Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA - CERTIFICATE IN ROCK MECHANICS PAPER 1 : THEORY	**EXAMINER:** H YILMAZ
SUBJECT CODE: COMRMC1	**MODERATOR:** G KOTZE
EXAMINATION DATE: 8 OCTOBER 2019	
TIME: 14:30 – 17:30	**TOTAL MARKS:** [100]
	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.

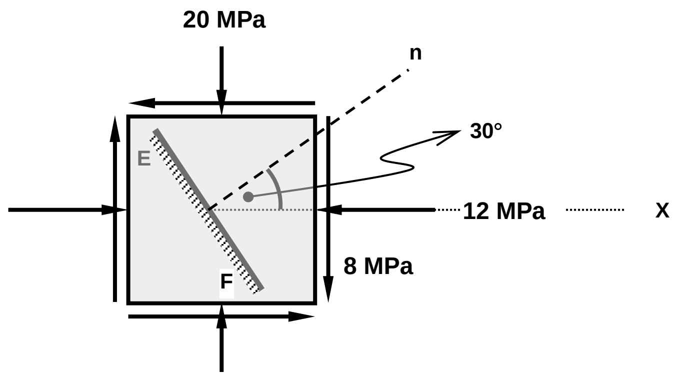
3. Show all calculations **and check calculations on which the answers are based.**
4. **Only non-programmable basic scientific calculators** may be used for calculations.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers 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.

QUESTION 1

1.1 The element shown in the figure below is subject to biaxial loading, with stress components shown.



i) Construct the Mohr's circle diagram representing this state of stress.

(4)

ii) Determine, from the Mohr's circle, the normal and shear stress components on the plane EF oriented as shown.

(4)

iii) Plot the stresses determined in (ii) on the plane EF.

(2)

iv) Determine, from the Mohr's circle, the magnitudes of the principal stresses, and the orientation of the principal directions relative to the x reference direction.

(7)

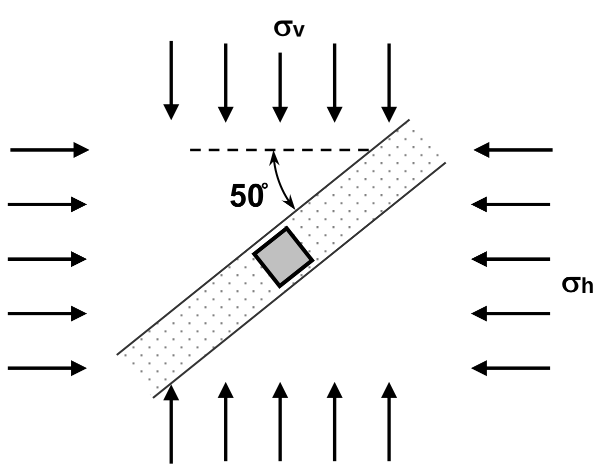
1.2 A section, perpendicular to the strike, of an inclined reef is shown below. As indicated, the virgin state of stress in the plane of the cross-section is defined by the far-field stress components σ_v and σ_h.

i) Calculate the normal and shear stress components acting on the sides of the small element shown for the conditions σ_v = 80 MPa and σ_h = 40 MPa.

(6)

ii) Plot the orientations of the stress components acting on the element.

(2)



[25]

QUESTION 2

2.1 A strain rosette is used to determine the strain on a free surface of an isotropic elastic body:

Direction	Angle	Strain
o	0^0	0,0001
c	60	0,0001
r	120	-0,0001

Determine the principal strains and their directions relative to direction "o". (16)

