Day 05

PERMEABILITY

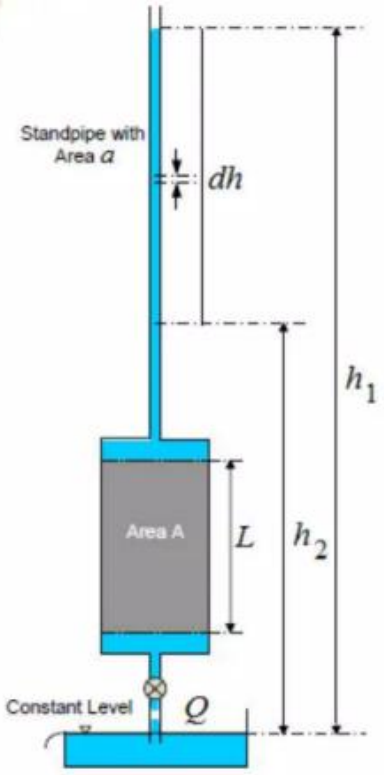
- Property of soil which enables the flow of water through it.
- Or, It is the property which describes quantitatively, the ease with which water flows through that soil.
- **DARCY LAW:**
  - In 1856, Darcy demonstrated experiment that for laminar flow in a homogenous soil, the velocity of flow (v) is given by: $\boldsymbol{v = ki}$
  - Where; k= coefficient of permeability and i= hydraulic gradient
  - $\boldsymbol{i = \frac{head\ loss}{length\ of\ flow}}$
  - $\boldsymbol{Discharge\ through\ soil\ (q) = kiA}$
  - The coefficient of permeability is defined as the velocity of flow which would occur under unit hydraulic gradient. It is the unit of length/time (mm/sec).
- Darcy law is valid if the flow through the soil is laminar. (Since pores are so small that the flow of water is almost always laminar)
- Here, $v = ki$, represents the **superficial or fictitious velocity** of flow because actual flow is through pores in the cross section and not through the entire cross section area A.
- The actual velocity of water flowing in the voids is called Seepage Velocity (v_s).

$$v_s = \frac{v}{n} = \frac{ki}{n} = \left(\frac{k}{n}\right) i = k_p . i$$

- k_p = Coefficient of percolation ; n = porosity

Falling Head Permeability Test

- Used for relatively less permeable soil (fine grained soil)



❑ Rate of flow of water through the specimen at any time 't' can be given by;

$$q = k\frac{h}{L}A = -a\frac{dh}{dt}$$

q: rate of flow

a: cross sectional area of standpipe

A: cross sectional area of the soil sample

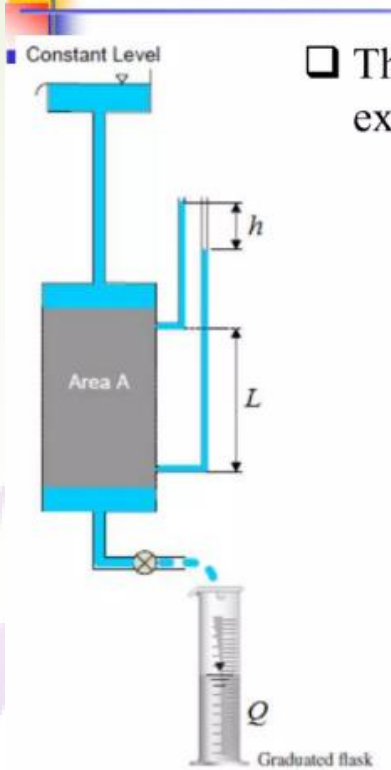
$$dt = \frac{aL}{Ak}\left(-\frac{dh}{h}\right) \Rightarrow \int_0^{t_1} dt = -\frac{aL}{Ak}\int_{h_2}^{h_1}\frac{dh}{h}$$

$$t = \frac{aL}{Ak}\ln\frac{h_1}{h_2} \Rightarrow k = \frac{aL}{At}\ln\frac{h_1}{h_2}$$

$$k = 2.303\frac{aL}{At}\log\frac{h_1}{h_2}$$

h_1 = head at the start of test

h_2 = head at the end of test



❑ The total *volume of collected water* may be expressed as;

$$Q = q \cdot t = (Av) \cdot t = A \cdot (ki) \cdot t$$

$$i = \frac{h}{L} \qquad Q = A\left(k\frac{h}{L}\right)t$$

$$k = \frac{QL}{Aht}$$

Q = volume of water collected

A = x-sec area of soil specimen

t = duration of water collection

Constant Head Permeability Test

- Used for relatively more permeable soil (coarse grained soil)

