| | | UNIT-IV | | | |
|---|---|---|---|---|---|
| 8 | a) | List out all factors affecting Compaction. | L2 | CO4 | 5 M |
| | b) | Explain in detail field compaction control methods. | L3 | CO4 | 5 M |
| | | **OR** | | | |
| 9 | a) | Explain with spring analogy, Terzaghi's theory of one-dimensional consolidation. | L3 | CO4 | 5 M |
| | b) | Define the following terms:<br>i. Coefficient of compressibility<br>ii. Coefficient of volume compressibility<br>iii. Compression Index<br>iv. Degree of consolidation | L1 | CO4 | 5 M |
| | | **UNIT-V** | | | |
| 10 | a) | What are the factors affecting the shear strength of soil? | L2 | CO5 | 5 M |
| | b) | What are the advantages and disadvantages of direct shear test over triaxial test? | L2 | CO5 | 5 M |
| | | **OR** | | | |
| 11 | a) | A direct shear test was performed on a 6cm x 6cm sample of dry sand with normal load of 360N. The failure occurred at a shear load of 180N. Plot the Mohr's strength envelope and determine $\phi$. Assume c=0. | L3 | CO5 | 5 M |
| | b) | Explain about unconfined compressive strength (UCS). Also, draw stress strain behavior of clayey soil under UCS test. | L2 | CO5 | 5 M |





Code: 23CE3503

**III B.Tech - I Semester - Regular Examinations - NOVEMBER 2025**

# GEOTECHNICAL ENGINEERING - I
## (CIVIL ENGINEERING)

Duration: 3 hours                                        Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level                                        CO – Course Outcome

## PART – A

| | | BL | CO |
|---|---|---|---|
| 1.a) | Define Relative Density? | L1 | CO1 |
| 1.b) | Write the relation between Air Content, Porosity and Percentage Air voids. | L1 | CO1 |
| 1.c) | State Darcy's law and its limitations. | L1 | CO2 |
| 1.d) | Define permeability. | L1 | CO2 |
| 1.e) | What is Phreatic Line? | L1 | CO3 |
| 1.f) | Define Total Stress. | L1 | CO3 |
| 1.g) | Differentiate normally consolidated and over consolidated clays. | L2 | CO4 |
| 1.h) | List the types of rollers used in compaction. | L2 | CO4 |
| 1.i) | Explain Stress-Strain behavior of Sands. | L2 | CO5 |
| 1.j) | Name the types of shear tests based on drainage conditions. | L2 | CO5 |

## PART – B

| | | | BL | CO | Max. Marks |
|---|---|---|---|---|---|
| | | **UNIT-I** | | | |
| 2 | a) | Derive the relation between e, S, G and w. | L3 | CO1 | 5 M |
| | b) | The plastic limit of soil is 30% and its plasticity index is 10%. When the soil is dried from its state to plastic limit, the volume change is 27% of its volume at plastic limit. Similarly, the corresponding volume change from the liquid limit to the dry state is 36% of its volume at liquid limit. Determine the shrinkage limit and the shrinkage ratio. | L3 | CO1 | 5 M |
| | | **OR** | | | |
| 3 | a) | Explain with neat sketches types of soil structure. | L2 | CO1 | 5 M |
| | b) | The following results refer to a liquid limit test: The plastic limit is 23.5%. Determine the plasticity index and toughness index | L3 | CO1 | 5 M |

| No of blows | 33 | 25 | 15 | 9 |
|---|---|---|---|---|
| Water content (%) | 41.5 | 49.5 | 52.5 | 57.5 |

| | | | BL | CO | Max. Marks |
|---|---|---|---|---|---|
| | | **UNIT-II** | | | |
| 4 | a) | Write a short note on<br>i) seepage velocity<br>ii)coefficient of permeability<br>iii)quick sand condition. | L2 | CO2 | 5 M |



| | | | | | |
|---|---|---|---|---|---|
| | b) | With the help of neat sketch, derive the equation to determine permeability by the falling head permeability test. | L3 | CO2 | 5 M |
| | | **OR** | | | |
| 5 | a) | Determine the average coefficient of permeability in directions parallel and perpendicular to the planes of a stratified deposit of soil consisting of 3 layers of total thickness 3 m. The top and bottom layers are 0.5 m and 0.8 m thick. The values of K for top, middle and bottom layers are $2\times10^{-4}$ cm/s, $3\times10^{-3}$ cm/s, $1\times10^{-2}$ cm/s respectively | L3 | CO2 | 5 M |
| | b) | Explain the factors affecting the permeability of soil. | L2 | CO2 | 5 M |
| | | **UNIT-III** | | | |
| 6 | a) | What is Flow net? Explain in detail with neat sketches. | L2 | CO3 | 5 M |
| | b) | Write the expression for critical hydraulic gradient. Also, find the critical hydraulic gradient for soil having void ratio of 0.65 and specific gravity 2.72. | L3 | CO3 | 5 M |
| | | **OR** | | | |
| 7 | a) | Derive the principle of construction of Newmark's chart. | L3 | CO3 | 5 M |
| | b) | As per Boussinesq's theory, derive the expression for vertical stress at any point in a soil mass due to point load. | L3 | CO3 | 5 M |

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# III B. TECH / I SEM / End Examination-Regular- Nov 2025
# 23CE3503-Geotechnical Engineering-1
(CIVIL ENGINEERING)
## Scheme of valuation

