1. $V_1 = 60$ m/s, $T_1 = 323$ K, $p_1 = 35$ kPa, $Q = 1160$ kJ/kg

$$M_1 = \frac{V_1}{a_1} = 0.167$$

From isentropic tables, $\frac{T_{01}}{T_1} = 0.994$

$$\Rightarrow T_{01} = 324.95 \text{ K}$$

$$Q = c_p (T_{02} - T_{01})$$

$$\Rightarrow T_{02} = 1479.18 \text{ K}$$

$$\frac{T_{02}}{T_{01}} = \frac{(T_0/T^*)_{M_2}}{(T_0/T^*)_{M_1}} \Rightarrow \left(\frac{T_0}{T^*}\right)_{M_2} = 0.5663$$

$$\Rightarrow M_2 = 0.42$$

$$T_2 = \frac{T_2/T^*}{T_1/T^*} \cdot T_1 = 1399.56 \text{ K}$$

$$p_2 = \frac{p_2/p^*}{p_1/p^*} \cdot p_1 = 29.1725 \text{ kPa}$$

2. $D = 0.16$, $M_1 = 0.36$, $f = 0.0025$, $(p_{01} - p_{02})/p_{01} = 0.1$

$$\frac{p_{02}}{p_{01}} = 0.9 = \frac{(p_0/p_0^*)_{M_2}}{(p_0/p_0^*)_{M_1}}$$

$$\Rightarrow \frac{p_{02}}{p_0^*} = 1.5622 \Rightarrow M_2 = 0.41$$

$$\frac{4f l_{12}}{D} = 3.1801 - 2.14145 = 1.03905$$

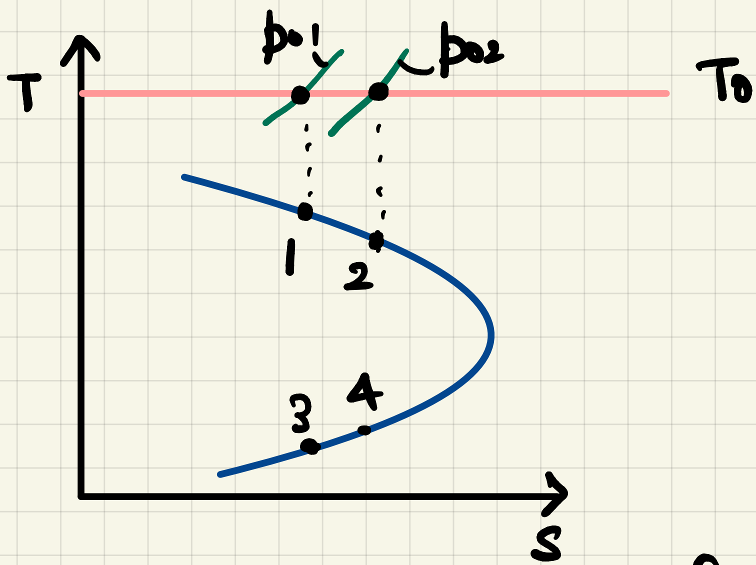
$$\Rightarrow L = 16.625 \text{ m}$$

For sonic outlet

$$\frac{p_{02}}{p_{01}} = \frac{p_0^*}{p_{01}} = 0.576$$

$$\Rightarrow \frac{p_{02} - p_{01}}{p_{01}} = 0.424 \ (42.4\%)$$

3. (a, b)



Direction of the process is always from 1 to 2 and 3 to 4 (increasing entropy)

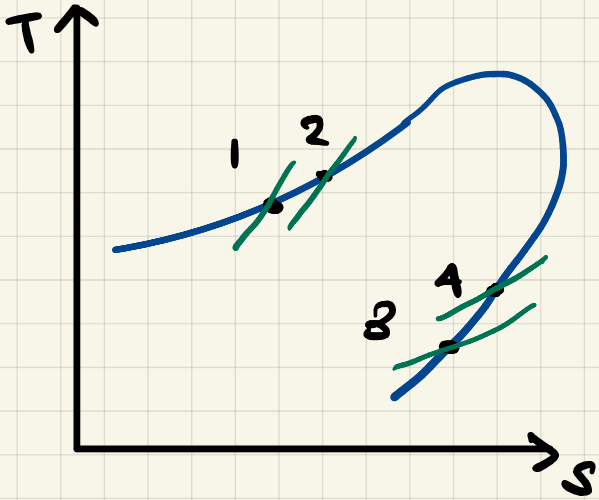
Looking at the direction of increasing p_0 on a T-s graph (from bottom right to top left, we have $p_{02} < p_{01}$ i.e. stagnation pressure decreases from 1 to 2

$$T_0 = T + \frac{V^2}{2C_p} = T + \frac{\overbrace{(\rho V)}^{\text{constant}}{}^2}{2\rho^2 C_p}$$

