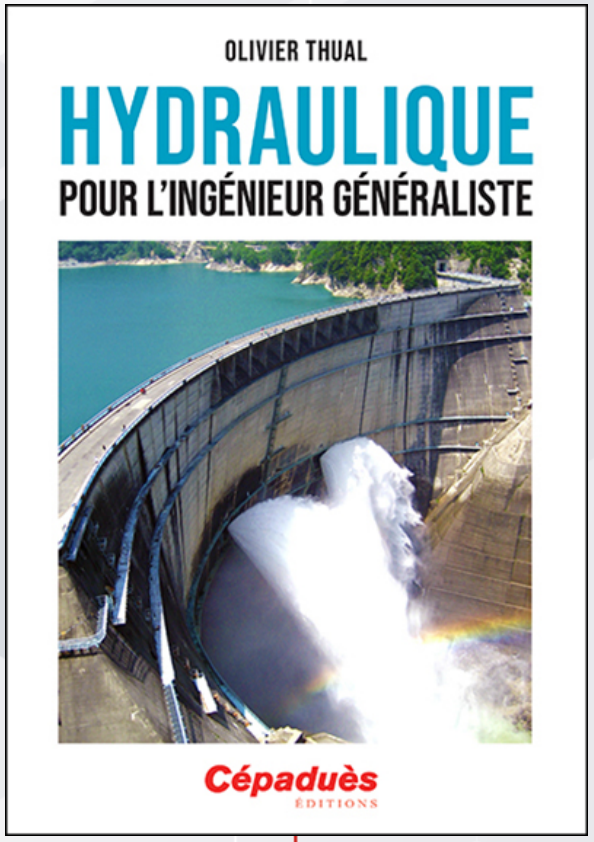
Dans le cadre de la
Formation « Hydraulique Fondamentale »
Unité de Formation pour la Performance Industrielle

