



<u>FACULTY</u>	: Science
<u>DEPARTMENT</u>	: Geology
<u>CAMPUS</u>	: DFC
<u>MODULE</u>	: CEGB211 ENGINEERING GEOLOGY 2B
<u>SEMESTER</u>	: Second
<u>EXAM</u>	: November 2019

<u>DATE</u>	:	16 November 2019	<u>SESSION</u>	: 08:30-11:30
<u>ASSESSOR(S)</u>	:	Mr. F.E.D. SENZANI		
<u>MODERATOR</u>	:	Dr. D.H. ROSE		
<u>DURATION</u>	:	3 HOURS	<u>MARKS</u>	: 185

NUMBER OF PAGES: **22 PAGES**

STUDENT NUMBER	
STUDENT INITIALS	
STUDENT SURNAME	
STUDENT SERIAL NUMBER (SEE REGISTER)	

INSTRUCTIONS:

1. Fill in **ALL** your personal details in the table above **IN FULL**.
2. Answer **ALL THE QUESTIONS** in Sections A and B, using the table on Page 10, and any five in Section C.
3. Numbered spaces in this document must be used to answer the questions. Request additional paper if you need additional space.
4. Submit all of this document

SECTION A – TRUE OR FALSE QUESTIONS
INSTRUCTIONS FOR SECTION A ONLY

- (i) **Write the full word “TRUE” OR “FALSE” in the right space in the table on page 10. Do not use “T” OR “F” instead.**
- (ii) **Each question carries a 0.5 mark, with the total for the section being 30 marks.**
- (1) The inner and outer core of the earth have the same composition.
 - (2) Continental and oceanic crust, have the same thickness.
 - (3) The solid earth’s average density is 15gcm^{-3} .
 - (4) Seismic studies were used to determine the layering of the solid earth.
 - (5) The half-life of a radioactive atom must be known in order to use it for dating of rocks.
 - (6) The regular structure of atoms in a mineral is known as the crystal shape.
 - (7) The streak of a mineral is a property dependent on its reaction to hydrochloric acid.
 - (8) The appearance of a mineral exposed to light is known as its streak.
 - (9) Habit is the colour shown by a mineral in a finely powdered form when rubbed against a piece of unglazed porcelain.
 - (10) Anorthite and albite are members of the feldspar group of minerals.
 - (11) A coarse-grained igneous rock composed of alkali feldspars with quartz as the essential minerals is a gabbro.
 - (12) Igneous rocks form by crystallisation of melted materials.
 - (13) The bulk of the magma consists of nine elements, oxygen, silicon, aluminium, iron, calcium, sodium, potassium, magnesium, and titanium without any gaseous components.
 - (14) If the silica content of a magma is relatively high, the magma is said to be acidic.
 - (15) When the temperature of the magma falls slowly, it begins to crystallise different minerals in any order.
 - (16) Generally the order of minerals crystallised in a slowly cooling magma is one of decreasing silica content.

- (17) During physical weathering, water, carbon-dioxide and oxygen react with rocks and minerals.
- (18) Burial and compaction of the sediment together with cementation of adjoining grains occurs during a process called diagenesis.
- (19) For sedimentary rocks to form source rocks must be exposed on the earth's surface.
- (20) During diagenesis, sediment changes into a rock through increase in density, cohesion and porosity.
- (21) During lithification, the grain size of a sediment increases.
- (22) Metamorphism is the solid-state transformation of pre-existing rocks into texturally or mineralogically distinct rocks as a result of increased temperature, increased pressure, or both.
- (23) Contact metamorphism occurs due to increase in temperature.
- (24) Migmatite is produced, after felsic minerals have melted, while mafic minerals remain solid, in the same rock.
- (25) Hornfelsic rocks form at relatively high temperature and low pressure conditions.
- (26) The axial planes of symmetric folds are vertical.
- (27) Non-horizontal fold axes are known as plunge.
- (28) In a strike fault, the footwall moves upwards along the fault plane.
- (29) Shear joints are not perpendicular to the axial plane of a fold.
- (30) After crossing a dextral strike-slip fault from a point, the observer has to move to the right on the other side of the fault in order to find the corresponding point.
- (31) The Barberton Supergroup predates the Witwatersrand Supergroup.
- (32) The Witwatersrand Supergroup is composed mostly of an unmetamorphosed clastic sequence of rocks.
- (33) The Karoo Supergroup was deposited before the Bushveld Complex was intruded.
- (34) The smallest mappable unit in stratigraphy is known as a formation.
- (35) Several succeeding rock formations are collectively known as a group.
- (36) A subgroup may be composed of several formations.
- (37) The size of voids in a rock have no effect on the rate at which the groundwater flows.
- (38) The main force driving groundwater is gravity.

