POSTAL BOOK PACKAGE 2027

CIVIL ENGINEERING

OBJECTIVE PRACTICE SETS VOLUME - III

CONTENTS

FLUID MECHANICS, OCF AND HYDRAULIC MACHINES

OBJECTIVE PRACTICE SETS

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Part-I

1 CHAPTER

Fluid Mechanics

Fluid Properties

Q.1 Which one of the following is the bulk modulus K of a fluid? (Symbols have the usual meaning)

(a) $\rho \frac{dp}{d\rho}$ (b) $\frac{dp}{\rho d\rho}$

(c) $\rho \frac{d\rho}{dp}$ (d) $\frac{d\rho}{\rho dp}$

Q.2 **Statement (I):** In fluid, the rate of deformation is far more important than the total deformation itself.
Statement (II): A fluid continues to deform so long as the external forces are applied.

(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Q.3 In a quiescent sea, density of water at free surface is ρ_0 and at a point much below the surface density is ρ. Neglecting variation in gravitational acceleration g and assuming a constant value of bulk modulus K, the depth h of the point from the free surface is

(a) $\frac{K}{g}\left(\frac{1}{\rho_0}+\frac{1}{\rho}\right)$ (b) $\frac{K}{g}\frac{(\rho-\rho_0)}{(\rho+\rho_0)^2}$

(c) $\frac{K}{g}\left(\frac{1}{\rho_0}-\frac{1}{\rho}\right)$ (d) $\frac{K}{g}\left(\frac{\rho\rho_0}{\rho+\rho_0}\right)$

Q.4 A thin plane lamina of area A and weight W, slides down a fixed plane inclined to the vertical at an angle α and maintains a uniform gap ε from the surface of the plane, the gap being filled with oil of constant viscosity μ. The terminal velocity of plane lamina is

(a) $\frac{\varepsilon \cos\alpha}{\mu WA}$ (b) $\frac{\varepsilon\mu W}{A\sin\alpha}$

(c) $\frac{\varepsilon W\cos\alpha}{A\mu}$ (d) $\frac{\mu W\sin\alpha}{\varepsilon A}$

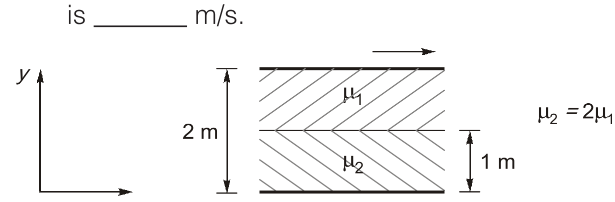
Q.5 A 50 mm diameter and 0.1 m long cylindrical body slides vertically down in a 52 mm diameter cylindrical tube. The space between the cylindrical body and tube wall is filled with oil of dynamic viscosity 1.9 Ns/m^2. The velocity of fall if its weight is 16 N will be

(a) 0.536 m/s (b) 0.268 m/s
(c) 0.804 m/s (d) 0.638 m/s

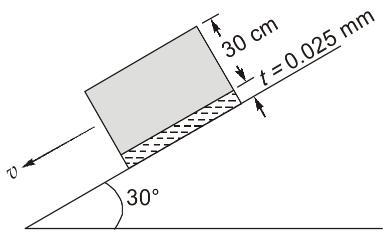
Q.6 Two immiscible, incompressible, viscous fluids having same densities but different viscosities are contained between two infinite horizontal parallel plates, 2 m apart as shown below. The bottom plate is fixed and the upper plate moves to the right with a constant velocity of 3 m/s. With the assumptions of Newtonian fluid, steady, and fully developed laminar flow with zero pressure gradient in all directions, the momentum equations simplify to

$$\frac{d^2u}{dy^2} = 0$$

If the dynamic viscosity of the lower fluid, μ_2, is twice that of the upper fluid, μ_1, then the velocity at the interface (round off to two decimal places) is _______ m/s.



Q.7 As shown in the figure, a cubical block of 30 cm side and of 30 kg weight is allowed to slide down along a plane inclined at 30° to the horizontal on which there is a film of oil having viscosity of 2×10^{-3} N-s/m^2. The film thickness is 0.025 mm. The terminal velocity of the block is

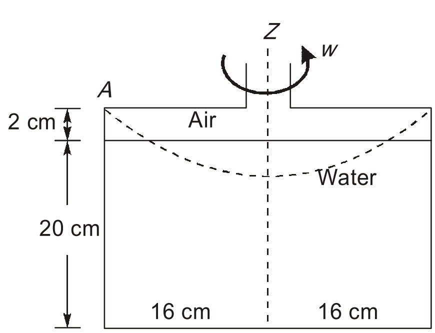


(a) 12.44 m/s (b) 16.89 m/s
(c) 20.44 m/s (d) 22.22 m/s

Q.8 A plate 0.03 mm distant from a fixed plate, moves at 80 cm/s and requires a force of 4 N per unit area to maintain this speed. The fluid viscosity between the plates is
(a) 1.5×10^{-4} poise (b) 2.5×10^{-3} poise
(c) 1.5×10^{-3} poise (d) 2.5×10^{-4} poise

Q.9 The equation of a velocity profile over a plate is $V = 7y^2 + y$ (where V is the velocity in m/s). The viscosity of the liquid is 8.35 poise. The shear stress at $y = 7.5$ cm is
(a) 1.71 N/m^2 (b) 3.42 N/m^2
(c) 4.62 N/m^2 (d) 4.78 N/m^2

Q.10 A cylinder is rotated about the central axis as shown in figure. The force (in N) on the bottom of the cylinder, when the rotation speed is such that the water just touches the point A will be



(a) 157.8 (b) 187.5
(c) 142.1 (d) 117.5

Q.11 The shear stress in a fluid may be expressed as:

$$\tau \propto \left(\frac{dv}{dy}\right)^n$$

where $\frac{dv}{dy}$ is the velocity gradient and n is constant. The n value for Newtonian and Non-newtonian fluids will be respectively
(a) $n = 1$ and $n > 1$ (b) $n < 1$ and $n > 1$
(c) $n = 1$ and $n < 1$ (d) $n = 1$ and $n \neq 1$

Q.12 Classify the fluid based upon the following results of a test on their rheological behaviour

Shear rate, $\frac{\partial u}{\partial y}$	0	0.50	1.0	1.5	2.0
Shear stress, τ	1	2	3	4	5

(a) Ideal fluid (b) Newtonion fluid
(c) Bingham plastic (d) Pseudo plastic

Q.13 The dynamic viscosity of fluid is 0.5 poise and its specific gravity is 0.5. The kinematic viscosity of this fluid (in stokes) is:
(a) 0.25 (b) 0.5
(c) 1.0 (d) 1.5

Q.14 The equation of a velocity distribution over a plate is given by $u = 2y - y^2$ where u is the velocity in m/s at a point y meter from the plate measured perpendicularly. Assuming μ = 8.60 poise, the shear stress at a point 15 cm from the boundary is
(a) 1.72 N/m^2 (b) 1.46 N/m^2
(c) 14.62 N/m^2 (d) 17.20 N/m^2

Directions : Each of the next items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Q.15 **Statement (I):** In general, viscosity in liquids increases and in gases it decreases with rise in temperature.
Statement (II): Viscosity is caused by intermolecular forces of cohesion and due to transfer of molecular momentum between fluid

layers; of which in liquids the former and in gases the later contribute the major part towards viscosity.

