4.32 $\frac{p_e}{p_o} = \left(1 + \frac{\gamma - 1}{2} M_e^2\right)^{\frac{-\gamma}{\gamma-1}}$

Hence,

$$M_e^2 = \frac{2}{\gamma - 1}\left[\left(\frac{p_e}{p_o}\right)^{\frac{1-\gamma}{\gamma}} - 1\right]$$

$$M_e^2 = 5[(0.2)^{-0.286} - 1] = 2.92$$

$$M_e = 1.71$$

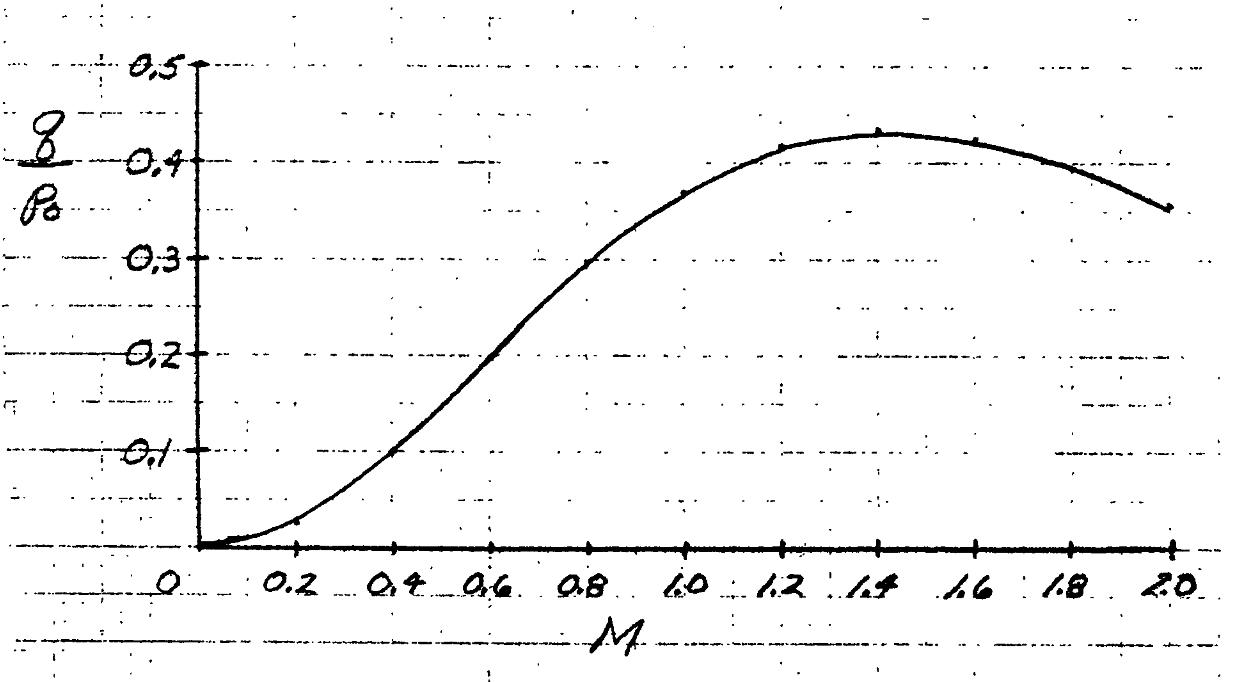
$$\left(\frac{A_e}{A_t}\right)^2 = \frac{1}{M_e^2}\left[\frac{2}{\gamma + 1}\left(1 + \frac{\gamma - 1}{\gamma}\right)M^2\right]^{(\gamma+1)/(\gamma-1)}$$

$$\left(\frac{A_e}{A_t}\right)^2 = \frac{1}{(1.71)^2}\,[(0.833)(1 + 0.2\,(1.71)^2)]^6$$

$$\frac{A_e}{A_t} = \boxed{1.35}$$

4.33 $\frac{q}{p_o} = \frac{\gamma}{2}\frac{p}{p_o}M^2 = \frac{\gamma}{2}M^2\left[1 + \frac{\gamma - 1}{2}M^2\right]^{-\gamma/(\gamma-1)} = 0.7\,M^2\,(1 + 0.2\,M^2)^{-3.5}$

$\underline{M}$	$\underline{M^2}$	q/p_o
0	0	0
0.2	0.04	0.027
0.4	0.16	0.100
0.6	0.36	0.198
0.8	0.64	0.294
1.0	1.0	0.370
1.2	1.44	0.416
1.4	1.96	0.431
1.6	2.56	0.422
1.8	3.24	0.395
2.0	4.00	0.358



Note that the dynamic pressure increases with Mach number for $M < 1.4$ but decreases with Mach number for $M > 1.4$. I.e., in an isentropic nozzle expansion, there is a peak local dynamic pressure which occurs at $M = 1.4$

4.34 First, calculate the value of the Reynolds number.

$$\mathrm{Re_L} = \frac{\rho_\infty V_\infty L}{\mu_\infty} = \frac{(1.225)(200)(3)}{(1.7894 \ \mathrm{x} \ 10^{-5})} = 4.10 \ \mathrm{x} \ 10^{7}$$

The dynamic pressure is

$$q_\infty = \frac{1}{2}\rho_\infty V_\infty^{\ 2} = \frac{1}{2}\ (1.225)(200)^2 = 2.45 \ \mathrm{x} \ 10^4 \ \mathrm{N/m^2}$$

Hence,

$$\delta_L = \frac{5.2L}{\sqrt{\mathrm{Re_L}}} = \frac{5.2(3)}{\sqrt{4.1 \ \mathrm{x} \ 10^7}} = 0.0024\mathrm{m} = \boxed{0.24 \ \mathrm{cm}}$$

and

$$C_f = \frac{1.328}{\sqrt{\mathrm{Re_L}}} = \frac{1.328}{\sqrt{4.1 \ \mathrm{x} \ 10^7}} = 0.00021$$

The skin friction drag on one side of the plate is:

$$D_f = q_\infty S c_f = (2.45 \ \mathrm{x} \ 10^4)(3)(17.5)(0.00021)$$

$$D_f = 270\mathrm{N}$$

The total skin friction drag, accounting for both the top and the bottom of the plate is twice this value, namely

$$\text{Total } D_f = \boxed{540\mathrm{N}}$$

4.35 $$\delta = \frac{0.37L}{(\mathrm{Re_L})^{0.2}} = \frac{0.37(3)}{(4.1 \ \mathrm{x} \ 10^7)^{0.2}} = 0.033\mathrm{m} = \boxed{3.3 \ \mathrm{cm}}$$

From problem 4.24, we find

$$\delta_{\mathrm{turbulent}}/\delta_{\mathrm{laminar}} = \frac{3.3}{0.24} = \boxed{13.75}$$

... more than an order of magnitude thicker than the laminar boundary layer.

$$C_f = \frac{0.074}{(Re_L)^{0.2}} = \frac{0.074}{(4.1 \times 10^7)^{0.2}} = 0.0022$$

The skin friction drag on one side is then

$$D_f = q_\infty S c_f = (2/45 \times 10^4)(3)(17.5)(0.0022)$$

$$D_f = 2830N$$

The total, accounting for both top and bottom is

$$\text{Total } D_f = \boxed{5660N}$$

From problem 4.24, we find

$$\left(D_{f_{turbulent}}\right) / \left(D_{f_{laminar}}\right) = \frac{5660}{540} = \boxed{10.5}$$

The turbulent skin friction drag is an order of magnitude larger than the laminar value.

4.36 $R_{e_{x_{cr}}} = \frac{\rho_\infty V_\infty x_{cr}}{}$