- (39) In areas of South Africa underlain by generally non-porous and non-permeable rocks, there still is some ground water.
- (40) Quartz in a rock undergoes mainly chemical disintegration during weathering.
- (41) The presence of water in soil increases the likelihood of collapse of the wall of a surface excavation.
- (42) Physical disintegration refers to the mechanical breakdown of rocks.
- (43) Kaolinite-rich clays are produced from breakdown of potassic feldspars.
- (44) Hydrolysis of rock-forming minerals is an example of the physical breakdown of rocks.
- (45) Lower confining pressure reduces the shear strength of rock material.
- (46) Rock material at depth has greater strength than similar rock material closer to, or at the surface.
- (47) The strength of limestone rock material is influenced by post-depositional (diagenetic) changes.
- (48) The presence of water in soil increases the likelihood of collapse of the wall of an excavation.
- (49) Shear zones are rock discontinuities but folds are not.
- (50) Calculation of the “Stress Reduction Factor” is an essential part of Bieniawski’s method of classifying a rock mass.
- (51) In the Bieniawski rock mass rating (RMR) system, one of the parameters is the “Rock Quality Designation”.
- (52) Strong rocks will permit excavations with steeply-dipping walls, while weak rocks will only support gently-dipping walls.
- (53) A steep slope in shale is more stable than one in a massive plutonic igneous rock.
- (54) Where the dip of discontinuities is from the wall into the excavation, the wall of the excavation is unstable.
- (55) In site investigations for determining the type of foundations, the mass of the building needs to be known.
- (56) Additional stress caused by the weight of water in a dam may cause failure in the rocks forming the base or walls of the dam.
- (57) Rocks in the catchment area of a dam, if soft and easily weathered, will cause siltation of the dam.
- (58) Dams are built where the river passes through a gorge to reduce the thickness of the wall.

- (59) Gorges forming dam sites occur in areas where the underlying rocks are homogenous and very stable.
- (60) Sites of dams are chosen because they are underlain by suitable rocks in the catchment, reservoir and dam wall areas.

SECTION B – MULTIPLE CHOICE QUESTIONS

INSTRUCTIONS FOR SECTION B ONLY

- (i) **Select the correct answer, and enter your response in the table on page 10**
- (ii) **There is only one correct or best answer for each question.**
- (iii) **Each question carries 1 mark, total 30 marks**
- (61) The following form parts of the solid earth, but not
- (A) tectonic plate.
 - (B) lithosphere.
 - (C) biosphere.
 - (D) outer core.
 - (E) upper mantle.
- (62) The margins of a tectonic plate may be
- (A) zones of extention.
 - (B) zones of shear.
 - (C) zones of collision.
 - (D) all of the above.
 - (E) none of the above.
- (63) The mantle of the earth is rich in
- (A) silicon and oxygen.
 - (B) magnesium and iron.
 - (C) iron and nickel.
 - (D) aluminium and silicon.
 - (E) none of the above.
- (64) Geology involves the study of
- (A) earth structures.
 - (B) earth processes.
 - (C) earth materials.
 - (D) all of the above.
- (65) This mineral is not used in the dating of rocks:
- (A) potassium.
 - (B) oxygen.
 - (C) uranium.
 - (D) carbon.
 - (E) rubidium.

