Exam 1, Soil Physics (Agron 577), Spring 2003

Toby's Answers in italics

Part 1: Building Blocks:

1: In the following table, each line (row) concerns a single equation. Fill in the missing entries (1/2 pt each). If the equation doesn't have a name, state what it defines (e.g., Coulomb's envelope).

Name	Equation	Physical situation described
Darcy's Law	$q = -K\frac{\Delta P}{\Delta L}$	*Steady-state, saturated flow through soil*
Capillary rise	$h = \frac{2\gamma\cos(\alpha)}{(\rho_w - \rho_a)gR}$	*Height of rise of a wetting liquid in a capillary tube*
Coulomb envelope	$\tau = \tau_0 + \sigma\tan\phi$	*Region of states of stress that can be borne by a soil without failing*
Terzaghi's effective stress equation	$\sigma_E = \sigma_T - P$	*Effective stress is stress borne by soil particles, taking into account that some stress is borne by water.*
Poiseuille's law	$\bar{v} = \frac{R^2}{8\eta}\frac{\Delta P}{\Delta L}$	Mean velocity of flow through a tube
Effective radius (or effective hydraulic radius)	$R_{eff} = \frac{Area}{Perimeter}$	*Radius to use to calculate flow through a non-circular pore using Poiseuille's law*
Stokes' law, or Stokes' settling	$v = \frac{d^2 g(\rho_p - \rho_f)}{18\eta}$	Velocity of a spherical particle settling in a viscous fluid

2: Give units for the following (1/2 pt each). Use base SI units where you can.

Pressure: *Force / Area, Newtons/m^2*	Permeability: *Area (length squared)*
Gravitational head: *Length (pressure also acceptable)*	Strain: *Unitless (volume / volume)*
Stress: *See pressure*	Volume wetness: *Unitless (volume/volume)*
Flux density: *Volume per (area * time), m^2 s*	Particle density: *Mass/volume, kg m^{-3}*

3: Briefly define and describe the following (1-2 sentences) (2 pts each):

Dilatancy: *The phenomenon of expansion during shearing, as in sand particles that roll over each other.*

Secondary mineral: *A mineral formed by weathering from a primary mineral. Example: clay.*

Part 2: Comprehension: (5 pts each except for # 7: 6 pts)

4: For a given mass of soil and water in, say, and Iowa loam, which is greater: mass wetness or volume wetness?

From the conversion equations: $w = \theta \rho_w / \rho_b$. *But* $\rho_w / \rho_b < 1$, *so* $\theta > w$.

5: Describe a consequence of water having a high dielectric.

Charges are compensated within a short distance, so high solubility of polar and especially ionic solutes (e.g., salts).

6: What is the mineralogical difference between silt and clay?

Silt is generally composed of primary minerals, while clay is a secondary mineral.

7: Fill in the table:

	Maximum possible	**Minimum possible**	**"Typical" value**
Degree of saturation	*1 (pure water)*	*0 (dry soil)*	*0.2*
Porosity	*1 (no soil)*	*0 (absolutely compacted)*	*0.5*
Bulk density (assume $\rho_p = 2.65$ gm cm^{-3})	*2.65*	*0 (no soil) or ~1*	*1.4*

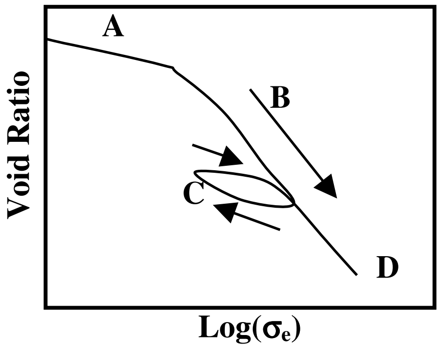
8: How can you measure bulk density (ρ_b)?

Density is mass / volume. Mass is easy to measure, but volume is harder. The simplest method is to take a sample of known volume (pound a ring into the ground), dry it, and weigh it.

9: When wet sodium-saturated montmorillonite is changed to calcium-saturated, what happens to the double layer (sketch if you want)? What happens to the clay as a whole?

The double layer decreases: charge is compensated within a shorter distance. The clay goes from a dispersed to a flocculated state.

10: Explain the diagram:



A: elastic (non-virgin) compression.
B: virgin compression (steeper slope)
C: pressure released – material doesn't behave purely elastically or purely plastically, so it is an elasto-plastic material.
D: failure (shears, breaks)

11: Why is water so different from chemically similar compounds such as H_2S and NH_3?

1) There are 2 + and 2 – points on a water molecule: balance. In other words, there isn't an excess of + or of -.
2) O has a small radius, allowing molecules to get close to each other.
3) Result: lots of hydrogen bonding.

12: What factors most strongly influence soil respiration?

Temperature (the book stresses this point)
Also availability of water, nutrients, and oxygen (or other terminal electron acceptor).
Presence of microbes can generally be assumed.