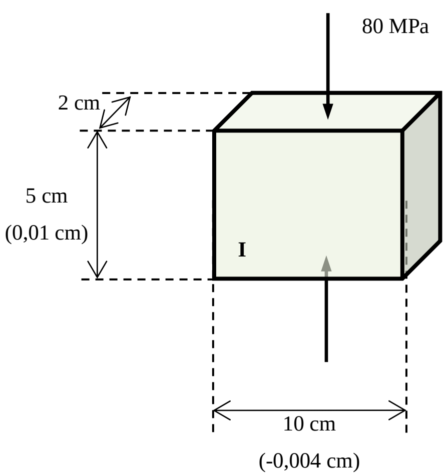
2.2

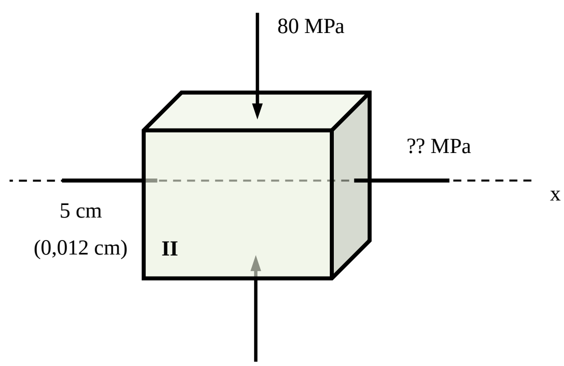
i) A rock material with Elastic Modulus of 40 GPa is compressed uni-axially as shown in drawing I. The original dimensions and the measured deformations (in parenthesis) are indicated. Assume that the material behaves in a linear-elastic manner and does not fail. Calculate the Poisson's ratio.

(4)

ii) In a new experiment, a specimen is selected from the same material and subjected to the bi-axial state of stress as shown in drawing II. The side having an original dimension of 5 cm is observed to shorten by 0,012 cm. Calculate the magnitude of the stress along the direction x.

(5)

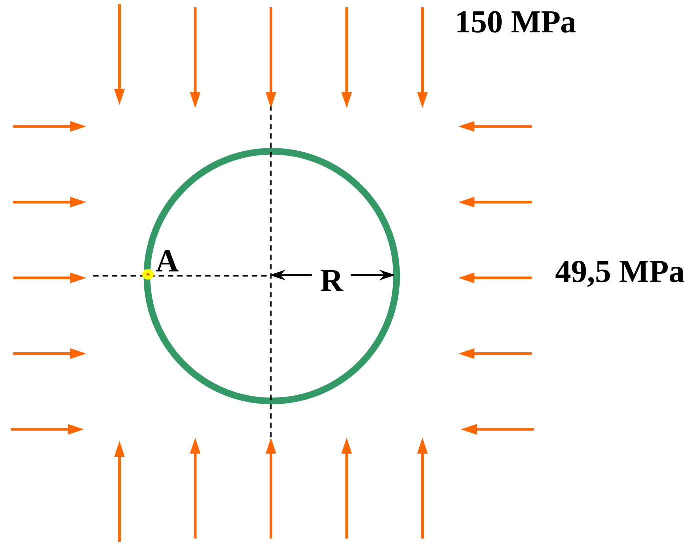




[25]

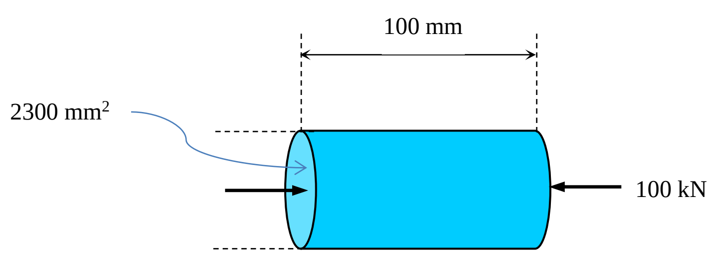
QUESTION 3

a) Calculate the resultant and induced stresses (σ_r, σ_θ, and $\tau_{r\theta}$) at point A for the loading condition shown for a tunnel.



(9)

b) A rock specimen of length 100 mm, cross sectional area 2300 mm^2, modulus of elasticity 60 GPa is compressed along its long axis by 100 kN. Calculate the total strain energy stored in the specimen. You may assume that the specimen remains in an elastic state.



(5)

c) Write down your answer – True or False, - to the following

i) Poisson's ratio has no units and the typical value for intact rocks is around 0,5.

ii) Cohesion is simply the value on the τ axis at maximum normal stress.

iii) Tectonic stresses are caused by the excavations made in the rock mass.

iv) The basic friction angle is generally measured by testing sawn or ground rock surfaces.

v) The undulations and asperities on a natural joint surface, generally, decrease the shear strength of the surface.

vi) Strain rosettes may be used to calculate the orientation of principal stresses.

vii) Pore water pressure increases the shear strength of discontinuities.

viii) An increase in volume with compression is known as dilatancy.

ix) A material is called elastic if, after loading and subsequent unloading to zero stress, the strain returns to zero.

x) A shear fracture typically appears in uniaxial tension.

xi) "Biaxial" loading is when the loading of a specimen consists of major, minor and intermediate stresses, each of them having different value.

