The following equations and information may or may not be needed to work some of the problems. They are here for your reference if you need them.

The capillary rise equation has 2 different forms, depending on whether you're measuring pressure directly, or looking at height of rise. Use whichever form of the equation is most convenient for the application at hand.

$$\Delta P = \frac{2\sigma}{R} \quad \text{or} \quad \rho_w gh = \frac{2\sigma}{R}$$

Assume contact angle = 0°

$$\sigma = surface\ tension = 72.7\ \frac{dyn}{cm} = 72.7\ \frac{g}{\sec^2}$$ (Use the appropriate units for the equation you use.)

1 bar pressure = $10^6\ \frac{\text{dyn}}{\text{cm}^2}$

h = height of rise above free surface
R = radius of tube
ΔP = pressure difference across interface
g = grav. accel. = 9.8 m/sec^2
ρ_w = density water = 1 g/cm^3
remember 1 μm = 10^{-6} m

Darcy's Law

$$q = -K\frac{\Delta H}{\Delta L} \quad \text{or} \quad Q = -KA\frac{\Delta H}{\Delta L}$$

Poiseuille's Law

$$Q = -\frac{\pi R^4 \rho g \Delta H}{8nL}$$

Assume $n = 1x10^{-2}\ \frac{g}{cm \sec}$

ρ = 1.0 g/cm^3
g = 9.8 m/sec^2

$$K_{EFFECTIVE} = \frac{L_{TOTAL}}{\frac{L_1}{K_1} + \frac{L_2}{K_2}}$$

Name ________________________

Agry 560 Exam
November 9, 2006
(150 points) (14 pages)

(3) 1. In the auger-hole method for measuring saturated hydraulic conductivity below a water table, what is actually measured?
a) infiltration into dry soil
b) vertical conductivity
c) horizontal conductivity
d) some combination of horizontal and vertical conductivity

(3) 2. What is the force that causes water to flow out of the soil samples and the soil to equilibrate at the desired matric potential in the pressure plate method?
a) the weight of the soil samples
b) the higher pressure inside the pressure pot
c) the attraction of the ceramic plate for the water
d) the column of water from under the plate to the outlet tube

(3) 3. In the aggregate size distribution lab, if the moist samples had been broken to pass through a 14 mm screen rather than the usual 8 mm screen, and then wet-sieved with the usual nest of sieves of 4.76 mm, 2mm, 1mm, and 0.21 mm, what would the maximum possible value of MWD be?
a) 14 mm
b) 9.38 mm
c) 7 mm
d) 6.38 mm
e) 4.76 mm

(3) 4. In the wet aggregate stability analysis, the purpose in crushing aggregates and then washing them back through the sieves is:
a) clean the sieves
b) correct the aggregate weight for sand and stones
c) correct the MWD for humus
d) determine the primary-particle size distribution
e) all of the above

(3) 5. Tensiometers measure what in the soil? (circle all true statements)
a) volumetric water content
b) gravimetric water content
c) matric potential
d) osmotic potential
e) hydrogen concentration

(3) 6. TDR (time domain reflectometry) as used to determine soil water, measures the dielectric constant which is directly related to:
a) Volumetric water content
b) Gravimetric water content
c) Matric potential
d) Osmotic potential
e) Hydrogen concentration

(3) 7. Neutron probes should be calibrated for your soil. What are the purposes of calibration? (circle all true statements)
a) to adjust readings for soil pH
b) to adjust readings for hydrogen present in clays and soil organic matter
c) to adjust readings for application of fertilizer salts such as potassium nitrate (KNO_3)
d) to adjust readings for slow neutron absorbers such as boron, chloride and cadmium (B, Cl, Cd)
e) to adjust readings for hysteresis in the soil water retention curve

(3) 8. In the pressure plate method for soil water retention measurements, what happens if the ceramic plate is not fully saturated?
a) the soil equilibrates twice as fast due to extra air movement
b) the applied pressure (ie 15 bars) is not maintained in the pot
c) water flow through the soil occurs very quickly and equilibrium cannot be reached
d) none of the above

(3) 9. When a field tile is working and draining water from the soil, the zone immediately around the tile will have a ψ_P of
a) 0.0 bar
b) -0.1 bar
c) -0.3 bar
d) -15 bar

(2) 10. When calculating water potentials in a system at equilibrium, the H_{TOT} (or Ψ_{TOT}) is ___________________________________ throughout the system.

(2)11. When calculating water potential in a system at equilibrium when the reference elevation is set at the **water table**, then the H_{TOT} is exactly ___________________________ throughout the system.