Q.16 **Statement (I):** The kinematic viscosity of both air and water decreases as the temperature increases.
Statement (II): The kinematic viscosity of liquids and gases at a given pressure is a function of temperature.

Q.17 Consider the following statements related to the fluid properties:
1. Vapour pressure of water at 373 K is 101.5×10^3 N/m^2.
2. Capillary height in cm for water in contact with glass tube and air is (tube diameter)/0.268.
3. Blood is a Newtonian fluid.

Which of these statements is/are correct?
(a) 1 only (b) 1 and 3
(c) 1 and 2 (d) 2 only

Q.18 Consider the following statements:
1. A small bubble of one fluid immersed in another fluid has a spherical shape.
2. The droplets of a fluid move upward or downward in another fluid due to unbalance between gravitational and buoyant forces.
3. Droplets of bubbles attached to a solid surface can remain stationary in a gravitational fluid if the surface tension exceeds buoyant forces.
4. Surface tension of a bubble is proportional to its radius while buoyant force is proportional to the cube of its radius.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 4 only
(c) 1 and 3 only (d) 2, 3 and 4 only

Q.19 A 150 mm diameter shaft rotates at 1500 rpm within a 200 mm long journal bearing with 150.5 mm internal diameter. The uniform annular space between the shaft and the bearing is filled with oil of dynamic viscosity 0.8 poise. The shear stress on the shaft will be
(a) 1.77 kN/m^2 (b) 2.77 kN/m^2
(c) 3.77 kN/m^2 (d) 4.77 kN/m^2

Q.20 The work done in blowing a soap bubble of diameter 20 cm is ________ $\times 10^{-3}$ Nm.
[Assume the surface tension of soap solution as 0.040 N/m.]
(a) 14.88 (b) 10.05
(c) 6.01 (d) 4.32

Q.21 In an experiment, the tip of a glass tube with an internal diameter of 2 mm is immersed to a depth of 1.5 cm into a liquid of specific gravity 0.85. Air is forced into the tube to form a spherical bubble just at the lower end of the tube. If the air pressure in the bubble is 200 N/m^2, then the surface tension of the liquid will be
(a) 0.018 N/m (b) 0.025 N/m
(c) 0.037 N/m (d) 0.042 N/m

Q.22 If the surface tension at air-water interface is 0.073 N/m, the pressure difference between inside and outside of an air bubble of diameter 0.1 mm will be __________ kPa.

Q.23 If angle of contact of a drop of liquid is acute, then
(a) cohesion is equal to adhesion
(b) cohesion is more than adhesion
(c) adhesion is more than cohesion
(d) both adhesion and cohesion have no connection with angle of contact

Q.24 **Statement (I) :** The mercury level inside the tube shall rise above the level of mercury outside.
Statement (II) : The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.
(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Q.25 The surface tension of water at 20°C is 75×10^{-3} N/m. The difference in water surfaces within and outside an open-ended capillary tube of 1 mm internal bore, inserted at the water surface, would nearly be
(a) 7 mm (b) 11 mm
(c) 15 mm (d) 19 mm

Q.26 A clean tube of internal diameter 3 mm is immersed in a liquid with a coefficient of surface tension of 0.48 N/m. The angle of contact of the liquid with the glass can be assumed to be 130°. The density of the liquid is 13600 kg/m^3. What would be the level of the liquid in the tube relative to the free surface of the liquid outside the tube? [Take sin 40° = 0.643]

(a) 1.54 mm (b) –1.54 mm
(c) 3.08 mm (d) –3.08 mm

Q.27 Consider the following statements:
1. In thixotropic fluid, viscosity decreases at higher shear stress.
2. Viscosity of Rheopactic fluid decreases at higher shear stress.
3. In thixotropic fluid, viscosity increases at higher shear stress.
4. Viscosity of Rheopactic fluid increases at higher shear stress.

Which of the above statements are CORRECT?

(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) None of the above

Q.28 Oil in a hydraulic cylinder is compressed from an initial volume 2 m^3 to 1.96 m^3. If the pressure of oil in the cylinder changes from 40 MPa to 80 MPa during compression, the bulk modulus of elasticity of oil is

(a) 1000 MPa (b) 2000 MPa
(c) 4000 MPa (d) 8000 MPa

Multiple Select Questions (MSQ)

Q.29 Calculate the capillary effect in mm in a glass tube of 4 mm diameter when immersed in water and mercury respectively.
Temperature of the liquid = 20°C
Surface tension of water in contact with air = 0.073 N/m
Surface tension of mercury in contact with air = 0.51 N/m
Angle of contact for water is zero and for mercury is 130°
Density of water = 998 kg/m^3

(a) Capillary rise of 2.46 mm for mercury
(b) Capillary depression of 7.46 mm for water
(c) Capillary depression of 2.46 mm for mercury
(d) Capillary rise of 7.46 mm for water.

Q.30 Consider the following statements:

(a) For rheopectic fluids, apparent viscosity (η) increases with time under constant shear stress.
(b) For thixotropic fluids, dynamic viscosity (μ) decreases with time under constant shear stress.
(c) Variation of viscosity with temperature in case of gases is due to molecular cohesion.
(d) Dilatant fluids are shear thickening fluids.

Q.31 If a tube of diameter 5 mm is inserted in mercury (G_s = 13.6) above which water lies, then the capillary height will be (θ = 120°) (σ = 0.51 N/m)

(a) Capillary rise of 3.30 mm
(b) Capillary depression of 1.65 mm
(c) Capillary depression of 3.30 mm
(d) Capillary rise of 1.65 mm

■■■■

Answers **Fluid Properties**

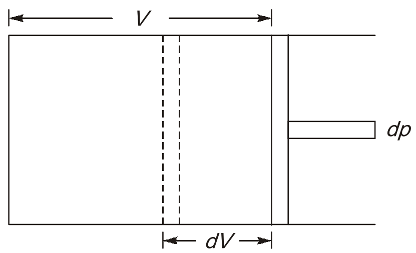
1. (a) 2. (a) 3. (c) 4. (c) 5. (a) 6. 1 7. (c) 8. (c) 9. (a) 10. (a)
11. (d) 12. (c) 13. (c) 14. (b) 15. (d) 16. (d) 17. (a) 18. (a) 19. (c) 20. (b)
21. (c) 22. 2.92 23. (c) 24. (d) 25. (c) 26. (d) 27. (b) 28. (b) 29. (c, d)
30. (a, b, d) 31. (b)

