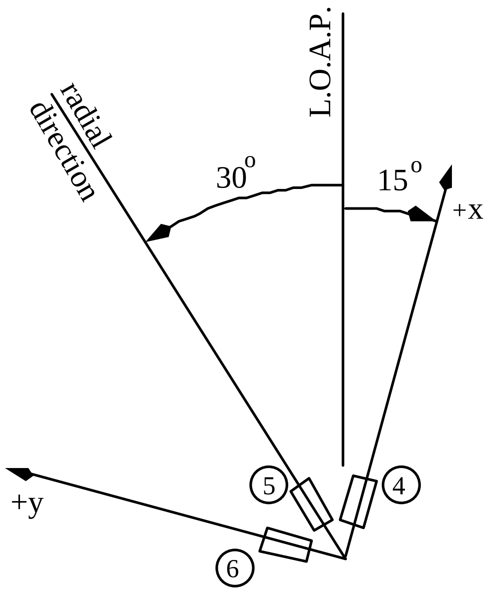
ME556 LAB #3 - SAMPLE CALCULATIONS AND SUMMARY OF TYPICAL RESULTS

I will use measurements obtained using rosette B to illustrate all calculation steps. Rosette B consisted of gages 4, 5, and 6, where gage 5 is aligned with the 30˚ radial direction. The sensing directions of gages 4 and 6 are defined as the x- and y-axes, respectively (see following sketch). Note that, having defined the +x-axis in this way, the angle between the +x-axis and the LOAP is -15° (i.e., 15° CW *from* the LOAP *to* the x-axis).



1) A linear curve fit of the data set I collected resulted in:

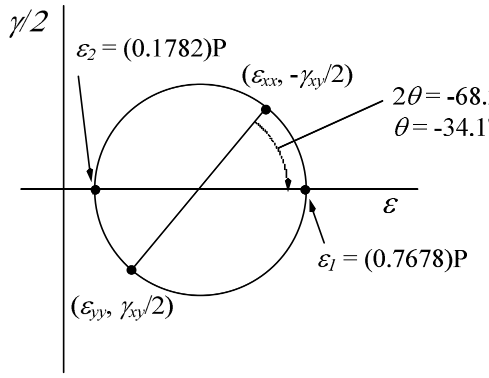
$$\varepsilon_4 = (0.5822)P - 6.46$$
$$\varepsilon_5 = (0.1992)P - 0.875$$
$$\varepsilon_6 = (0.3638)P + 5.63$$

These slopes and intercepts are included in Table 1, pg 4. Of course, these curve fits may differ slightly from the data set you collected. Since the intercepts are "small" they are ignored in all following calculations. Thus, in all following calculations I will use $\varepsilon_4 = (0.5822)P$, $\varepsilon_5 = (0.1992)P$, and $\varepsilon_6 = (0.3638)P$.

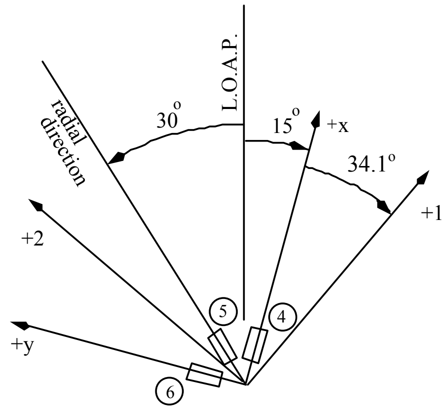
2) Using the rosette equations for a rectangular rosette, strains in the x-y coordinate system are found to be:

$\varepsilon_x = \varepsilon_4 = (0.5822)P$ $\qquad$ $\varepsilon_y = \varepsilon_6 = (0.3638)P$ $\qquad$ $\gamma_{xy} = 2\varepsilon_5 - (\varepsilon_4 + \varepsilon_6) = (-0.5476)P$

