UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2011/2012

COURSE NAME	:	ENGINEERING GEOLOGY
COURSE CODE	:	BFC 21303 / BFC 3013
PROGRAMME	:	2 BFF/3 BFF
DATE	:	JANUARY 2012
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ANY **FOUR (4)** QUESTIONS ONLY

THIS PAPER CONSISTS SEVENTEEN (17) PAGES

Q1 (a) Illustrate the compositional layers and mechanical layers of earth.

(3 marks)

(b) Explain **FOUR (4)** plate motions with the aid of related diagrams.

(10 marks)

(c) Earth has undergone great changes over million of years. Describe the geologic processes that change the earth's structure.

(6 marks)

(d) Discuss relationship between geologic time, porosity and rock strength.

(6 marks)

Q2 (a) A mineral is a naturally occurring inorganic solid possessing a definite chemical structure that gives it a unique set of physical properties. State **FOUR (4)** minerals including its uses in industry.

(4 marks)

(b) The internal structure of a mineral is formed by the arrangement of the smallest structure parts, the atoms, ions or molecules and by packaging in regular order, it will forms as crystal lattice or crystalline. Illustrate the schematic presentation of the crystal lattice of NaCl and describe briefly on the diagram.

(4 marks)

(c) Distinguish the colour and streak of a mineral.

(2 marks)

(d) Transparency is the degree to which a medium allows light to pass through it. Explain **FOUR (4)** types of transparency.

(8 marks)

(e) Explain why the silicate mineral group is the Chief Rock Forming Minerals.

(3 marks)

(f) (i) Define Silicon-Oxygen Tetrahedron
(ii) Illustrate **THREE (3)** linkages on how Silicon-Oxygen Tetrahedron is arranged in silica minerals.

(4 marks)

Q3 (a) Describe the formation process for each of the following rock types:
(i) Igneous rock
(ii) Sedimentary rock
(iii) Metamorphic rock

(6 marks)

(b) Explain and illustrate the related diagram on the distinctive features or texture of igneous rocks.

(8 marks)

(c) Explain the following classification of sedimentary rocks:
(i) Detrital or Clastic Sedimentary Rocks
(ii) Chemical Sedimentary Rocks

(4 marks)

(d) State and illustrate **THREE (3)** types of sedimentary structures in sedimentary rocks.

(3 marks)

(e) Define foliation in metamorphic rocks.

(2 marks)

(f) Justify how foliation planes in metamorphic rocks may becomes critical to the stability of the material in rock slope or excavation.

(2 marks)

Q4 (a) State **TWO (2)** main types of weathering in rocks.

(2 marks)

(b) Explain **TWO (2)** different processes of weathering.

(4 marks)

(c) Discuss **TWO (2)** factors affect the rate of weathering processes

(4 marks)

(d) Two types of rocks, granite and basalt, are exposed at the surface in tropical region.

(i) Explain type of weathering will predominate.

(2 marks)

(ii) Justify your answer which rock will weather most rapidly.

(5 marks)

(e) Compare the differences between the following pairs using diagrams (draw and label) to explain;

(i) Normal fault and strike slip fault
(ii) Anticline and overturned fold
(iii) Conformity and angular unconformity
(iv) Erosion by water and by wind

(8 marks)

Q5 (a) Explain **THREE (3)** different core logging calculations methods that are used in practice.

(3 marks)

(b) Investigate the purpose of the following tests;

(i) Ultrasonic test
(ii) Point load test
(iii) Schmidt rebound number
(iv) Slake durability test
(v) Seismic refraction

(10 marks)

(c) An 20 m span of access tunnel for an underground mine will be excavated at a depth of 100 m below ground surface. The rock mass contains multiple occurances of weakneses zones containing clay. These joints are rough or irregular, planar and the rock wall contact is softening, or low friction clay mineral coatings. Laboratory test on core samples of intact rock give an average Uniaxial Compressive Strength of 260

MPa. The principal stress are approximately vertical and horizontal and the magnitude of the horizontal principal stress is approximately 1.5 times that of the vertical principal stress. The rock is having a stress problem with a large inflow or high pressure in competent rock with unfilled joints. By using the RQD value 65%, calculate Q based on data given in Figure **Q5(c)**.

