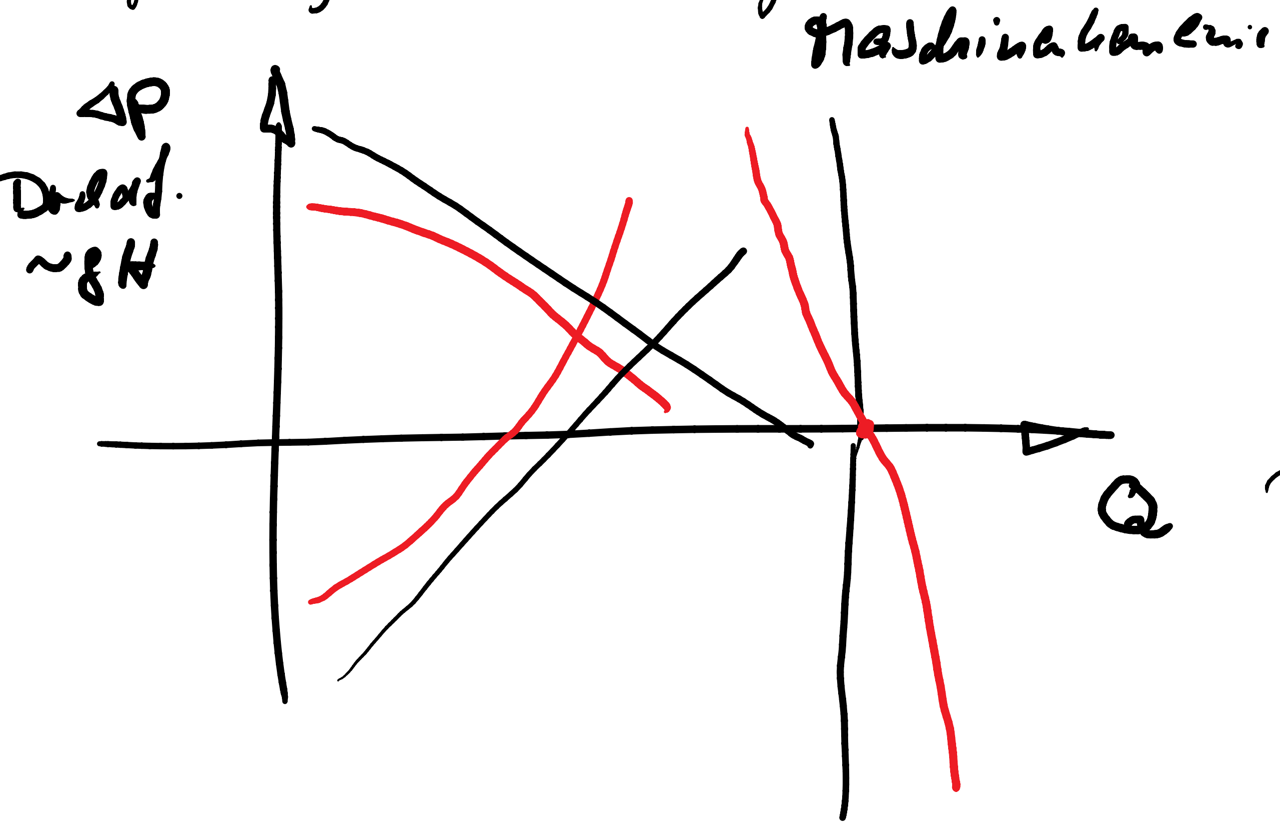
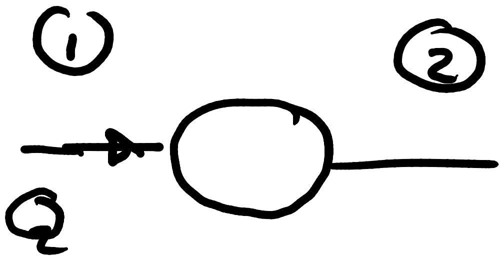
Aufwertung und vollständige Ähnlichkeit



Arbeitsm.
↕
Volumenstr.
↕
Kraftm.

