9 CHAPTER

# Groundwater

Q.1 A geological formation which is essentially impermeable for flow of water even though it may contain water in its pores is called
(a) aquifer (b) aquifuge
(c) aquitard (d) aquiclude

Q.2 An aquifer confined at the bottom but not at the top is called as
(a) semiconfined aquifer
(b) unconfined aquifer
(c) confined aquifer
(d) perched aquifer

Q.3 The surface joining the static water levels in several wells penetrating a confined aquifer represents
(a) water table surface
(b) capillary fringe
(c) piezometric surface of the aquifer
(d) cone of depression

Q.4 Flowing artesian wells are expected in areas where
(a) the water table is very close to the land surface
(b) the aquifer is condition
(c) the elevation of the piezometric head line is above the elevation of the ground surface
(d) the rainfall is intense

Q.5 Water present in artesian aquifers is usually
(a) at sub atmospheric pressure
(b) at atmospheric pressure
(c) at 0.5 times the atmospheric pressure
(d) above atmospheric pressure

Q.6 The volume of water that can be extracted by force of gravity from a unit volume of aquifer material is called
(a) specific retention
(b) specific yield
(c) specific storage
(d) specific capacity

Q.7 Which of the pair of terms used in groundwater hydrology are not synonymous?
(a) Permeability and hydraulic conductivity
(b) Storage coefficient and storativity
(c) Actual velocity of flow and discharge velocity
(d) Water table aquifer and unconfined aquifer

Q.8 The permeability of a soil sample at the standard temperature of 20°C was 0.01 cm/s. The permeability of the same material at a flow temperature of 10°C is in cm/s
(a) <0.01
(b) >0.01
(c) =0.01
(d) depends upon the porous material

Q.9 A soil has a coefficient of permeability of 0.51 cm/s. If the kinematic viscosity of water is 0.009 $cm^2/s$, the intrinsic permeability (in Darcys) is about
(a) $5.3 \times 10^4$ (b) 474
(c) $4.7 \times 10^7$ (d) 4000

Q.10 Darcy's law is valid in a porous media flow if the Reynold's number is less than unity. This Reynold's number is defined as
(a) (discharge velocity × maximum grain size)/μ
(b) (actual velocity × average grain size)/ν
(c) (discharge velocity × average grain size)/ν
(d) (discharge velocity × pore size)/ν

Q.11 Two observation wells penetrating into a confined aquifer are located 1.5 km apart in the direction of flow. Heads of 45 m and 20 m are indicated at these two observation wells. If the coefficient of permeability of the aquifer is 30 m/day and the porosity is 0.25, the time of travel of an inert tracer from one well to another is about
(a) 417 days (b) 500 days
(c) 750 days (d) 3000 days

Q.12 A sand sample was found to have a porosity of 40%. For an aquifer of this material, the specific yield is
(a) = 40%
(b) > 40%
(c) < 40%
(d) dependent on the clay fraction

Q.13 An unconfined aquifer of porosity 35%, permeability 35 m/day and specific yield of 0.15 has an area of 100 $km^2$. The water table falls by 0.20 m during a drought. The volume of water lost from storage in $Mm^3$ is
(a) 7.0 (b) 3.0
(c) 4.0 (d) 18.0

Q.14 The unit of intrinsic permeability is
(a) cm/day (b) m/day
(c) darcy/day (d) $cm^2$

Q.15 The dimensions of the storage coefficient $S$ are
(a) $L^3$ (b) $LT^{-1}$
(c) $L^3/T$ (d) dimensionless

Q.16 The dimensions of the coefficient of transmissibility $T$ are
(a) $L^2/T$ (b) $L^3T^2$
(c) $L/T^2$ (d) dimensionless

Q.17 The coefficient of permeability of a sample of aquifer material is found to be 5 m/day in a laboratory test conducted with water at 10°C. If the kinematic viscosity of water at various temperatures is as below:

| Temp. in °C | 10 | 20 | 30 |
|---|---|---|---|
| $\nu$ ($m^2/s$) | $1.30 \times 10^{6}$ | $1.00 \times 10^{6}$ | $0.80 \times 10^{4}$ |

the standard value of the coefficient of permeability of the material, in m/day, is about
(a) 4.0 (b) 5.0
(c) 6.5 (d) 9.0

