Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA - CERTIFICATE IN ROCK MECHANICS PAPER 1 : THEORY		**EXAMINER:**	Halil YILMAZ
		MODERATOR:	Gerrit KOTZE
SUBJECT CODE:	COMRMC1		
EXAMINATION DATE:	03 NOVEMBER 2020	**TOTAL MARKS:**	[100]
TIME:	14:30 – 17:30	**PASS MARK:**	(60%)

NUMBER OF PAGES: 7

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer **all four questions**. Answer the questions **legibly** in English.
2. Write your **ID Number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations **and check calculations on which the answers are based.**
4. **Only non-programmable basic scientific calculators** may be used for calculations.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. **Final answers** must be given to an accuracy which is typical of practical conditions, However be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers

NB: Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used even if the calculated value is correct.

8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.
11. Formulas sheets are on page 6 and 7 of this questionnaire.

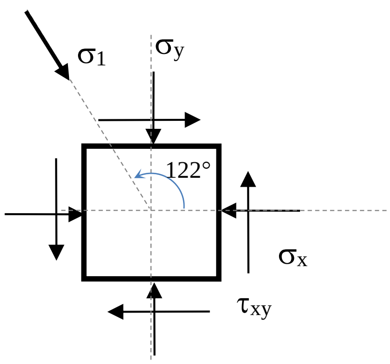
QUESTION 1 **[TOTAL: 25]**

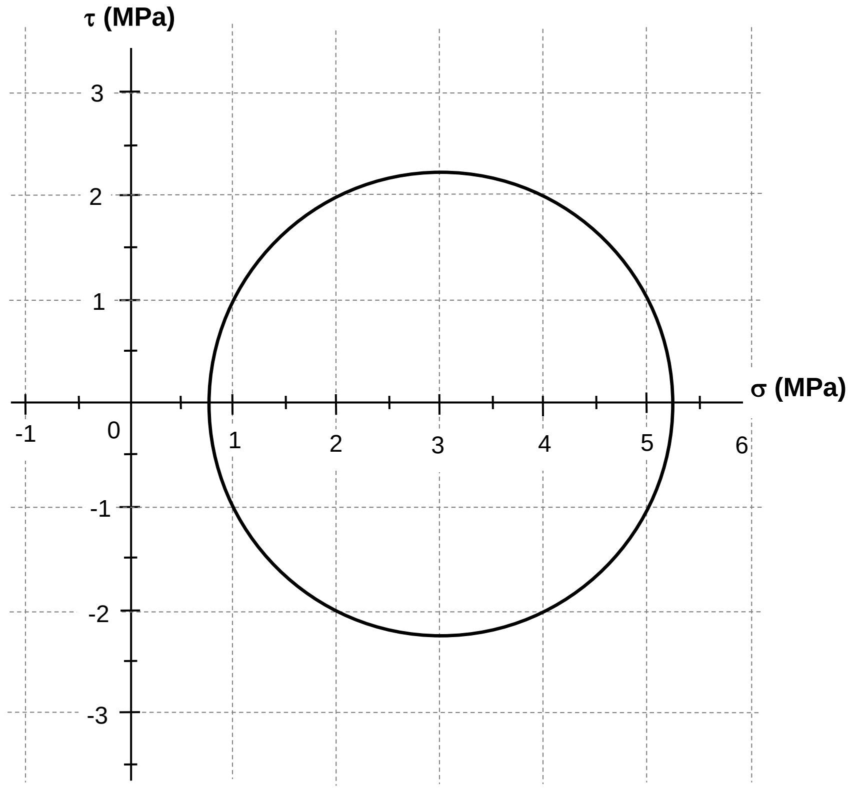
1.1 The Mohr's stress circle shown on the right is for the state of stress on the element shown on the left. The major principal stresses is located 122° from X direction. Using the Mohr's stress circle determine (no calculations);

i) the magnitudes of the stresses σ_1, σ_2, σ_x, σ_y and τ_{xy} (13)