Factors Affecting Permeability

$$k = C\frac{\gamma_w}{\mu}\frac{e^3}{1+e}D^2$$ Hazen-Poisseuille Equation:

- Particle Size: $k \propto D^2$
- Void Ratio: $k \propto \frac{e^3}{1+e}$ (Higher void ratio, higher permeability)
  - **But**, The soil with largest void ratio (i.e., clays) are least pervious. This is because individual void passages in clays are extremely small.
- Properties of water:

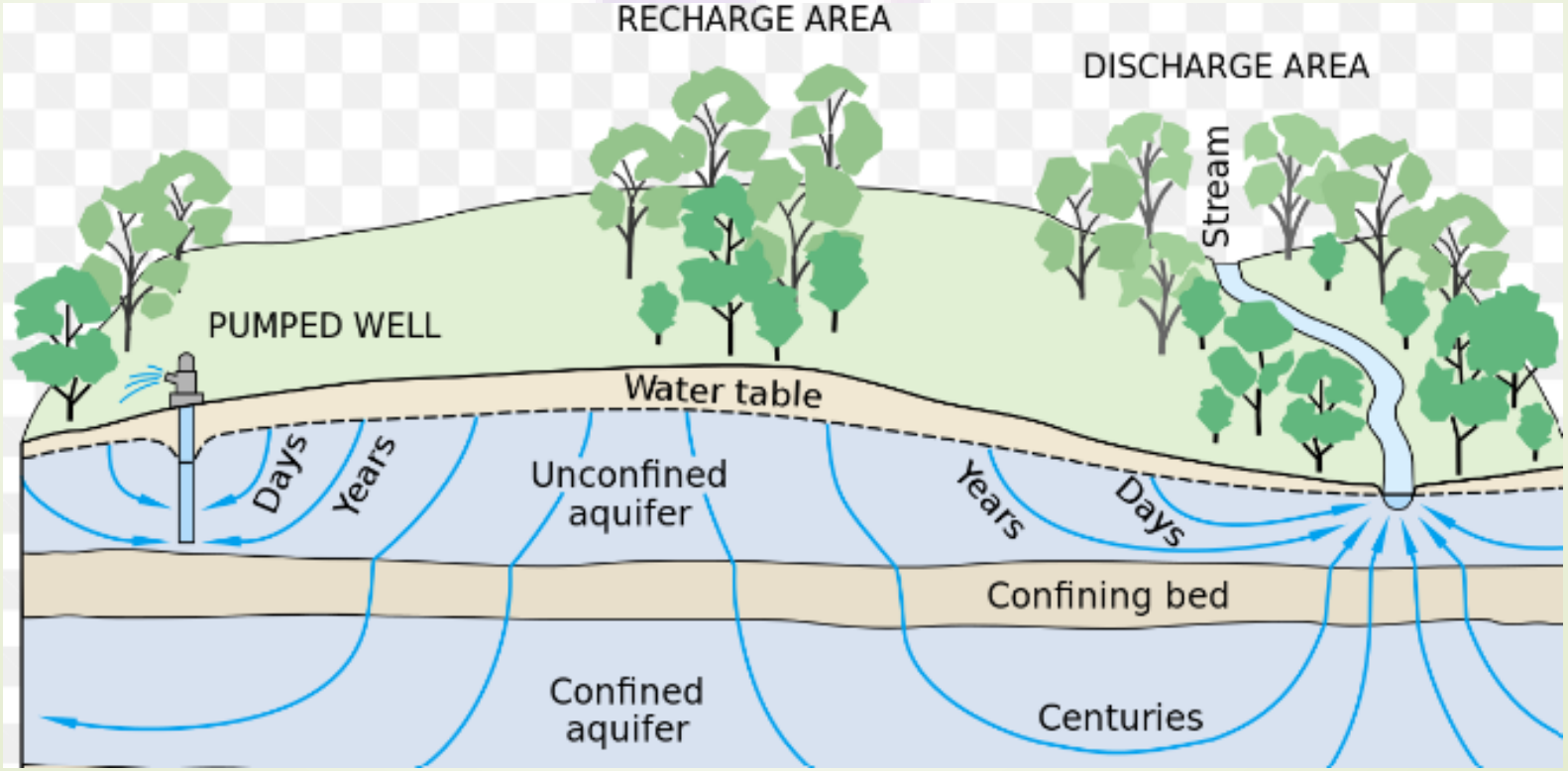
$$k \propto \frac{\gamma_w}{\mu}$$

  - If temperature increases, viscosity decreases. As viscosity decreases, permeability increases. Hence, increase in temperature, increases permeability.
- Degree of saturation: (Unsaturated soil has lesser permeability)
- Presence of Adsorbed water, impurities in water in the soil reduces permeability.
- Shape of the particles:
  - For same void ratio, the **soils with angular particles are less permeable** than those with rounded particles as permeability is inversely proportional to the specific surface area (Angular particles have greater surface area)
- Structure of soil: (Permeability is higher for flocculated structure than dispersed)

  Permeability higher along the stratification than perpendicular to the stratification.

Seepage Pressure:

Seepage is the flow of water under gravitational forces in a permeable medium through voids. Flow of water takes place from the point of high head to a point of low head. The loss of head per unit length of flow through soil is called hydraulic gradient. The hydraulic gradient provided at the downstream side of a hydraulic structure is called exit gradient or downstream gradient or tail water gradient. Seepage through the soil is generally laminar. **Seepage pressure** is the pressure exerted by water on the soil through which it percolates. The seepage pressure always acts in the direction of flow.

