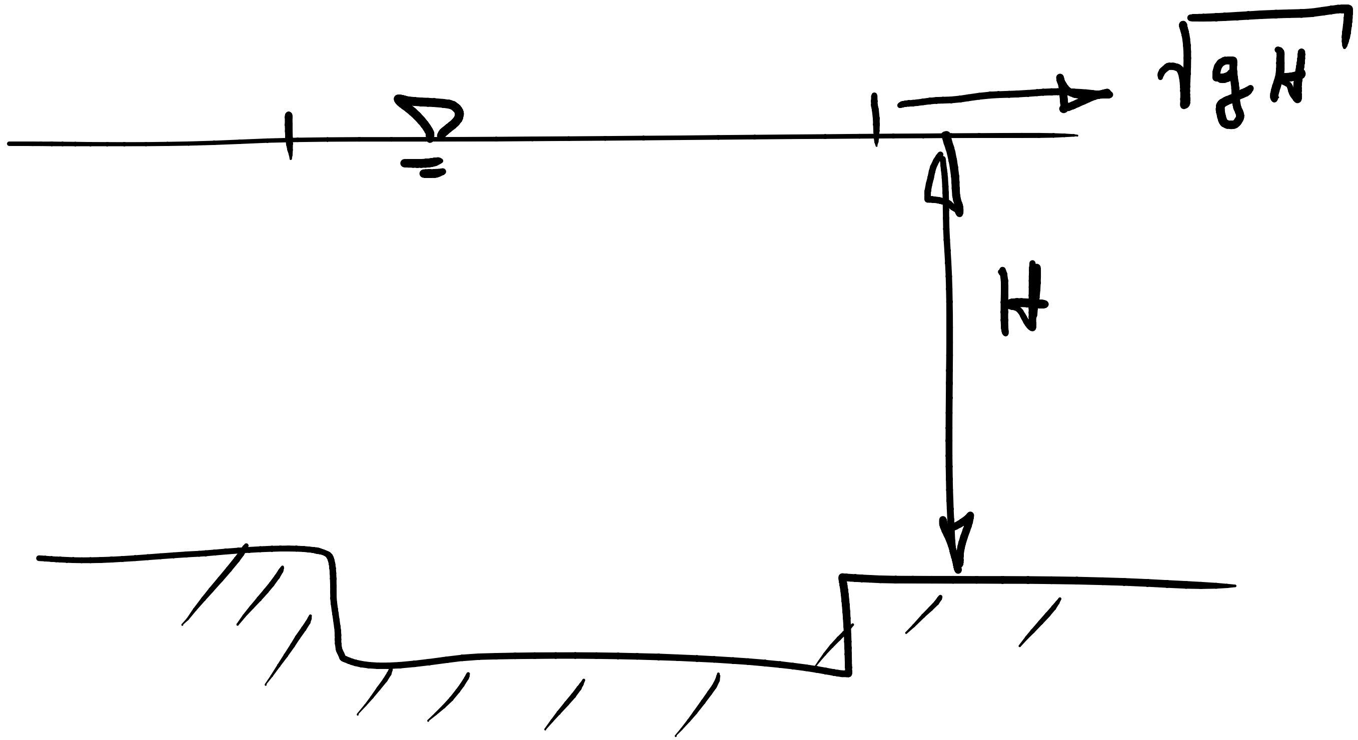
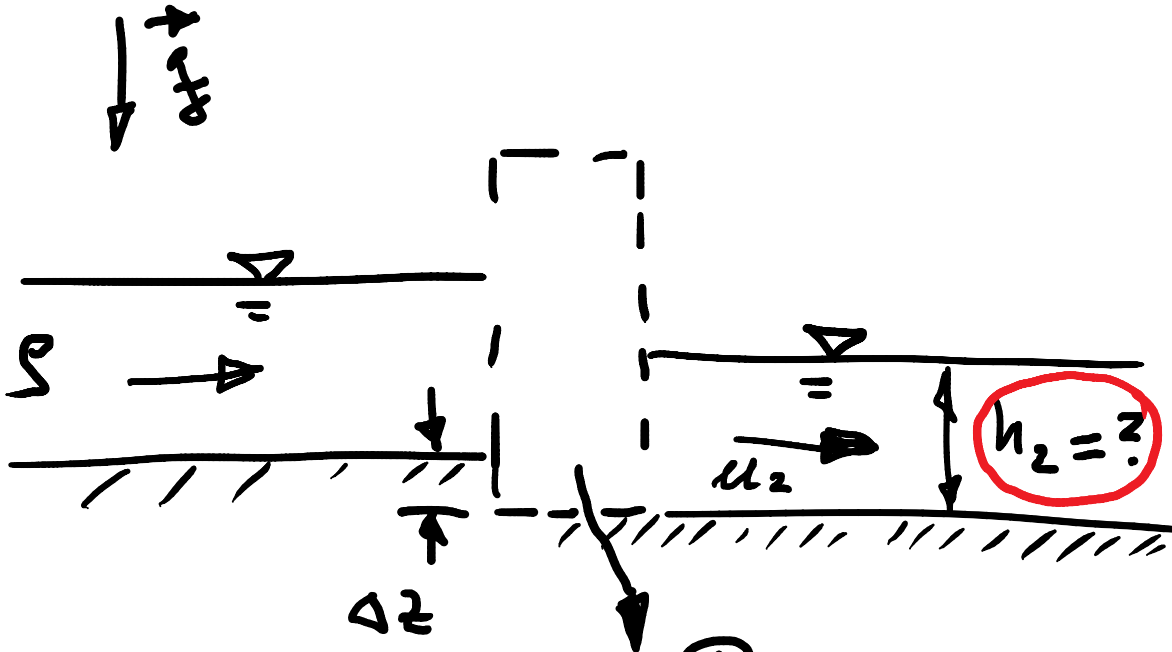
Gerinne - Strömung



