QUIZ PE-WR

PE Practice Problems

Civil: Water Resources and Environmental

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Problem 1. Two flow depths for flow in an open channel have the same specific energy, one corresponding to subcritical flow and the other to supercritical flow. These depths constitute a pair of:

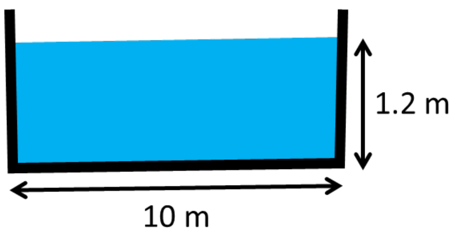
A) Sequent depths.

B) Converse depths.

C) Alternate depths.

D) Parallel depths.

Problem 2. A concrete rectangular channel has a width of 10 m and a normal depth of 1.2 m. The bottom slope of the channel is 0.001, and the Manning roughness coefficient of the channel lining is 0.011. The discharge (m^3/s) for uniform flow in this channel is most nearly:



A) 12

B) 20

C) 34

D) 48

Problem 3. For a given discharge, the critical flow depth in a channel depends on:

A) Geometry only.

B) Geometry and bed slope.

C) Geometry, bed slope, and roughness.

D) Geometry, bed slope, roughness, and Reynolds number.

Problem 4. A rectangular channel 5 m wide laid to a mild bed slope conveys a discharge of 8 m^3/s at a uniform flow depth of 1.3 m. The critical depth (m) of this channel is most nearly:

A) 0.25

B) 0.64

C) 1.10

D) 1.55

Problem 5. The approach Froude number in a hydraulic jump is 6. Thus, the jump may be classified as a:

A) Weak jump.

B) Oscillating jump.

C) Steady jump.

D) Strong jump.

Problem 6. The standard step method is a model used to analyze which type of open channel flow?

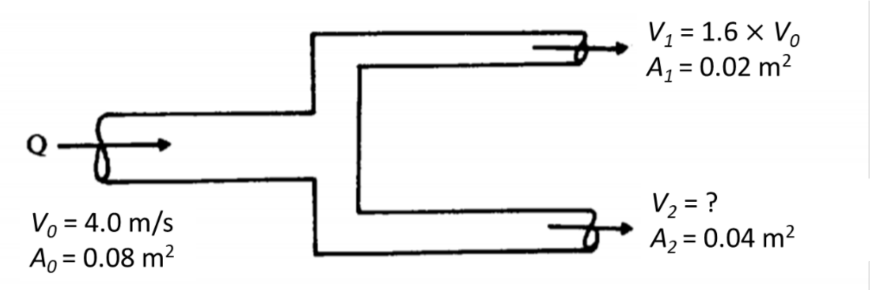
A) Steady uniform flow.

B) Gradually varied flow.

C) Rapidly varied flow.

D) Unsteady uniform flow.

Problem 7. A pipeline of 0.08-m^2 cross-sectional area carries water at an average velocity of 4 m/s. The main pipeline branches into two pipes, one with 0.02-m^2 cross-sectional area and another with 0.04-m^2 cross-sectional area, as shown. The flow velocity in the 0.02-m^2 segment is 1.6 times the velocity in the main pipeline. The flow velocity (m/s) in the 0.04-m^2 segment is most nearly:



A) 4.8

B) 6.0

C) 7.2

D) 8.5

Problem 8. A pump conveys water at 20°C with velocity of 0.2 m/s through a cast iron pipe of 0.5 m diameter. The relative pipe roughness is 0.01. The Darcy-Weisbach friction factor for this pipe flow is most nearly:

A) 0.02

B) 0.04

C) 0.06

D) 0.08

Problem 9. In which of the following flow regimes does the Darcy-Weisbach friction factor become independent of the Reynolds number?

A) Laminar flow.

B) Transitional flow.

C) Hydraulically smooth turbulent flow.

D) Hydraulically rough turbulent flow.

Problem 10. The kinetic energy correction factor for fully-developed laminar flow through a circular pipe is:

A) 1.0

B) 1.33

C) 1.50

D) 2.0

Problem 11. Cavitation is caused by:

A) Low pressure.

B) High temperature.

C) Low temperature.

D) High velocity.

Problem 12. A 1-hour rainfall of 2 cm intensity has a return period of 10 years. The probability that 1 hour of rainfall with intensity of 2 cm or more will occur in two successive years is most nearly:

A) 0.01

B) 0.02

C) 0.1

D) 0.2

Problem 13. The return period for the maximum annual flood of a given magnitude is 8 years. The probability that the flood magnitude will be exceeded at least once during the next 5 years is most nearly:

A) 0.33

B) 0.49

C) 0.65

D) 0.82

Problem 14. It is estimated that 60% of annual precipitation in a basin with a drainage area of 20,000 acres is evaporated. If the average annual river flow at the outlet of the basin has been observed to be 3 cfs, the annual precipitation (in./year) in the basin is most nearly:

A) 1.2

B) 2.1

C) 3.3

D) 4.5

Problem 15. The rainfall intensity of a typical storm in a region is given below. The maximum intensity of rainfall (mm/min) for 20 minutes duration of the storm is most nearly:

Time Interval (minutes)	Intensity of Rainfall (mm/min)
0 → 10	0.7
10 → 20	1.1
20 → 30	2.2
30 → 40	1.5
40 → 50	1.2
50 → 60	1.3
60 → 70	0.9
70 → 80	0.4

