ME 356: Hypersonic Aerothermodynamics, Spring 2019
Stanford University
Homework 2: Hypersonic Inviscid Flows (II)
Due Thursday, May 2, in class.

Guidelines: Please turn in a neat and clean homework that gives all the formulae that you have used as well as details that are required for the grader to understand your solution. Attach these sheets to your solutions. In the calculations, assume a calorically perfect gas with $\gamma = 1.4$ unless stated otherwise.

Student’s Name: .......................................................... Student’s ID: ..........................................

Questions (100 pts)

1. Calculate the hypersonic wave drag coefficients on a sphere of radius $R$ at Mach $M_a = 7$ at 25 km altitude above sea level using the straight Newtonian theory and the modified Newtonian theory, and provide an estimate of the pressure predicted near the fore stagnation point in each case.

2. Show that the velocity downstream of an oblique shock is given by $U_2 = U_1 \cos \beta + O(\epsilon^2)$ at hypersonic Mach numbers, where $\epsilon = \rho_1/\rho_2 \ll 1$ is the density ratio, $U_1$ is the velocity of the pre-shock gas, and $\beta$ is the shock incidence angle, which is assumed to be of order unity. Is this result valid only for a calorically perfect gas?

3. Briefly explain what an entropy layer is and how is it formed downstream of the nose shock around blunt bodies.

4. Describe the character of the high-speed inviscid flow around a two-dimensional slender wedge of semi-angle $\delta = 4^\circ$ as the Mach number is increased from 2 to 20, indicating whether the flow is subsonic, supersonic, hypersonic, and whether it can be described using small-disturbance theories for the velocity perturbations.

5. In the figure below, the surface pressure coefficient at point Q on the fuselage of projectile #1 is $C_p = 0.2$. Assuming $c/\lambda_1 = 1/7$ and $\lambda_2 = \lambda_1/2$, at what Mach number would van Dyke’s hypersonic similarity rule studied in class could be used to obtain a value of $C_p$ at point Q on the fuselage of projectile #2? Provide the resulting value of $C_p$.

\[ M_a = 12 \quad \text{Ma}_\infty = ? \]