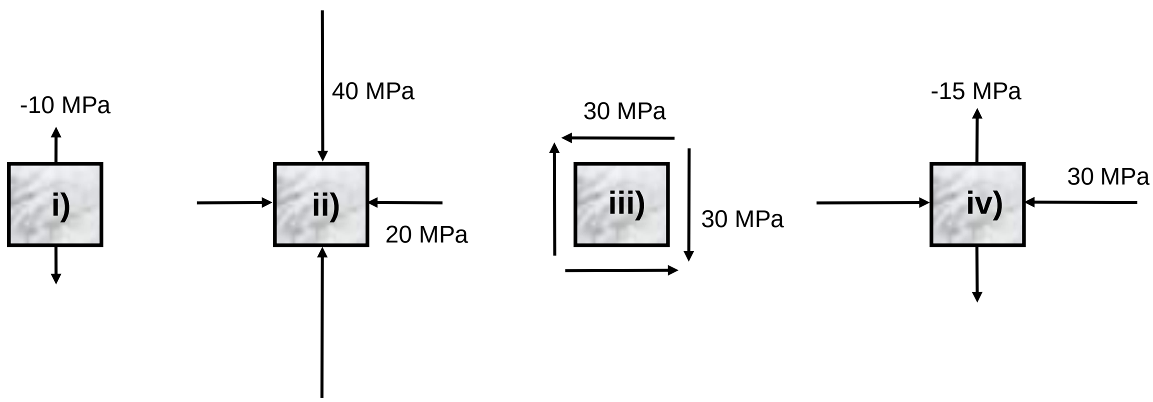
ii) the maximum shear stress and its orientation from the x-axis. (4)

Indicate the angles and stress values on the circle and the direction of axes for each part of the question. (You may do your solution on this sheet and attach it on the answer book)





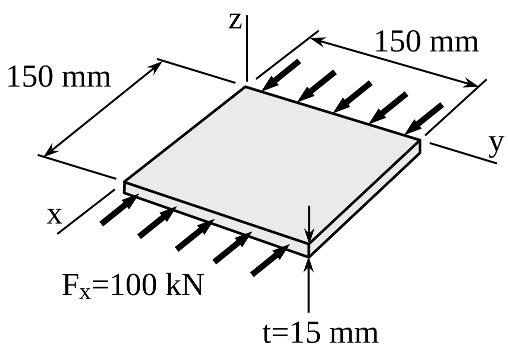
1.2 Draw the Mohr's circles on the graph paper for the following states of stresses. Clearly indicate the stress magnitudes for each part of the question: (8)



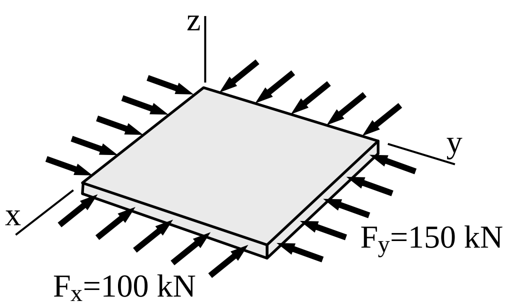
QUESTION 2 [TOTAL: 25]

2.1 A rock material is subjected to several loading cases, with normal stress through the thickness, i.e. σ_z, being zero. The material has an Elastic Modulus of 40 GPa, Poisson's ratio of 0.3, and is subjected to the evenly distributed forces indicated. Given the **original** dimensions provided below, consider the following three cases:

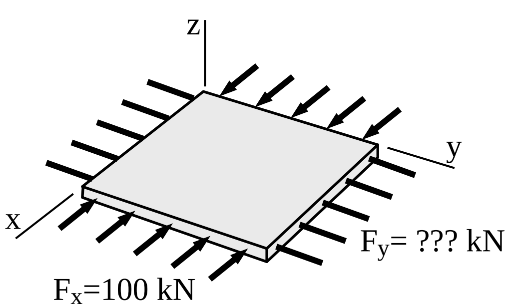
i) Calculate the change in thickness of the sheet, cut from the rock material, δt. (6)



ii) Calculate the change in thickness of the sheet (same original dimensions) for the new case shown below. (8)

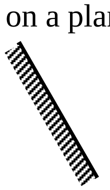


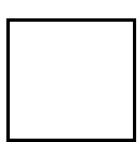
iii) Given F_x=100 kN, determine the force F_y required to produce no change in the thickness of the sheet (i.e. same original dimensions and δt=0). (6)

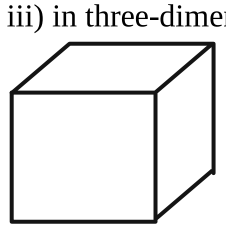


2.2 Plot the stress components required to define the state of stress at a point on the following diagrams: (5)

i) on a plane, ii) in two-dimensions iii) in three-dimensions.







