A1 $\det(\underline{\underline{T}} - \lambda \underline{\underline{1}}) = 0$

A2 $\underline{n} = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

$\underline{s} = \underline{\underline{T}} \cdot \underline{n} \qquad \sigma_n = \underline{s} \cdot \underline{n}$

A3 $\sigma_n = 0 \rightarrow \underline{\sigma_n} = \underline{0}$

$\underline{\tau_n} = \underline{s} - \underline{\sigma_n}$

A4 minimal $\hat{=}$ am negativsten
$\neq$ kleinsten Betrag

B1 symmetrisch

B2 $\gamma_{max} = \varepsilon_{max} - \varepsilon_{min}$

$\varepsilon_z = 0 = \varepsilon_z$

$\begin{bmatrix} 12 & -3 \\ -3 & 4 \end{bmatrix}_{xy}$

C2 $\varepsilon_x = \varepsilon_z = 0$

$\sigma_x = \sigma_z$

$\sigma_y = -\frac{F}{A}$

$\varepsilon_y = \ldots\ldots$

$\varepsilon_x = 0 = \ldots\ldots$

D1 Löcher haben eine negative Fläche

$$\xi_S = \frac{\frac{3}{2} a \cdot 6a^2 - a\pi \frac{a^2}{4}}{6a^2 - \pi \frac{a^2}{4}}$$

D2 $\rightarrow$ Additivität der Flächenträgheitsmomente

$I_z^{Rechteck} - I_z^{Kreis}$

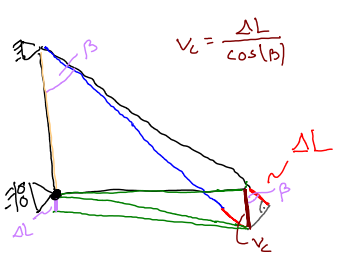
E1 $\Sigma_z^{in\,0}$

E2 Knotengleichgewicht
B-C Freischneiden

E3 $\Delta L = \varepsilon L_0 = \frac{\sigma}{E} L_0 = \frac{F_N L_0}{AE}$

$\rightarrow \Delta L = \frac{F_N L_0}{AE}$

E4

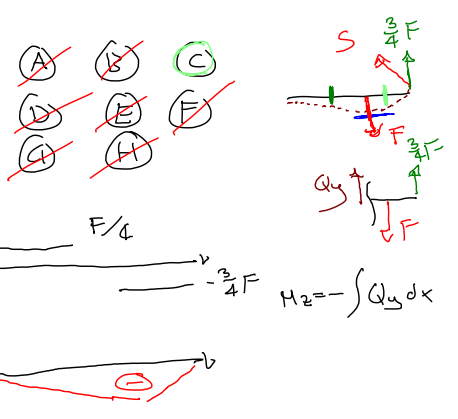


E5 $\rightarrow$ Lager: $M_z = 0$

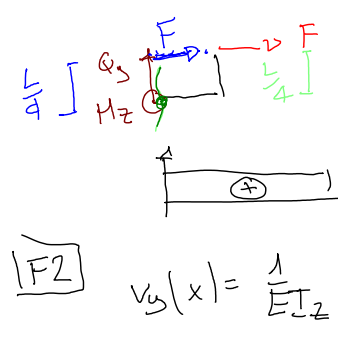
$\rightarrow$ Freies Ende: $M_z = 0$

$\rightarrow$ Einzelmoment
$\hookrightarrow$ würde einen Sprung verursachen

$\rightarrow$ Zug auf der Unterseite
$\hookrightarrow$ M_z negativ ist

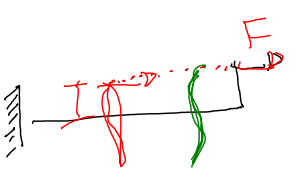


F1 $\rightarrow$ Zug auf der Oberseite
$\hookrightarrow$ M_z positiv



$Q_y = 0$

$M_z = F\frac{L}{4}$



F2 $v_y(x) = \frac{1}{EI_z} \iint M_z(x)\, dx = \frac{1}{EI_z} \iint \frac{FL}{4}\, dx$

