

MEK4300/9300
Mandatory exercise 2
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Part 1, Flat-plate flows

Consider a fluid in 2D flowing over a flat horizontal rigid plate located at $y = 0$ with a constant horizontal inlet velocity $u(x = 0, y, t) = U$. The flow is unbounded in the positive y -direction.

Exercise 1

Write down the boundary layer equations that describe this flow together with the appropriate boundary conditions.

Exercise 2

Solve the Blasius equation for this flow problem. You should show

1. how you find the appropriate similarity variable $\eta = y\sqrt{U/2\nu x}$ with ν the kinematic viscosity.
2. how the velocity components are expressed via a stream function.
3. how you find Blasius equation $f''' + ff'' = 0$ with $f(\eta)$ being the similarity function to be determined, and how the boundary conditions are expressed through f .
4. the numerical solution to the equation.

Exercise 3

Make a numerical finite difference solver for the boundary layer equations in Exercise 1. You should show

1. how the equations and boundary conditions are discretised.
2. relevant stability criteria for your chosen scheme.
3. comparison of the numerical flow profile solution to the Blasius solution found in exercise 2.

Note: There are quite a lot of information on how to derive these numerical schemes in the book (White, chapter 4).

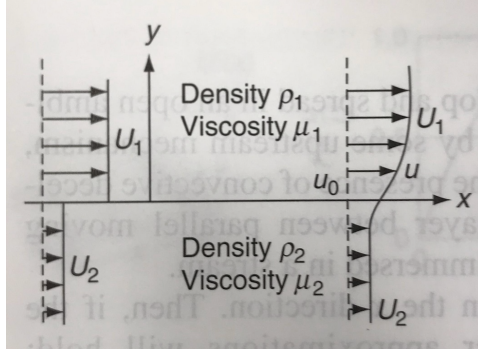


Figure 1: Illustration of the flow problem considered in Part 2.

Part 2, Free-shear flows

Consider two immiscible parallel uniform streams of fluids as depicted in figure 1. The two fluids have different viscosities and densities and their inlet velocity at $x = 0$ is U_1 and U_2 for the upper and bottom fluid, respectively. The two fluids interface is located at $y = 0$ with fluid 1 being unbounded in the positive y -direction and fluid 2 being unbounded in the negative y -direction. Repeat exercise 1-3 from part one for this scenario. In addition, find a stability criterion for the flow (ref: chapter 5, White).

Note: Exercise 3 may be difficult. If you have problems you can consider 2 options: 1) consider solving the one fluid problem with a spatially dependent viscosity and density. This can be modelled using a $\tanh(y)$ -type of function. 2) Consider the scenario where $U_2/U_1 = 0$.