Optimierung des Betriebsverhaltens einer Wasserkraftanlage in einem Gerinne.



$Q = q_2 b$ $\qquad q_2 = ?$

$P_{T\max} = ?$:

$$\left.\begin{aligned} \frac{\partial P_T}{\partial h_2} &\overset{!}{=} 0 \\ \frac{\partial P_T}{\partial q_2} &\overset{!}{=} 0 \end{aligned}\right\} \quad \begin{aligned} &h_{2opt} \\ &q_{2opt} \end{aligned}$$

smart hydro

kleine Wasserkraft.

Q Volumenstrom ($\dot{V}$)

b Gerinnebreite

$q = \frac{Q}{b}$ Volumenstrom pro Breite

$u = \frac{Q}{bh}$

h Wassertiefe.

q

h

$\frac{u}{\sqrt{gh}} = Fr = \frac{q}{g^{\frac{1}{2}} h^{3/2}}$

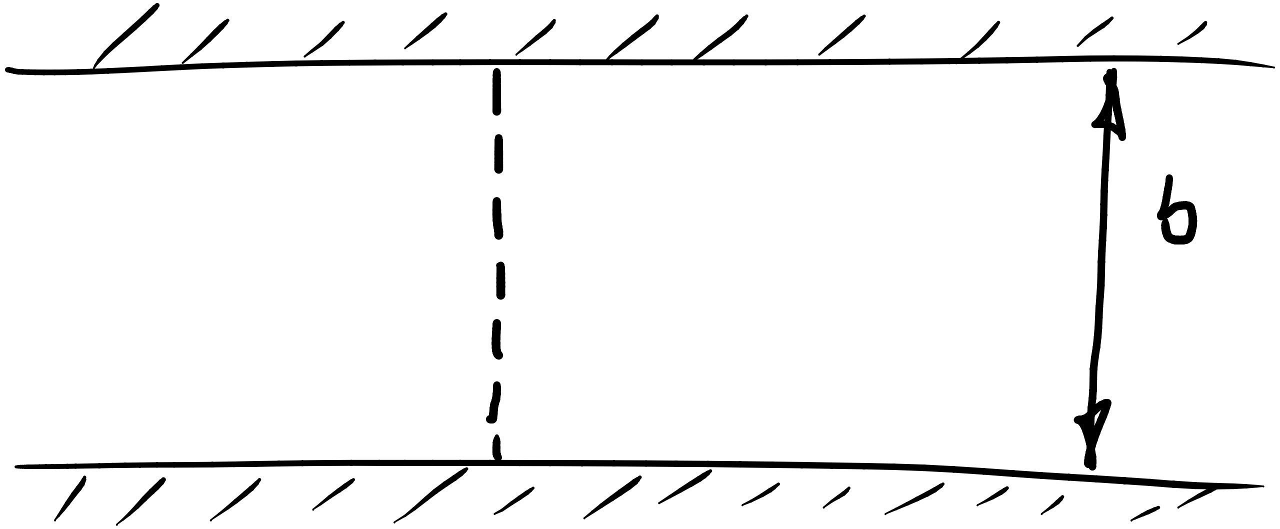
h

TECHNISCHE UNIVERSITÄT DARMSTADT

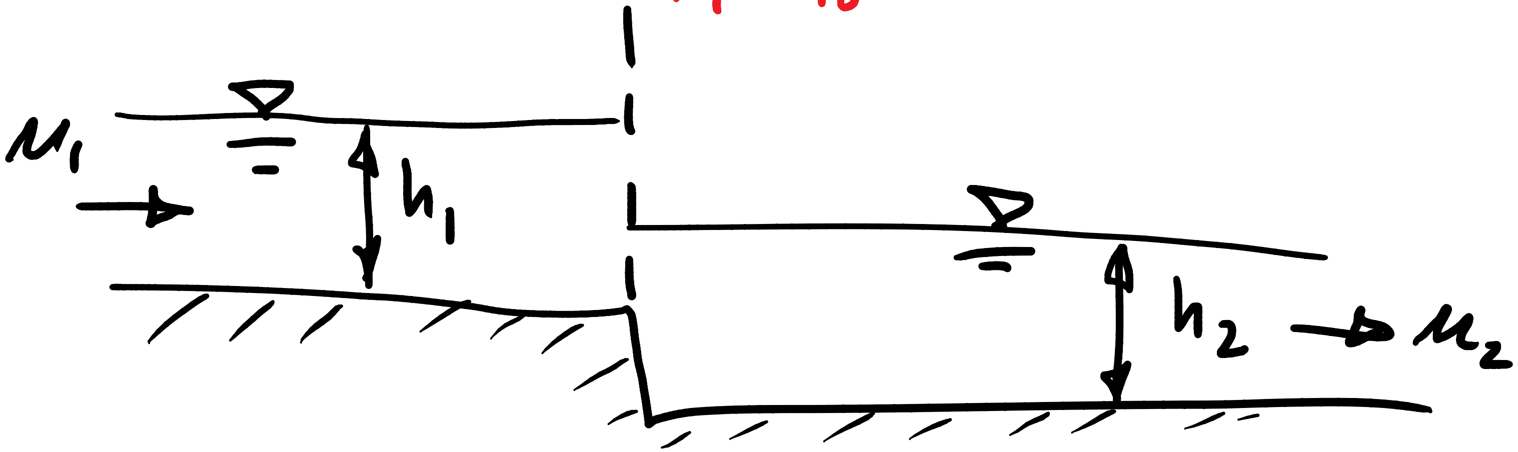
FLUID SYSTEM TECHNIK

Optimierung und Skalierung von Fluidsystemen

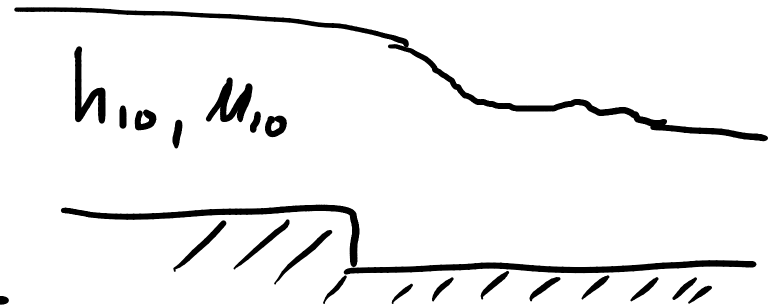
Draufsicht mit Maschine.



$h_{10} \neq h_1$ $u_1 \neq u_{10}$



ohne Maschine.



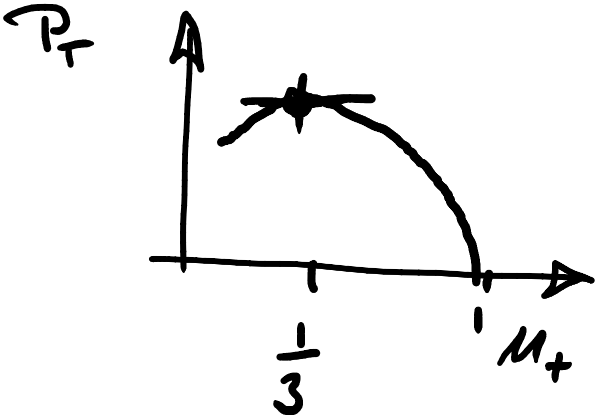
Hier: Wir optimieren unabhängig von gesetzlichen Vorschriften

„... dem Anderen das Wasser abgraben..."

fischfreundliche Turbine aus gesellschaftlicher Akzeptanz.