(11)

[25]

QUESTION 4

a) State the effects of the following factors on the compressive strength of intact rock material in laboratory testing:

Factor	**Condition**	**Compressive Strength (increases or decreases?)**
Rate of loading	Decreases	?
Moisture content	Decreases	?
Porosity	Increases	?
Temperature	Increases	?
Length to diameter ratio	Decreases	?
Size of specimen	Increases	?
Confinement	Increases	?

(7)

b) i - List and briefly discuss the inputs into the following two rock mass classification systems: the Q system and Laubscher's mining rock mass rating system. For the Q system, indicate clearly which parameters are used to express block size, joint shear strength and confining stress. (8)

ii - List the most common applications of these two classification systems.

(4)

c) State the similarities and differences between the Finite Element Method (FEM) and the Boundary Element Method (BEM).

(6)

[25]

TOTAL MARKS: [100]

FORMULAE SHEET

1. $m_i = 2(\beta_o - 1)$
2. F = mg
3. $q_v = \rho gh$
4. $\beta_o = \frac{(1+\sin\varphi_i)}{(1-\sin\varphi_i)}$
5. RQD = 115 – 3.3 Jv
6. RMR = 9 ln Q + 44
7. $\tau = C_o + \mu\sigma_n$
8. $\sigma_1 = \sigma_c + \beta_o\sigma_3$
9. $\mu = tan\varphi_i$
10. $\mathbf{s} = \mathbf{e}^{\frac{(\mathbf{RMR}-\mathbf{100})}{\mathbf{9}}}$
11. $\mathbf{m} = \mathbf{m_i}\,\mathbf{e}^{\frac{(\mathbf{RMR}-\mathbf{100})}{\mathbf{28}}}$
12. $\sigma_1 = \sigma_3 + \sqrt{(s\sigma_c^2 + m\sigma_c\sigma_3)}$
13. $k = \frac{v}{1-v}$
14. $K = \frac{E}{3(1-2v)}$
15. $G = \frac{E}{2(1+v)}$
16. $W = \frac{1}{2}\sigma\varepsilon$
17. $Q = \frac{1}{2}\sigma\varepsilon \times \text{Volume}$
18. $\varepsilon = \Delta\ell / \ell_o$
19. $E = \sigma/\varepsilon$
20. $\varepsilon_r = -v\varepsilon_a$
21. $\sigma_{xx} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{xx} + v\left(\varepsilon_{yy} + \varepsilon_{zz}\right)\right]$
22. $\sigma_{yy} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{yy} + v(\varepsilon_{xx} + \varepsilon_{zz})\right]$
23. $\sigma_{zz} = \left[\frac{E}{(1+v)(1-2v)}\right]\left[(1-v)\varepsilon_{zz} + v\left(\varepsilon_{xx} + \varepsilon_{yy}\right)\right]$
24. $\tau_{xy} = G\gamma_{xy}$ $\quad \tau_{xz} = G\gamma_{xz}$ $\quad \tau_{yz} = G\gamma_{yz}$
25. $\sigma_n = \sigma_1 cos^2\theta + \sigma_2 sin^2\theta$
26. $\tau_{nm} = -\frac{1}{2}(\sigma_1 - \sigma_2)sin2\theta$

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

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

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

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

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

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

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

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

35.
$$\varepsilon_1 + \varepsilon_2 = \frac{2}{3}(\varepsilon_{0^\circ} + \varepsilon_{60^\circ} + \varepsilon_{120^\circ}),$$
$$(\varepsilon_1 - \varepsilon_2)^2 = \frac{4}{3}(\varepsilon_{60^\circ} - \varepsilon_{120^\circ})^2 + \frac{4}{9}(2\,\varepsilon_{0^\circ} - \varepsilon_{60^\circ} - \varepsilon_{120^\circ})^2$$
$$\tan 2\theta = \frac{\sqrt{3}(\varepsilon_{60^\circ} - \varepsilon_{120^\circ})}{2\,\varepsilon_{0^\circ} - \varepsilon_{60^\circ} - \varepsilon_{120^\circ}}$$

36. $\varepsilon_x = \frac{1}{E}(\sigma_x - v\sigma_y)$

37. $\varepsilon_y = \frac{1}{E}(\sigma_y - v\sigma_x)$

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

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

40. $J_v = \frac{1}{J_1} + \frac{1}{J_2} + \frac{1}{J_3}$

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

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

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

44. $Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$