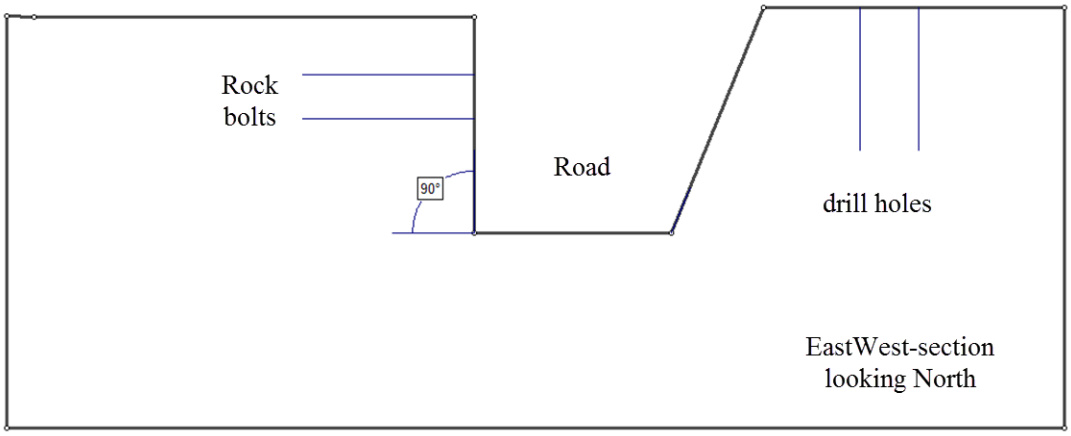
ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2016 session

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-GE-A5 Rock Mechanics

Question 1 (25 points)
A road to be excavated is presented in the following figure.

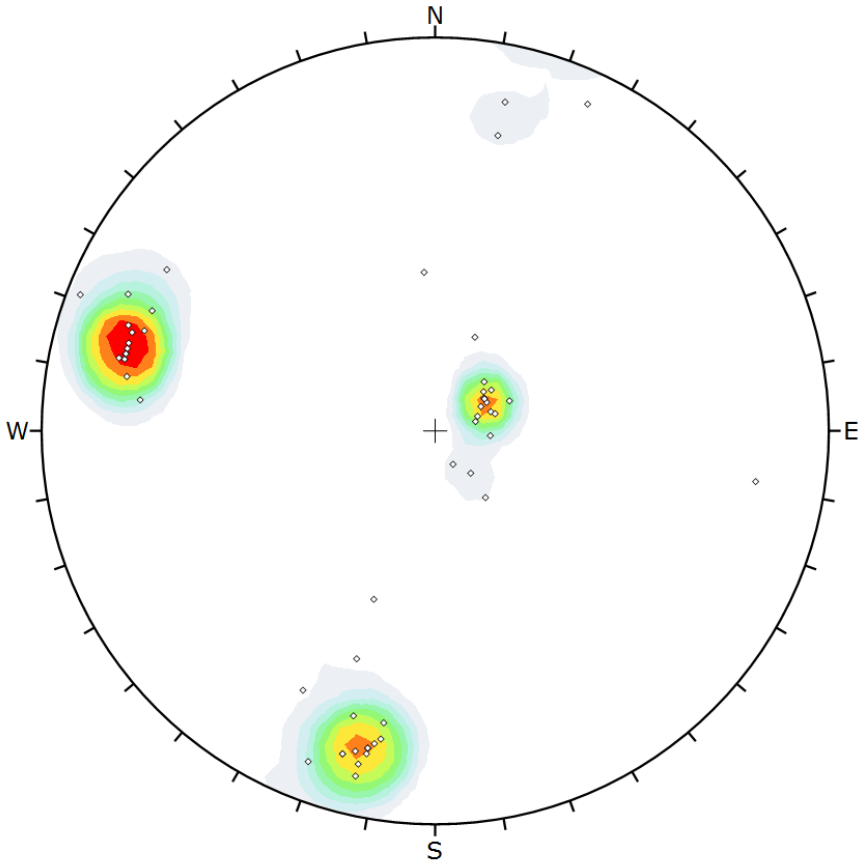


Geotechnical drilling allowed identifying 3 fracture sets. The following table is presenting the mean orientation of these sets as well as the fracture frequency along the vertical drill holes.

	Dip (°)	Dip Direction (°)	Fracture frequency along the drill hole. (m-1)
Set 1	45	045	2.0
Set 2	75	045	3.0
Set 3	00	180	1.0

1. Compute RQD along the drill holes.
2. Compute the normal fracture frequency of these sets.
3. Compute the set fracture frequency along the 5m rock bolts
4. How many fractures should intercept the rock bolts?

