NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND SPATIAL SCIENCE
DEPARTMENT OF MINING AND PROCESS ENGINEERING

QUALIFICATION : BACHELORS OF ENGINEERING IN MINING ENGINEERING	
QUALIFICATION CODE: BEMIN	LEVEL: 6
COURSE CODE: RMC711S	COURSE NAME: ROCK MECHANICS
SESSION: JUNE 2022	PAPER: THEORY
DURATION: 3 HOURS	MARKS: 100

FIRST OPPORTUNITY QUESTION PAPER	
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MODERATOR:	Prof. Mapani Benjamin

INSTRUCTIONS
1. Answer all questions. 2. Read all the questions carefully before answering. 3. Marks for each question are indicated at the end of each question. 4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.
2. Two Graph Papers
3. Mathematical Instruments

THIS QUESTION PAPER CONSISTS OF 4 PAGES (Including this front page)

Instructions: Answer Question 1 and any 4 other questions. Excess questions will not be marked.

Question 1 is compulsory.

Time allowed: 3 hours

Question 1 Short answer questions (20)

a) What the difference between rock and rock mass?

b) What is the range of 'Q' value in 'Q' classification system?

c) What is the maximum length of drill core run used to measure RQD?

d) How do the water in the joints influence the stability of rock mass?

e) Which side the Mohr's circle moves when pore pressure is increased?

f) What are the parameters associated with Bieniawski's RMR?

g) Direction of major principal stress for a rock is 35° from x-axis. What is the major shear stress direction with respect to y-axis [both x, y-axes are perpendicular to each other]

h) RQD is the first quantitative rock mass classification system developed by John Deer [1964]. Nevertheless, it has two major problems with respect to rock mass classification, what are they?

i) In triaxial testing, which of confining stress and axial stress, is constant?

j) Shear strength failure criteria for a rock sample is $\tau = 25 + \sigma_n \text{Tan } 23.6^{\circ}$, then what is the angle between failure plane and major principal stress direction? [2]

Question 2 Briefly discuss the following characteristics of discontinuities and their effect on stability of rockmass with diagrams wherever possible (20)

a) Joint spacing
b) Joint orientation
c) Fracture aperture
d) Fracture roughness
e) Fracture filling

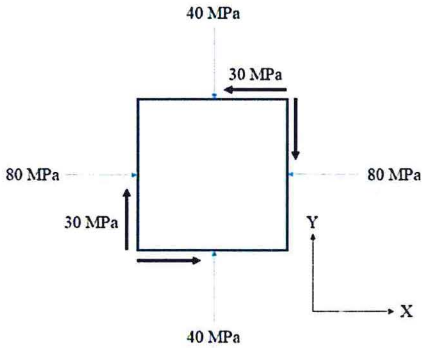
Question 3 A competent sandstone rock mass is fractured by three joint sets plus random fractures. The average RQD is 75%; the average joint spacing is 0.18 m. The joint surfaces are slightly rough and slightly weathered. The joints are in contact with apertures generally less than 1 mm; no clay is found on the surfaces. The point load strength index of the sandstone is 3.5 MPa. The tunnel is to be excavated at 50 m below the ground level and the ground water table is 20 m below the ground surface, thus large inflow of water expected. Estimate the Q-value. (20)

Question 4

a) What are methods used to measure in situ stresses and classify them according to the amount of disturbance caused during measurement (6)

b) Briefly describe with help of figures, in situ stress measurement using flatjack method (14)

Question 5 The state of stress in a rockmass is represented as shown in Fig. 1. Employ Mohr's circle to determine (a) the magnitude and orientation of the principal stresses with respect of x-direction and (b) the magnitude and orientation of the maximum shear stress with respect to x- direction and associated normal stresses. (20)



Question 6

a) What are the limitations of Mohr Coulomb failure criteria? (8)

b) In a series of triaxial compression test on sandstone, the following represent the stresses at peak load conditions. (12)

Test	σ_3 (MPa)	σ_1(MPa)
1	10	99.2
2	20	129.3
3	30	160
4	40	189.1

Determine cohesion and angle of internal friction that best fit the data

Table 1. Description and ratings for the input parameters of the Q-system (simplified from Grimstad and Barton, 1993).

***RQD** (Rock Quality Designation)*

Very poor	RQD = 0 - 25%
Poor	25 - 50
Fair	50 - 75
Good	75 - 90
Excellent	90 - 100

Notes:

(i) Where RQD is reported or measured as < 10 (including 0), a nominal value of 10 is used to evaluate Q

(ii) RQD intervals of 5, i.e. 100, 95, 90, etc. are sufficiently accurate

***Jn** (joint set number)*

Massive, no or few joints	Jn = 0.5 - 1
One joint set	2
One joint set plus random joints	3
Two joint sets	4
Two joint sets plus random joints	6
Three joint sets	9
Three joint sets plus random joints	12
Four or more joint sets, heavily jointed, "sugar-cube", etc.	15
Crushed rock, earthlike	20

