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

Final Examination – Thursday May 6th, 2004 – 110 minutes
Answer all questions.

Name: ____

Include extra sheets, as needed, and return entire packet

Question	Points	Score
1	100	
2	100	
3	100	
Total	200	

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. Six-phase, resistance, or Joule heating.

2. Core barrel.

3. Capillary pressure, p_c.

4. Gaseous retardation coefficient, R_g.

5. Leverett J factor.

6. Ground penetrating radar, GPR.

7. Non-dimensional Henry's Law Coefficient, H.

8. Finite differences.

9. Effective solubility, S_e.

10. Bubbling pressure, p_b.

Question 2

A two-component DNAPL cocktail has been spilled into the vadose zone in a sand aquifer. Samples from the vadose zone yield aqueous (c_a) and solid concentrations (c_s), presumed representative of chemical equilibrium conditions.
The porosity of the sand aquifer is n=25%, the bulk density is ρ_b=1800 kg/m^3, and the mean volumetric moisture content in the vadose zone is θ=5%. The mean soil temperature is 20^oC. Solubility of each of the components increase by approximately 10% with an increase in temperature from 20^o to 60^oC. The non-dimensional Henry's law coefficient, H, increases by approximately 15% over the same temperature range.

Component	c_a *mg/l*	c_s *mg/kg*	Henry's Law Coef. $H(20^oC)$ *[dimensionless]*	Mole fraction, X_i %
Trichloroethane (TCA)	0.13×10^3	325	0.4	60
Methyl Chloride	0.6×10^4	600	0.6	40

Component	Gaseous Conc. $c_g(20^oC)$ *mg/l*	Aqueous Conc. c_a (60^oC) *mg/l*	Gaseous Conc. c_g (60^oC) *mg/l*
Trichloroethane (TCA)			
Methyl Chloride			

1. Complete the missing entries in the table above.

2. Evaluate the gaseous retardation coefficients in the vadose zone at 20^oC.

3. Some of the free-product has penetrated the water table. If the concentrations in the vadose zone are broadly representative of the equilibrium concentrations below the water table, evaluate the aqueous retardation coefficients at 20^oC, for the saturated zone.

4. If both groundwater and (gaseous) diffusive fluxes are small in the saturated and vadose zones, respectively, which compound arrives first in wells in (i) groundwater, and (ii) the vadose zone.

5. Approximately 20,000 *l* of the cocktail is to be removed from the vadose zone, where it is present in solubilized form. Evaluate the time taken to remove this material if the system is flushed with air at 20^oC, at a rate of 200 m^3/day. Assume that mole fraction approximates mass fraction, and that mean density of the NAPL is 1400 kg/m^3.

6. To improve removal rates, the injected air is pre-heated to 60^oC. This lowered viscosity enables a larger throughput of fluid to flush the system. If the heated injection results in an increased circulation of 300 m^3/day at 60^oC, evaluate the rate of removal. How long will it now take to clean the system for each of the components?

Question 3

TCE has been spilled in a thin layer of soil overlaying fractured granite. The sandy soil is 0.5 m thick, and is underlain by 20 m of weathered granite with a matrix porosity of 1%, and in turn underlain by fresh granite with a matrix porosity of less than 0.1%. Fractures are present at 3 per meter in the weathered zone, and at a spacing greater than 2 meters below this.

1. Describe an appropriate (direct) site investigation for this site to:
    a. Evaluate stratigraphy and geology.
    b. Determine the extent of NAPL (free product) and dissolved product contamination.
    c. Determine the potential for offsite migration of the aqueous plume.

   Use note form, if you wish, to itemize your choices and explain their relevance.

2. The site investigation indicates that the water table is present at 5 meters bgs and free product is present over an area of about $100 m^2$. The matrix permeability of the weathered and unweathered granite matrix is everywhere less than 10^{-17} m^2. The bulk permeability of the weathered and unweathered granite mass (i.e. including fractures) is 10^{-14} and 10^{-12} m^2, respectively. The viscosity of water is $\mu = 1.12 \times 10^{-3}$ $N.s/m^2$.

   Identify, and describe the operating principles of <u>three</u> remedial techniques that may be applied to this site. For each of these three applicable techniques, identify <u>three</u> factors that make the technique particularly applicable to the site. Use note form to answer if you wish.