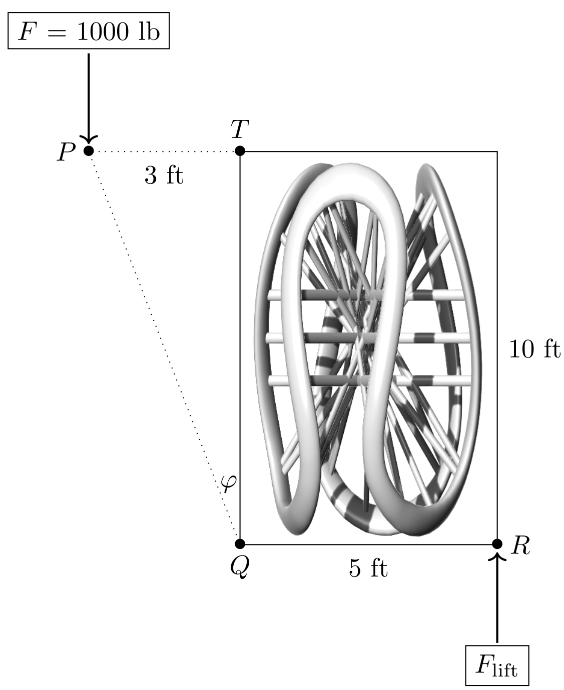
Uplift Calculations for 'Twenty Seven'

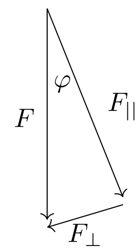
Here we compute the vertical uplift force on the structure during various scenarios. This allows us to make sure the structure is secured to the ground using anchors with enough pullout strength to avoid toppling even in extreme situations.

Scenario 1: Climbers leaning off the top of the structure

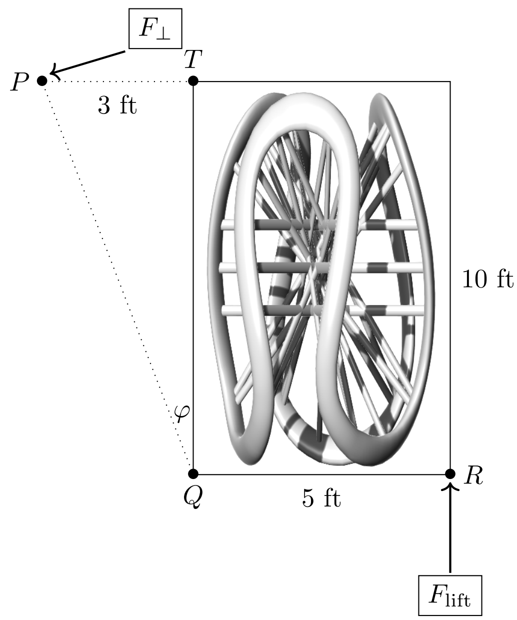
For this scenario, we assume a group of participants climb the structure to the top, and all collectively lean over the edge on the same side. We assume the total collective weight of the climbers is 1000 pounds, and that their center of mass is 3 feet over the edge or the structure (these are both almost certainly exaggerations of what is possible, so these computations should confirm that our structure can handle even unrealistically exaggerated stress). This setup is summarized in the following diagram, the goal is to compute the force F_{lift} in on the point labelled R.



We first decompose the 1000 pound force F on the point P the components parallel and orthogonal to the line $PQ-$ call them $F_{||}$ and $F_{\perp}$ respectively. This is done using the following triangle:



Thus $\sin\varphi = F_\perp/F$ so that $F_\perp = 1000\sin\varphi$. We can compute $\sin\varphi$ to be $3/\sqrt{109}$ using triangle PQT in the first diagram, noting that the length of the segment PQ is $\sqrt{109}$ by the Pythagorean theorem. Therefore we have computed $F_\perp = 3000/\sqrt{109}$ lb. We can put this back into our original diagram.



To conclude, we use that $F_\perp$ and F_{lift} are both rotating around Q, and we therefore have the identity:

$$F_\perp \cdot |PQ| = F_{\text{lift}} \cdot |QR|.$$

We can therefore solve for:

$$F_{\text{lift}} = F_\perp \cdot \frac{|PQ|}{|PR|} = \frac{3000}{\sqrt{109}} \cdot \frac{\sqrt{109}}{5} = 600.$$

So our uplift in this scenario is 600 lb.

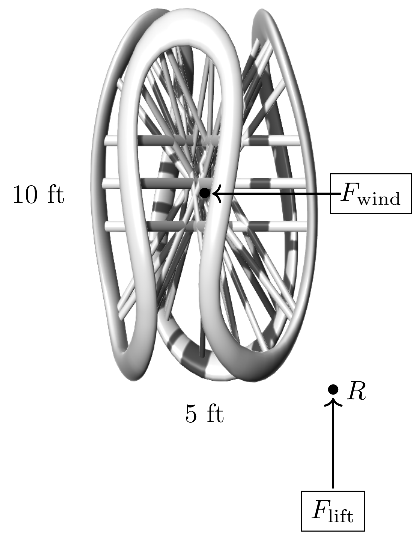
Scenario 2: 70mph winds

For this scenario we assume that a 70mph occurs producing lateral force on the structure. We use that a 70mph wind produces 12.5 lb/ft^2 of pressure.[1]. The structure sits at 5ft by 10ft, but is mostly a skeleton of piping, occupying less than half of the space. Therefore we assume (exaggeratedly again) that the wind pressure acts on 25 ft^2 of surface area of the structure, giving a force of:

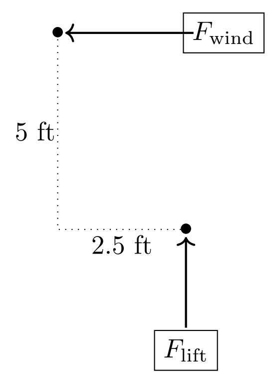
$$F_{\text{wind}} = 12.5 \text{ lb/ft}^2 \cdot 25 \text{ ft}^2 = 312.5 \text{ lb}.$$

We will assume that this force acts on the center of mass. This gives the following diagram.

[1]`https://communities.bentley.com/products/pipe_stress_analysis/w/pipe_stress_analysis__wiki/33136/22-how-to-convert-from-wind-loads-from-mph-to-psf-in-autopipe`



Extracting the triangle of importance we have:



Therefore arguing as above, we have $5 \cdot F_{\text{wind}} = 2.5 \cdot F_{\text{lift}}$ so that:

$$F_{\text{lift}} = 2 \cdot F_{\text{wind}} = 2 \cdot 312.5 = 625 \text{ lb.}$$

Therefore a 70 mile per hour wind would produce 625 pounds of lifting force on the structure.

Conclusion

It is possible that scenarios 1 and 2 occur at the same time, gusts don't take breaks just because folks are climbing art. In this situation there would be a potential of a lifting force of 1225 pounds. The structure has 3 contact points with the ground, and each one must be secured against such a force (independently). We will therefore make sure each contact point is anchored to the ground to obtain a pullout force of double what we calculated: 2450 lbs. To achieve this we will use 16" lag bolts, spaced 6 inches apart. These have pullout strengths of approximately 400 pounds in playa, so 6 on each leg should do it!