Name: BITS ID:

BITS Pilani, Pilani campus, First semester 2023-2024

ME F415 Gas Dynamics

Comprehensive Examination- Regular

Date: 06/12/2023, 9:00 am to 12:00 noon, Total marks: 40, and Weightage: 40%

Instructions

i. This is an open-book examination. However, the use of Textbook (Gas Dynamics by Ethirajan Rathakrishnan), R1 (Modern Compressible Flow by John D. Anderson), class slides and handwritten notes are only permitted.
ii. State assumptions if any and assume any missing data.

Questions

1. Carbon dioxide flows in a horizontal duct at 7 atm and 300 K with a velocity of 10 m/s. At a downstream location the pressure is 3.5 atm and the temperature is 10 ^{o}C. If 1.4 × 10^4 J/kg of heat is lost by the fluid between these locations:

(a) Determine the velocity at the second location.

(b) Compute the ratio of initial to final areas.

(Note: 1 atm = 1.01×10^{5} N/m^{2})

(4 marks)

2. Air is flowing out of a driven section of a shock tube post a diaphragm rupture at a velocity of 300 m/s with a temperature of 30 ^{o}C and a pressure of 100 kPa. A valve at the end of the duct is suddenly closed. Find the pressure acting on the valve immediately after the valve closure.

(4 marks)

3. A simple wedge with a total included angle of 30^{o} is used to measure the Mach number of supersonic flows. When inserted into a wind tunnel and aligned with the flow, oblique shocks are observed at 45^{o} angles to the free stream.

(a) What is the Mach number in the wind tunnel?

(b) For the above calculated flow, if the wedge is tilted by an angle 5^{o}, what will be the effect on the shock angle?

(c) Through what range of Mach numbers could this wedge be useful?

(d) How do the angle measurements affect the Mach number measurement in this method? Discuss them briefly.

(8 marks)

4. A smooth concave turn turns the flow through a 20^{o} angle. The fluid is air and it approaches the turn at M1 = 3.0.

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(a) Compute M2, T2/T1, and p2/p1 via the Prandtl–Meyer compression which occurs close to the wall.

(b) Compute M2, T2/T1, and p2/p1 via the oblique shock that forms away from the wall. Assume that this flow is also deflected by 20^o.

(c) Can these two regions coexist next to one another? Elaborate briefly.

(d) Draw a T –s diagram showing each process.

(8 marks)

5. Air enters a 20 cm diameter duct with a velocity of 100 m/s. The pressure is 1 atm and the temperature is 30 ^{o}C.

(a) Explain Rayleigh curve with a neat plot.

(b) What do you mean by thermal choking and briefly elaborate on any of its practical use.

(c) How much heat must be added to the flow to create the maximum (static) temperature?

(d) Determine the final temperature and pressure for the conditions of part (c).

(8 marks)

6. Air enters a circular duct with a Mach number of 3.0. The diameter is 20 cm and the friction factor is 0.01.

(a) How long a duct is required to reduce the Mach number to 2.0?

(b) What is the change in temperature, pressure, and density for part (a)?

(c) Determine the entropy increase of the air.

(d) Assume the same length of duct as computed in part (a), but the initial Mach number is 0.3. Compute the percentage change in temperature, pressure, density, and the entropy increase for this case. Compare the changes in the same length duct for subsonic and supersonic flow.

(8 marks)