(8)12. Draw a sketch of a soil water retention curve (desorption), for a sand and a silt loam (include both curves on the same graph). Explain the reasons for the differences in the shapes of the two curves. (Be sure to label the axes!)

(6) 13. Write out Richards' equation. Discuss how Richards' equation is an "extension" of Darcy's Law.

(8) 14. Describe the crust test method for measuring unsaturated hydraulic conductivity in soil. Describe the general methodology, and state whether the method is a steady-state or a transient method.

(3) 15. The total soil water potential (Ψ_T) is made up of 3 major components. Name those 3 components, and briefly describe the forces responsible for each of those components of water potential.

(4) 16. List at least 3 reasons why infiltration rates may decline with time during an infiltration event.

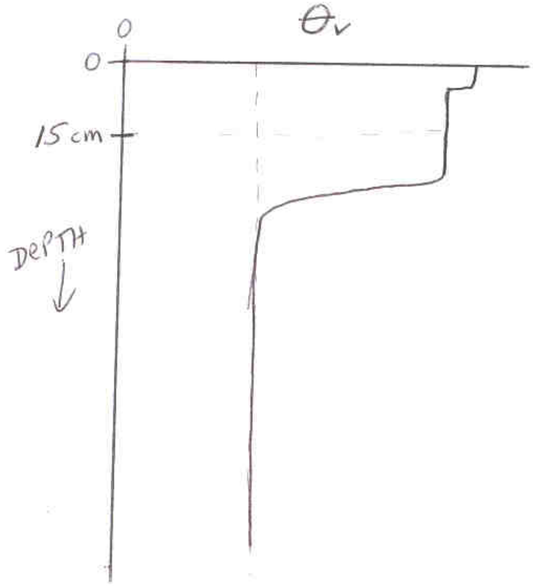


FIG. A

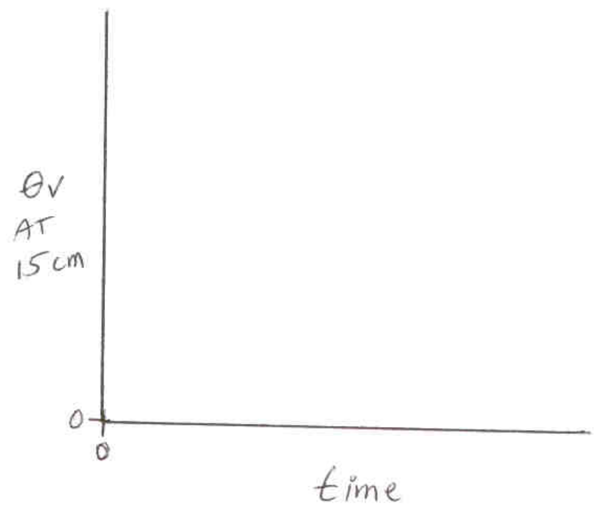


FIG. B

(12) 17. Figure A shows a water content profile in a silt loam soil immediately at the end of a rainfall event.

1) On that same graph, sketch the water content vs. depth profile for some time later, perhaps one day, for example. Explain why you drew it that way.

2) On Fig. B, sketch a curve to illustrate the water content at the 15 cm depth (see 15 cm depicted on Fig. A) vs. time, over a one-week period.

3) Use these diagrams to define and explain the concept of "field capacity." (use the back of this sheet if you need more space.)

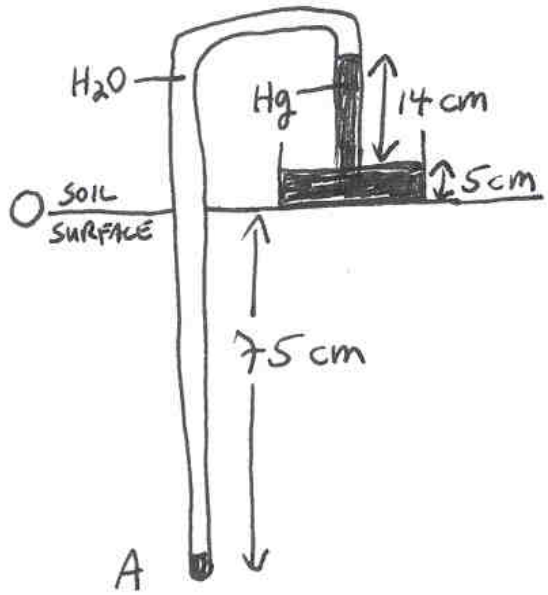
(10) 18. Draw a sketch of a sand table and label all the parts. Explain the theory and operation of the sand table for water retention measurements. Also explain the range of matric potentials where it is used, and why it can be used only in that range.