Explanations **Fluid Properties**

1. (a)

Bulk modulus,

$$K = -\frac{dp}{dv/v} \quad \text{... (i)}$$



Specific volume,

$$v = \frac{1}{\rho} = \rho^{-1}$$

Taking $\log_e$ both sides, we get

$$\log_e v = -\log_e \rho$$

On differentiating

$$\frac{dv}{v} = -\frac{d\rho}{\rho}$$

Substituting $\frac{dv}{v} = -\frac{d\rho}{\rho}$ in Eq (i), we get

$$K = \frac{-dp}{-d\rho/\rho} = \rho\frac{dp}{d\rho}$$

3. (c)

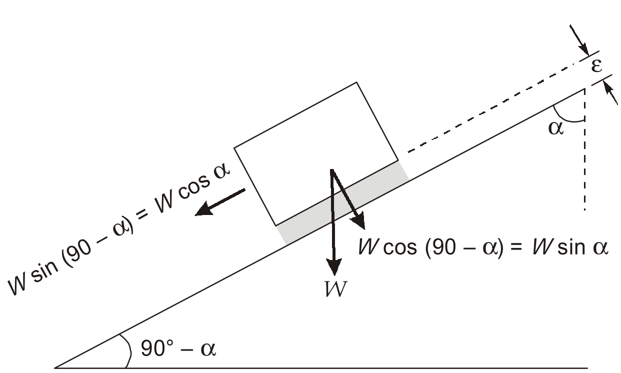
$$K = \frac{\rho dp}{d\rho}$$

$$\frac{d\rho}{\rho} = \frac{\rho g dh}{K}$$

$$\left[-\frac{1}{\rho}\right]_{\rho}^{\rho_0} = \frac{gh}{K}$$

$$h = \frac{K}{g}\left[\frac{1}{\rho_0} - \frac{1}{\rho}\right]$$

4. (c)



For zero acceleration,

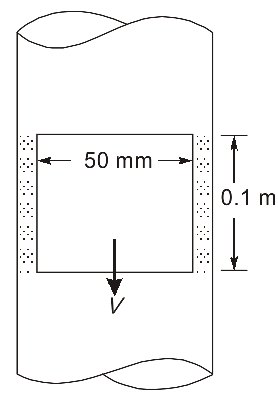
$$W\cos\alpha = \text{Drag force}$$

$$\text{Here, Drag force} = \text{Shear force} = \mu A\frac{V}{\varepsilon}$$

$$\Rightarrow \quad W\cos\alpha = \mu A\frac{V}{\varepsilon}$$

$$\Rightarrow \quad V = \frac{\varepsilon W\cos\alpha}{\mu A}$$

5. (a)



Let V be its terminal velocity of fall

Shear stress τ will be

$$\tau = \mu\frac{dv}{dy} = 1.9 \times \frac{V}{1 \times 10^{-3}}$$

$$= 1.9 \times 10^3 \, V \, \text{N/mm}^2$$

The shear stress will act on the surface of the cylinder.

Hence, Total force,

$$F = \tau \times A$$

$$= 1.9 \times 10^3 \times V \times 3.142 \times 50 \times 10^{-3} \times 0.1$$

$$= 29.849 \, U$$

Under equilibrium condition, the weight will be balanced by total shear force.

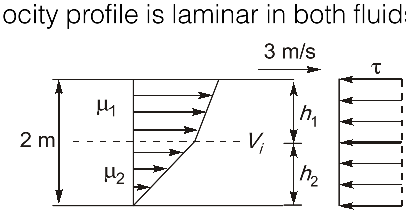
Hence,

$$16 = 29.849 \, U$$

or $\quad U = 0.536$ m/s

6. (1)

Velocity profile is laminar in both fluids



$$\frac{d^2u}{dy^2} = 0$$

$$\frac{du}{dy} = c_1$$

$$u = c_1 y + c_2$$

i.e. we can assume linear velocity profile.

If velocity profile is linear shear stress will be constant in gap everywhere i.e. in fluid (1) and fluid (2)

Also at the interface shear stress will be constant.

$$\tau_1 = \tau_2$$

$$\mu_2 \frac{V_i}{h_2} = \mu_1 \frac{(V - V_i)}{h_1}$$

where V_i is velocity at the interface.

$$2\mu_1 \frac{V_i}{1} = \frac{\mu_1(3 - V_i)}{1}$$

$$2V_i = 3 - V_i$$

$$3V_i = 3$$

$$V_i = 1 \text{ m/s}$$

7. (c)

Weight of block = 25 kg

Block dimensions = 30 × 30 × 30 cm^3

Driving force along the plane,

$$F = W \sin 30°$$
$$= 30 \times 9.81 \times 0.5$$
$$= 147.15 \text{ N}$$

Shear force, $\tau = \frac{F}{A} = \frac{147.15}{(0.3)^2} = 1635 \text{ N/m}^2$

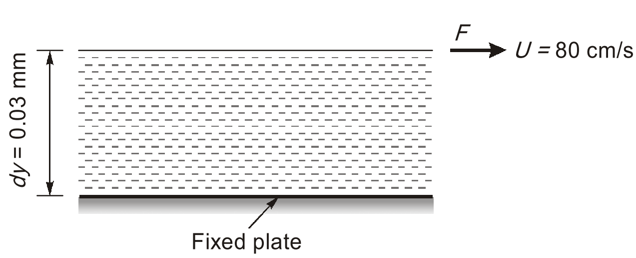
Contact area, $A = 0.3 \times 0.3 \text{ m}^2$

Also, $\tau = \mu \frac{dv}{dy}$

$$\Rightarrow 1635 = 2 \times 10^{-3} \times \frac{V}{0.025 \times 10^{-3}}$$

$$\Rightarrow V = \frac{1635 \times 0.025}{2} = 817.5 \times 0.25 = 20.44 \text{ m/s}$$

8. (c)



Distance between plates,

$$dy = 0.03 \text{ mm} = 3 \times 10^{-5} \text{ m}$$

Velocity of upper plate,

$$u = 80 \text{ cm/s} = 0.8 \text{ m/s}$$

Force on upper plate,

$$F = 4 \text{ N/m}^2$$

This is the value of shear stress i.e. τ

Let the fluid viscosity between the plates is μ

$$\Rightarrow \tau = \mu \frac{du}{dy}$$

$$4.0 = \mu \times \frac{0.80}{3 \times 10^{-5}}$$

$$\mu = \frac{4 \times 3 \times 10^{-5}}{80} = \frac{3 \times 10^{-5}}{20} = 0.15 \times 10^{-5}$$

$= 1.5 \times 10^{-4} \times 10$ poise $= 1.5 \times 10^{-3}$ poise

9. (a)

