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

Mid-term Examination – Tuesday February 28th, 2006 – 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. Relative permeability, k_r .

2. Peclet number, Pe .

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

4. Saturated permeability of fractured media, k .

5. Aqueous retardation factor, R_a .

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

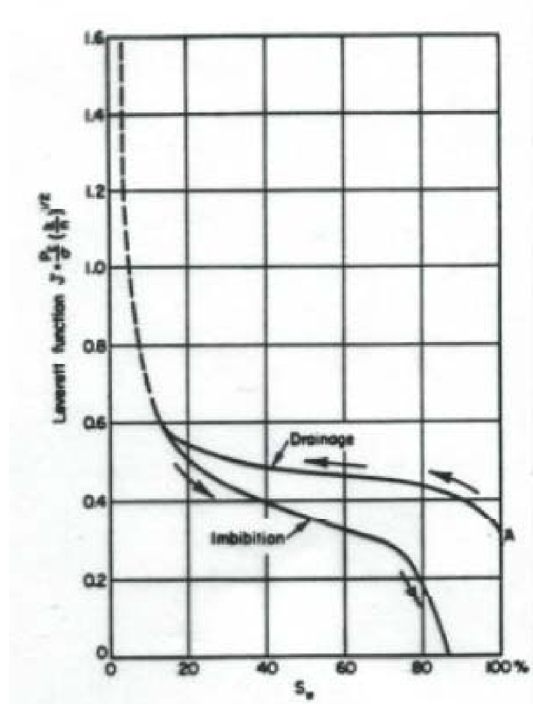
7. Longitudinal dispersion, D_L .

8. Fick's law, $F = -D * \frac{\partial C}{\partial x}$

9. Critical ganglion height, $h_{\min}$.

10. NAPL free-product thickness within wells.

Question 2



The Leverett curve defines the relationship between water saturation, S_w, and a non-dimensional capillary pressure, J, where $J = \frac{p_c}{\sigma}\sqrt{\frac{k}{n}}$. For a site where the water table is $3\ m$ below the ground surface, with a porosity of 30%, and a permeability of $10^{-12}\ m^2$, compute the following:

1. The height of the capillary rise above the water table.
2. The water saturation at the ground surface. How close is this to the irreducible saturation of water?
3. At a nearby site, the water table is at the ground surface. Evaluate the height of TCE required to penetrate the aquifer. All parameters of permeability and porosity are the same.
4. If an overpressure is supplied at the ground surface, which is just sufficient to force TCE into the soil, at what depth will it be possible for the NAPL saturation to reach 40%?
5. If it is observed that the permeability is due to the presence of fractures, what impact do you expect this to have on the above results? Will the entry pressures be lower or higher? And will the saturations at any given depth be lower or higher? State your rationale.

Question 3

For the figure, showing the plume resulting from pulse injection of chloride tracer in well graded sands at the Borden aquifer, determine the following. (Use the shape of the plume after 647 days.)

Note: $M = c_o V$; $c = \dfrac{M}{8(\pi t)^{3/2}\sqrt{D_x D_y D_z}} \exp[-\dfrac{X^2}{4D_x t} - \dfrac{Y^2}{4D_y t} - \dfrac{Z^2}{4D_z t}]$.

1. The longitudinal dispersivity, D_L.
2. The coefficient of longitudinal hydrodynamic dispersion, α_L.
3. The transverse dispersivity, D_T.
4. How far downgradient from the source will the center of mass of the plume be 10 years after the initial injection?
5. What will be the peak concentration of the plume after 10 years if the peak concentration after 647 days is 30 ppm?
6. What is the approximate volume of fluid comprising the plume, if the porosity fo the aquifer is 0.3? Use the area of a rectangle to approximate the area of an ellipse.
7. What is the mass of chloride comprising the plume?