Midterm 01 (100 points)

One report per team is enough, but make sure everyone is listed in the authors list.

Discuss the relevant physics equations, describe your solution, show results. Report page limit is 10 pages excluding listings which should be in appendixes, font size to be no less than 12pt. The emailed submission must have all relevant listings in the attachments.

Your company just bought a new ship (actually a barge) with name which reads something "... ... fitted". May be it is "Sea worthy fitted".

Unfortunately, not much is known about it. You know that the ship has length $L = 50$ m and exactly the same cross section, orthogonal to the long side, through the whole length of the ship. Yep, nobody tried to reduce the drag, looks like designers were not worried about a fuel price tag.

Luckily, you were able to find the original designer of this ship, and she recalled, that the ship cross section (orthogonal to the long side) is described by the following formula

$$y = a\sqrt{1 - \left(\frac{x}{b}\right)^2} + ce^{-|x|/d} \tag{1}$$

where y is the position measured from the top of the hull; x is the distance from the center line (the point (0,0) is at the center top of the ship); a, b, c, and d are some unknown parameters, but definitely $a < 0$ and $c < 0$. Easy to see, that at least there is symmetry with respect to the y axis. But none of the relevant parameters are known.

Being a big boss, you send a young apprentice to do some measurements of the hull to recover the a, b, c, and d parameters. She comeback with a data file which has measurements only of the starboard side of the ship. They are in the data file `'hull_shape.dat'` where all measurements are in meters, the first column is x position and the second one is y.

At this point you begins to realize, that the actual name of the ship is "To be fitted" and nobody but you has the required training to do it.

Problem 1

Find the unknown coefficients describing the hull shape. Do not forget the uncertainties.

Problem 2

Estimate the precision of the y measurements done by the apprentice.

Problem 3

Find the weight which this ship can carry when it is submerged to the very top of the hull. Recall the buoyancy force expression, i.e., that this force is equivalent to the weight of the displaced water.

Note, with this "elegant" hull shape, she cannot be used in a sea voyage, so we are limited to a fresh water environment where density of water $\rho = 1000$ kg/m^3. Assume, that your company stuck gold and bought the ship made from the exotic nonobtanium material which is very strong and lightweight, so, in your calculations, you can disregard volume and mass taken by the hull.

Problem 4

Find the weight which this ship can carry when it submerged to the point $y_m = (a+c)/2$. Report, how far from the center line (y axis) the hull meets the water.

Bonus is harder but it is within reach!

Bonus (10 points):

Similar to problem 3. Find a maximum load capacity for a more elegant hull shape cross section. The cross section is described by the same expression as equation 1 but coefficients b and d have the following dependence on z

$$b(z) = b_0 f(z), \tag{2}$$

$$d(z) = d_0 f(z), \tag{3}$$

where

$$f(z) = 1 - \tanh\left(10\left(\frac{2|z|}{L}\right)^8\right) \tag{4}$$

Here b_0 and d_0 are equal to values b and d found in problem 1; z is distance from the center of the ship along measured along the long side.