Part 3: Application: (15 pts each)

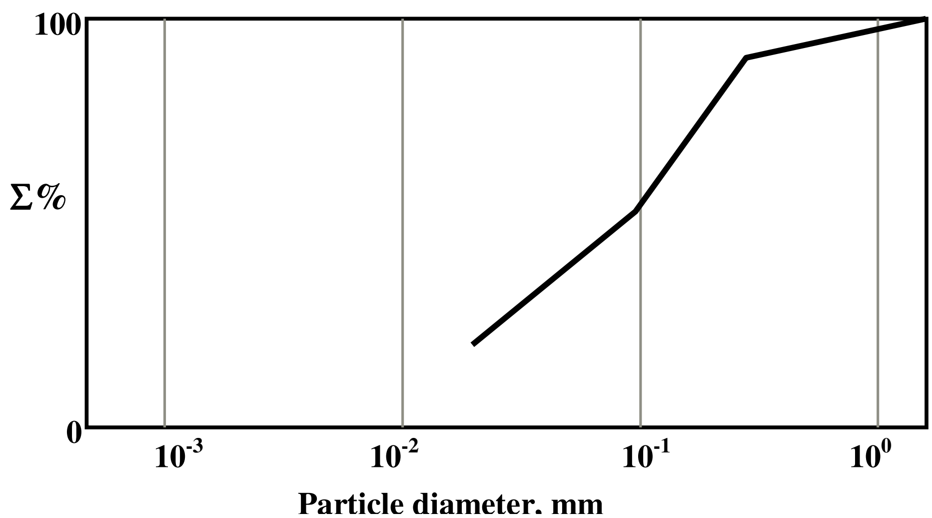
For all the calculations, assume that the following values apply:

Fluid viscosity: 1.25×10^{-2} kg m^{-1} s^{-1} Interfacial tension: 7.3×10^{-2} kg s^{-2}
Particle density: 2650 kg m^{-3} Fluid density: 1030 kg m^{-3}
Gravitational acceleration = 9.81 m s^{-2}

13: You disperse 1 gm of soil in 1 liter of water. You then take 10 ml samples at a 15 cm depth and obtain the following data:

Time	**Sample mass, g**	**Diameter, mm**
30 sec	0.009	*0.266*
4 min	0.005	*0.094*
2 hour	0.002	*0.017*

1) Calculate the particle diameter corresponding to each sampling event.
2) Plot the points on the graph below as a cumulative particle size distribution.
3) What particular assumption was especially violated in performing this experiment and calculation?



1: use the equation $d = \sqrt{\dfrac{18H\eta}{tg(\rho_p - \rho_f)}}$. *H=0.15 m, density difference = 1620. See table.*

2: see figure

3: The assumption that was especially violated here is that particles fall independently. We put in the whole soil, including sand, and the soil is high in sand. So silt and clay particles would have been "sucked down" behind the falling sand particles. Other particularly violated assumptions: spherical particles, laminar flow.

14: You have a "soil sample" consisting of a cubic cm of solid iron, with 0.2 mm holes drilled through it in one direction only. What is the hydraulic conductivity of this "soil" if the porosity is 0.1?

Mean velocity through a <u>*single*</u> *tube is (Poiseuille's law)* $\bar{v} = \frac{R^2}{8\eta}\frac{\Delta H}{\Delta L}$

For conductivity, assume a unit gradient, so the gradient term = 1.

Flux density is mean velocity times porosity, so here it is 1/10 times the velocity.

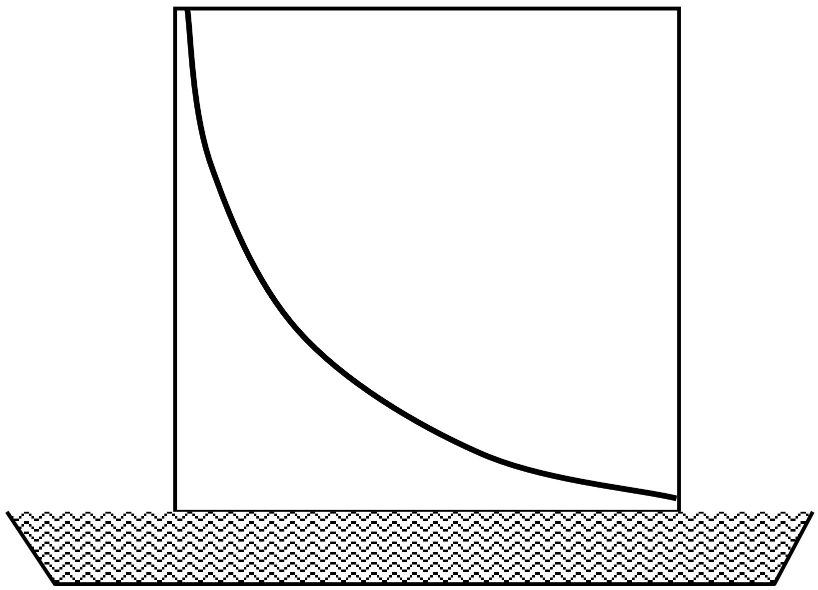
Solving, $q = 4 \text{ x } 10^{-6}\ m\ s^{-1}$.

Of course, in 4 of 6 orthogonal directions, the hydraulic conductivity is zero – the pores go in only a single direction!

Compare hydraulic conductivity of sand (10^{-5} *to* 01^{-3} *m/s) and silt (*10^{-8} *to* 10^{-6} *m/s). This block has sand-sized pores, but lower porosity than sand.*

15: You have two clean silica plates, each 1 m^2, whose bottom edges are touching a free water surface (see sketch). The plates are touching along the left edge, and 0.5 mm apart along the right edge.

1) Calculate the height of the water (above the free water surface) rise at each edge.
2) Draw the height profile in the sketch



The relevant equation here is the capillary rise equations, but for rise between parallel plates we remove the "2". So $h = \frac{\gamma \cos\alpha}{\Delta\rho g r}$ *where r is the plate separation.*

At left: plates touch, so infinite rise. But rise can't exceed height of plates, so actual rise = 1.0.

At right: rise = ~1.4 cm

Where is rise exactly 1 m? <u>*Very*</u> *close to left edge (I got* 7.2×10^{-6} *m from left edge)*

The curve is a y = 1/x type curve. See sketch.