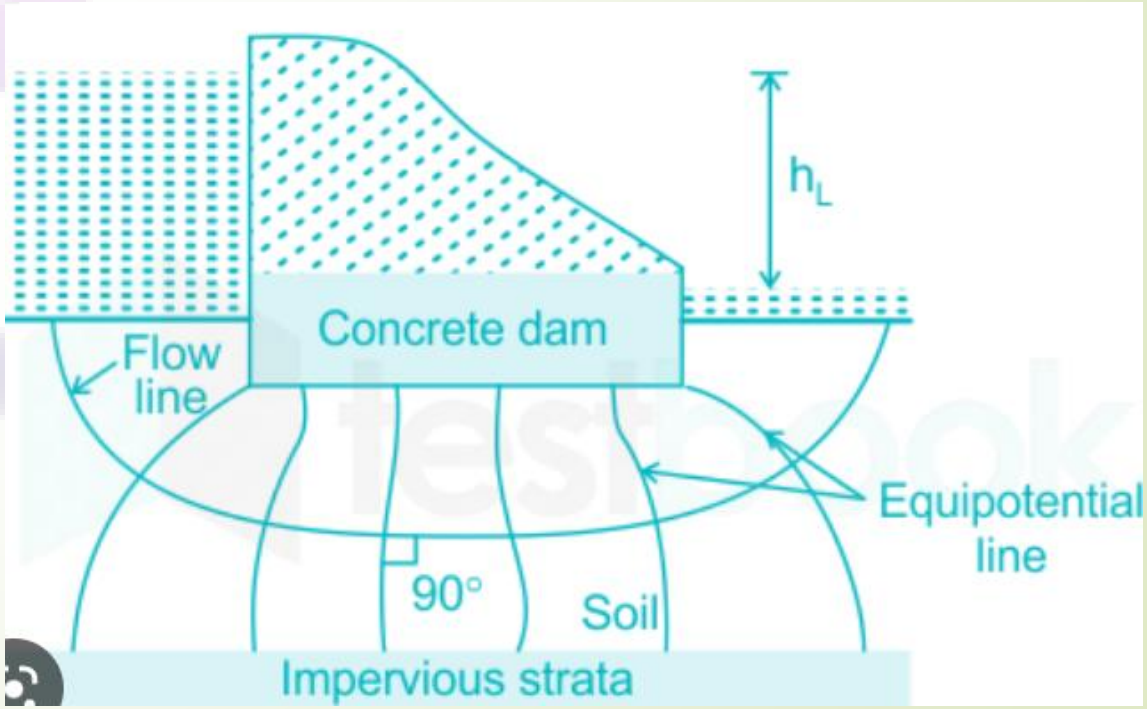


Flow Net

For studying seepage force, Laplace equation is best suited. The solution of two Laplace equations for the potential functions and flow functions takes the form of two sets of orthogonal curves. These two sets of orthogonal curves represent **flow net** which consists flow lines and equipotential lines. **Flow line or stream lines** are the path followed by percolating water through a saturated soil mass under laminar flow conditions. The portion of flow net bounded by two adjacent flow lines, is known as flow channel. Water do not cross flow lines. Other set of curves connecting the points of equal head of water is called **Equipotential line.** The portion between two successive equipotential lines and successive flow lines is called field.

The properties of flow net are as follow:

- The flow lines and equipotential lines cross each other at right angles.
- The discharge between any two adjacent flow line is constant and drops of head between the two adjacent equipotential lines (potential drop) is also constant.
- Velocity of flow is more in small size **square** figures, so as to keep the discharge same.



Application of flow net:

- Quantity of seepage: The discharge passing through a flow net for isotropic soil is given by,

