FLUIDS I
Example sheet 2: Fluid Behaviour & Similarity

$\nu = 1.14 \times 10^{-6}$ in water and 1.47×10^{-5} in air

1. Flow over the leading edge of a ship hull can be idealised by the flow over a sharp edged flat plate. The Reynolds number, based on distance from the leading edge Re_x, at which an incompressible fluid becomes turbulent is given by 5×10^5. Find the distance from the leading edge at which the flow becomes turbulent for the flow fully submerged in a) air only and b) water only, when the ship moves at 3m/s through still air and water.
[Ans: a) 2.45m, b) 0.19m]

2. Flow over the leading edge of a formula-1 car's front wing is again approximated by the flow over a sharp edged flat plate. The Reynolds number, based on distance from the leading edge Re_x, at which an incompressible fluid becomes turbulent is again given by 5×10^5. Find the distance from the leading edge at which the flow becomes turbulent when the car moves at 80m/s (near F1 top speeds). Compare this to the transition length if the car were moving at 204m/s (approximately Mach 0.6 at sea level)
[Ans: 9.2mm, 3.6mm]

3. The spoiler of a formula 1 car has a rounded rather than a sharp edge. Do you expect this round leading edge to make the length before the flow becomes turbulent longer or shorter? Why?

4. The Drag Coefficient of a laminar flow around an elipse, of aspect ratio 1:2, is 0.6. The drag coefficient of the same elipse in turbulent flow is approximately 0.2. The component of drag due to friction is greater in the turbulent flow due to the increased shear stress at the surface; however the drag coefficient falls to 0.2. Explain this result

5. The drag and lift forces on an aircraft at a speed of 100 m/s are 1000N and 10000N respectively. Assuming force coefficients are approximately constant for small changes in Reynolds Number and the flow is incompressible, what are the drag and lift forces on the same aircraft at a speed of 90 m/s.
[Ans:810N, 8100N]

6. A 1/5th scale model of a car is placed in a wind tunnel, what would the wind tunnel air speed need to be to reproduce the Reynolds number of the flow around the full scale car at 20m/s (assume the viscosity and density are unchanged).
Using the speed of sound equation: $a = \sqrt{\gamma R T}$ (where γ R and T are 1.403, 287 J/kg K and 288.15°K)
what is the Mach number of the onset flow in the wind tunnel. What impact does this have on scale testing?
If a 1/10th scale model were placed in water, what flow speed would match the original Reynolds number.
[Ans:100m/s, 0.294, 15.51m/s]