Q.18 A stratified unconfined aquifer has three horizontal layers as given below:

| Layer | Coefficient of permeability (m/day) | Depth (m) |
|---|---|---|
| 1. | 6 | 2.0 |
| 2. | 16 | 4.0 |
| 3. | 24 | 3.0 |

The effective vertical coefficient of permeability of this aquifer, in m/day, is about
(a) 13 (b) 15
(c) 21 (d) 16

Q.19 An aquifer confined at top and bottom by impervious layers is stratified into three layers as follows:

| Layer | Thickness (m) | Permeability (m/day) |
|---|---|---|
| Top layer | 3.0 | 30 |
| Middle layer | 2.0 | 10 |
| Bottom layer | 5.0 | 20 |

The transmissibility of the aquifer in $m^2$/day is
(a) 6000 (b) 18.2
(c) 20 (d) 210

Q.20 The specific storage is
(a) storage coefficient/aquifer depth
(b) specific yield per unit area
(c) specific capacity per unit depth of aquifer
(d) porosity specific detention

Q.21 When there is an increase in the atmospheric pressure, the water level in a well penetrating a confined aquifer

(a) decreases
(b) increases
(c) does not undergo any change
(d) decreases or increase depending on the elevation of the ground

**Q.22** In one dimensional flow in an unconfined aquifer between two water bodies, when there is a recharge, the water table profile is
(a) a parabola (b) part of an ellipse
(c) a straight line (d) an arc of a circle

**Q.23** In one dimensional flow in a confined aquifer between two water bodies, the piezometric head line is
(a) a straight line (b) a part of an ellipse
(c) a parabola (d) an arc of a circle

**Q.24** For one dimensional flow without recharge in an unconfined aquifer between two water bodies, the steady water table profile is
(a) a straight line (b) a parabola
(c) an ellipse (d) an arc of a circle

**Q.25** The discharge per unit drawdown at a well is known as
(a) specific yield (b) specific storage
(c) safe yield (d) specific capacity

**Q.26** The specific capacity of a well in confined aquifer under equilibrium conditions and within the working limits of drawdown
(a) can be taken as constant
(b) decreases as the drawdown increases
(c) increases as the drawdown increases
(d) increases or decreases depending upon the size of the well

**Q.27** An artesian aquifer has thickness of 30 m and coefficient of permeability to be 35 m/day. The yield of aquifer for a drawdown of 3 m when the diameter of the well is 20 cm is: ($R$ = 300 m)
(a) 120.70 $m^3$/hr (b) 210.70 $m^3$/hr
(c) 102.70 $m^3$/hr (d) 110.70 $m^3$/hr

**Q.28** A well having size 7.70 m × 4.65 m in lateritic soil has its normal water level 5.08 below ground level. After pumping for 1.5 hours, the water level depressed to 5.93 m and pumping was stopped. The water level after 4 hours from time after pumping stopped is 5.68 m. The specific capacity of the well is:
(a) 1.58 $m^2$/hr (b) 3.58 $m^2$/hr
(c) 2.58 $m^2$/hr (d) None of the above

**Q.29** In a alluvial basin having area 100 $km^2$, 90 $Mm^3$ of ground water was pumped in a year and the ground water table during the year dropped by about 5 m. The specific retention is 120%. Assuming no replenishment, the porosity of the soil is:
(a) 20% (b) 25%
(c) 30% (d) 35%

**Q.30** The artesian aquifer has a thickness of 30 m and has a porosity of 25% and bulk modulus of compression 2000 kg/$cm^2$. The storage coefficient of the aquifer is:
($k_w$ = 2.4 × $10^4$ kg/$cm^2$)
(a) 2.34 × $10^{-3}$ (b) 1.74 × $10^{-3}$
(c) 1.54 × $10^{-3}$ (d) 2.74 × $10^{-3}$

**Q.31** After a long period of pumping from a 20 cm well which penetrates 30 m below static water level (GWT) at rate of 1800 lmp, the drawdowns in the observation wells at 12 m and 36 m from the pumped well are 1.2 m and 0.5 m, respectively. The transmissibility of the aquifer is:
(a) 581 $m^2$/day (b) 851 $m^2$/day
(c) 681 $m^2$/day (d) 861 $m^2$/day