***Notes:** (i) For tunnel intersections, use (3.0 x Jn); (ii) For portals, use (2.0 x Jn)*

***Jr** (joint roughness number)*

a) Rock-wall contact, b) rock-wall contact before 10 cm shear	
Discontinuous joints	Jr = 4
Rough or irregular, undulating	3
Smooth, undulating	2
Slickensided, undulating	1.5
Rough or irregular, planar	1.5
Smooth, planar	1.0
Slickensided, planar	0.5

***Note :** i) Descriptions refer to small scale features, and intermediate scale features, in that order*

c) No rock-wall contact when sheared	
Zone containing clay minerals thick enough to prevent rock-wall contact	Jr = 1.0
Sandy, gravelly or crushed zone thick enough to prevent rock-wall contact	1.0

Notes:

i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m

ii) Jr = 0.5 can be used for planar, slickensided joints having lineations, provided the lineations are oriented for minimum strength

***Ja** (joint alteration number)*

	JOINT WALL CHARACTER		Condition	***Wall contact***
Contact between joint walls	CLEAN JOINTS	Healed or welded joints:	filling of quartz, epidote, etc.	Ja = 0.75
		Fresh joint walls:	no coating or filling, except from staining (rust)	1
		Slightly altered joint walls:	non-softening mineral coatings, clay-free particles, etc.	2
	COATING OR THIN FILLING	Friction materials:	sand, silt, calcite, etc. (non-softening)	3
		Cohesive materials:	clay, chlorite, talc, etc. (softening)	4

	FILLING OF:	Type	***Some wall contact*** *Thin filling (< 5 mm)*	***No wall contact*** *Thick filling*
Some or no wall contact	Friction materials	sand, silt calcite, etc. (non-softening)	Ja = 4	Ja = 8
	Hard cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	5 - 10
	Soft cohesive materials	medium to low overconsolidated clay, chlorite, talc,	8	12
	Swelling clay materials	filling material exhibits swelling properties	8 - 12	13 - 20

***Jw** (joint water reduction factor)*

Dry excavations or minor inflow, i.e. < 5 l/min locally	p_w < 1 kg/cm^2	Jw = 1
Medium inflow or pressure, occasional outwash of joint fillings	1 - 2.5	0.66
Large inflow or high pressure in competent rock with unfilled joints	2.5 - 10	0.5
Large inflow or high pressure, considerable outwash of joint fillings	2.5 - 10	0.3
Exceptionally high inflow or water pressure at blasting, decaying with time	> 10	0.2 - 0.1
Exceptionally high inflow or water pressure continuing without noticeable decay	> 10	0.1 - 0.05

***Note:** (i) The last four factors are crude estimates. Increase Jw if drainage measures are installed*

(ii) Special problems caused by ice formation are not considered

***SRF** (Stress Reduction Factor)*

Weakness zones intersecting excavation	Multiple weakness zones with clay or chemically disintegrated rock, very loose surrounding rock (any depth)	SRF = 10
	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation < 50 m)	5
	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation > 50 m)	2.5
	Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
	Single shear zones in competent rock (clay-free), loose surrounding rock (depth of excavation < 50 m)	5
	Single shear zones in competent rock (clay-free), loose surrounding rock (depth of excavation > 50 m)	2.5
	Loose, open joints, heavily jointed or "sugar-cube", etc. (any depth)	5

***Note:** (i) Reduce these SRF values by 25 - 50% if the relevant shear zones only influence, but do not intersect the excavation.*

		σ_c / σ_1	σ_θ / σ_c	SRF
Competent rock, rock stress problems	Low stress, near surface, open joints	> 200	< 0.01	2.5
	Medium stress, favourable stress condition	200 - 10	0.01 - 0.3	1
	High stress, very tight structure. Usually favourable to stability, may be except for walls	10 - 5	0.3 - 0.4	0.5 - 2
	Moderate slabbing after > 1 hour in massive rock	5 - 3	0.5 - 0.65	5 - 50
	Slabbing and rock burst after a few minutes in massive rock	3 - 2	0.65 - 1	50 - 200
	Heavy rock burst (strain burst) and immediate dynamic deformation in massive rock	< 2	> 1	200 - 400

***Notes:** (ii) For strongly anisotropic stress field (if measured): when 5 < σ_1/σ_3 <10, reduce σ_c to 0.75 σ_c. When $\sigma 1/\sigma 3$ > 10, reduce σ_c to 0.5σ_c*

(iii) Few case records available where depth of crown below surface is less than span width. Suggest SRF increase from 2.5 to 5 for low stress cases

			σ_θ / σ_c	SRF
Squeezing rock	*Plastic flow of incompetent rock under the influence of high pressure*	Mild squeezing rock pressure	1 - 5	5 - 10
		Heavy squeezing rock pressure	> 5	10 - 20
Swelling rock	*Chemical swelling activity depending on presence of water*	Mild swelling rock pressure		5 - 10
		Heavy swelling rock pressure		10 - 15