A) 1.15

B) 1.35

C) 1.85

D) 2.05

Problem 16. A 8-hour storm in a small catchment varied in intensity according to the table given below. The runoff depth was 6.6 in. The ϕ index (in./h) for this storm is most nearly:

Time Interval (hours)	Intensity of Rainfall (in./h)
0 → 1	1.1
1 → 3	1.8
3 → 5	2.6
5 → 8	1.3

A) 0.45

B) 0.9

C) 1.35

D) 1.8

Problem 17. watershed has a drainage area of 1000 ha. The annual rainfall is 930 mm, the expected evaporation loss is 290 mm per year, and the estimated loss to groundwater is 90 mm per year. The daily water consumption is 200 L/(day·person). The number of persons that can be served over the course of a year is most nearly:

A) 25,000

B) 50,000

C) 75,000

D) 100,000

Problem 18. A storm hydrograph represents 3 hours of effective rainfall. It contained 6 cm of direct runoff. The ordinates of the direct runoff hydrograph of this storm:

A) When divided by 3 give the ordinates of a 3-h unit hydrograph.

B) When divided by 6 give the ordinates of a 3-h unit hydrograph.

C) When divided by 3 give the ordinates of a 6-h unit hydrograph.

D) When divided by 6 give the ordinates of a 6-h unit hydrograph.

Problem 19. A triangular direct runoff hydrograph due to a storm has a time base of 60 h and a peak flow of 30 m^3/s occurring at 30 h from the start. The catchment area is 300 km^2. The rainfall excess (mm) is most nearly:

A) 10

B) 20

C) 30

D) 40

Problem 20. A 3-hour storm over a watershed had an average depth of 27 mm. The resulting flood hydrograph was found to have a peak flow of 200 m^3/s and a base flow of 20 m^3/s. If the loss rate could be estimated as 0.3 cm/hr, a 3-h unit hydrograph for this watershed will have a peak (m^3/s) of, most nearly:

A) 33.3

B) 66.7

C) 100

D) 111

Problem 21. An average rainfall of 16 cm occurs over a catchment during a period of 12 hours with uniform intensity. The unit hydrograph (unit depth = 1 cm, duration = 6 hours) of the catchment rises linearly from 0 to 30 m^3/s in six hours and then falls linearly from 30 m^3/s to 0 in the next 12 hours. The ϕ index is known to be 0.5 cm/hr. Base flow in the river is known to be 5 m^3/s. The area of the catchment (hectares) is most nearly:

A) 2500

B) 4900

C) 7100

D) 9700

Problem 22. A watershed of area 90 ha has a runoff coefficient of 0.4. A storm of duration larger than the time of concentration of the watershed and of intensity 4.5 cm/h creates a peak discharge (m^3/s) of most nearly:

A) 1.5

B) 3.0

C) 4.5

D) 6.0

Problem 23. A small watershed is 200 ha in size has soil classified as Group C in the Soil Conservation Service (SCS) runoff model. The land cover can be classified as 30% open forest (curve number = 60) and 70% poor quality pasture (curve number = 85). The initial abstraction is estimated as $0.2 \times S$, where S is the retention parameter. The direct runoff volume (m^3) for a rainfall of 68 mm in one day is most nearly:

A) 10,800
B) 21,500
C) 32,400
D) 44,600

Problem 24. A water sample has the ion concentrations provided. The total hardness (mg/L as $CaCO_3$) of the sample is most nearly:

Ion	Na^+	Ca^{2+}	Mg^{2+}	K^+
Concentration (mg/L)	40	40	15	5

A) 52
B) 108
C) 151
D) 207

Problem 25. A water plant feeds sodium fluoride from a dry feeder. Operators use 5.2 lb of 98%-pure chemical to fluoridate 240,000 gal of water. The calculated fluorine dosage (mg/L) is most nearly:

A) 0.761
B) 1.15
C) 1.44
D) 1.70

Problem 26. Which of the following microbe species is particularly resistant to disinfection by chlorination?

A) *Cryptosporidium parvum*.
B) *Legionella pneumophila*.
C) *Escherichia coli*.
D) *Clostridium botulinum*.

Problem 27. A water treatment plant uses 50 kg/day of chlorine to treat 38,000 m^3 of water. The residual chlorine after 30-min contact time is 0.52 mg/L. The chlorine demand (mg/L) of the water treated by this plant is most nearly:

A) 0.40
B) 0.60
C) 0.80
D) 1.00

Problem 28. In drinking water treatment, what is the purpose of rapid mixing?

A) Eliminate microbes that may not be extinguished in the disinfection process.
B) Increase the viscosity of the filtrate and thereby accelerate subsequent treatment processes.
C) Promote flocculation after the coagulant has been added.
D) Promote chemical oxidation after oxidants such as ozone have been added.

Problem 29. A settling tank is designed for a surface overflow rate of 30 $m^3/(day \times m^2)$. Assuming that the specific gravity of sediment particles of 2.65, the unit weight of water is 9810 kN/m^3, the dynamic viscosity of water is 0.001 Ns/m^2, and considering Stokes' law to be valid, the minimum size (mm) of particles that can be completely removed is most nearly:

A) 0.01
B) 0.02
C) 0.03
D) 0.04

Problem 30. A city is to install rapid sand filters downstream of the clarifiers. The design loading rate is selected to be 150 $m^3/(m^2 \cdot day)$. The design capacity of the waterworks is 0.35 m^3/s. The maximum surface per filter is limited to 36 m^2. The minimum number of filters is:

A) 6

B) 7

C) 8

D) 9

Problem 31. Water samples (1 and 2) from two different sources were brought to a laboratory for the measurement of dissolved oxygen (DO) using the Winkler method. Samples were transferred to 300-mL BOD bottles. 2 mL of $MnSO_4$ solution and 2 mL of alkaliodide-azide reagent were added to the bottles and mixed. Sample 1 developed a brown precipitate, whereas sample 2 developed a white precipitate. Which of the following is true?

