#4. A boat that is propelled by a constant force will start to speed up. As the boat speeds up, its force of drag will increase. Eventually the boat will speed up to the point where its force of drag equals the force that propels the boat. At this point, the forces on the boat are balanced, so it no longer accelerates. It has reached its final (terminal) velocity.

Factors that determine terminal velocity are components of the drag equation, where the propelling force has been substituted for drag.

2. Drag coefficient

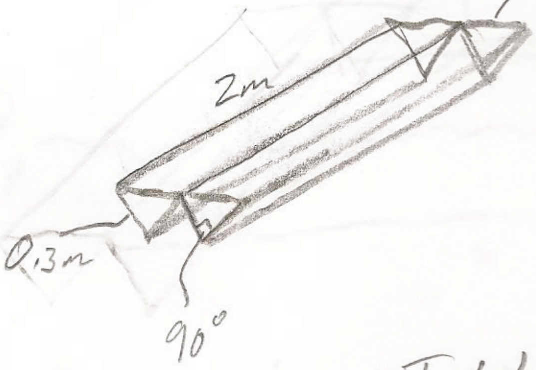
4. fluid density

1. Propelling force

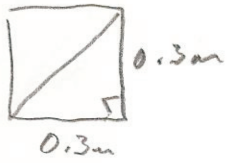
$$\boxed{F_{propelling}} = \frac{1}{2} \boxed{A}\, \boxed{C_d}\, \boxed{\rho}\, v^2$$

3. Cross-sectional area

4.



Ends are half-squares, so diagonals equal



$0.3m(\sqrt{2}) = 0.424m$

Total length of metal bars $= [(0.424m)4] + [2m(5)] + [0.3m(8)]$

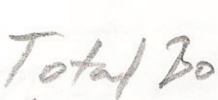
$= 1.7m + 10m + 2.4m$

Total Bar Length $= 14.1m$

Total Boat mass (since plastic is negligible) $= \overset{\text{bar length}}{14.1m}\left(\overset{\text{bar mass per meter}}{2kg/m}\right) = \underline{28.2kg}$

Mass of water displaced $=$ Boat mass $= 28.2kg$

$\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho} \Rightarrow$ $\underline{\text{Volume } H_2O \text{ displaced}} = \frac{\overset{\text{Boat mass}}{28.2kg}}{\underset{H_2O \text{ density}}{1000kg/m^3}} = \underline{0.0282m^3}$



cross-section of a pontoon

Area $= \underline{h^2}$

Area $= \frac{1}{2}$ base(h)

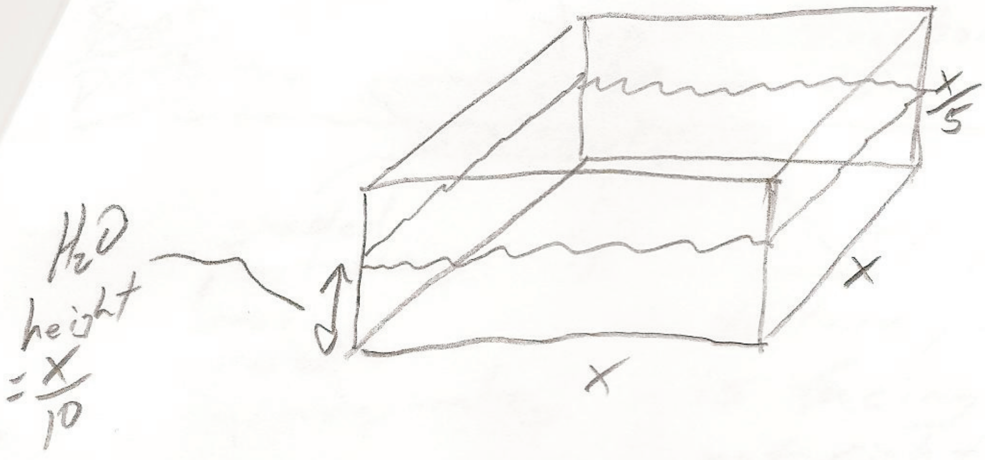
Volume of one pontoon $= \overset{\text{area of end}}{h^2}\left(\overset{\text{length}}{2m}\right)$

Volume of both pontoons $= 4m\,h^2 = \overset{\text{water displaced}}{0.0282m^3}$

$h^2 = 7.05\times10^{-3} m^2$

sink depth $\rightarrow$ $\boxed{h = 0.084m = 8.4cm}$

5.



Archimedes ⇒ Mass of Boat + passenger = Mass of displaced H_2O

$$\text{Mass of bottom} = \text{Area of Bottom}\left(\text{mass}/\text{area}\right)$$
$$= x^2\left(15\,kg/m^2\right) = 15x^2\,kg/m^2$$

$$\text{Mass of a side} = x\left(\frac{x}{5}\right)\left(15\,kg/m^2\right) = 3x^2\,kg/m^2$$

Total floating mass = Bottom + 4sides + passenger

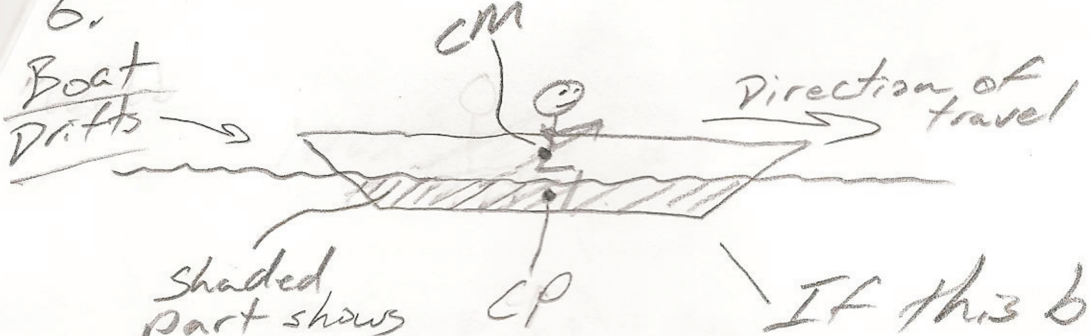
$$= 15x^2\,kg/m^2 + 12x^2\,kg/m^2 + 70kg$$
$$= 27x^2\,kg/m^2 + 70kg$$

$$\rho = \frac{m}{V} \Rightarrow m = \rho V \Rightarrow \text{Displaced Water mass} = 1000\,kg/m^3\underbrace{\left[\underset{\uparrow\,(\text{Area of bottom})}{x^2}\left(\underset{\uparrow\,(H_2O\text{ height})}{\frac{x}{10}}\right)\right]}_{\text{displaced } H_2O \text{ Volume}} = 100x^3\,\frac{kg}{m^3}$$

$$\overbrace{27x^2\,\frac{kg}{m^2} + 70kg}^{\text{Mass, Boat + Passenger}} = \overbrace{100x^3\,kg/m^3}^{\text{mass displaced } H_2O}$$

$$\boxed{x = 0.987m}$$ (Used Excel to "guess + check")

6.



Shaded part shows area exposed to oncoming water.

If this boat starts to turn, so that its side is facing forward, it will not right itself, because... From the side, its CM and CP (center of pressure) are in the same location.

Both boats "track" straight, because CP is behind the CM.

As the boat rotates around its CM, the "big end" (end with CP) will get pushed backward by more force, causing the boat's nose to rotate toward the direction of travel. [A rudder can accomplish this more effectively, because it can be placed farther from the CM, giving a longer torque arm.]