### PART-A

1 a) **Define Relative Density?**
Definition and formula: (2 mark)

1 b) **Write the relation between Air Content, Porosity and Percentage Air voids.**
Expression of Relation (2 marks)

1 c) **State Darcy's law and its limitations.**
Definition and limitations (2 marks)

1 d) **Define permeability.**
Definition of K: (2 marks)

1 e) **What is Phreatic Line?**
Explanation: (2 marks)

1 f) **Define Total Stress.**
Definition of total stress: (2 mark)

1 g) **Differentiate normally consolidated and over consolidated clays.**
Difference of NCC and OCC clay: (2 marks)

1 h) **List the types of rollers used in compaction.**
List any two rollers: (2 marks)

1 i) **Explain Stress-Strain behavior of Sands.**
Draw figure or explanation: (2 marks)

1 j) **Name the types of shear tests based on drainage conditions.**
List the test methods: (2 marks)

### PART-B

2 a) **Derive the relation between e, S, G and w.** **(5 marks)**
Definition of void ratio (e, s) – 2M
Relation using phase diagram →2M
Final expression clearly written – 1M

2 b) **The plastic limit of soil is 30% and its plasticity index is 10%. When the soil is dried from its state to plastic limit, the volume change is 27% of its volume at plastic limit. Similarly, the corresponding volume change from the liquid limit to the dry state is 36% of its volume at liquid limit. Determine the shrinkage limit and the shrinkage ratio.** **(5 marks)**
Given: PL, PI, volume changes - 1M
Calculation of LL (LL = PL + PI = 40%) – 1M
Formula for shrinkage limit – 1M
Numerical substitution – 1M
Shrinkage ratio (SR)– 1M

3 a) **Explain with neat sketches types of soil structure.** **(5 marks)**

Listing types (Single grained, honeycomb, flocculated, dispersed) – 2M
Neat sketches (any 2 good sketches) – 2M
Short description of each – 1M

3b) **The following results refer to a liquid limit test: The plastic limit is 23.5%. Determine the plasticity index and toughness index**

| No of blows | 33 | 25 | 15 | 9 |
|---|---|---|---|---|
| Water content (%) | 41.5 | 49.5 | 52.5 | 57.5 |

**(5 marks)**

Given values clearly stated – 1M
Compute PI = LL – PL – 1M
Definition of toughness index (TI)– 1M
Liquid limit data use – 1M
Final values – 1M

4 a) **Write a short note on**
**i) seepage velocity**
**ii)coefficient of permeability**
**iii)quick sand condition.** **(5 marks)**
i) Seepage velocity – 1.5M
ii) Coefficient of permeability – 1.5M
iii) Quick sand condition – 2M

4 b) **With the help of neat sketch, derive the equation to determine permeability by the falling head permeability test.** **(5 marks)**
Sketch of falling head apparatus – 1M
Darcy's law statement – 1M
Derivation steps – 2M and final formula- 1M

5 a) **Determine the average coefficient of permeability in directions parallel and perpendicular to the planes of a stratified deposit of soil consisting of 3 layers of total thickness 3 m. The top and bottom layers are 0.5 m and 0.8 m thick. The values of K for top, middle and bottom layers are 2x10-4 cm/s, 3×10-3 cm/s 1×10-2 cm/s respectively.** **(5 marks)**
Thickness identification – 1M
Parallel permeability formula – 1M
Perpendicular permeability formula – 1M
Substitution and calculation – 1M
Final values – 1M

5 b) **Explain the factors affecting the permeability of soil.** **(5 marks)**
Any five factors = 1M each
(Grain size, void ratio, soil structure, adsorbed water, impurities, degree of saturation etc.)

6 a) **What is Flow net? Explain in detail with neat sketches.** **(5 marks)**
Definition – 1M
Sketch of flow net, Flow lines, equipotential lines description – 3M
Applications/Characteristics – 1M

6 b) **Write the expression for critical hydraulic gradient. Also, find the critical hydraulic gradient for soil having void ratio of 0.65 and specific gravity 2.72.** **(5 marks)**

Expression: – 2M
Substitution of values – 2M
Final value – 1M

7 a) **Derive the principle of construction of Newmark's chart.** **(5 marks)**

Need for stress distribution – 1M
Construction concept – 2M
Influence factor explanation – 1M
Use in footing pressure – 1M

7 b) **As per Boussinesq's theory, derive the expression for vertical stress at any point in a soil mass due to point load.** **(5 marks)**

Point load concept – 1M
Assumptions – 1M
Derivation steps – 2M
Final formula: – 1M

8 a) **List out all factors affecting Compaction.** **(5 marks)**

Any five factors: 1M each
(Moisture content, soil type, compaction effort, thickness of layer, method of compaction, contact pressure, drainage)

8 b) **Explain in detail field compaction control methods.** **(5 marks)**

Field density tests (sand replacement / core cutter) – 2M
Proctor test comparison – 1M
Quality checks (MDD and OMC)– 2M

9 a) **Explain with spring analogy, Terzaghi's theory of one-dimensional consolidation.** **(5 marks)**

Spring analogy explanation – 2M
Governing equation – 1M
Sketch – 2M

9b) **Define the following terms:**
**i. Coefficient of compressibility**
**ii. Coefficient of volume compressibility**
**iii. Compression Index**
**iv. Degree of consolidation** **(5 marks)**

i) Coefficient of compressibility – 1.5M
ii) Coefficient of volume compressibility– 1.5M
iii) Compression index– 1M
iv) Degree of consolidation– 1M

10 a) **What are the factors affecting the shear strength of soil?** **(5 marks)**

Any five factors = 1M each
(Saturation, density, drainage, stress history, mineralogy, strain rate etc.)