- (66) A rock-forming mineral is
- (A) a naturally occurring substance.
 - (B) an artificial made substance.
 - (C) a substance with a definite chemical composition.
 - (D) a substance whose chemical components have a definite 3-dimensional order.
 - (E) all of the above
- (67) Any one of the following physical properties is adequate to identify any mineral:
- (A) colour
 - (B) form
 - (C) cleavage
 - (D) fracture
 - (E) all of the above
 - (F) none of the above
- (68) Native minerals
- (A) are minerals composed of single chemical elements.
 - (B) are defined by a unique chemical formula.
 - (C) are sulphides.
 - (D) are oxides and carbonates.
 - (E) a and b
 - (F) b and c
 - (G) c and d
 - (H) all of the above;
- (69) The hardest mineral on Moh's Scale of Hardness is
- (A) gypsum.
 - (B) talc.
 - (C) fluorite.
 - (D) none of the above.
- (70) When a basic magma crystallises, the first minerals to crystallise are rich in
- (A) FeO
 - (B) SiO₂
 - (C) Na₂O
 - (D) K₂O
- (71) Drakensberg lavas are examples of
- (A) intrusive rocks
 - (B) extrusive rocks
 - (C) sedimentary rocks
 - (D) metamorphic rocks
 - (E) all of the above
 - (F) none of the above
- (72) The rocks below are examples of chemical sedimentary deposits except
- (A) dolomite.
 - (B) sandstone.
 - (C) ironstone.
 - (D) chert.

- (73) Siltstones and mudstones are examples of
- (A) rudaceous rocks.
 - (B) arenaceous rocks.
 - (C) argillaceous rocks.
 - (D) sandstones.
 - (E) all of the above
 - (F) none of the above
- (74) When ions precipitate out of water to form rocks, the rocks are said to be
- (A) pyroclastically formed.
 - (B) clastically formed.
 - (C) organically formed.
 - (D) chemically-formed.
- (75) Metamorphism involves the character change in rocks due to
- (A) heat
 - (B) pressure
 - (C) invasion of reactive fluids
 - (D) all of the above
 - (E) none of the above
- (76) A metamorphic aureole is a result of
- (A) contact metamorphism.
 - (B) dynamic metamorphism.
 - (C) dynamothermal metamorphism.
 - (D) diffusion of chemical substances.
 - (E) all of the above
- (77) Slaty cleavage and schistosity are typical products of
- (A) thermal metamorphism.
 - (B) dynamic metamorphism.
 - (C) fluid invasion.
 - (D) all of the above
 - (E) none of the above
- (78) The term "metamorphic facies" refers to
- (A) different ranges of temperatures of formation of metamorphic rocks.
 - (B) different ranges of pressure of formation of metamorphic rocks.
 - (C) different ranges of pressure and temperature of formation of metamorphic rocks.
 - (D) The ranges of compositions of invading fluids during formation of metamorphic rocks.
- (79) The throw of a fault is
- (A) the relative horizontal movement of the moving blocks.
 - (B) the relative vertical movement of the moving blocks.
 - (C) the relative upward movement of the moving blocks.
 - (D) the relative downward movement of the moving blocks.
 - (E) all of the above.
 - (F) none of the above.

- (80) The axis of a fold
- (A) follows the hinge of the fold.
 - (B) bisects the angle between the fold limbs.
 - (C) is a horizontal line on one of the limbs.
 - (D) all of the above.
 - (E) none of the above.
- (81) These divisions of South African rocks are listed in order of increasing age:
- (A) The Transvaal Supergroup, the Karroo Supergroup, the Ventersdorp Supergroup and the Bushveld Complex.
 - (B) The Bushveld Complex, the Transvaal Supergroup, the Karroo Supergroup and the Ventersdorp Supergroup.
 - (C) The Ventersdorp Supergroup, the Bushveld Complex, the Transvaal Supergroup, the Karroo Supergroup.
 - (D) The Karroo Supergroup, the Bushveld Complex, the Transvaal Supergroup and the Ventersdorp Supergroup.
 - (E) None shows the correct order.
- (82) The Onverwacht Group is found _____ the Barberton Supergroup*
- (A) at the base of
 - (B) in the middle of
 - (C) at the top of
 - (D) cross-cutting
- (83) Porosity in a sandstone depends partly on*
- (A) grain size distribution or sorting.
 - (B) the shape and arrangement of grains.
 - (C) the amount of cement
 - (D) all of the above.
 - (E) none of the above.
- (84) The formation of manganiferous wad accompanies the occurrence of*
- (A) dolines
 - (B) sinkholes.
 - (C) caverns.
 - (D) none of the above
- (85) As the spaces between grains in a clastic rock are filled with cement, the rock* becomes
- (A) more porous.
 - (B) more permeable.
 - (C) less porous.
 - (D) none of the the above
- (86) Residual soils may be found
- (A) On top of andesitic source rocks.
 - (B) On top of rhyolitic source rocks.
 - (C) On top of porphyritic source rocks.
 - (D) On top of gneissic source rocks.
 - (E) All of the above
 - (F) None of the above