**Q.32** During field test, a time of 6 hour was required for the tracer to travel between two observation wells 42 m apart. If the difference in water-table elevations in these wells were 0.85 m and the porosity of the aquifer is 20%, the coefficient of permeability of the aquifer is:
(a) 0.92 cm/sec (b) 2.29 cm/sec
(c) 1.92 cm/sec (d) 1.29 cm/sec

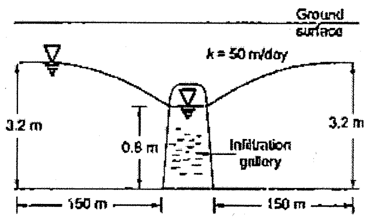
**Q.33** An aquifer is having groundwater flow in N30°$E$ direction. Three wells $A$, $B$ and $C$ are drilled to tap this aquifer. The well $B$ is east of $A$ and the well $C$ is to be North of $A$. The following are data regarding wells

| Distance | | $AB$ | $AC$ |
|---|---|---|---|
| Well | $A$ | $B$ | $C$ |
| Ground surface elevation (m above datum) | 160 | 159 | 158 |
| Water table elevation (m above datum) | 157.0 | 156.50 | ? |

An elevation of water table at well $C$ when wells are not pumping is
(a) 156.459 m (b) 172.680 m
(c) 186.269 m (d) 193.258 m

**Q.34** The thickness of confined horizontal aquifer is 15 m and permeability $k$ = 20 m/day connects two reservoirs $D$ & $E$ situated 1.5 km apart. The elevations of water surface in reservoir $D$ & $E$ measured from top of aquifer are 30.00 m and 10.00 m resp. If reservoir $D$ is polluted by contaminant suddenly, the time taken by pullant to reach the reservoir $E$ assuming porosity $n$ = 0.3:
(a) 2.3 years (b) 4.6 years
(c) 6.9 years (d) 3.2 years

**Q.35** An unconfined aquifer ($k$ = 50 m/day) is tapped in a infiltration gallery over a horizontal impervious bed as given below:




The discharge collected per unit length of gallery is:
(a) 3.2 $m^3$/s/m (b) 4.8 $m^3$/s/m
(c) 1.6 $m^3$/s/m (d) 3.8 $m^3$/s/m

**Q.36** The length of strainer is 30 m for 20 cm diameter tubewell tapped in artesian aquifer and coefficient permeability of aquifer is 35 m/day. Assume radius of influence as 300 m. If all conditions remains same, the percentage change in yield if diameter of tubewell is doubled:
(a) 9.5% decrease (b) 11.5% increase
(c) 11.5% decrease (d) 9.5% increase

**Q.37** A confined aquifer of thickness $T$ has fully penetrating well of radius of $r$ pumping a discharge $Q$ at a steady rate. An observation well $N$ is located at a distance $R$ from pumping well. The travel time for water to travel from well $N$ to pumping well is: ($n$ = porosity of aquifer)
(a) $\frac{\pi T_n}{Q}(R^2 - r^3)$ (b) $\frac{\pi T}{nQ}(R^2 - r^2)$
(c) $\frac{\pi T n^2}{Q}(R^3 - r^3)$ (d) $\frac{\pi T n}{Q}(R^2 - r^2)$

**Q.38** Due to disuse of 1.2 m diameter pipe provided in the reservoir, it was buried and completely clogged up for some length by sediments. It was found fine sand ($k_1$ = 10 m/day) deposit for length of 100 m at upstream end and of coarse sand ($k_2$ = 50 m/day) at downstream end for length of 50 m. In between these two layers, the presence of silty sand ($k_3$ = 0.10 m/day) for some length identified. For head difference of 20 m on either side of clogged length, the seepage discharge found to be 0.8 $m^3$/day the length of pipe filled by silty sand is:
(a) 2.13 m (b) 2.27 m
(c) 1.23 m (d) 1.73 m