Velocity profile,

$$V = 7y^2 + y$$

Coefficient of dynamic viscosity,

$$\mu = 8.35 \text{ poise} = 8.35 \times 10^{-1} \text{ Ns/m}^2$$

Velocity gradient,

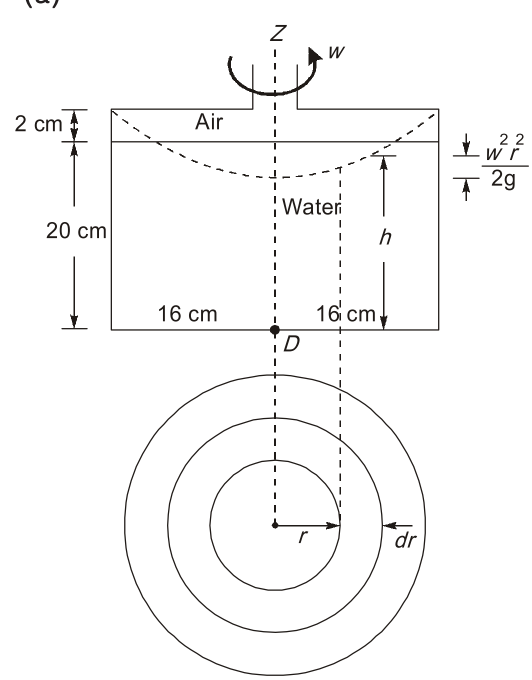
$$\frac{dv}{dy} = 14y + 1$$

$$\tau = \mu \frac{dV}{dy} = \mu(14y + 1)$$

At $y = 7.5 \text{ cm} = 0.075 \text{ m}$

$$\tau = 8.35 \times 10^{-1} \times (14 \times 0.075 + 1)$$
$$= 1.71 \text{ N/m}^2$$

10. (a)



$\because$ Water just touches point A

$$\therefore 0.04 = \frac{w^2(0.16)^2}{2g}$$

$$dF = \text{Pressure} \times \text{Area} = \rho g h \times 2\pi r dr$$

$$\therefore \quad F = \int dF$$

$$= \int \rho g\left(0.18 + \frac{w^2r^2}{2g}\right) \times 2\pi r dr$$

$$\Rightarrow \quad F = 2\pi\rho g \int_0^{0.16}\left(0.18 + \frac{w^2r^2}{2g}\right) r dr$$

$$= 2\pi\rho g\left[\frac{0.18r^2}{2} + \frac{w^2}{2g} \times \frac{r^4}{4}\right]_0^{0.16}$$

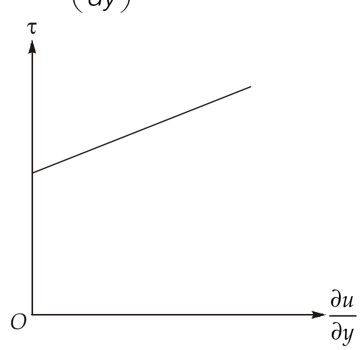
$$= 2\pi\rho g\left[0.09(0.16)^2 + \frac{w^2(0.16)^2}{2g} + \frac{(0.16)^2}{4}\right]$$

$$= 157.8 \text{ N}$$

12. (c)

Given fluid has linear shear stress vs shear rate behaviour, however at $\frac{\partial u}{\partial y} = 0$, the shear stress is 1 unit. Hence the fluid is classified as Bingham plastic. A general relationship between shear stress and velocity gradient (rate of shear strain) for non-newtonion fluid is

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$



At $\tau = 1$ and $\frac{du}{dy} = 0$

$B \neq 0$ and also, $n = 1$

$\Rightarrow$ Fluid is Bingham plastic.

13. (c)

Poise is the unit of dynamic viscosity (μ) in C.G.S. system. Stokes is the unit of kinematic viscosity (v) in C.G.S. system.

$$\text{Specific gravity } G = \frac{\rho}{\rho_w} = \frac{(\mu/v)}{\rho_w}$$

$$\therefore \quad v = \frac{0.5}{0.5} = 1 \text{ stokes}$$

14. (b)

$$\frac{du}{dy} = 2 - 2y; \quad \left.\frac{du}{dy}\right|_{y=0.15} = 1.7$$

$$\tau = \mu\frac{du}{dy} = 0.86 \times 1.7 = \textbf{1.46 N/m}^2$$

15. (d)

In liquid, viscosity is due to cohesion with rise in temperature, volume of liquid increases, the distance between molecules increases, thus decreasing the cohesion. Therefore the viscosity of liquid decreases with rise in temperature.

In case of gases, viscosity is due to molecular momentum exchange with rise in temperature of gas, kinetic energy of molecules increases, thus increasing the molecular momentum exchange. Therefore, the viscosity of gases increases with rise in temperature.

16. (d)

When temperature is increased the reduction of cohesion in the water molecules reduces viscosity. For air, the molecular momentum transfer increases and the viscosity also increases.

17. (a)

Only first statement is correct.

(i) Vapour pressure of water at 373K is $101.5 \times 10^3 \times$ N/m^2

(ii) Capillary height in cm for water in contact with glass tube = 0.3/d

(iii) Blood is a pseudoplastic fluid.

20. (b)

The soap bubble has two interfaces and thus work done

= Surface tension × Total surface area

$$= 0.040 \times 4\pi \times \left(\frac{20}{2} \times 10^{-2}\right)^2 \times 2$$

$$= 10.05 \times 10^{-3} \text{ N.m}$$

21. (c)

Pressure inside the bubble = 200 N/m^2

Pressure outside the bubble = $\rho g h$

$$= 1000 \times 9.81 \times \frac{1.5}{100} \times 0.85 = 125.1 \text{ N/m}^2$$

$$\because \quad \Delta P = \frac{2\sigma}{R} = (200 - 125.10) = \frac{2 \times \sigma}{1 \times 10^{-3}}$$

$$\Rightarrow \quad \sigma = 0.037 \text{ N/m}$$

22. (2.92)

Air bubble in water will have only one surface,

$$\Delta p = \frac{2\sigma}{R} = \frac{2 \times 0.073}{\left(\frac{0.1}{2}\right) \times 10^{-3}} = 2920 \text{ N/m}^2$$

$$= 2.92 \text{ kPa}$$

24. (d)
Cohesive force is the action or property of like molecules sticking together, being mutually attractive. Mercury has large adhesion force with most container materials and strong cohesive forces. This causes the depression in mercury level inside the tube.

25. (c)
In this problem, the bore is not defined properly. Here bore is used for radius.

$$h = \frac{2\sigma\cos\theta}{\rho \cdot g \cdot R}$$

$$= \frac{2\left(75\times10^{-3}\right)}{10^3\times9.81\times\left(1\times10^{-3}\right)}$$

$$= 15.29 \text{ mm}$$

26. (d)
The capillary rise,

$$h = \frac{4T\cos\theta}{\rho g d}$$

$\because$ cos 130° = cos (90° + 40°) = –sin 40°

$$\therefore \quad h = -\frac{4\times0.48\times(0.643)}{13600\times9.81\times3\times10^{-3}}$$

$$= -3.08\times10^{-3} \text{ m} = -3.08 \text{ mm}$$

Therefore, there is capillary depression of 3.08 mm.

