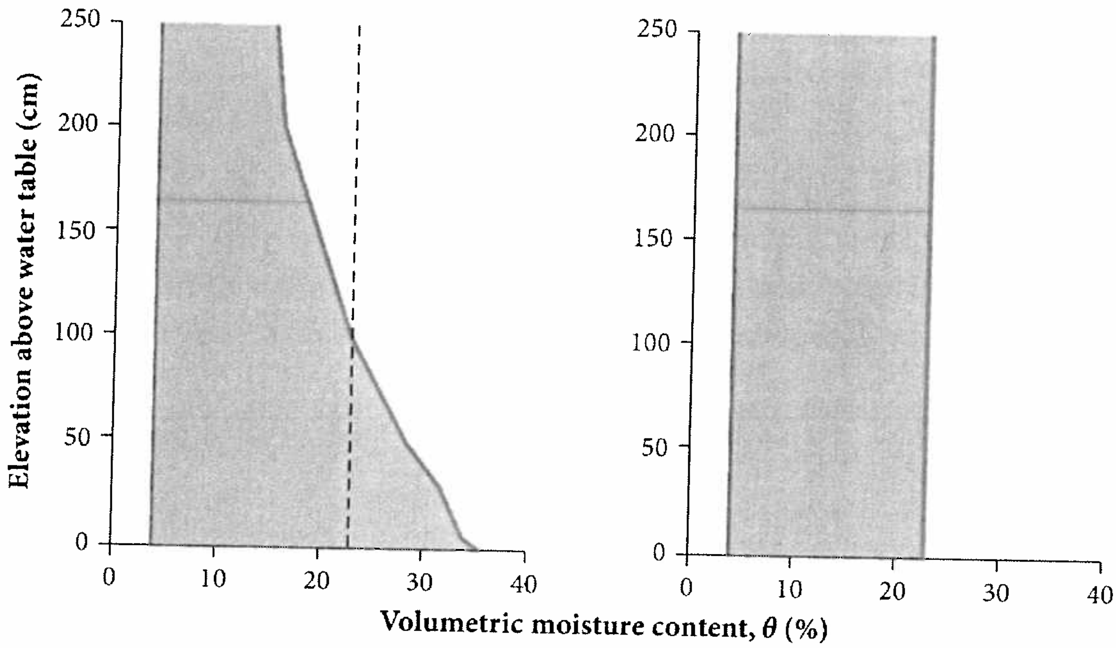
Final Exam GEO4-4417 Unsaturated Zone Hydrology (Feb. 3 2011)

Present arguments with all your answers!
Total number of credits to be earned: 65 (= 10 judicial points).
Total time: 2.5 hours

Question 1 (5 credits: a: 1; b: 1; c:2; d:1)

a. Explain the method of Wind to estimate the relation between unsaturated conductivity and soil moisture.
b. What is the advantage of using TDR compared to FDR to measure soil moisture content? What is the disadvantage?
c. Name two methods of soil moisture remote sensing including the basic principle behind the methods.
d. What are pedo-transfer functions?

Question 2 (5 credits)



(a) (b)

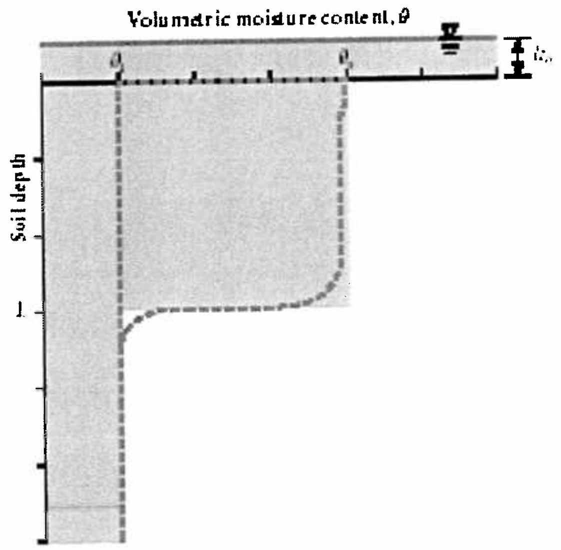
A physical model (a) and an approximation model (b) of the available soil water for plants with a water table at 2.5 m below the land surface – the approximation model uses $\theta_{pF=2.0} - \theta_{pF=4.2} = 23\% - 4\% = 19\% = 7.6$ cm water for a root depth of 40 cm

By stating the necessary adjustments to the above figures, clearly explain in what way (direction) the *pF*-value for field capacity should be changed to approximate the available soil water for plants for a situation with a deeper water table.

Question 3 (5 credits)

A natural soil pipe (formed by mole activity) is surrounded by a homogeneous soil matrix without cracks. Clearly explain the mechanism for this natural soil pipe to receive water from the surrounding matrix, for a changing moisture content of the matrix from dry to saturation.