(6 marks)

(d) A tunnel is constructed and driven through highly weathered sandstone with a dominant joint set dipping at 70° against the direction of the tunnel drive. The discontinuities strike perpendicular to the tunnel axis. Based on the point load test, the rock strength is 25 MPa. The joints are slightly rough, unweathered and average length of the joint is 15 m with an aperture less than 2 mm without infilling materials and spacing between the joints is 0.25 m. Groundwater of the tunneling condition is anticipated to be dripping. By using the RQD value 55%, calculate the Rock Mass Rating (RMR) value based on the data given in Figure **Q5(d)**.

(6 marks)

Q6 (a) Discuss **ONE (1)** factor affected the strength of rock intact for schist metamorphic rock.

(2 marks)

(b) Discuss **ONE (1)** factor affected the strength of rock mass for schist metamorphic rock.

(2 marks)

(c) A granites rock mass have 4 representative joint sets as listed in **Table 1.**

Table 1

Joint number	Dip direction bearing (°)	Magnitude of Dip (°)
J1	96	58
J2	136	46
J3	320	22
J4	266	14

Note:
Basic friction angle for all the joints is 30°. The joints in the four sets are all persistent (continuous), wet with a cohesive clay infill.

Using the equatorial net given in Figure **Q6(c),** answer the following;

(i) Plot great circles for the 4 joints.

(ii) Plot poles for the 4 joints.

(iii) Determine the magnitude and direction of the lines of intersection between them, if any.

(iv) A cut slope having a dip of 55° in a direction having a bearing of 142° was being proposed in a highway project. Investigate the stability of the slope, by considering each of the possible types of failures. Tabulate your answers.

(11 marks)

(d) The following additional and relevant information was obtained from both field and laboratory study for the slope in part **Q6(c)**.

1.	Unit weight of rock	= 25 kN/ m^3
2.	Unit weight of water	= 9.81 kN/m^3
3.	Slope height	= 30 m
4.	Tension crack depth	= 2 m
5.	Cohesion of the clay infill	= 50 kPa
6.	Inclination of anchor bars	= 20°
7.	Yield stress for one (1) anchor bar	= 100kN

Using the equations given in Figure **Q6(d),**

(i) Calculate the factor of safety against plane failure and comment about the stability.

(5 marks)

(ii) Determine the number of rock anchors if the required factor of safety is 1.6.

(5 marks)

S1 (a) Lukiskan gambarajah lapisan komposisi dan lapisan mekanikal planet bumi.

(3 markah)

(b) Jelaskan **EMPAT (4)** pergerakan plat dengan bantuan gambarajah yang berkaitan.

(10 markah)

(c) Bumi telah mengalami perubahan yang besar sejak berjuta tahun yang lampau. Terangkan proses-proses geologi yang mengubah struktur bumi.

(6 markah)

(d) Bincangkan hubungan diantara masa geologi, keliangan dan kekuatan batuan.

(6 markah)

S2 (a) Mineral merupakan bahan pejal bukan organik yang semulajadi yang memiliki struktur kimia tertentu untuk menghasilkan sifat-sifat fizikalnya yang unik. Nyatakan **EMPAT (4)** mineral-mineral termasuk kegunaannya dalam industri.

(4 markah)

(b) Struktur dalaman mineral dibentuk oleh susunan bahagian-bahagian strukturnya termasuk atom-atom, ion-ion atau molekul-molekul kimia dan disusun mengikut susunan yang tertentu sehingga membentuk *crystal lattice* atau *crystalline*. Lukiskan gambarajah *crystal lattice* yang mengandungi elemen NaCl dan terangkan secara ringkas gambarajah tersebut.

(4 markah)

(c) Bezakan maksud warna dan *streak* dalam mineral.

(2 markah)

(d) Lutsinar adalah darjah cahaya yang dibenarkan untuk melalui sesuatu medium. Jelaskan **EMPAT (4)** jenis lutsinar dalam mineral.