A) Both samples contained DO.

B) Sample 1 contained DO and sample 2 was devoid of DO.

C) Sample 1 was devoid of DO and sample 2 contained DO.

D) Both samples were devoid of DO.

Problem 32. The ultimate biochemical oxygen demand of a drinking water sample was measured as 450 mg/L after a 30-day incubation period. Suppose the BOD is described by a first-order reaction with rate constant k = 0.05 day^{-1}. The BOD after 5 days (BOD5, mg/L) is most nearly:

A) 58.4

B) 106

C) 158

D) 210

Problem 33. A well fully penetrates a 25-m thick confined aquifer. After a long period of pumping at a constant rate of 0.04 m^3/s, the drawdowns at distances of 50 and 150 m from the well were observed to be 3 m and 1.2 m, respectively. The transmissivity (m^2/day) of the aquifer is most nearly:

A) 60.5

B) 140

C) 220

D) 300

Problem 34. Two rivers are located 1600 m apart and fully penetrate an unconfined aquifer. The water elevations of the rivers are 50.6 m and 45.1 m above the impermeable bed. The hydraulic conductivity of the aquifer is 0.60 m/day. The daily discharge per unit width (m^2/day) between the two rivers, neglecting recharge, is most nearly:

A) 0.1

B) 0.3

C) 0.5

D) 0.7

Problem 35. A 1-m diameter well penetrates vertically through a confined aquifer 25 m thick. When the well is pumped at 2700 m^3/day, the drawdown in a well 15 m away is 1.6 m; in another well 50 m away, it is 0.5 m. The initial piezometric level is 40 m above the datum. The well's radius of influence (m) is most nearly:

A) 67

B) 86

C) 110

D) 130

Problem 36. Two primary clarifiers of circular cross-section are being designed for a wastewater treatment plant. The average flow rate of the wastewater is 34,000 m^3/day, to be divided evenly between the clarifiers, with a suspended solids concentration of 320 mg/L. The goal is to remove 60% suspended solids in primary treatment. The diameter (m) of each primary clarifier for a surface overflow rate of 43 $m^3/m^2 \cdot$day is most nearly::

A) 8.5
B) 14
C) 22
D) 31

Problem 37. Reconsidering the system of the previous problem, the mass of solids (kg/day) removed by both clarifiers on a daily basis is most nearly:

A) 2000
B) 3500
C) 5000
D) 6500

Problem 38. In a 1 MGD waterworks, 1300 lb of dry solids are generated per million gallons of water treated. The sludge is concentrated to 4% and then applied to an intermittent sand drying bed at a 18-in. depth, with 20 beds used per year. The surface area (ft^2) needed for the drying bed is most nearly:

A) 3000
B) 4700
C) 6300
D) 8000

Problem 39. A conventional wastewater treatment plant treats 14,000 m^3/day of municipal wastewater with a suspended solids concentration of 200 mg/L. The removal efficiency of the primary clarifier is 55% for suspended solids. The water content of the sludge is 95%, and the specific gravity is 1.05. The volume rate (m^3/day) of sludge produced in the primary clarifier is most nearly:

A) 10
B) 20
C) 30
D) 40

Problem 40. A wastewater treatment plant treats 1800 m^3/day of high strength wastewater in an anaerobic reactor operated at 35°C. The biodegradable soluble chemical oxygen demand (COD) concentration of the wastewater is 3600 mg/L. The molar volume of methane gas for the given conditions is 25 L/mol. The volume of methane (m^3/day) that will be produced with 90% COD removal is most nearly:

A) 2300
B) 4000
C) 5700
D) 7500

▸ SOLUTIONS

P.1 ■ Solution

The depths in question are known as *alternate depths*. They should not be confused with the depths that occur before and after a hydraulic jump, which are known as *sequent depths*.

▸ The correct answer is **C**.

P.2 ■ Solution

This is a straightforward application of the Manning formula,

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

where A = 10 × 1.2 = 12 m^2, n = 0.011, S_0 = 0.001, and the hydraulic radius R is given by

$$R = \frac{A}{P} = \frac{12}{2\times1.2+10} = 0.968 \text{ m}$$

Accordingly, the discharge Q is calculated as

$$Q = \frac{1}{0.011} \times 12 \times 0.968^{2/3} \times 0.001^{1/2} = \boxed{33.8 \text{ m}^3/\text{s}}$$

► The correct answer is **C**.

P.3 ■ Solution

The critical depth can be computed by setting the Froude number to unity, Fr = 1.0, with the result that

$$\text{Fr} = 1 \rightarrow \frac{V}{\sqrt{gD\cos\theta/\alpha}} = 1$$

$$\therefore \frac{Q/A}{\sqrt{gD\cos\theta/\alpha}} = 1$$

$$\therefore Z = A\sqrt{D} = \frac{Q/\sqrt{\cos\theta}}{\sqrt{g/\alpha}}$$

where Q is discharge, A is the cross-sectional area, g is the acceleration due to gravity, D is the hydraulic diameter, θ is the longitudinal slope angle, and α is the velocity-head coefficient. We see that, for a given discharge, bed slope, and other dynamic parameters, the critical depth depends only on the product $A\sqrt{D}$ (sometimes called the *section factor*), which in turn depends only on the geometry of the channel cross-section. There is no direct dependence on bed slope, roughness, or Reynolds number.

