AE236: Compressible Fluid Mechanics
End semester examination
April 24, 2021

Duration: 120 minutes **Maximum Marks: 30**

Step marks will not be given for incorrect solution procedure.
Answer all questions. All the best!

1. Air at -20^0C and $0.86bar$ enters a turbojet engine at a relative velocity of $120m/s$ through the intake area of $0.4m^2$. The combustion products leave the engine at $0.8bar$ with a velocity of $330m/s$ through an exit area of $0.6m^2$. Assume that the mass of fuel added for combustion is negligible and the combustion products have the same properties as air. Find the net thrust developed as a result of flow through the engine. (3)

2. Air at a pressure of $50kPa$ and a temperature of $330K$ is to be isentropically expanded from a Mach number of 1.5 to achieve a pressure of $20kPa$. Find out the flow deflection angle required. Also find the final Mach number and temperature of the gas. (3)

3. A converging-diverging nozzle with an area ratio of 5 is attached to a reservoir whose stagnation conditions are $800kPa$ and $500K$. Identify the back pressure range for the four regions of nozzle operation: (4)
(i) subsonic flow throughout the nozzle,
(ii) normal shock wave within the nozzle,
(iii) oblique shock wave at the lip of the nozzle, and
(iv) expansion wave at the lip of the nozzle.

4. A conical diffuser has an inlet diameter of $40cm$ and exit diameter of $80cm$. Air enters the diffuser with a static pressure of $200kPa$ and a static temperature of 37^0C. The average velocity of the flow at inlet to the diffuser is $265m/s$. Calculate the mass flow rate and the pressure, temperature and velocity at the exit section. (4)

5. A c-d nozzle having a throat diameter of $7.5mm$ supplies air to an insulated duct of diameter $15mm$. The stagnation properties of air at entry to the nozzle are $7.5bar$ and $300K$. The flow through the nozzle is isentropic. The mean friction factor for the duct is 0.005. Calculate the maximum length of the duct that can be provided without any discontinuity in the nozzle or duct. Also find the stagnation temperature, stagnation pressure, pressure and temperature at the exit for this duct length. (5)

6. A normal shock wave moves through a duct of a constant cross-section with a velocity of $500m/s$. The air in the duct is stationary and is at a pressure and temperature of $0.1MPa$ and $290K$ respectively. Determine the velocity of air after the passage of the shock. Also, find the pressure, temperature, Mach number and stagnation temperature imparted upstream of the wave. (5)

7. A combustion chamber in a gas-turbine power plant receives air at $300K$, $55kPa$ and $60m/s$. The fuel-air ratio is 29 and the calorific value of the fuel is $42MJ/kg$. Assuming $]gamma = 1.4$ and $R = 0.287kJ/kgK$ for the gas, determine: (6)
(i) Mach number at the inlet and exit;
(ii) pressure, temperature and velocity of the gas at the exit of the combustion chamber;
(iii) maximum attainable stagnation temperature.