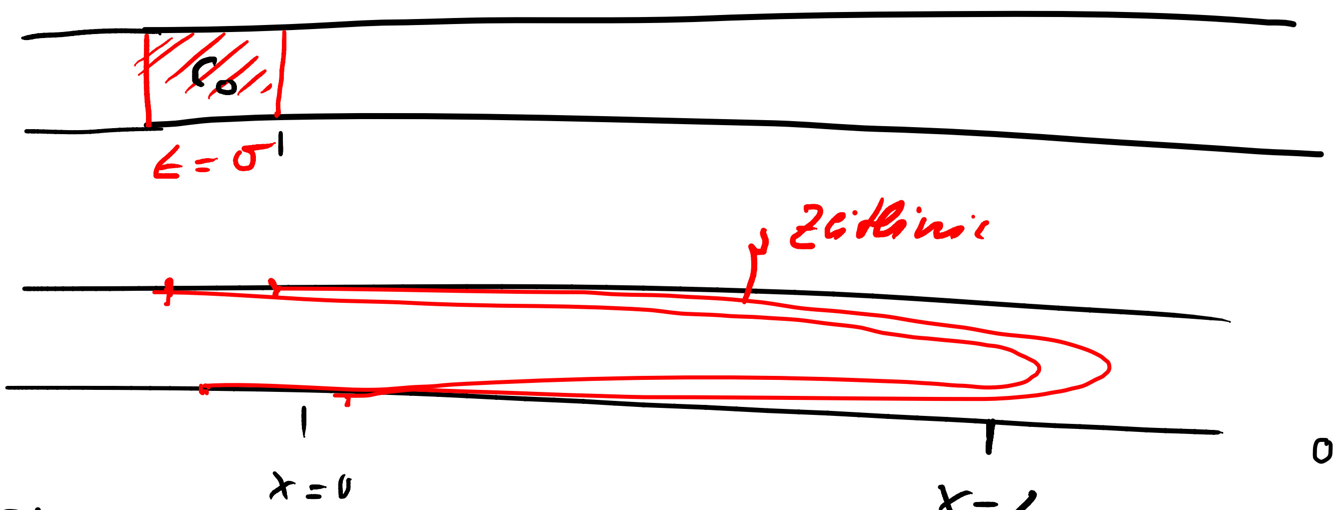
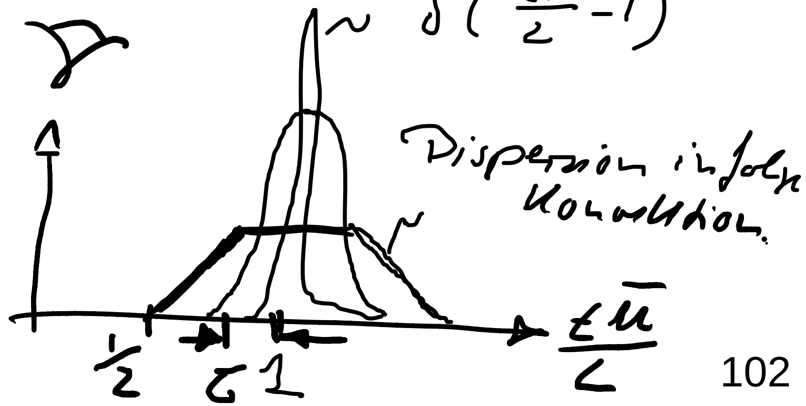
Taylor-Aris Dispersion

$$Pe_D = \frac{\bar{u} d}{D} \gg 1, \quad Re < Re_c$$



Standardabweichung.

$$\sigma = \frac{D_T}{\bar{u} L} \, f\!\left(\frac{L}{d}\right)$$



D_T Dispersionskoeffizient.

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Wintersemester 2010/11
Biofluidmechanik
Vorlesung 21

1) $Pe_D \ll 1$ $D_T = D$ const

2) $1 \lesssim Pe_D \lesssim 10^2$ moderate Pe-Zahl.

$$D_T = D\left(\frac{4\beta}{Pe_D^2} + 1\right)$$

$Re < Re_c$

3) $Pe_D \gg 10^2$

$D_T = \bar{u}\, d$ const.

turbulent Strömung.

$D_T = u_* d$ const. $u_* = \sqrt{\frac{\tau_w}{\rho}}$

$Re > Re_c$.

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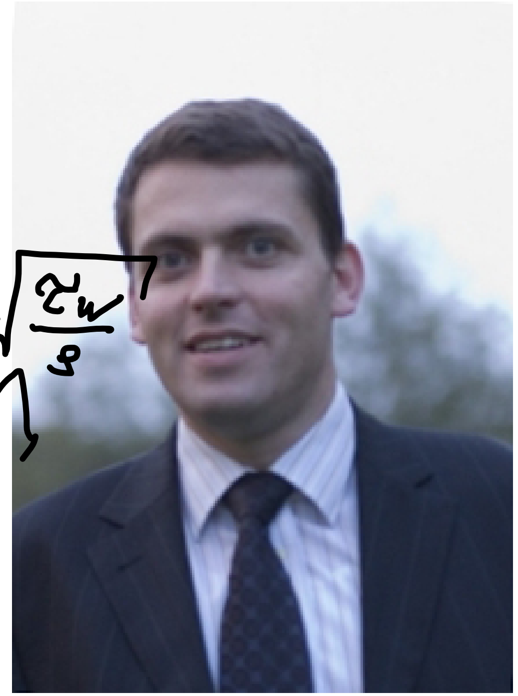

