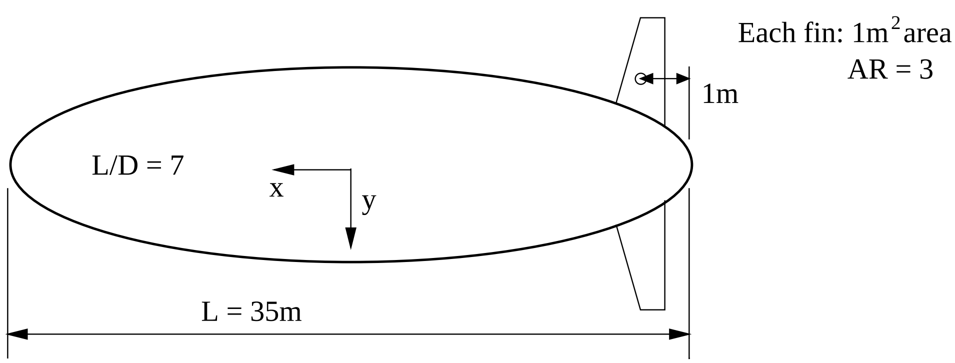
13.49 Homework #4

We will calculate the pitch derivative due to an angle of attack, M_w, for a small submarine, using several different methods.
The submarine has the same hull shape as used in the last question of Homework #3, i.e., it is a rotationally symmetric ellipsoid with $L/D = 7$, $L = 35m$. We fix the body origin to the midpoint as shown below. The body is now appended with two fins as shown in the figure: each has an area of $1m^2$, geometric aspect ratio of 3, and has its longitudinal center of action $1m$ fwd of the body stern.

1. Apply wing theory to characterize M_w due to the fins alone.
2. Apply slender body theory to estimate M_w for the body alone.
3. Linearize the Munk moment, and give a corrected slender-body value for M_w of the body.
4. Apply Jorgensen's approximate formulas to estimate M_w for the body; make linearizations where necessary.
5. Use the experimental data from Hoerner (p. 13.2) below to estimate M_w for the body.
6. Use the Hoerner result and your result from wing theory to write a net M_w for the body plus fins.
7. What is the location of the net aerodynamic center? If it has an unstable location forward of the midpoint, what increase in fin area would bring it back to the midpoint?
8. What is the diameter of a flat stern that will allow the slender body theory to give the same moment as the Hoerner (experimental) data, for the body alone?
9. What is the diameter of a flat stern that allows the approximate formulas of Jorgensen to give the same moment as the Hoerner data, for the body alone?



Hoerner p. 13.2:
Symmetric body of revolution with $L/D = 6.7$.
Force and moment referenced to body midpoint:
$Z = -0.5\rho U^2 D^2 C_{ydb} \tan(w/u)$. $C_y = 1.20$.
$M = 0.5\rho U^2 D^2 L C_{nb} \tan(w/u)$. $C_m = 0.53$. DESTABILIZING