- (87) This measurement does not reveal the strength of a rock:
- (A) Compressive stress.
 - (B) Tensile strength.
 - (C) Shear strength.
 - (D) Point load strength.
 - (E) None of the above.
- (88) The strength of a rock is determined by*
- (A) by measuring its porosity.
 - (B) by measuring its grain size.
 - (C) by measuring its water content.
 - (D) by measuring its composition
 - (E) by determining its confining pressure
 - (F) all of the above
 - (G) none of the above
- (89) Rock mass refers to
- (A) a body of rock including its discontinuities.
 - (B) a body of intact rock without any discontinuities.
 - (C) the weight of the rocks being studied.
 - (D) all of the above.
 - (E) none of the above.
- (90) The rock mass rating (RMR) system of classification uses the
- (A) strength of intact material.
 - (B) rock quality designation.
 - (C) spacing of joints.
 - (D) conditions of joints.
 - (E) conditions of groundwater.
 - (F) all of the above
 - (G) none of the above

Answer page for sections A and B and Questions 1 to 90

Section A; Write TRUE or FALSE in FULL				Section B; use the upper case (CAPITAL LETTER)	
1	16	31	46	61	76
2	17	32	47	62	77
3	18	33	48	63	78
4	19	34	49	64	79
5	20	35	50	65	80
6	21	36	51	66	81
7	22	37	52	67	82
8	23	38	53	68	83
9	24	39	54	69	84
10	25	40	55	70	85
11	26	41	56	71	86
12	27	42	57	72	87
13	28	43	58	73	88
14	29	44	59	74	89
15	30	45	60	75	90

INSTRUCTIONS FOR SECTION C ONLY

- (i) Answer any five questions. Use the numbered corresponding spaces provided.
- (ii) Give only brief answers. Only “bullet” points, preferably one per line, or clearly separated, if on the same line, need be given.
- (iii) The questions carry equal marks – Total: 125 marks.

QUESTION 91

- (A) Rocks are solid earth materials. Explain how it is that they may contain water. Use sketches if necessary. (03 marks)

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- (B) With respect to groundwater, give an account of the term porosity. (03 marks)

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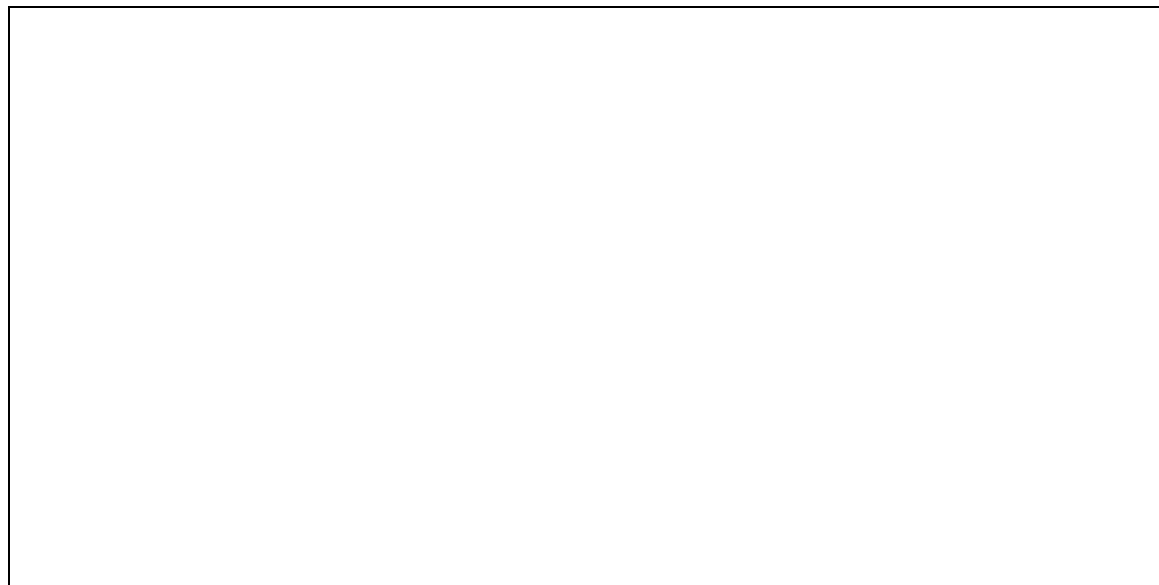
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- (C) What are springs? (02 marks)