Mohr's circle for this state of strain is shown on the following page. Using Mohr's circle: $\varepsilon_1 = (0.7678)P$, $\varepsilon_2 = (0.1782)P$, and the angle *from* the *x*-axis *to* the +1-axis is θ_1 = -34.1°. Hence, the angle *from* the LOAP *to* the +1-axis is (-15° - 34.1°) = -49.1° (see sketch). Alternatively, principal strains and angle θ_1 can be calculated directly, without using Mohr's circle:



MOHR'S CIRCLE



ORIENTATION OF THE PRINCIPAL COORDINATE SYSTEM

$$\varepsilon_{1,2} = \frac{\varepsilon_x + \varepsilon_y}{2} \pm \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\varepsilon_{1,2} = \frac{0.5822P + 0.3638P}{2} \pm \sqrt{\left(\frac{0.5822P - 0.3638P}{2}\right)^2 + \left(\frac{-0.5476P}{2}\right)^2}$$

$$\varepsilon_{1,2} = 0.7678P, 0.1782P$$

$$\theta_1 = \tan^{-1}\left[\frac{2(\varepsilon_1 - \varepsilon_x)}{\gamma_{xy}}\right] = \tan^{-1}\left[\frac{2(0.7678P - 0.5822P)}{-0.5476P}\right] = -34.1°$$

As before, the angle *from* the LOAP *to* the +1-axis is therefore (-15° - 34.1°) = -49.1° These slopes and angle are included in Table 2, pg 4

3) Using Hooke's Law for plane stress, the principal stresses calculated based on measured strains are:

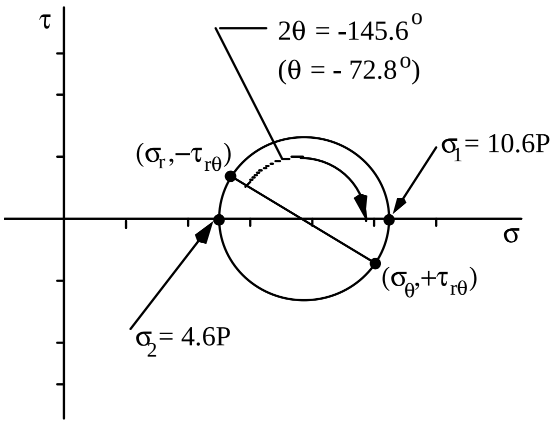
$$\sigma_1 = \frac{E}{1-\nu^2}\left[\varepsilon_1 + \nu\varepsilon_2\right] = \frac{10.4Msi}{1-(0.32)^2}\left[0.7678P + (0.32)0.1782P\right] = 9.56P$$

$$\sigma_2 = \frac{E}{1-\nu^2}\left[\varepsilon_2 + \nu\varepsilon_1\right] = \frac{10.4Msi}{1-(0.32)^2}\left[0.1782P + (0.32)0.7678P\right] = 4.91P$$

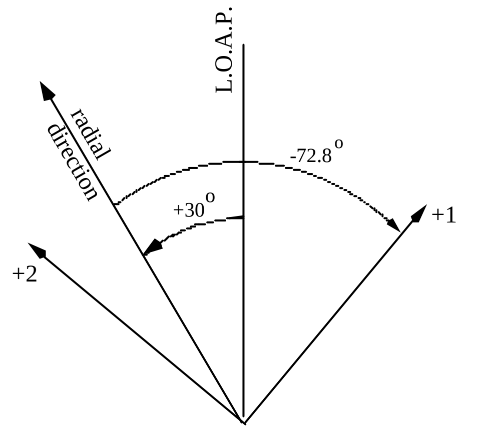
These slopes are included in Table 3, pg 4.

