9.55 Air, supplied by a reservoir at 450 kPa, flows through a converging-diverging nozzle whose throat area is 12 cm^2. A normal shock stands where $A_1 = 20$ cm^2. (a) Compute the pressure just downstream of this shock. Still farther downstream, where $A_3 = 30$ cm^2, estimate (b) p_3; (c) A_3^*; and (d) Ma_3.

Solution: If a shock forms, the throat must be **choked** (sonic). Use the area ratio at (1):

$$\frac{A_1}{A^*} = \frac{20}{12} = 1.67, \quad \text{or} \quad Ma_1 \approx 1.985, \quad \text{whence} \quad p_1 = \frac{450}{[1 + 0.2(1.985)^2]^{3.5}} \approx 59 \text{ kPa}$$

$$\text{Then, across the shock,} \quad \frac{p_2}{p_1} = \frac{2.8(1.985)^2 - 0.4}{2.4} = 4.43,$$

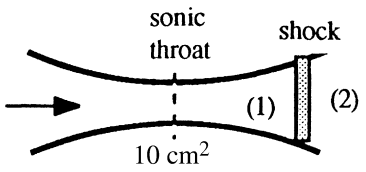
$$p_2 = 4.43(59) \approx \mathbf{261\ kPa} \quad \textit{Ans.}\ (a)$$

$$\text{Across the shock, at } Ma_1 = 1.985, \quad \frac{A_2^*}{A_1^*} = 1.374, \quad A_2^* = 1.374(12) \approx \mathbf{16.5\ cm^2} \quad \textit{Ans.}\ (c)$$

$$\text{At } A_3 = 30 \text{ cm}^2, \quad \frac{A_3}{A_2^*} = \frac{30}{16.5} = 1.82, \quad \text{whence subsonic } Ma_3 \approx \mathbf{0.34} \quad \textit{Ans.}\ (d)$$

$$\text{Finally,} \quad p_{o2} = \frac{p_{o1}}{1.374} = 328 \text{ kPa}, \quad p_3 = \frac{328}{[1 + 0.2(0.34)^2]^{3.5}} \approx \mathbf{303\ kPa} \quad \textit{Ans.}\ (b)$$

9.56 Air from a reservoir at 20°C and 500 kPa flows through a duct and forms a normal shock downstream of a throat of area 10 cm^2. By an odd coincidence it is found that the stagnation pressure downstream of this shock exactly equals the throat pressure. What is the area where the shock wave stands?



Solution: If a shock forms, the throat is **sonic**, $A^* = 10$ cm^2. Now

$$p_1^* = 0.5283 p_{o1} = 0.5283(500) \approx \mathbf{264\ kPa} = p_{o2} \quad \text{also}$$

$$\text{Then} \quad \frac{p_{o2}}{p_{o1}} = \frac{264}{500} = 0.5283: \quad \text{Table B.2, read } Ma_1 \approx 2.43$$

$$\text{So} \quad A_1/A_1^* = \frac{[1 + 0.2(2.43)^2]^{3.0}}{1.728(2.43)} \approx 2.47, \quad \text{or} \quad A_1(\text{at shock}) = 2.47(10) \approx \mathbf{24.7\ cm^2} \quad \textit{Ans.}$$