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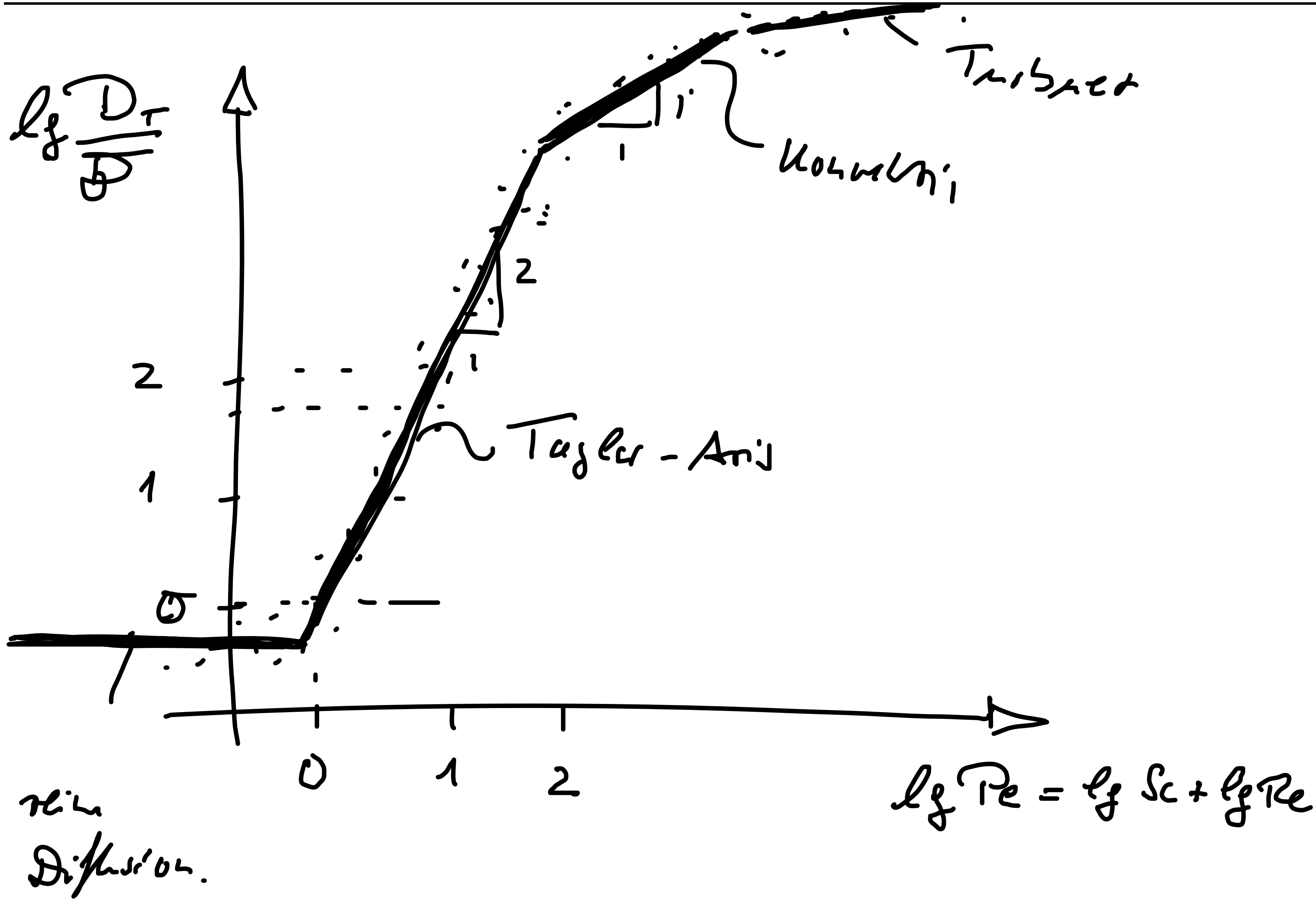

