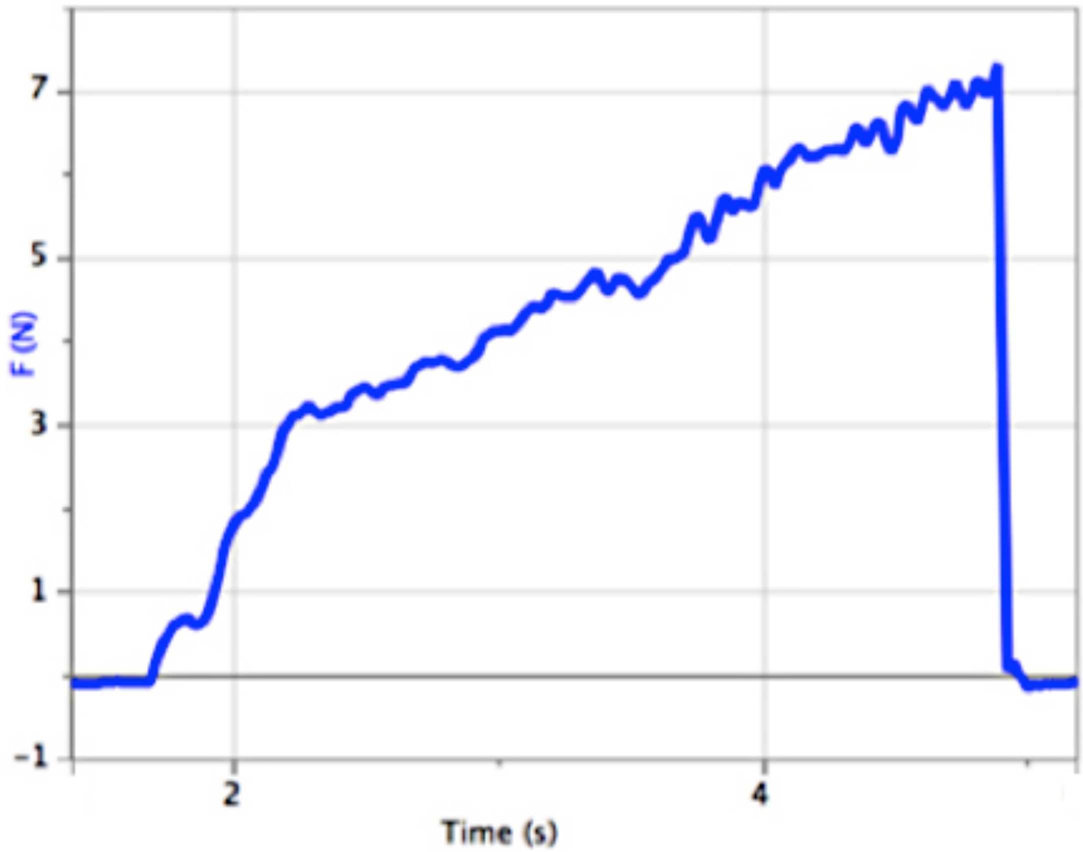
A second method

A balance can be read just before the cup lets go by taking a video but there are other ways to do this. I used a smaller cup cut from a toy ball that sticks if you throw it at a window and a Vernier force probe.

If your school has force probes you could use one of those to pull a cup off a flat surface and plot a force-time graph on a computer screen.

Using a small plastic cup with an area of 1.0 square cm just before it lets go, and a force probe connected to a computer, gives the graph below when the cup was pressed down on a tile and pulled off with the hook on the force probe.

A typical force-time graph



The force applied to the cup rises steadily until it lets go about just before 5 seconds.

The maximum force applied to the probe just before the cup let go was about 7 newtons. The area of the cup was one square cm. The cup held about 70% of the maximum possible weight.

Questions

What would you expect to measure as the maximum force if this cup was pushed down onto a tile on the floor of a swimming pool that was 2 metres deep?

Suppose the pool was 10 metres deep. What would you expect the maximum force to be then?