DEPARTMENT OF CIVIL ENGINEERING, IIT BOMBAY

CE 221 Solid Mechanics

Tutorial Sheet = 8 Instructor : A. Laskar/N. K. Chandiramani

1. For the engineering structures shown in Fig. 1 determine the normal and shear stresses at the point shown. Sketch an element in each case showing the magnitude and sense of the stresses on each face.
2. For the elements illustrated in Fig. 2 calculate the stress components on the inclined planes.
3. Find the principal normal and maximum shearing stresses and show their sense on a properly oriented element for the state of stress (in MPa) shown in Table 1. by (a) analytically and (b) Mohr's circle of stresses.
4. A chemical pressure vessel is to be manufactured from glass fibres in an epoxy matrix as shown in Fig. 3. If the optimum orientation of fibre is that in which the fibres are subjected to tensile stress with no transverse or shear stresses, determine the optimum value of α.
5. Draw Mohr's circle of strain and determine principal normal and shear strains and their directions for the elements having the strains as in Table 2. Verify your results analytically. Also, determine principal normal and shearing stresses. Take E=200 GPa and ν=0.3.
6. Data from rectangular strain rosette glued to steel plate are as follows ε_{0^o} = -0.00022, ε_{45^o} = 0.00012 and ε_{90^o} = 0.00022. What are the principal stresses and in which direction do they act? E=200 GPa and ν=0.3.
7. Data from equiangular strain rosette attached to aluminium alloy are as follows ε_{0^o} = 0.0004, ε_{60^o} = 0.0004 and ε_{120^o} = -0.0006. What are the principal stresses and their directions. E=70 GPa and ν=0.25

Table - 1

Element.	σ_x	σ_y	τ_{xy}
1.	60	20	0
2.	-30	50	-40
3.	200	0	80
4.	20	30	20

Table - 2

Element.	ε_x	ε_y	γ_{xy}
1.	-0.00012	0.00112	-0.0002
2.	0.0008	0.0020	0.0008

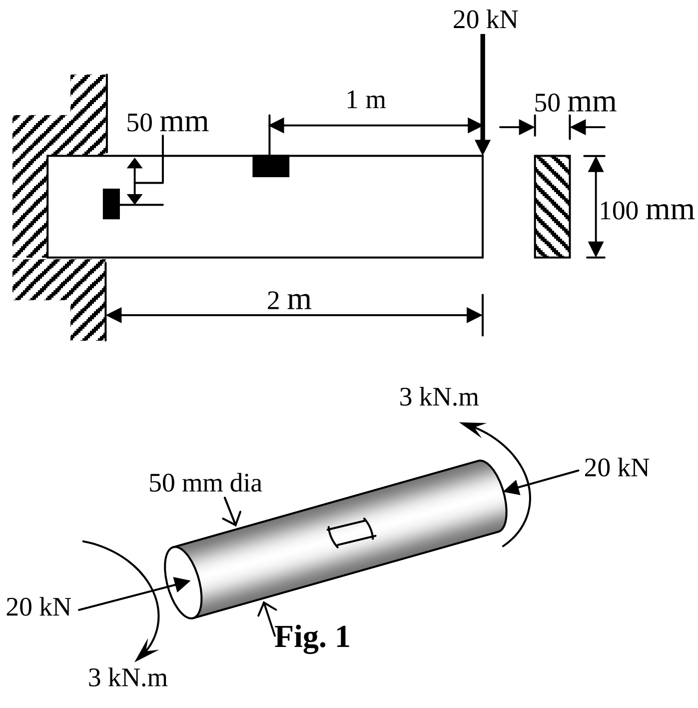

Fig. 1

(in MPa)

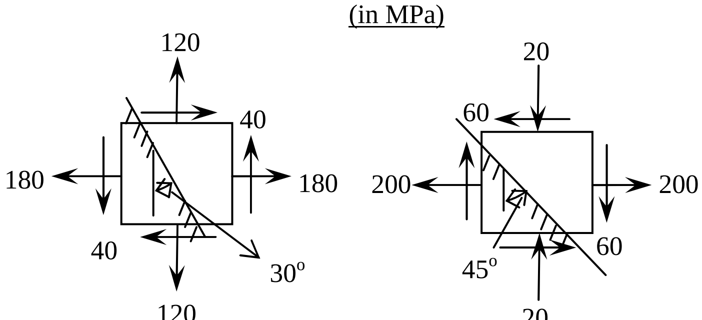

Fig. 2

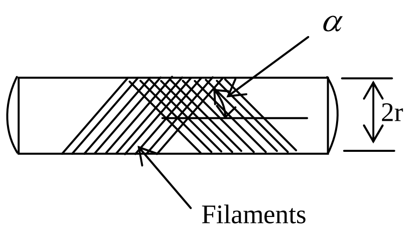

Fig. 3

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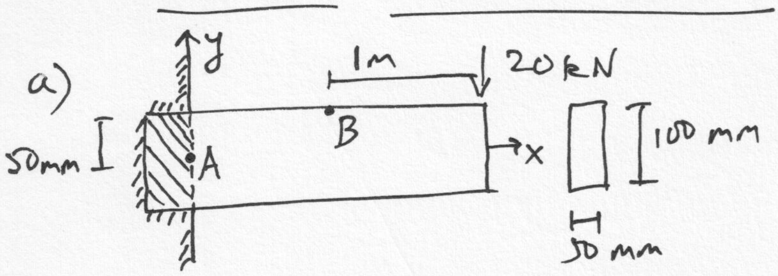
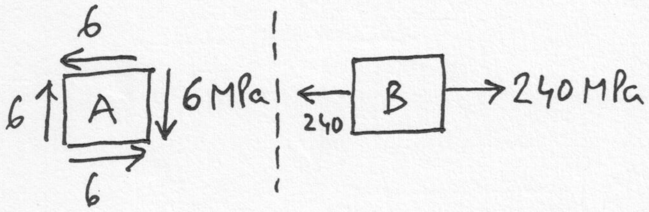
1) a)



Point A: $\sigma_x = 0$, $\tau_{xy} = \dfrac{(20E3)(50)(50)(25)}{(50)\frac{(100)^3}{12}(50)}$

$\sigma_y = 0$

$= 6\,\text{MPa}$.

