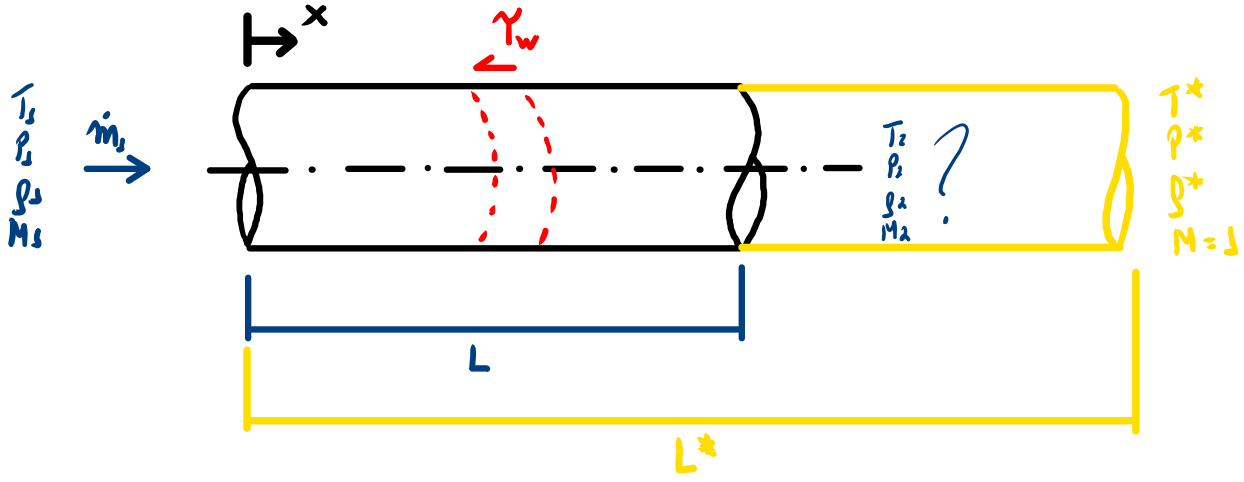
ESCOAMENTO COMPRESSÍVEL

ESCOAMENTO DE FANNO

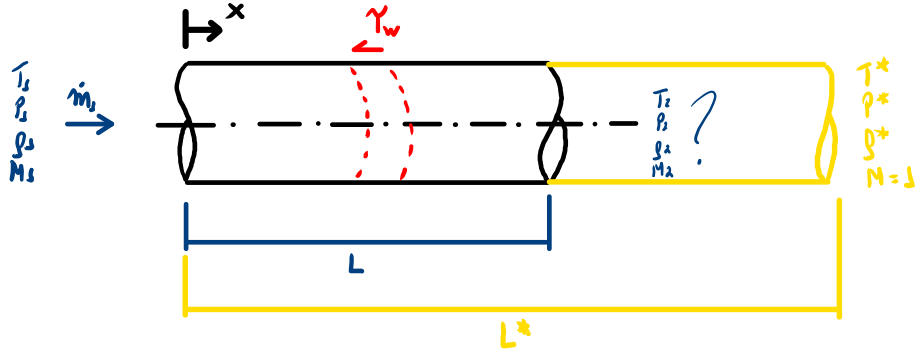
EXERCÍCIO UTILIZANDO TABELA PARA CONDIÇÃO SÔNICA



ESCOAMENTO DE FANNO

ESCOAMENTO COM ATRITO

Escoamento de Fanno se refere a um escoamento adiabático com atrito, através de um duto de área constante.



$$\int_{x_1}^{x_2} 4\frac{f}{D}\,dx = \left[-\frac{1}{kM^2} - \frac{k+1}{2k} \ln\left(\frac{M^2}{1+\frac{k-1}{2}M^2} \right) \right]_{M_1}^{M_2}$$

$$\frac{T_2}{T_1} = \frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}$$

$$\frac{\rho_2}{\rho_1} = \frac{M_1}{M_2}\left[\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2} \right]^{1/2}$$

$$\frac{Q_2}{Q_1} = \frac{M_1}{M_2}\left[\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2} \right]^{-1/2}$$

$$\frac{p_{o2}}{p_{o1}} = \frac{M_1}{M_2}\left[\frac{2+(k-1)M_2^2}{2+(k-1)M_1^2} \right]^{\frac{(k+1)}{2(k-1)}}$$

