Name: BITS ID:

BITS Pilani, Pilani campus, First semester 2023-2024

ME F415 Gas Dynamics

Mid-semester Examination

Date: 09/10/2023, 9:00 am to 10:30 am, Total marks: 30, and Weightage: 30%

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. Derive the energy equation for steady, one-dimensional, inviscid flow with heat transfer using the Reynolds Transport Theorem. [6 marks]
2. Assume that the flow of air through a duct is adiabatic. The velocity, pressure, and temperature at a point are measured to be 250 m/s, 150 kPa, and 300 K respectively. Calculate the Mach number and all the stagnation properties (p_{01}, T_{01}, and ρ_{01}) at this point. At a point downstream, if the velocity and pressure are measured to be 300 m/s, and 125 kPa respectively, estimate the Mach number and all the stagnation properties (p_{02}, T_{02}, and ρ_{02}) at this point as well. [8 marks]
3. An explosion in the air creates a spherical shockwave propagating radially into the air at 100 kPa and 300 K and let us analyse this shockwave assuming it to be a normal shockwave. Suppose the pressure just inside the shock wave at a time instant is measured to be 1500 kPa. Calculate the shock strength ($(p_2-p_1)/p_1$) and shock speed at the given time instant. Also, calculate the air temperature and velocity just inside the shock at the same time instant. Assume air is a calorically perfect gas with $\gamma=1.4$. [7 marks]
4. A convergent-divergent nozzle is designed to expand air from a reservoir to produce Mach 2.5 flow at its exit. The stagnation pressure and temperature at the nozzle inlet are 8 bar and 300 K respectively. The throat area is 0.1 m^2. Calculate:
   (a) The exit area of the nozzle.
   (b) The design back pressure.
   (c) The mass flow rate through the nozzle when operating at the design conditions.
   (d) The lowest back pressure for which there is only subsonic flow in the nozzle.
   (e) The back pressure at which there will be a normal shock wave on the exit plane of the nozzle.
   (f) The back pressure below which there are no shock waves in the nozzle.
   (g) The range of back pressure over which there are oblique shock waves in the exhaust from the nozzle.
   (h) The range of back pressures over which there are expansion waves in the exhaust from the nozzle.

   [9 marks]