$$q = KH\frac{N_F}{N_D}$$

Where, K = permeability constant

H= total hydraulic head causing flow

N_F = Numbers of flow channels

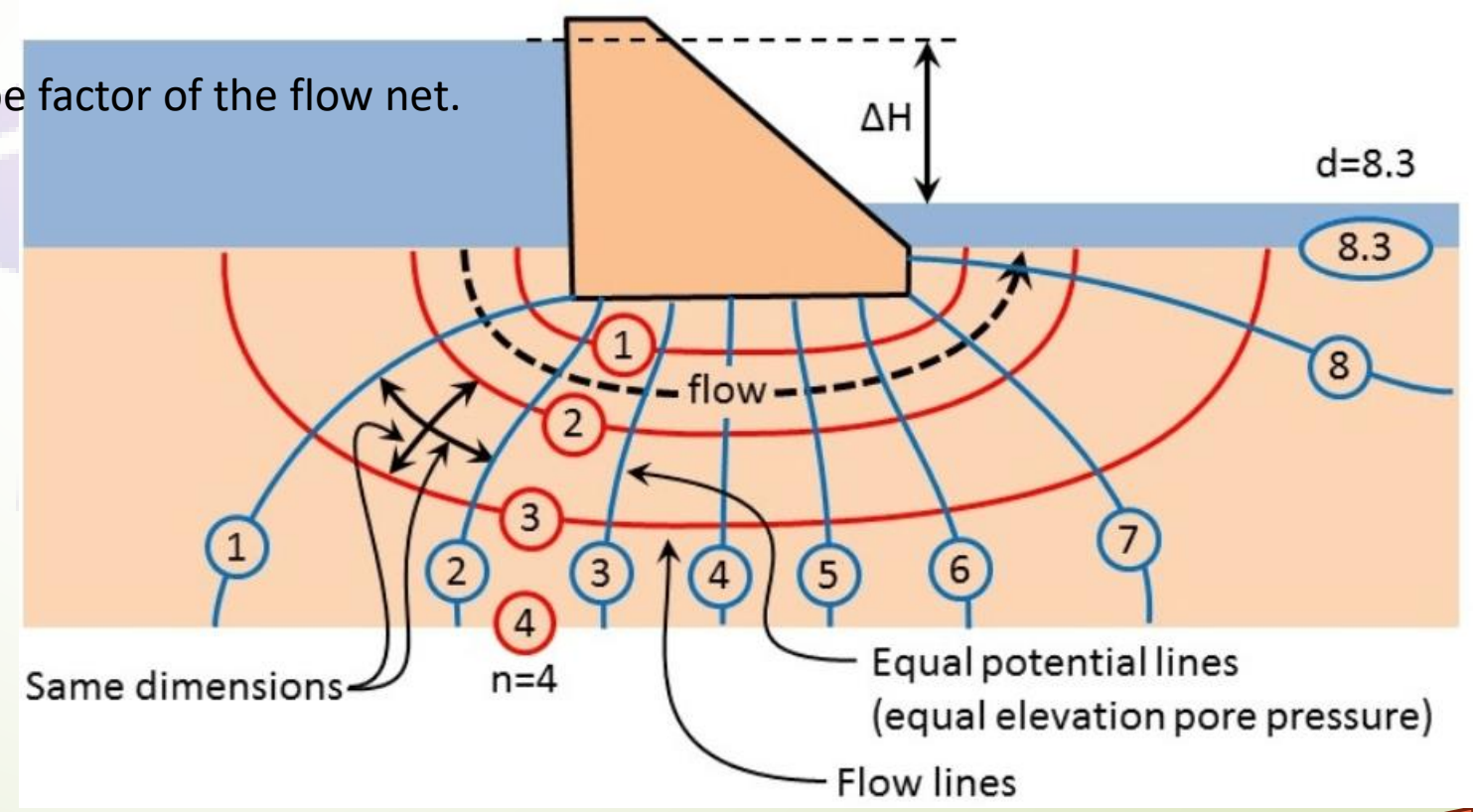
N_D = Number of potential drops

The ratio $^{N_F}/_{N_D}$ is called the shape factor of the flow net.

- Amount of seepage pressure