(12) 19. Describe (equipment, procedures, theory, etc.) both the double-ring infiltrometer method and the sprinkling infiltrometer method, for measuring infiltration rates in the field. Be sure to include the major advantages and disadvantages of each method (use sketches to help your discussion).

(12) 20. a) Discuss the main advantages and disadvantages of each of the following methods for measuring soil water content: 1) soil sampling and drying, 2) neutron probe, 3) TDR, and 4) electrical resistance.

b) If you want to be able to know the precise times that the wetting front reaches certain depths, which technique(s) might be suitable? Why?

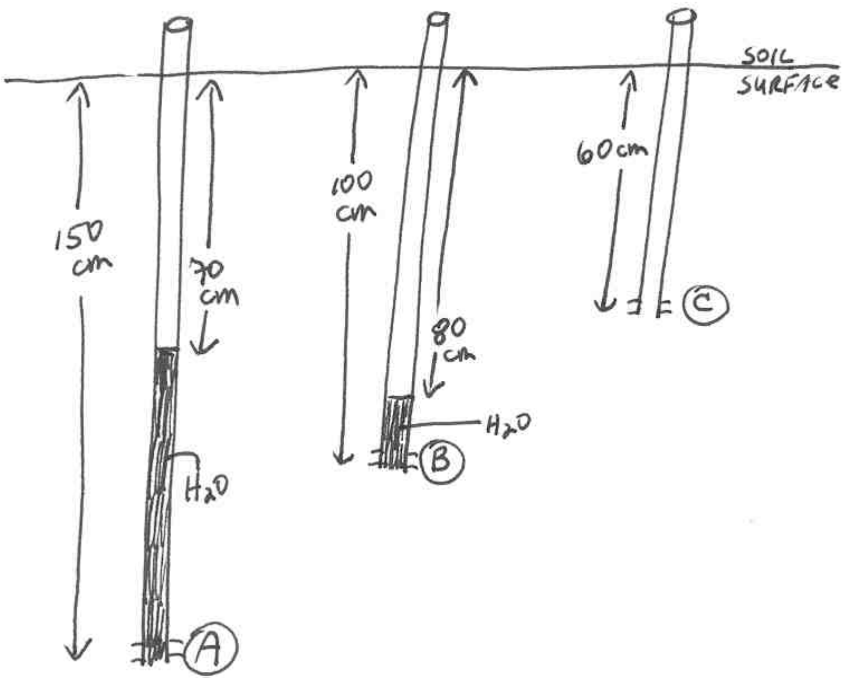
(8) 21. A mercury tensiometer is installed in the soil as shown. Calculate the pressure head, gravitational head, and total hydraulic head of the soil at point A, using the soil surface as the reference elevation. **SHOW ALL WORK AND UNITS!**



(8) 22. A nest of piezometers is installed as shown.

a) List the pressure head, gravitational head, and total hydraulic head of the soil at points A, B, and C, relative to the soil surface.

b) What is the best estimate of the water table depth in this profile, given the data?

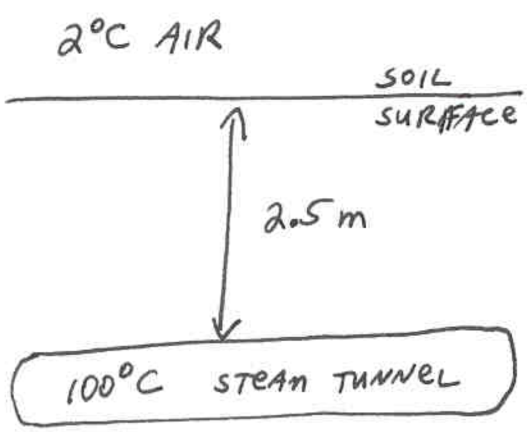


(8) 23. Steam tunnels conduct heat from a power plant to numerous classroom buildings on a renowned university campus. (Location of steam tunnels are noticeable as strips of melted snow across the lawns.) As a first estimate of the amount of heat lost from the top of these buried tunnels up through soil to the air above, let's assume steady-state
1-dimensional flow of heat through the soil and no movement of water or vapor. Calculate the heat loss per m^2 of tunnel roof area, assuming a constant air temperature of 2ºC, constant tunnel roof temperature of 100ºC, tunnel roof depth of 2.5 m, and soil thermal conductivity of $4 x 10^{-3}$ cal/cm secºC. SHOW ALL WORK AND UNITS! **Your final answer should be expressed in units of** $\frac{\text{cal}}{\text{m}^2\text{day}}$ **and be expressed in scientific notation!**