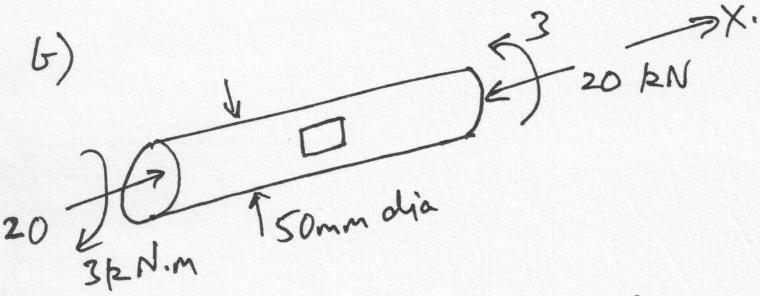


Point B: $\tau_{xy} = 0$, $\sigma_x = -\dfrac{(-20E3.1E3)(50)}{\frac{(50)(100)^3}{12}}$

$\sigma_y = 0$

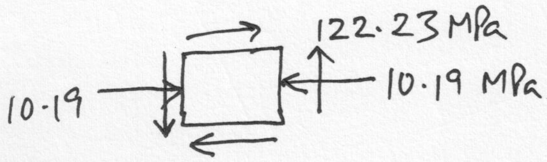
$= 240\,\text{MPa}$

b)



$\tau = \dfrac{(3E6)(50)}{\frac{\pi}{32}(50^4)} = \dfrac{244.46}{2} = 122.23$ MPa

$\sigma_x = -\dfrac{20E3}{\frac{\pi}{4}50^2} = -10.19\,\text{MPa}$

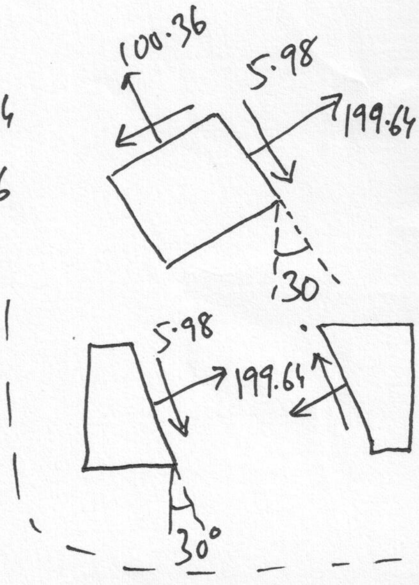


2). a) $\sigma_x = 180$, $\sigma_y = 120$, $\tau_{xy} = 40$, $\theta = 30°$

$\sigma_{x'} = \dfrac{180+120}{2} + \dfrac{180-120}{2}\cos 60 + 40\sin 60 = 199.64$

(not reqd) → $\sigma_{y'} =$ " − " − " $= 100.36$

$\tau_{x'y'} = -\left(\dfrac{180-120}{2}\right)\sin 60 + 40\cos 60 = -5.98$

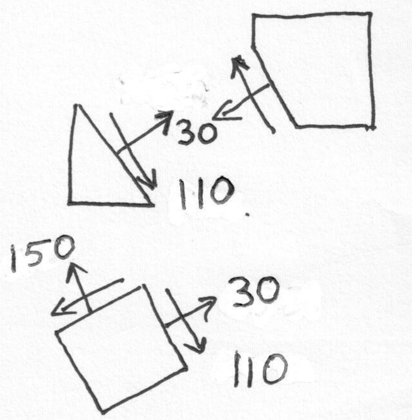


b) $\sigma_x = 200$, $\sigma_y = -20$, $\tau_{xy} = -60$, $\theta = 45°$

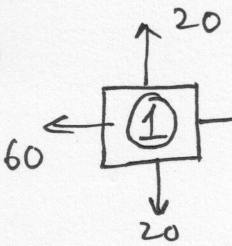
$\sigma_{x'} = \dfrac{200-20}{2} + \dfrac{200+20}{2}\cos 90 - 60\sin 90 = 30$

(not reqd) → $\sigma_{y'} =$ " − " + " $= 150$

$\tau_{x'y'} = -\left(\dfrac{200+20}{2}\right)\sin 90 - 60\cos 90 = -110$



3)



Principal element

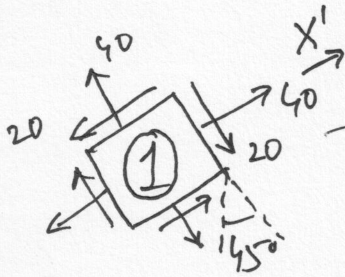
$\because \tau_{xy} = 0$, it is the principal element itself.

$\sigma_{max} = 60, \quad \sigma_{min} = 20.$

$$\tau_{max} = \left| \frac{60-20}{2} \right| = 20$$

On max τ plane, $\sigma_{x'} = \sigma_{y'} = \sigma_{ave} = \frac{60+20}{2} = 40.$

τ_{max} planes make $45°$ with principal planes

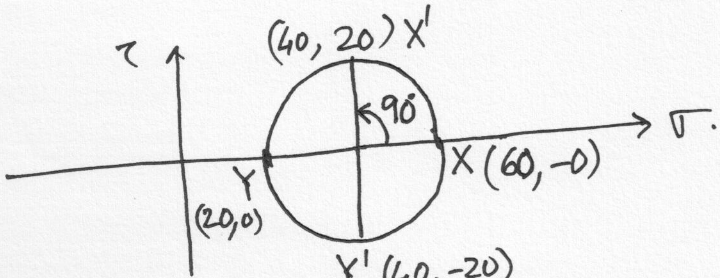


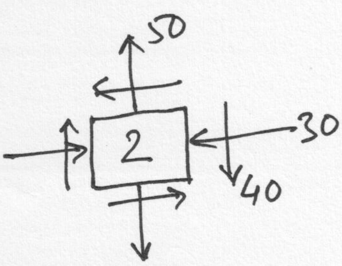
$\longrightarrow$ For direction of τ_{max}, use

$$\tau_{x'y'} = -\left(\frac{60-20}{2}\right) \sin 2\theta + (0) \cos 2\theta = -20$$