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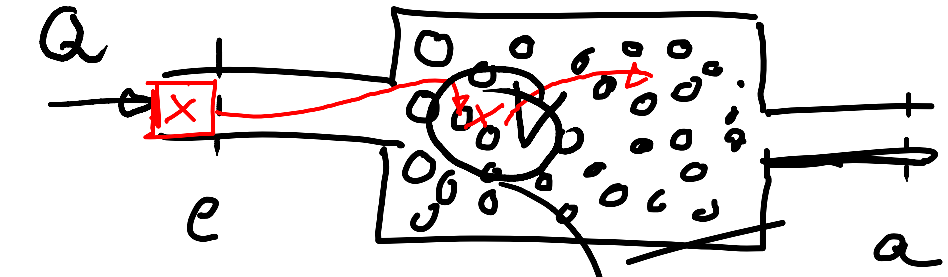
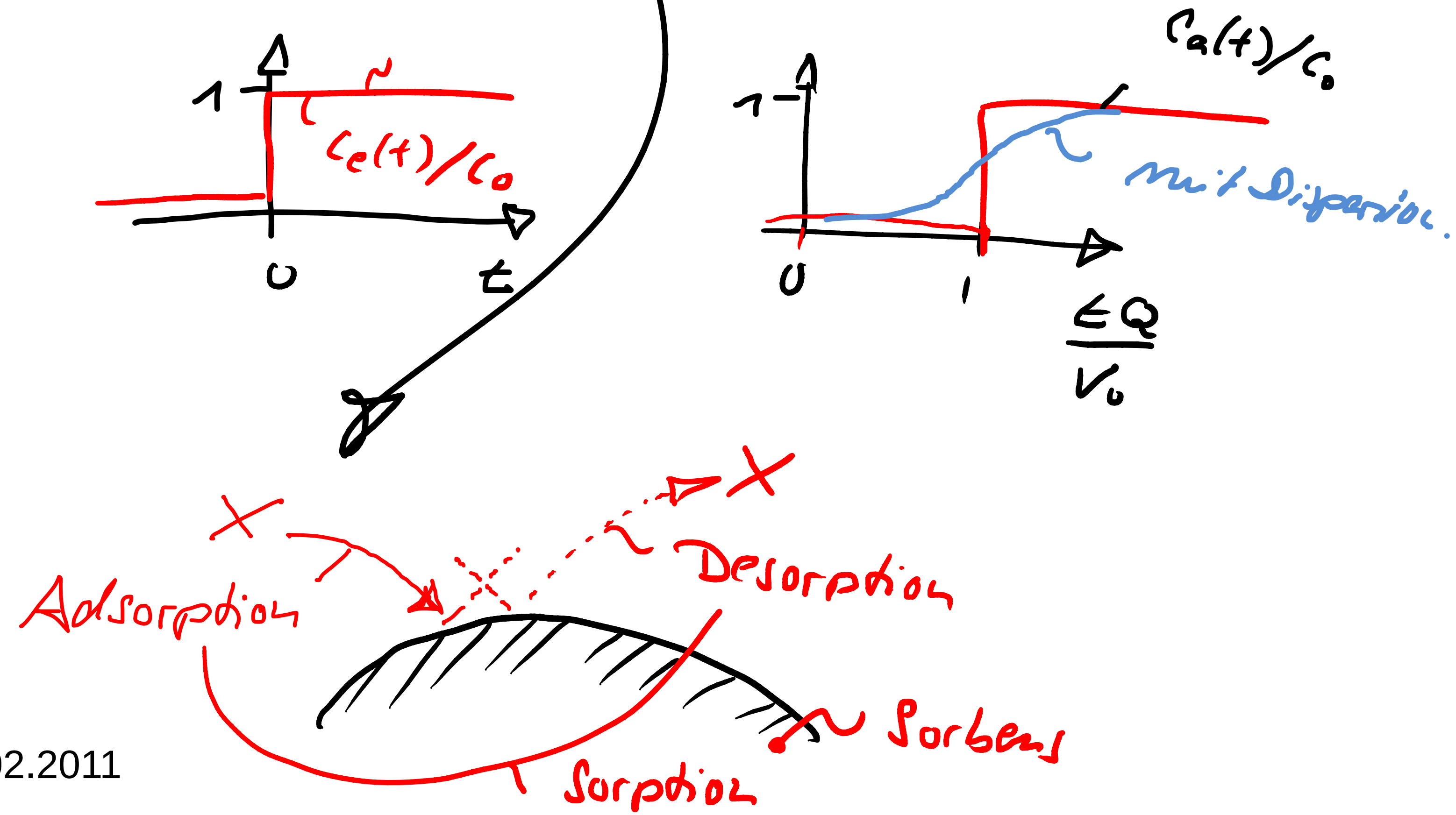
Durchbruchkurve: Antwort am Ausgang a auf eine unstetige Konzentrationsänderung am Eingang e