10b) **What are the advantages and disadvantages of direct shear test over triaxial test?** **(5 marks)**

Two advantages – 3M
Two disadvantages – 2M

11a) **A direct shear test was performed on a 6cm x 6cm sample of dry sand with normal load of 360N. The failure occurred at a shear load of 180N. Plot the Mohr's strength envelope and determine Assume c=0** **(5 marks)**

Given data and area calculation – 1M
Compute normal stress and shear stress – 2M
Draw Mohr circle + straight line – 1M
Angle of friction φ from $\tau = \sigma \tan\varphi$ – 1M

11b) **Explain about unconfined compressive strength (UCS). Also, draw stress strain behavior of clayey soil under UCS test.** **(5 marks)**

Definition of UCS – 1M
Test procedure – 3M
Stress–strain curve for clayey soil – 1M

# III B. TECH / I SEM / End Examination-Regular- Nov 2025
# 23CE3503-Geotechnical Engineering-1
## (CIVIL ENGINEERING)

**PART-A**

1 a) **Define Relative Density?**

Relative density is a measure of the compactness of a granular soil (sand). It shows how dense the soil is compared to its loosest and densest states.

$$D_r = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100$$

(Where $e$ = natural void ratio; $e\_max$ = void ratio at loosest state; $e\_min$ = void ratio at densest state)

1 b) **Write the relation between Air Content, Porosity and Percentage Air voids.**

$$\text{Percentage Air Voids } (A_v) = n \times a$$

Where: $n$ = porosity $a$ = air content

1 c) **State Darcy's law and its limitations.**

The rate of flow of water through soil is directly proportional to the hydraulic gradient.

v=ki

Limitations:

Applicable only for laminar flow. Valid for fully saturated soils.

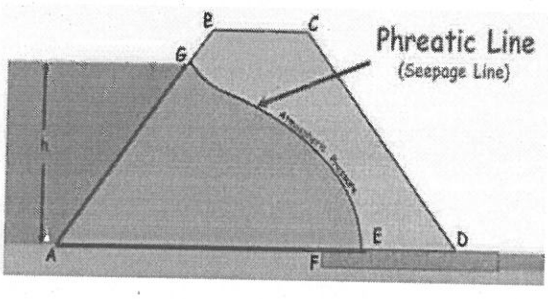
1 d) **Define permeability.**

Permeability is the property of soil that allows water to flow through its voids.

The coefficient of permeability (k) indicates the ease with which water passes through soil.

1 e) **What is Phreatic Line?**

Phreatic line is the line in an earth dam or soil mass that represents the upper surface of the seepage flow.




1 f) **Define Total Stress.**

Total stress is the force per unit area applied to a soil mass from the weight of soil and water above it.

$\sigma = \gamma \times z$ = Load/Area

1 g) **Differentiate normally consolidated and over consolidated clays.**

Normally Consolidated Clay (NCC): Never been subjected to stress greater than present stress, High compressibility, Low shear strength.

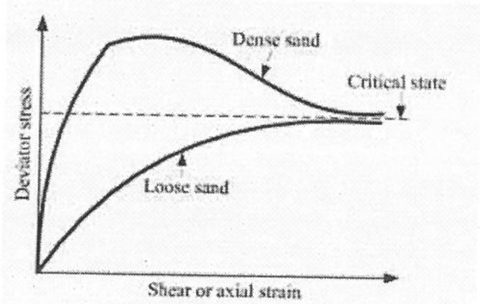
Over Consolidated Clay (OCC): Has been subjected to higher stress in the past than the present stress, Low compressibility, High shear strength. (Any two points)

**1 h) List the types of rollers used in compaction.**

- Smooth wheel roller
- Sheep foot roller
- Pneumatic tyre roller
- Vibratory roller (any two)

**1 i) Explain Stress-Strain behavior of Sands.**

Sands show an initial linear elastic behavior.
Dense sand shows peak strength followed by strain softening.
Loose sand shows continuous strain hardening without a clear peak.




**1 j) Name the types of shear tests based on drainage conditions.**

Unconsolidated Undrained Test (UU)
Consolidated Undrained Test (CU)
Consolidated Drained Test (CD)

## PART-B

**2 a) Derive the relation between e, S, G and w.** **(5 marks)**

**Step 1**

- Void ratio $e = \frac{V_v}{V_s}$where $V_v$= volume of voids, $V_s$= volume of solids.
- Degree of saturation $S = \frac{V_w}{V_v}$where $V_w$= volume of water.
- Water content $w = \frac{W_w}{W_s}$(mass of water / mass of solids).
- Specific gravity $G = \frac{\rho_s}{\rho_w} = \frac{W_s/V_s}{\rho_w}$.