Wind

$$\frac{u_2}{u_1} := u_+$$

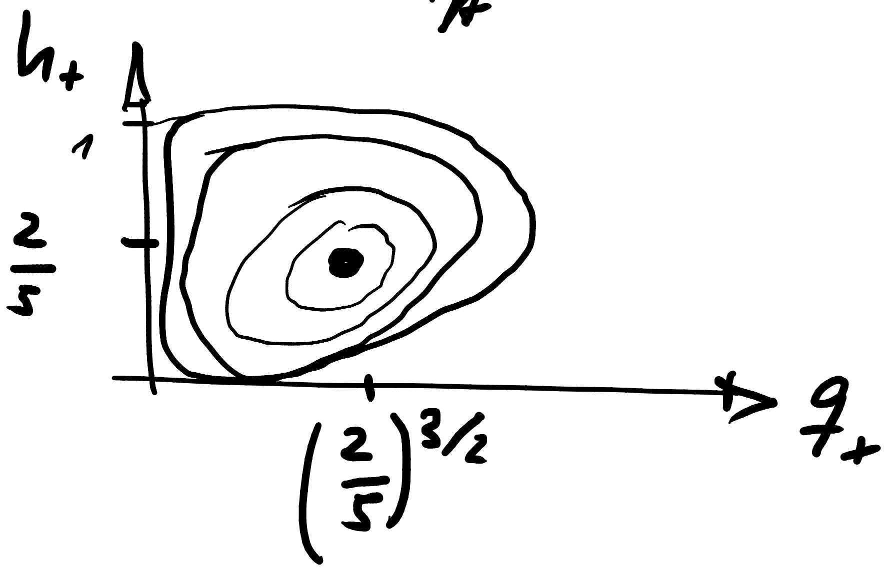


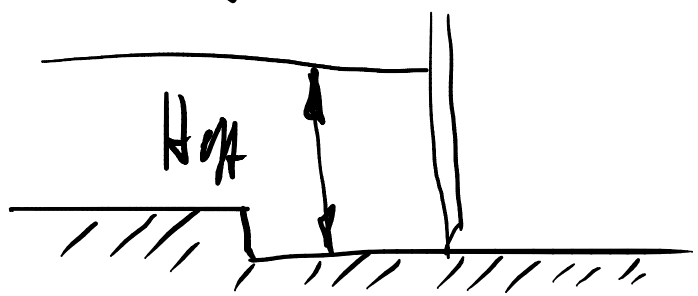
$$P_{avail} := \frac{\rho}{2} u_1^3 A$$

$$c_p := \frac{P_T}{P_{avail}}$$

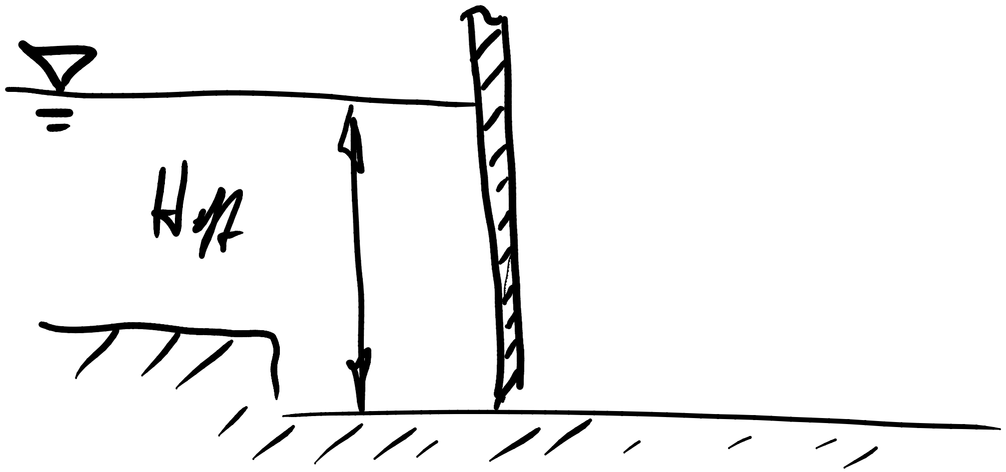
kleine Wasserkraft

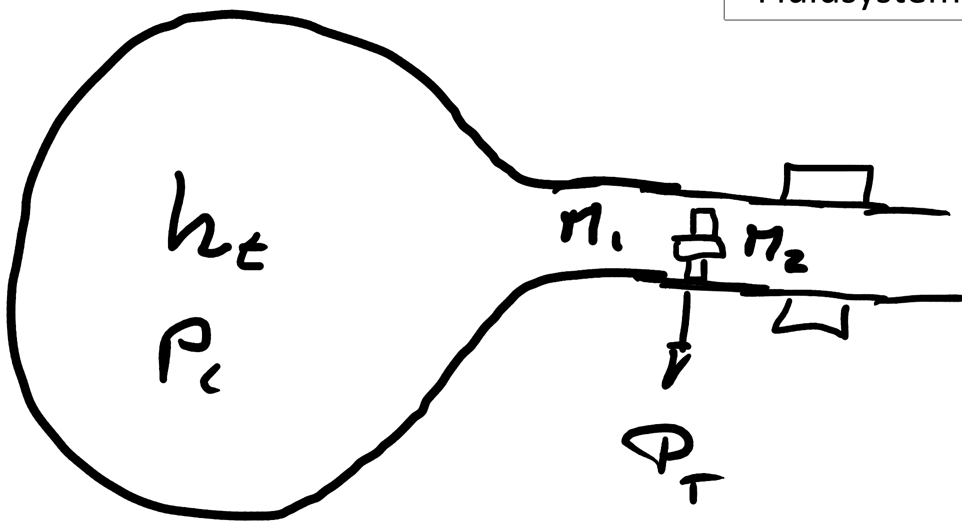
$$q_+ := \frac{q_z}{g^{1/2} H_{eff}^{3/2}} , \quad h_+ := \frac{h_z}{H_{eff}}$$