EDF

en collaboration avec l'INP-ENSEEIHT



Olivier THUAL
Toulouse INP
ENSEEIHT

INP TOULOUSE ENSEEIHT

Chapitre 4
Hydraulique en charge

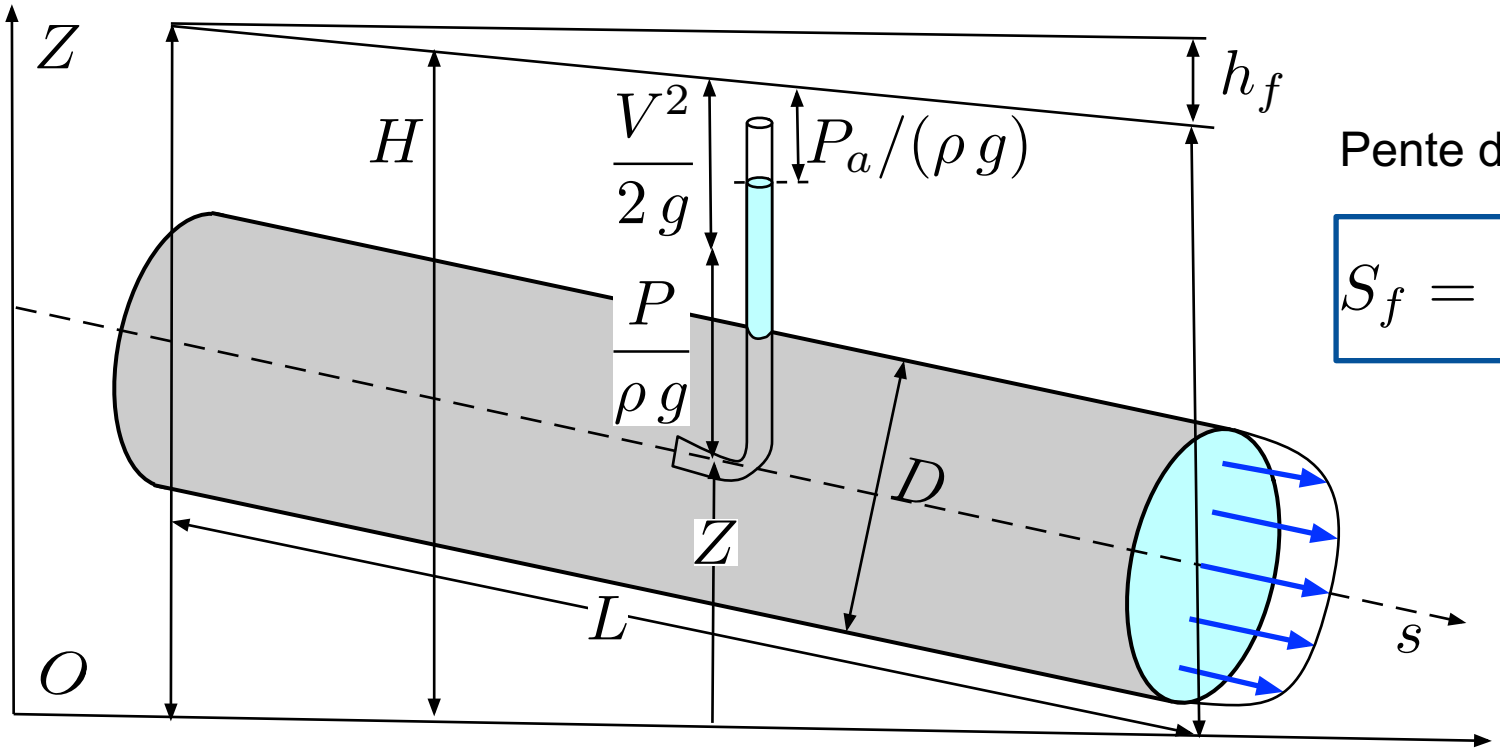
Conduites circulaires en charge

Charge hydraulique

$$H = Z + \frac{P}{\rho\, g} + \frac{V^2}{2\, g}$$

Darcy-Weisbach

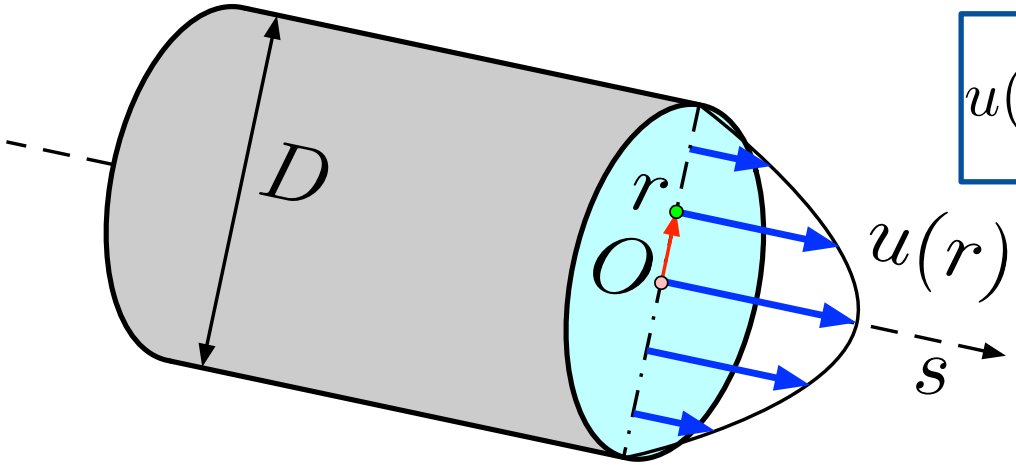
$$S_f = f(r, Re)\, \frac{V^2}{2\, g\, D}$$