28. (b)
Given data:

$V_1 = 2\ m^3$, $V_2 = 1.96\ m^3$

$\therefore \quad dV = V_2 - V_1 = 1.96 - 2 = -0.04\ m^3$

$p_1 = 40$ MPa, $p_2 = 80$ MPa

$\therefore \quad dp = p_2 - p_1 = 80 - 40 = 40$ MPa

Bulk modulus of elasticity,

$$K = -\frac{dp}{dV/V_1} = -V_1\frac{dp}{dV} = \frac{-2\times40}{-0.04}$$

$$= \mathbf{2000\ MPa}$$

29. (c, d)
Diameter of tube = 4×10^{-3} m

$$h = \frac{4\sigma}{\rho g d}$$

$$= \frac{4\times0.073\times\cos0°}{998\times9.81\times4\times10^{-3}}$$

$$= 7.46\times10^{-3} \text{ m}$$

In case of mercury

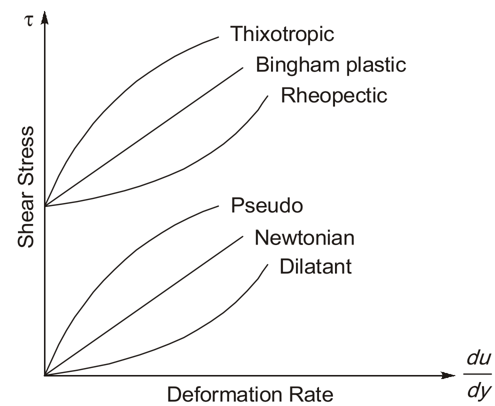
$$h = \frac{4\sigma\cos\theta}{\rho_{Hg} g d}$$

$$= \frac{4\times0.51\times\cos130°}{13.6\times998\times9.81\times4\times10^{-3}}$$

$$= -2.46\times10^{-3} \text{ m} = -2.46 \text{ mm}$$

(–ve) sign indicates capillary depression of 2.46 mm.

30. (a, b, d)



(a) In Rheopectic fluids, apparent viscosity increases with time under constant shear stress.
(b) In Thixotropic fluids apparent viscosity decreases with time under constant shear stress but dynamic viscosity remains constant.
(c) Variation of viscosity is gases is due to molecular momentum transfer (number of collisions).
(d) Dilatant fluid is shear thickening fluid.

31. (b)
For tube of radius '*r*' inserted in mercury also which another liquid is placed then capillary rise.

$$h = \frac{2\sigma\cos\theta}{r\gamma_w(S_1 - S_2)}$$

$$= \frac{2\times0.51\times\cos120°}{(2.5\times10^{-3})\times9.81\times(13.6-1)}$$

$$= -1.650\times10^{-3} \text{ m}$$

$$= -1.65 \text{ mm}$$

$\therefore$ There is capillary depression of 1.65 mm.

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ENVIRONMENTAL ENGINEERING

OBJECTIVE PRACTICE SETS

Page No. 178 - 263

Water Demand

Q.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Freeman's formula
B. Kuichling's formula
C. Boston's formula
D. National Board of Fire Underwriters formula

List-II

1. $4637\sqrt{P}\left[1-0.01\sqrt{P}\right]$
2. $1136\left[\frac{P}{5}+10\right]$
3. $5663\sqrt{P}$
4. $3182\sqrt{P}$

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	2	1	3	4
(c)	3	1	2	4
(d)	3	4	2	1

Q.2 The design period for demand reservoir as recommended by the GOI manual on water supply is

(a) 30 years (b) 50 years
(c) 15 years (d) 40 years

Q.3 Which of the following are correctly matched pairs?

1. Arithmetic increase method : Old cities only
2. Geometric increase method : New cities only
3. Incremental increase method: Old cities only

Select the correct option

(a) 1 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1, 2 and 3

Q.4 The total water requirement of a city is generally assessed on the basis of

(a) maximum hourly demand
(b) maximum daily demand + fire demand
(c) average daily demand + fire demand
(d) greater of (a) and (b)

Q.5 The per capita water demand includes

(a) domestic water demand only
(b) domestic and commercial demand
(c) domestic, commercial and industrial demand
(d) domestic, commercial, public, fire and industrial demand

Q.6 Per capita demand for water is affected by which of the following:

1. Size of the city
2. System of supply
3. Cost of water
4. Climatic conditions

Select the correct answer:

(a) 1 and 2 (b) 1, 3 and 4
(c) 1, 2 and 3 (d) 1, 2, 3 and 4

Q.7 If the average weekly consumption of a city is 650000 m^3, the maximum weekly consumption will be

(a) 832000 m^3 (b) 962000 m^3
(c) 1170000 m^3 (d) 1755000 m^3

Q.8 Which of the following factors govern design period of a water supply unit?

(a) Useful life of component structures
(b) Ease and difficulty that is likely to be faced in expansions, if undertaken at future dates
(c) Both (a) and (b)
(d) None of the above

Q.9 The fire demand of a city having a population of 140000 using "National Board of Fire Underwriter's formula” will be ________ cumecs.

Q.10 In a city with a population of 70,000 water is drawn for domestic purpose from a bell-mouth intake in a canal which runs only for 10 hours a day with flow depth of 1.5 m. If the average consumption per person is 150 lpd, then the intake load is

(a) $0.31\ m^3/s$ (b) $0.29\ m^3/s$
(c) $0.27\ m^3/s$ (d) $0.25\ m^3/s$

Q.11 If the population of a growing town in three consecutive decades are 42000, 50000 and 55000, then the saturation value of population of town is

(a) 56233 (b) 70539
(c) 58278 (d) 60526

Q.12 The population of a town in four consecutive year are 5500, 6800, 7500 and 8150 respectively. The population of the town in the fifth consecutive year according to geometrical increase method is

(a) 8321 (b) 8926
(c) 9291 (d) 9829

Q.13 In the equation $P = \dfrac{P_s}{1 + m\log_e^{-1}(nt)}$ of a logistic curve of population growth, 'n' is

(a) $2.3t_1\log_{10}\left[\dfrac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$

(b) $\dfrac{2.3}{t_1}\log_{10}\left[\dfrac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$

(c) $\dfrac{2.3}{t_1}\log_{10}\left[\dfrac{P_1(P_s - P_0)}{P_0(P_s - P_1)}\right]$

(d) $2.3t_1\log_{10}\left[\dfrac{P_1(P_s - P_0)}{P_0(P_s - P_1)}\right]$

Q.14 **Statement (I):** The future population is predicted on the basis of knowledge of city and its environment.