Bernoulli'sche Konstante

$$\mathcal{C} = \frac{c^2}{2} + \Psi + \mathcal{P}; \quad \mathcal{P} = \int \frac{dp}{\rho} \begin{cases} \frac{p}{\rho} & \rho = \text{const} \\ \frac{\gamma}{\gamma-1}\frac{p}{\rho} & s = \text{const.} \end{cases}$$



$\rho g H := p_{t2} - p_{t1}$: $\rho = \text{const}$

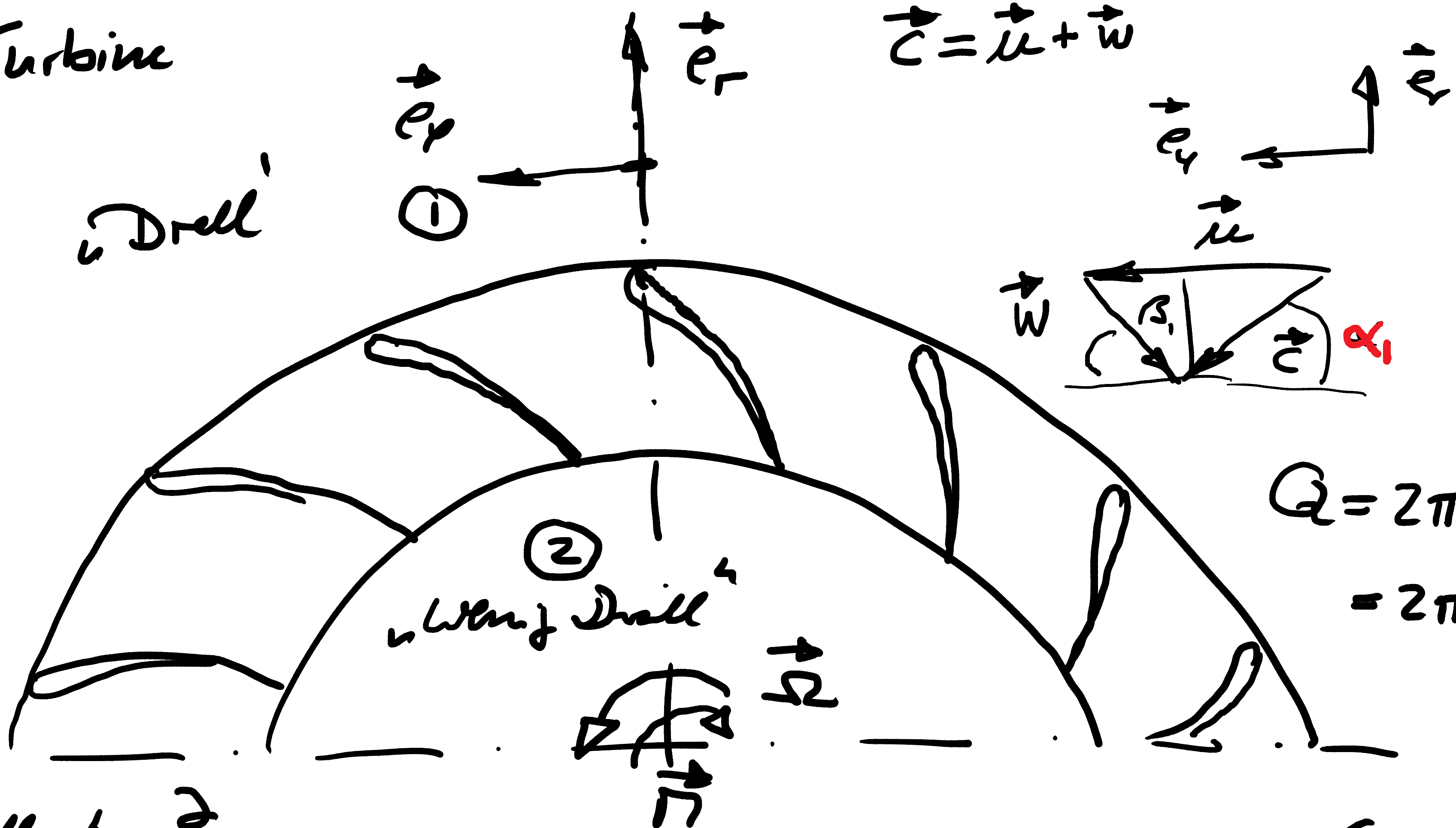
$g H := \mathcal{C}_2 - \mathcal{C}_1$: $\rho \neq \text{const.}$

$gH > 0$ Arbeitsm.

$gH < 0$ Kraftm.