**Step 2 —**

$$w = \frac{W_w}{W_s} = \frac{\rho_w V_w}{\rho_s V_s} = \frac{V_w}{V_s} \cdot \frac{\rho_w}{\rho_s}$$

Use $\rho_s = G\rho_w$, so $\frac{\rho_w}{\rho_s} = \frac{1}{G}$. Also $V_w = S\,V_v = S(eV_s)$. Thus

$$\frac{V_w}{V_s} = S\,e.$$

Substitute into $w$:

$$w = (Se) \cdot \frac{1}{G} \Longrightarrow w = \frac{Se}{G}.$$

**Step 3** — Rearranged final relations $\boxed{e = \frac{Gw}{S} \text{ or } S = \frac{Gw}{e}}$

2 b) **The plastic limit of soil is 30% and its plasticity index is 10%. When the soil is dried from its state to plastic limit, the volume change is 27% of its volume at plastic limit. Similarly, the corresponding volume change from the liquid limit to the dry state is 36% of its volume at liquid limit. Determine the shrinkage limit and the shrinkage ratio.**
**(5 marks)**

**Given:**

- Plastic limit $PL = 30\%$
- Plasticity index $PI = 10\% \rightarrow$ Liquid limit $LL = PL + PI = 40\%$. *(1 mark)*
- Volume change on drying from PL to dry = $27\%$ of $V_{PL}$.
- Volume change on drying from LL to dry = $36\%$ of $V_{LL}$.

**Step 1 — Express volume changes relative to dry volume $V_d$.**

From PL: $V_d = 0.73\ V_{PL}$ so

$$\frac{V_{PL} - V_d}{V_d} = \frac{0.27}{0.73} = 0.369863$$

From LL: $V_d = 0.64\ V_{LL}$ so

$$\frac{V_{LL} - V_d}{V_d} = \frac{0.36}{0.64} = 0.5625$$

**Step 2 — Use the shrinkage relation**

$$\frac{V - V_d}{V_d} \times 100 = R\,(w - w_s)$$

where $R$= shrinkage ratio (percent volumetric change per % water), $w$= water content at the state, $w_s$= shrinkage limit (%).

For PL ($w = 30\%$):

$$R(30 - w_s) = 36.98630137 (1)$$

For LL ($w = 40\%$):

$$R(40 - w_s) = 56.25 (2)$$

Subtract (1) from (2):

$$R(10) = 56.25 - 36.98630137 = 19.26369863 \Rightarrow R = 1.92637$$

Now from (1):

$$30 - w_s = \frac{36.98630137}{1.92637} = 19.20237 \Rightarrow w_s = 30 - 19.20237 = 10.7976\%$$

$\boxed{\text{Shrinkage limit } w_s \approx 10.80\%}$ and $\boxed{\text{Shrinkage ratio } R \approx 1.926}$

**3 a) Explain with neat sketches types of soil structure.** **(5 marks)**

Soil structure refers to the arrangement of soil particles (sand, silt, clay) and the way they group together to form aggregates.

Single-Grained Structure

- Found in coarse soils like sand.
- Each particle behaves independently; no cohesion.
- High permeability, low compressibility

Honeycomb Structure

- Occurs in silt and very fine sands.
- Particles form open, honeycomb-like frameworks.
- Leads to high void ratio and collapses under load.

Flocculent (Flocculated) Structure

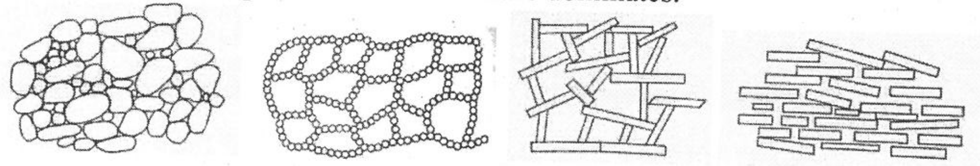
- Common in clay soils in saline water.
- Particles come together edge-to-face, forming a random, loose arrangement.
- High void ratio, high compressibility.

Dispersed Structure

- Occurs in clay soils in fresh water.
- Particles orient face-to-face, forming a dense and parallel arrangement.
- Lower void ratio and less compressible than flocculent.

Composite or Mixed Structure

- Many natural soils have a combination of flocculent + dispersed or honeycomb + flocculent arrangements.
- Properties depend on which structure dominates.



**3b) The following results refer to a liquid limit test: The plastic limit is 23.5%. Determine the plasticity index and toughness index**

| **No of blows** | **33** | **25** | **15** | **9** |
|---|---|---|---|---|
| **Water content (%)** | **41.5** | **49.5** | **52.5** | **57.5** |

**(5 marks)**

Given data

Number of blows $N$: 33, 25, 15, 9

Water content $w(\%)$: 41.5, 49.5, 52.5, 57.5

Plastic limit $PL = 23.5\%$

Step 1 — Liquid limit (LL)

For Casagrande/Liquid-limit test the liquid limit is the water content corresponding to $N =$ 25blows.

$$\boxed{LL = 49.5\%}$$

Step 2 — Plasticity Index (PI)

$$PI = LL - PL = 49.5 - 23.5 = \boxed{26.0\%}$$

Step 3 — Flow index $I_f$(from the flow curve)

Plot $w$(vertical) vs $\log_{10} N$(horizontal) and draw the best-fit straight line (flow curve). We find the slope of this line (change of water content per unit change in $\log_{10} N$).