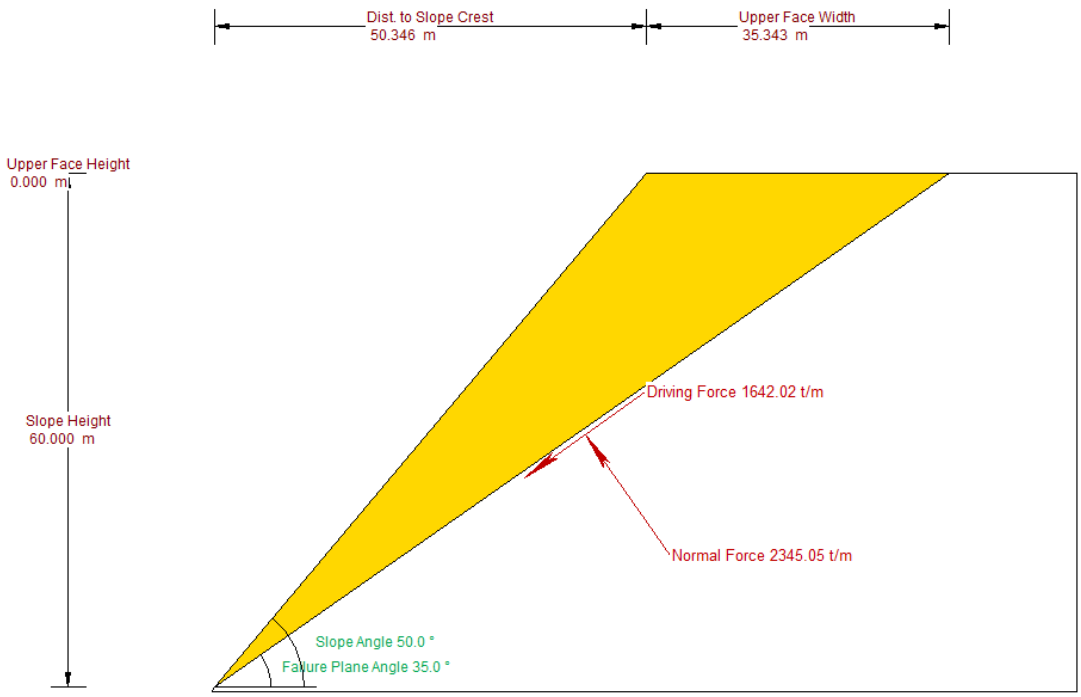
Question 2 (20 points)



A field campaign allowed quantifying the orientation of 60 fractures. The previous figure presents the poles of these fractures. If a rock slope is to be excavated at a dip of 085 degrees and a dip direction of 090 degrees within this fractured rockmass; identify the potential modes of structural failure. Identify the sliding direction and the associated sliding planes. The friction angle of the fractures is estimated at 30 degrees. Repeat the same exercise for a rock slope excavated at a dip of 85 degrees and a dip direction of 180 degrees.

Question 3 (20 points)

You want to analyse the stability of a rock slope. The design criterion for such a slope is a factor of safety (FoS) of 1.3. The friction angle of the fracture is 35 degrees and the cohesion 100 kPa. The unit weight of the rockmass is 27 kN/m^3.



a) Compute the FoS if the rockmass is dry (no presence of water in the rock mass).
b) Performed a sensitivity analysis on the impact of the level of the water table. Discuss you results.
c) Compute the FoS if the rock mass is fully saturated and subject to a seismic coefficient of 0.08.
d) Compute the maximal water table level allowing a FoS greater or equal to 1.3.

Question 4 (20 points)

The following results were obtained during direct shear testing on dry and rough fractures.

Normal stress σ_n (MPa)	Shear stress (peak) τ_{peak} (MPa)
0.25	0.30
0.50	0.60
1.00	1.22
2.00	1.62
3.00	2.03
4.00	2.41

a) Suggest two failure criterions (with numerical values) to characterize the mechanical behavior of the fracture (one criterion must be linear and the other one bi-linear)
b) Which of the 2 proposed criterion is the most appropriate to define the behavior of the fracture? Discuss.
c) Describe the behavior of the fracture if it is subjected to a stress state defined by $\sigma 1$ = 10 MPa and $\sigma 3$ = 3 MPa.