Turbine

$\vec{c} = \vec{u} + \vec{w}$



$$Q = 2\pi r_1 b\, w_{r1} (-1)$$
$$= 2\pi r_1 b\, c_{r2} (-1)$$

Drallsatz $\frac{\partial}{\partial t} = 0$

$$d M_z = d\dot{m} (r_2 c_{u2} - r_1 c_{u1}) \quad \Big| \cdot \Omega$$

$$d P_s = d\dot{m} (\underbrace{u_2 c_{u2} - u_1}_{Q} c_{u1})$$

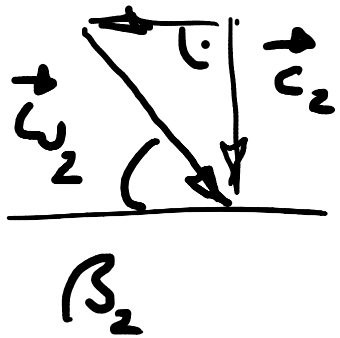
1. HS $\left(\dot{Q} = 0, \frac{\partial}{\partial t} = 0\right)$

$$d P_s = d\dot{m} (h_{t2} - h_{t1})$$

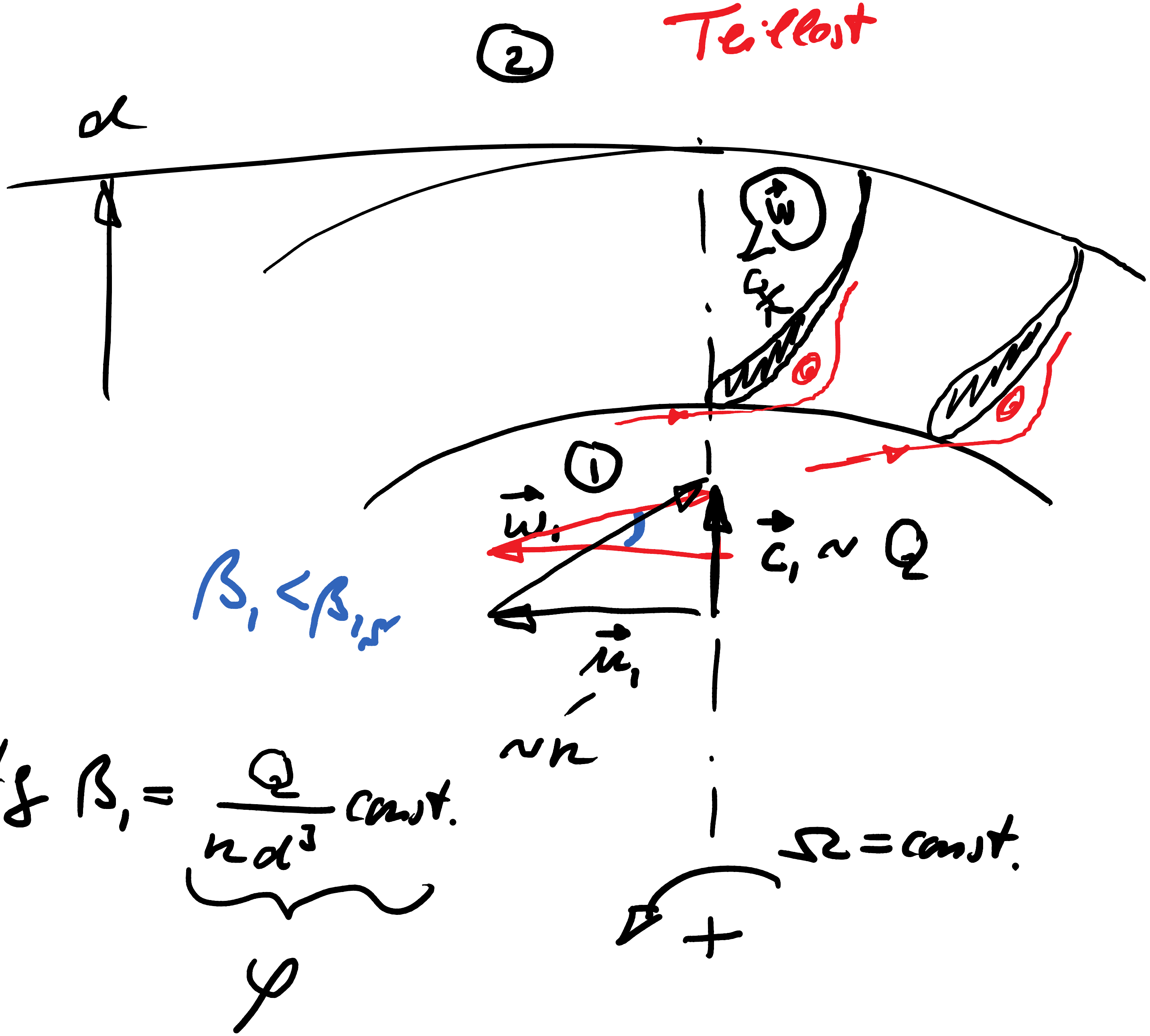
$$\Longleftrightarrow \quad = d\dot{m} \left[\underbrace{(c_2 - c_1)}_{gH} + (e_2 - e_1) \right]$$