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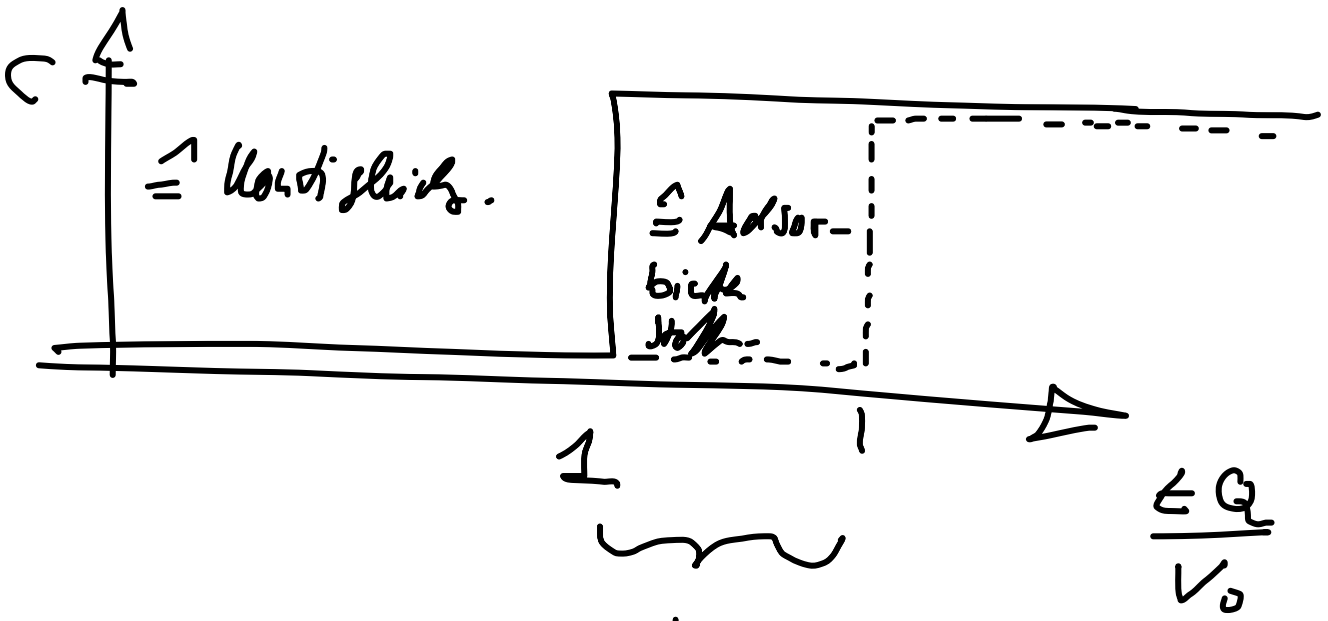

Retardierende ~~Mom~~ Zeit.

$\boxed{\text{Sorption ist einfach messbar.!}}$

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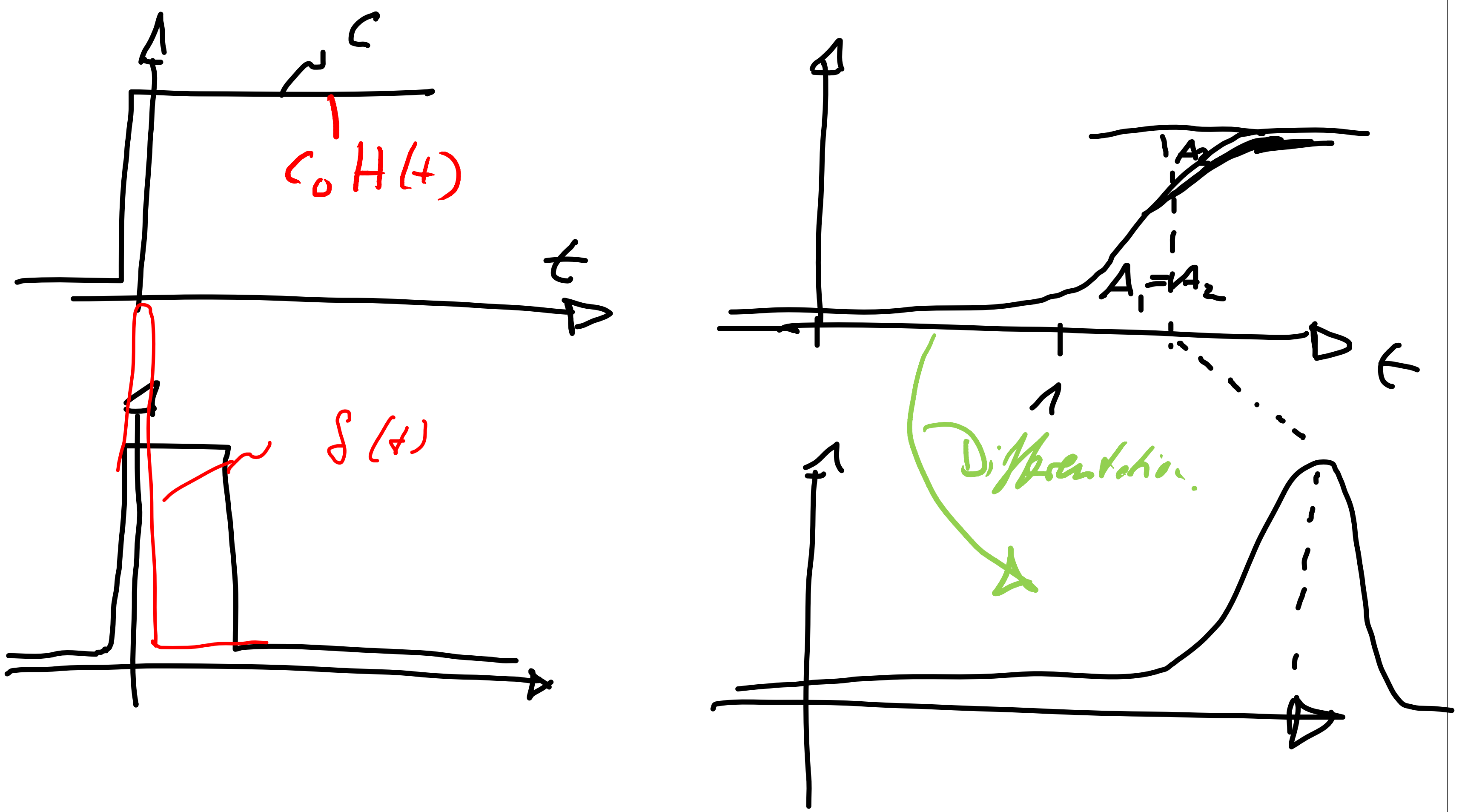