Question 4 (15 credits: a 10; b: 5)

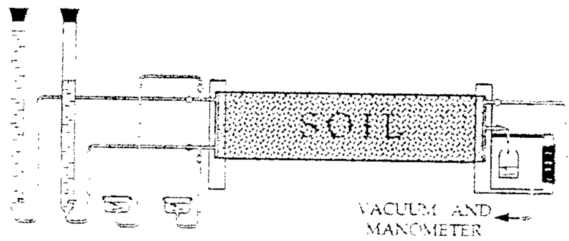


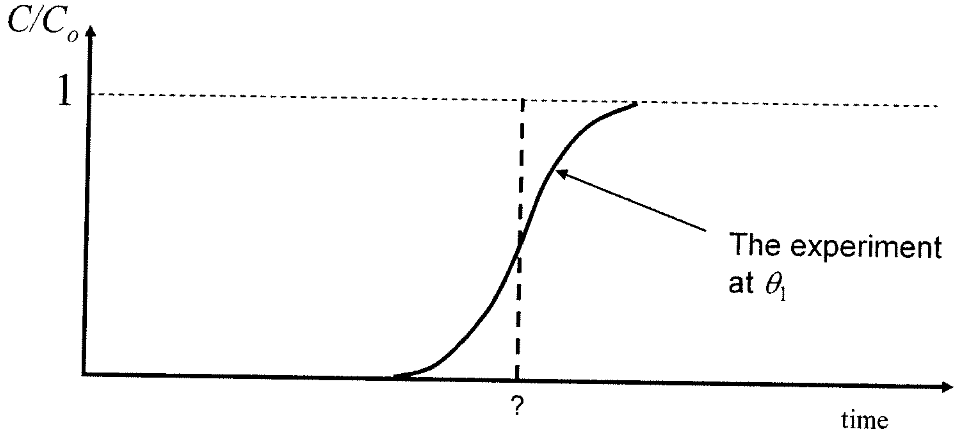
The water level above flat terrain during an experiment with a double ring infiltrometer is 20 mm. The saturated hydraulic conductivity K of the soil is 20 mm hour^{-1}. The matric potential at the wetting front equals –60 mm. The initial moisture content θ_i is 20% and the effective porosity n_e equals 45%. Infiltration is (simplified as) block-shaped: see the above figure (Green and Ampt's approach).

a. Apply Bernoulli's law and Darcy's law (Green and Ampt's approach) to determine the infiltration rate (mm hour^{-1}) and the cumulative infiltration (mm) when the wetting front is 20, 40, 80, 160, 320, 640 and 1280 mm below the soil surface; the **cumulative infiltration** (mm) is the total volume of water (mm^3) added to the soil by infiltration per square unit of land surface (mm^2).
b. Clearly explain why the infiltration rate diminishes with time.

$$q = -20 \; \frac{-60-20-20}{-20} =$$

Question 5 (10 credits: a: 5; b: 5)





From a breakthrough experiment in a horizontal column of length L the breakthrough curve is recorded. The experiment is performed at soil moisture content θ_1 and a constant water flux density q. At t= 0 a sodium chloride solution (NaCl) is added to the water and the breakthrough curve of the chloride ions Cl^- is recorded (see the figure above).

a. Give the equation for the average time of breakthrough (denoted by the dotted vertical line).

b. The water flux density q is such that the Peclet number Pe=30. The experiment is repeated with the same water flux density, but now at lower soil moisture content $\theta_2 < \theta_1$. Draw the breakthrough curve of this experiment together with the one from the first experiment. Explain its form both in terms of average time of breakthrough as well as in terms of the variance of breakthrough times.

Question 6 (15 credits: a: 4; b: 3; c 3; d: 5)

A small container is partially filled with water to a depth of 10 cm. We stick a long glass capillary tube, with a radius of 0.1 mm, into the water.

a. How far will the water rise in the capillary? You need to calculate the height of air-water meniscus in the capillary tube with respect to the bottom of the container. Neglect the change in the volume of water in the container as a result of rise of water in the capillary. See below for values of some quantities.
b. What happens to the meniscus, if we now slowly pour 10 cm more water into the **container** (Note: not into the tube)? Give the new position of the air-water meniscus in the tube with respect to the bottom of the container.
c. What happens if, ***instead of additional water***, we slowly pour 10 cm of benzene on top of the water in the container? Calculate the new position of the air-water meniscus in the tube with respect to the bottom of the container. Note that benzene does not enter the tube.
d. After the step in part (c), i.e. with benzene on top of water in the container, we now slowly pour 10 cm of benzene into the capillary tube. Now, give the position of the air-benzene meniscus in the tube with respect to the bottom of the container. (See fig. below)

The relationship between the height h (in m) of a fluid in a glass capillary with radius r (in m), interfacial tension and fluid/air/glass contact angle is given by:

$$h = \frac{2\sigma}{r\rho g}\cos\theta$$

Air-water interfacial tension $\sigma_{aw} = 0.072\ kg/s^2$
Air-benzene interfacial tension $\sigma_{ba} = 0.030\ kg/s^2$
Water-benzene interfacial tension $\sigma_{wb} = 0.035\ kg/s^2$
Air-water-glass contact angle $\theta_{awg} = 0$
Air-benzene-glass contact angle $\theta_{bag} = 30$ (cos 30= 0.866)
Water-benzene-glass contact angle $\theta_{wbg} = 15$ (cos 15= 0.966)
Water mass density $\rho_w = 1000$ kg/m^3
Benzene mass density $\rho_b = 900$ kg/m^3
Gravity acceleration g =10 m/s^2