$$\rho_e = \frac{100000}{287(261)} = 1.34\ \frac{\text{kg}}{\text{m}^3}, \quad a_e = 324\ \frac{\text{m}}{\text{s}}, \quad V_e = 254\ \frac{\text{m}}{\text{s}},$$

$$\dot{\mathbf{m}} = \rho_e A_e V_e \approx \mathbf{0.0068}\ \frac{\mathbf{kg}}{\mathbf{s}} \quad \textit{Ans.}\ (B)$$

Nozzle **A**: $\dot{m} = \dot{m}_{max} = \dfrac{0.6847(150000)(0.0002)}{\sqrt{287(293)}} \approx \mathbf{0.071}\ \dfrac{\mathbf{kg}}{\mathbf{s}}$ (5% more) *Ans.* (A)

9.79 A large reservoir at 600 K supplies air flow through a converging-diverging nozzle with a throat area of 2 cm^2. A normal shock wave forms at a section of area 6 cm^2. Just downstream of this shock, the pressure is 150 kPa. Calculate (a) the pressure in the throat; (b) the mass flow; and (c) the pressure in the reservoir.

Solution: The throat is choked, and just upstream of the shock is a supersonic flow at an area ratio $A/A^* = (6\ \text{cm}^2)/(2\ \text{cm}^2) = 3.0$. From Table B.1 estimate $Ma_1 = 2.64$. That is,

$$\frac{A_1}{A^*} = 3.0 = \frac{\left(1 + 0.2Ma_1^2\right)^3}{1.728Ma_1}, \quad \text{Solve} \quad Ma_1 = 2.637$$

(a, c) The pressure ratio across the shock is given by Eq. (9.55) or Table B.2:

$$\frac{p_2}{p_1} = \frac{150\,\text{kPa}}{p_1} = \frac{1}{k+1}\left(2kMa_1^2 - k + 1\right)$$

$$= \frac{1}{2.4}[2(1.4)(2.637)^2 - 0.4] = 7.95, \quad \text{or} \quad p_1 = 18.9\ \text{kPa}$$

$$p_{tank} = p_o = p_1\left(1 + 0.2Ma_1^2\right)^{3.5} = (18.9)[1 + 0.2(2.637)^2]^{3.5} = \mathbf{399\ kPa} \quad \textit{Ans.}\ (c)$$

At the throat, $p = p^* = 0.5283p_o = (0.5283)(399\ \text{kPa}) = \mathbf{211\ kPa}$ *Ans.* (a)

(b) To avoid bothering with density and velocity, Eq. (9.46b) is handy for choked flow.

$$\dot{m}_{max} = \frac{0.6847p_oA^*}{\sqrt{RT_o}} = \frac{0.6847(399000\,\text{Pa})(0.0002\ \text{m}^2)}{\sqrt{(287\,\text{m}^2/\text{s}^2\text{K})(600\,\text{K})}} = \mathbf{0.132\ kg/s} \quad \textit{Ans.}\ (b)$$

9.80 A sea-level automobile tire is initially at 32 lbf/in^2 gage pressure and 75°F. When it is punctured with a hole which resembles a converging nozzle, its pressure drops to 15 lbf/in^2 gage in 12 min. Estimate the size of the hole, in thousandths of an inch.