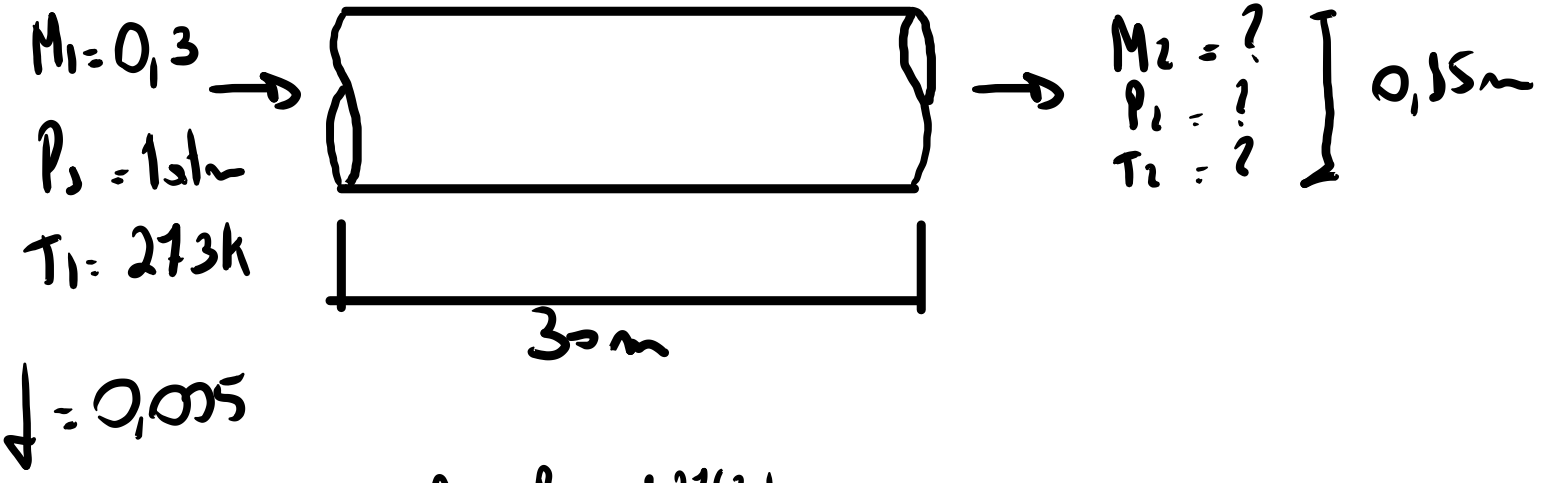
$$\frac{T^*}{T} = \frac{2+(k-1)M^2}{k+1}$$

$$\frac{p^*}{p} = M\left[\frac{2+(k-1)M^2}{k+1} \right]^{1/2}$$

$$\frac{\rho^*}{\rho} = M\left[\frac{2+(k-1)M^2}{k+1} \right]^{-1/2}$$

$$\frac{p_o^*}{p_o} = M\left[\frac{k+1}{2+(k-1)M^2} \right]^{\frac{(k+1)}{2(k-1)}}$$

Considere o escoamento de ar ao longo de um duto com diâmetro D=0,15m e comprimento 30m. As condições de entrada são M_1=0,3 P_1=1atm T_1=273K. Assumindo f=0,005, calcule as condições no escoamento na saída. M_2,T_2,P_2, P_{o2}



$$\rho_1 = \frac{P_1}{RT_1} = 1,2763 \frac{kg}{m^3}$$

$$\frac{P_{o1}}{P_1} = \left(\frac{T_{o1}}{T_1}\right)^{k/k-1} = \left(1 + \frac{k-1}{2} M_1^2\right)^{k/k-1} \Rightarrow P_{o1} = 1,0644\ atm$$

CALCULAR PROPRIEDADES SÔNICAS

Tabela 1.4 – Tabela para Escoamento unidimensional com atrito. $k = 1,4$

M	$\frac{T}{T^*}$	$\frac{P}{P^*}$	$\frac{\rho}{\rho^*}$	$\frac{P_0}{P_0^*}$	$\frac{4fL^*}{D}$
0,02	1,19990	54,77006	45,64537	28,94213	1778,44988
0,04	1,19962	27,38175	22,82542	14,48149	440,35221
0,06	1,19914	18,25085	15,21999	9,66591	193,03108
0,08	1,19847	13,68431	11,41819	7,26161	106,71822
0,1	1,19760	10,94351	9,13783	5,82183	66,92156
0,12	1,19655	9,11559	7,61820	4,86432	45,40796
0,14	1,19531	7,80932	6,53327	4,18240	32,51131
0,16	1,19389	6,82907	5,72003	3,67274	24,19783
0,18	1,19227	6,06618	5,08791	3,27793	18,54265
0,2	1,19048	5,45545	4,58258	2,96352	14,53327
0,22	1,18850	4,95537	4,16945	2,70760	11,59605
0,24	1,18633	4,53829	3,82548	2,49556	9,38648
0,26	1,18399	4,18505	3,53470	2,31729	7,68757
0,28	1,18147	3,88199	3,28571	2,16555	6,35721
0,3	1,17878	3,61906	3,07017	2,03507	5,29925
0,32	1,17592	3,38874	2,88179	1,92185	4,44674

