Name: BITS ID:

BITS Pilani, Pilani campus

Comprehensive examination, First semester 2022-2023

ME F415 Gas Dynamics

Total marks: 40, Weightage: 40%, and Date & Time: 19/12/2022 & 9:00 am to 12:00 noon.

Assume any missing data and state the assumptions if any.

Questions

1. (a) Briefly explain the general characteristics of hypersonic flows.
   (b) During the entry of a space vehicle into the Earth's atmosphere, the Mach number at a given point on the trajectory was M = 32 and the atmosphere conditions were 1.0 Pa and 235 K. (i) Calculate the temperature at the stagnation point of the vehicle, assuming a calorically perfect gas with $\gamma = 1.4$. (ii) Do you think the calculation of temperature at the stagnation point leads to overestimation or underestimation? Why is that so?

   [5 marks]

2. A jet plane is flying at an altitude of 10000 m with a cabin pressure of 101 kPa and a cabin temperature of 22 ^{o}C. Suddenly a bullet is fired inside the cabin and pierces the fuselage; the resultant hole is 2 cm in diameter. Assume that the temperature within the cabin remains constant and that the flow through the hole behaves as that through a converging nozzle with an exit diameter of 2.0 cm. Take the cabin volume to be 100 m^3. Calculate the time for the cabin pressure to decrease to one-half the initial value.
   For altitude h (in m) <11000 m,
   T (in ^{o}C) = 15.04 - 0.00649 * h
   p (in kPa) = 101.29 * $[(T + 273.1)/288.08]^{5.256}$.

   [5 marks]

3. (a) Consider air entering a heated duct at p_1 = 3 bar, T_1 = 300 K and M_1= 0.15. Calculate the amount of heat per unit mass (in J/kg) necessary to choke the flow at the exit of the duct.
   (b) For conditions given in part (a), estimate the pressure and temperature at the duct exit.
   (c) For the same inlet pressure and temperature in part (a), but for M_1 = 1.5, estimate the amount of heat per unit mass (in J/kg) necessary to choke the flow at the exit of the duct as well as the pressure and temperature at the duct exit.

   [6 marks]

4. Air (with $\gamma = 1.4$) flows into a constant-area insulated duct with M_1= 0.20. For a duct diameter of 1 cm and Darcy's friction coefficient (f_D= 4*f) of 0.02, (a) determine the duct length required to reach M_2= 0.60. (b) Determine the length required to attain M_2= 1. (c) Finally if an additional 75 cm is added to the duct length needed to reach M_2= 1, while the initial stagnation conditions are maintained, determine the reduction in flow rate that would occur.

   [6 marks]

5. The driver and driven gases of a pressure-driven shock tube are both air at 300 K. The diaphragm pressure ratio is $p_4/p_1 = 5$.

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(a) Determine the strength of the incident shock (p_2/p_1), and strength of the reflected shock (p_5/p_2).
(b) Assume that there is a test body (say, a small sphere) located in the driven section at 50 cm from the diaphragm. The driven tube is to be made long enough so that a period of 10 milliseconds is provided between the time of passage over the body of the initial shock and the time of passage of the shock reflected from the closed end of the tube. Calculate the total length of driven section.
(c) Determine the strength of the incident expansion wave (p_3/p_4).

[10 marks]

6. For the infinitely thin flat plate shown in Fig. 1, calculate the flow Mach numbers at zones 2, 2′,3, and 3′, assuming the slipstream deflection to be negligible. Also, calculate the lift and drag coefficients.

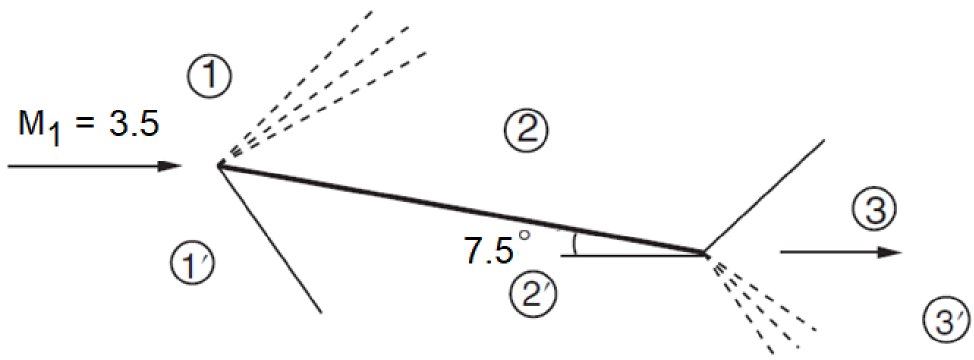

Fig. 1

[8 marks]