$$Seepage\ pressure = (H - N_D\Delta h).$$

Here, N_D is the number of potential drops (by a value of Δh). This seepage pressure acts in the direction of flow.



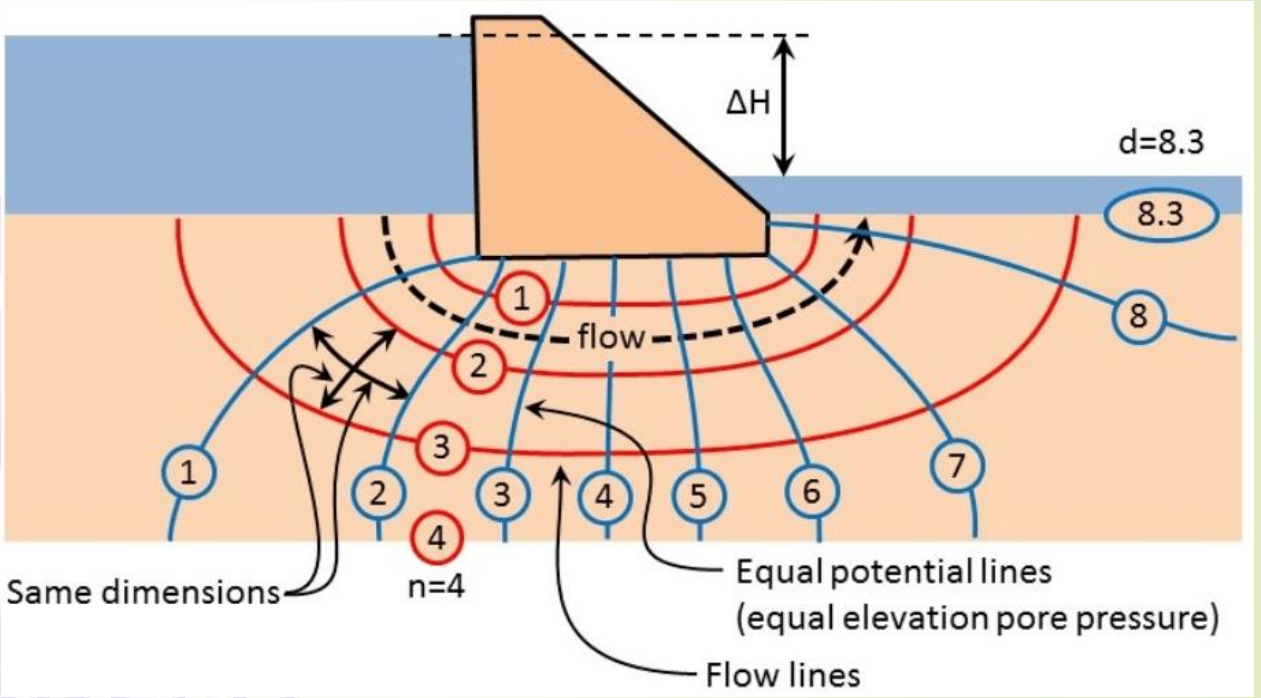
- $Uplift\ pressure = h_w \gamma_w, where\ h_w\ is\ piezometric\ head.$