Using linear fit through the given points:

$$w = m\log_{10} N + c \Rightarrow m \approx -25.599$$

The flow index is the magnitude of this slope:

$$I_f \approx 25.60 \ \% \text{ water per log-cycle}$$

Step 4 — Toughness index $I_T$

$$I_T = \frac{PI}{I_f} = \frac{26.0}{25.599} \approx \boxed{1.016}$$

4 a) **Write a short note on**
**i) seepage velocity**
**ii)coefficient of permeability**
**iii)quick sand condition.** **(5 marks)**

**(i) Seepage Velocity *(1.5 marks)***

Seepage velocity is the actual velocity with which water moves through the void spaces of a soil. The discharge velocity (Darcy velocity) is based on the total cross-sectional area, but seepage occurs only through voids, so seepage velocity is always greater than Darcy velocity.

$$v_s = \frac{v}{n}$$

where

$v_s$= seepage velocity, $v$= Darcy velocity, $n$= porosity of soil.

It represents the real speed of groundwater movement inside the soil pores.

**(ii) Coefficient of Permeability (k)**

Coefficient of permeability is a measure of the ability of soil to allow water to flow through it under a hydraulic gradient.

- Coarse soils (sand, gravel) → high k
- Fine soils (clays) → very low k

It depends on grain size, void ratio, soil structure, fluid viscosity, and temperature.

**(iii) Quick Sand Condition**

Quick sand condition occurs when upward seepage pressure in saturated sand becomes equal to or greater than the effective stress.

Under this condition:

- Soil loses shear strength,
- Particles behave like a liquid,
- Soil becomes unable to support loads.

4 b) **With the help of neat sketch, derive the equation to determine permeability by the falling head permeability test. (5 marks)**

Flow through the soil (Darcy's law for vertical flow): Instantaneous discharge through the specimen

$$Q = k\,A\,\frac{h(t)}{L}$$

(head difference across soil ≈ $h(t)$if outlet head = 0 reference).

Rate of fall of head in standpipe: The rate of loss of volume in the standpipe equals the discharge through the sample:

$$Q = -a\,\frac{dh}{dt}$$

(negative sign because $h$decreases with time).

Equate the two expressions for $Q$:

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

Rearrange and separate variables:

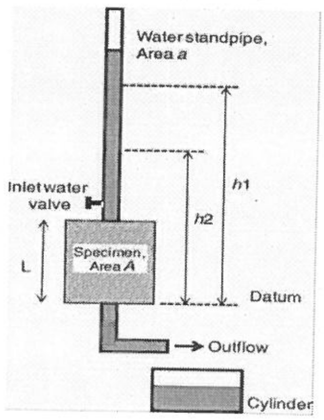
$$\frac{dh}{h} = -\frac{kA}{aL}\,dt$$

Integrate from $h_1$at $t = 0$to $h_2$at $t = t$:

$$\int_{h_1}^{h_2} \frac{1}{h}\,dh = -\frac{kA}{aL}\int_0^t dt$$

$$\ln\left(\frac{h_2}{h_1}\right) = -\frac{kA}{aL}\,t$$

Rearrange to solve for $k$:




$$\ln\left(\frac{h_1}{h_2}\right) = \frac{kA}{aL}\,t \Rightarrow \boxed{k = \frac{aL}{A\,t}\ln\left(\frac{h_1}{h_2}\right)}$$

5 a) **Determine the average coefficient of permeability in directions parallel and perpendicular to the planes of a stratified deposit of soil consisting of 3 layers of total thickness 3 m. The top and bottom layers are 0.5 m and 0.8 m thick. The values of K for top, middle and bottom layers are $2 \times 10^{-4}$ cm/s, $3 \times 10^{-3}$ cm/s $1 \times 10^{-2}$ cm/s respectively. (5 marks)**

Flow parallel to layers (horizontal effective K, arithmetic mean weighted by thickness):

$$K_h = \frac{\sum K_i Z_i}{\sum Z_i}$$

Flow perpendicular to layers (vertical effective K, harmonic mean weighted by thickness):

$$K_v = \frac{\sum Z_i}{\sum \frac{Z_i}{K_i}}$$

Calculations

Parallel (horizontal) permeability

$$K_h = \frac{K_1 z_1 + K_2 z_2 + K_3 z_3}{z_1 + z_2 + z_3} = \frac{(2 \times 10^{-4})(50) + (3 \times 10^{-3})(170) + (1 \times 10^{-2})(80)}{300}$$

$$K_h = \frac{0.01 + 0.51 + 0.80}{300} = \frac{1.32}{300} = 0.0044 \text{ cm/s}$$

Perpendicular (vertical) permeability

$$K_v = \frac{300}{\frac{50}{2 \times 10^{-4}} + \frac{170}{3 \times 10^{-3}} + \frac{80}{1 \times 10^{-2}}}$$

Compute denominators:

$$K_v = \frac{300}{314666.67} \approx 9.5339 \times 10^{-4} \text{ cm/s}$$

$$\boxed{K_{\text{parallel}} = K_h = 4.40 \times 10^{-3} \text{ cm/s}}$$

$$\boxed{K_{\text{perpendicular}} = K_v \approx 9.53 \times 10^{-4} \text{ cm/s}}$$

5 b) **Explain the factors affecting the permeability of soil.** **(5 marks)**

Any five factors

The permeability of soil is influenced by several physical and environmental factors. The major factors are:

**1. Grain Size**

- Coarse-grained soils (sand, gravel) have larger pore spaces → high permeability.
- Fine-grained soils (clay, silt) have very small pores → low permeability.

