*x*

*y*

F3

F1

F2

F0 (93 lbs.)

*c*

L1

L2

L3

D = 2.17’

*x*





Note: Forces are just weights (gravity is ignored as it will simply cancel out anyway)

F1, F2, F3 are the forces (weights) for the three robots

L1, L2, L3 are the lengths from the center of the climb bar (*c*) to where the robot attaches to the bar

F0 is the force (weight)) for the climb apparatus itself which has a center of gravity 2.17’ below the top and has a weight of 93 lbs which is labeled as D

θ is the angle that bar tilts at equilibrium

Δx is the displacement along the x axis when the bar is tilted at angle θ

Each Force will exert a torque T which are equal to … Note that the side that is tilted upwards has a minus sign and the side that is tilted downward has a + sign. This can be determined by finding which is greater F1L1 or F2L2 + F3L3 with the smaller value getting a minus sign and the heavier side a + sign.

|T1| = F1L1cos - F1Dsin

|T2| = F2L2cos + F2Dsin

|T3| = F3L3cos + F3Dsin

|T0| = F0Dsin

At equilibrium (the bar is not moving, but not necessarily horizontal) the absolute values of the torques subtracted from one another will equal 0.

|T1| - |T2| - |T3| - |T0| = 0

(F1L1cos - F1Dsin- F2L2cos - F2Dsin -F3L3cos - F3Dsin-F0Dsin

rearranging we get …

cos F1L1 -F2L2 -F3L3) – sin (F1D + F2D + F3D + F0D)

cos / sin = (F1L1 -F2L2 -F3L3) / D(F1 + F2 + F3 + F0)

 = tan-1 [(F1L1 -F2L2 -F3L3) / D(F1 + F2 + F3 + F0)]

General Findings …

* If a robot can hang in the middle do so, it just makes things easier as the torque from the bar increases by the weight of the robot at the center
* If two robots are climbing have them climb as close to the center as possible as it increases the error range of how far off the mark you can be and still be within the 8 degs.
  + For example, if two robots attached 2’ on either side of the center there can be a 50 lb difference in their weights and still be within 7.7 degs.
* If a three robot climb, and neither can hang in the center, choosing something like 0.5 and 4.5 feet for the robots on the other side makes sense as it will be easy for them to lineup at those positions and there is always a place on the bar that will make things level (assuming we are max weight and no robot weights less than 50 lbs.)