Pente de frottement

$$S_f = -\frac{dH}{ds} = \frac{h_f}{L}$$

Écoulement laminaire



$$u(r) = -K_p \frac{dH}{ds} \left(2 - 8 \frac{r^2}{D^2}\right)$$

avec $$K_p = \frac{D^2\, g}{32\, \nu}$$

$$\Longrightarrow \quad V = -K_p \frac{dH}{ds}$$

$$\Longleftrightarrow \quad S_f = f_{lami}(Re) \frac{V^2}{2\, g\, D}$$

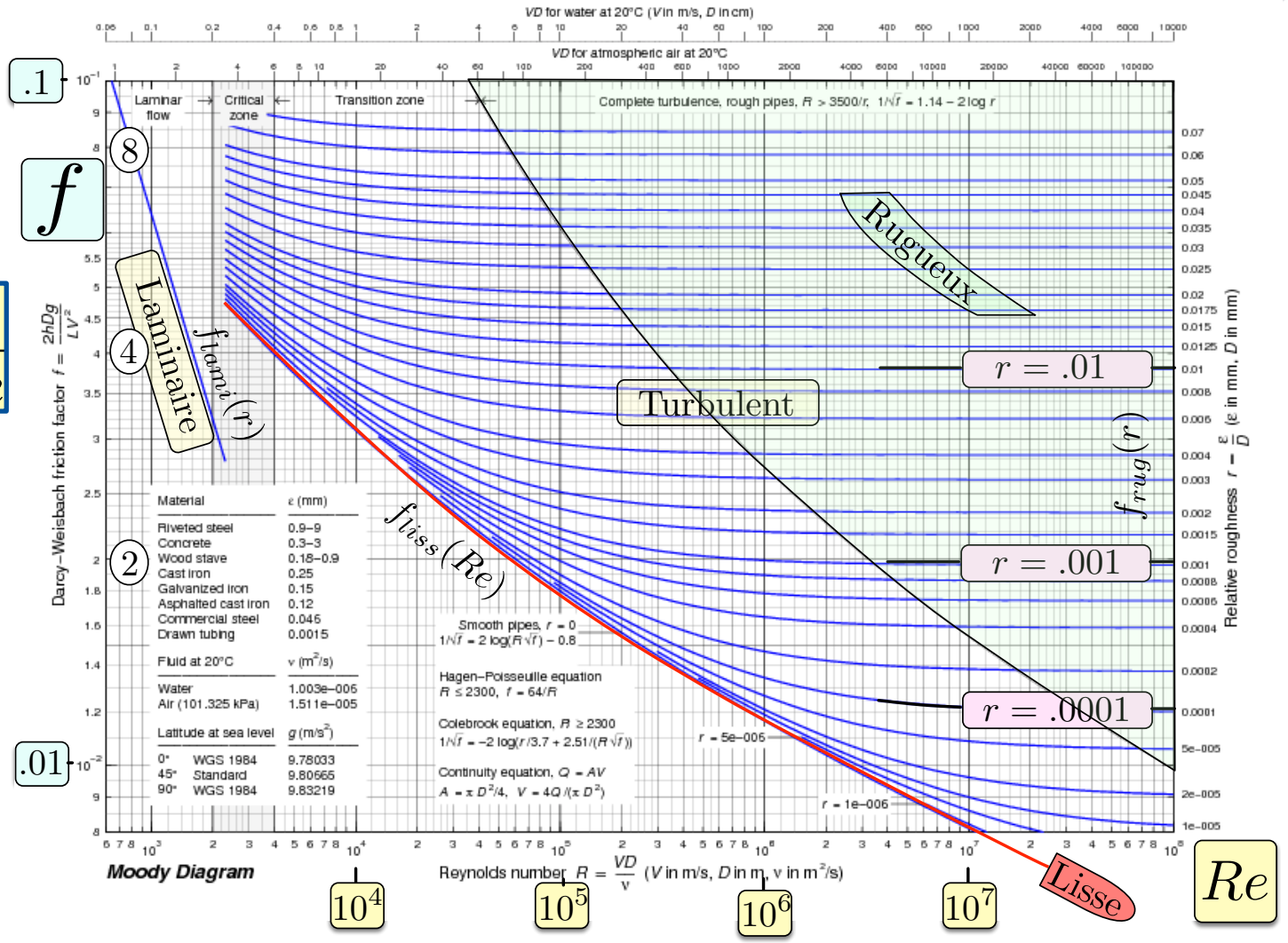
avec $$f_{lami}(Re) = \frac{64}{Re}$$

Diagramme de Moody

$$f_{lami}(Re) = \frac{64}{Re}$$

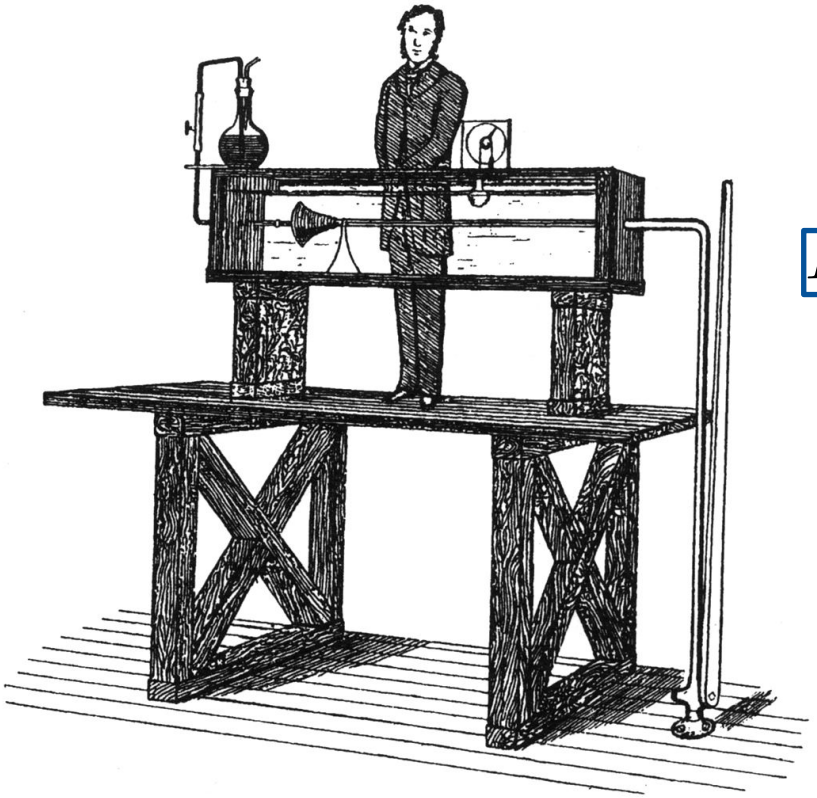
Nombre de Reynolds

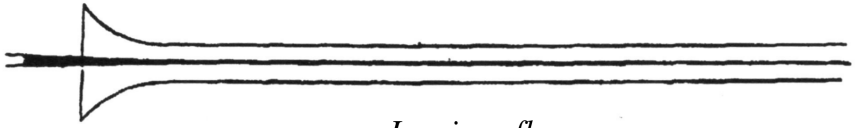