**2. Void Ratio (e)**

- Higher void ratio means more open spaces for water to flow → higher permeability.
- When soil becomes dense (low e), permeability decreases.

**3. Properties of Pore Fluid**

- Permeability increases with decrease in viscosity of water.
- Hot water has lower viscosity → permeability increases at higher temperatures.
- Presence of dissolved salts can also affect viscosity.

**4. Soil Structure**

- Flocculated structure (clay in salt water) has larger channels → higher permeability.
- Dispersed structure (clay in fresh water) reduces flow paths → low permeability.
- Laminated or stratified soils show different permeability in horizontal and vertical directions.

**5. Degree of Saturation**

- Fully saturated soils have continuous water channels → higher permeability.
- Partially saturated soils contain air → obstruct flow → lower permeability.

**6. Shape and Arrangement of Particles**

- Angular particles create larger interconnected voids → higher permeability.
- Rounded particles pack more tightly → lower permeability.

**7. Adsorbed Water in Clays**

- Clay particles are surrounded by a layer of adsorbed water.
- This layer reduces the effective pore space → permeability becomes very low.

**8. Presence of Foreign Matter**

- Organic matter, colloids, or impurities can clog pores → reduce permeability.
- Cracks, root channels, and fissures increase permeability locally.

6 a) **What is Flow net? Explain in detail with neat sketches.** **(5 marks)**

A flow net is a graphical representation of the two-dimensional flow of water through soil. It consists of two families of curves:

1. Flow lines – represent the path followed by water particles.
2. Equipotential lines – represent points having the same hydraulic head.

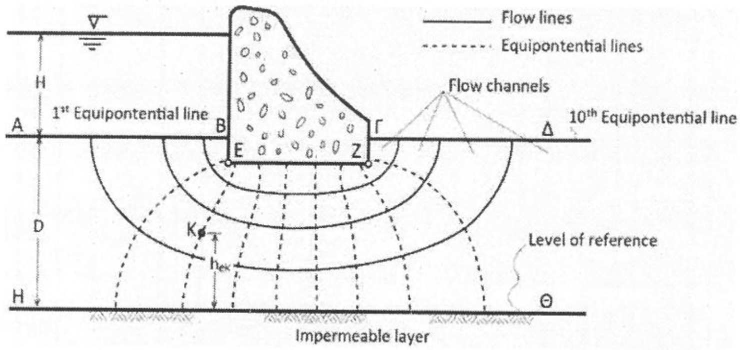
The network formed by these two sets of curves helps in analyzing seepage, determining seepage quantity, uplift pressure, exit gradients, and pore water pressure in soils.

**Components of a Flow Net**

1. Flow Lines: Curves showing the direction of water flow.
2. Equipotential Lines: Lines joining points with equal total head.
3. Flow Channels: The space between two adjacent flow lines.
4. Potential Drops: The total head loss is divided equally between potential drops.

**Important Properties of a Flow Net**

- Flow lines and equipotential lines intersect at right angles (90°).
- The small figures formed are approximate squares.
- The same quantity of water flows through each flow channel.
- The drop in head between two equipotential lines is constant.




**6 b) Write the expression for critical hydraulic gradient. Also, find the critical hydraulic gradient for soil having void ratio of 0.65 and specific gravity 2.72. (5 marks)**

The critical hydraulic gradient (ic) is given by:

$$i_c = \frac{G-1}{1+e}$$

Where: $G$= Specific gravity of soil solids $e$= Void ratio

This gradient corresponds to the condition when effective stress becomes zero, leading to boiling or quicksand condition.

Given:

Void ratio, $e = 0.65$ Specific gravity, $G = 2.72$

$$i_c = \frac{G-1}{1+e}$$

$$i_c = \frac{2.72-1}{1+0.65}$$

$$i_c = \frac{1.72}{1.65}$$

$$i_c = 1.042$$

**7 a) Derive the principle of construction of Newmark's chart. (5 marks)**

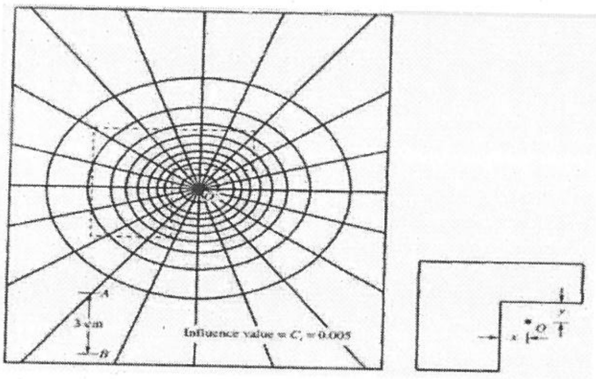
Newmark's chart gives a quick graphical value of the influence factor $I$such that the vertical stress increase at a point beneath a uniformly loaded rectangular area is

$$\Delta\sigma_z = q\,I$$

where $q$is the uniform pressure on the area.

