Report # (3) (1-D flow in variable area duct)

(1) At section (1) in the isentropic flow of CO_2, P_1=40 kPa(abs,) T_1=60 °C, and V_1=350m/s. Determine the flow velocity, V_2, in m/s at another section (2), where the Mach number is M_2=2.0. Also calculate area ratio, A_2/A_1. Sketch the duct shape A_1 to A_2 (assume γ=1.3).

---

(2) Air flowing through an adiabatic, frictionless duct is supplied from a large supply tank in which P = 500 kPa and T = 400 K. What are the Mach number Ma. the temperature T, density , and fluid V at a location in this duct where the pressure is 430 kPa?

---

(3) During a reaction test of a turbo-jet engine, the measurements (relative to the engine) gave an engine thrust force of 8800 N when the air flow rate was=14 kg/s. The flow temperature at the entrance to the thrust nozzle was T_1=1053 K and the velocity was V_1 =90 m/s. The nozzle had no divergent part and the exhaust stream reached atmospheric pressure some where outside the exit plane of the nozzle (i.e., $P_{exit} \neq P_{atm}$). Assume no heat loss from the gases and that the direction of air stream entering the engine was perpendicular to the direction of the thrust and that the nozzle is frictionless. Find the pressure and area at the inlet and exit planes (assume γ&R for the gases as those for air).

---

(4) Air at 300 kPa(abs) and 500K flows from a large reservoir through a duct having a throat area of 0.093 m^2. Further downstream the throat, a normal shock wave takes place at 2 A*. The duct exit area = 3 A*. Find all conditions (P, T, V and Ma) just upstream and down stream the normal shock wave. Find also P, T, V and Ma at the exit area of the duct. Sketch the duct shape and T-S diagram for the process and find the entropy change S_2-S_1.

---

(5) Air at 300 kPa(abs) and 500K flows from a large reservoir through a duct having a throat area of 0.093 m^2. Further downstream the throat, a normal shock wave takes place **some where before the exit plane**. The duct exit area =3A* and the exit pressure is 150 kPa. Find all conditions (P, T, V and Ma) just upstream and down stream the normal shock wave. Find also T, V and Ma at the exit area of the duct. Sketch the duct shape and T-S diagram for the process and find the entropy change S_2-S_1.

---

(6) Nitrogen of γ=1.3 at 300 kPa(abs) and 500K flows from a large reservoir through a duct having a throat area of 0.093 m^2. Further downstream the throat, a normal shock wave takes place **some where before the exit plane**. The duct exit area =3A* and the exit pressure is 150 kPa. Find all conditions (P, T, V and Ma) just upstream and down stream the normal shock wave. Find also T, V and Ma at the exit area of the duct. Sketch the duct shape and T-S diagram for the process and find the entropy change S_2-S_1.

---

(7) **Example: Converging-Diverging Nozzle (with N.S.W)**

Air is supplied to the converging-diverging nozzle shown here from a large tank where P = 2 Mpa and T = 400 K. A normal shock wave in the diverging section of this nozzle forms at a point $P_{o1} = P_{o2} = 2\ MPa$ where the upstream Mach number is 1.4. The ratio of the nozzle exit area to the throat area is 1.6. Determine (a) the Mach number downstream of the shock wave, (b) the Mach number at the nozzle exit, (c) the pressure at the nozzle exit, and (d) the temperature at the nozzle exit.