- Exit Gradient, (i_e)

  The maximum hydraulic gradient at downstream end of flow lines is termed the exit gradient. In other words, it is the hydraulic gradient where the percolating water leaves the soil mass and emerges into free water. At exit, the direction of seepage is nearly vertically upward and seepage pressure tends to dislodge the soil grain. Exit gradient is importance in seepage analysis.

$$i_e = \frac{\Delta h}{L}$$

$$= \frac{Head\ loss\ over\ the\ last\ field}{Length\ of\ the\ smallest\ square\ in\ the\ last\ field}$$



BCDBC

1. The property of soil which allows water to flow through the soil is known as:
   a. Capillarity
   b. Permeability
   c. Fluidity
   d. Viscosity
2. The law which states that the velocity of flow through porous medium is directly proportional to the hydraulic gradient is:
   a. Newton's Law
   b. Stroke's Law
   c. Darcy's Law
   d. Reynold's Law
3. Darcy's Law is applicable if the soil is:
   a. Homogenous
   b. Incompressible
   c. Isotropic
   d. All of the above
4. The Constant of proportionality between seepage velocity and hydraulic gradient is called:
   a. Coefficient of Permeability
   b. Coefficient of Percolation
   c. Coefficient of Transmissibility
   d. Seepage Coefficient
5. The coefficient of percolation and coefficient of permeability are related by:
   a. $K=K_p/n$
   b. $K=K_pn$
   c. $K_p=K/n$
   d. None

CADBB

6. A soil which doesn't permit the passage or seepage of any permeant through its voids, is known as:
   a. Solid Soil
   b. Hard Soil
   c. Impermeable soil
   d. Honey Comb soil
7. In Most of the practical flow problems in soil mechanics, the flow is:
   a. Laminar
   b. Turbulent
   c. Supersonic
   d. Subsonic
8. The Reynold's number for laminar flow through soil is:
   a. Less than 1000
   b. Less than 100
   c. Less than 10
   d. Less than 1
9. The velocity of percolation is defined as:
   a. The discharge per unit gross cross-sectional area
   b. The discharge per unit net cross-sectional area
   c. The discharge per unit total cross-sectional area
   d. None of the above
10. Permeability of Soil varies
    a. Inversely as square of the grain size
    b. As square of the grain size
    c. As grain size
    d. Inversely as grain size

CABBA

11. Physical properties of permeant which influence the permeability is/are:
    a. Viscosity only
    b. Unit weight only
    c. Both viscosity and unit weight
    d. None
12. Select the correct statement. The permeability is
    a. Directly proportional to the unit weight, inversely proportional to the viscosity
    b. Directly proportional to the viscosity and inversely proportional to the unit weight
    c. Directly proportional to both viscosity and unit weight
    d. Inversely Proportional to both viscosity and unit weight
13. Coefficient of permeability of soil
    a. Increases with the decrease in temperature
    b. Increase with the increase in temperature
    c. Does not depend upon temperature
    d. None of the above
14. Void ratios of two soil ‘A’ and ‘B’ are 0.80 and 1.20 respectively. Which one is more pervious?
    a. Soil A
    b. Soil B
    c. Both
    d. None
15. A sand has e=0.8 and another clay has e=1.2; which is more pervious?
    a. Sand
    b. Clay
    c. Both
    d. None