Geschwindigkeitsdreieck am Austritt

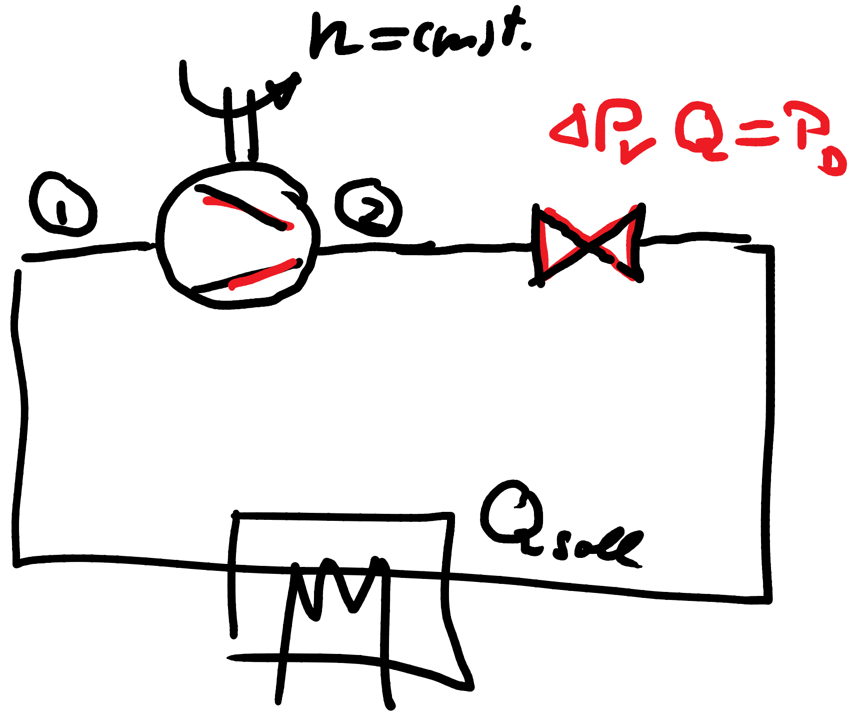
$\vec{u}_2 < \vec{u}_1$, da $r_2 < r_1$



$\vec{c}_2$: drallfreie Abströmung.