Question 5 (15 points)

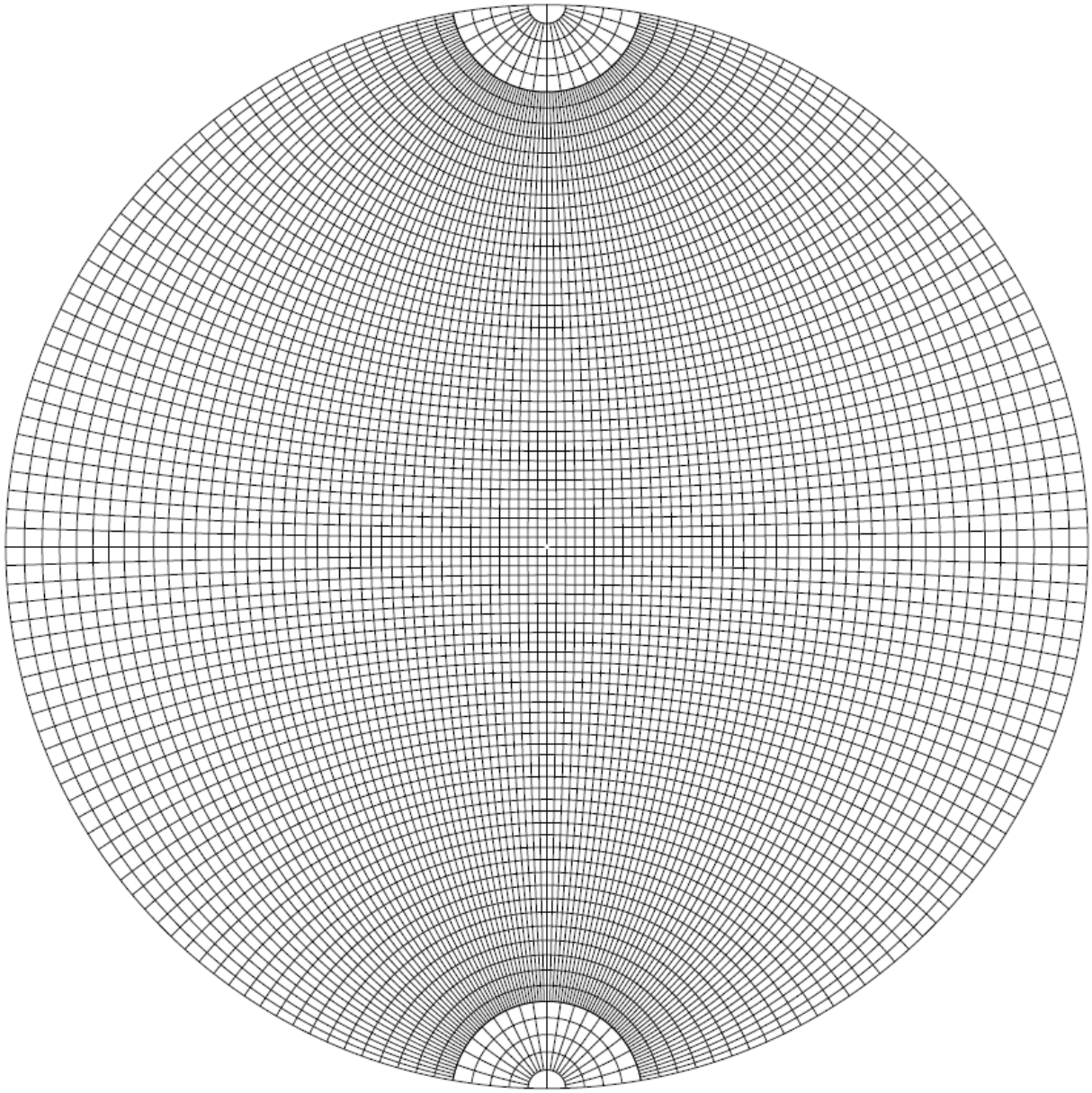
A series of laboratory tests were performed on intact sandstone samples.

Triaxial compressive strength results ($\sigma_2 = \sigma_3$)		
sample	σ_1 (MPa)	σ_3 (MPa)
1	60	0
2	90	5
3	150	10
4	190	15
5	240	20

a) Draw the σ_1 -σ_3 diagram corresponding to every sample tested.

b) Draw the Mohr diagram corresponding to every sample tested.

c) Compute the associated Mohr-Coulomb failure criterion.

d) Using the Mohr diagram, describe the behavior of a rock sample subjected to a stress state given by a σ_1 = 180 MPa and σ_3 = 20 MPa.

Useful information