THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ENERGY AND GEO-ENVIRONMENTAL ENGINEERING
ENVSE 408 CONTAMINANT HYDROLOGY

Mid-term Examination – Tuesday February 27th, 2018 – 75 minutes
Answer all three questions.
For water (in contact with air): $\sigma = 7.3 \times 10^{-2}$ *N/m*; $\mu = 1.12 \times 10^{-3}$ *Pa.s*

Name: _____

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

Include extra sheets, as needed, and return entire packet

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, $F = -D\frac{\partial c}{\partial x}$

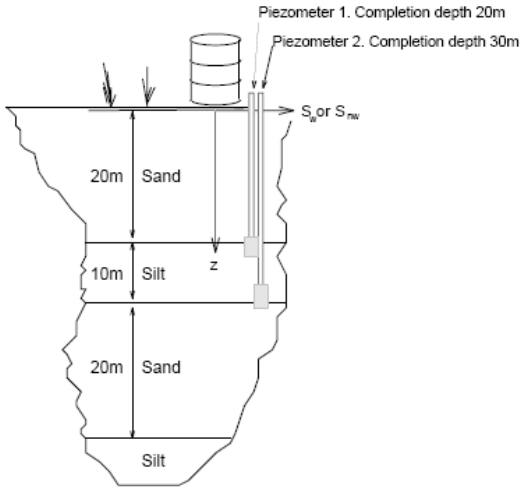
Question 2

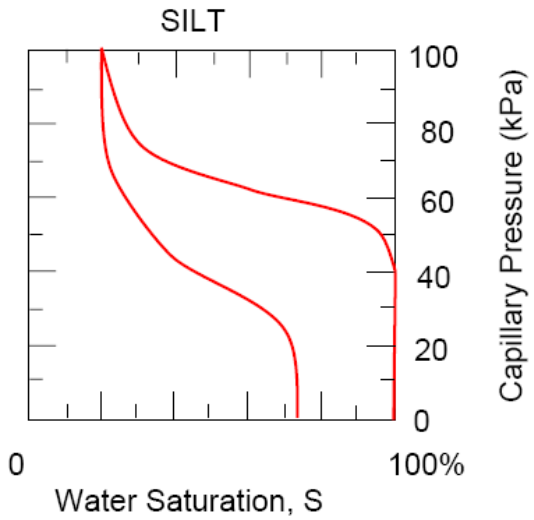
A spill of TCE occurs at the surface for the stratigraphy given in the figure. The profile includes laterally extensive and horizontally bedded sands and silts. An approximate capillary pressure curve is available for TCE penetration into the sand. Unit weight of TCE is $15.6\ KN/m^3$ and for water $9.8\ KN/m^3$. The dynamic viscosity of water is $1.12\times10^{-3} N.s/m^2$ and for TCE is $0.96\times10^{-3} N.s/m^2$.

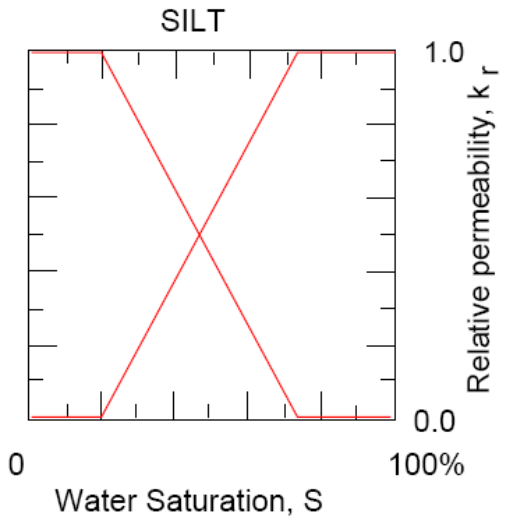
The capillary pressure relationship is defined for the silt units, as shown, and the piezometers measure pressures in the silt. Hydraulic conductivity magnitudes are available from pumping tests that yield $K_{silt} = 2.5\times10^{-5} cm/s$. The porosity of the sand and the silt are both 31%.

1. Water pressures are hydrostatic, with the water-table at the ground surface. Evaluate water pressures at the piezometer locations.

2. The piezometers measure TCE pressures in the silt layer. The TCE pressure in the upper piezometer is 280 kPa, and 436 kPa in the lower piezometer. Determine the capillary pressures at the upper and lower piezometer locations. Are these positive or negative.







3. Evaluate the effective water and TCE saturations at the locations of each of the piezometers. Explain your rationale for choice of drainage or imbibition curves.

4. What is the permeability of the silt to TCE? State your assumptions.

5. What is the volumetric flow rate in the vertical direction per plan area of 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^o 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 $20^{o}C$, 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.