(with $\theta = +45°$)

τ Max element





$$\sigma_{ave} = \frac{-30+50}{2} = 10, \quad R = \sqrt{\left(\frac{-30-50}{2}\right)^2 + (-40)^2} = 40\sqrt{2}$$

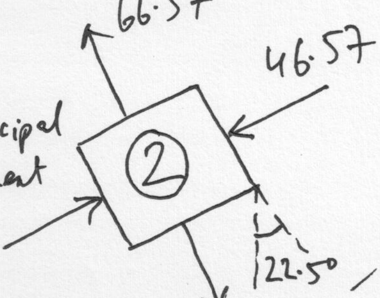
$\sigma_{max} = \sigma_{ave} + R = 66.57, \quad \sigma_{min} = \sigma_{ave} - R = -46.57$

$R = \tau_{max} = 40\sqrt{2} = 56.57$

$$\theta_p = \frac{1}{2} \tan^{-1}\left(\frac{2 * (-40)}{-30-50}\right) = 22.5°, \ 112.5°.$$

$$\theta_s = 22.5 \pm 45 = 67.5°, \ -22.5°.$$

Principal element

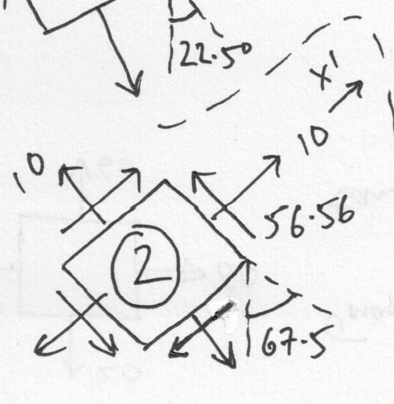


$$\sigma_{x'}\Big|_{\theta=\theta_p=22.5} = \left(\frac{-30+50}{2}\right) + \left(\frac{-30-50}{2}\right)\cos 45 - 40 \sin 45$$

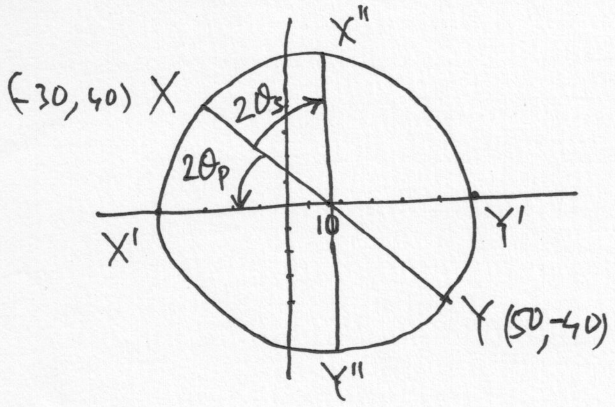
$$= -46.57$$

$$\tau_{x'y'}\Big|_{\theta=\theta_s=67.5°} = -\left(\frac{-30-50}{2}\right) \sin(2*67.5) - 40 \cos(2*67.5)$$

$$= 56.56.$$



τ_{max} element



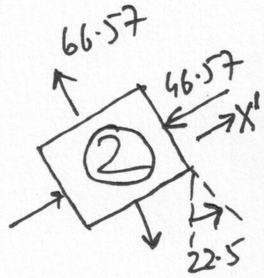
$$R = \frac{1}{2}\sqrt{(50+30)^2 + (40+40)^2} = 56.57 = 40\sqrt{2}$$

$$\sigma_{min} (\equiv X') = 10 - R = -46.57.$$

$$\sigma_{max} (\equiv Y') = 10 + R = 66.57$$

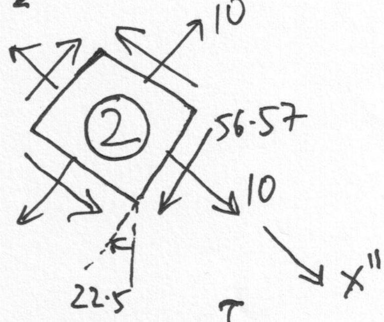
$$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{40}{R}\right) = 22.5^\circ$$

$$\theta_s = 22.5^\circ$$



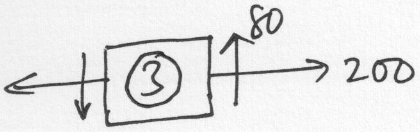
Principal element

(Same results as from formulae)



Max ~~shear~~ τ element.

———— X ————



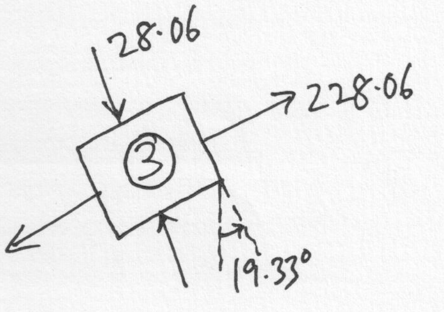
$$\sigma_{ave} = \frac{200+0}{2} = 100, \quad R = \sqrt{\left(\frac{200-0}{2}\right)^2 + 80^2} = 128.06$$

$$\sigma_{max} = 228.06, \quad \sigma_{min} = 100 - 128.06 = -28.06$$

$$\tau_{max} = 128.06$$

$$\theta_p = \frac{1}{2}\tan^{-1}\left(\frac{2*80}{200-0}\right) = 19.33^\circ, \ 109.33^\circ$$

$$\theta_s = 19.33 \pm 45^\circ = 64.33^\circ, -25.67^\circ$$



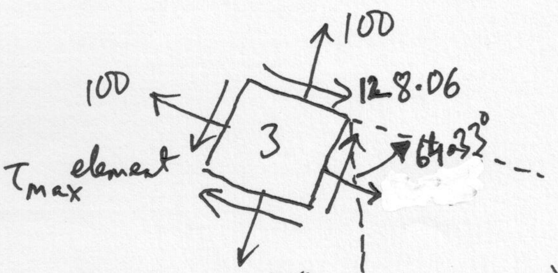
Principal element.