$= \frac{1}{EI_z} \int \left(\frac{FL}{4} x + C_1 \right) dx$

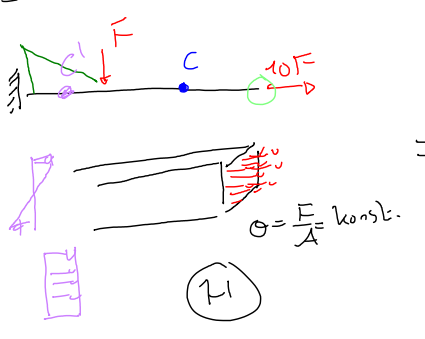
$v_y(x=L) =$

$v'_y(x=0) = 0$
$\hookrightarrow C_1 = 0$

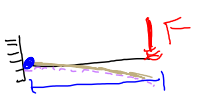
$= \frac{1}{EI_z} \left(\frac{FL}{4} \frac{x^2}{2} + C_2 \right)$

$v_y(x=0) = 0$
$\hookrightarrow C_2 = 0$

G1



G2



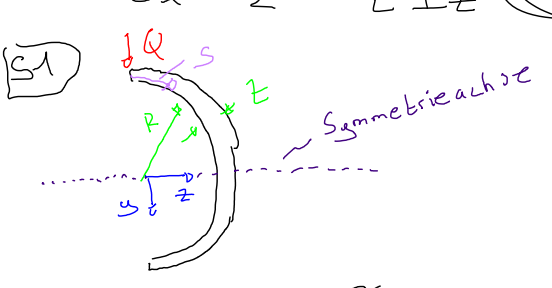
$\sigma_x = -E\left(-\frac{a}{2}\right) v''_y(x=0)$

$v''_y \sim M_z$

$\sigma_x = \frac{a}{2} E \frac{M_z(x=0)}{EI_z} = \frac{30F}{a^2} + \frac{10F}{a^2}$

$= \frac{40F}{a^2}$

S1



1.) Schubspannungen τ_{xs}

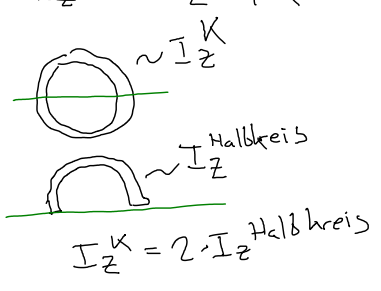
$\tau_{xs}(x,s) = -\frac{Q_y}{I_z} \frac{M_z(s)}{e(s)} \qquad Q_y = Q, \quad e(s) = t$

$I_z = \frac{1}{2} \frac{\pi}{4} \left((R+t)^4 - R^4 \right) = \frac{\pi}{8} \left((R+t)^2 (R+t)^2 - R^4 \right)$ $\qquad t \ll R$

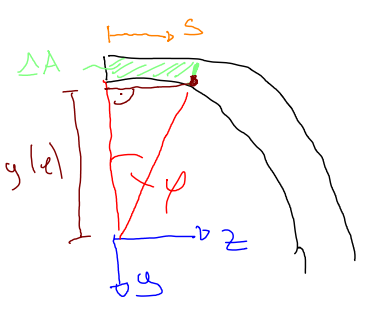
$= \frac{\pi}{8} \left((R^2 + 2Rt + t^2)^2 - R^4 \right)$

$= \frac{\pi}{8} \left(\cancel{R^4} + \cancel{4R^2t^2} + \cancel{t^4} + 4R^3t + \cancel{2R^2t^2} + \cancel{4Rt^3} - \cancel{R^4} \right)$

$= \frac{\pi}{8} 4R^3 t = \frac{\pi R^3 t}{2}$



$I_z^K = 2 \cdot I_z^{Halbkreis}$



$M_z(s) = \int_0^s y(\varphi)\, e(\varphi)\, \underbrace{d\varphi}_{dA}$ $\qquad t, R$

$y(\varphi) = R\cos(\varphi)(-1)$

$M_z(s) = -tR^2 \int_0^s \cos(\varphi)\, d\varphi = -tR^2 \left[\sin(\varphi) \right]_0^s$

$= -tR^2 \sin(s)$

$\tau_{xs}(x,s) = + \frac{Q \cdot 2}{\pi R^3 t} \frac{+\cancel{tR^2} \sin(s)}{\cancel{t}} = \frac{2Q}{\pi R t} \sin(s)$

3.) $T = \Delta x \cdot F = R \iint_A \tau_{xs}\, dA$

$= R \int_0^{\pi} \int_R^{R+t} \frac{2Q}{\pi R t} \sin(\varphi)\, \rho\, d\rho\, d\varphi$

$= \frac{2Q}{\pi R t} \int_0^{\pi} \int_R^{R+t} \sin(\varphi)\, \rho\, d\rho\, d\varphi$

