Tutorial – 01 & 02

1. Air flows isentropically through a constant-area duct at M = 0.4. The stagnation pressure is p_0 = 1.3 bar and the stagnation density is ρ_0 = 1.0 kg/m^3. What is the static enthalpy of air at this state? (Ans: $440\frac{kJ}{kg}$)

2. Air flows through a device such that the stagnation pressure is 0.6 MPa, the stagnation temperature is 400°C, and the velocity is 570 m/s. Determine the static pressure and temperature of the air at this state. Assume the flow to be isentropic.
(Ans: $511\ K$,$0.23\ MPa$)

3. Air at 320 K is flowing in a duct at a velocity of (a) 1, (b) 10, (c) 100, and (d) 1000 m/s. Determine the temperature that a stationary probe inserted into the duct will read for each case. (Ans: a) $320.0\ K$ b) $320.1\ K$ c) $325.0\ K$ d) $817.5\ K$)

4. Air flows isothermally (400 K) through a duct, the pressure and velocity at point 1 are p_1 = 0.5 bar, V_1= 320 m/s.
   a) Calculate the Mach number at point 1. (Ans: 0.8)
   b) What is the pressure at a downstream point 2, where the Mach number is M_2 = 0.3? (Ans:$0.73\ bar$)
   c) If the area of duct at point 1 is 0.5 m^2, what is the area of duct at point 2? (Ans: $1.945\ m^2$)

5. Find the variation of mass flow rate with Mach number for a fixed area duct at a given total pressure and total temperature. Find the Mach number at which the limiting maximum value of mass flow rate occurs.
(Ans: $\dot{m} = \frac{A \times p_o}{\sqrt{T_o}} \times \sqrt{(\gamma / R)} \times M \times \left(1 + \frac{\gamma-1}{2} \times M^2\right)^{-(\gamma+1)/2(\gamma-1)}, M = 1$)

6. Products of combustion enter a gas turbine with a stagnation pressure of 0.75 MPa and a stagnation temperature of 690°C, and they expand to a stagnation pressure of 100 kPa. Taking γ = 1.33 and R = 0.287 kJ/kg·K for the products of combustion, and assuming the expansion process to be isentropic, determine the power output of the turbine per unit mass flow. (Ans: $584.2\ K$)

7. A pitot-static tube is placed in a subsonic airflow. The static pressure and temperature in the flow are 96 kPa and 27°C respectively. The difference between the pitot and static pressures is measured and found to be 32 kPa. Find the air velocity (a) assuming an incompressible flow, (b) assuming compressible flow. (Ans: a) 239.6 m/s, b) $225.7\ m/s$)

8. A gas with a molar mass of 4 and a specific heat ratio of 1.3 flows through a variable area duct. At some point in the flow, the velocity is 150 m/s, the pressure is 100 kPa and the temperature is 15°C. Find the Mach number at this point in the flow. At some other point

in the flow the temperature is found to be -10°C. Find the Mach number, pressure and velocity at this second point in the flow assuming the flow to be isentropic and one-dimensional.
(Ans: $M_1 = 0.17, M_2 = 0.81, p_2 = 67.5\ kPa,\ V_2 = \ 687.6\ m/s$)

9. A weak pressure wave (a sound wave) across which the pressure rise is 0.05 kPa is travelling down a pipe into air at a temperature of 30°C and a pressure of 105 kPa. Estimate the velocity of the air behind the wave. (Ans: $\Delta u = \ 0.118\ m/s$)

   (Note: In Fig.2, the flow seems to be coming towards the wave from both directions but $\Delta u - V < 0$, so the flow is actually going away from the wave in this region.)

Figure 1: Tube with piston set in motion at $t = 0$, with small velocity, Δu.

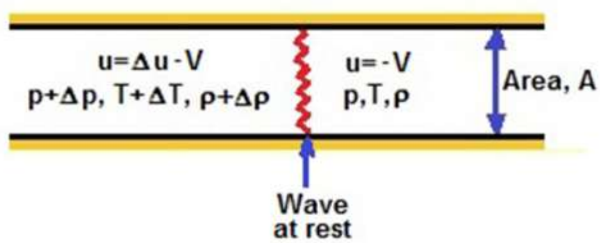

Figure 2: Flow with wave at rest.