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## **Answers** Groundwater

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. (d) | 2. (b) | 3. (c) | 4. (c) | 5. (d) | 6. (b) | 7. (c) | 8. (a) | 9. (b) | 10. (c) |
| 11. (c) | 12. (b) | 13. (d) | 14. (d) | 15. (d) | 16. (a) | 17. (c) | 18. (a) | 19. (d) | 20. (a) |
| 21. (a) | 22. (b) | 23. (a) | 24. (b) | 25. (d) | 26. (b) | 27. (c) | 28. (b) | 29. (c) | 30. (c) |
| 31. (c) | 32. (c) | 33. (a) | 34. (b) | 35. (a) | 36. (d) | 37. (d) | 38. (d) | | |

## **Explanations** Groundwater

**8. (a)**

$$k \propto \frac{P}{\mu}$$

If $T(\uparrow), \mu(\downarrow)$ $\quad \therefore k(\uparrow)$

**11. (c)**

$$V = ki$$

$$0.25 \times \frac{1500}{t} = 30 \times \frac{25}{1500}$$

$$t = 750 \text{ days}$$

**17. (c)**

$$k \propto \frac{1}{v}$$

$$\frac{k_1}{k_2} = \frac{v_2}{v_1}$$

$$k_1 = \frac{1.3\times10^6}{1\times10^6}\times 5 = 6.5 \text{ m/day}$$

**18. (a)**

$$k_e = \frac{2+4+3}{\frac{2}{6}+\frac{4}{16}+\frac{3}{24}} = \frac{9\times24}{8+6+3}$$

$$= 12.69 \simeq 13 \text{ m/day}$$

**19. (d)**

$$k_e = \frac{3\times30+2\times10+5\times20}{10} = 21$$

$$T = 21 \times 10 = 210 \text{ m}^2\text{/day}$$

**27. (c)**

Using Dupuit's equation,

$$Q = \frac{2.72T(H-hw)}{\log_{10}(R/rw)} \qquad T \Rightarrow kB$$

$$\Rightarrow \quad Q = \frac{2.72\times\left(\frac{35}{24}\right)\times(30)\times3}{\log\left(\frac{300}{0.10}\right)}$$

$$\Rightarrow \quad Q = 102700 \; lph = 102.70 \text{ m}^3\text{/hr}$$

**28. (b)**

Specific yield of soil, $C = \frac{2.303}{T}\log_{10}\left(\frac{S_1}{S_2}\right)$

$$= \frac{2.303}{4}\log_{10}\left[\frac{5.93-5.08}{5.68-5.08}\right]$$

$$= 0.09 \text{ hr}^{-1}$$

Specific capacity of the well is its yield per unit drawdown

$$Q = CAH$$

$\therefore$ Specific capacity $= \frac{Q}{H} = CA$

$$= 0.09\times(7.70\times4.65)$$

$$= 3.58 \text{ m}^2\text{/hr}$$

**29. (c)**

Change in ground water storage

$$\Delta_{GWS} = A_{aq}\times\Delta_{GWT}\times S_y$$

$$90\times10^6 = (100\times10^6)\times5\times S_y$$

$$S_y = 0.18$$

We know,

Porosity, $n = S_y + S_r = 0.18 + 0.12$

$= 0.30$ or $30\%$

**30. (c)**

We know,

Storage coefficient,

$$S = \gamma_w nb\left(\frac{1}{K_w}+\frac{1}{nK_s}\right)$$

$$= 1000\times0.25\times30\left[\frac{2}{2.14\times10^8}+\frac{1}{0.25\times2\times10^7}\right]$$

$= 7500\times(0.467\times10^{-8}+20\times10^{-8})$

$= 1.54\times10^{-3}$

**31. (c)**

We know, $\quad Q = \frac{\pi k(h_2^2-h_1^2)}{2.303\log_{10}(r_2/r_1)}$

$h_2 = H - S_2 = 30 - 0.5 = 29.5$ m,

$h_1 = H - S_1 = 30 - 1.2 = 28.8$ m

$$\Rightarrow \quad \frac{1.800}{60} = \frac{\pi k(29.5^2-28.8^2)}{2.303\log_{10}(36/12)}$$