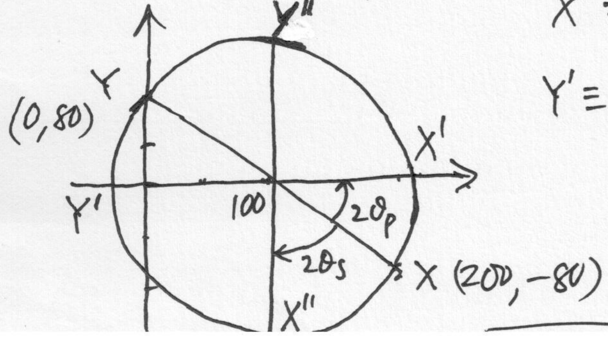
$$\sigma_{x'}\Big|_{\theta=\theta_p=19.33} = \frac{200+0}{2} + \left(\frac{200-0}{2}\right)\cos(2*19.33) + 80\sin(2*19.33)$$

$$= 228.06.$$

$$\tau_{x'y'}\Big|_{\theta_s=64.33} = -\left(\frac{200-0}{2}\right)\sin(2*64.33) + 80\cos(2*64.33)$$

$$= -128.06$$



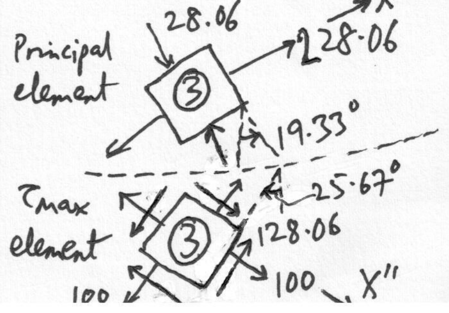


$$X' \equiv \sigma_{max} = 100 + R = 228.06, \quad R = \frac{1}{2}\sqrt{(200-0)^2 + (80*2)^2} = 128.06$$

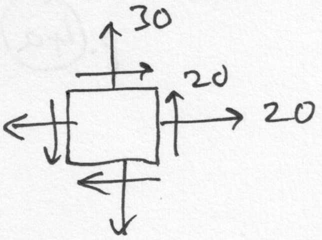
$$Y' \equiv \sigma_{min} = 100 - R = -28.06.$$

$$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{80}{R}\right) = 19.33^\circ$$

$$\theta_s = 45 - \theta_p = 25.67^\circ$$



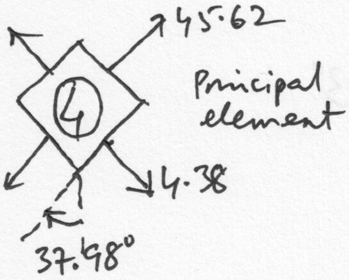
———— X ————



$$\sigma_{av} = \frac{20+30}{2} = 25, \quad R = \sqrt{\left(\frac{20-30}{2}\right)^2 + 20^2} = 20.62 = 5\sqrt{17}$$

$$\sigma_{max} = 25 + 20.62 = 45.62, \quad \sigma_{min} = 25 - 20.62 = 4.38$$

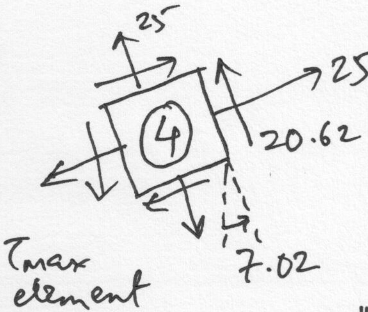
$$\tau_{max} = 20.62$$



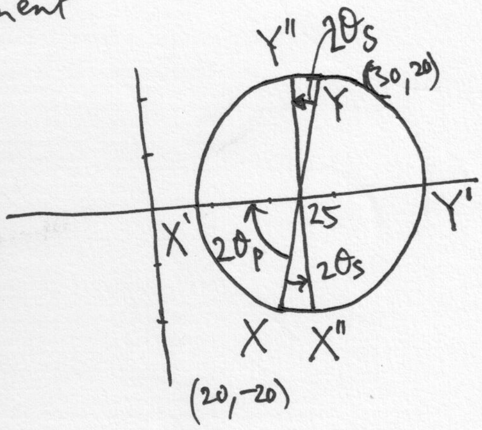
$$\theta_p = \frac{1}{2}\tan^{-1}\left(\frac{2*20}{20-30}\right) = -37.98°, 52.02°$$

$$\theta_s = -37.98 \pm 45 = 7.02°, -82.98°$$

$$\sigma_{x'}\Big|_{\theta=\theta_p=-37.98°} = \frac{20+30}{2} + \frac{20-30}{2}\cos(2*-37.98) + 20\sin(2*-37.98) = 4.38$$



$$\tau_{x'y'}\Big|_{\theta_s=7.02} = -\left(\frac{20-30}{2}\right)\sin(2*7.02) + 20\cos(2*7.02) = 20.62$$

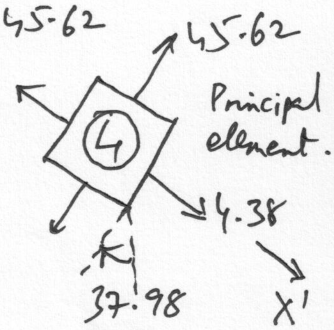


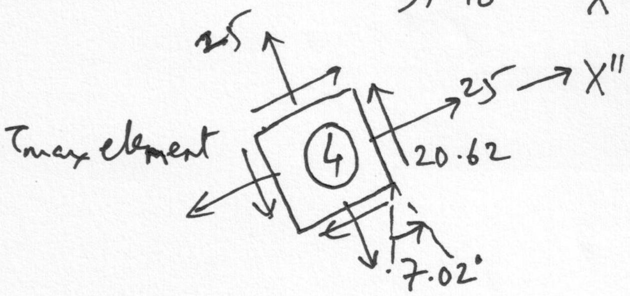
$$X' \equiv \sigma_{min} = 25 - \frac{1}{2}\sqrt{40^2+10^2} = 4.38 \; ; R = \frac{1}{2}\sqrt{40^2+10^2} = 20.62$$