► The correct answer is **A**.

P.4 ■ Solution

This is a straightforward application of the formula

$$y_c = \sqrt[3]{\frac{q^2}{g}}$$

where the flow rate per unit width is 8/5.0 = 1.6 m^2/s, so that

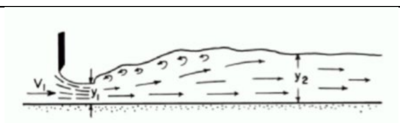
$$y_c = \sqrt[3]{\frac{1.6^2}{9.81}} = \boxed{0.639 \text{ m}}$$

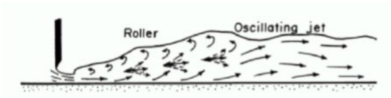
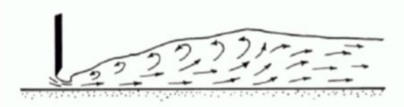
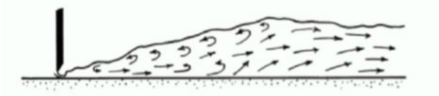
Since the uniform flow depth is greater than y_c, we can surmise that the flow is subcritical.

► The correct answer is **B**.

P.5 ■ Solution

According to the Peterka classification, a jump with approach Froude number between 4.5 and 9 is named a steady jump. The classification model in question is briefly summarized below.

Jump Type	Froude Number Range	Details
 Weak jump	$1.0 < \text{Fr} < 2.5$	The sequent depths are close to each other and only a slight ruffle is formed on the water surface. There is minimal energy dissipation.

 Oscillating jump	$2.5 < \mathrm{Fr} < 4.5$	The jet at the entrance to the jump oscillates from the bottom to the top at an irregular period. These oscillations result in the formation of irregular waves, which may persist for a long distance downstream of the jump.
 Steady jump	$4.5 < \mathrm{Fr} < 9$	The jump forms steadily at the same location, and the position of the jump is least sensitive to downstream flow conditions. Energy dissipation is considerable.
 Strong jump	$\mathrm{Fr} > 9$	The difference between the conjugate depths is large. At irregular intervals, slugs of water roll down the front of the jump face into high-velocity jet and generate additional waves. The dissipation rate is high.

► The correct answer is **C**.

P.6 ■ Solution

The standard step method is perhaps the simplest model available to describe gradually varied flow in prismatic channels. A flow is classified as gradually varied if the flow depth varies slowly with distance.

► The correct answer is **B.**

P.7 ■ Solution

This is a straightforward application of conservation of mass. Applying the continuity equation, we have

$$Q_0 = Q_1 + Q_2 \rightarrow A_0 V_0 = A_1 V_1 + A_2 V_2$$

$$\therefore 0.08 \times 4.0 = 0.02 \times (1.6 \times 4.0) + 0.04 \times V_2$$

$$\therefore \boxed{V_2 = 4.8 \text{ m/s}}$$

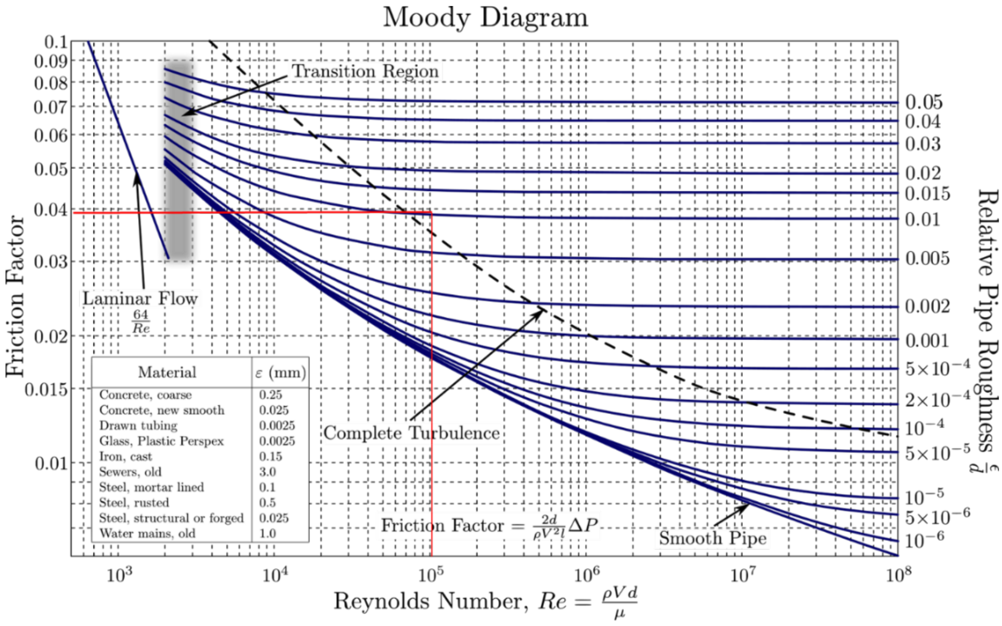
► The correct answer is **A**.

P.8 ■ Solution

The kinematic viscosity of water at 20°C is about 1.0 × 10^{-6} m^2/s. The Reynolds number for the flow in question is

$$\mathrm{Re} = \frac{VD}{\nu} = \frac{0.20 \times 0.50}{1.0 \times 10^{-6}} = 100{,}000$$

Since *Re* > 2000, flow is turbulent. The Darcy-Weisbach friction factor can be obtained by mapping the foregoing value of *Re* and the relative pipe roughness (=0.01) onto the Moody chart. The friction factor is determined to be 0.04 (see below).