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- (D) Draw and label all parts of an artesian spring. (07 marks)



(E) Why is it important to map out any springs that occur in an area targeted for construction? (02 marks)

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(F) What are the impacts of the presence of water at a construction site? (04 marks)

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(G) How can any negative impacts of the presence of water at a construction site? (04 marks)

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(Total 25 marks)

QUESTION 92

- (A) Define the term “soil” in terms of civil construction. (02 marks)

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- (B) Explain the term “physical weathering” of rocks. (01 marks)

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- (C) Give examples of physical weathering, in each case briefly describing the process. (08 marks)

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- (D) List the factors that determine the strength of a soil. For each factor, describe how it varies, and how the variation may decrease or increase the strength. (14 marks)

[illegible]

(Total 25 marks)

QUESTION 93

- (A) Define the concept “the strength of rock material”, including how this is determined. (05 marks)

- (B) What factors determine the level of strength of rock material? For each, describe how it varies, and how the variation increases and decreases the strength. (18 marks)

[illegible]

- (C) Give an example of a strong rock. What are the properties which give the chosen rock its high level of strength? (02 marks)

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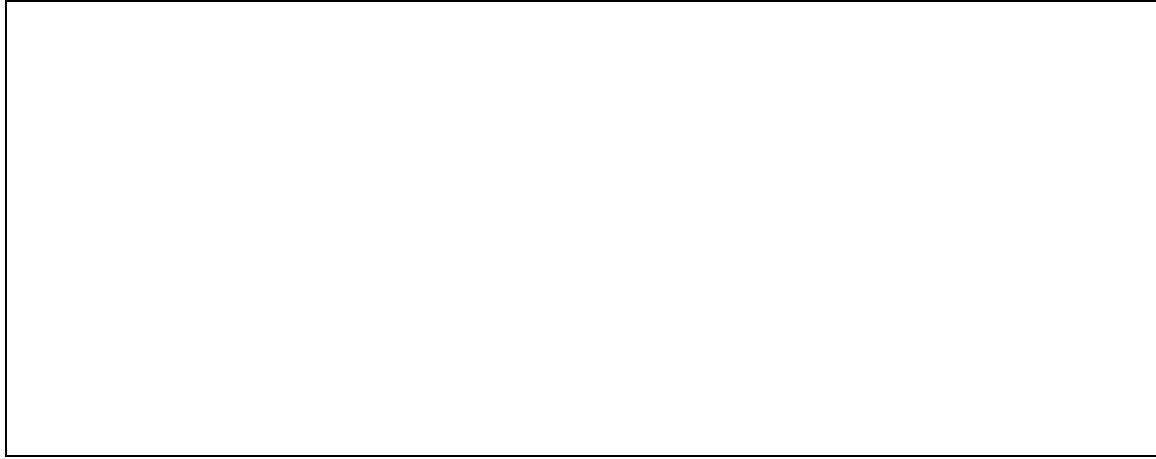
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(Total 25 marks)

QUESTION 94

A tunnel is being developed in a northward direction over very gently dipping strata. The strata dip less than 20 degrees to the south.

