National Exams May 2011

04-Geol-A2, Hydrogeology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.
6. Assume water density = 1,000 kg/m^3, water viscosity = 0.001 kg/m-sec, g = 9.81 m/s^2.

Marking Scheme

1. (a) 8 mks, (b) 7 mks, (c) 5 mks
2. (a) 10 mks, (b) 10 mks
3. (a) 8 mks, (b) 4 mks, (c) 4 mks, d) 4 mks
4. (a) 8 mks, (b) 6 mks, (c) 4 mks, (d) 2 mks
5. (a) 4 mks, (b) 4 mks, (c) 4 mks, (d) 4 mks, (e) 4 mks
6. (a) 8 mks, (b) 6 mks, (c) 6 mks
7. (a) 6 mks, (b) 14 mks

1.

a) An aquitard consists of a 50 cm thick layer of silty clay ($k = 1 \times 10^{-15}\ m^2$) above a 150 cm thick layer of clay ($k = 8 \times 10^{-17}\ m^2$).The water pressure head at the top of the aquitard is 122 m, and at the bottom of the aquitard the water pressure head is 124.5 m. Both soil layers have a porosity of 0.38. Determine the Darcy velocity (direction and magnitude) across the aquitard, the linear porewater velocity, and the water pressure head at the interface between the silty clay layer and the clay layer.

b) A confined aquifer consists of a 25 m thick layer of coarse sand ($K = 2 \times 10^{-2}$ cm/sec) above a 35 m thick layer of fine sand ($K = 3.\ 10^{-3}$ cm/sec). A well of 20 cm diameter is pumping water from the entire depth of the aquifer and aquifer conditions are at steady state. Determine the drawdown at the well if the pumping rate is 12 L/min and the aquifer is bounded by constant head boundaries in all directions at a radial distance of 100 m from the well.

c) An unconfined aquifer has an initial undisturbed thickness of 50 m. The aquifer is pumped at 10 L/min until steady state water levels are reached. If the drawdowns are 5 m at a distance of 3 m from the pumping well, and 1 m at a distance of 20 m from the well, what is the hydraulic conductivity of the aquifer?

2.

a) A fresh water (water density = 1000 kg/m^3) aquifer is separated from an underlying saline (density of 1150 kg/m^3) aquifer by a 40 m thick aquitard ($K = 2.\ X\ 10^{-7}$cm/s). A well screened at the top of the aquitard in the fresh water aquifer contains 10 m of fresh water above the top of the aquitard. A well screened at the bottom of the aquitard in the saline aquifer contains 50 m of saline water measured from the bottom of the aquitard. Determine the magnitude and direction of water flow across the aquitard if i) the density of the saline aquifer water was assumed to be 1000 kg/m^3, ii) if the true density of the saline aquifer water was used

b) At a desert site the water table is 250 m below the ground surface. If there is no vertical air flow, and the subsurface temperature is 15 C, determine the air pressure at the water table if i) the air is incompressible, ii) the air is compressible. The molecular weight of air is approximately 29 g/mol.

3. A 600 m wide unconfined aquifer has a hydraulic conductivity of 1.5×10^{-5} m/sec, and the bottom of the aquifer is 55 m below the ground surface. The water level in well A in the aquifer is 43 m from the bottom of the aquifer. In a second well (B) located 120 m away from well A in the direction of groundwater flow the water level is 32 m from the aquifer bottom.
   a) Determine the total flow through the aquifer, assuming that aquifer recharge is negligible.
   b) Determine the head at a point 80 m from Well A and 40 m from Well B, assuming that aquifer recharge is negligible.
   c) Determine the Darcy velocity in the aquifer at the point 80 m from Well A and 40 m from Well B, assuming that aquifer recharge is negligible.
   d) If the vertical recharge to the aquifer increases to 0.15 m/year, but all other conditions are unchanged calculate the water level 80 m from well A and 40 m from Well B

4. A 50 m thick aquifer has a hydraulic conductivity of 2×10^{-3} cm/sec and a specific storage of 2×10^{-5} m^{-1}. A pumping well is installed in the aquifer, followed by installation of a monitoring well 100 m due north of the pumping well. Determine the drawdown at the observation well after 24 hours if the well is pumped continuously at 10 L/sec for this 24 hours for the following conditions:
   a) The aquifer is bounded by a constant head boundary that is 100 m due east of the pumping and observation wells.
   b) The aquifer is infinite in extent, and bounded above by a 10 m thick aquitard with $K = 1 \times 10^{-7}$ cm/sec (negligible storage).
   c) Explain what assumptions are involved in the solution method used in (b).
   d) Explain what the impact of aquitard storage would be on the drawdown in (b).

5.
   a) Define specific yield and specific storage.
   b) A confined aquifer is 50 m thick and has a specific storage of 1.0×10^{-5} m^{-1}. Pumping a well for 24 hours lowered the piezometric surface by an average of 2.5 m over a circular area of radius 100 m. How much water was pumped from the aquifer during this time period?
   c) In the aquifer in (b) it was determined that the transmissivity of the aquifer was 1.0×10^{-5} m^2/sec. What are the hydraulic conductivity and intrinsic permeability of the aquifer?
   d) A fracture has an aperture of 25 microns. What is the hydraulic conductivity of the fracture?
   e) A soil sample has a bulk density of 1.8 g/cm^3, and a particle density of 2.5 g/cm^3. Determine the porosity of the sample.