► The correct answer is **B**.

P.9 ■ Solution

In laminar flow (i.e., when $Re < 2000$), the friction factor is related to Reynolds number by

$$f = \frac{64}{\text{Re}}$$

In transitional flow (i.e., when $2000 < Re < 4000$), the relation between friction factor and Reynolds number is uncertain. In smooth and transitional turbulence, f varies with both Reynolds number and relative roughness k_s/D. Finally, when the conduit attains rough turbulence, the friction factor remains constant for a given relative roughness, and is independent of *Re*.

► The correct answer is **D**.

P.10 ■ Solution

The kinetic energy correction factor for laminar flow through a pipe is 2.0. For turbulent flow through a pipe, its value ranges from 1.01 to 1.20.

► The correct answer is **D**.

P.11 ■ Solution

Cavitation occurs when the local pressure becomes lower than the vapor pressure of the flowing liquid, which equals 17.5 torr for water at 20°C.

► The correct answer is **A**.

P.12 ■ Solution

The probability of occurrence of the rainfall in question is $p = 1/10 = 0.1$. The probability that this rainfall intensity will be attained in the next two years is $0.1 \times 0.1 = 0.01$.

► The correct answer is **A**.

P.13 ■ Solution

The probability that the flood will *not* occur in the next year is $p = 1 - 1/8 = 0.875$. The probability that the flood will not occur in any of the five following years is $p(r = 0) = 0.875^5$, and the probability that the flood will occur at least once in the period in question follows as

$$p(r \geq 1) = 1 - p(r = 0)$$

$$\therefore p(r \geq 1) = 1 - 0.875^5 = \boxed{0.487}$$

► The correct answer is **B**.

P.14 ■ Solution

The long term water balance for the basin is

$$P - E - Q = 0$$

where P is precipitation, E is evapotranspiration, and Q is net flow. We are told that the evaporation is 60% of the precipitation, so $E = 0.6P$. Substituting this result in the foregoing equation and solving for P gives

$$P - 0.6P - Q = 0 \rightarrow P = 2.5Q$$

$$\therefore P = 2.5Q = 2.5 \times 3 = 7.5 \text{ cfs}$$

With some quick unit conversion, we obtain

$$P_{\text{depth}} = \frac{P_{\text{vol}}}{A} = \frac{7.5 \text{ ft}^3/\text{s}}{15{,}000 \text{ acres}} \times \frac{1}{43{,}560} \frac{\text{acre}}{\text{ft}^2} \times \frac{3600}{1} \frac{\text{s}}{\text{hr}} \times \frac{24}{1} \frac{\text{h}}{\text{day}} \times \frac{365}{1} \frac{\text{days}}{\text{year}} = 0.271 \text{ ft/year}$$

or, in inches,

$$P_{\text{depth}} = 0.271\ \frac{\text{ft}}{\text{year}} \times \frac{12\ \text{in.}}{1\ \ \text{ft}} = \boxed{3.25\ \text{in./year}}$$

► The correct answer is **C**.

P.15 ■ Solution

By inspection, we see that the maximum 20-min. rainfall intensity takes place between the 10 – 20 min. period, for which the intensity is 2.2 mm/min., and the 20 – 30 min. period, for which the intensity is 1.5 mm/min. The maximum intensity is, accordingly,

$$\text{Intensity} = \frac{2.2\times10+1.5\times10}{20} = \boxed{1.85\ \text{mm/min}}$$

► The correct answer is **C**.

P.16 ■ Solution

The first step is to compute the total rainfall,

$$\text{Total rainfall} = (1-0)\times1.1+(3-1)\times1.8+(5-3)\times2.6+(8-5)\times1.3 = 13.8\ \text{in.}$$

The depth of infiltration is 13.8 – 6.6 = 7.2 in. Lastly, the ϕ-index is determined as

$$\phi\times8 = 7.2 \rightarrow \phi = \frac{7.2}{8} = \boxed{0.9\ \text{in./h}}$$

► The correct answer is **B**.

P.17 ■ Solution

Applying a mass balance, we can write

$$\text{Rainfall excess} = \text{Precipitation} - \text{Evaporation} - \text{Loss to groundwater}$$

$$\therefore R = 930-290-90 = 550\ \text{mm}$$

Expressing this quantity as a volume, we have

$$R = 550\ \text{mm}\times\frac{1\ \text{m}}{1000\ \text{mm}}\times1000\ \text{ha}\times\frac{10{,}000\ \text{m}^2}{1\ \text{ha}}\times\frac{1000\ \text{L}}{1\ \text{m}^3} = 5.50\times10^9\ \text{L}$$

The annual consumption per capita is

$$\text{Annual usage per capita} = 200\ \frac{\text{L}}{\text{person}\cdot\text{day}}\times365\ \text{days} = 73{,}000\ \text{L/person}$$

The number of people served follows as

$$\text{No. of people served} = \frac{5.50\times10^9\ \text{L}}{73{,}000\ \text{L/person}} = \boxed{75{,}300\ \text{p}}$$

► The correct answer is **C**.

P.18 ■ Solution

Since

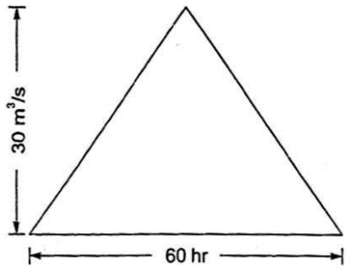
$$\text{Unit hydrograph} = \frac{\text{Direct runoff hydrograph}}{\text{Effective runoff}}$$

it follows that, upon dividing the ordinates of the DRH by 6 (= the direct runoff), the 3-hour unit hydrograph will result.