- (A) Present a fully labelled sketch (or fully labelled sketches) of the situation just described above. (10 marks)



- (B) Will the walls be stable? Why or why not? (03 marks)

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- (C) Will the roof be stable? Why or why not? (03 marks)

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- (D) What is the impact on stability for the walls if the tunnel is developed in an east-west direction, and why? (03 marks)

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- (E) What is the impact on stability for the roof if the wall is developed in an east-west direction, and why? (03 marks)

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- (F) Comparing the two tunnel development directions, which one would you prefer, and why? (03 marks)

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QUESTION 95

- (A) List and briefly describe the different uses of rocks in construction.(06 marks)

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- (B) Separately, for each of the above uses, list the properties of suitable rocks.
(11 marks)

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- (C) For each of the above uses, list one suitable rock. Do not mention the same rock for more than one use. (03 marks)

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- (D) For each of the above uses, list one unsuitable rock. Do not mention the same rock for more than one use. (03 marks)

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- (E) Why are rocks rich in pyrite unsuitable for any of the above uses? (02 marks)

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(Total 25 marks)

QUESTION 96

For the Witwatersrand Supergroup, write notes on the following:

(A) its chronological age, (02 marks)

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(B) its main stratigraphic components, (06 marks)

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(C) its region of occurrence in South Africa (04 marks)

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(D) the principal constituent rocks (06 marks)

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(E) the main concerns when foundations of building construction are considered for any one of the constituent rocks mentioned in (D). (07 marks)

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(Total 25 marks)

QUESTION 97

Rocks to be tunneled through, during construction of storage caverns for a water treatment plant, are being examined. You are supplied with a list of the Geomechanical Field characteristics of the body of rock, the ratings of the same characteristics, a graph of RMR/MRMR, a graph of the stand-up times of unsupported spans, an equivalent support ratio table, and a graph of remedial steps for specific intended uses of underground excavations.

Geomechanics Field Data

Item	Description
Rock quality designation	Length of drilled core = 1500m Length of core <100mm = 750m
Number of joint sets	One, plus random joints
Description of joint surface roughness	Planes containing gouge, thick enough to prevent wall contact, and undulating
Condition of groundwater	Exceptionally high inflow upon excavation, decreasing with time
Description of gouge	Tightly healed, hard, non-softening impermeable rock mineral filling
Stress reduction factor data	Uniaxial compressive strength = 242Mpa Depth of tunnel = 1155m Average density of overlying rocks = 2200kgm ⁻³ Acceleration due to gravity = 9.81ms ⁻²

(A) Determine Barton's Q-value for the body of rock given the formula:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{J_a} \times \frac{J_w}{SRF}$$

In which RQD is the rock quality designation
 J_n is the joint set number
 J_r is the joint roughness number
 J_a is the joint alteration number
 J_w is the joint water reduction factor
 SRF is the stress reduction factor.
 (08 marks)

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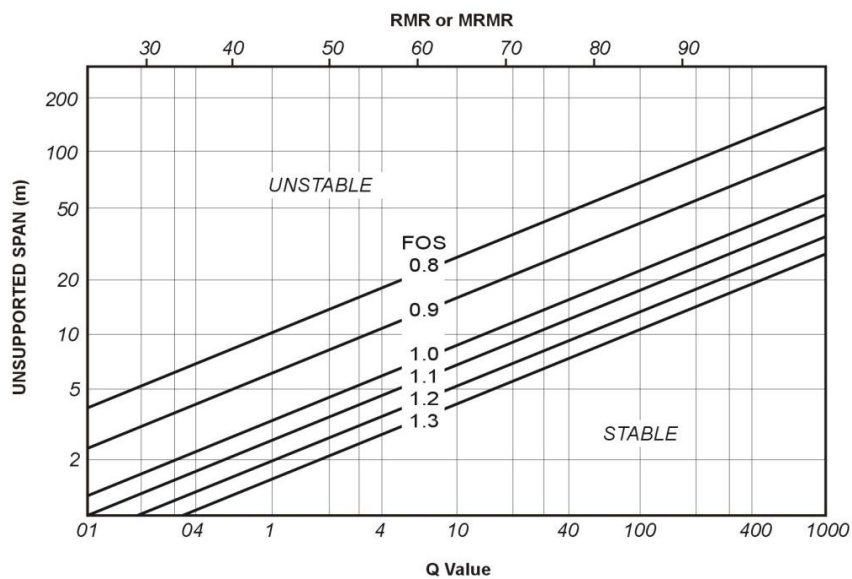
(B) Determine Bieniawski's rock mass rating (RMR) for the body of rock, given that
 $RMR = 9 \times \ln Q + 44$. (03 marks)

