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

Mid-term Examination – Tuesday March 8th, 2007 – 75 minutes
Answer all three questions.

For water (in contact with air): $\sigma = 7.3 \times 10^{-2}\ N/m$; $\mu = 1.12 \times 10^{-3}\ N.s/m^2$

For TCE (in contact with water): $\sigma = 3.5 \times 10^{-2}\ N/m$; $\mu = 0.96 \times 10^{-3} N.s/m^2$; $\rho_{TCE} = 1540\ kg/m^3$

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. Dispersivities, α_L, α_T .

2. Bubbling pressure, p_{c0}

3. Capillary pressure versus saturation relationship defined in terms of the Leverett J-function, J .

4. Gaseous retardation factor, R_g .

5. Darcy's law defined in terms of fluid pressures.

6. Relative permeability, k_r .

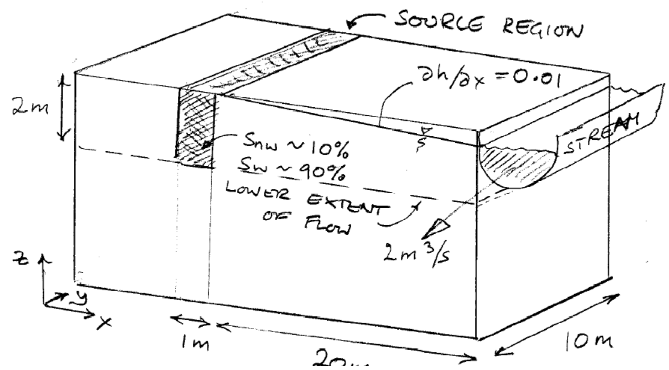
7. Van Genuchten $p_c - vs - \theta_e$ curves.

8. NAPL free-product thickness within wells.

9. Equivalent contaminant mass within plume, $M_T = c_a n V R_a$.

10. Pendular through funicular saturations.

Question 2
[Select any 4 of 6 parts and circle those numbers]



A surface spill of gasoline has penetrated into the subsurface. It previously rested on the groundwater table, which has fallen and subsequently risen, to smear it as shown. The floating free-product has been removed, and the smeared zone is below the water table and at a residual saturation of 90% water and 10% LNAPL.

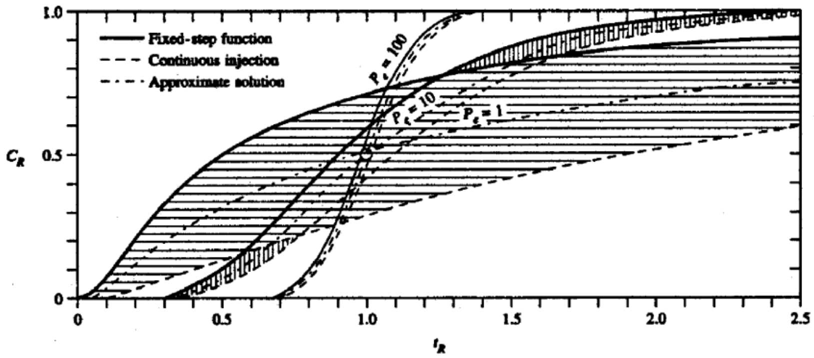
The hydraulic conductivity of the aquifer is $K = 10^{-4} m/s$, and is at a relative permeability of $k_r = 1$ for water. The aquifer has a porosity of $n = 20\%$, and retardation is insignificant. The LNAPL is immobile, and comprises principal components of benzene and ethyl benzene.

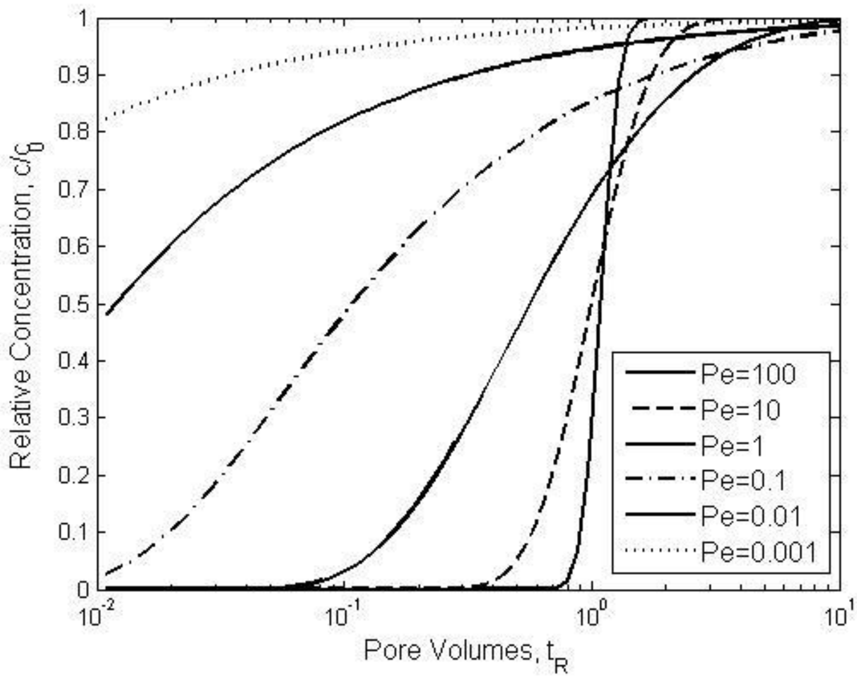
	Solubility (mg/L)	**Mass Fraction**	**Molecular Weight**	**Density** (kg/L)	**Mole Fraction**	**Effective Solubility**
Benzene	1780	30%	78.12	0.877		
Ethyl-benzene	140	70%	106.18	0.867		