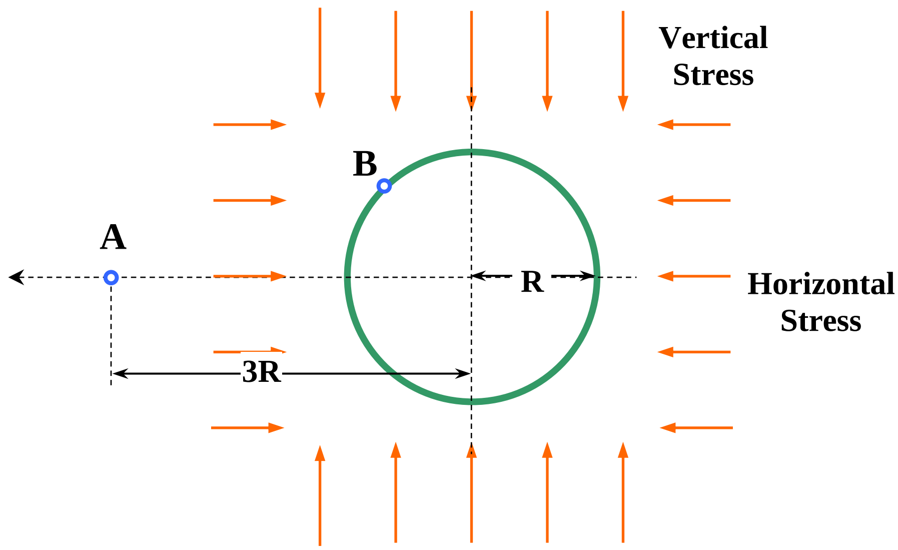
QUESTION 3 **[TOTAL: 25]**

A circular tunnel is excavated 3500 m below surface where rock density is 3000 kg/m^3 and k-ratio is 0.5. Assume that the hole is in a state of plane strain, E = 80 GPa, ν = 0,33 and that the virgin shear stress is zero at the Vertical-Horizontal reference directions.

i) Calculate the components of strain (ε_r, ε_θ, ε_z and $\gamma_{r\theta}$) at point A. (18)

ii) Calculate the strain energy density at point A. (4)

iii) Explain how the stresses σ_r, σ_θ and σ_z would be influenced at point B (on tunnel surface) if the radius of the tunnel was doubled (no calculations necessary). (3)



QUESTION 4 [TOTAL: 25]

a) A granite specimen was tested under uniaxial compression with strain measurements obtaining the following summarised data:

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Ref       : Granite
Diameter  :  47,5 mm
Length    : 103,0 mm
Mass      : 471,1 g
Load at failure: 445 kN
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Load	Stress	Total Strain x 1/1000	
kN	MPa	Axial	Radial
0	0	0.00	0.00
40	23	0.93	-0.08
120	68	2.01	-0.31
200	113	2.85	-0.56
280	158	3.62	-0.89
360	203	4.38	-1.40
440	249	5.18	-2.76

Use the information provided and plot the necessary graph to facilitate the determination of the following parameters: (3)

i) Uniaxial Compressive Strength (2)
ii) Modulus of Elasticity (any method of your choice) (4)
iii) Poisson's Ratio (4)

b) The results of triaxial compressive strength testing of quartzite are summarised in the following table.

Confinement (MPa)	Diameter (mm)	Length (mm)	Mass (g)	Load at Failure (kN)	Triaxial Strength (MPa)
4	41.8	84.2	313.8	324	**?**
12	41.8	84.2	311.4	406	**?**
20	41.8	84.2	314.1	468	**?**
24	41.8	84.2	311.1	508	**?**

i) Plot the triaxial compressive strength as a function of confining stress and estimate the uniaxial compressive strength and the strengthening parameter. (8)
ii) Determine the angle of internal friction (ϕ) and cohesion (c). (4)

TOTAL EXAM MARKS: [100]

