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M.E. WATER RESOURCES AND HYDRAULIC ENGG.
1st YEAR SECOND SEMESTER - 2024
Groundwater Dynamics
(Paper - II)

Time: Three hours

Full Marks: 100

Answers any five questions.
Each question carries 20 marks.

1.(a) Write down the limitations of Darcy's Law.

(b) How the intrinsic permeability is related to structure coefficient, porosity function and effective grain size? Derive it with dimensional analysis.

(c) Laboratory analyses of an aquifer material indicate a porosity of 0.40 and a grain-size distribution as follows:

Grain size (mm)	Percent finer (%)
4.760	96.0
2.000	80.0
0.840	52.0
0.420	38.0
0.250	25.0
0.149	12.0
0.074	5.0

Determine the hydraulic conductivity of the soil samples using two valid empirical formula and mention the reason why these two equations are valid for this particular sample.

3+7+10=20

2. (a) Deduce the 2D governing equation for unsteady, compressible, anisotropic, homogenous confined aquifer.

(b) A confined aquifer composed of a dense sandy-gravel matrix is 20 m thick and has a porosity of 0.3. If the compressibility coefficient of the aquifer material is estimated to be 8×10^{-9} m^2/N, estimate the storage coefficient of the aquifer. Compare your result to the estimate given by the Lohman (1979) equation.

$$S = 3 \times 10^{-6} b$$

where b is the aquifer thickness. Explain the reasons for any discrepancy. Assume that the temperature of the groundwater is 15°C. [Assume Bulk modulus of water is as 2×10^9 Pa]

10+10=20

[Turn over

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3. (a) Write down the Dupit-Forchheimer assumptions for unconfined aquifers. Derive the depth integrated governing equation of saturated unconfined aquifer.

(b) The steady-state head distribution in a large homogeneous isotropic aquifer caused by pumping at a rate Q from the location x_0', y_0', z_0' is given by:

$$\phi(x', y', z') = -\frac{Q}{4\pi} \frac{1}{\sqrt{(x' - x_0')^2 + (y' - y_0')^2 + (z' - z_0')^2}}$$

Determine the head distribution caused by pumping at a rate Q in a homogeneous anisotropic aquifer where $K_{xx} = 12$ *m/d*, $K_{yy} = 7$ *m/d, and* $K_{zz} = 3$ *m/d*

14+6=20

4. (a) What are the boundary conditions to get Theis solution from unsteady radial flow in confined aquifer?

(b) Write the expression of well function in terms of incomplete Gamma-Function and expand it in terms of infinite series.

(c) A homogeneous anisotropic confined aquifer is 25 m thick and has principal hydraulic conductivities of K_{xx} = 34 m/d and K_{yy} = 15 m/d. Determine the principal transmissivities and state the differential equation describing the piezometric head distribution in the absence of recharge. Would the governing equation be any different if the aquifer were 50-m thick, K_{xx} = 17 m/d, and K_{yy} = 7.5 m/d?

(d) Differentiate between perched aquifer and leaky aquifer with diagram.

4+6+6+4=20

5. (a) Briefly describe the approach and objective of groundwater modelling.

(b) An R.C network analog has to be constructed to simulate a confined aquifer of 40 km × 60 km with an average thickness of 30 m, permeability of 25 m/day, and storage coefficient 4×10^{-4} . The maximum head is 40 m. The model can be represented by 40 × 60 nodes. Resistor of 3000 Ω and capacitors of 0.01 μF are available; model voltage =8 V. Work out the scale factors. If a calibrating resistor of 2500 Ω is used for simulating pumping rate, determine the current pulse and excitation voltage to simulate a pumping rate 1000 m^3/day at a particular node.

6+14=20

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6. (a) Briefly describe the term "response of an unconfined aquifer to pumping."

(b) A test was conducted with an unconfined aquifer near Burdwan, Damodar River. The well was pumped at constant rate of 5887 m^3/day. The drawdown measured in an observation well 23 m away are listed in below table. Aquifer thickness is 24 m. Assuming fully penetrating well calculate the hydraulic parameters for the aquifer using Neuman's straight-line method.