(8 markah)

(e) Terangkan kenapa kumpulan mineral silikat merupakan Mineral Utama Pembentukan Batu.

(3 markah)

(f) (i) Berikan definisi *Silicon-Oxygen Tetrahedron.*
(ii) ilustrasi **TIGA (3)** sambungan rantaian *Silicon-Oxygen Tetrahedron* disusun dalam mineral-mineral silika.

(4 markah)

S3 (a) Terangkan proses pembentukan bagi setiap jenis batuan berikut:
(i) Batu Igneus
(ii) Batu Sedimentari
(iii) Batu Metamorfik

(6 markah)

(b) Jelaskan dan ilustrasikan gambarajah berkaitan dengan ciri-ciri tersendiri atau tekstur pelbagai batuan igneus.

(8 markah)

(c) Jelaskan pengkelasan batuan sedimentari berikut:
(i) *Detrital* atau *Clastic Sedimentary Rocks*
(ii) *Chemical Sedimentary Rocks*

(4 markah)

(d) Nyatakan dan ilustrasikan **TIGA (3)** jenis struktur sedimentari dalam batuan sedimentari.

(3 markah)

(e) Berikan definisi *foliasi* dalam batuan metamorfik.

(2 markah)

(f) Berikan justifikasi bagaimana satah *foliasi* dalam batuan metamorfik boleh menjadi kritikal kepada penstabilan material dalam cerun batuan atau pengorekan batuan.

(2 markah)

S4 (a) Nyatakan **DUA (2)** jenis luluhawa yang berlaku pada batuan.

(2 markah)

(b) Jelaskan **DUA (2)** proses luluhawa.

(4 markah)

(c) Bincangkan **DUA (2)** faktor yang menpengaruhi kadar luluhawa.

(4 markah)

(d) Dua jenis batuan, granit dan gabro, terdedah di permukaan dikawasan tropika.

(i) Jelaskan jenis luluhawa yang utama yang akan terjadi pada batuan terebut.

(2 markah)

(ii) Antara dua batuan tersebut yang manakah yang akan terluluhawa dengan lebih pantas? Berikan justifikasi jawapan tersebut.

(5 markah)

(e) Jelaskan perbandingan diantara pasangan yang akan dinyatakan dibawah dengan bantuan lukisan dan label;

(i) Normal fault dan strike slip fault
(ii) Anticline dan overturned fold
(iii) *Conformity dan angular unconformity*
(iv) Hakisan oleh air dan angin.

(8 markah)

S5 (a) Jelaskan **TIGA (3)** perbezaan kaedah pengiraan teras gerudi batuan (*core logging*) yang diamalkan.

(3 markah)

(b) Siasat tujuan ujian dibawah dilakukan:

(i) Ultrasonic test
(ii) Point load test
(iii) Schmidt rebound number
(iv) Slake durability test
(v) *Seismic refraction*

(10 markah)

(c) Satu terowong sepanjang 20 m untuk lombong bawah tanah akan dikorek pada kedalaman 100 m dari aras permukaan bumi. Jasad batuan menunjukkan kehadiran beberapa set kekar terhancur yang terisi bahan lempung. Kekar tersebut adalah kasar dan bersatah. Sentuhan dinding batuan dilapisi tanah liat yang berjelekitan rendah. Ujikaji makmal pada sampel korekan batuan sempurna memberikan nilai purata kekuatan mampatan satu paksi sebanyak 260 MPa. Arah tegasan prinsip adalah dianggarkan mendatar dan pugak dan magnitud tegasan prinsip mendatar adalah dianggarkan sebanyak 1.5 lebih daripada tegasan prinsip pugak. Jasad batuan mumpunyai masalah tekanan tinggi air dengan kekar tidak terisi. Dengan menggunakan nilai PMB 65%, kirakan nilai Q dengan berpandukan Rajah **Q5(c)**.