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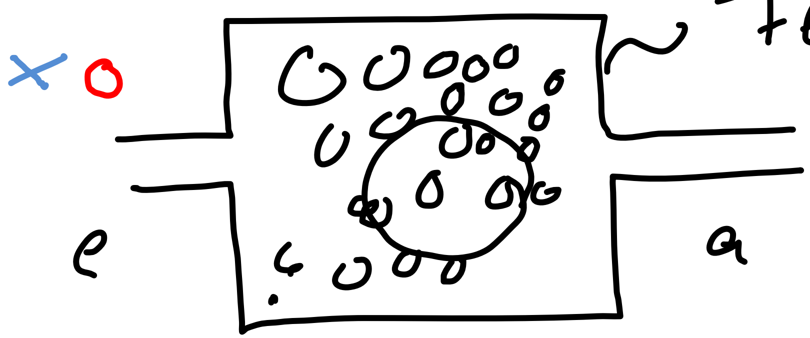
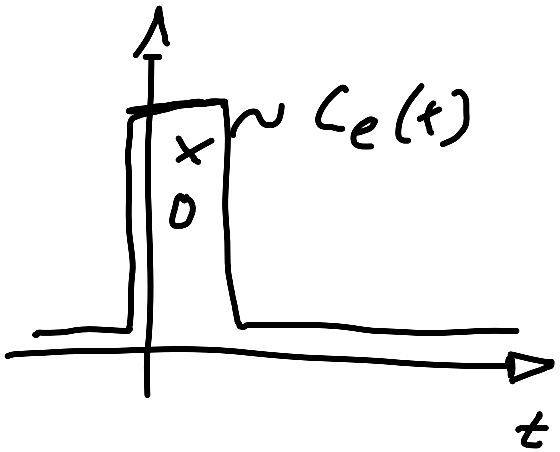


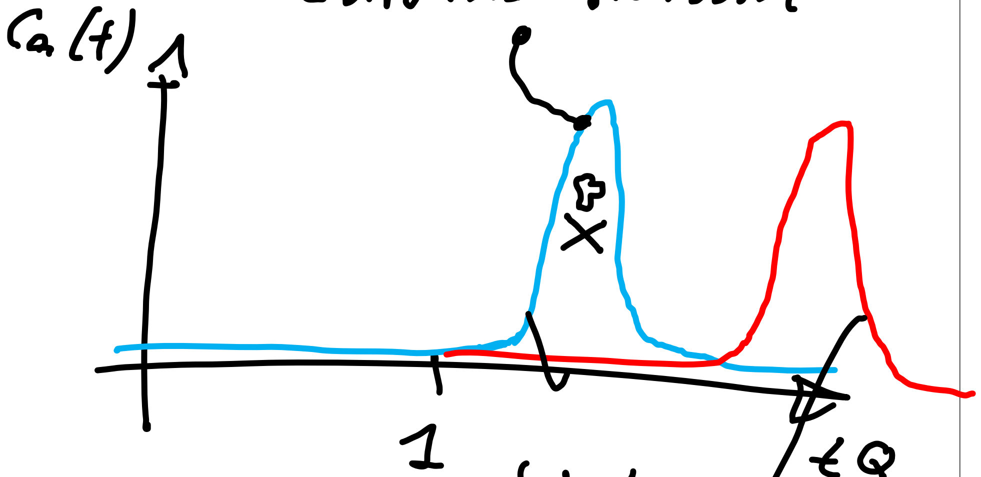
Flüssigkeitschromatographie

HPLC

High performance Liquid chromatographie

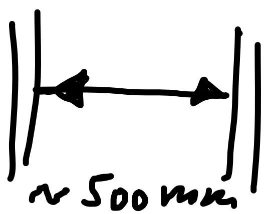
Chromatogramm





Anwendung: 1. Chemische Analyse.