$$Re = \frac{V\,D}{\nu}$$



Transition vers la turbulence

Nombre de Reynolds : $$Re = \frac{V\,D}{\nu}$$

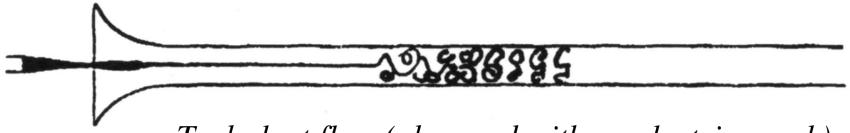




Laminar flow

$$Re_c \sim 2\,300$$

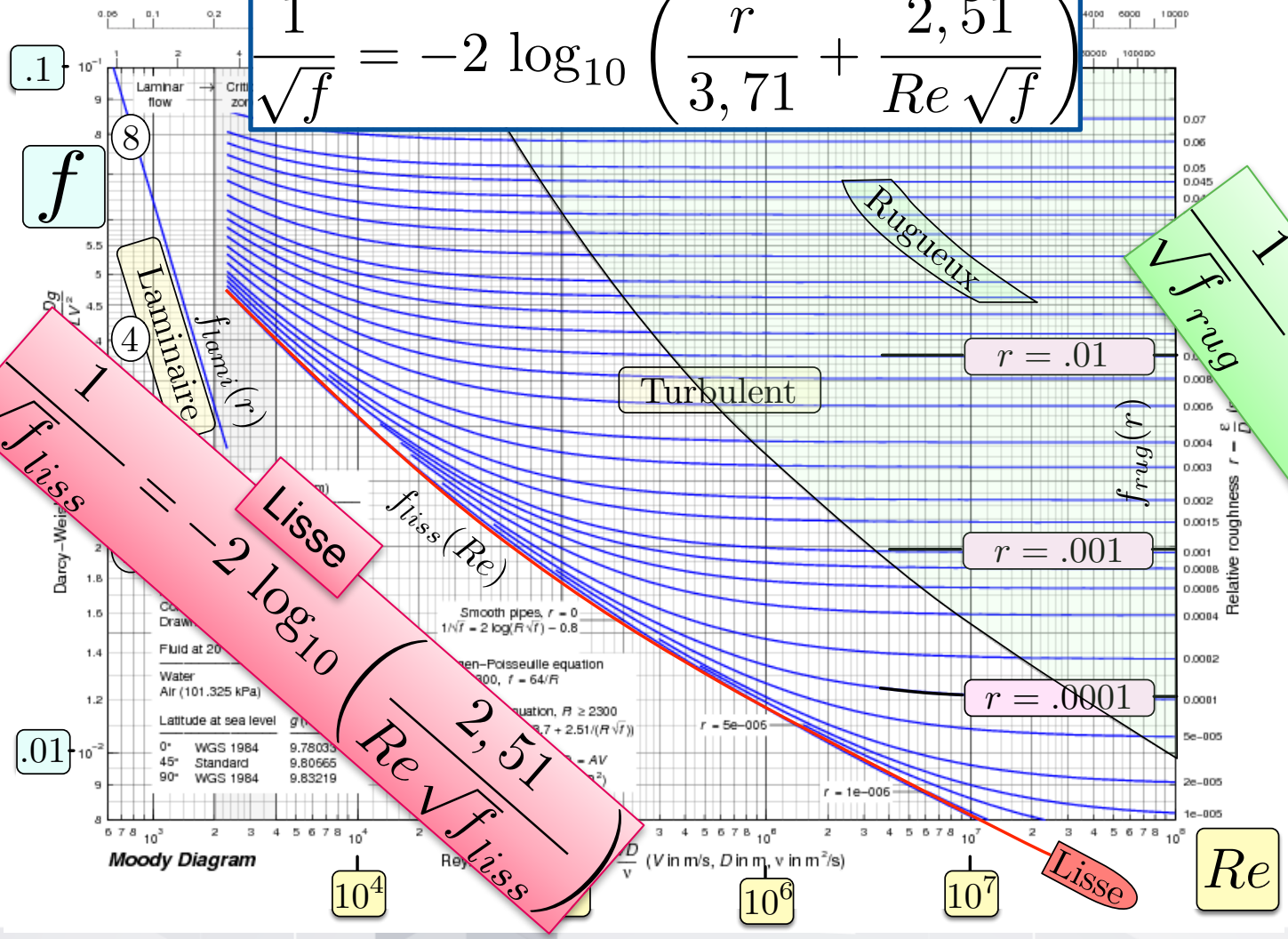
Turbulent flow



Turbulent flow (observed with an electric spark)

Formule de Colebrook

$$\frac{1}{\sqrt{f}} = -2\,\log_{10}\left(\frac{r}{3,71} + \frac{2,51}{Re\,\sqrt{f}}\right)$$



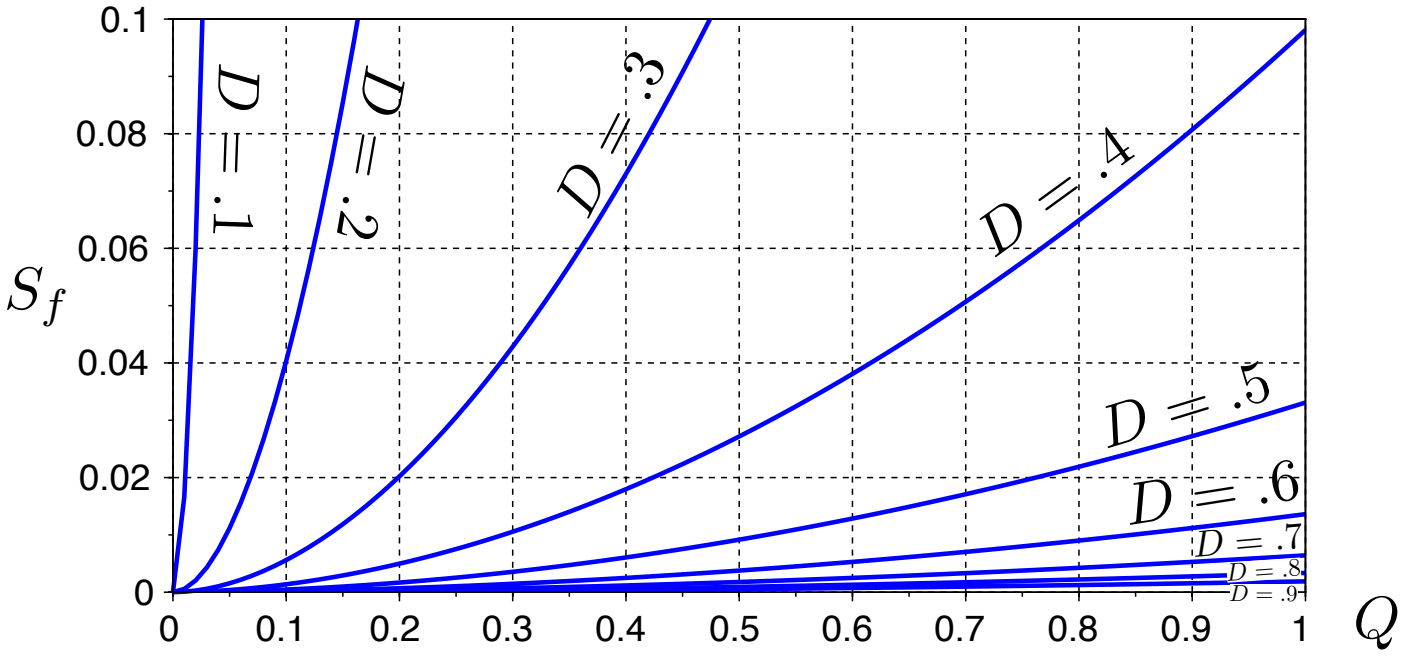
$$\frac{1}{\sqrt{f_{liss}}} = -2\,\log_{10}\left(\frac{2,51}{Re\,\sqrt{f_{liss}}}\right)$$

