The Pennsylvania State University
Department of Mineral Engineering
GeoEE 408 Characterization of Groundwater Systems

Mid-term Examination - Tuesday March 3rd - 75 minutes
Select any three out of four questions. Total score out of 200.

Name/Name: ________________________________

SSN: ________________________________

Include extra sheets, as needed, and return entire packet.

Question	Points	Score
1	60	
2	60	
3	70	
4	70	
Total	200	

Question 1

Define the following terms, and identify the units [MLT] of the quantity, where relevant. Be as specific in your definitions as possible.

1. Advective flux, F_x.

2. Matric potential, ψ.

3. Relative permeability, k_r.

4. Scanning curves.

5. Capillary pressure, p_c.

6. Coefficients of mechanical dispersion, α_L, α_T.

7. Advection-dispersion equation, $\frac{\partial c}{\partial t} = D_L \frac{\partial^2 c}{\partial x^2} - v_x^a \frac{\partial c}{\partial x}$.

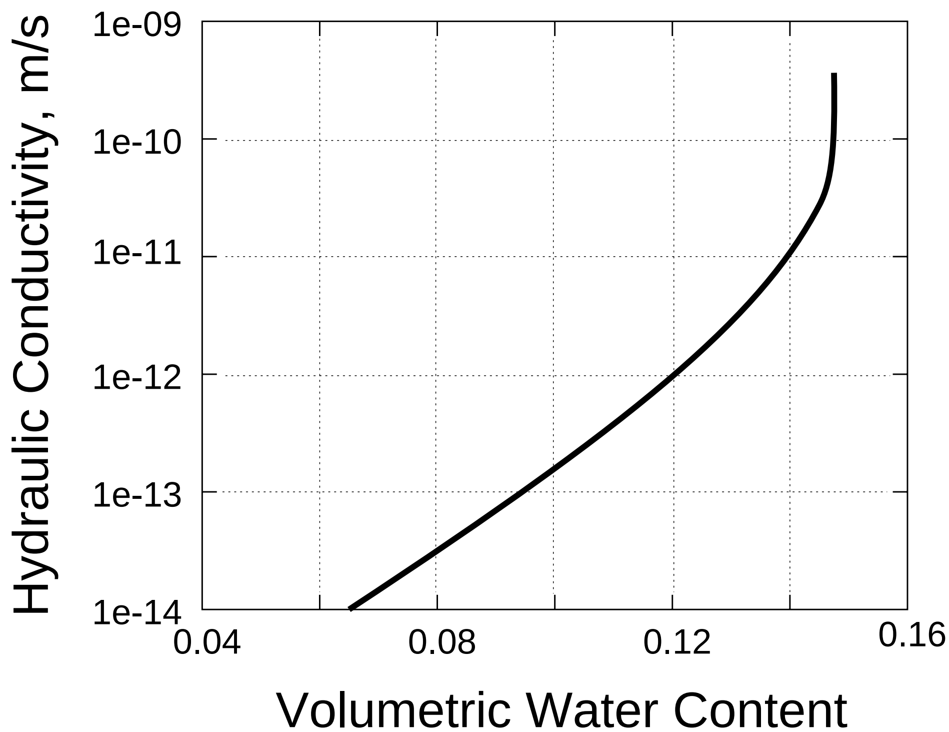
8. Mass concentration, c.

9. Fick's first law.

Question 2

Given the attached curve for hydraulic conductivity (K) versus volumetric water content (θ) relation for a core originally saturated with water and subject to drying:

1. Determine the relative permeability at a water saturation of 80%.
2. If this is the measured field saturation, evaluate the maximum infiltration flux possible at this saturation. Recall that during infiltration, the only agent driving flow is gravity, $i.e. \partial h/\partial x = 1$.
3. These data are for Topopah Springs Tuff. Evaluate the maximum infiltration (per square meter of area) per year. Again, only gravity drives the flow.

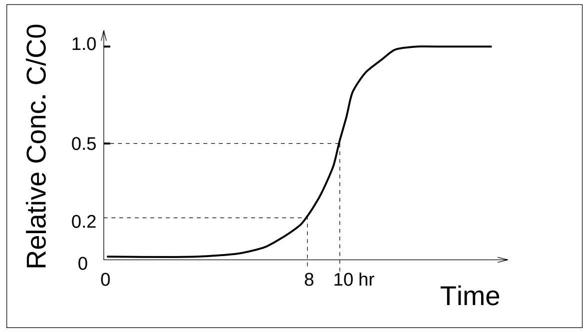


Question 3

A laboratory dispersion test is completed on a sand core. The core is $5\ cm$ in diameter and $20\ cm$ long, with a porosity of 25%. A constant (in time) volumetric flow rate is applied through the core. The flow is axial along the core, from one end to the other, the sides are sealed. Sodium chloride in solution is introduced to the flowstream at the upstream end of the sample at time $t = 0$. Inlet concentration is c_0. The breakthrough curve for this conservative tracer at the far end of the sample is as shown.

For this data, evaluate:

1. The advective flow velocity.
2. The magnitude of the longitudinal dispersivity, D_L.
3. What magnitude of the dispersion coefficient, α_L, results from this.
4. How does this compare with estimates from field values for this dispersion coefficient, α_L.
5. If the flow velocity is doubled, how will D_L change.
6. Is this magnitude useful in application to a plume that is $400\ m$ in length.



x	erfc(x)	x	erfc(x)
0	1.0	1.1	0.119795
0.05	0.943628	1.2	0.089686
0.1	0.887537	1.3	0.065992
0.15	0.832004	1.4	0.047715
0.2	0.777297	1.5	0.033895
0.25	0.723674	1.6	0.023652
0.3	0.671373	1.7	0.016210
0.35	0.620618	1.8	0.010909
0.4	0.571608	1.9	0.007210
0.45	0.524518	2.0	0.004678
0.5	0.479500	2.1	0.002979
0.55	0.436677	2.2	0.001863
0.6	0.396144	2.3	0.001143
0.65	0.357971	2.4	0.000689
0.7	0.322199	2.5	0.000407
0.75	0.288844	2.6	0.000236
0.8	0.257899	2.7	0.000134
0.85	0.229332	2.8	0.000075
0.9	0.203092	2.9	0.000041
0.95	0.179109	3.0	0.000022
1.0	0.157299		

Question 4

In situ permeability tests have been completed at a site, in fractured clay, to determine the variation in permeability with depth. The water table is present at the ground surface, and fractures and matrix are assumed saturated. Permeability magnitudes are given, as below. Assume matrix permeabilties are so low as to be negligible. The site investigation reveals only one set of vertical fractures, with approximately four fractures per meter. The permeability of fractures decrease with depth, due to fracture closure as lateral stresses increase.

Given the following data:

	$\sigma\ (N/m)$	$\mu\ (N.s/m^2)$	$\gamma\ (kN/m^3)$
TCE	2.4×10^{-2} (DNAPL/water ($\theta = 0$))	$.96 \times 10^{-3}$	15.6
Water	7.3×10^{-2} (Water/air ($\theta = 0$))	1.12×10^{-3}	9.8

1. Complete the following table:

Depth(m)	Permeability (m^2)	Estimated TCE Entry Pressures	Required Critical Height of TCE for Ganglion Mobility
1	1×10^{-15}		
2	100×10^{-18}		
4	10×10^{-18}		

2. Given this knowledge that permeability decreases by one order of magnitude with each doubling in the depth of measurement, how deep will free product TCE be able to penetrate? Assume the TCE may only be present to a maximum elevation of the ground surface.

3. If the water table is lowered, will the TCE penetration depth (as free product) increase or decrease? Describe why.