► The correct answer is **B**.

P.19 ■ Solution

The hydrograph in question is illustrated below.



The volume of excess rainfall is the area of the hydrograph,

$$V = \frac{1}{2} \times 30 \times 60 \times 60 \times 60 = 3.24 \times 10^6 \ \text{m}^3$$

The rainfall excess is obtained by dividing this volume by the area of the catchment,

$$\text{Depth of excess rainfall} = \frac{\text{Volume}}{\text{Catchment area}}$$

$$\therefore \text{Depth of excess rainfall} = \frac{3.24 \times 10^6}{320 \times 10^6} \times 10^3 = \boxed{10.1 \text{ mm}}$$

▶ The correct answer is **A**.

P.20 ■ Solution

The runoff depth is given by the difference

$$\text{Runoff depth} = \text{Rainfall} - \text{Loss}$$
$$\therefore \text{Runoff depth} = 2.7 - 0.3 \times 3 = 1.8 \text{ cm}$$

The peak flow of the direct runoff hydrograph is, in turn,

$$\text{Peak of DRH} = \text{Peak of flood hydrograph} - \text{Base flow}$$
$$\therefore \text{Peak of DRH} = 200 - 20 = 180 \ \text{m}^3/\text{s}$$

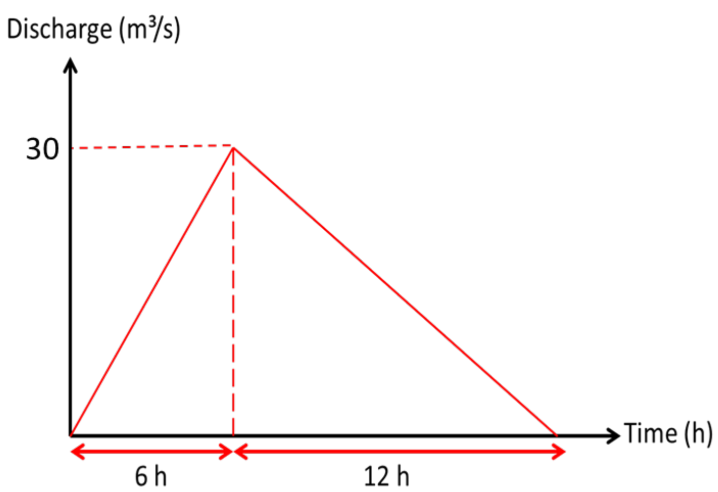
Lastly, the peak of the 3-h UH follows as

$$P = \frac{\text{Peak of DRH}}{\text{Runoff depth}} = \frac{180}{1.8} = \boxed{100 \ \text{m}^3/\text{s}}$$

▶ The correct answer is **C**.

P.21 ■ Solution

The hydrograph is shown below.



Given the unit depth of 1 cm, the volume of runoff is expressed as

$$\text{Volume} = A \times \left(1 \times 10^{-2}\right)$$

where A is the area of the catchment. However, the volume of runoff is also given by the area of the foregoing hydrograph,

$$\text{Volume} = \frac{1}{2}\times(6+12)\times 30\times 3600 = 972{,}000\ \text{m}^3$$

Equating the two preceding relations, it follows that

$$A\times\left(1\times 10^{-2}\right) = 972{,}000$$

$$\therefore A = 9.72\times 10^{7}\ \text{m}^2 = \boxed{9720\ \text{ha}}$$

▶ The correct answer is **D**.

P.22 ■ Solution

Given the runoff coefficient C = 0.4, the rainfall intensity i_{t_c} = 45 mm/h and the watershed area A = 0.90 km^2, we have, applying the rational method formula,

$$Q = \frac{Ci_{t_c}A}{3.6} = \frac{0.4\times 45\times 0.90}{3.6} = \boxed{4.5\ \text{m}^3/\text{s}}$$

▶ The correct answer is **C**.

P.23 ■ Solution

The products of territory percentage and curve number are computed below.

Land use	%	CN	Product
Open forest	30	60	1800
Poor quality pasture	70	85	5950
Sum =	100		7750

The average CN = 7750/100 = 77.5, and the retention parameter is

$$S = \frac{25{,}400}{CN} - 254 = \frac{25{,}400}{77.5} - 254 = 73.7$$

The runoff depth is estimated with the SCS equation,

$$Q = \frac{(P-0.2S)^2}{P+0.8S} = \frac{(68-0.2\times 73.7)^2}{68+0.8\times 73.7} = 22.3\,\text{mm}$$

The total runoff volume over the catchment follows as

$$V = \text{Area}\times Q = \left(200\times 10^4\right)\times 22.3/1000 = \boxed{44{,}600\ \text{m}^3}$$

▶ The correct answer is **D**.

P.24 ■ Solution

The contribution of calcium ions to the water hardness is

$$H_{\text{Ca}} = \frac{(\text{mg/L of Ca})\times(\text{Molar mass of CaCO}_3)}{\text{Equivalent weight of Ca}} = \frac{55\times 50}{20} = 138\ \text{mg/L as CaCO}_3$$

Similarly, the contribution of magnesium to hardness is

$$H_{\text{Mg}} = \frac{55\times 50}{40.1} = 68.6\ \text{mg/L as CaCO}_3$$

The total hardness of the water sample is then

$$H = H_{\text{Ca}} + H_{\text{Mg}} = 138 + 68.6 = \boxed{207\ \text{mg/L as CaCO}_3}$$

▶ The correct answer is **D**.