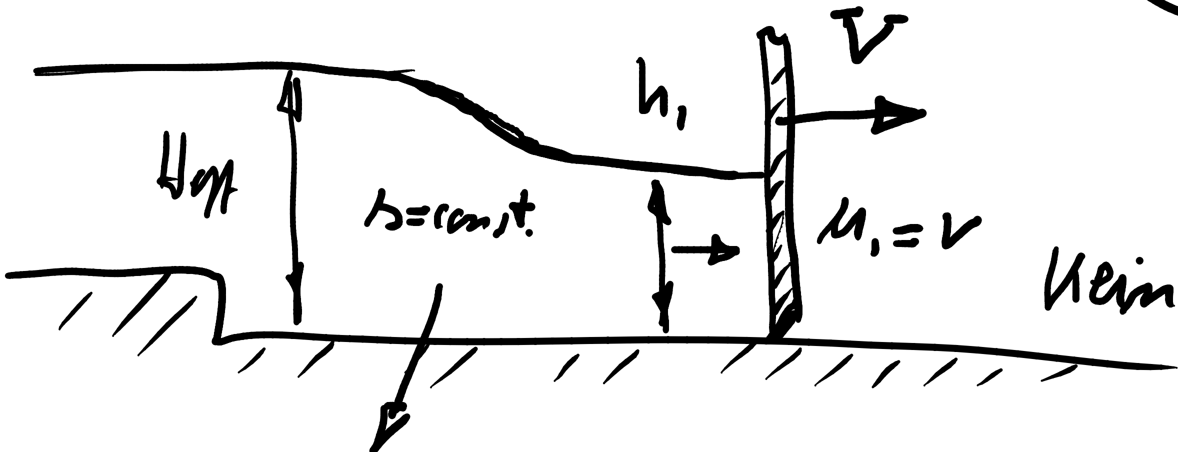


Die ideale Wasserkraftmaschine.





⇝ Exergie.



Kein Unterwasser.

Verdünnungswelle.

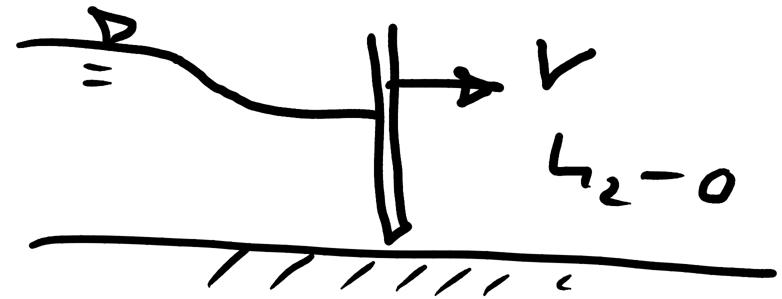
Optimierung und Skalierung von Fluidsystemen

TECHNISCHE UNIVERSITÄT DARMSTADT
FLUID SYSTEM TECHNIK
Prof. Dr.-Ing. Peter Pelz

Wellenleistung für die ideale Wasserkraftmaschine.