$$\frac{1}{\sqrt{f_{rug}}} = -2\,\log_{10}\left(\frac{r}{3,71}\right)$$

Formule de Hazen-Williams

$$S_f = 10,675 \left(\frac{Q}{C_{HW}} \right)^{1,852} \frac{1}{D^{4,87}}$$

Matériaux	C_{HW}
Polytéthylène	150
Cuivre	130-140
Acier	110-120
Fonte	100-140
Béton	90-130

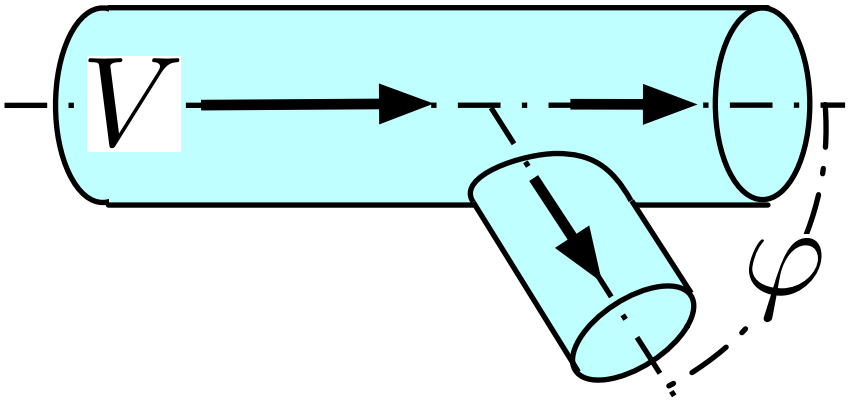


Perte de charge singulière

$$h_s = K \frac{V^2}{2\,g}$$

Basée sur la vitesse en amont

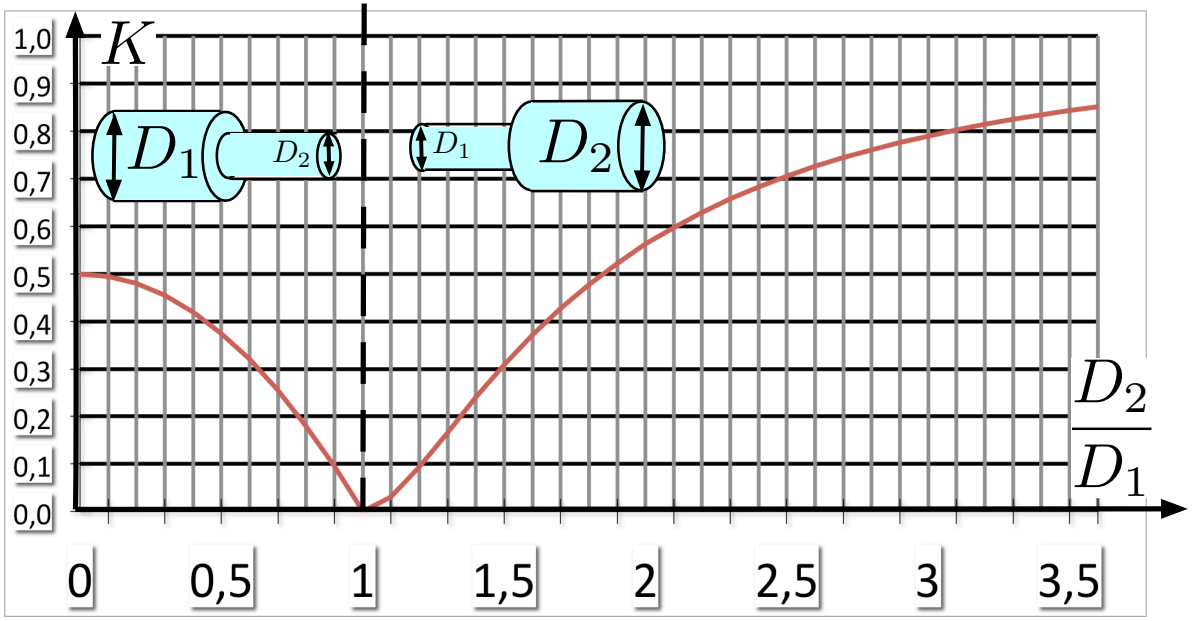
Coefficient de perte de charge singulière



