

## National Exams December 2015

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.
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 =  $1000 \text{ kg/m}^3$ , water viscosity =  $0.001 \text{ kg/m-sec}$ , and  $g = 9.81 \text{ m/s}^2$ .

### Marking Scheme

1. (a) 5 marks (b) 2 marks (c) 3 marks (d) 2 marks (e) 5 marks (f) 3 marks
2. (a) 10 marks (b) 10 marks
3. (a) 5 marks (b) 5 marks (c) 5 marks (d) 5 marks
4. (a) 8 marks (b) 8 marks (c) 4 marks
5. (a) 10 marks (b) 10 marks

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## Question 1

- a) Answer **True** or **False** to the following questions. Please note for a statement to be true it must ALWAYS be true!
- I. \_\_\_ An aquitard is a high permeability layer, usually separating aquifers.
  - II. \_\_\_ Evaporation is part of the hydrologic cycle
  - III. \_\_\_ Hydraulic conductivity is a function of soil only
  - IV. \_\_\_ A groundwater divide is a streamline
  - V. \_\_\_ Slug tests require a pumping well and an observation well
- b) A soil has a bulk density of  $1.96 \text{ g/cm}^3$  and a porosity of 0.35. Determine the soil solid particle density.
- c) An unconfined aquifer has a specific yield of 0.07 and is rectangular in shape with a width of 900 m and a length of 2200 m. What volume of water would be released  $\square$  from the aquifer if the water table was lowered by 1.2 m?
- d) A fully confined aquifer has a specific storativity of  $1.1 \times 10^{-6} \text{ m}^{-1}$ , a thickness of 50 m a width of 1500 m and a length of 2500 m. What volume of water would be pumped to  $\square$  lower the piezometric head in the aquifer by 2.5 m.  $\square$
- e) Three wells (A, B, and C) are drilled in an aquifer. Well B is 250m directly north of Well  $\square$ A. Well C is 250 m directly east of Well A. The water level in Well A is 180 m.a.s.l., in Well B it is 195 m.a.s.l. In Well C the water level is 180 m.a.s.l. Estimate the magnitude and direction of the hydraulic head in the aquifer. Include a sketch showing the basis for your calculations.  $\square\square$
- f) The water pressure head at the top of a 10 m thick aquitard is 162 m. The water pressure head at the bottom of the aquitard is 175 m. Determine the hydraulic head gradient and the direction of water flow across the aquitard.

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**Question 2**

- a) An aquitard consists of two layers of soil, each 5 m thick. If the water pressure at the top of the aquitard is 105 kPa, and the water pressure at the bottom of the aquitard is 210 kPa, determine the magnitude and direction of the Darcy velocity across the aquitard if the aquitard contains water with a density of  $1000 \text{ kg/m}^3$  and a viscosity of  $0.001 \text{ kg/m}\cdot\text{sec}$ . The top soil layer has a hydraulic conductivity of  $10^{-8} \text{ cm/sec}$  and the lower soil layer has a hydraulic conductivity of  $10^{-6} \text{ cm/sec}$ . □
- b) Repeat part a) if the aquitard contained briny water with a density of  $1150 \text{ kg/m}^3$  and a viscosity of  $0.001 \text{ kg/m}\cdot\text{sec}$ .

**Question 3**

Two wells are drilled in a 2500 m wide unconfined aquifer that has a hydraulic conductivity of  $3 \times 10^{-3} \text{ cm/sec}$ , 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 10 m below the ground surface at the second well. The aquifer porosity is 0.33. Aquifer recharge is negligible.

- a) Determine the total flow through the aquifer.
- b) Determine the head at a point halfway between the wells.
- c) Determine the pore water (linear) velocity at the halfway point. □
- d) If the vertical recharge to the aquifer is  $0.25 \text{ m/year}$  and all other conditions are unchanged determine the head at a point halfway between the wells.

**Question 4**

A well pumps water from a confined aquifer at a rate of  $15 \text{ l/s}$ . The aquifer has a transmissivity of  $10^{-2} \text{ m}^2/\text{s}$ , a storativity of  $10^{-4}$ , and a hydraulic conductivity of  $10^{-3} \text{ cm/sec}$ . The aquitard above the aquifer has a thickness of 5 m. □

- a) Determine the drawdown at an observation well 150 m from the pumping well after 24 hours of pumping if the aquitard was impermeable
- b) Determine the drawdown at an observation well 150 m from the pumping well if the aquitard had a hydraulic conductivity of  $10^{-6} \text{ cm/sec}$ . □
- c) If the aquitard storativity was significant would the drawdown be larger or smaller than the value you have calculated?

**04-Geol-A2, Hydrogeology****Question 5**

A fully penetrating well installed in a 30m thick fully confined aquifer with a specific storativity of  $2.3 \times 10^{-5}$  and a hydraulic conductivity of  $1.2 \times 10^{-5}$  m sec<sup>-1</sup>, is pumped at 50m<sup>3</sup>/hr for 24 hours. The pumping well is 200m west of a river that recharges the aquifer sufficiently to maintain a constant head in the aquifer below the river.

- a) Calculate the drawdown at an observation well located 60m directly south of the pumping well after 24 and 36 hours.
- b) If there was an impermeable boundary instead of the river, determine the drawdown in the aquifer at an observation well located 200 m south from the pumping well 36 hours after the start of the pump test.

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**Table 5.1**  
**Values of  $W(\mu)$  for values of  $\mu$  (from Wenzel, 1942)**

$\mu$	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. Copyright by Amer. Geophys. Union.