$\Rightarrow$ density decreases from 1 to 2 as $T_1 > T_2$ on the T-s diagram

$\|^{ly}$ p_0 decreases from 3 to 4 and ρ increases as $T_3 < T_4$ on the T-s diagram

(c, d)



Direction of process is from 1 to 2 and 3 to 4 (for $q > 0$)

Looking at the direction of increasing p_0 on a T-s graph (from bottom right to top left, we have $p_{02} < p_{01}$ i.e. stagnation pressure decreases from 1 to 2

or $\frac{dp_0}{\rho} + ds(T_0 - T) = 0$

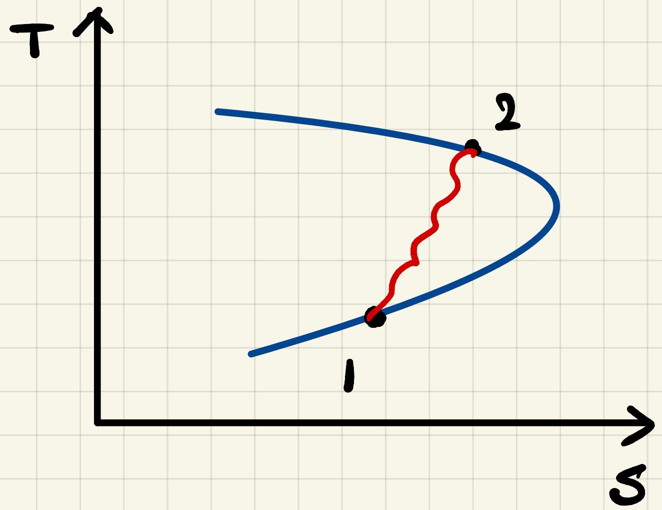
$\Rightarrow dp_0 < 0$ for $ds > 0$

$\parallel^{ly}$ stagnation pressure decreases from 3 to 4.

Also, $$p + \frac{\overbrace{(\rho v)^2}^{\text{const}}}{\rho} = \text{constant}$$

we have $p_1 > p_2$ and $p_4 > p_3$ on T-s diagram

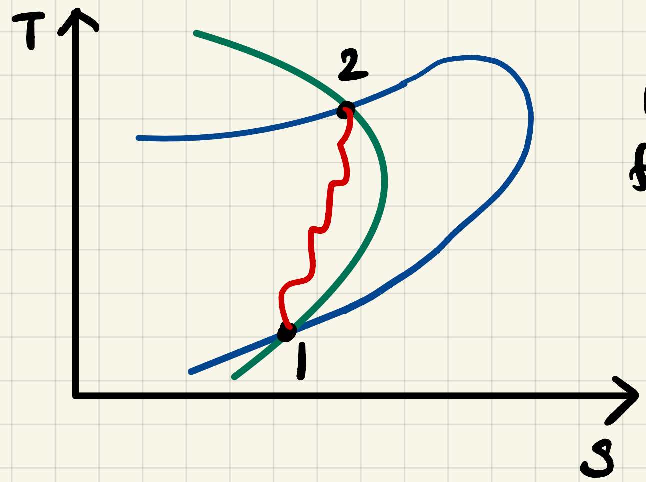
$\Rightarrow$ density decreases from 1 to 2 and increases from 3 to 4 e)



Shock increases entropy

Along a Fanno line T_0 is fixed. T_0 is also fixed for a normal shock. The points before and after the normal shock have the same mass flow per unit area (ρv) and the same value of $p + \rho v^2$. For Fanno flow, there are only two points that have the same value of $p + \rho v^2$ (one subsonic and other supersonic, 1 & 2). Only at these two points are the shock conditions satisfied

f)



Normal shock from 1 to 2

Only at points 1 & 2 are all the conditions for a normal shock satisfied, $\rho v = \text{const}$, $p + \rho v^2 = \text{const}$ & $T + \frac{v^2}{2c_p} = \text{const}$