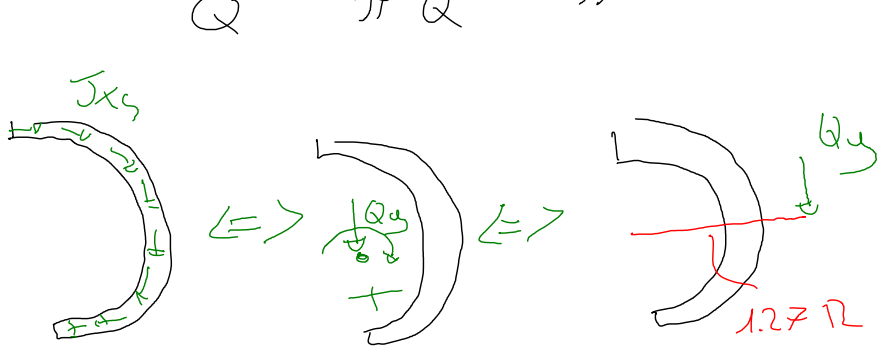
$= \frac{2Q}{\pi R t} \int_0^{\pi} \sin(\varphi) \left[\frac{\rho^2}{2} \right]_R^{R+t} d\varphi$

$= \frac{\cancel{2}Q}{\pi R \cancel{t^2}} \int_0^{\pi} \sin(\varphi) \left[\cancel{R^2} + 2Rt + \underbrace{\cancel{t^2}}_{\approx 0} - \cancel{R^2} \right] d\varphi$

$= -\frac{2RtQ}{\pi t} \left[\cos(\varphi) \right]_0^{\pi}$

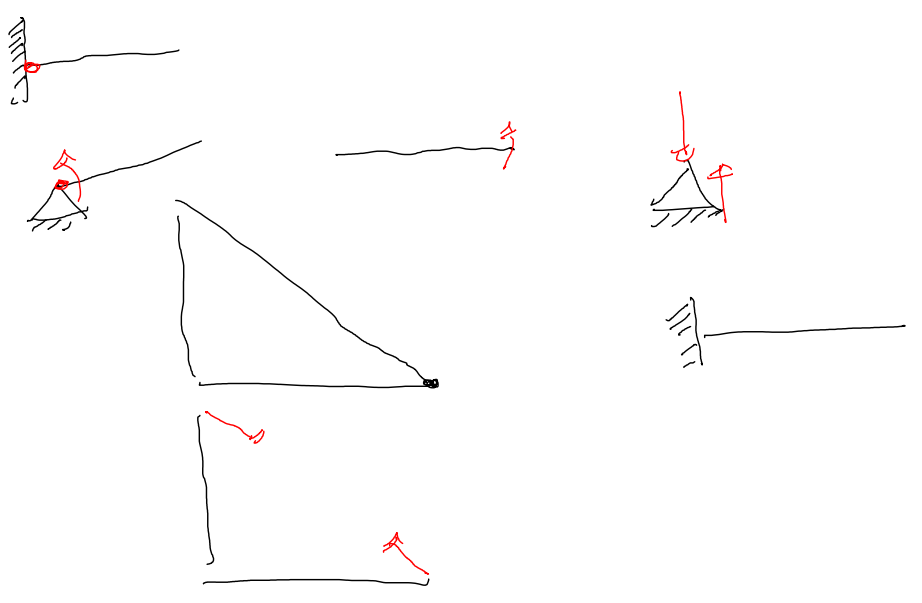
$= -\frac{2RQ}{\pi} (-1 - 1) = \frac{4RQ}{\pi}$

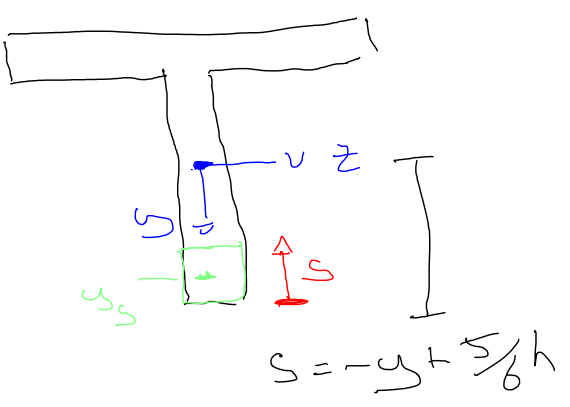
4.) $\Delta z_M = \frac{T}{Q} = \frac{4RQ}{\pi Q} = \frac{4R}{\pi} \approx 1.27 R$



$R = 10\,m$
$t = 0.1\,m$

$t^2 = (0.1\,m)^2 = \left(\frac{1}{10}\right)^2 m^2$
$= \frac{1}{100} m^2$
$= 0.01$





$s = -y + \frac{5}{6} h$