$\frac{T}{T^*} = 1,17878 \rightarrow T^* = 231,535\,K$

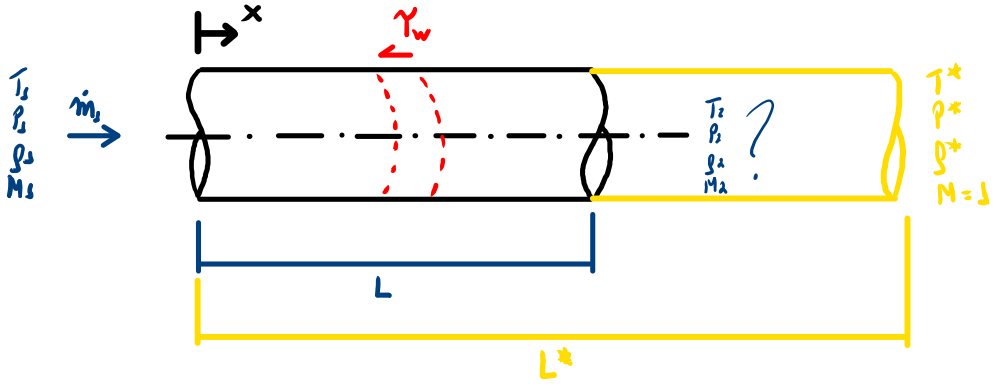
$\frac{P}{P^*} = 3,61906 \rightarrow P^* = 0,2763\,atm$

$\frac{\rho}{\rho^*} = 3,07017 \rightarrow \rho^* = 0,4157\,\frac{kg}{m^3}$

$\frac{P_0}{P_0^*} = 2,03507 \rightarrow P_0^* = 0,5230\,atm$

$\frac{4fL^*}{D} = 5,29925 \rightarrow L^* = 39,7443\,m$

CALCULAR L^* e L_2



$L^* = 33,14\ m$ ⇒ $L_2 = L^* - L$

$L_2 = 33,14 - 30 = 3,14\ m$

$$\frac{4}{D}L^* = \frac{4 \times 0,005 \times 3,14}{0,15} = 1,29325$$

Tabela 1.4 – Tabela para Escoamento unidimensional com atrito. $k = 1,4$

M	$\frac{T}{T*}$	$\frac{P}{P*}$	$\frac{\rho}{\rho*}$	$\frac{P_o}{P_{o}*}$	$\frac{4fL*}{D}$
0,02	1,19990	54,77006	45,64537	28,94213	1778,44988
0,04	1,19962	27,38175	22,82542	14,48149	440,35221
0,06	1,19914	18,25085	15,21999	9,66591	193,03108
0,08	1,19847	13,68431	11,41819	7,26161	106,71822
0,1	1,19760	10,94351	9,13783	5,82183	66,92156
0,12	1,19655	9,11559	7,61820	4,86432	45,40796
0,14	1,19531	7,80932	6,53327	4,18240	32,51131
0,16	1,19389	6,82907	5,72003	3,67274	24,19783
0,18	1,19227	6,06618	5,08791	3,27793	18,54265
0,2	1,19048	5,45545	4,58258	2,96352	14,53327
0,22	1,18850	4,95537	4,16945	2,70760	11,59605
0,24	1,18633	4,53829	3,82548	2,49556	9,38648
0,26	1,18399	4,18505	3,53470	2,31729	7,68757
0,28	1,18147	3,88199	3,28571	2,16555	6,35721
0,3	1,17878	3,61906	3,07017	2,03507	5,29925
0,32	1,17592	3,38874	2,88179	1,92185	4,44674
0,34	1,17288	3,18529	2,71577	1,82288	3,75195
0,36	1,16968	3,00422	2,56841	1,73578	3,18012
0,38	1,16632	2,84200	2,43673	1,65870	2,70545
0,4	1,16279	2,69582	2,31840	1,59014	2,30849
0,42	1,15911	2,56338	2,21151	1,52890	1,97437
0,44	1,15527	2,44280	2,11449	1,47401	1,69152
0,46	1,15128	2,33256	2,02606	1,42463	1,45091
0,48	1,14714	2,23135	1,94514	1,38010	1,24534
0,5	1,14286	2,13809	1,87083	1,33984	1,06906

$T^* = 231,595\ K$; $P^* = 0,2763\ atm$;
$\rho^* = 0,4157\ kg/m^3$; $P_o^* = 0,5230\ atm$;

CIÊNCIAS TÉRMICAS .com

1,45031	0,46	1,15128	2,33256	2,02606	1,42463
1,29325	M	T/T^*	P/P^*	ρ/ρ^*	P_o/P_o^*
1,24534	0,48	1,14714	2,23135	1,94514	1,38010

$M_2 = 0,4747$ (0,4745)

$\frac{T}{T^*} = 1,1482 \rightarrow T_2 = 265,92K$ (265,94)

$\frac{P}{P^*} = 2,2573 \rightarrow P_2 = 0,6238$ (0,624)

$\frac{\rho}{\rho^*} = 1,9664 \rightarrow \rho_2 = 0,8174\ kg/m^3$ (0,8176)

$\frac{P_o}{P_o^*} = 1,3938 \rightarrow P_{o2} = 0,7279\ atm$ (0,728)

$$\Delta s = c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

$$\Delta s = 1{,}004 \frac{kJ}{kg\,K} \ln\left(\frac{265{,}32}{273}\right) - 0{,}287 \frac{kJ}{kg\,K} \ln\left(\frac{0{,}6238}{1}\right)$$

$$\Delta s = 0{,}109 \frac{kJ}{kg\,K}$$

CIÊNCIAS TÉRMICAS .com