$$Y' \equiv \sigma_{max} = 25 + \frac{1}{2}\sqrt{40^2+10^2} = 45.62$$

$$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{20}{R}\right) = 37.98°$$

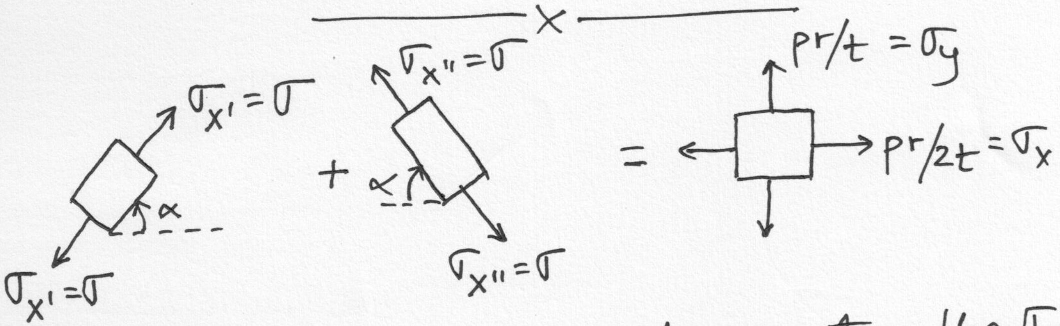
$$\theta_s = \frac{1}{2}\cos^{-1}\left(\frac{20}{R}\right) = 7.02°$$





————— x —————

4)



Transform from x' & x'' systems to x system. Use $\sigma_{y'} = \sigma_{y''} = \tau_{x'y'} = \tau_{x''y''} = 0$

$$\sigma_x = \frac{pr}{2t} = \frac{\sigma_{x'}}{2} + \frac{\sigma_{x'}}{2}\cos 2\alpha + \frac{\sigma_{x''}}{2} + \frac{\sigma_{x''}}{2}\cos 2\alpha = \sigma(1+\cos 2\alpha) \rightarrow 1$$

$$\sigma_y = \frac{pr}{t} = \frac{\sigma_{x'}}{2} - \frac{\sigma_{x'}}{2}\cos 2\alpha + \frac{\sigma_{x''}}{2} - \frac{\sigma_{x''}}{2}\cos 2\alpha = \sigma(1-\cos 2\alpha) \rightarrow 2$$

$$\tau_{xy} = 0 = \frac{\sigma_{x'}}{2}\sin 2\alpha - \frac{\sigma_{x''}}{2}\sin 2\alpha = \frac{\sigma}{2}(\sin 2\alpha - \sin 2\alpha) = 0 \rightarrow 3$$

satisfied identically

$\tau_{xy} = 0$

$\sigma_x = \frac{pr}{2t}$

$\sigma_y = \frac{pr}{t}$

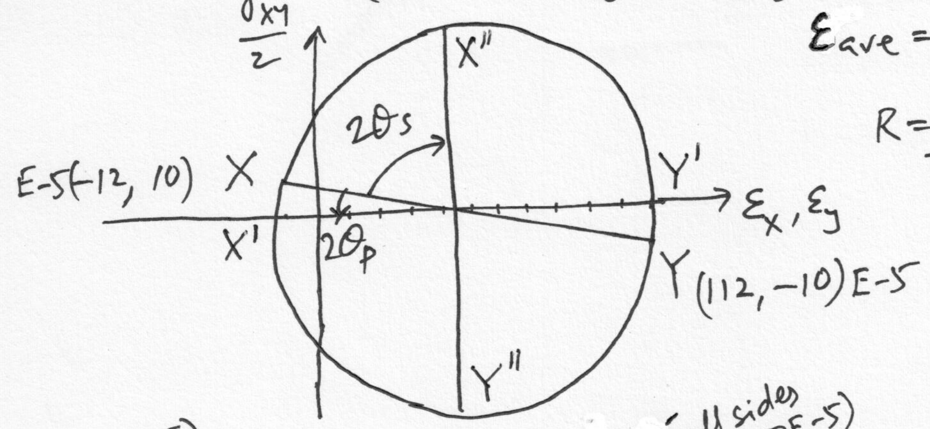
4) contd

solve ①, ②,

$$2\sigma = \frac{3}{2}\frac{pr}{t} \Rightarrow \sigma = \frac{3}{4}\frac{pr}{t}$$

$$\Rightarrow \cos 2\alpha = -1 + \frac{2}{3} = -\frac{1}{3} \Rightarrow \alpha = 54.73^\circ$$

5) $(\varepsilon_x = -12,\ \varepsilon_y = 112,\ \gamma_{xy} = -20) * E\text{-}5.$ 5



$\varepsilon_{ave} = \frac{112-12}{2} = 50$

$R = \frac{1}{2}\sqrt{(112+12)^2 + 20^2} = 62.80$

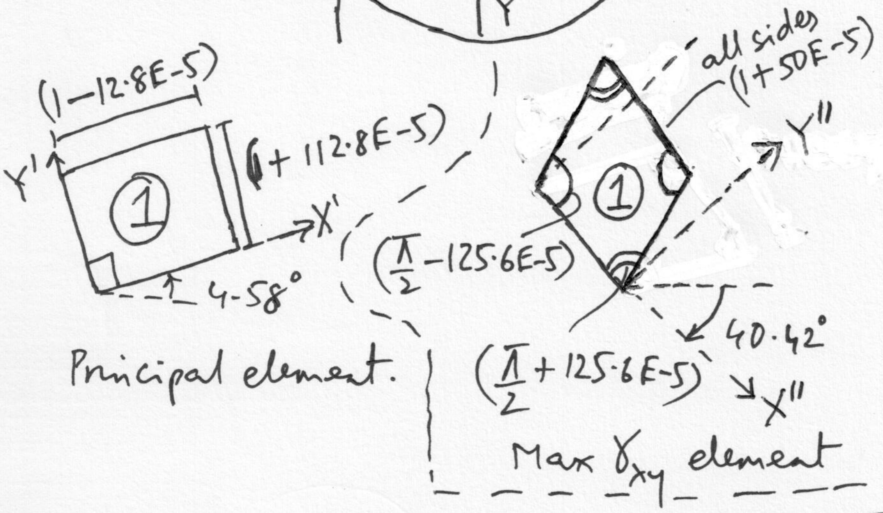
$\varepsilon_{max} = 50 + 62.8 = 112.8\,E\text{-}5$