2. Preparative Trennung



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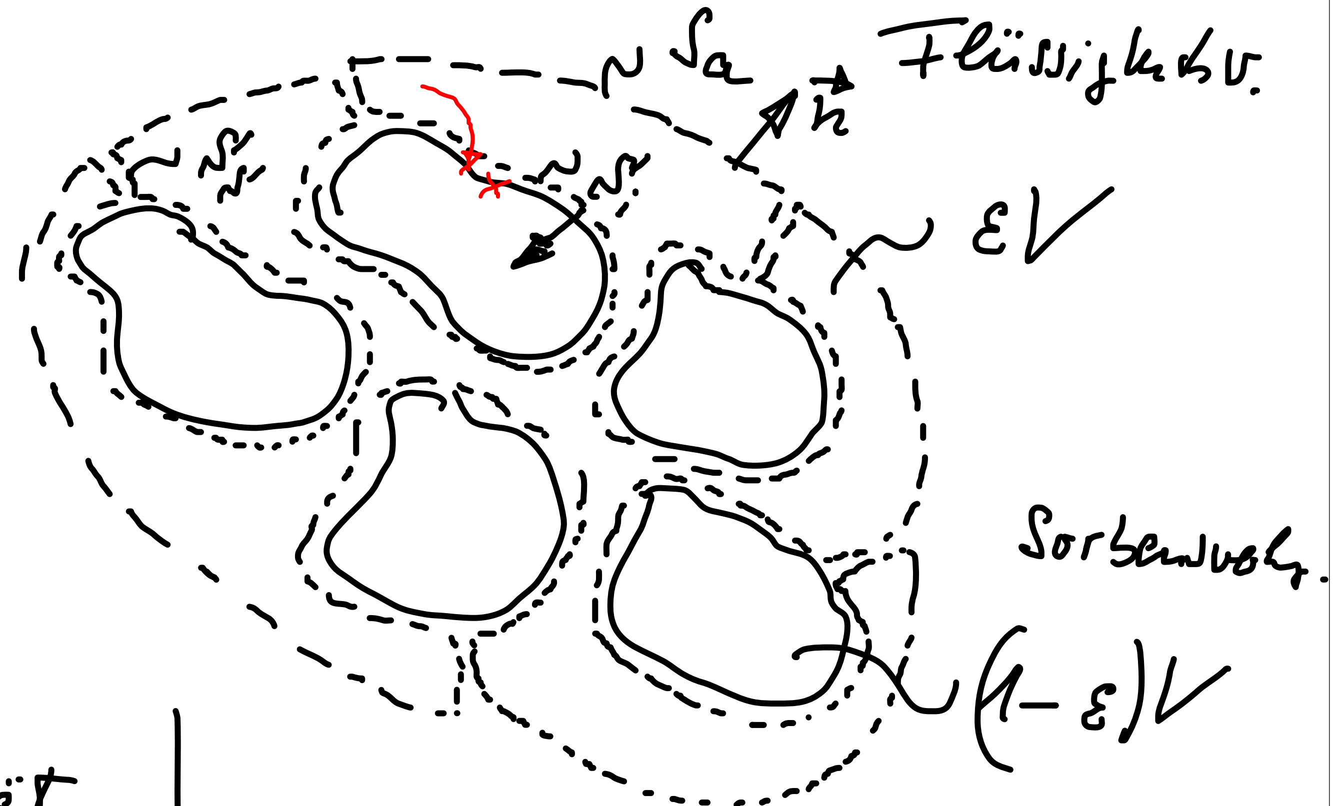
Frage: Wie bestimmt sich die Retardationszeit?



ε Porosität

$$\varepsilon := \frac{V_{Fl}}{V_{gesamt}}$$

1. Stoffbilanz für die Flüssigkeit.
2. " " " Sorbens.

Sorption.

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Wintersemester 2010/11
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Stoffbilanz in integraler Form

Die zeitliche Änderung der Stoffmenge N im Fl.-Volumen ist gleich der Stoffproduktion pro Zeiteinheit durch Reaktion R plus den Stofftransport über die Oberfläche des materiellen Volumens J.

$$\frac{DN}{Dt} = R + J.$$

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$$N = \int_{V(t)} c \, dV \; ; \quad R = \int_{V} r \, dV \; ;$$

$$J = -\int_{S} \vec{j} \cdot \vec{n} \, dS$$

$$\frac{D}{Dt} \int_{EV(t)} c \, dV = \int_{EV} r \, dV - \int_{S} \vec{j} \cdot \vec{n} \, dS$$

$$\frac{\partial}{\partial t} \int_{EV} c \, dV + \int_{S_a} c \, \vec{u} \cdot \vec{n} \, dS = \int_{EV} r \, dV - \int_{S_a} \vec{j} \cdot \vec{n} \, dS - \underbrace{\int_{S_i} \vec{j} \cdot \vec{n} \, dS}_{\text{Diffusion.}}$$

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FLUID SYSTEM TECHNIK

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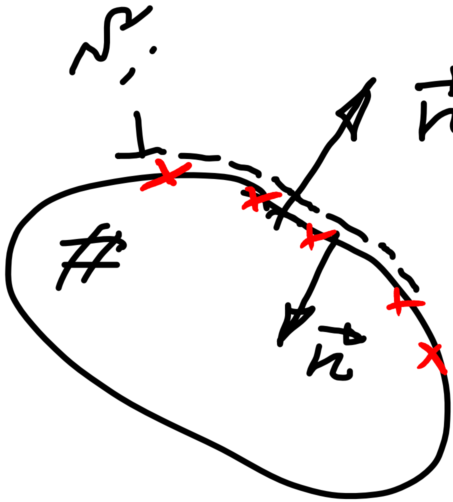
Stoffbilanz für das Sorbens

Stetigkeit des Stoffstromes.

$$\vec{j}\cdot\vec{n}_q \overset{!}{=} -\vec{j}\cdot\vec{n}$$



$$\vec{n}_q = -\vec{n}$$

$$\frac{\partial}{\partial t}\int\limits_{(1-\varepsilon)V} q\,dV = \overbrace{-\int\limits_{\dot S_i} \vec{j}\cdot\vec{n}_q\,dS'} + \int\limits_{(1-\varepsilon)V} r_q\,dV$$

$q :=$ Zahl der Moleküle / Volumeneinheit Sorbens.

r_q Volumenspez. Reaktionsrate im Sorbens.