- Newmark's chart is used to find the vertical stress below a uniformly loaded area.
- It is based on Boussinesq's theory for stress due to a point load.
- A uniformly loaded area is divided into many small elements $dA$.
- Each small element is treated as a point load $dP = q\,dA$.
- The vertical stress from each element is calculated using the Boussinesq equation.
- All these elemental stresses are added (integrated) to get the total stress.
- This integration gives a dimensionless influence factor $I$so that $\Delta\sigma_z = qI$.
- The results are normalised using ratios like $z/B$and $L/B$.
- These values of $I$are plotted as curves or contours to form the Newmark chart.

- Engineers use the chart to directly read $I$and compute vertical stress easily without lengthy calculations.




**7 b) As per Boussinesq's theory, derive the expression for vertical stress at any point in a soil mass due to point load. (5 marks)**

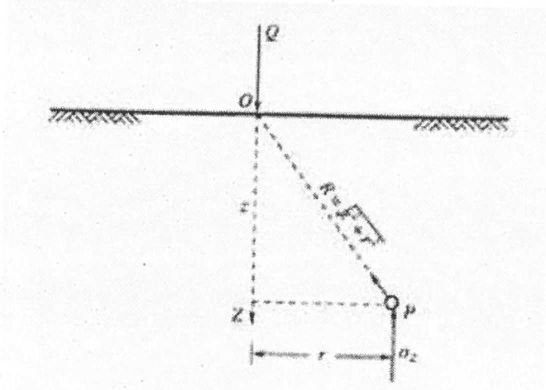
- Consider a vertical point load $P$acting at the surface of a semi-infinite, homogeneous, elastic soil mass.
- Let the stress be determined at a point located at depth $z$and radial distance $r$from the load.
- The straight-line distance from the load to the point is $R = \sqrt{r^2 + z^2}$.
- Boussinesq assumed the soil behaves as a linear elastic, isotropic, homogeneous material.
- Using elasticity theory, displacement potentials are written for a point load in an elastic medium.
- Boundary conditions (zero shear stress on the ground surface) are applied using the method of images.
- Solving the elasticity equations and differentiating the stress potentials gives expressions for stress components.
- The vertical stress component at depth $z$is obtained as:

$$\sigma_z = \frac{3Pz^3}{2\pi(r^2 + z^2)^{5/2}}$$

This can also be written using $\cos\theta = z/R$:

$$\sigma_z = \frac{3P}{2\pi R^2}\cos^3\theta$$

Thus, Boussinesq's theory provides the vertical stress at any point due to a surface point load, assuming elastic behavior.



8 a) **List out all factors affecting Compaction.** **(5 marks)**

- **Soil Type**: Clayey soils compact best at higher moisture content. Sandy/gravely soils compact best at low moisture.
- **Moisture Content**: Each soil has an optimum moisture content (OMC) at which maximum dry density is achieved.
- **Compactive Effort**: Higher effort (more energy, heavier rollers, more blows) → higher dry density.
- **Method of Compaction**: Kneading, rolling, impact, or vibration affect compaction results differently.
- **Layer Thickness**: Thinner layers compact more effectively than thick layers.
- **Number of Passes**: More roller passes increase dry density up to an optimum limit.
- **Soil Gradation**: Well-graded soils compact better than uniformly graded soils.
- **Soil Structure / Fabric**: Flocculated vs. dispersed structure affects compactability, especially in clays.
- **Environmental Conditions**: Temperature, drainage condition, and weather influence compaction efficiency.
- **Additives** (if used): Lime, cement, or fly ash can improve soil properties and compaction results. (Any five)

8 b) **Explain in detail field compaction control methods.** **(5 marks)**

Field compaction control ensures that the soil placed at a site achieves the **required dry** density and moisture content specified in design. The following methods are commonly used:

Proctor Test Comparison (Standard Method): Field density obtained is compared with laboratory Proctor test results.

- Sand Cone Method (Density Test)
- Core Cutter Method (For Fine-Grained Soils)
- Field Moisture Content Test

Relative compaction or degree of compaction

$$R.C. = \frac{\gamma_{d-field}}{\gamma_{d\,max-laboratory}} \times 100\%$$

*Typical required R.C. >= 95%*

And, OMC ±2%

Engineer monitors number of roller passes, lift thickness, moisture content, and roller type. Ensures field operations match compaction specifications.

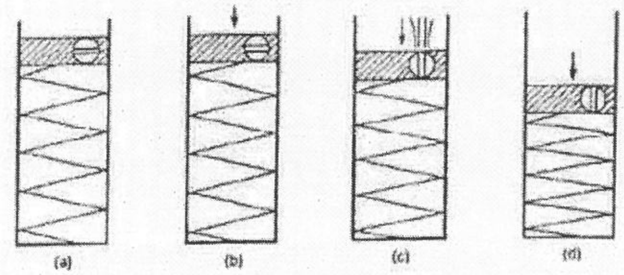
9 a) **Explain with spring analogy, Terzaghi's theory of one-dimensional consolidation.** **(5 marks)**

**Terzaghi's One-Dimensional Consolidation (Spring Analogy)**

Soil is imagined as a combination of springs (soil grains) and a dashpot (water in voids).

- The springs represent the compressibility of the soil skeleton.
- The dashpot represents the resistance of water flow, similar to low permeability of clay.
- When a load is suddenly applied, the soil grains cannot compress immediately.
- So, the entire load is initially taken by pore water, creating excess pore water pressure ($u_0$).