Statement (II): The future population depends on the trade and expansion of the city, discovery of mineral deposits, power generation, etc.

(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Multiple Select Questions (MSQ)

Q.15 In estimating population for assessing water supply demand, using geometric progression method, which of the following statement(s) is/are correct?

(a) This method gives conservative higher values of forecasted population.
(b) In this method percentage growth rate is assumed to be constant.
(c) This method gives correct estimates for a developed city.
(d) In this method, compounding is done every decade.

Q.16 For projecting the population of the town in the year AD 2000 by incremental increase method the following data was available:

Year	Population
1940	25000
1950	27500
1960	34100
1970	41500
1980	54500

Assume the rate of water supply is 200 lpcd in the year 2000. Which of the following option(s) is/are correct?

(a) Expected population at the end of year 2000 is 69250.
(b) Water requirement in year 2000 is 13.85 MLD.
(c) Expected population at the end of year 2000 is 79750.
(d) Water requirement in year 2000 is 15.95 MLD.

■■■■

Answers Water Demand

1. (a)	2. (b)	3. (c)	4. (d)	5. (d)	6. (d)	7. (b)	8. (c)	9. 0.806
10. (b)	11. (d)	12. (c)	13. (b)	14. (b)	15. (a, b, d)		16. (c, d)	

Explanations Water Demand

2. (b)
Design period of demand reservoir in recommended to be of 50 year. Design life of pipe caring raw water as well as treated water in recommended to be 30 years.

3. (c)
Geometric increase method gives high results which is suitable for cities growing with fast rate such as new cities whereas arithmetic increase method gives low results which is suitable for cities growing with slow rate such as old cities, however, incremental increase method gives moderate results which can be used for new and old cities both.

4. (d)
For general community purposes, the total draft is not taken as the sum of maximum hourly demand and fire demand, but is taken as the sum of maximum daily demand and fire demand, or the maximum hourly demand, whichever is more. The maximum daily demand (i.e. 1.8 times the average daily demand) when added to fire draft for working out total draft, is known as coincident draft.

6. (d)
Factors affecting per capita demand for water are:
- Size of city
- Climatic conditions
- Type of gentry and habits of people
- Industrial and commercial activities
- Quality of water supply
- Pressure in the distribution systems
- Development of sewage facilities
- System of supply
- Cost of water
- Policy of metering and method of charging

7. (b)
According to Godrich, the ratio of maximum weekly demand to average weekly demand is 1.48.
So, maximum weekly consumption

$$= 1.48 \times 650000 = 962000 \text{ m}^3$$

9. 0.806 (0.750 to 0.850)
According to National Board of Fire Underwriter's formula,
Fire demand,

$$Q = 4637\sqrt{P}\left(1-0.01\sqrt{P}\right)$$

[Where P in thousand]

$$= 4637\sqrt{140}\left(1-0.01\sqrt{140}\right) l/\text{min}$$

$$= 48374 \text{ litres/min}$$

$$= 0.806 \text{ cumecs}$$

10. (b)
Average daily requirement of water

$$= 70{,}000 \times 150 = 10500 \text{ m}^3/d$$

This water shall be withdrawn in 10 hours. So

$$\text{Intake load} = \frac{10500}{60 \times 10 \times 60} = \frac{10.5}{36}$$

$$= \frac{3.5}{12} = 0.29 \text{ m}^3/\text{s}$$

11. (d)
Using logistic curve method;
Saturation population is given as,

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

where, $P_0 = 42000$
$P_1 = 50000$
$P_2 = 55000$

So we get,

$$P_s = 60526$$

12. (c)

Assumed growth rate,

$$r = \left(\frac{P_2}{P_1}\right)^{1/t} - 1$$

where,

P_2 is final known population = 8150

P_1 is initial known population = 5500

t is no. of years (period) between P_1 and P_2,

$t = 3$

So, $$r = \left(\frac{8150}{5500}\right)^{1/3} - 1 = 0.14$$

or, r = 14%

Population of town in fifth consecutive year,

$$P_5 = P_4\left(1+\frac{r}{100}\right)^1$$

$$= 8150 \times 1.14 = 9291$$

13. (b)

According to P.F. verhulst, the logistic curve is represented by equation

$$\log_e\left(\frac{P_s - P}{P}\right) - \log_e\left(\frac{P_s - P_0}{P_0}\right) = -K P_s t$$

$$\therefore \log_e\left[\left(\frac{P_s - P}{P_0}\right)\times\left(\frac{P_0}{P_s - P_0}\right)\right] = -K P_s t$$

or, $$\frac{P_s - P}{P}\times\frac{P_0}{P_S - P_0} = \log_e^{-1}(-K P_s t)$$

or, $$P = \frac{P_s}{1+\left(\frac{P_s - P_0}{P_0}\right)\log_e^{-1}(-K P_s t)}$$

Assume $m = \frac{P_s - P_0}{P_0}$ where and $n = -K\,P_s$ are constant.

If three pairs of characteristic value P_0, P_1 and P_2 at time $t = t_0$, $t = t_1$ and $t_2 = 2t$ are selected, the value of m and n can be found as follows;

$$n = \frac{1}{t_1}\log_e\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

Option (b) is correct.

15. (a, b, d)

This method is suitable for young cities and rapidly developing cities with a vast scope of expansion.

16. (c, d)

Year	Population	Increase in Population	Increment over the increase
1940	25000		
1950	27500	2500	
1960	34100	6600	4100
1970	41500	7400	800
1980	54500	13000	5600
Total		29500	10500
Average per decade		$\bar{x} = 7375$	$\bar{y} = 3500$

$$\therefore \quad P_{2000} = 54500 + 2\times 7375 + \frac{2\times 3}{2}\times 3500$$

$$= 79750$$

Water requirement @ 200 lpcd

$$= \frac{79750\times 200}{10^6}\text{ MLD} = 15.95\text{ MLD}$$

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ENGINEERING HYDROLOGY

OBJECTIVE PRACTICE SETS

Page No. 264 - 326

1 CHAPTER

Introduction and General Aspect of Hydrology

Q.1 What is 'Hydrological Cycle?
(a) Processes involved in the transfer of moisture from sea to land
(b) Processes involved in the transfer of moisture from sea back to sea again
(c) Processes involved in the transfer of water from snowmelt in mountains to sea
(d) Processes involved in the transfer of moisture from sea to land and back to sea again

Q.2 If the average annual rainfall and evaporation over land masses and oceans of the earth are considered it would be found that
(a) over the land mass the annual evaporation is the same as the annual precipitation
(b) about 9% more water evaporates from the oceans than what falls back on them as precipitation
(c) over the ocean about 19% more rain falls than what is evaporated
(d) over the oceans about 19% more water evaporates than what falls back on them as precipitation