$$P_{T,h_2=0} = b\int_0^{h_1} \rho g y u_1\, dy$$

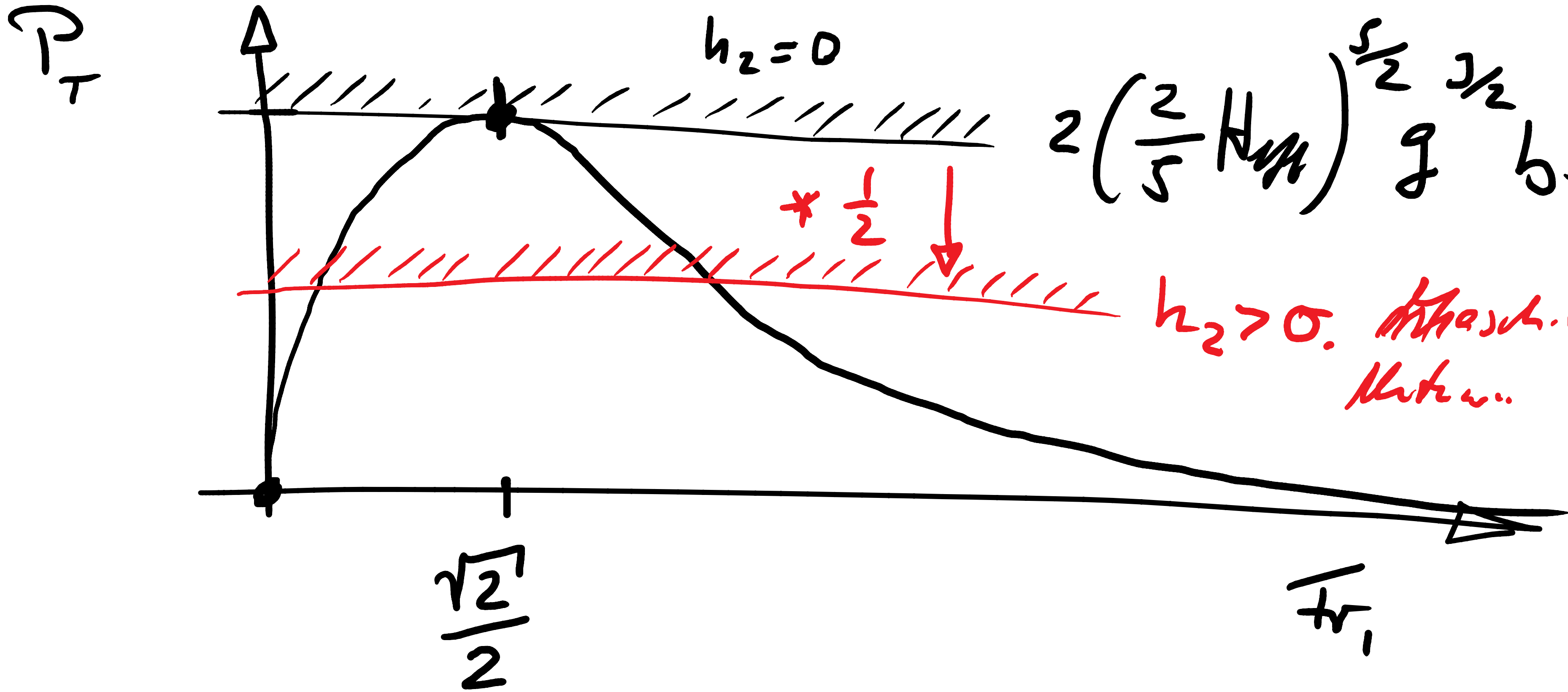
$$= \frac{1}{2}\rho g h_1^2 u_1 b.$$



$$H_A = h_{10} + \frac{u_{10}^2}{2g} = h_1 + \frac{u_1^2}{2g}$$ Stauhöhe.

$$Fr_2 = \frac{u_2}{\sqrt{g h_2}}$$

$$P_{T,h_2=0} = \rho\, b\, H_{eff}^{5/2}\, g^{3/2}\, \frac{2\sqrt{2}\, Fr_1}{\left(2+Fr_1^2\right)^{5/2}}$$

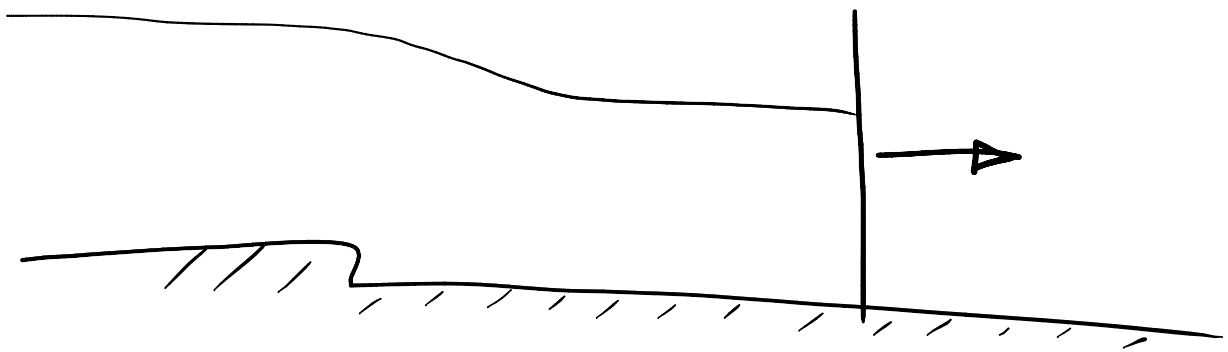


$$2\left(\frac{2}{5}H_{eff}\right)^{5/2} g^{3/2}\, b\, \rho$$

$h_2>0$. Abschätzung mit Modellen...