(6 markah)

(d) Sebuah terowong dibina melalui batupasir terluluhawa gred tinggi dengan keadaan kekar dominan bersudut kemiringan 70° dan miring bertentangan arah laluan masuk pembinaan terowong. Jurus ketakselanjaran adalah berserenjang dengan paksi terowong. Berdasarkan ujian beban titik, kekuatan batuan adalah 25 MPa. Kekar menunjukkan sifat permukaan sedikit kasar, tidak terluluhawa, panjang kekar berpurata 15 m, bukaan kekar berukuran kurang 2 mm dengan tiada bahan isian dan purata jarak antara kekar adalah 0.25 mm. Keadaan aras air bumi terowong adalah di dalam keadaan mengalir. Dengan menggunakan nilai PMB 55%, kirakan nilai *Rock Mass Rating* (RMR) dengan berpandukan kepada Rajah **Q5(d)**.

(6 markah)

S6 (a) Bincangkan **SATU (1)** faktor yang mempengaruhi kekuatan sampel batuan syis termetamorf.

(2 markah)

(b) Bincangkan **SATU (1)** faktor yang mempengaruhi kekuatan massa batuan syis termetamorf.

(2 markah)

(c) Batuan massa granit mempunyai 4 set ketakselanjaran yang di tunjukkan di dalam **Jadual 1.**

Jadual 1

Nombor ketakselanjaran	Arah kemiringan (°)	Sudut kemiringan (°)
J1	96	58
J2	136	46
J3	320	22
J4	266	14

Catatan:
Sudut jelekitan semua satah ketakselanjaran ialah 30°. Kesemua 4 set satah ketakselanjaran mempunyai kepanjangan yang berterusan, berkeadaan basah dan bukaan diisi oleh lempung.

Dengan menggunakan jaringan sama luas yang diberikan dalam Rajah **Q6(c)**. Plotkan

(i) Bulatan besar untuk kesemua 4 set ketakselanjaran;
(ii) Kutub untuk semua set ketakselanjaran;
(vi) Tentukan jumlah dan arah titik persilangan dua set ketakselanjaran, jika ada;
(vii) Cerun batuan mempunyai kemiringan 55° dan mempunyai arah kemiringan 142° telah dicadangkan untuk pembinaan lebuhraya. Siasat kestabilan cerun batuan tersebut dengan mengambil kira kesemua mod kegagalan cerun yang telah dipelajari. Persembahkan jawapan dalam bentuk jadual.

(11 markah)

(d) Berikut adalah infomasi tambahan yang diperolehi dari cerapan lapangan dan juga makmal untuk cerun batuan dari soalan **S6(c)**.

1.	Berat unit batuan	= 25 kN/ m^3
2.	Berat unit air	= 9.81 kN/m^3
3.	Tinggi cerun	= 30 m
4.	Kedalaman rekahan	= 2 m
5.	Daya jelekitan kesemua satah ketakselanjaran	= 50 kPa
6.	Kecondongan tetulang besi	= 20°
7.	Kekuatan satu (1) tetulang besi	= 100kN

Dengan menggunakan formula yang diberi didalam Rajah **Q6(d)**:

(i) Kirakan faktor keselamatan kegagalan satah dan komen tentang kestabilannya,

(5 markah)

(ii) Kirakan jumlah tetulang besi yang diperlukan sekiranya cerun tersebut memerlukan faktor keselamatan 1.6.

(5 markah)

