Problem 1 (40 points): The supersonic stream \((M_1 = 4.0)\) flowing in the two-dimensional channel sketched in the figure encounters a wedge with angle \(\delta_1 = 15^\circ\). The oblique shock generated at the corner is reflected at the opposite wall. Determine the Mach numbers \(M_2\) and \(M_3\) as well as the angle \(\alpha\) between the reflected shock and the wall. Compute the temperature and pressure behind the reflected shock, giving the result in the form \(T_3/T_1\) and \(p_3/p_1\). Calculate the entropy change, giving the result in the form \((s_3 - s_1)/c_v\). For \(M_1 = 4.0\) determine the limiting value of \(\delta_1\) beyond which a regular shock reflection at the upper wall is no longer possible.

Problem 2 (60 points): A small rocket engine is equipped with a convergent-divergent nozzle with throat area \(A_t = 0.272 \times 10^{-4} \text{ m}^2\) and exit area \(A_e = 10^{-4} \text{ m}^2\). The conditions in the combustion chamber, where the existing Mach number is very small, are \(p_0 = 2.5 \times 10^6 \text{ Pa}\) and \(T_0 = 2,000 \text{ K}\). The flow conditions in the nozzle depend on the ambient pressure \(p_a\). In the following calculations, assume that \(\gamma = 1.4\) and \(R_g = 287 \text{ J/(Kg K)}\).

1. Obtain the value of \(p_a = p_{CH}\) for which the flow is everywhere subsonic, except at the throat, where it is sonic. Determine the mass flow rate \(\dot{m}\) (in Kg/s) and the temperature at the nozzle exit \(T_e\).

2. Calculate the value of \(p_a = p_{SJ}\) for which the nozzle discharge occurs as a supersonic jet with \(p_e = p_a\). Determine the corresponding values of the mass flow rate \(\dot{m}\) and the temperature at the nozzle exit \(T_e\).

3. Find the value of \(p_a = p_{NS}\) for which a normal shock is found at the nozzle exit section. Determine the corresponding values of the mass flow rate \(\dot{m}\) and the temperature \(T_d\) behind the shock.

4. For \(p_a = (p_{CH} + p_0)/2\) obtain the values of the Mach number at the exit and at the throat \(M_e\) and \(M_t\). Determine the mass flow rate \(\dot{m}\).

5. For \(p_a = (p_{SJ} + p_{NS})/2\), an oblique shock is formed at the exit section. Near the nozzle rim, where the flow is quasi-planar, determine the Mach number found immediately downstream from the shock \(M_d\) as well as the deflection angle \(\delta\).

6. For \(p_a = 0.1 \times p_{SJ}\) an expansion is formed right outside the nozzle exit. Near the nozzle rim, the expansion is quasi-planar and can be described with the Prandtl-Meyer solution. For that local solution, determine the Mach number found immediately downstream from the expansion \(M_d\) as well as the deflection angle \(\theta\).