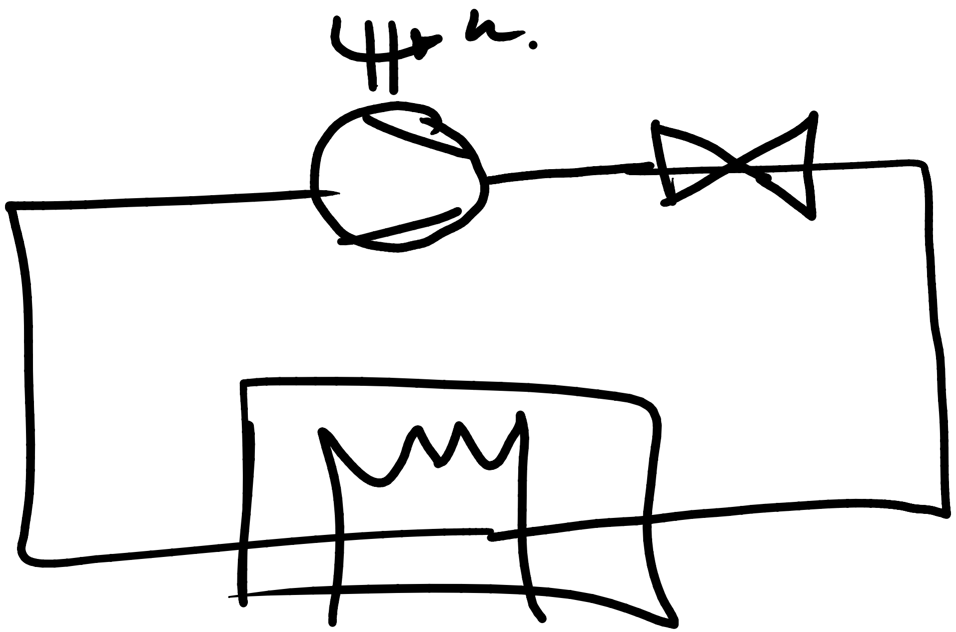


$$\tan \beta_1 = \underbrace{\frac{Q}{n d^3}}_{\varphi} const.$$



$\varphi \overset{!}{=} \varphi_S$ Drehzahlregelg an Pump

↳ $\eta = \eta_{opt}$



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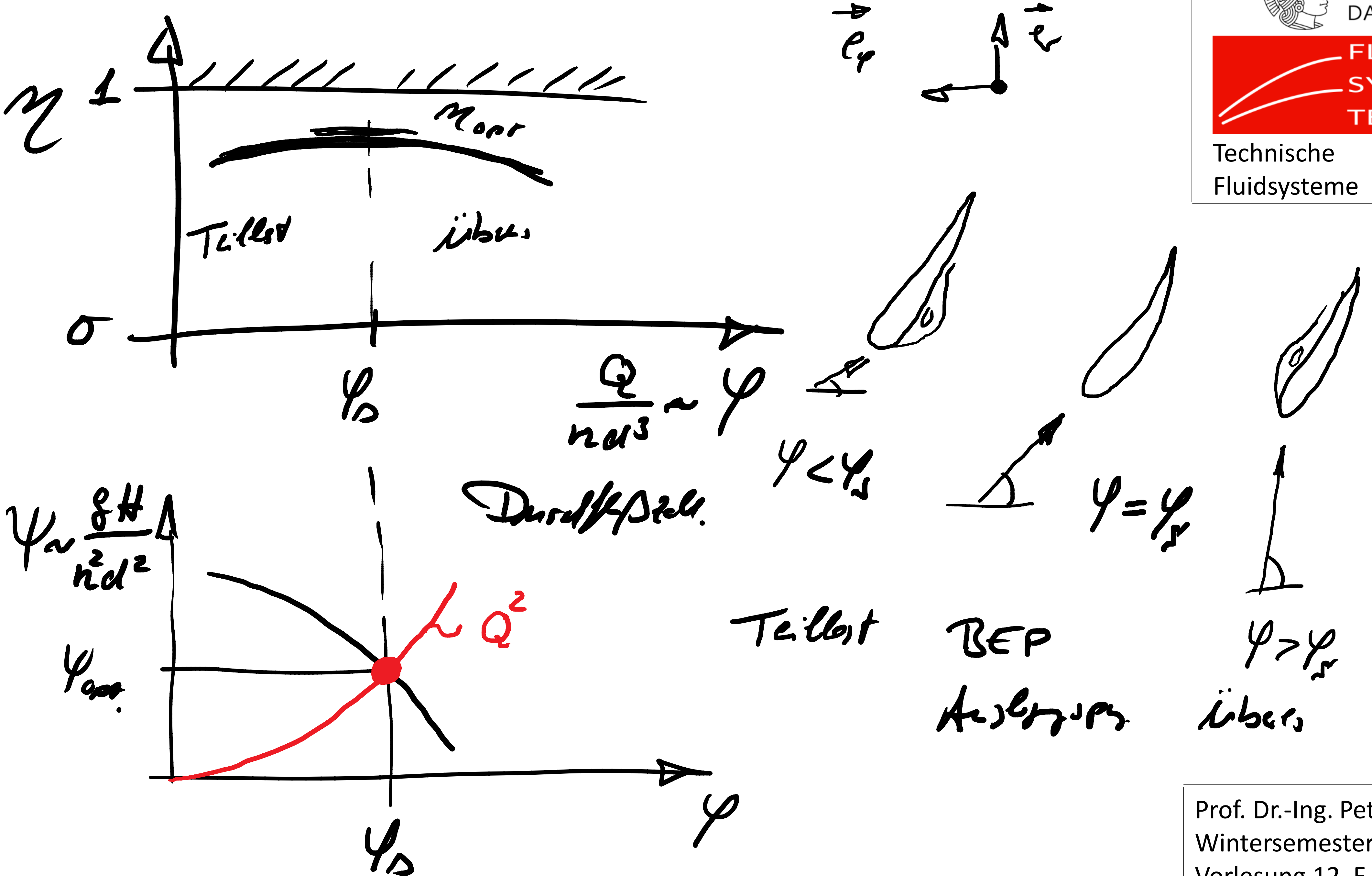
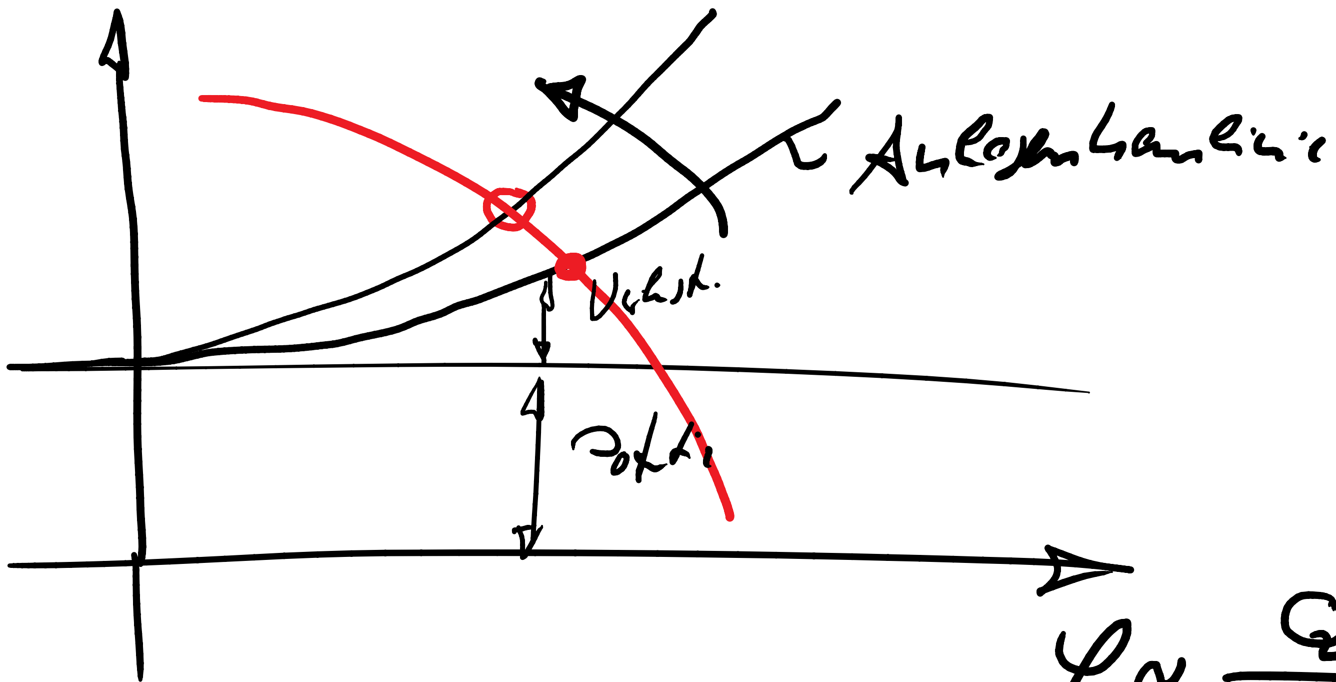
FLUID SYSTEM TECHNIK