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303

DESCRIPTION	VALUE	NOTES
1. ROCK QUALITY DESIGNATION	***RQD***	
A. Very poor	0 - 25	1. Where *RQD* is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate *Q*.
B. Poor	25 - 50	
C. Fair	50 - 75	
D. Good	75 - 90	2. *RQD* intervals of 5, i.e. 100, 95, 90 etc. are sufficiently accurate.
E. Excellent	90 - 100	
2. JOINT SET NUMBER	J_n	
A. Massive, no or few joints	0.5 - 1.0	
B. One joint set	2	
C. One joint set plus random	3	
D. Two joint sets	4	
E. Two joint sets plus random	6	
F. Three joint sets	9	1. For intersections use $(3.0 \times J_n)$
G. Three joint sets plus random	12	
H. Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use $(2.0 \times J_n)$
J. Crushed rock, earthlike	20	
3. JOINT ROUGHNESS NUMBER	J_r	
a. Rock wall contact		
b. Rock wall contact before 10 cm shear		
A. Discontinuous joints	4	
B. Rough and irregular, undulating	3	
C. Smooth undulating	2	
D. Slickensided undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m.
E. Rough or irregular, planar	1.5	
F. Smooth, planar	1.0	
G. Slickensided, planar	0.5	2. $J_r = 0.5$ can be used for planar, slickensided joints having lineations, provided that the lineations are oriented for minimum strength.
c. No rock wall contact when sheared		
H. Zones containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)	
J. Sandy, gravely or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)	
4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)
a. Rock wall contact		
A. Tightly healed, hard, non-softening, impermeable filling	0.75	
B. Unaltered joint walls, surface staining only	1.0	25 - 35
C. Slightly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	2.0	25 - 30
D. Silty-, or sandy-clay coatings, small clay-fraction (non-softening)	3.0	20 - 25
E. Softening or low-friction clay mineral coatings, i.e. kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1 - 2 mm or less)	4.0	8 - 16

1. Values of ϕr, the residual friction angle, are intended as an approximate guide to the mineralogical properties of the alteration products, if present.

FIGURE Q5(c)

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303

4. JOINT ALTERATION NUMBER	J_a	ϕ degrees (approx.)	
b. Rock wall contact before 10 cm shear			
F. Sandy particles, clay-free, disintegrating rock etc	4.0	25 - 30	
G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick)	6.0	16 - 24	
H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 - 16	
J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water	8.0 - 12.0	6 - 12	
c. No rock wall contact when sheared			
K. Zones or bands of disintegrated or crushed	6.0		
L. rock and clay (see G, H and J for clay	8.0		
M. conditions)	8.0 - 12.0	6 - 24	
N. Zones or bands of silty- or sandy-clay, small clay fraction, non-softening	5.0		
O. Thick continuous zones or bands of clay	10.0 - 13.0		
P. & R. (see G,H and J for clay conditions)	6.0 - 24.0		
5. JOINT WATER REDUCTION	J_w	approx. water pressure (kgf/cm^2)	
A. Dry excavation or minor inflow i.e. < 5 l/m locally	1.0	< 1.0	
B. Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C. Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates; increase J_w if drainage installed.
D. Large inflow or high pressure	0.33	2.5 - 10.0	
E. Exceptionally high inflow or pressure at blasting, decaying with time	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered
F. Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6. STRESS REDUCTION FACTOR		***SRF***	
a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth)		10.0	1. Reduce these values of SRF by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth < 50 m)		5.0	
C. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth > 50 m)		2.5	
D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E. Single shear zone in competent rock (clay free), (depth of excavation < 50 m)		5.0	
F. Single shear zone in competent rock (clay free), (depth of excavation > 50 m)		2.5	
G. Loose open joints, heavily jointed or 'sugar cube', (any depth)		5.0	

FIGURE Q5(c) continued

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303

DESCRIPTION	VALUE			NOTES
6. STRESS REDUCTION FACTOR			***SRF***	
b. Competent rock, rock stress problems				
	σ_c/σ_1	σ_t/σ_1		2. For strongly anisotropic virgin stress field
H. Low stress, near surface	> 200	> 13	2.5	(if measured): when $5 \le \sigma_1/\sigma_3 \le 10$, reduce σ_c
J. Medium stress	200 - 10	13 - 0.66	1.0	to $0.8\sigma_c$ and σ_t to $0.8\sigma_t$. When $\sigma_1/\sigma_3 > 10$,
K. High stress, very tight structure	10 - 5	0.66 - 0.33	0.5 - 2	reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$, where
(usually favourable to stability, may				σ_c = unconfined compressive strength, and
be unfavourable to wall stability)				σ_t = tensile strength (point load) and σ_1 and
L. Mild rockburst (massive rock)	5 - 2.5	0.33 - 0.16	5 - 10	σ_3 are the major and minor principal stresses.
M. Heavy rockburst (massive rock)	< 2.5	< 0.16	10 - 20	3. Few case records available where depth of
c. Squeezing rock, plastic flow of incompetent rock				crown below surface is less than span width.
under influence of high rock pressure				Suggest *SRF* increase from 2.5 to 5 for such
N. Mild squeezing rock pressure			5 - 10	cases (see H).
O. Heavy squeezing rock pressure			10 - 20	
d. Swelling rock, chemical swelling activity depending on presence of water				
P. Mild swelling rock pressure			5 - 10	
R. Heavy swelling rock pressure			10 - 15	

