Hydraulics

Tutorial Sheet 1 – Drag on bodies

Unless advised otherwise, in all problems below the density of fresh water may be assumed to be $\rho = 1000\,\mathrm{kg\,m^{-3}}$, the density of seawater $1025\,\mathrm{kg\,m^{-3}}$, the acceleration due to gravity $9.8\,\mathrm{m\,s^{-2}}$, and the kinematic viscosity of water to be $10^{-6}\,\mathrm{m^2\,s^{-1}}$.

1. What effects does gravity have on the nature of "internal" flows such as those we have been considering – flow past bluff bodies *etc*, where there is no free surface?
2. The drag coefficient of a wide plate normal to a flow is approximately $C_\mathrm{D} \approx 2$. Let the free stream conditions be U_0 and p_0. If the average pressure on the front of the plate is approximately equal to the stagnation pressure $p_0 + \frac{1}{2}\rho U_0^2$, what is the average pressure on the rear? (*Ans.*: it is approximately $p_0 - \frac{1}{2}\rho U_0^2$, so, less than the ambient).
3. A cylindrical chimney is $2\,\mathrm{m}$ in diameter and $40\,\mathrm{m}$ high. When it is subject to an $80\,\mathrm{km\,h^{-1}}$ storm wind, what is the force on it, and where does it occur? (The drag coefficient of a cylinder can vary between 0.3 and 1, depending on the Reynolds number; $\rho_\mathrm{air} = 1.2\,\mathrm{kg\,m^{-3}}$ at $20\,^\circ\mathrm{C}$).
4. A pizza delivery vehicle has a long thin rectangular sign on top aligned with the direction of travel. If the car travels at $50\,\mathrm{km\,h^{-1}}$, estimate (a) the force on the sign with no crosswind, and (b) discuss the effect of a crosswind.