4) According to the elasticity solution, the stresses induced at the location of rosette B (r = 1.75 in, θ = 30°) are predicted to be:

$$\sigma_r = 5.134P \qquad \sigma_\theta = 10.04P \qquad \tau_{r\theta} = -1.680P$$



MOHR'S CIRCLE



PREDICTED ORIENTATION OF THE PRINCIPAL COORDINATE SYSTEM

Mohr's circle for this state of stress is shown above. Using Mohr's circle: $\sigma_1 = 10.6P$, $\sigma_2 = 4.6P$, and the angle between the radial direction and the +1-axis is -72.8°. Hence, the angle *from* the LOAP *to* the +1-axis is (30° - 72.8°) = -42.8° (see sketch above). These slopes and angle are included in Table 4, pg 4

5) Using Hooke's Law for plane stress, the "predicted" principal strains are:

$$\varepsilon_1 = \frac{1}{E}\left[\sigma_1 - \nu\sigma_2\right] = \frac{1}{10.4X10^6\,psi}\left[10.6P - (0.32)4.6P\right] = 0.878P\ (\mu in/in/lbf)$$

$$\varepsilon_2 = \frac{1}{E}\left[\sigma_2 - \nu\sigma_1\right] = \frac{1}{10.4X10^6\,psi}\left[4.6P - (0.32)10.6P\right] = 0.116P\ (\mu in/in/lbf)$$

These slopes are included in Table 2, pg 4.

6) A summary of the comparison between measured and predicted stresses and orientation of the principal axes for all rosette locations is shown in Figures 1 and 2 on page 5. In my judgement the agreement is good, and I conclude that the elasticity solution is correct (!).

ME 556 LAB #3 - SUMMARY OF RESULTS

Table 1. Linear regression of raw data:

Rosette	Gage Number	m (μin/in/lb_f)	b (μin/in)
A	1	1.144	5.65
	2	-0.6089	-0.0581
	3	0.6383	-6.26
B	4	0.5822	-6.46
	5	0.1992	-0.875
	6	0.3638	5.63
C	7	0.6448	4.89
	8	0.3687	0.977
	9	-0.01775	-5.17
D	10	-0.2031	-3.37
	11	0.5841	-0.032
	12	-0.1442	3.98
E	13	-0.327	1.17
	14	0.4625	0.714
	15	-0.4804	-2.62

Table 2. Principal strains:

	Experimental		Predicted	
Rosette	Principal Strains	$m_{\varepsilon1}$, $m_{\varepsilon2}$, or θ (μin/in/lb_f or degs)	Principal Strains	$m_{\varepsilon1}$, $m_{\varepsilon2}$, or θ (μin/in/lb_f or degs)
A	ε_1	2.41	ε_1	2.17
	ε_2	-0.630	ε_2	-.486
	θ	-55.2	θ	-57.6
B	ε_1	0.768	ε_1	.878
	ε_2	0.178	ε_2	.116
	θ	-49.1	θ	-42.8
C	ε_1	0.649	ε_1	.509
	ε_2	0.0223	ε_2	.027
	θ	-10.3	θ	2.0
D	ε_1	0.585	ε_1	.523
	ε_2	-0.932	ε_2	-.797
	θ	31.1	θ	25.1
E	ε_1	0.466	ε_1	.455
	ε_2	-1.27	ε_2	-1.31
	θ	27.5	θ	29.5

Table 3. Principal stresses:

	Experimental		Predicted	
Rosette	Principal Stresses	$m_{\sigma1}$, $m_{\sigma2}$, or θ (psi/lb_f or degs)	Principal Stresses	$m_{\sigma1}$, $m_{\sigma2}$, or θ (psi/lb_f or degs)
A	σ_1	25.6	σ_1	23.3
	σ_2	1.65	σ_2	2.4
	θ	-55.2	θ	-57.6
B	σ_1	9.56	σ_1	10.6
	σ_2	4.91	σ_2	4.6
	θ	-49.1	θ	-42.8
C	σ_1	7.44	σ_1	6.0
	σ_2	2.15	σ_2	2.2
	θ	-10.3	θ	2.0
D	σ_1	3.32	σ_1	3.1
	σ_2	-8.63	σ_2	-7.3
	θ	31.1	θ	25.1
E	σ_1	0.676	σ_1	.41
	σ_2	-13.0	σ_2	-13.5
	θ	27.5	θ	29.5