FORMULAE SHEET

1. $m_i = 2(\beta_o - 1)$
2. $F = mg$
3. $\sigma = F/A$
4. $q_v = \rho gh$
5. $q_h = kq_v$
6. $\beta_o = \frac{(1+\sin\varphi_i)}{(1-\sin\varphi_i)}$
7. $C_o = \frac{\sigma_c}{2\sqrt{\beta_o}}$
8. $\varphi_i = asin\left(\frac{\beta_o-1}{\beta_o+1}\right)$
9. $\tau = C_o + \mu\sigma_n$
10. $\sigma_1 = \sigma_c + \beta_o\sigma_3$
11. $\mu = tan\varphi_i$
12. $k = \frac{v}{1-v}$
13. $K = \frac{E}{3(1-2v)}$
14. $G = \frac{E}{2(1+v)}$
15. $W = \frac{1}{2}\sigma\varepsilon$
16. $Q = \frac{1}{2}\sigma\varepsilon \times \text{Volume}$
17. $\varepsilon = \Delta\ell / \ell_o$
18. $E = \sigma/\varepsilon$
19. $\varepsilon_r = -v\varepsilon_a$
20. $\sigma_{xx} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{xx} + v\left(\varepsilon_{yy} + \varepsilon_{zz}\right)\right]$
21. $\sigma_{yy} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{yy} + v(\varepsilon_{xx} + \varepsilon_{zz})\right]$
22. $\sigma_{zz} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{zz} + v\left(\varepsilon_{xx} + \varepsilon_{yy}\right)\right]$
23. $\tau_{xy} = G\gamma_{xy}$ $\tau_{xz} = G\gamma_{xz}$ $\tau_{yz} = G\gamma_{yz}$
24. $\sigma_n = \sigma_1 cos^2\theta + \sigma_2 sin^2\theta$
25. $\tau_{nm} = -\frac{1}{2}(\sigma_1 - \sigma_2)sin2\theta$

26. $\sigma_1 = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}\sqrt{\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]}$

27. $\sigma_2 = \frac{1}{2}(\sigma_x + \sigma_y) - \frac{1}{2}\sqrt{\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]}$

28. $\theta = \frac{1}{2} arc \tan\left[2\tau_{xy}/(\sigma_x - \sigma_y)\right]$

29. $\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2)$

30. $\sigma_{x\prime} = \sigma_x cos^2\theta + 2\tau_{xy}\sin\theta\cos\theta + \sigma_y sin^2\theta$

31. $\sigma_{y\prime} = \sigma_x sin^2\theta - 2\tau_{xy}\sin\theta\cos\theta + \sigma_y cos^2\theta$

32. $\tau_{x\prime y\prime} = \frac{1}{2}(\sigma_y - \sigma_x)\sin 2\theta + \tau_{xy}\cos 2\theta$

33. $\varepsilon_{x'} = \varepsilon_x \cos^2\theta + \gamma_{xy} \sin\theta\cos\theta + \varepsilon_y \sin^2\theta$

34. $\tan 2\theta = \dfrac{\gamma_{xy}}{\varepsilon_x - \varepsilon_y}$

35. $\varepsilon_x = \frac{1}{E}\left(\sigma_x - v(\sigma_y + \sigma_z)\right)$

36. $\varepsilon_y = \frac{1}{E}\left(\sigma_y - v(\sigma_x + \sigma_z)\right)$

37. $\varepsilon_z = \frac{1}{E}\left(\sigma_z - v(\sigma_x + \sigma_y)\right)$

38. $\varepsilon_r = \frac{1}{E}\left(\sigma_r - v(\sigma_\theta + \sigma_z)\right)$

39. $\varepsilon_\theta = \frac{1}{E}\left(\sigma_\theta - v(\sigma_r + \sigma_z)\right)$

40. $\varepsilon_z = \frac{1}{E}\left(\sigma_z - v(\sigma_r + \sigma_\theta)\right)$

41. $\varepsilon_1 = \frac{1}{2}(\varepsilon_x + \varepsilon_y) + \frac{1}{2}\sqrt{\left[(\varepsilon_x - \varepsilon_y)^2 + \gamma_{xy}^2\right]}$

42. $\varepsilon_2 = \frac{1}{2}(\varepsilon_x + \varepsilon_y) - \frac{1}{2}\sqrt{\left[(\varepsilon_x - \varepsilon_y)^2 + \gamma_{xy}^2\right]}$

43. $\sigma_r = \dfrac{1}{2} q(1+k)\left(1 - \dfrac{R^2}{r^2}\right) - \dfrac{1}{2} q(1-k)\left(1 - \dfrac{4R^2}{r^2} + \dfrac{3R^4}{r^4}\right)\cos 2\theta$

44. $\sigma_\theta = \dfrac{1}{2} q(1+k)\left(1 + \dfrac{R^2}{r^2}\right) + \dfrac{1}{2} q(1-k)\left(1 + \dfrac{3R^4}{r^4}\right)\cos 2\theta$

45. $\tau_{r\theta} = \dfrac{1}{2} q(1-k)\left(1 + \dfrac{2R^2}{r^2} - \dfrac{3R^4}{r^4}\right) \sin 2\theta$

46. $\sigma_z^t = \sigma_z^v + \nu\,(\sigma_r^i + \sigma_\theta^i)$