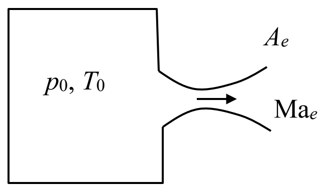
A large tank supplies helium through a converging-diverging nozzle to the atmosphere. Pressure in the tank remains constant at 8.00 MPa (abs) and temperature remains constant at 1000 K. There are no shock waves in the nozzle. The nozzle is designed to discharge at an exit Mach number of 3.5. The exit area of the nozzle is 100 mm^2. Note that for helium the specific heat ratio is 1.66 and the ideal gas constant is 2077 J/(kg·K).

a. Determine the pressure at the exit of the converging/diverging nozzle.
b. Determine the mass flow rate through the device.
c. Sketch the flow process from the tank through the converging/diverging nozzle to the exit on a *T-s* diagram.

SOLUTION:



p_0 = 8.00e6 Pa (abs)
T_0 = 1000 K
Ma_e = 3.5
A_e = 1.0e-4 m^2
γ = 1.66
R = 2077 J/(kg.K)
Assume isentropic flow.

$$\frac{p_e}{p_0} = \left(1 + \frac{\gamma - 1}{2}\text{Ma}_e^2\right)^{\frac{\gamma}{1-\gamma}} \Rightarrow \boxed{p_e = 137 \text{ kPa}} \quad (1)$$

$$\frac{T_e}{T_0} = \left(1 + \frac{\gamma - 1}{2}\text{Ma}_e^2\right)^{-1} \Rightarrow T_e = 198 \text{ K} \quad (2)$$

$$\rho_e = \frac{p_e}{RT_e} \Rightarrow \rho_e = 0.332 \text{ kg/m}^3 \quad (3)$$

$$V_e = \text{Ma}_e\sqrt{\gamma R T_e} \Rightarrow V_e = 2890 \text{ m/s} \quad (4)$$

$$\dot{m} = \rho_e V_e A_e \Rightarrow \boxed{\dot{m} = 9.59\text{e-6 kg/s}} \quad (5)$$