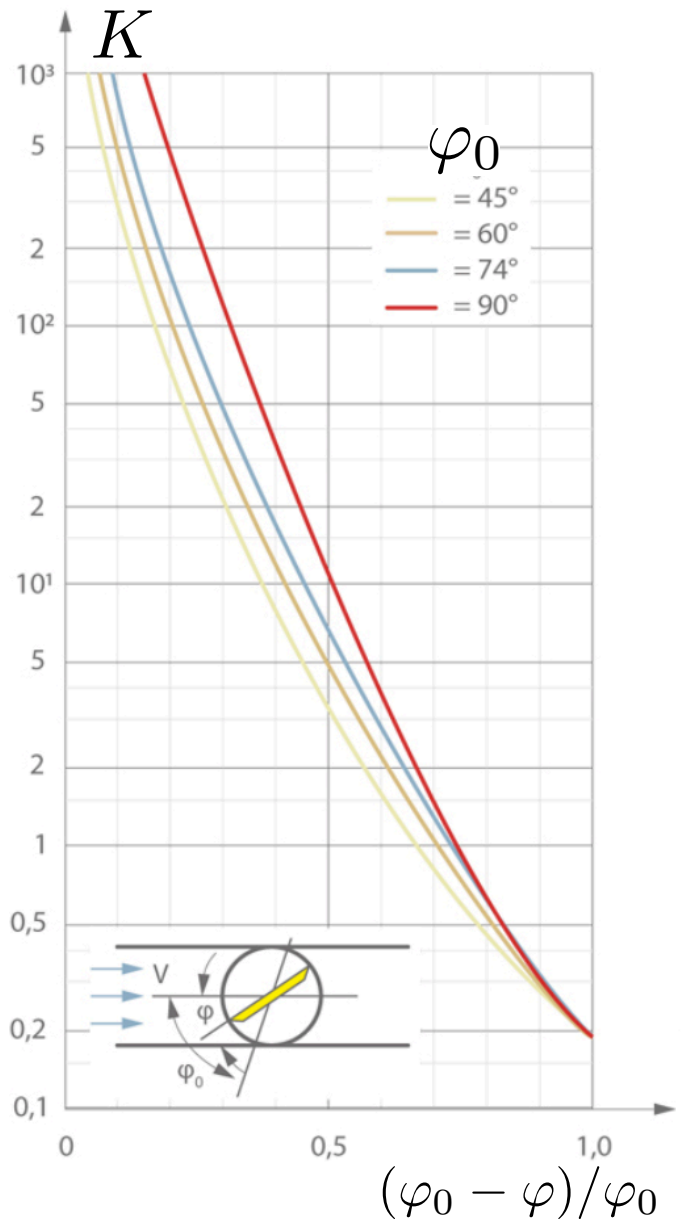
φ	$\pi/12$	$\pi/6$	$\pi/4$	$3\,\pi/6$	$\pi/2$
K	0,1	0,3	0,5	0,7	1,3

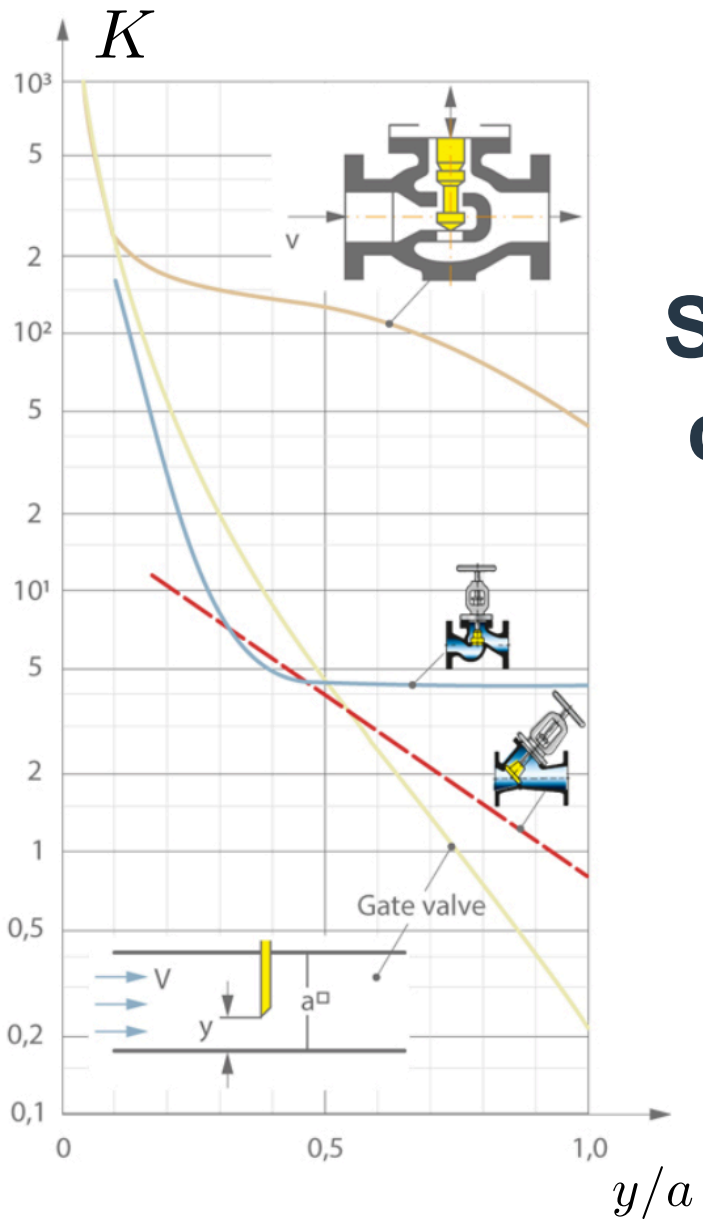
Variation brusque de section

$$K = \begin{cases} 0,5\left[1-\left(\frac{D_2}{D_1}\right)^2\right] & \text{si} \quad D_1 > D_2\ , \\ \left[1-\left(\frac{D_2}{D_1}\right)^{-2}\right]^2 & \text{si} \quad D_1 < D_2\ . \end{cases}$$