INFORMATION YOU MAY OR MAY NOT NEED:

Heat flow equation $q_H = -K \frac{\Delta T}{\Delta Z}$

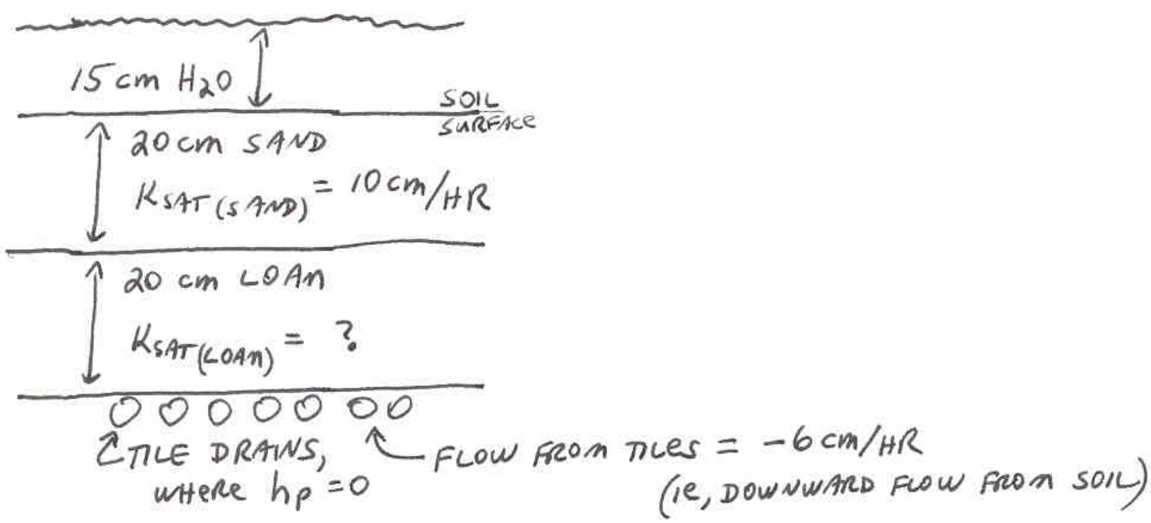
Soil thermal conductivity = $4x10^{-3}$ cal/cm secºC
Soil organic matter content = 2.5%
Soil bulk density = 1.25 g/cm^3



(10) 24. An athletic field has 20 cm of sand overlying 20 cm of loam. You know the saturated hydraulic conductivity of the sand but want to also determine the saturated conductivity of the loam. Your thorough knowledge of soil physics gives you the idea that you can easily calculate the conductivity of the loam, if you simply measure the water flux out the bottom of the soil into the tile drains. You pond 15 cm of water on top of the soil profile, and measure a study-state flux of -6 cm/hr (ie, downward flow). **Calculate the saturated hydraulic conductivity of the loam.** (Hint: several steps will be needed. SHOW ALL WORK AND UNITS, and partial credit will be given if you outline your approach so I can follow it.)

Darcy's Law $q = -K\frac{\Delta H}{\Delta L}$ or $Q = -KA\frac{\Delta H}{\Delta L}$

$$K_{EFFECTIVE} = \frac{L_{TOTAL}}{\frac{L_1}{K_1} + \frac{L_2}{K_2}}$$



(10) 25. Mean annual temperature at the soil surface in east central Indiana is about 10^oC. Soil temperature variation at the surface (z = 0) during the year is predicted by this equation:

$$T_o = T_{ave} + A_o \sin(\omega t) \quad = 10^oC + 14^o C \sin \; (\omega t)$$

Plot the predicted temperature wave for a year at the surface and at a depth of 150 cm.
Equations and information that may be useful follow. **Show all calculations on this sheet. Plot both curves on the graph paper on next page**.

Thermal diffusivity = $D_H = 1.095 \times 10^5 \ cm^2/yr$

d = damping depth = $\sqrt{\dfrac{D_H \tau}{\pi}}$

τ is time period, in this case 1 year

$A_z = A_o e^{-z/d}$

$\omega = 2\pi/\tau$

timelag = $\Delta t \;=\; z/\omega d$

z is soil depth of interest