Q.3 The hydrologic equation states that :
(a) Σ Inflow – Σ outflow = constant
(b) Sub-surface inflow = sub-surface outflow
(c) Inflow into the basin = outflow from the basin
(d) Inflow – outflow = change in storage

Q.4 A watershed has an area of 300 ha. Due to a 10 cm rainfall event over the watershed a stream flow is generated and at the outlet of the watershed it lasts for 10 hours. Assuming a runoff/rainfall ratio of 0.20 for this event, the average stream flow rate at the outlet in this period of 10 hours is
(a) 1.33 m^3/s (b) 16.7 m^3/s
(c) 100 m^3/minute (d) 60000 m^3/h

Q.5 Rainfall of intensity of 20 mm/h occurred over a watershed of area 100 ha for a duration of 6 h. measured direct runoff volume in the stream draining the watershed was found to be 30,000 m^3. The precipitation not available to runoff in this case is
(a) 9 cm (b) 3 cm
(c) 17.5 mm (d) 5 mm

Q.6 A catchment of area 120 km^2 has three distinct zones as below:

Zone	Area (km^2)	Annual runoff (cm)
A	61	52
B	39	42
C	20	32

The annual runoff from the catchment, is
(a) 126.0 cm (b) 42.0 cm
(c) 45.4 cm (d) 47.3 cm

Q.7 The quantitative statement of the balance between water gains and losses in a certain basin during a specified period of time is known as which one of the following ?
1. Water budget
2. Hydrologic budget
3. Ground budget
(a) 1 only (b) 2 only
(c) 3 only (d) None of these

Q.8 Which one of the following pairs is not correctly matched?
(a) Water losses — Evaporation
(b) Runoff — Stream flow
(c) Percolation — Soil erosion
(d) Storm — Precipitation

Q.9 The total rainfall precipitated during a storm is 10.0 mm and the antecedent moisture at the root in the soil was 5.0 mm, the loss of water due to seepage was 2.5 mm, losses due to percolation 2.0 mm, surface run-off 3.0 mm and the moisture retained in the soil is 1.0 mm. The amount of evapotranspiration from the area will be _________ mm.

Q.10 A reservoir has average water spread over 4 km^2. During two months period of study, surface inflow = 240 ha-m, surface outflow = 192 ha-m: rainfall = 28 cm; change in storage = (+)72 ha-m. By the hydrologic equation, the estimated reservoir losses are

(a) 160 ha-m (b) 120 ha-m
(c) 88 ha-m (d) 232 ha-m

Q.11 The catchment area of the irrigation tank is 50 km^2. The uniform precipitation in the month of October over the catchment was recorded to be 100 mm. 60% of the precipitation reaches the tank. The irrigation canal discharges at a uniform rate of 1 m^3/s in this month. If seepage loss is 50% of the evaporation loss, then evaporation loss is _______ $\times$ 10^6 m^3.

[Assume losses take place due to evaporation and seepage only]

(a) 0.33 (b) 0.21
(c) 0.495 (d) 1.5

Q.12 A reservoir receives 5 ha-m water and the loss due to evaporation from the pan is 11 cm. It receives the rainfall of 5 cm over its plan area of 100 ha. The decrease in the level is observed as 3 cm. Taking the pan factor as 0.7, loss due to seepage will be

(a) 5 ha-m (b) 6 ha-m
(c) 7.3 ha-m (d) 5.3 ha-m

Q.13 **Statement (I):** Condensation of water vapour into droplets precedes the precipitation process.

Statement (II): Formation of precipitation droplets is predicted on the presence of condensation nuclei.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

Q.14 The average surface area of a reservoir in the month of June is 20 km^2. In the same month, the average rate of inflow is 10 m^3/s, outflow rate is 15 m^3/s, monthly rainfall is 10 cm, monthly seepage loss is 1.8 cm and the storage change is 16 million m^3. The evaporation (in cm) in that month is

(a) 46.8 (b) 136.0
(c) 13.6 (d) 23.4

Q.15 Which of the following components of precipitation constitute direct runoff?

1. Snow melt
2. Through flow
3. Rainfall on the surface of the stream

Select the correct answer using the codes given.

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

Q.16 Consider the following statements regarding hydrological cycle:

1. The hydrological cycle is sun driven process.
2. It is existing 1 km in lithosphere and 15 km in troposphere in tropical region.
3. Convenient starting point to describe the cycle is Oceans.

Which of the above statement(s) is/are correct?

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

Q.17 **Statement (I):** Residence time of Ocean is larger than that of global ground water.

Statement (II): Oceans have a large amount of water.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

Q.18 A rainfall of 2 cm/hr is occurred in a catchment. Due to catchment divide 30% of the rainfall will be discharge in a stream "*A*". Actual discharge in stream is reached as 0.6 m^3/sec.

If catchment area is 0.864 km^2. Then the area of catchment leakage ________ km^2.

(If runoff coefficient equal to 0.5)

Q.19 An unregulated stream provides the following volumes through each successive 4-day period over a 40 day duration at a possible reservoir site of storage capacity 16 m^3. The average outflow needed in 4 days to ensure maintaining the constant flow over these 40 days is _______ Mm^3. (If the reservoir is full to start with)

(Day)	0	4	8	12	16	20	24	28	32	36	40
Runoff Vol. (Mm^3)	0	9.6	5.4	2.3	3.5	2.3	2.2	1.4	6.4	12.4	10.9

Q.20 If the total rainfall precipitated during a storm is 10.0 mm. Given, the antecedent moisture at the root in the soil was 5.00 mm, the loss of water due to seepage 2.5 mm, losses due to percolation 2.00 mm, surface runoff 3.00 mm, and the moisture retained in the soil is 1.00 mm, then the amount of evapotranspiration from an area is

(a) 6.5 mm (b) 2.9 mm
(c) 8.4 mm (d) 9.2 mm

Answers — Introduction and General Aspect of Hydrology

1. (d)	2. (b)	3. (d)	4. (c)	5. (a)	6. (c)	7. (a)	8. (c)	9. 6.5	10. (c)
11. (b)	12. (d)	13. (a)	14. (d)	15. (d)	16. (d)	17. (a)	18. 0.144	19. 5.64	20. (a)

Explanations — Introduction and General Aspect of Hydrology

1. (d)

Most of the earth's water sources such as rivers, lakes, oceans, ground water, etc. get their supplies from rain, while the rain water in itself is derived from the evaporation from these sources. Water is infect lost to the atmosphere as vapour from the earth, which is then precipitated back in the form of rain, snow, hail, dew, sleet or frost, etc. This evaporation and precipitation continues forever and thereby, a balance is maintained between the two. This process is known as 'Hydrologic Cycle'.