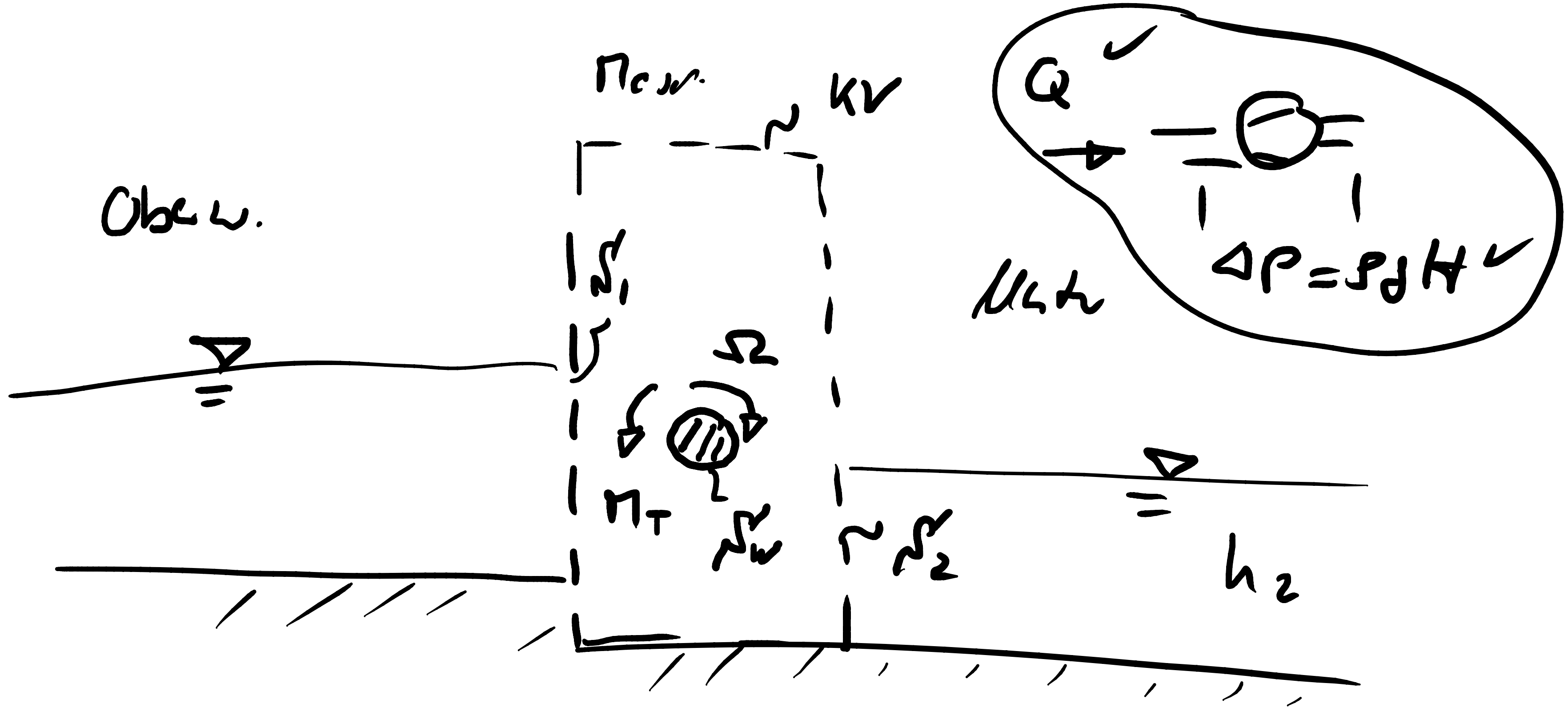
Upper Limit for Hydropower in an Open-Channel Flow
↳ Pelz.

$C_p = 1$



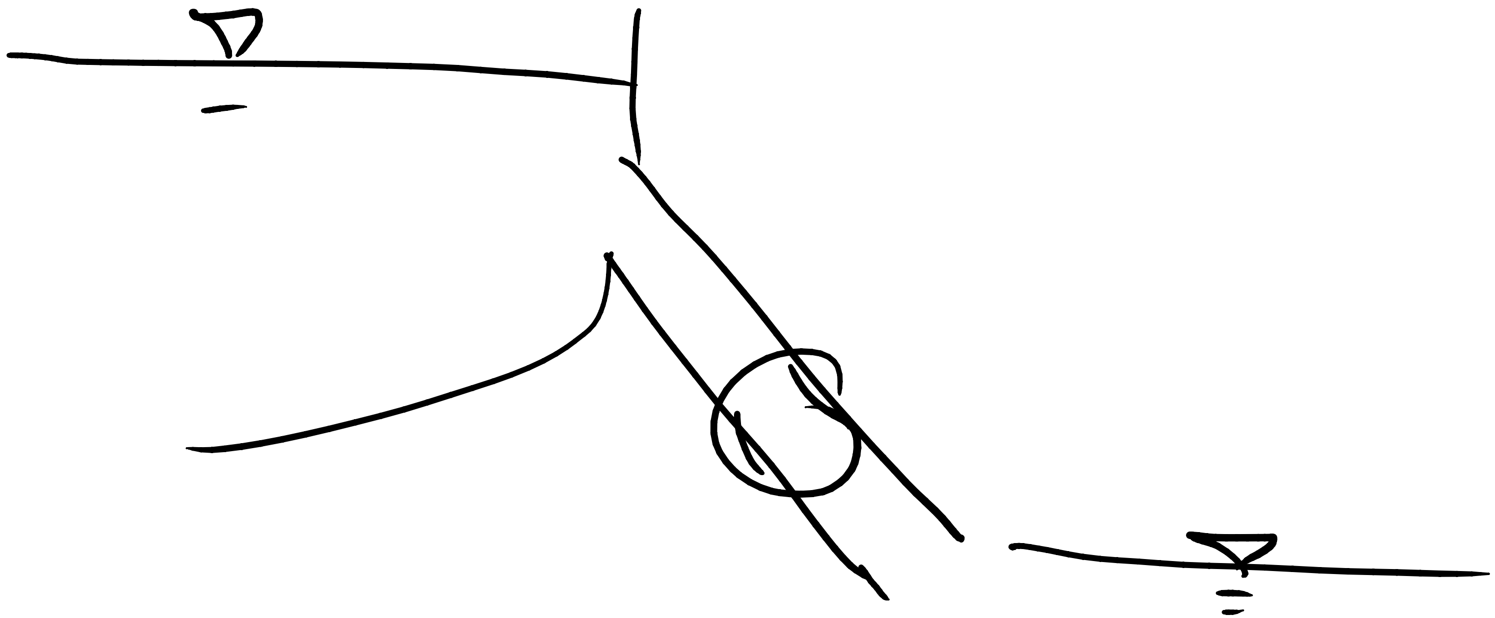
$$P_{avail} := 2\left(\frac{2}{5}H\right)^{5/2} g^{3/2}\, b\rho$$

