National Exams - December 2018

18-Geol-A2, Hydrogeology

Duration: 3 hours

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.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important. Please show your work.

6. Unless otherwise specified, use water density = 1000 kg/m^3, water viscosity = 0.001 kg/m-sec, and g = 9.81 m/s^2.

Marking Scheme:

1.	(a) 6 marks;	(b) 8 marks;	(c) 6 marks
2.	(a) 6 marks;	(b) 6 marks;	(c) 8 marks
3.	(a) 6 marks;	(b) 8 marks;	(c) 6 marks
4.	(a) 9 marks;	(b) 7 marks;	(c) 4 marks
5.	(a) 4 marks;	(b) 8 marks;	(c) 8 marks

Question 1

a) A core sample of sand (5.5 cm diameter, 10 cm length) has a mass of 510g when completely water saturated. After oven drying the sample has a mass of 460 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/cm3. **(6 marks)**

b) The soil in an aquifer system is determined to have a horizontal hydraulic conductivity tensor with $K_{xx}= 10^{-3}$ cm/sec, $K_{xy}= 5.0 \times 10^{-4}$ cm/sec, and $K_{yy}= 10^{-4}$ cm/sec. If the aquifer has dh/dx = 0.01, and dh/dy = -0.005, determine the Darcy velocities in the x and y directions in the aquifer and the overall magnitude and direction (show a sketch with angle identified in degrees) of the Darcy velocity vector. **(8 marks)**

c) A falling-head permeameter has a falling-head tube diameter of 1.8 cm, a sample tube diameter of 12.5 cm, and flow length of 15 cm. The initial head is 6.0 cm and it falls to 0.50 cm over a period of 550 minutes. If the test is conducted at 25 °C for the entire duration of the test, determine the hydraulic conductivity and intrinsic permeability of the soil. **(6 marks)**

Question 2

a) 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 20 m thick with a permeability of 4.3×10^{-12} m^2 and the bottom layer is 35 m thick with a permeability of 2×10^{-13} m^2. Determine the average (effective) vertical and horizontal hydraulic conductivities of the entire system. **(6 marks)**

b) Determine the vertical Darcy velocity through the entire system in **Question 2 (a)** if the pressure head at the top of the system is 20 m of water, and the pressure head at the bottom of the aquifer is 90 m of water. **(6 marks)**

c) Two piezometers were installed in the confined aquifer (in Question 2a) at locations 200 m apart. It was determined that flow in the aquifer was horizontal in all three layers, and the water levels in the two piezometers were 260 and 245 m. Determine the volumetric flow rate through the entire aquifer if it was 200 m in extent in the direction perpendicular to the groundwater flow direction. **(8 marks)**

Question 3

a) A water supply well pumped water from a 100 m thick confined aquifer at a rate of 24 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 9 m. 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). **(6 marks)**

b) Determine the drawdown at an observation well 150 m from the pumping well in **Question 3 (a)** if the if the aquifer was infinite in areal extent and the aquitard had a hydraulic conductivity of 10^{-6} cm/sec. You may assume negligible aquitard storage effects. What would be the effect on drawdown if the aquitard had significant storage?
(8 marks)

c) What are the advantages and disadvantages of using geophysics, remote sensing, and borehole investigations for groundwater exploration? List two advantages and two disadvantages for each method. **(6 marks)**

Question 4

a) A pump test is conducted in an aquifer that is characterized as fully confined. The well pumps at a rate of 8 L/sec for 12 hours, and then pumps at a rate of 5 L/sec for an additional 12 hours and is then shut off completely. Determine the drawdown in the aquifer at a point 100 m from the pumping well 36 hours after the start of the pump test. The aquifer is 40 m thick, has a hydraulic conductivity of 1.3×10^{-3} cm/sec and a specific storativity of 1.2×10^{-5} m^{-1}. **(9 marks)**

b) Two wells are drilled in a 2400 m wide unconfined aquifer that has a hydraulic conductivity of 3×10^{-3} cm/sec, 150 m apart, one directly downstream from the other. The bottom of the aquifer is 30 m below the ground surface. The water level is 8 m below the ground surface at one well, and 11 m below the ground surface at the second well. The aquifer porosity is 0.33. Aquifer recharge is negligible. (i) Determine the total flow through the aquifer; (ii) Determine the head at a point halfway between the wells; and (iii) Determine the pore water (linear) velocity at the halfway point? **(7 marks)**

c) If the vertical recharge to the aquifer in **Question 4 (a)** is 0.25 m/year and all other conditions are unchanged determine the head at a point halfway between the wells. **(4 marks)**

Question 5

a) Discuss the advantages and disadvantages of slug tests compared to pump tests. List two advantages and two disadvantages. **(4 marks)**

b) A slug test was carried out in an unconfined aquifer using a well with a casing radius of 7.5 cm, a screened section radius (including gravel pack) of 10 cm, and a screened section length of 2 m. At the beginning of the slug test the water level in the well was 0.7 m above the original water level in the well. After 15 seconds the water level in the well was 0.05 m above the original water level. Determine the aquifer hydraulic conductivity if the radius of influence of the well was 85 m. **(8 marks)**

c) A slug test was conducted in a confined aquifer in a well with a casing radius of 5 cm, and a screened section radius of 5 cm. Using the Cooper-Bredehoeft-Papadopolous curve matching method to determine aquifer storativity and transmissivity the match point was $t_1 = 15$ seconds (for $Tt/rc^2 = 1$) and the best match was to the curve for $\log \mu = -4$. Determine the storativity and transmissivity of the aquifer. **(8 marks)**

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.