Technische Fluidsysteme



$$\frac{gH}{n^2 d^2} \sim \psi$$



$$\varphi \sim \frac{Q}{n d^3}$$

ψ Druckziffer

φ Durchflussziffer.

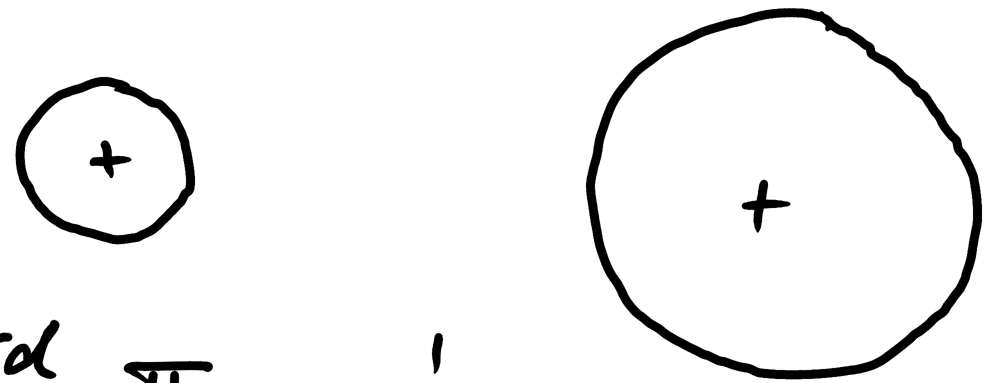
η Wirkungsgrad

$$\psi = \psi(\varphi, \text{Gestalt}, Re, Ma, \delta, \frac{k}{d}, \frac{s}{d})$$

$$\eta = \eta(\varphi, \text{Gestalt}, Re, Ma, \delta, \frac{k}{d}, \frac{s}{d})$$

Gestalt $\Pi_1 = \frac{d_i}{d}$, $\Pi_2 = \frac{b}{d}$, $\Pi_3 = \beta_{S1}$, ... $\Pi_i = \frac{k}{d}$

$\frac{s}{d}$



$\frac{\pi d}{d} = \pi \overset{!}{=} \pi'$

Geometrische Ähnlichkeit

$\Pi_i = \Pi_i'$ für $i = 1 \ldots n$ für eine Baureihe.