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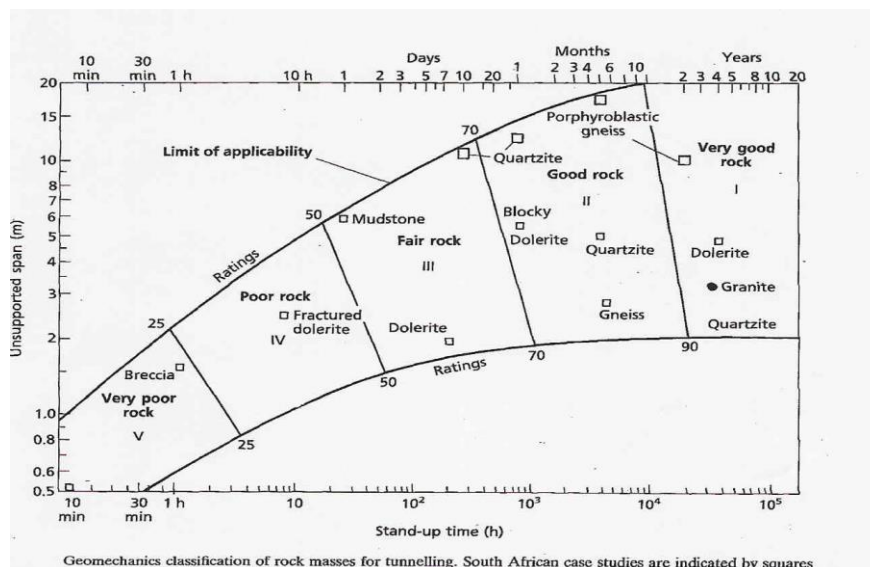
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- (C) Plot the RMR on the graph of RMR/MRMR, Q-Value and the Factor of Safety (FOS), and determine, for a tunnel of 7 meters, the Factor of Safety (FOS). What is the FOS?

(03 marks)



- (D) Plot the RMR on the graph of the stand-up times of unsupported spans and determine the stand-up time for the 3m wide tunnel. (03 marks)



Stand-up time:

- (E) What would be the consequence of limiting the span to 2 metres on
- (i) the stand-up time, and

(01 marks)

- (ii) the Factor of Safety?

(01 marks)

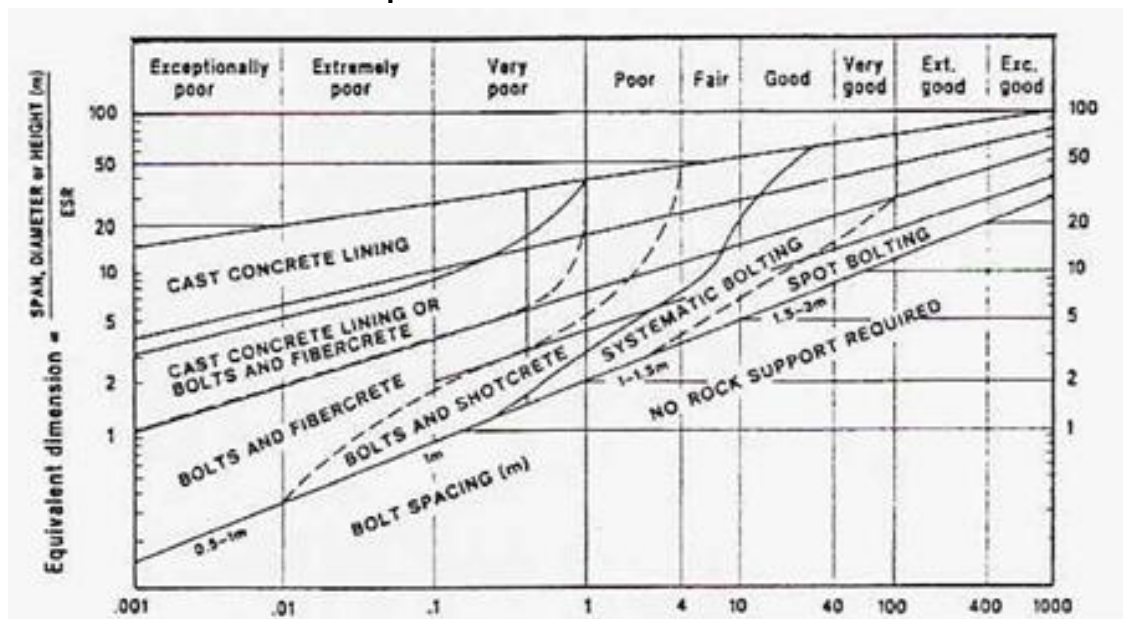
- (F) Using the ESR table, and the graph of pre-emptive work, what is the work necessary to ensure stability of the 7m-wide tunnel?