P.25 ■ Solution

The calculated dosage is given by

$$C = \frac{\text{Fluoride fed} \times \text{AFI} \times \text{Chemical purity}}{\text{Production}\left(\text{MGD}\right)\times 8.34 \ \text{lb/gal}}$$

where AFI is the available fluoride ion concentration, which is given by

$$AFI = \frac{\text{Molecular weight of fluoride}}{\text{Molecular weight of NaF}} = \frac{19}{23+19} = 0.452$$

Substituting this and other data in the equation for *C*, we obtain

$$C = \frac{5.2\times 0.452\times 0.98}{0.24\times 8.34} = \boxed{1.15 \text{ mg/L}}$$

► The correct answer is **B**.

P.26 ■ Solution

The cysts of *Crypstosporidium parvum*, the pathogen that causes cryptosporidiosis, and *Giardia lamblia*, which causes giardiasis, are known to be especially resistant to disinfection by chlorination. When these microbes are known to occur in the water being treated, plant operators often complement chlorination with additional biocidal techniques, such as irradiation by UV light.

► The correct answer is **A**.

P.27 ■ Solution

The chlorine demand is the difference between chlorine dosage and chlorine residual,

$$\text{Cl demand} = \text{Cl dosage} - \text{Cl residual}$$

The chlorine dosage is

$$\text{Chlorine dosage} = \frac{50 \text{ kg/day}}{38{,}000 \text{ m}^3\text{/day}} \times \frac{1000 \text{ mg/L}}{1 \text{ kg/m}^3} = 1.32 \text{ mg/L}$$

The chlorine demand is then

$$\text{Chlorine demand} = 1.32 - 0.52 = \boxed{0.80 \text{ mg/L}}$$

► The correct answer is **C**.

P.28 ■ Solution

Rapid mixing is employed to mix and evenly distribute the coagulant, thereby enhancing the flocculation process.

► The correct answer is **C**.

P.29 ■ Solution

Equating settling velocity to overflow rate, we have V_0 = 30 m^3/(day·m^2) = 3.47 × 10^{-4} m/s. Appealing to Stokes' law, we find that

$$V = \frac{(G_s - 1)\gamma_w d^2}{18\mu} \rightarrow d = \left[\frac{18\mu V}{(G_s - 1)\gamma_w}\right]^{1/2}$$

$$\therefore d = \left[\frac{18\times 0.001\times\left(3.47\times 10^{-4}\right)}{(2.65-1)\times 9810}\right]^{1/2} = 1.96\times 10^{-5} \text{ m} \approx \boxed{0.02 \text{ mm}}$$

► The correct answer is **B**.

P.30 ■ Solution

The total surface area required is

$$A = \frac{Q}{v} = \frac{0.35 \times 86,400}{150} = 202\ \text{m}^2$$

The number of filters follows as

$$n = \frac{202}{36} = 5.61$$

Accordingly, the minimum number of filters is 6.

► The correct answer is **A**.

P.31 ■ Solution

In the Winkler method, if the sample being tested does not have dissolved oxygen, a pure white precipitate is formed when $MnSO_4$ and alkali-iodide reagent (NaOH + KI) is added to the sample. The pertaining reaction is

$$\text{Mn}^{2+} + 2\text{OH}^- \rightarrow \text{Mn(OH)}_2\ \text{(White precipitate)}$$

If, on the other hand, the sample does have some oxygen, Mn^{2+} is oxidized to Mn^{4+} and precipitates brown hydrated oxide following the reaction

$$\text{Mn}^{2+} + 2\text{OH}^- + 0.5\text{O}_2 \rightarrow \text{MnO}_2\ \text{(Brown hydrated precipitate)} + \text{H}_2\text{O}$$

► The correct answer is **B**.

P.32 ■ Solution

If the reaction in question follows first-order kinetics, the BOD after *t* days must follow the relation

$$BOD_t = U\left(1 - e^{-kt}\right)$$

where *U* = 480 mg/L is the ultimate BOD, *k* = 0.05 day^{-1} is the rate constant, and *t* is time. Substituting *t* = 5 days and other pertaining variables, we get

$$BOD_5 = 480 \times \left(1 - e^{-0.05 \times 5}\right) = \boxed{106\ \text{mg/L}}$$

► The correct answer is **B**.

P.33 ■ Solution

A flow of 0.04 m^3/s corresponds to 0.04 × 86,400 = 3460 m^3/day. The hydraulic conductivity is calculated as

$$k = \frac{Q}{2\pi b\left(h_2 - h_1\right)} \ln\left(\frac{r_2}{r_1}\right) = \frac{3460}{2\pi \times 25 \times (3.2 - 1.2)} \times \ln\left(\frac{150}{50}\right) = 12.1\ \text{m/day}$$

The transmissivity, in turn, follows as

$$T = kb = 12.1 \times 25 = \boxed{303\ \text{m}^2/\text{day}}$$

► The correct answer is **D**.

P.34 ■ Solution

This is a straightforward application of the Dupuit equation,

$$q = \frac{k\left(h_1^2 - h_2^2\right)}{2L} = \frac{0.60 \times \left(50.6^2 - 45.1^2\right)}{2 \times 1600} = \boxed{0.0987\ \text{m}^2/\text{day}}$$

► The correct answer is **A**.

