Assuming an isentropic expansion to $Ma_e \approx 3.06$, we can compute the throat area:

$$\frac{A_e}{A^*} = \frac{36.6}{A^*} = \frac{1}{3.06}\left[\frac{2+0.38(3.06)^2}{1.38+1}\right]^{\frac{2.38}{2(0.38)}} = 4.65, \quad \text{or} \quad A^* = \frac{36.6}{4.65} = 7.87\ \text{ft}^2 = \frac{\pi}{4}D^{*2}$$

Solve for throat diameter $\mathbf{D^* \approx 3.2\ ft}$ *Ans.* (b)

9.84 Air flows through a duct as in Fig. P9.84, where $A_1 = 24\ \text{cm}^2$, $A_2 = 18\ \text{cm}^2$, and $A_3 = 32\ \text{cm}^2$. A normal shock stands at section 2. Compute (a) the mass flow, (b) the Mach number, and (c) the stagnation pressure at section 3.

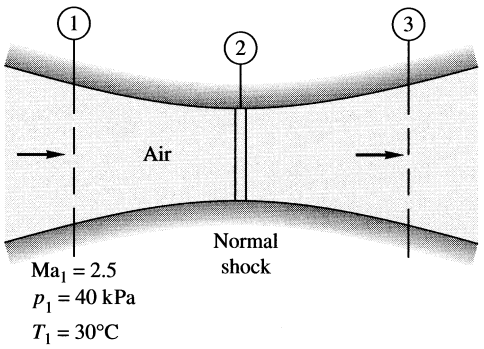

Fig. P9.84

Solution: We have enough information at section 1 to compute the mass flow:

$$a_1 = \sqrt{1.4(287)(30+273)} \approx 349\ \text{m/s}, \quad V_1 = 2.5(349) = 872\ \frac{\text{m}}{\text{s}}, \quad \rho_1 = \frac{p_1}{RT_1} = 0.46\ \frac{\text{kg}}{\text{m}^3}$$

$$\text{Then} \quad \dot{m} = \rho_e A_e V_e = 0.46(0.0024)(872) \approx \mathbf{0.96\ kg/s} \quad \textit{Ans.}\ (a)$$

Now move isentropically from 1 to 2 upstream of the shock and thence across to 3:

$$Ma_1 = 2.5, \quad \therefore \quad \frac{A_1}{A_1^*} = 2.64, \quad A_1^* = \frac{24}{2.64} = 9.1\ \text{cm}^2, \quad \text{and} \quad \frac{A_2}{A_1^*} = \frac{18}{9.1} = 1.98$$

$$\text{Read} \quad Ma_{2,\text{upstream}} \approx \mathbf{2.18}, \quad p_{o1} = p_{o2} = 40[1+0.2(2.5)^2]^{3.5} \approx 683\ \text{kPa}, \quad \text{across the}$$

$$\text{shock}, \quad \frac{A_3^*}{A_2^*} = 1.57, \quad A_3^* = 14.3\ \text{cm}^2, \quad \frac{A_3}{A_3^*} = 2.24\,\Big|_{\text{sub}}, \quad \mathbf{Ma_3 \approx 0.27} \quad \textit{Ans.}\ (b)$$

Finally, go back and get the stagnation pressure ratio across the shock:

$$\text{at } Ma_2 \approx 2.18, \ \frac{p_{o3}}{p_{o2}} \approx 0.637, \quad \therefore \quad p_{o3} = 0.637(683) \approx \mathbf{435\ kPa} \quad \textit{Ans.}\ (c)$$

9.85 A large tank at 300 kPa delivers air through a nozzle of 1-cm^2 throat area and 2.2-cm^2 exit area. A normal shock wave stands in the exit plane. The temperature just downstream