a) For the upstream section to be independent of the exit pressure, the duct must be choked. We must have $M = 1$ at the throat, so $A^* = A_t$

From isentropic flow table (Anderson App.A), for $M = 0.6$, \( A/A^* = 1,188 \)

\[
\frac{A}{A^*} = \frac{1}{1.188} = 0.84175
\]

\[\text{M}=0.6 \quad \longrightarrow \quad \text{M}=1
\]

b) $P_e$ must be reduced enough to reach $M=1$ at throat.

Since $A_e = A = 1.188 A^*$, $M_e = 0.6$ (same as in test section).

\[P_o = P_r = 5 \times 10^5 \text{ Pa} \quad P_e = P_o e \left[1 + \frac{k}{2} M_e^2\right]^{\frac{k}{k-1}} = 0.784 P_r = 3.92 \times 10^5 \text{ Pa}
\]

$P_e$ can be lower than this, so $P_e \leq 3.92 \times 10^5 \text{ Pa}$

The temperature $T_r$ is irrelevant here (curve ball!)

c) Flow is again choked, since we have a shock behind throat.

This time $A/A^* = \frac{1}{0.9} = 1.111$

From table, $M = 1.39$

\[P_1 = P_r \left[1 + \frac{k}{2} M_1^2\right]^{\frac{k}{k-1}} = 0.319 P_r = 1.59 \times 10^5 \text{ Pa}
\]

From normal-shock table (App.B), \( \frac{P_e}{P_1} = 2.10 \) (for $M_1 = 1.39$)

\[P_e = P_2 = 2.10 P_1 = 3.35 \times 10^5 \text{ Pa}
\]

From table, $M_2 = 0.745$ \( T_0 = T_{o1} = T_r = 300 \text{ K} \)

\[T_2 = T_0 \left[1 + \frac{k}{2} M_2^2\right]^{\frac{k}{k-1}} = 0.9 T_r = 270 \text{ K}
\]

Could also use shock temp. ratio \( \frac{T_2}{T_1} = 1.25 \), with $T_1 = T_0 \left[1 + \frac{k}{2} M_1^2\right]^{-1} = 216 \text{ K}$

$T_2 = 1.25 T_1 = 270 \text{ K}$ same result,