THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ENERGY AND MINERAL ENGINEERING
ENVSE 408 CONTAMINANT HYDROLOGY

Mid-term Examination – Tuesday March 1st, 2022 – 75 minutes
Answer all three questions.
For water (in contact with air): $\sigma = 7.3 \times 10^{-2}$ *N/m*; $\mu = 1.12 \times 10^{-3}$ *N.s/m²*

Name: _____

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

Question 1

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

1. Advective velocity, v_a .

2. Irreducible saturation of the wetting phase, S_{w_0} .

3. Leverett J-function.

4. Van Genuchten relations.

5. Laboratory measurement of $p_c - vs - S_w$.

6. Relative permeability, $k_r(S_w)$.

7. Estimating capillary behavior from field measured permeability.

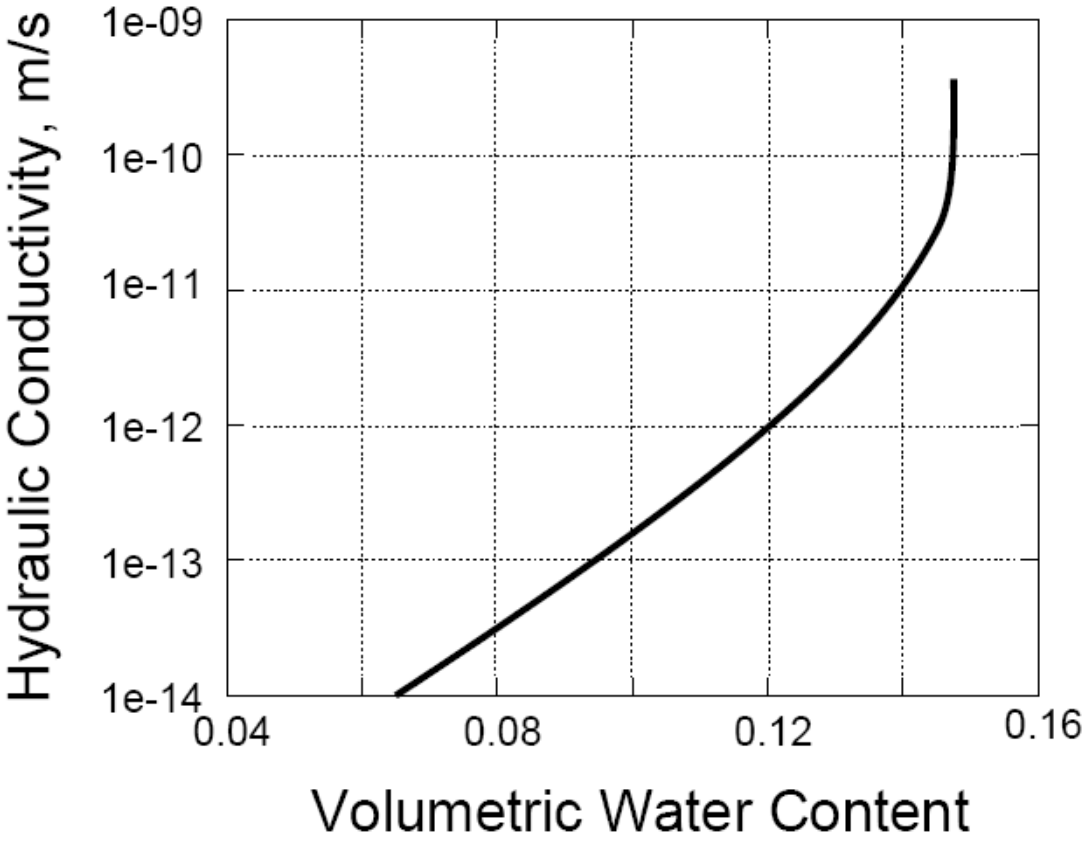
8. Pendular saturation.

9. Hydrodynamic dispersion, $D_L = D^* + \alpha_L v^a{}_L$.

10. Fick's first law, $F = -D\frac{\partial c}{\partial x}$

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.* $\partial h / \partial z = 1$.

3. These data are for Topopah Springs Tuff. Evaluate the maximum infiltration (per square meter of plan area) per year. Again, only gravity drives the flow.

Question 3

A two-component DNAPL cocktail has been spilled through the vadose zone in a sand aquifer and has reached and penetrated the saturated zone. Soil samples are taken from the saturated zone within (an arbitrary) part of the aquifer where a dissolved plume is presumed to have developed. The sample is centrifuged to remove the pore fluids, and the fluid assayed to determine aqueous concentrations, c_a. Components are desorbed from the solid grains to define the presumed equilibrium sorbed concentrations, c_s. The porosity of the sand aquifer is n=25%, the bulk density is ρ_b=1200 kg/m^3, and the mean volumetric moisture content in the vadose zone is θ=5%. The mean soil temperature is 20^oC. Aqueous solubility of each of the components approximately triple with an increase in temperature from 20° to 60^oC.

Component	c_a *mg/l*	c_s *mg/kg*	Mole fraction, X_i *%*
Trichloroethane (TCA)	0.13×10^3	325	60
Methyl Chloride	0.6×10^4	600	40

Component	Aqueous Conc. c_a (60^oC) *mg/l*
Trichloroethane (TCA)	
Methyl Chloride	

1. Complete the missing entries in the table above.

2. Approximately 10,000 *l* of the cocktail is to be removed from the system. Evaluate the time taken to remove this material from the aquifer if the system is flushed with water at 20^oC, at a rate of 40 m^3/day. Assume that mole fraction approximates mass fraction, and that mean density of the NAPL is 1400 kg/m^3.

3. What is the time taken to remove the material if warm water is used.