Cannizaro Science Quiz ~ December 2019

The noticeboard was recently erected by the Volunteers' team of The Friends of Cannizaro.

Initially, it did not have the green metal struts. These were installed because we started worrying that the wind would blow it over. We know that South-Westerly winds blow strongly across the lawn from the direction of the pond because we often see that benches have been blown over but just how much force will the wind exert on the noticeboard?

Assuming that:

- the peak gusts have a speed of 72 km/hr
- the density of dry* air at 20°C is 1.2 kg/m^3
- the noticeboard is 1m high x 1.5m wide
- the wind direction is perpendicular to the face of the board
- the struts are installed at an angle of 45° to the ground

*Unexpectedly, dry air is denser than moist air

1. What is the peak force on the noticeboard?
2. What is the force in each strut?
3. Will it blow over?

Compiled by the Womble

Solution

For the horizontal force on the noticeboard we are indebted to the Swiss scientist Daniel Bernoulli (1700 – 1782). He showed that, for an incompressible fluid moving horizontally, if P = pressure, ρ = density and V = velocity, at all points ($P + ½\rho V^2$) is constant. I have been assured that air can be considered to be incompressible in these conditions.

Ignoring atmospheric pressure, which is the same on both sides of the board, we can say that at point 1, some distance from the board, the pressure is zero and the velocity is 72 km/hr = 20 m/s. At the surface of the board the velocity is zero and the pressure is what we want to find out. So,

$$\underset{\text{At Point 1}}{P + ½\rho V^2} = \underset{\text{At surface of the board}}{P + ½\rho V^2} = \text{a constant}$$

becomes $0 + ½\rho V^2 = P + 0$

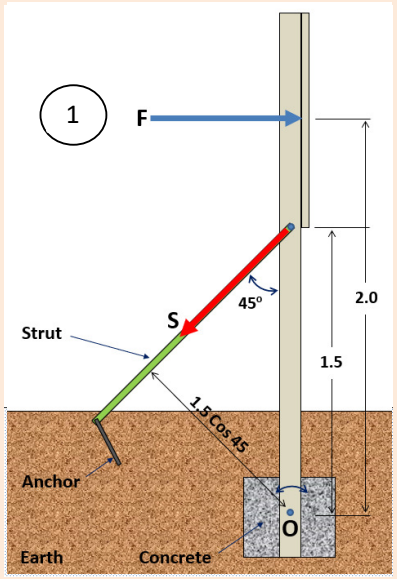
We want the force and Force = Pressure x Area so we multiply both sides by A and get

$$F = P \times A = ½A\rho V^2$$

Substituting the known values: **F** = ½ x 1.5 x 1.2 x 20^2 = 360 N = 36 Kg

My friend the aerodynamicist tells me that there is complex air flow at the edges of a board like this which introduces a factor called the coefficient of drag. For our problem this would be ~ 1.2 so he predicts that the force would 36 x 1.2 = **43 Kg**

To calculate the force in the struts we have to assume that, if the struts were removed, the noticeboard would tip over, rotating about some point below ground level. I have estimated that it will rotate about the point O shown in the sketch. To stop the rotation the struts must exert a balancing turning moment at point O. F tries to turn it clockwise with a moment (defined as Force x Perpendicular Distance) of F x 2 while the struts oppose it with an anti-clockwise turning moment of S x 1.5 Cos 45 = S x 1.1
Therefore S x 1.1 = F x 2.2 so S = F x 2 = 86 Kg
There are two struts so the tension in each one will be **43 Kg** and steel struts will easily support this load.



For the noticeboard to blow over, the concrete blocks buried 50 cm below the surface would need to become a hinge and the strut anchors would need to pull out of the ground so I think we're OK.