National Exams December 2008

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. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.
5. 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) 5 mks, (b) 5 mks, (c) 5 mks, (d) 5 mks
2. (a) 5 mks, (b) 5 mks, (c) 5 mks, (d) 5 mks
3. (a) 10 mks, (b) 10 mks,
4. (a) 6 mks, (b) 7 mks, (c) 7 mks
5. (a) 14 mks, (b) 6 mks
6. (a) 7 mks, (b) 7 mks, (c) 6 mks

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1. a) A core sample of sand (6 cm diameter, 10 cm length) has a mass of 500g when completely water saturated. After oven drying, the sample has a mass of 450 g. Determine the bulk density, void ratio, water content (gravimetric and volumetric), porosity, and saturation percentage of the core sample. Assume the sand is primarily quartz with a solid density of 2.65 g/cm^3.

   b) The specific storage of a 50 m thick confined aquifer is 2×10^{-5} m^{-1}. If the piezometric surface of the aquifer was lowered by 2 m over an area of 1 km^2, how much water would be produced?

   c) How much water would be produced from an unconfined aquifer an area of 1 km^2 if the specific yield of the aquifer was 0.25?

   d) A confined aquifer has a porosity of 0.3 and a specific storage of 3×10^{-3} m^{-1}. If the compressibility of water is 4.6×10^{-10} m^2/N what is the compressibility of the aquifer skeleton?

2. A subsurface system has three layers. The top layer is 25 m thick with a permeability of 3.2×10^{-11} m^2, the middle layer is 18 m thick with a permeability of 4.3×10^{-12} m^2 and the bottom layer is 40 m thick with a permeability of 2×10^{-13} m^2.

   a) Determine the average (effective) vertical and horizontal hydraulic conductivities of the entire system.

   b) Determine the vertical Darcy velocity through the entire system if the pressure head at the top of the system is 25 m of water, and the pressure head at the bottom of the aquifer is 85 m water.

   c) Determine the hydraulic heads at the interfaces between the layers under the conditions described in (b).

   d) If flow in the system was horizontal and pressure heads were 80 m water and 78.5 m water at points that were 250 m apart in the north-south direction, determine the volumetric flow rate through the system if it was 500 m in extent in the east-west direction.

3. a) You have been asked to design an investigative study to evaluate the potential of an aquifer to supply water for a new subdivision. Outline the steps that you would include in this study, including discussion of any techniques you would use in the investigation, any aquifer properties you would determine, and equipment needed.

   b) Outline the steps you would take in planning a dewatering operation, including a discussion of any analysis techniques you would use, and any equipment required.

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4. A water supply well pumped water from a 100 m thick confined aquifer at a rate of 25 L/s. The aquifer had a specific storativity of 10^{-6} m^{-1} and a hydraulic conductivity of 10^{-3} cm/sec. The aquitard thickness above the aquifer was 8 m.

a) Determine the drawdown at an observation well 150 m from the pumping well after 24 hours of pumping if the aquifer was infinite in areal extent and the aquitard was impermeable.

b) Determine the drawdown at an observation well 150 m north of the pumping well after 24 hours of pumping if the aquifer was bounded by a constant recharge boundary that ran in a north-south direction and was 150 m due east of the pumping and observation wells (the aquitard was impermeable)

c) Determine the drawdown at an observation well 150 m from the pumping well in (a) after 24 hours if the aquifer was infinite in areal extent and the aquitard had a hydraulic conductivity of 10^{-6} cm/sec. List any assumptions involved in your solution.

5.a) A pump test is conducted in an aquifer that is characterized as fully confined. The well pumps at a rate of 5 l/sec for 12 hours, and then pumps at a rate of 10 l/sec for a further 12 hours and is then shut off completely. Determine the drawdown in the aquifer at a point 150 m from the pumping well at 12 hours, 24 hours, and 36 hours after the start of the pump test. The aquifer is 50 m thick, has a hydraulic conductivity of 10^{-3} cm/sec and a specific storativity of 1.0×10^{-5} m^{-1}.

b) Draw a qualitatively correct sketch of the logarithm of drawdown versus logarithm of time for the conditions in (a) and explain what principle you used in your solution in (a).

6. a) Two wells in an unconfined aquifer are at distances of 25 and 50 m from a pumping well. The steady state water level in the observation well 25 m from the pumping well is 250 m.a.s.l. and the water level in the second well is 255 m.a.s.l. If the pumping well withdraws 5 l/sec from the aquifer determine the hydraulic conductivity of the unconfined aquifer if the base of the aquifer is 200 m.a.s.l.

b) A fresh water (water density = 1000 kg/m^3) aquifer is separated from an underlying saline (density of 1120 kg/m^3) aquifer by a 20 m thick aquitard. A well screened at the top of the aquitard in the fresh water aquifer contains 10 m of fresh water. A well screened at the bottom of the aquitard in the saline aquifer contains 30 m of saline water. Determine the 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.

c) A slug test is performed in a confined aquifer in a well that has a casing radius of 5 cm, screened section radius of 8 cm, and a screened section length of 3 m. At the beginning of the slug test the water level in the well is 0.5 m above the original level. After 3 seconds the water level in the well is 0.185 m above the original level. Determine the hydraulic conductivity of the aquifer.

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

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