Equivalent support ratio (ESR) for different excavations

Excavation Category		Equivalent Support Ratio (ESR)
1	Temporary mine openings	3-5
2	Vertical shafts; circular section	2.5
	Vertical shafts; rectangular/square section	2.0
3	Permanent mine openings; water tunnels for hydropower (excluding high-pressure penstocks); pilot tunnels; drifts; headings for large excavations	1.6
4	Storage caverns, water treatment plants; minor highway and railway tunnels; surge chambers; access tunnels	1.4
5	Power stations; major highway or railroad tunnels; civil defence chambers; portals; intersections	1.0
6	Underground nuclear power stations; railroad stations; factories	0.8

Equivalent Support Ratio: (01 marks)

Pre-emptive measures to stabilize tunnel



Pre-emptive work necessary: (05 marks)

(Total 25 marks)

Joint set number reference table

Number of Joint Sets	Joint Set No. Jn
Intact, no or few joints	0.5 — 1.0
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, random, heavily jointed, sugar cube, etc.	15
Crushed rock, earth-like	20

Joint roughness number reference table

Description of Joint Surface Roughness	Discontinuous	Undulating	Planar
Rough	4.0	3.0	1.5
Smooth	3.0*	2.0	1.0
Slickensided	2.0*	1.5	0.5
Planes containing gouge thick enough to prevent rock wall contact	1.5*	1.0	1.0

Joint alteration number reference table

Description of Gouge		Joint Alteration Number Ja for Joint Separation (mm)		
		<1.01	1.0-5.02	>5.03
Tightly healed, hard, non-softening impermeable rock mineral filling		0.75		
Unaltered joint walls, surface staining only		1.0		
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling		2.0	4.0	6.0
Non-softening, slightly clayey non-cohesive filling		3.0	6.0*	10.0*
Non-softening strongly over-consolidated clay mineral filling, with or without crushed rock		3.0*	6.04	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays		4.0	8.0*	13.0*
(F)	Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0*	8.04	13.0
(G)	Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0*	10.04	18.0

Joint water reduction factor reference table

Condition of Groundwater	Head of water (m)	Joint Water Reduction Factor J_w
Dry excavation or minor inflow 5 litre/minute locally	<10	1.0
Medium inflow, occasional outwash of joint/fissure fillings	10 – 25	0.66
Large inflow in competent ground with unfilled joints/fissures	25-100	0.5
Large inflow with considerable outwash of joint/fissure fillings	25-100	0.33
Exceptionally high inflow upon excavation, decaying with time	>100	0.2-0.1
Exceptionally high inflow continuing without noticeable decay	>100	0.1-0.05

Stress reduction factor reference table 1

For Zones of weakness	SRF Value
Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)	10
Single weakness zones containing clay or chemically disintegrated rock (depth of excavation < 50m)	5
Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth)	2.5
Single shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
Single shear zones in competent rock (clay-free) (depth of excavation < 50m)	5.0
Single shear zones in competent rock (clay-free) (depth of excavation > 50m)	2.5
Loose open joints, heavily jointed or "sugar-cube" etc (any depth)	5.0

Stress reduction factor reference table 2

(Principal stress = $\rho gh = \sigma_1$) where $g = 9.81$

Competent rock/Stress problems	UCS / σ_1	σ_t / σ_1	SRF Value
Low stress, near-surface	>200	>13	2.5
Medium stress	200-10	13-0.66	1.0
High stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability)	10-5	0.66-0.33	0.5-2
Mild rock burst (massive rock)	5-2.5	0.33-0.16	5-10
Heavy rock burst (massive rock)	<2.5	<0.16	10-20

End of November 2019 Engineering Geology CEGB211 (Construction Management) Examination