P.35 ■ Solution

The first step is to determine the hydraulic conductivity of the aquifer,

$$k=\frac{Q}{2\pi b\left(s_1-s_2\right)}\ln\left(\frac{r_2}{r_1}\right)=\frac{2700}{2\pi\times 25\times(1.6-0.5)}\times\ln\left(\frac{50}{15}\right)=18.8\text{ m/day}$$

Next, the radius of influence is estimated as

$$R=r_1\exp\left[\frac{2\pi Kb\left(h_0-h_1\right)}{Q}\right]=15\times\exp\left\{\frac{2\pi\times 18.8\times 25\times\left[40-(40-1.6)\right]}{2700}\right\}=\boxed{86.3\text{ m}}$$

► The correct answer is **B**.

P.36 ■ Solution

With 2 circular clarifiers, the flow in each clarifier is 34,000/2 = 17,000 m^3/day. From the equation of surface overflow rate, the area of each clarifier is computed as

$$v=\frac{Q}{A_s}\rightarrow A_s=\frac{Q}{v}$$

$$\therefore A_s=\frac{17{,}000}{43}=395\text{ m}^2$$

The diameter of the clarifier follows as

$$395=\frac{\pi\times D^2}{4}\rightarrow D=\sqrt{\frac{4\times 395}{\pi}}$$

$$\therefore \boxed{D=22.4\text{ m}}$$

► The correct answer is **C**.

P.37 ■ Solution

The mass of solids removed by the clarifiers is calculated as

$$\text{Mass of solids removed}=\text{Flow}\times\text{Concentration}$$

$$\therefore \text{Mass of solids removed}=\left(34{,}000\text{ m}^3\text{/day}\times 320\text{ mg/L}\times 0.60\right)\times 10^3\,\frac{\text{L}}{\text{m}^3}\times 10^{-6}\,\frac{\text{kg}}{\text{mg}}$$

$$\therefore \text{Mass of solids removed}=\boxed{6{,}530\text{ kg/day}}$$

► The correct answer is **D**.

P.38 ■ Solution

The mass of sludge produced per day is

$$v=1300\text{ lb/Mgal}\times 1\text{Mgal/d/0.04}=32{,}500\text{ lb/day}$$

The corresponding volume produced in a year is computed as

$$v=32{,}500\times 365/62.4=190{,}000\text{ ft}^3$$

Given the depth h = 18/12 = 1.5 ft and the annual number of applications n = 20, the surface area needed for the drying bed is found as

$$v=Ahn\rightarrow A=\frac{v}{hn}$$

$$\therefore A=\frac{190{,}000}{1.5\times 20}=\boxed{6330\text{ ft}^2}$$

► The correct answer is **C**.

P.39 ■ Solution

Given the wastewater flow rate Q = 14,000 m^3/day, the concentration of suspended solids C = 200 mg/L = 0.2 kg/m^3 and the solids removal efficiency of the primary clarifier E_p = 55%, the mass of primary sludge is determined as

$$M_1 = Q \times C \times E_p = 14,000 \times 0.2 \times 0.55 = 1,540 \text{ kg/day}$$

The solids content of the sludge is 100 – 95 = 5%, the specific gravity is 1.05, and the density of water is 1000 kg/m^3; the volume rate of sludge is then

$$V = \frac{M_1}{G_s \rho_w P} = \frac{1,540}{1.05 \times 1000 \times 0.05} = \boxed{29.3 \text{ m}^3/\text{day}}$$

► The correct answer is **C.**

P.40 ■ Solution

Writing a mass balance for the chemical oxygen demand in the anaerobic reactor, we have

$$\text{Accumulation} = \text{Influent COD} - \text{Effluent COD} - \text{COD Converted to Methane}$$

The influent COD is calculated as

$$\text{Influent COD} = 1800 \text{ m}^3/\text{day} \times 3.6 \text{ kg/m}^3 = 6480 \text{ kg/day}$$

The effluent COD, in turn, follows as

$$\text{Effluent COD} = (1 - 0.9) \times 6480 \text{ kg/day} = 648 \text{ kg/day}$$

Noting that the mass balance above should yield zero, we have

$$0 = 6{,}480 - 648 - \text{COD Converted to Methane}$$
$$\therefore \text{COD Converted to Methane} = 5,830 \text{ kg COD/day}$$

Since 64 g of oxygen is required to oxidize one mole of methane, the methane equivalent of COD converted is

$$\frac{25 \text{ L CH}_4/\text{mol}}{64 \text{ g COD/mol}} = 0.391 \frac{\text{m}^3 \text{ CH}_4}{\text{kg COD}}$$

Accordingly, the volume of methane produced per day is determined to be

$$\text{CH}_4 \text{ produced} = 5,830 \frac{\text{kg COD}}{\text{day}} \times 0.391 \frac{\text{m}^3 \text{ CH}_4}{\text{kg COD}} = \boxed{2,280 \text{ m}^3/\text{day}}$$

► The correct answer is **A**.

▸ ANSWER SUMMARY

1	**C**	21	**D**
2	**C**	22	**C**
3	**A**	23	**D**
4	**B**	24	**D**
5	**C**	25	**B**
6	**B**	26	**A**
7	**A**	27	**C**
8	**B**	28	**C**
9	**D**	29	**B**
10	**D**	30	**A**
11	**A**	31	**B**
12	**A**	32	**B**
13	**B**	33	**D**
14	**C**	34	**A**
15	**C**	35	**B**
16	**B**	36	**C**
17	**C**	37	**D**
18	**B**	38	**C**
19	**A**	39	**C**
20	**C**	40	**A**

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