$\varepsilon_{min} = 50 - 62.8 = -12.8\,E\text{-}5$

$(\gamma_{xy})_{max} = 2R = 125.6\,E\text{-}5$

$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{10}{R}\right) = 4.58^\circ$

$\theta_s = \frac{1}{2}\cos^{-1}\left(\frac{10}{R}\right) = 40.42^\circ$



$$\varepsilon_{max,min} = \left(\frac{-12+112}{2}\right) \pm \overbrace{\sqrt{\left(\frac{-12-112}{2}\right)^2 + \left(\frac{-20}{2}\right)^2}}^{R.} = (112.8, -12.8)\,E\text{-}5.$$

$(\gamma_{xy})_{max} = 2R = 125.6\,E\text{-}5.$

$\theta_p = \frac{1}{2}\tan^{-1}\left(\frac{-20}{-12-112}\right) = 4.58^\circ, 94.58^\circ \ ; \ \theta_s = \theta_p \pm 45^\circ = 49.58^\circ, -40.42^\circ$

$$\varepsilon_{x'}\Big|_{\theta=\theta_p=4.58} = \left(\frac{-12+112}{2}\right) + \left(\frac{-12-112}{2}\right)\cos(2*4.58) + \left(\frac{-20}{2}\right)\sin(2*4.58)$$

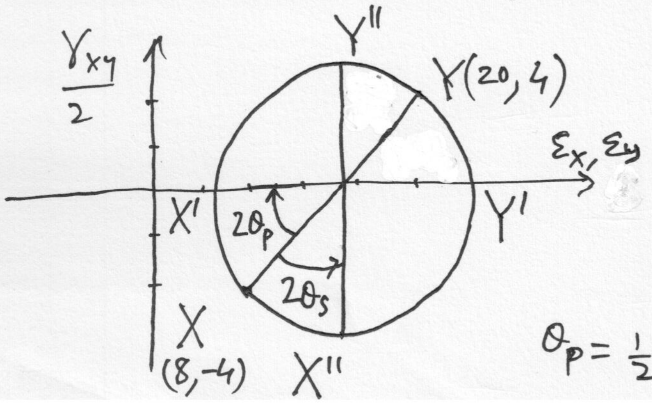
$= -12.8\,E\text{-}5.$ ✓ So it checks out with Mohr circle

$$\gamma_{x'y'}\Big|_{\theta_s=-40.42} = -(-12-112)\sin(2*-40.42) + (-20)\cos(2*-40.42) = -125.6E\text{-}5$$

✓ So it checks out with Mohr circle.

——— x ———

$(\varepsilon_x = 8,\ \varepsilon_y = 20,\ \gamma_{xy} = 8)\,E\text{-}4.$



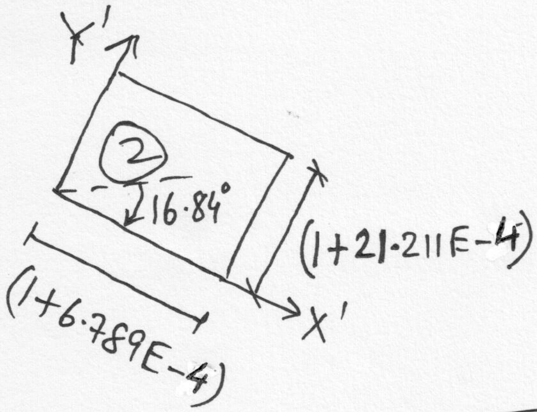
$\varepsilon_{ave} = \frac{8+20}{2} = 14$

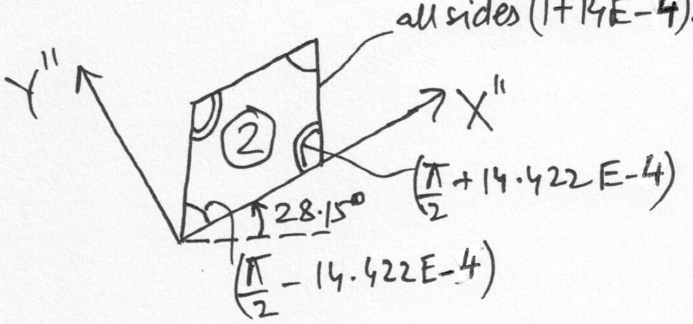
$R = \frac{1}{2}\sqrt{(20-8)^2 + 8^2} = 7.211$

$\varepsilon_{max} = 14 + 7.211 = 21.211\,E\text{-}5, \ \varepsilon_{min} = 14 - 7.211 = 6.789\,E\text{-}4.$

$(\gamma_{xy})_{max} = 2R = 14.422\,E\text{-}4$

$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{4}{R}\right) = 16.84, \ \theta_s = \left(\frac{\pi}{2} - 2\theta_p\right)\frac{1}{2} = 28.15^\circ$





$$\varepsilon_{max,min} = \left(\frac{8+20}{2}\right) \pm \overbrace{\sqrt{\left(\frac{8-20}{2}\right)^2 + \left(\frac{8}{2}\right)^2}}^{R} = (21.211,\ 6.789)E-4$$

$$(\gamma_{xy})_{max} = 2R = 2\sqrt{52} = 14.422E-4$$

$$\theta_p = \frac{1}{2}\tan^{-1}\left(\frac{8}{8-20}\right) = -16.84°,\ 73.15°,\quad \theta_s = \pm 45 + \theta_p = 28.16°, -61.84°$$

$$\varepsilon_{x'}\Big|_{\theta=\theta_p=-16.84°} = \left(\frac{8+20}{2}\right) + \left(\frac{8-20}{2}\right)\cos(2*-16.84) + \frac{8}{2}\sin(2*-16.84) = 6.789E-4$$

checks out with Mohr circle

$$\gamma_{x'y'}\Big|_{\theta=\theta_s=28.16°} = -(8-20)\sin(28.16*2) + 8\cos(2*28.16) = 14.422E-4.$$

checks out with Mohr circle

THEORY.