Time (minute)	**S (m)**	**Time (minute)**	**S (m)**	**Time (minute)**	**S (m)**	**Time (minute)**	**S (m)**
1.01	0.04	2.77	0.26	20	0.32	700	0.61
1.1	0.06	2.89	0.27	25	0.33	800	0.64
1.2	0.08	2.98	0.27	30	0.34	900	0.66
1.28	0.10	3	0.28	35	0.35	1000	0.67
1.36	0.12	3.15	0.28	40	0.36	1200	0.69
1.44	0.13	3.28	0.28	50	0.36	1500	0.72
1.52	0.15	3.4	0.29	60	0.37	2000	0.76
1.6	0.16	3.5	0.29	70	0.38	2500	0.79
1.71	0.17	4	0.30	80	0.39	3000	0.81
1.75	0.19	4.5	0.30	90	0.39		
1.8	0.20	5	0.30	100	0.40		
1.85	0.20	6	0.30	120	0.41		
1.95	0.21	7	0.30	150	0.44		
1.98	0.22	8	0.31	200	0.46		
2	0.23	9	0.31	250	0.48		
2.1	0.23	10	0.31	300	0.50		
2.28	0.24	12	0.31	400	0.52		
2.42	0.25	15	0.32	500	0.56		
2.66	0.26	18	0.32	600	0.59		

3+17=20

7. (a) What do you mean by upconing? With the help of a schematic diagram, describe the equation of maximum discharge to prevent the phenomenon of upconing.

(b) A well pumps at 5 lps in a 30m thick coastal aquifer that has a hydraulic conductivity of 100 m/day. How close the saltwater wedge approach the well before the quality of the pumped water is affected?

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(c) The water levels in two monitoring wells far from the shoreline are 0.5m and 1m above sea level. The distance between the two wells is 1000 m. The hydraulic conductivity is 10 m/day. If the aquifer thickness is 50 m, calculate the length of the saltwater wedge and the interface between the freshwater and saltwater. In terms of the given data find out the equation describing the interface.

6+6+8=20

8. (a) Develop Cooper Jacob equation from Theis solution for transient flow in a fully penetrating confined aquifer. State the assumptions made.

(b) In a test of a confined aquifer the pumping rate was 500 m^3/day. Drawdown data (given below) were collected in an observation well, 300 m away. Using Cooper Jacob method, determine the hydraulic conductivity and storativity of the aquifer.

Drawdown measured at an observation well 300 m away

Time (min)	s (m)
1.0	0.3
4.2	0.41
8.5	0.8
13.7	1.11
17.4	1.27
22.1	1.44
28.1	1.61
35.6	1.79
57.4	2.15
92.4	2.52
148.7	2.89
239.5	3.26
385.7	3.64
621.0	4.02
1000.0	4.39

5+15=20

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9. (a) Why it is a good practice to measure residual drawdown for determining the parameters of aquifer?

(b) In an aquifer test, drawdowns are recorded in the observation well. In the table (given below), the first column is the time since the pumping started, the second column is the drawdown during the pumping period and the third column is the time since the pumping stopped. A constant pumping rate of 4.6 m3/min was maintained during the pumping part of the test (800 min). The observation well is 30.5 m away from the pumping well. Calculate the hydraulic parameters using the recovery data.

Table Aquifer test data in the observation well

t (min)	s (m)	t' (min)	s' (m)
5	0.024	5	0.54
10	0.067	10	0.5
15	0.101	15	0.47
20	0.124	20	0.44
25	0.1524	25	0.42
30	0.168	30	0.40
40	0.201	40	0.37
50	0.223	50	0.35
60	0.244	60	0.33
70	0.262	70	0.31
80	0.280	80	0.30
90	0.293	90	0.29
100	0.305	100	0.27
110	0.317	110	0.265
120	0.326	120	0.26
180	0.378	180	0.21
240	0.411	240	0.19
300	0.442	300	0.16
360	0.463	360	0.15
420	0.484	420	0.14
480	0.503	480	0.12
540	0.521	540	0.11
600	0.527	600	0.11
660	0.539	660	0.10
720	0.552	720	0.09
800	0.567	800	0.09

3+17=20