

THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF MINERAL ENGINEERING
GEOEE 408 CHARACTERIZATION OF GROUNDWATER SYSTEMS

Final Examination - Monday May 5th
1 hour 50 minutes

$$\bar{R} = 8.206 \times 10^{-5} (atm.m^3)/(mol.^{\circ}K)$$

Name: _____

SSN: _____

Question	Points	Score
1	70	
2	90	
3	90	
Total	250	

Question 1

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

1. Shelby tube and split-spoon sampler.

2. Henry's law constant, H .

3. Distribution coefficient, k_d .

4. Residual NAPL saturation, S_{nw0} .

5. Raoult's Law, $S_i^e = X_i S_i$.
6. Dielectric constant, ϵ and GPR.
7. Gaseous retardation coefficient, R_g .
8. van Genuchten relations.
9. Thermal remediation processes, specifically CROW.
10. Hollow stem auger.

Question 2

A three component DNAPL cocktail has been spilled through the vadose zone in a sand aquifer and has reached and penetrated 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 $\rho_b = 1200 \text{ kg/m}^3$ and the mean volumetric moisture content in the vadose zone is $\theta = 5\%$. The mean soil temperature is 10°C .

Component	c_a mg/l	c_s mg/kg	Henry's law coeff., H' $(\text{atm.m}^3)/\text{mol.}$	Distribution coeff., k_d m^3/kg	Mole fraction, X_i %
Trichloroethane (TCA)	0.13×10^3	325	1.8×10^{-2}	_____	20
Trichloroethene (TCE)	0.32×10^3	672	9.1×10^{-3}	_____	40
Methylene Chloride	0.6×10^4	600	2.0×10^{-3}	_____	40

Component	Gaseous concentration, c_g mg/l	Aqueous retardation coeff., R_a —	Gaseous retardation coeff., R_g —
Trichloroethane (TCA)	_____	_____	_____
Trichloroethene (TCE)	_____	_____	_____
Methylene Chloride	_____	_____	_____

1. Complete the missing entries in the tables above, assuming aqueous concentrations in the vadose zone are the same as those in the saturated zone, c_a .
2. If advective velocity in the groundwater zone is 100 m/yr , determine the time lag between the spill hitting the water-table and arrivals in a shallow piezometer 30 m downstream of the spill site. Neglect dispersion.
3. Evaluate the times of arrival (following the spill) of components sampled by capillary tube from the vadose zone. The monitoring location is 20 m downstream of the spill and advective gas velocities in the vadose zone are 1000 m/yr . Neglect diffusion.
4. If air sparging is used as a remedial technique, and throughput of the sparging system is $100 \text{ m}^3/\text{d}$, evaluate the time required to clean a 5000 l spill to less than 5 ppb for each of the components. Assume that mole fraction approximates mass fraction, and mean density of the NAPL is 1400 kg/m^3 .

Question 3

A spill of 5000 l of gasoline has occurred at a site where silty sands overlay thick shales with a weathered upper interface.

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 6 m of sand overlies the fractured shale aquiclude. The upper 2 m of the shale is highly weathered and fractured ($K = 10^{-2} \text{ cm/s}$), and below that is tight. The water table is 2 m below the ground surface and free product is present over an area of about 100 m².

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