6. A 40 m thick aquifer has a hydraulic conductivity of 1.2×10^{-3} cm/sec and a specific storage of 2×10^{-5} m^{-1}. In a pump test water is removed from the aquifer at a rate of 1.0 m^3/min for a period of 24 hours. The well is then turned off for 24 hours and subsequently pumped for a further 24 hours at 1.5 m^3/min.
   a) Determine the drawdown after 24 hours at an observation well that is 100 m from the pumping well if the aquifer is fully confined.
   b) Determine the drawdown after 48 hours at an observation well that is 100 m from the pumping well if the aquifer is fully confined.
   c) Determine the drawdown after 72 hours at an observation well that is 100 m from the pumping well if the aquifer is fully confined.

7.
a) Discuss the methods that may be used to determine aquifer properties, clearly identifying which properties may be determined by each method, and distinguishing the differences between the methods with respect to the parameters measured.
b) Describe three methods for geophysical well logging, including a description of the underlying principles of operation of the method, the information provided by each method, and the advantages and disadvantages of each method.

Table 5.1

Values of $W(u)$ for values of u (from Wenzel, 1942)

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$\times 1$	0.219	0.049	0.013	0.0038	0.0011	0.00036	0.00012	0.000038	0.000012
$\times 10^{-1}$	1.82	1.22	0.91	0.70	0.56	0.45	0.37	0.31	0.26
$\times 10^{-2}$	4.04	3.35	2.96	2.68	2.47	2.30	2.15	2.03	1.92
$\times 10^{-3}$	6.33	5.64	5.23	4.95	4.73	4.54	4.39	4.26	4.14
$\times 10^{-4}$	8.63	7.94	7.53	7.25	7.02	6.84	6.69	6.55	6.44
$\times 10^{-5}$	10.94	10.24	9.84	9.55	9.33	9.14	8.99	8.86	8.74
$\times 10^{-6}$	13.24	12.55	12.14	11.85	11.63	11.45	11.29	11.16	11.04
$\times 10^{-7}$	15.54	14.85	14.44	14.15	13.93	13.75	13.60	13.46	13.34
$\times 10^{-8}$	17.84	17.15	16.74	16.46	16.23	16.05	15.90	15.76	15.65
$\times 10^{-9}$	20.15	19.45	19.05	18.76	18.54	18.35	18.20	18.07	17.95
$\times 10^{-10}$	22.45	21.76	21.35	21.06	20.84	20.66	20.50	20.37	20.25
$\times 10^{-11}$	24.75	24.06	23.65	23.36	23.14	22.96	22.81	22.67	22.55
$\times 10^{-12}$	27.05	26.36	25.96	25.67	25.44	25.26	25.11	24.97	24.86
$\times 10^{-13}$	29.36	28.66	28.26	27.97	27.75	27.56	27.41	27.28	27.16
$\times 10^{-14}$	31.66	30.97	30.56	30.27	30.05	29.87	29.71	29.58	29.46
$\times 10^{-15}$	33.96	33.27	32.86	32.58	32.35	32.17	32.02	31.88	31.76

Table 5.2
Values of $W(u\ r/B)$ (after Hantush, 1956)*

u \ r/B	0.01	0.015	0.03	0.05	0.075	0.10	0.15	0.2	0.3	0.4
0.000001										
0.000005	9.4413									
0.00001	9.4176	8.6313								
0.00005	8.8827	8.4533	7.2450							
0.0001	8.3983	8.1414	7.2122	6.2282	5.4228					
0.0005	6.9750	6.9152	6.6219	6.0821	5.4062	4.8530				
0.001	6.3069	6.2765	6.1202	5.7965	5.3078	4.8292	4.0595	3.5054		
0.005	4.7212	4.7152	4.6829	4.6084	4.4713	4.2960	3.8821	3.4567	2.7428	2.2290
0.01	4.0356	4.0326	4.0167	3.9795	3.9091	3.8150	3.5725	3.2875	2.7104	2.2253
0.05	2.4675	2.4670	2.4642	2.4576	2.4448	2.4271	2.3776	2.3110	1.9283	1.7075
0.1	1.8227	1.8225	1.8213	1.8184	1.8128	1.8050	1.7829	1.7527	1.6704	1.5644
0.5	0.5598	0.5597	0.5596	0.5594	0.5588	0.5581	0.5561	0.5532	0.5453	0.5344
1.0	0.2194	0.2194	0.2193	0.2193	0.2191	0.2190	0.2186	0.2179	0.2161	0.2135
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011

u \ r/B	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5
0.000001									
0.000005									
0.00001									
0.00005									
0.0001									
0.0005									
0.001									
0.005									
0.01	1.8486	1.5550	1.3210	1.1307					
0.05	1.4927	1.2955	1.2955	1.1210	0.9700	0.8409			
0.1	1.4422	1.3115	1.1791	1.0505	0.9297	0.8190	0.4271	0.2278	
0.5	0.5206	0.5044	0.4860	0.4658	0.4440	0.4210	0.3007	0.1944	0.1174
1.0	0.2103	0.2065	0.2020	0.1970	0.1914	0.1855	0.1509	0.1139	0.0803
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0009

*Trans. Amer. Geophys. Union, 37, p. 702–714.