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Einsetzen der Erhaltungsgleichung Sorbens in die Erhaltungsgleichung für die Flüssigkeit

$$\frac{\partial}{\partial t}\int_{\varepsilon V} c\,dV + \overbrace{\int_{S_a} c\,\vec{u}\cdot\vec{n}\,dS}^{\text{Satz von Gauß}} = \int_{\varepsilon V} r\,dV - \overbrace{\int_{S_a} \vec{j}\cdot\vec{n}\,dS}^{\text{Satz von Gauß}} +$$

$$- \frac{\partial}{\partial t}\int_{(1-\varepsilon)V} q\,dV + \int_{(1-\varepsilon)V} r_q\,dV .$$

$$\boxed{\varphi_D := \frac{1}{V}\int_V \varphi\,dV}$$ Volumengemittelte Größen

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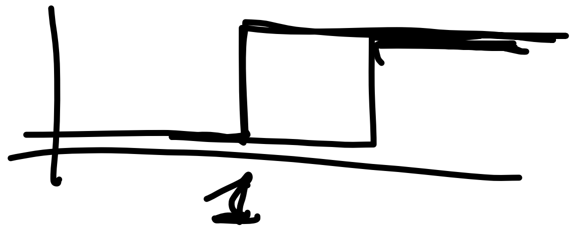
$$\frac{\partial c_D}{\partial t} + \vec{u}_D \cdot \nabla c_D = \underbrace{T_D}_{\text{Reaktion}} - \underbrace{\nabla \cdot \vec{j}_D}_{\text{Dispersion}} - \frac{1-\varepsilon}{\varepsilon}\left(\frac{\partial q_D}{\partial t} - T_{qD}\right)$$

Stoffbilanz in differentieller Form für ein poröses Teilchen.

Spezialfall:

1. Kein Stoffproduktion.
2. Kein Dispersion.
3. 1D-Problem.



$$\frac{\partial c_D}{\partial t} + u\frac{\partial c_D}{\partial x} = -\frac{1-\varepsilon}{\varepsilon}\frac{d q_D}{d c_D}\frac{\partial c_D}{\partial t}$$

$$\frac{\partial c_D}{\partial t} + \frac{u}{1+\frac{1-\varepsilon}{\varepsilon}\frac{d q_D}{d c_D}}\frac{\partial c_D}{\partial x} = 0.$$

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Wintersemester 2010/11
Biofluidmechanik
Vorlesung 21

$$\frac{\partial c}{\partial t} + \underbrace{\frac{u}{1 + \frac{dq}{dc}\,\frac{1-\varepsilon}{\varepsilon}}}_{u_B} \frac{\partial c}{\partial x} = 0 .$$

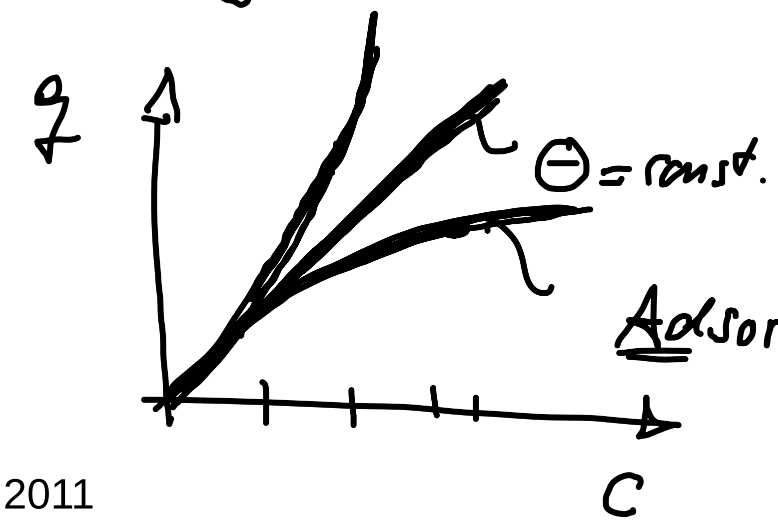
Hyperbolisch. Dgl.