$\Rightarrow \quad k = 2.62\times10^{-4}$ m/sec

or $\quad$ 22.7 m/day

Transmissibility, $T = kH = (2.62\times10^{-4})\times30$

$= 78.6\times10^{-4}$ m$^2$/sec

$= 22.7\times30 = 681$ m$^2$/day

**32. (c)**

$$V_a = \frac{42}{6\times60\times60} = 1.9444\times10^{-3} \text{ m/sec}$$

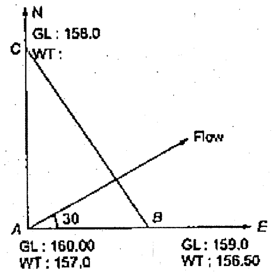
$V = nV_a = 0.2\times1.9444\times10^{-3}$

$= 3.889\times10^{-4}$ m/sec

$i = 0.85\times0.42 = 0.020238$

$K = v/i = 0.0192$ m/s $= 1.92$ cm/sec

**33. (a)**




$V_y = V\sin\theta = V\sin30° = 0.5\,V$

$V_x = V\cos\theta = 0.866\,V$

$$i_x = \frac{157-156.5}{800} = \frac{1}{1600}$$

$$V_x = k_x = \frac{k}{1600}$$

$$\frac{k}{1600} = 0.866\,V, \text{ or } V = \frac{k}{1847.50}$$

Similarly, $\quad V_y = k_i = 0.5\,V$

$$= 0.5\times\frac{k}{1847.50} = \frac{k}{3695}$$

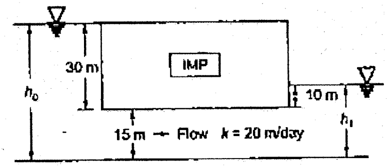
$$i_y = \frac{1}{3695} = -(\Delta H_y)/2000$$

$\Rightarrow \quad -\Delta H_y = 2000/3685 = 0.541 = H_a - H_c$

$\Rightarrow \quad H_c$ = Elevation of water table at $C$

$= 157000 - 0.541 = 156.459$ m

**34. (b)**




$h_0 = 30 + 15 = 45$ m

$h_1 = 10 + 15 = 25$ m

Gross velocity, $V = \frac{k(h_0-h_1)}{L} = \frac{20\times(45-25)}{1500}$

$= 0.267$ m/day

Actual velocity seepage,

$$V_a = \frac{V}{n} = \frac{0.267}{0.3} = 0.889 \text{ m/day}$$

Time to travel, $t = \left(\frac{1500}{0.889}\right) = 1687$ days

$= 4.6$ years

**35. (a)**

$q$ = discharge per unit length of gallery

$$= \frac{k(h_0^2-h_1^2)}{2L}\times2$$

$= \frac{50}{150}[(3.2)^2-(0.8)^2] = 3.2$ m$^3$/s/m length of gallery.

36. (d)

We know, $Q = \frac{2\pi k_B(h_2 - h_1)}{\ln(r_2 / r_1)}$

$$\Rightarrow \quad \frac{Q_n}{Q} = \frac{\ln(R / r_{w1})}{\ln(R / r_{w2})} = \frac{\ln\left(\frac{300}{0.10}\right)}{\ln\left(\frac{300}{0.20}\right)}$$

$$= 1.095$$

$\therefore$ % change in discharge = 9.5% increase.

37. (d)

$$V = \frac{Q}{2\pi rT} = \text{gross velocity}$$

Seepage velocity = $V_s = \frac{V}{n} = \frac{Q}{2\pi rT_n}$

$$dt = \frac{-dr}{V_s} = \frac{-2\pi rT_n}{Q}dr$$

$$\Rightarrow \int_0^t dt2 - \int_R^r \frac{-2\pi rT_n}{Q}dr \quad \Rightarrow \quad t = \frac{\pi T_n}{Q}(R^2 - r^2)$$

38. (d)

The flow is normal to be stratification. Hence,

$$k_e = \frac{\Sigma L_1}{\Sigma L/k} = \frac{100 + L + 50}{\left(\frac{100}{10} + \frac{L}{0.1} + \frac{50}{50}\right)} = \frac{150 + L}{10L + 11}$$

$\Rightarrow$ $Q = 0.8\ m^3/d = V(\pi/4) \times (1.2)^2$

$\therefore$ $V = 0.707$ m/day $= k_e i$

$$= k_e\left[\frac{20}{(120 + L)}\right] = \left[\frac{150 + L}{10L + 11}\right]\left[\frac{20}{120 + L}\right]$$

Solving, we get $L = 1.73$ m.

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