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Reynoldszahl $Re = \frac{d^2 n}{\nu} \overset{!}{=} Re' = \frac{d'^2 n'}{\nu'}$

Durchflusszahl $\varphi = \frac{Q}{n d^3} \overset{!}{=} \varphi' = \frac{Q'}{n' d'^3}$

$\vdots$

Vollständige Ähnlichkeit, wenn

$$\Pi_i \overset{!}{=} \Pi_i' \quad i = 1 \ldots N$$

$$\Leftrightarrow \eta = \eta'$$

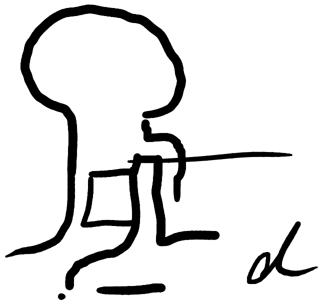
Prof. Dr.-Ing. Peter Pelz

Machzahl $\Pi_a = \frac{ud}{a}$

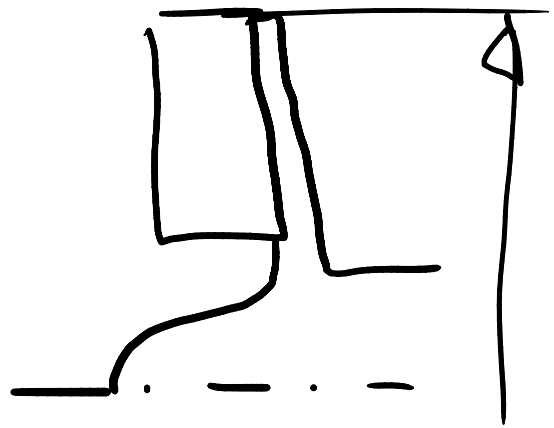
Kavitationszahl $\sigma = \frac{p_d - p_{min}}{\frac{\rho}{2} u^2}$

$p_d(T)$ Dampfdruck

$\eta = \eta(\varphi, Re, \mathcal{K}_i)$ ✓ $\quad \eta' = \eta'(\varphi, Re', \mathcal{K}_i)$ ✓



$d \sim .5m$ ✓



$d' = 5m$ ✓

Strömungsfelder

Bsp. $\quad M_d = \frac{d}{d'} = 0.1$

Vollständige Ähnlichkeit in Re

$$Re \overset{!}{=} Re' \Longleftrightarrow$$

$$\frac{d^2 n}{\nu} \overset{!}{=} \frac{d'^2 n'}{\nu'} \Longleftrightarrow \frac{M_d^2 M_n}{M_\nu} \overset{!}{=} 1$$

$$\frac{\left(\frac{d}{d'}\right)^2 \left(\frac{n}{n'}\right)}{\left(\nu/\nu'\right)} \overset{!}{=} 1$$

$$M_\nu = \frac{\nu_{Luft}}{\nu_{H_2O}} = 17.1$$

$M_\nu = 1$ ideal

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$$\Pi_\nu = 1$$

$$Re \overset{!}{=} Re' \quad \rightarrow \quad M_d = 0.1$$

$$\rightarrow \quad M_n = M_d^{-2} = 100$$

Zur Leistungsdichte einer Arbeitsm.