Assume an effective diffusion coefficient of both components to be $D^* = 10^{-9} m^2/s$. And a longitudinal dispersivity of α_L of one tenth of plume length.

The figures show the solution for the advection-diffusion equation for a constant upstream concentration (fixed step concentration), c_0, with Peclet number, $Pe = v_x L / D$, and pore volumes of flow past a point downstream at coordinate $x = L$, of $t_R = v_x t / L$, i.e. the solution for:

$$c/c_0 = 1/2[erfc(Pe/4t_R)^{1/2}(1-t_R) + \exp(Pe)erfc(Pe/4t_R)^{1/2}(1+t_R)]$$





1. Evaluate the equilibrium effective solubility of the two components.

2. Evaluate the arrival time of the mean concentration to the stream. What are the approximate times of the $0.1\,(10\%)$ and $0.9\,(90\%)$ c/c_0 arrivals?

3. What are the concentrations of each component when the plume arrives in the aquifer, immediately <u>before</u> discharging into the stream?

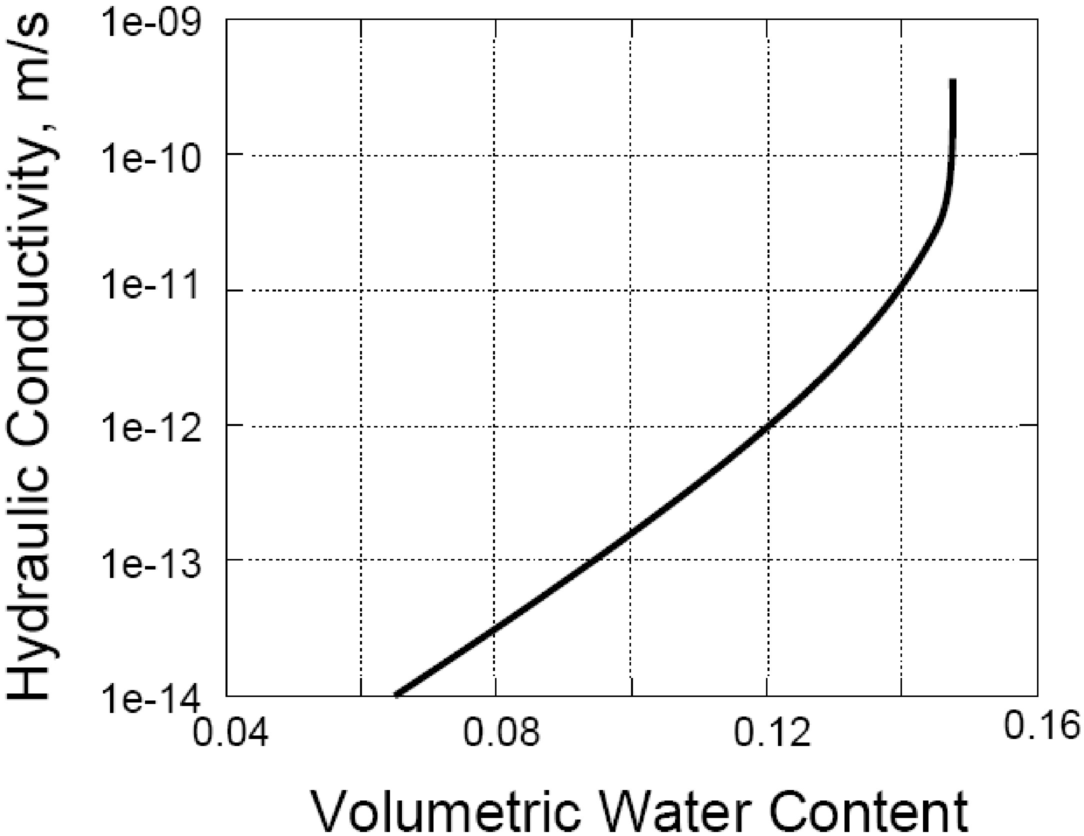
4. At this rate of transport from the source, approximately how long will it take to deplete the source by dissolution of the slowest-removed component?

5. The dissolved flux enters the stream, flowing at $2\,m^3/s$. To what dissolved concentration of ethyl benzene are aquatic life exposed?

6. If grouting the material between the source and the stream is used to slow the spread of the components, and the mean permeability is reduced to $K = 10^{-10}\,m/s$, without changing either the configuration of the groundwater table or the porosity, what is the approximate time of arrival of each of the components at the furthest downstream extent of the aquifer?

Question 3

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.