- As time passes, water begins to drain out from the soil through drainage boundaries.
- When water flows out, pore water pressure decreases, and effective stress increases.
- The springs start compressing gradually, representing soil settlement over time.
- This time-dependent settlement is called primary consolidation, governed by Terzaghi's equation.
- Consolidation completes when all excess pore water pressure dissipates, and the soil skeleton carries the full load.




9b) **Define the following terms:**
**i. Coefficient of compressibility**
**ii. Coefficient of volume compressibility**
**iii. Compression Index**
**iv. Degree of consolidation** **(5 marks)**

**i. Coefficient of Compressibility (av)**

It is the rate of change of void ratio of a soil with respect to change in effective stress.

- It shows how much a soil compresses when the effective stress increases.
- Units: $m^2/kN$ or 1/stress.

$$a_v = -\frac{\Delta e}{\Delta \sigma'}$$

**ii. Coefficient of Volume Compressibility (mv)**

It is the volume change per unit volume of soil per unit increase in effective stress.

- It indicates how much the soil volume decreases for a given stress increase.
- Units: $m^2/kN$.

$$m_v = \frac{\Delta e}{(1 + e_0)\,\Delta \sigma'}$$

**iii. Compression Index (Cc)**

It is the slope of the virgin compression curve (e–log σ′ plot) for normally consolidated soil.

- It indicates how much soil compresses under a large increase in stress.
- Used for calculating primary consolidation settlement.

$$C_c = \frac{\Delta e}{\Delta \log \sigma_{ef}}$$

**iv. Degree of Consolidation (U)**

It is the ratio of settlement completed at any time (St) to the final settlement (Sf).

- It shows how much consolidation has occurred at a given time.

$$U = \frac{S_t}{S_f} \times 100\%$$

10 a) **What are the factors affecting the shear strength of soil?** **(5 marks)**

- **Soil Type** – Sand, silt, and clay have different shear strength behaviors.
- **Density / Compaction** – Higher density increases shear strength.
- **Moisture Content** – Increase in water generally decreases shear strength in soils.
- **Effective Stress** – Higher effective stress increases shear strength.
- **Drainage Conditions** – Drained and undrained conditions affect strength differently.
- **Rate of Loading** – Rapid loading reduces drainage and lowers strength, especially in clays.
- **Soil Structure & Fabric** – Arrangement of particles affects strength.
- **Presence of Pore Water Pressure** – High pore pressure reduces effective stress and shear strength.
- **Cementation & Bonding** – Natural bonding between particles increases strength.
- **Overconsolidation Ratio (OCR)** – OCC soils have higher shear strength than NCC.

10b) **What are the advantages and disadvantages of direct shear test over triaxial test?** **(5 marks)**

**Advantages and disadvantages of the Direct Shear Test over the Triaxial Test**

**Advantages of Direct Shear Test**

- Simple and easy to conduct compared to triaxial test.
- Quick test, requires less time.
- Cheaper apparatus and low testing cost.
- Large number of tests can be performed quickly.
- Suitable for coarse-grained soils like sands and gravels.

**Disadvantages of Direct Shear Test**

- Stress distribution is non-uniform on the failure plane.
- Failure plane is predetermined and not natural, unlike triaxial test.
- Drainage cannot be fully controlled (only drained test possible).
- Pore water pressure cannot be measured during the test.
- Provides less accurate shear strength parameters compared to triaxial test.

11a) **A direct shear test was performed on a 6cm x 6cm sample of dry sand with normal load of 360N. The failure occurred at a shear load of 180N. Plot the Mohr's strength envelope and determine Assume c=0** **(5 marks)**

Sample area $A = 6 \text{ cm} \times 6 \text{ cm} = 36 \text{ cm2}$
Normal load $N = 360$ N.
Shear load at failure $T = 180$ N.
Assume cohesion $c = 0$.

$$\sigma = \frac{N}{A} = \frac{360}{0.0036} = 100000 \text{ Pa} = 100 \text{ kPa}$$
$$\tau = \frac{T}{A} = \frac{180}{0.0036} = 50000 \text{ Pa} = 50 \text{ kPa}$$

**Shear strength parameter (with $c = 0$)**

For $c = 0$: $\tau = \sigma \tan \phi \Rightarrow \tan \phi = \frac{\tau}{\sigma} = \frac{50}{100} = 0.5$.

$$\phi = \tan - 1\,(0.5) = 26.565° \approx \boxed{26.57°}$$

**11b) Explain about unconfined compressive strength (UCS). Also, draw stress strain behavior of clayey soil under UCS test. (5 marks)**

**Unconfined Compressive Strength (UCS)**

UCS is the maximum axial compressive stress a cohesive (clayey) soil can withstand without any lateral confinement. It is performed on a cylindrical sample without applying any cell pressure (i.e., $\sigma_3 = 0$).

Purpose: Used mainly for saturated clays. Helps determine undrained shear strength:

$$s_u = \frac{q_u}{2}$$

where $q_u$= unconfined compressive strength.

Test Procedure (Simple Steps)

- Prepare a cylindrical soil sample (usually 38 mm × 76 mm).
- Place the sample in the testing machine without confinement.
- Apply compression at a uniform strain rate (~1–2% per minute).
- Record load and deformation until failure.
- Compute:

$$q_u = \frac{P_{\text{failure}}}{A_c}$$

where $A_c$= corrected area at failure.

**Stress–Strain Behaviour of Clayey Soil Under UCS Test**