$$P_s = \frac{1}{2}\Delta p Q = \psi \rho n^2 d^2 \varphi n d^3 \frac{1}{2}$$

$$= \psi \varphi \rho n^3 d^5 \frac{1}{2}$$

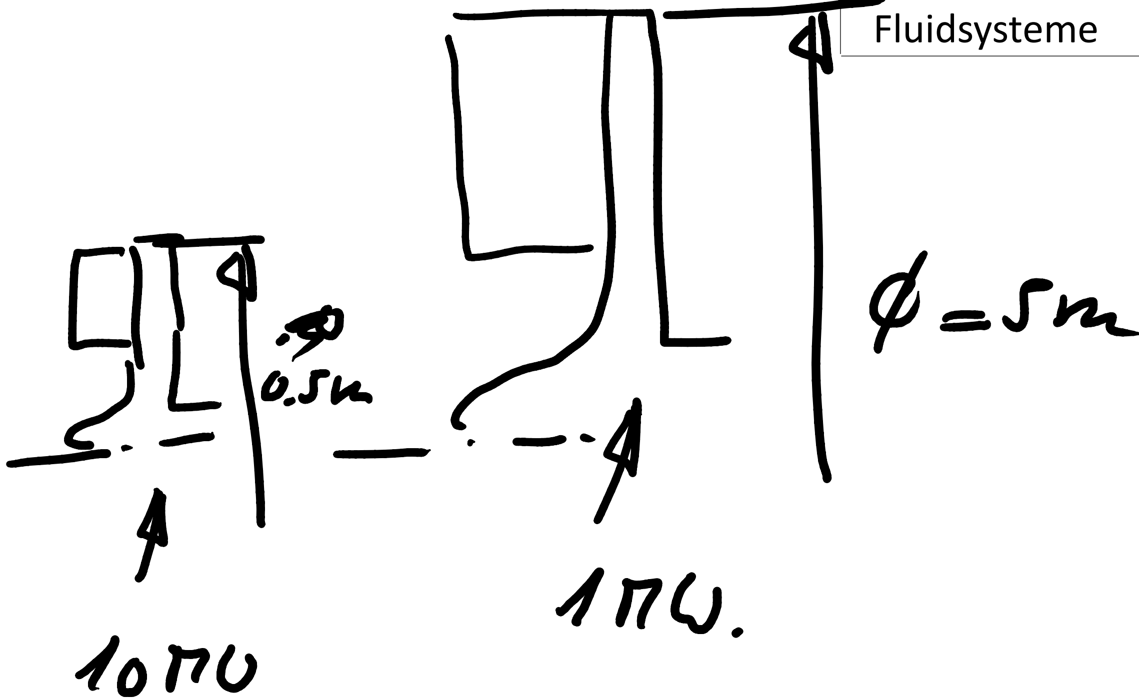
$$\frac{P_s}{\rho n^3 d^5} = \lambda = \psi \varphi \frac{1}{2}$$

$$\lambda = \psi \varphi \frac{1}{\zeta}$$

$$\eta_{Ps} = M_n^3 \, M_d^5 \, M_s^1$$

$$= (10^2)^3 \; 0.1^5 * 1$$

$$= 10^6 \; 10^{-5} = 10$$



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Vollständige Ähnlichkeit ist ggf. nicht zu erzielen.

$$Re \ll Re'$$

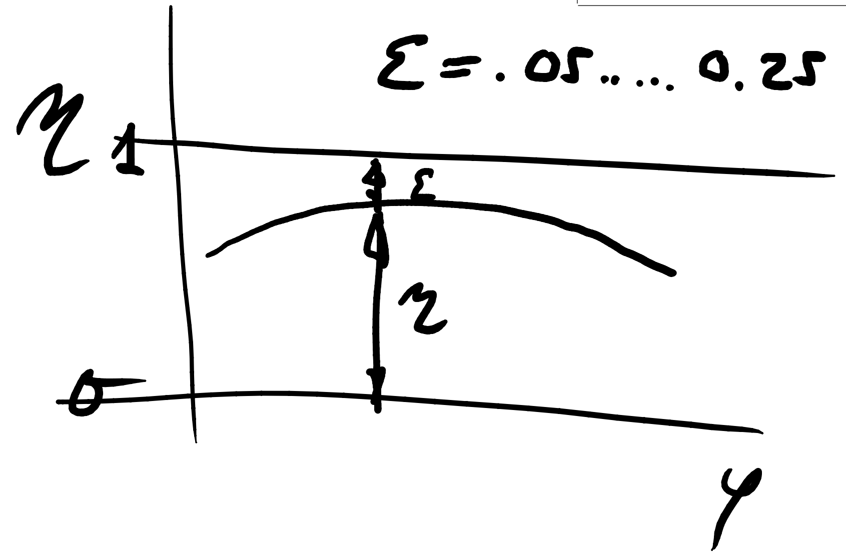
$$\eta < \eta'$$

} unvollständige Ähnlichkeit

$$\eta' - \eta = fn(Re' - Re)$$ Aufwertung.

$$1-\eta := \frac{P_{Loss}}{P_S}$$

$$\varepsilon := \frac{P_{Loss}}{P_S} \quad \Big| \quad d$$



$$\Rightarrow P_S = P_{Loss}/\varepsilon$$

$$d\varepsilon = \frac{dP_{Loss}}{P_S} - \frac{dP_S}{P_S}\frac{P_{Loss}}{P_S}$$

$$d\varepsilon = \varepsilon \frac{dP_{Loss}}{P_{Loss}} - \varepsilon^2 \frac{dP_S}{P_{Loss}} \approx \varepsilon \frac{dP_{Loss}}{P_{Loss}} = \varepsilon \frac{d\, c_f(Re, k/d)}{c_f(Re, k/d)}$$

$$c_f := \frac{W_f}{\frac{\rho}{2} u^2 L}$$

$$\boxed{\frac{\Delta \varepsilon}{\varepsilon} \approx \frac{\Delta c_f}{c_f}}$$

Anfang.

Moody Diagramm.