ADDITIONAL NOTES ON THE USE OF THESE TABLES

When making estimates of the rock mass Quality (Q), the following guidelines should be followed in addition to the notes listed in the tables:

1. When borehole core is unavailable, *RQD* can be estimated from the number of joints per unit volume, in which the number of joints per metre for each joint set are added. A simple relationship can be used to convert this number to *RQD* for the case of clay free rock masses: $RQD = 115 - 3.3\ J_v$ (approx.), where J_v = total number of joints per m^3 ($0 < RQD < 100$ for $35 > J_v > 4.5$).
2. The parameter J_n representing the number of joint sets will often be affected by foliation, schistosity, slaty cleavage or bedding etc. If strongly developed, these parallel 'joints' should obviously be counted as a complete joint set. However, if there are few 'joints' visible, or if only occasional breaks in the core are due to these features, then it will be more appropriate to count them as 'random' joints when evaluating J_n.
3. The parameters J_r and J_a (representing shear strength) should be relevant to the weakest significant joint set or clay filled discontinuity in the given zone. However, if the joint set or discontinuity with the minimum value of J_r/J_a is favourably oriented for stability, then a second, less favourably oriented joint set or discontinuity may sometimes be more significant, and its higher value of J_r/J_a should be used when evaluating Q. The value of J_r/J_a should in fact relate to the surface most likely to allow failure to initiate.
4. When a rock mass contains clay, the factor *SRF* appropriate to loosening loads should be evaluated. In such cases the strength of the intact rock is of little interest. However, when jointing is minimal and clay is completely absent, the strength of the intact rock may become the weakest link, and the stability will then depend on the ratio rock-stress/rock-strength. A strongly anisotropic stress field is unfavourable for stability and is roughly accounted for as in note 2 in the table for stress reduction factor evaluation.
5. The compressive and tensile strengths (σ_c and σ_t) of the intact rock should be evaluated in the saturated condition if this is appropriate to the present and future in situ conditions. A very conservative estimate of the strength should be made for those rocks that deteriorate when exposed to moist or saturated conditions.

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

FIGURE Q5(c) continued

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameter			Ranges of values						
1	Strength of intact rock material	Point-load strength index	>10MPa	4-10MPa	2-4MPa	1-2MPa	For this low range-uniaxial compressive test is preferred		
		Uniaxial Compression strength	>250MPa	100-250MPa	50-100MPa	25-50MPa	5-25MPa	1-5MPa	<1MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2m	0.6m-2m	200-600mm	60-200mm	<60mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces. Not continous. No separation. Unweathered wall rock.	Slightly rough surfaces. Separation <1mm. Slightly weathered walls.	Slightly rough surfaces. Separtion < 1 mm. Highly weathered walls.	Slickensided surfaces or Gouge<5 mm thick or Separtion 1-5 mm continous.	Soft gouge>5 mm thick or Separtion>5mm continous.		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	<10m	10-25	25-125	>125		
		(Joint water press)/ (Major principal)	0	<0.1	0.1-0.2	0.2-0.5	>0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		
B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATION (SEE F)									
Strike and dip orientations			Very favourable	Favourable	Fair	Unfavorable	Very Unfavorable		
Rating	Tunnels and mines		0	-2	-5	-10	-12		
	Foundations		0	-2	-7	-15	-25		
	Slopes		0	-5	-25	-50	0		
C. ROCK MASS CLASSES									
Rating			100-81	80-61	60-41	40-21	<21		
Class number			I	II	III	IV	V		
Description			Very good rock	Good rock	Fair rock	Poor rock	Very poor rock		
D. MEANING ROCK CLASSES									
Class number			I	II	III	IV	V		
Average stand-up time			20 years for 15 m span.	1 year for 10 m span.	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span		
Cohesion of rock mass (kPa)			>400	300-400	200-300	100-200	<100		
Friction angle of rock mass (degree)			>45	35-45	25-35	15-25	<15		
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS * (1) IS RATING									
Discontinuity length (persistence)			<1m 6	1-3m 4	3-10m 2	10-20m 1	>20 m 0		
Separation (aperture)			None 6	<0.1mm 5	0.1-1.0 mm 4	1-5 mm 1	>5 mm 0		
Roughness			Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0		
Infilling (gouge)			None 6	Hard filling <5mm 4	Hard filling >5mm 2	Soft filling<2 mm 2	Soft filling 5mm 0		
Weathering			Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0		
F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELING									
Strike perpendicular to tunnel axis					Strike parallel to tunnel axis				
Drive with dip- 45°-90°		Drive with dip- 20°-45°			Dip 45°-90°		Dip 20°-45°		
Very favourable		Favourable			Very unfavourable		Fair		
Drive against dip- 45°-90°		Drive against dip-20°-45°			Dip 0°-20° –Irrespective of strike				
Fair		Unfavourable			Fair				