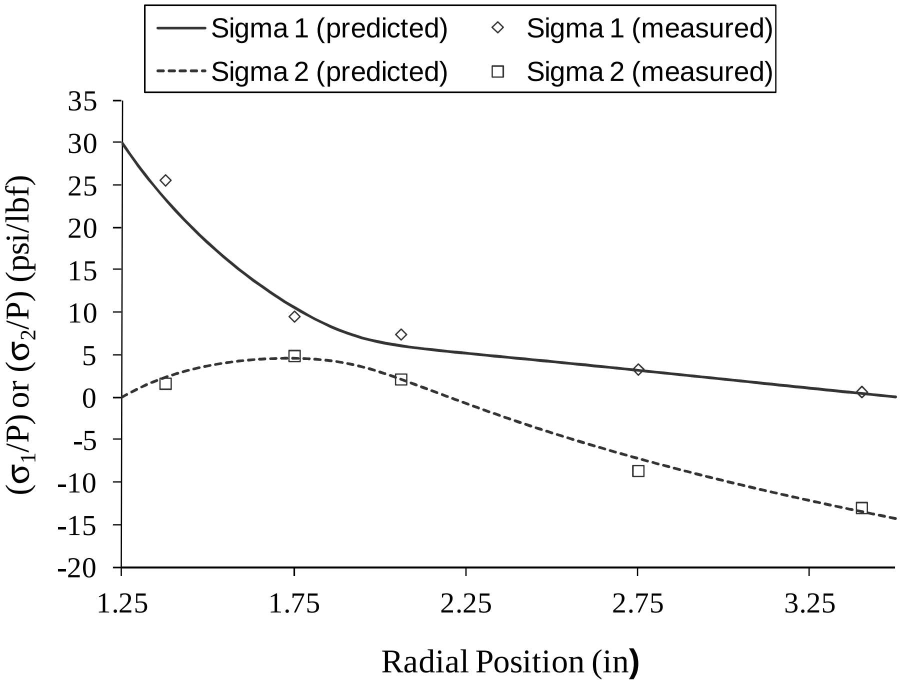


Figure 1: Normalized Principal Stresses Along θ = 30°

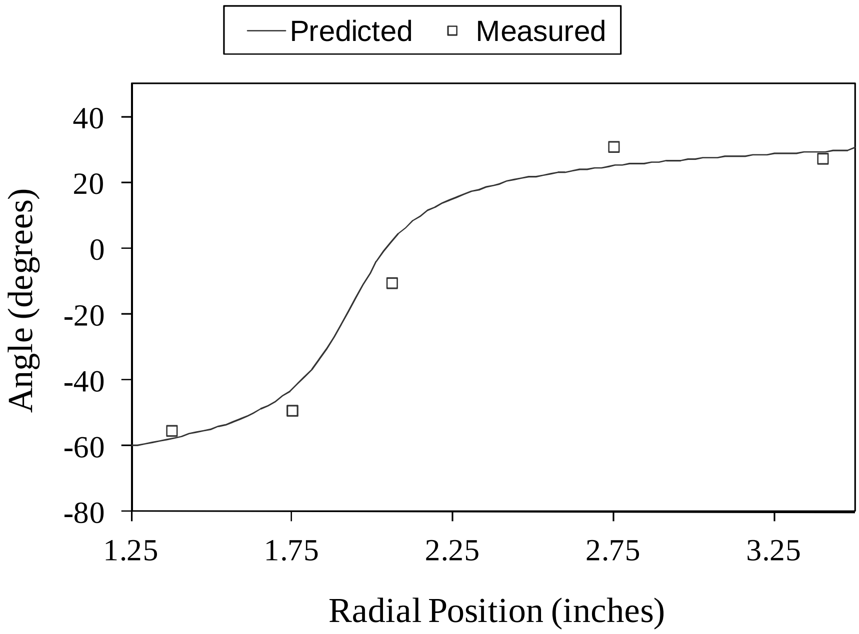


Figure 2: Angle between the +1-axis and the line-of-action of force P along θ = 30°