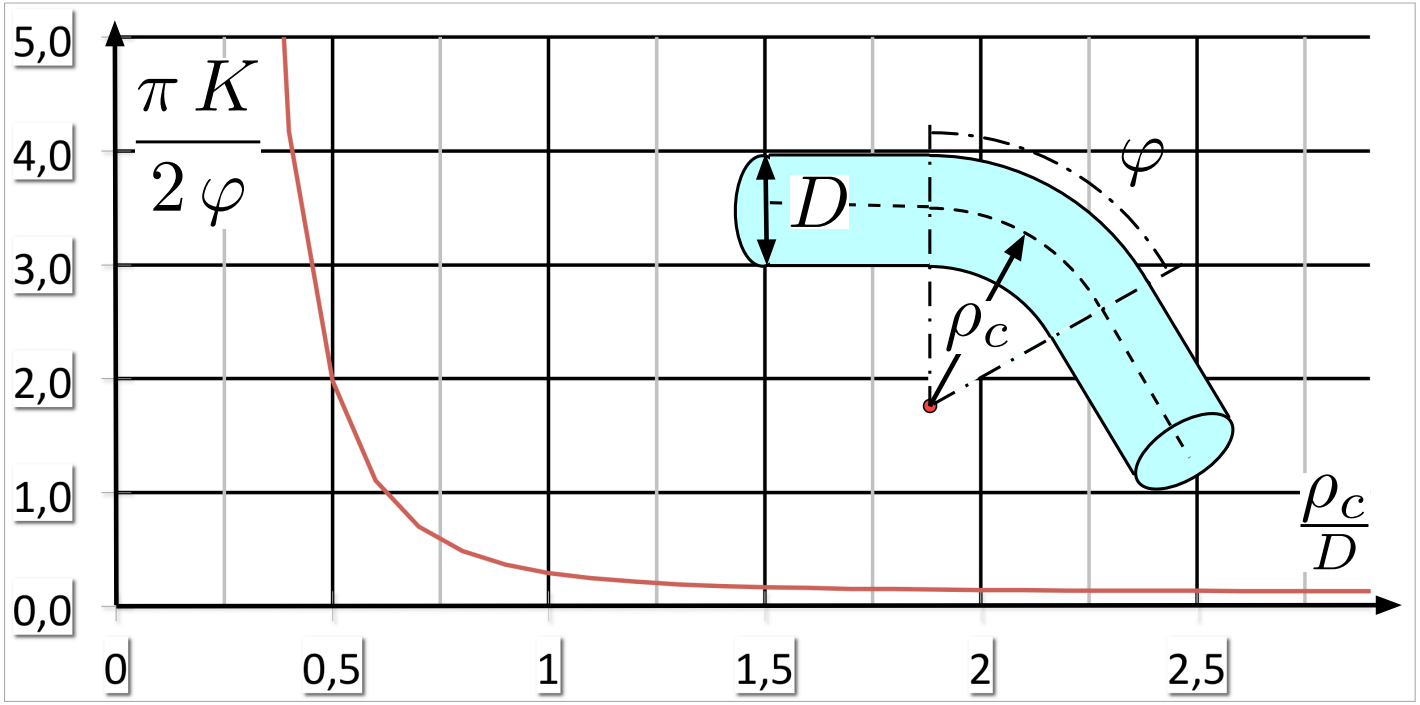
Singularités complexes



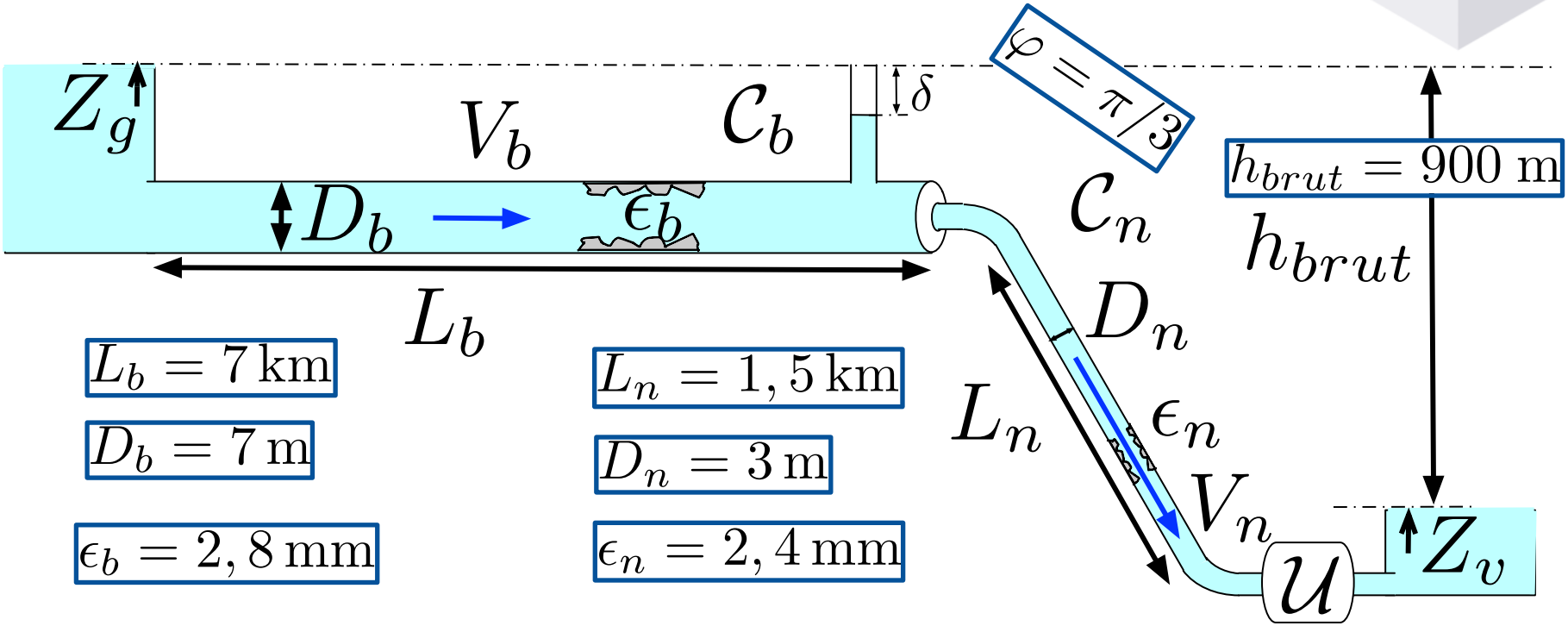


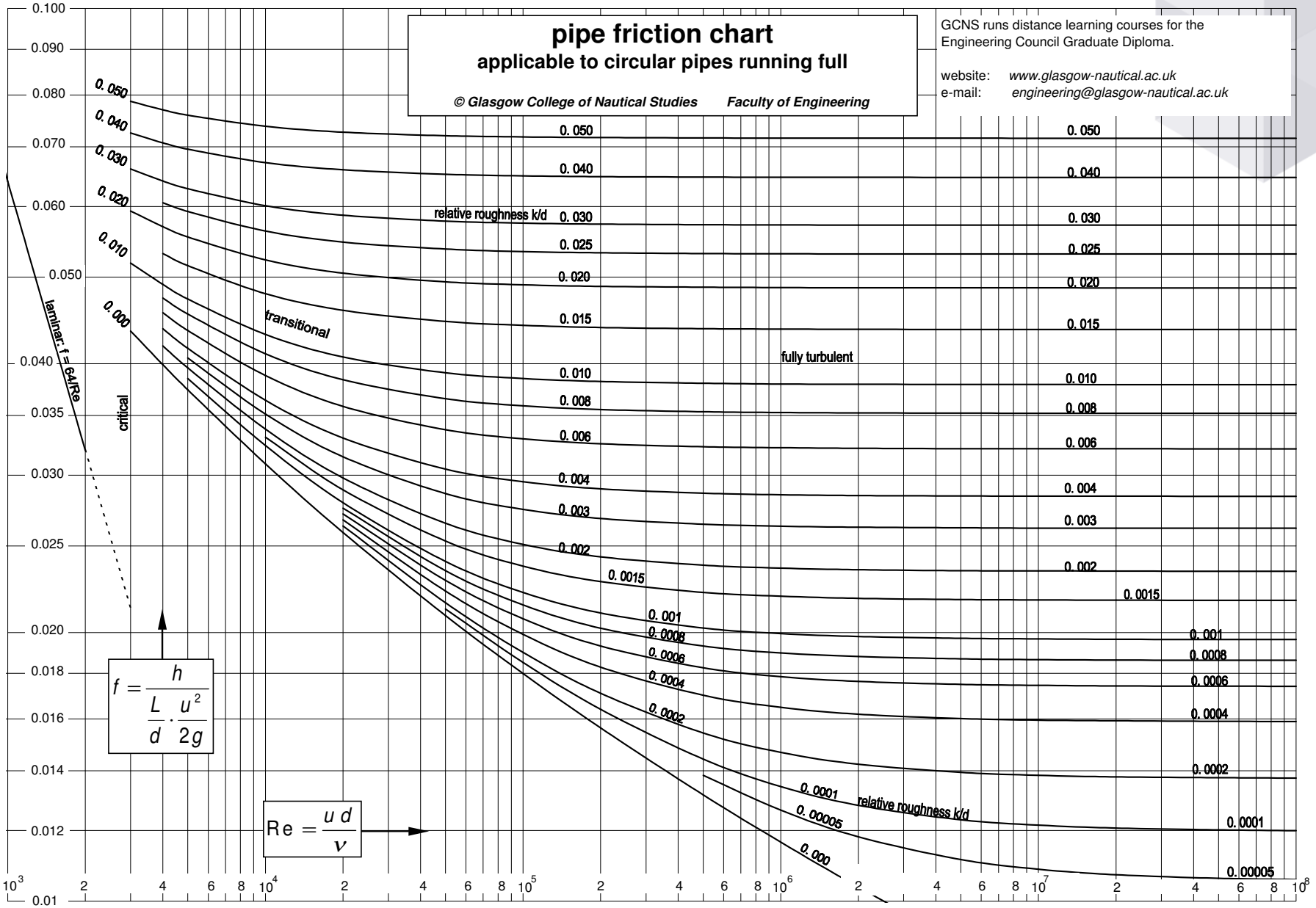
Coude

$$K = \frac{2\,\varphi}{\pi}\left[0,131 + 1,847\left(\frac{2\,\rho_c}{D}\right)^{-3,5}\right]$$



Rendement d'un barrage




pipe friction chart
applicable to circular pipes running full
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relative roughness k/d
0. 050
0. 040
0. 030
0. 025
0. 020
0. 015
0. 010
0. 008
0. 006
0. 004
0. 003
0. 002
0. 0015
0. 001
0. 0008
0. 0006
0. 0004
0. 0002
0. 0001
0. 00005
0. 000
laminar: f = 64/Re
critical
transitional
fully turbulent
$f = \frac{h}{\frac{L}{d} \cdot \frac{u^2}{2g}}$
$Re = \frac{u\,d}{\nu}$
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.035
0.030
0.025
0.020
0.018
0.016
0.014
0.012
0.01
10^3 2 4 6 8 10^4 2 4 6 8 10^5 2 4 6 8 10^6 2 4 6 8 10^7 2 4 6 8 10^8