$$C_p := \frac{P_T}{P_{avail}}$$



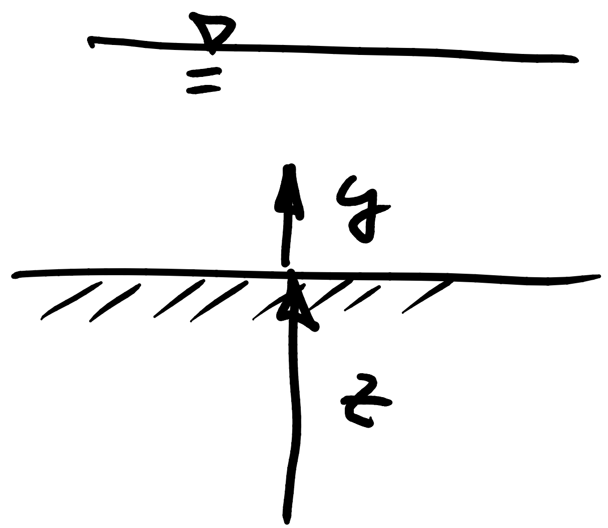
$$\frac{DK}{Dt}+\frac{DE}{Dt}=\oint_S \vec{t}\cdot\vec{u}\,dS+\int_V \rho\vec{k}\cdot\vec{u}\,dV-\cancel{\oint_S \vec{q}\cdot\vec{n}\,dS}$$

$$\frac{D}{Dt}\int_{V(t)}\rho\left(\frac{u^2}{2}+e\right)dV=\dots$$



- Im zeitlichen Mittel stationäre Zustände.

- $\vec{g}$ hat ein Potential. $\psi = g(z+y)$



$$-p\vec{n} = -(h-y)\rho g\vec{n}$$

$$\rho Q\left(\frac{u_2^2}{2} - \frac{u_1^2}{2}\right) + \rho Q(e_2 - e_1) = \overbrace{\int_{S_{Wall}} \vec{t}\cdot\vec{u}\,dS}^{-P_T} + \int_V \rho\vec{g}\cdot\vec{u}\,dV + \int_{S_1+S_2} \vec{t}\cdot\vec{u}\,dS$$

$$\rho Q\left(\frac{u_2^2}{2}-\frac{u_1^2}{2}\right)+\rho Q(e_2-e_1) = -P_T - \int_{S_1+S_2} \rho g(h-\cancel{z})\, u\, dS\ +$$

$$\psi = g(z+\cancel{h})$$

$$+ \oint_S -\rho\psi\, \vec{u}\cdot\vec{n}\, dS + \int_V \psi\, \underbrace{\nabla\cdot(\rho\vec{u})}_{\equiv 0}\, dV \qquad \frac{\partial\rho}{\partial t}=0$$

↑ Gaußscher Satz

$$\nabla\cdot(\ )\,dV = \vec{n}\cdot(\ )\,dS$$

$$\rho Q\left(\frac{u_2^2}{2}-\frac{u_1^2}{2}\right)+\rho Q(e_2-e_1)+\rho Q g\,(h_2+z_2-h_1-z_1) = -P_T \quad \Big/ \rho Q g$$

$$\left(h_1+\frac{u_1^2}{2g}+z_1\right)-\left(h_2+\frac{u_2^2}{2g}+z_2\right)+\frac{e_1-e_2}{g} = H_T$$

$H_T := \frac{P_T}{\rho Q g}$ Gefälle über die Maschine.

$h_{Loss} = \frac{e_2 - e_1}{g} = \frac{c}{g}(T_2 - T_1) > 0$ infolge Dissipation.

$d_t u = 0$. $c_p = c_v = c$ Wärmekapazität.

$$\boxed{H_1 - H_2 = H_T + h_L} = \frac{H_T}{\eta}$$

$H_1 := h_1 + z_1 + \frac{u^2}{2g}$ totale Höhe.