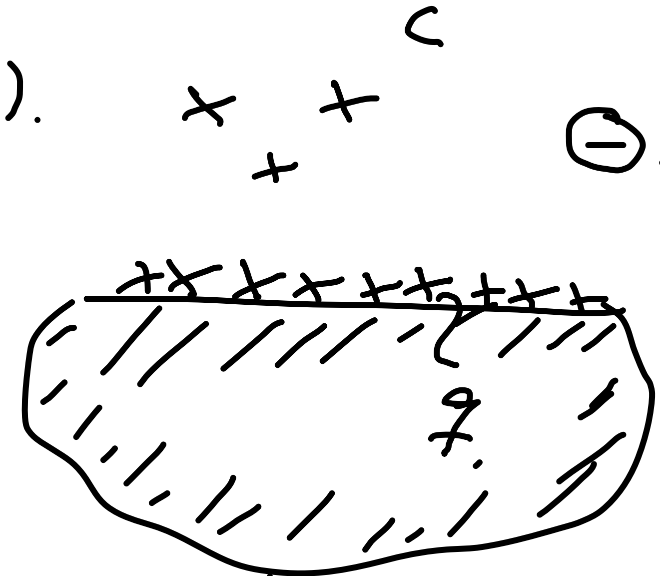
$$\frac{dc}{dt} = \frac{\partial c}{\partial t} + u_B \frac{\partial c}{\partial x} = 0 .$$

$$u_B = u_B(c).$$

$\Theta = \text{const.}$

$$u_B < u$$





Adsorptionsisotherme.

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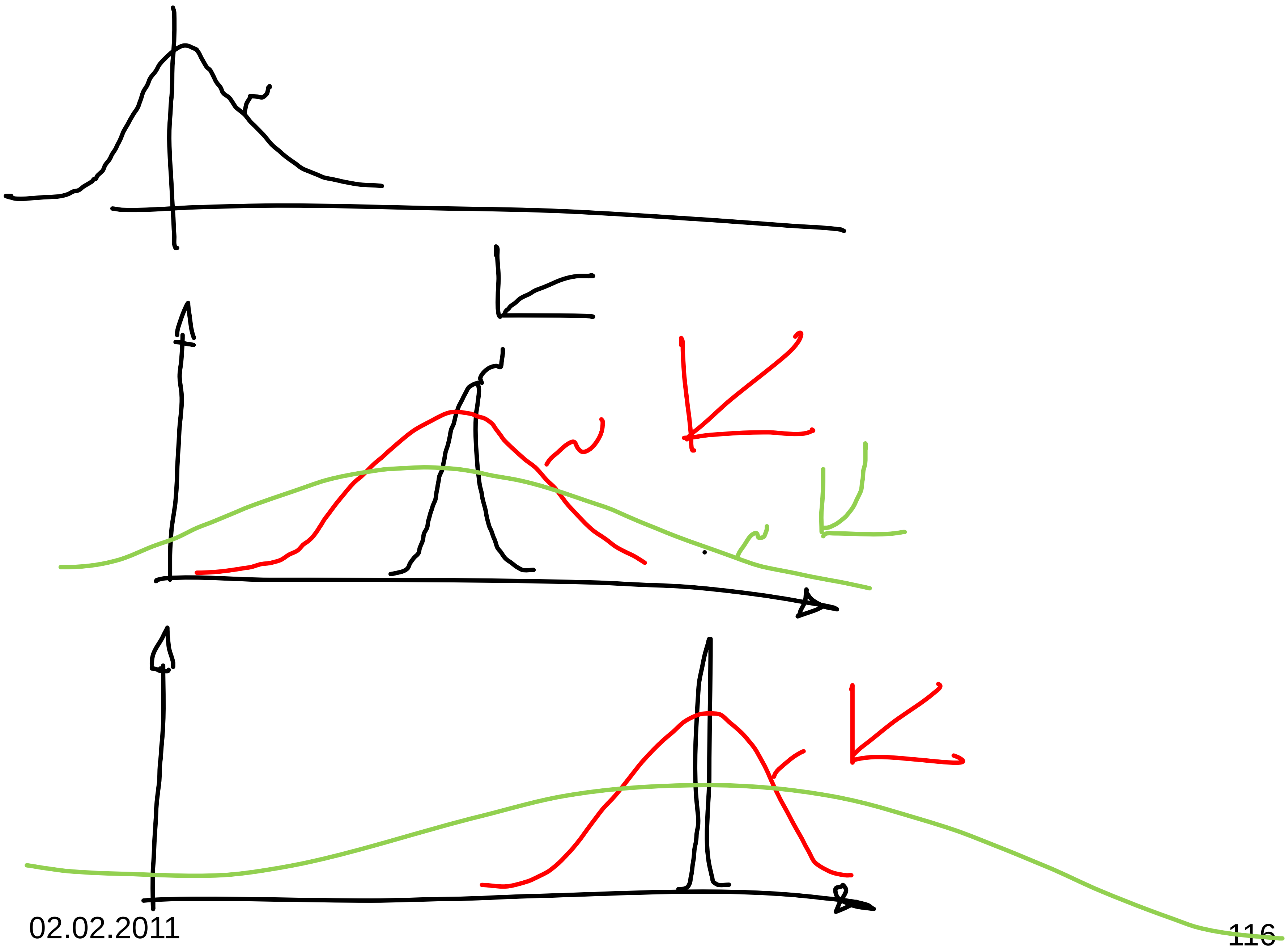
Vorlesung 21



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Wintersemester 2010/11
Biofluidmechanik
Vorlesung 21