Principal stresses, max shearing stresses from principal and max shearing strains.

From constitutive law $\tau_{xy} = G\gamma_{xy}$

So $\gamma_{xy} = 0 \Rightarrow \tau_{xy} = 0$, $\gamma_{xy} = max \Rightarrow \tau_{xy} = max$.

So principal planes & maximum shear planes of strain coincide with principal planes & max shear planes of stress.

$$\varepsilon_{x'} = \frac{\sigma_{x'}}{E} - \frac{\nu\sigma_{y'}}{E} - \frac{\nu}{E}\sigma_{z'} = \frac{1}{E}\left[(1-\nu^2)\sigma_{x'} - \nu(1+\nu)\sigma_{y'}\right]$$

$$\varepsilon_{y'} = \frac{\sigma_{y'}}{E} - \frac{\nu}{E}(\sigma_{x'} + \sigma_{z'}) = \frac{1}{E}\left[(1-\nu^2)\sigma_{y'} - \nu(1+\nu)\sigma_{x'}\right]$$

$$\varepsilon_{z'} = 0 = \frac{\sigma_{z'}}{E} - \frac{\nu}{E}(\sigma_{x'} + \sigma_{y'})$$

substitute

∵ plane strain

$$\Rightarrow \sigma_{x'} = \left[(1-\nu^2)\varepsilon_{x'} + \nu(1+\nu)\varepsilon_{y'}\right]\frac{E}{(1-\nu^2)^2 - \nu^2(1+\nu)^2} = \frac{E\left[(1-\nu)\varepsilon_{x'} + \nu\varepsilon_{y'}\right]}{(1+\nu)(1-2\nu)}$$

$$\left.\begin{aligned}
\sigma_{x'} &= \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_{x'} + \nu\varepsilon_{y'}\right] \\
\sigma_{y'} &= \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_{y'} + \nu\varepsilon_{x'}\right] \\
\sigma_{z'} &= \frac{E\nu}{(1+\nu)(1-2\nu)}\left(\varepsilon_{x'} + \varepsilon_{y'}\right)
\end{aligned}\right\}$$

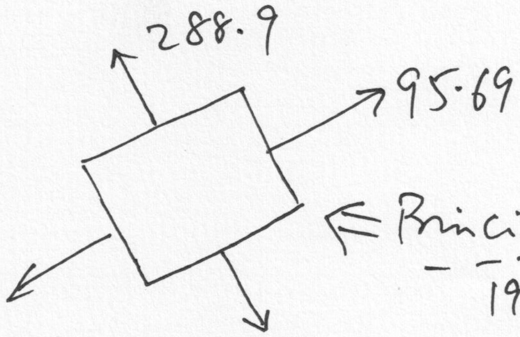
were derived in L2 _ axial loading chapter (slide 34).

Case I For principal strains, $\varepsilon_{x'} = \varepsilon_{min} = -12.8E-5$, $\varepsilon_{y'} = \varepsilon_{max} = 112.8E-5$, $\gamma_{x'y'} = 0$

$$\sigma_{x'} = \frac{200E3}{(1.3)(0.4)}\left[(0.7)(-12.8E-5) + (0.3)(112.8E-5)\right] = 95.69\,MPa = \sigma_{min}$$

$$\sigma_{y'} = \frac{200E3}{(1.3)(0.4)}\left[(0.7)(112.8E-5) + (0.3)(-12.8E-5)\right] = 288.9\,MPa = \sigma_{max}$$

$$\tau_{x'y'} = G\gamma_{x'y'} = 0$$



$\Leftarrow$ Principal element

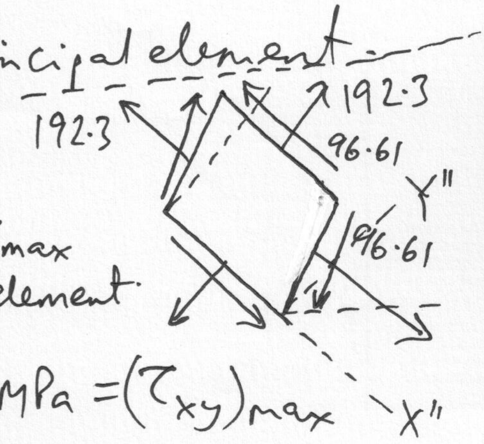
For max shear strain,

$\varepsilon_{x''} = \varepsilon_{y''} = \varepsilon_{ave} = 50E-5$

$\gamma_{x''y''} = -125.6E-5$

$$\sigma_{y''} = \sigma_{x''} = \frac{200E3}{(1.3)(0.4)}(50E-5) = 192.3\,MPa$$

τ_{max} element



$$\tau_{x''y''} = G\gamma_{x''y''} = \frac{200E3}{2(1.3)}(-125.6E-5) = -96.61\,MPa = (\tau_{xy})_{max}$$

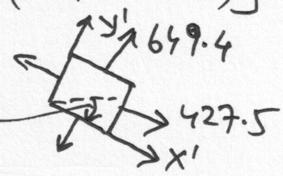
Case II For principal strains, $\varepsilon_{x'} = \varepsilon_{min} = 6.789E-4$, $\varepsilon_{y'} = \varepsilon_{max} = 21.211E-4$, $\gamma_{x'y'} = 0$

$$\sigma_{x'} = \frac{200E3}{(1.3)(0.4)}\left[(0.7)(6.789E-4) + (0.3)(21.211E-4)\right] = 427.5\,MPa = \sigma_{min}$$

$$\sigma_{y'} = \frac{200E3}{(1.3)(0.4)}\left[(0.7)(21.211E-4) + (0.3)(6.789E-4)\right] = 649.4\,MPa = \sigma_{max}$$

$$\tau_{x'y'} = G\gamma_{x'y'} = 0$$

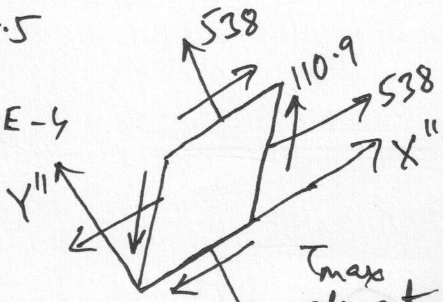
Principal element 16.84°



For max shear strains, $\varepsilon_{x''} = \varepsilon_{y''} = 14E-4$, $\gamma_{x''y''} = 14.422E-4$

$$\sigma_{x''} = \sigma_{y''} = \frac{200E3}{(1.3)(0.4)}(14E-4) = 538\,MPa$$

$$\tau_{x''y''} = G\gamma_{x''y''} = \frac{200E3}{2(1.3)}(14.422E-4) = 110.9\,MPa$$



τ_{max} element.