FIGURE Q5(d) : Rock Mass Rating System (After Bieniawski, 1989)

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303

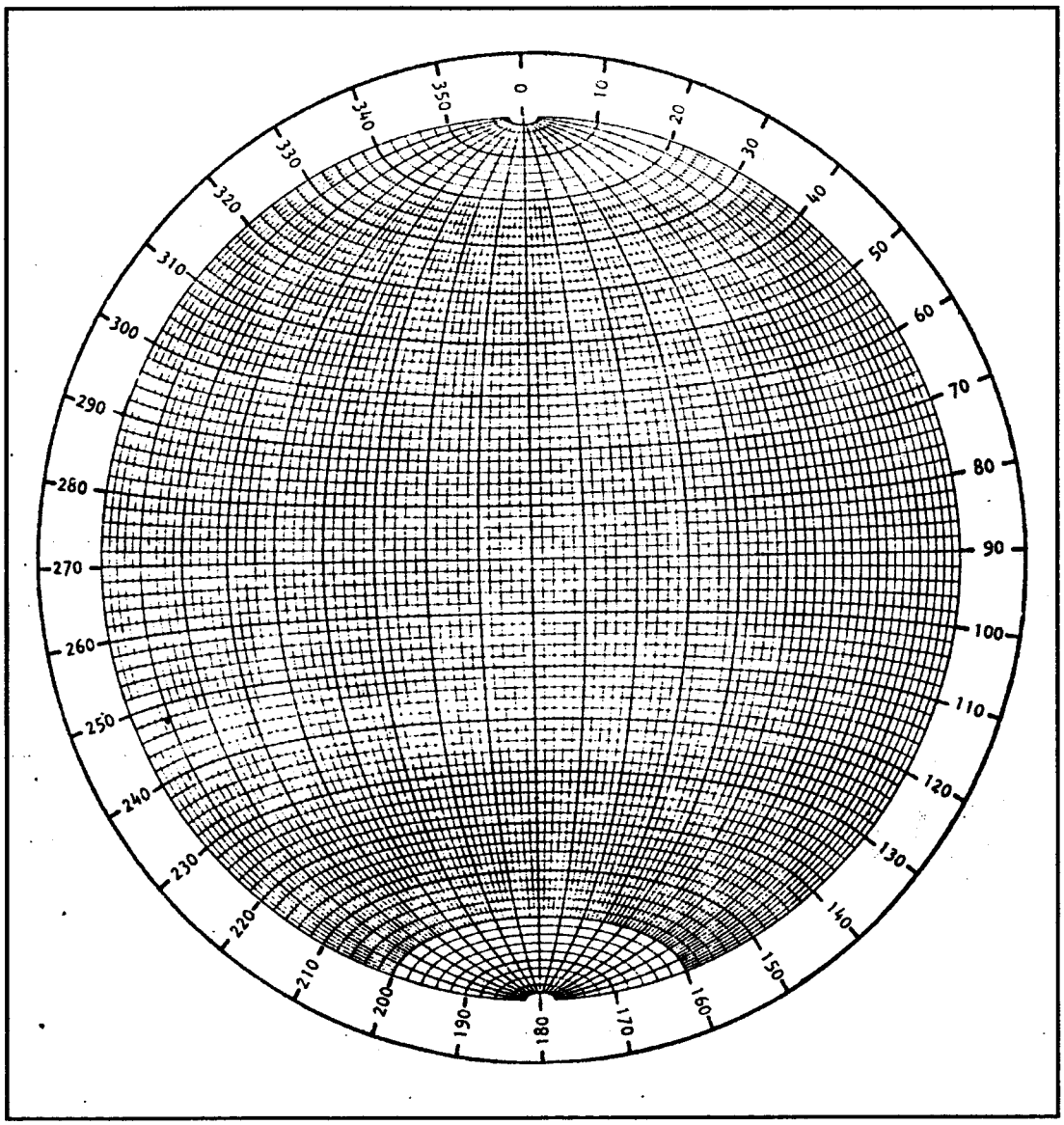
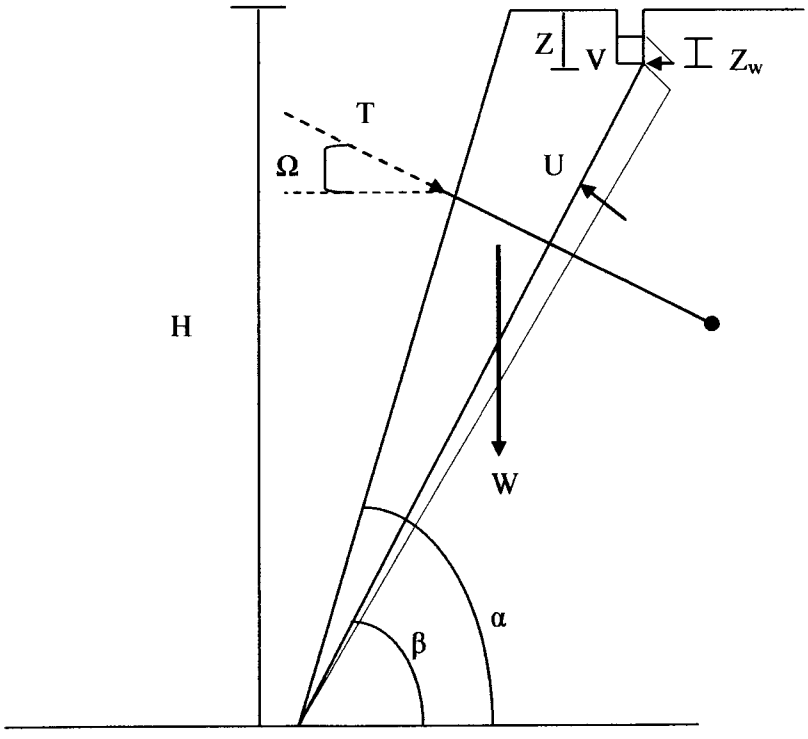


FIGURE Q6(c) : Equatorial equal-area stereo-net marked in 2° intervals

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2011/2012 PROGRAMME : 2 BFF / 3 BFF
COURSE : ENGINEERING GEOLOGY COURSE CODE : BFC 3013/21303



Given:

$$\textbf{FOS} = \frac{cA + (W\cos\beta - U - V\sin\beta + T\sin(\Omega+\beta))\tan\phi}{W\sin\beta + V\cos\beta - T\cos(\Omega+\beta)}$$

$A = (H-Z).\text{cosec}\,\beta$

$W = \frac{1}{2}\gamma_r . H^2 [(1-(Z/H)^2)\cot\beta - \cot\alpha]$

$U = \frac{1}{2}\gamma_w . Z_w . (H-Z).\text{cosec}\,\beta$

$V = \frac{1}{2}\gamma_w . Z_w^2$

cosec = 1/sin sec=1/cos cot=1/tan

FIGURE Q6(d)