3. (d)

The hydrologic equation is based on the law of conservation of mass and it state that

Mass inflow – mass outflow = Change in storage

$$I - O = \Delta_{storage}$$

4. (c)

Given, Area of watershed = 300 ha

Rainfall = 10 cm

Duration = 10 hrs

$$\frac{\text{Run-off}}{\text{Rainfall}} = 0.2$$

∴ Runoff = 0.2 × 10 = 2 cm

Average stream flow rate

$$= \frac{2\times10^{-2}\times300\times10^{4}}{10\times60}$$

$$= 100 \text{ m}^3\text{/minute}$$

5. (a)

Total precipitation

$$= 20 \times 6 = 120 \text{ mm} = 12 \text{ cm}$$

Total runoff

$$= \frac{30000}{100\times10^{4}} = 3\times10^{-2} \text{ m}$$

$$= 3 \text{ cm}$$

Precipitation not available to runoff

$$= 12 - 3 = 9 \text{ cm}$$

6. (c)

Annual runoff from the catchment

$$= \frac{\Sigma RA}{\Sigma A}$$

$$= \frac{61\times52+39\times42+20\times32}{120}$$

$$= 45.42 \text{ cm}$$

7. (a)

For a particular basin or catchment the equation showing the water gains and losses during a specified period of time is called water budget equation.

8. (c)

- Due to evaporation water losses occur.
- As a result of runoff, stream flow is generated.
- Percolation (infiltration) occurs due to vegetation, there is no soil erosion.
- Due to precipitation, storm generates.

9. 6.5 (5.9 to 6.9)

From water budget equation,

P + R – G – E – T= ΔS

Total rainfall, P = 10 mm

Antecedent moisture at root in the soil = 5 mm

Loss of water due to seepage = 2.5 mm

Loss of water due to percolation = 2 mm

Surface runoff = 3 mm

Moisture retained in the soil = 1 mm

So, 10 + 5 – 2.5 – 2 – 3 – T = 1

$\Rightarrow \quad 7.5 - T = 1$

$\Rightarrow \quad T = 6.5$ mm

∴ Amount of evapotranspiration = 6.5 mm

10. (c)

Area = 4 km^2

Surface inflow = 240 ha-m

Surface outflow = 192 ha-m

Rainfall = 28 cm

Change in storage

= +72 ha-m

Total mass inflow

= 240 ha-m + rainfall

= 240 ha-m + 0.28 × 400

= 352 ha-m

Let losses are Δ_L,

Using hydrologic equation,

Mass inflow – Mass out flow

= Change in storage

$352 - (192 + \Delta_L) = 72$

$\Delta_L = 352 - 192 - 72$

= 88 ha-m

Hence option (c) is correct.

11. (b)

$$\text{Total inflow} = 50 \times 10^6 \times \frac{100}{1000} \times 0.6 = 3 \times 10^6 m^3$$

Outflow from canal = 1 × 3600 × 24 × 31

= 2.678×10^6 m^3

∴ Loss of water = $3 \times 10^6 - 2.678 \times 10^6$

= 0.322×10^6 m^3

= Seepage loss + Evaporation loss

Since seepage loss = 50% of evaporation loss

∴ 1.5 × evaporation loss = 0.322×10^6

$$\text{Evaporation loss} = \frac{0.322 \times 10^6}{1.5} = 0.21 \times 10^6 \ m^3$$

12. (d)

$$\text{Evaporation loss} = 100 \times \frac{11}{100} \times 0.7 = 7.7 \text{ ha-m}$$

$$\text{Rainfall} = 100 \times \frac{5}{100} = 5 \text{ ha-m}$$

$$\text{Change in storage} = 100 \times \frac{3}{100} = 3 \text{ ha-m}$$

Now, (I + P) – (E + Seepage loss) = ΔS

⇒ (5 + 5) – (7.7 + X) = –3

⇒ 10 – 7.7 – X = –3

X = Seepage loss

= 5.3 ha-m

13. (a)

When water is saturated locally in the atmosphere, the water condenses and precipitates. Sufficient water nuclei must be present to aid condensation and thus cause precipitation.

14. (d)

Let 'x' cm evaporation takes place in month of June.

Total inflow = I + P

$$= \left(\frac{10 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100\right) + 10$$

= 139.6 cm

Total outflow = Q+ S+ E

$$= \left(\frac{15 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100\right) + 1.8 + x$$

= 196.2 + x cm

As total outflow is more than total inflow, therefore depression in storage takes place.

Depression in storage

$$= -\frac{16 \times 10^6}{20 \times 10^6} \times 100 = -80 \text{ cm}$$

⇒ 139.6 –(196.2 + x) = – 80

$-x$ = –80 + 56.6

∴ x = 23.4 cm

15. (d)

Direct runoff is that part of runoff which enters the stream immediately after the rainfall. It includes surface runoff, through flow and rainfall on the surface of stream. In case of snow melt, the resulting flow entering the stream is also a direct runoff.

A part of the precipitation that infilterates and moves laterally through upper crusts of the soil and returns to the surface at some location away from point of entry into the soil. This component of runoff is known variously as inter flow, through flow, storm seepage, sub-surface storm flow or quick return flow.

17. (a)

Large amount of water in the Oceans reflect the long residence time in Ocean.

18. 0.144 (0.10 to 0.16)

$$\text{Total discharge} = \frac{0.02 \times 0.864 \times 10^6}{3600}$$

$$= 4.8 \text{ m}^3/\text{sec}$$

$$\text{Runoff} = 0.5 \times 4.8 = 2.4 \text{ m}^3/\text{sec}$$

30% will be given to stream A

$$= 0.3 \times 2.4 = 0.72 \text{ m}^3/\text{sec}$$

But actually discharge = 0.6 m^3/sec

$$\therefore \text{ Catchment leakage} = \left(\frac{0.72 - 0.6}{0.72}\right) = 0.1666$$

So, area of catchment leakage

$$= 0.1666 \times 0.864 = 0.144 \text{ km}^2$$

19. 5.64 (5 to 6)

Total runoff volume

= 9.6 + 5.4 + 2.3 + 3.5 + 2.3 + 2.2 + 1.4 + 6.4 + 12.4 + 10.9 = 56.4 Mm^3

$$\text{Average flow} = \frac{56.4}{40} = 1.41 \text{Mm}^3/\text{day}$$

$\therefore$ Average flow in 4-days = 4 × 1.41 = 5.64 Mm^3

20. (a)

Given: Total rainfall (P) = 10 mm

Antecedent moisture in root, (R) = 5 mm

Seepage loss, (L_s) = 2.5 mm

Percolation loss, (L_p) = 2.0 mm

Surface runoff, (L_R) = 3 mm

Moisture retained in soil = 1 mm

As per water budget equation,

$P + R - L_S - L_P - L_R - L_e$ = Moisture retained

L_e = Loss due to evapotranspiration

$10 + 5 - 2.5 - 2.0 - 3 - L_e = 1.0$

$L_e = 6.5$ mm

$\therefore$ Amount of evapotranspiration = 6.5 mm.

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