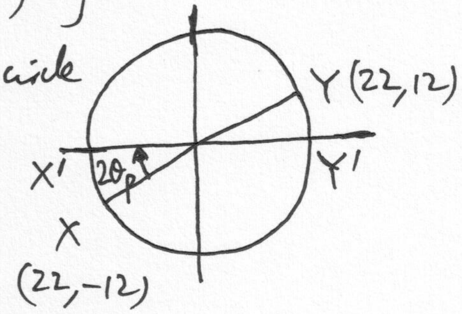
6) $\varepsilon_x = \varepsilon_{0°} = -22E{-}5$, $\varepsilon_y = \varepsilon_{90°} = 22E{-}5$

$\varepsilon_{45°} = 12E{-}5 = \left(\frac{-22+22}{2}\right)E{-}5 + \frac{\gamma_{xy}}{2} \Rightarrow \gamma_{xy} = 24E{-}5$

$\varepsilon_{max,min} = \left[\left(\frac{-22+22}{2}\right) \pm \underbrace{\sqrt{\left(\frac{-22-22}{2}\right)^2 + \left(\frac{24}{2}\right)^2}}_{R}\right]E{-}5 = \pm 25.06E{-}5$

$\theta_p = \frac{1}{2}\sin^{-1}\left(\frac{12}{R}\right) = 14.31°$

here used Mohr circle to determine planes of $\varepsilon_{min}, \varepsilon_{max}$

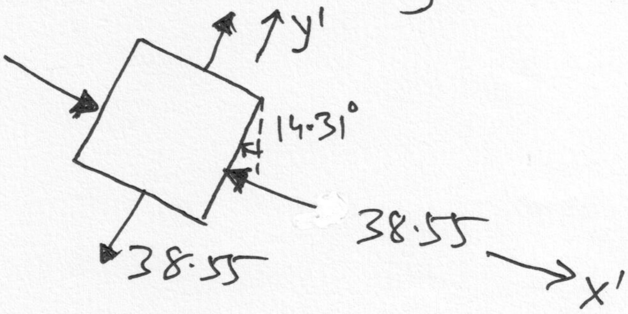


$\Rightarrow \varepsilon_{x'} = \varepsilon_{min} = -25.06E{-}5$, $\varepsilon_{y'} = \varepsilon_{max} = 25.06E{-}5$

$\gamma_{x'y'} = 0$

$\sigma_{x'} = \frac{200E3}{(1.3)(0.4)}\left[(0.7)(-25.06) + (0.3)(25.06)\right]E{-}5 = -38.55\,MPa$

$\sigma_{y'} = 38.55\,MPa$



7) $\varepsilon_x = \varepsilon_{0°} = 4E{-}4$

$\varepsilon_{60°} = 4E{-}4 = \varepsilon_x \frac{1}{4} + \varepsilon_y \frac{3}{4} + \gamma_{xy}\frac{\sqrt{3}}{2}\cdot\frac{1}{2} = 1.E{-}4 + \frac{3}{4}\varepsilon_y + \frac{\sqrt{3}}{4}\gamma_{xy}$

$-6E{-}4 = \varepsilon_{120°} = \varepsilon_x \frac{1}{4} + \varepsilon_y \frac{3}{4} + \gamma_{xy}\frac{\sqrt{3}}{2}\left(-\frac{1}{2}\right) = 1E{-}4 + \frac{3}{4}\varepsilon_y - \frac{\sqrt{3}}{4}\gamma_{xy}$

$\Rightarrow \varepsilon_y = \frac{2}{3}\cdot(-4E{-}4) = -\frac{8}{3}E{-}4$, $\gamma_{xy} = \frac{2}{\sqrt{3}}\cdot(10E{-}4) = \frac{20}{\sqrt{3}}E{-}4.$

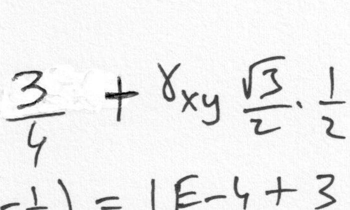
$\varepsilon_{max,min} = \frac{\left(4 - \frac{8}{3}\right)}{2} \pm \sqrt{\left(\frac{4+\frac{8}{3}}{2}\right)^2 + \left(\frac{20}{2\sqrt{3}}\right)^2} = (7.33, -6) * E{-}4$

$\theta_p = \frac{1}{2}\tan^{-1}\left[\frac{20/\sqrt{3}}{\left(4+\frac{8}{3}\right)}\right] = 30°, 120°$; $\varepsilon_{30°} = \left(4.\frac{3}{4} - \frac{8}{3}.\frac{1}{4} + \frac{20}{\sqrt{3}}\frac{\sqrt{3}}{2}.\frac{1}{2}\right)E{-}4$

$= 7.33E{-}4$

$\varepsilon_{x'} = \varepsilon_{max} = 7.33\,E{-}4$; $\varepsilon_{y'} = \varepsilon_{min} = -6E{-}4$

$\gamma_{x'y'} = 0$



here used transformation formulae to determine planes of $\varepsilon_{max}, \varepsilon_{min}$ (as an alternative to using Mohr's circle, as done above).

$\sigma_{x'} = \frac{70E3}{(1.25)(0.5)}\left[(0.75)(7.33) + (0.25)(-6)\right]E{-}4 = 44.8\,MPa$

$\sigma_{y'} = 70E3/(1.25)(0.5)\left[(0.75)(-6) + (0.25)(7.33)\right]E{-}4 = -29.87\,MPa$