BBBDD

16. Which one of the following has largest permeability?
    a. Sand
    b. Gravel
    c. Silt
    d. Clay
17. The presence of entrapped air in the soil will:
    a. Increase the permeability
    b. Decrease the permeability
    c. No effect on the permeability
    d. Can't Say
18. The presence of organic matter in the soil will:
    a. Increase the permeability
    b. Decrease the permeability
    c. No effect on the permeability
    d. Difficult to guess
19. A soil has a discharge velocity of $6*10^{-7}$ m/s and a void ratio of 0.5. What is the seepage velocity?
    a. $3*10^{-7}$ m/s
    b. $6*10^{-7}$ m/s
    c. $12*10^{-7}$ m/s
    d. $18*10^{-7}$ m/s
20. The seepage loss in cm^2/sec for a hydraulic structure if the flow net contains 5 flow lines and 9 equipotential lines and the head causing flow is 20 m, k = $2.6*10^{-6}$ cm/sec is:
    a. $1.88*10^{-3}$ b. $1.68*10^{-3}$ c. $2.88*10^{-3}$ d. $2.60*10^{-3}$

Discharge velocity (V) = 6×10^{-7} m/s

Void ratio = 0.5

Then porosity (n)

$$n = \frac{e}{1+e}$$

$$n = \frac{0.5}{1+0.5} = \frac{0.5}{1.5} = \frac{1}{3}$$

seepage velocity (V_s) = ?

seepage velocity $V_s = \frac{V}{n} = \frac{6\times10^{-7}}{1/3}$

$V_s = 18 \times 10^{-7}$ m/s

$$q = kh\frac{N_f}{N_d}$$

Where h = Hydraulic head or head difference between upstream and downstream level or head loss through the soil

N_f = Total number of flow channels = Floe lines - 1

N_d = Total number of equipotential drops = Equipotential lines -1

k = Coefficient of permeability

Given data

N_f = 5 - 1 = 4, N_d = 9 - 1 = 8, h = 20 m = 2000 cm

k = 2.6×10^{-6} cm/sec

∵ **seepage discharge(q),**

$$q = kh\frac{N_f}{N_d}$$

$$q = 2.6 \times 10^{-6} \times 2000 \times \frac{4}{8}$$

q = 2.60×10^{-3} cm^2/sec

ACCB

21. A flow line in seepage through a soil medium is defined as the:
    a. Path of particles of water through a saturated soil mass
    b. Line connecting points of equal head of water
    c. Flow of movement of fine particles of soil
    d. Direction of the flow particle.

22. During seepage through an earth mass, the direction of seepage is
    a. Parallel to the equipotential line
    b. Perpendicular to the streamlines
    c. Perpendicular to the equipotential line
    d. Along the direction of gravity

23. A flownet is drawn to obtain
    a. Seepage, coefficient of permeability and uplift pressure
    b. coefficient of permeability, uplift pressure and exit gradient
    c. uplift pressure, exit gradient and seepage quantity
    d. Exit gradient, seepage and coefficient of permeability

24. Flow between any two points in a soil depends only on the difference in
    a. Pressure head
    b. Total head
    c. Velocity head
    d. Datum head

Compaction	Consolidation
It is almost instantaneous	It is time dependent.
It occurs due to reduction of air voids.	It occurs due to expulsion of pore water from voids.
Soil is unsaturated.	Soil is saturated.
For a specified compaction energy, the compaction of a solid takes place only upto a certain limiting water content.	No limiting value of moisture content for the consolidation.

Compaction test: It includes determining optimum moisture content (OMC) with respect to corresponding maximum dry density. Normal range of OMC for sand is around 6 to 10%, whereas it is 14 to 20% for clay.

	Standard Proctor Test	Modified Proctor Test
Rammer mass	2.6 kg	4.89 kg
Layers of compaction	3 layers	5 layers
Drop height	310 mm	450 mm

Factors affecting compaction:

- Water content
  - ✓ For a given compactive effort the dry density of soil first increases with increase in water content. Beyond a certain value of water content, the trend is reversed.
  - ✓ The maximum value of dry density is obtained at optimum moisture content.
- Amount of compaction
  - ✓ Increase in the compaction energy will result in an increase in the maximum dry density (M.D.D) and a decrease in the Optimum moisture content (O.M.C).
- Type of soil
  - ✓ In general, coarse-grained soil can be compacted to higher dry density than fine-grained soil.
- Method of compaction
  - ✓ MDD can be increased by kneading action.
- Admixture
  - ✓ Addition of lime, cement, etc. improves compaction characteristics of soil.