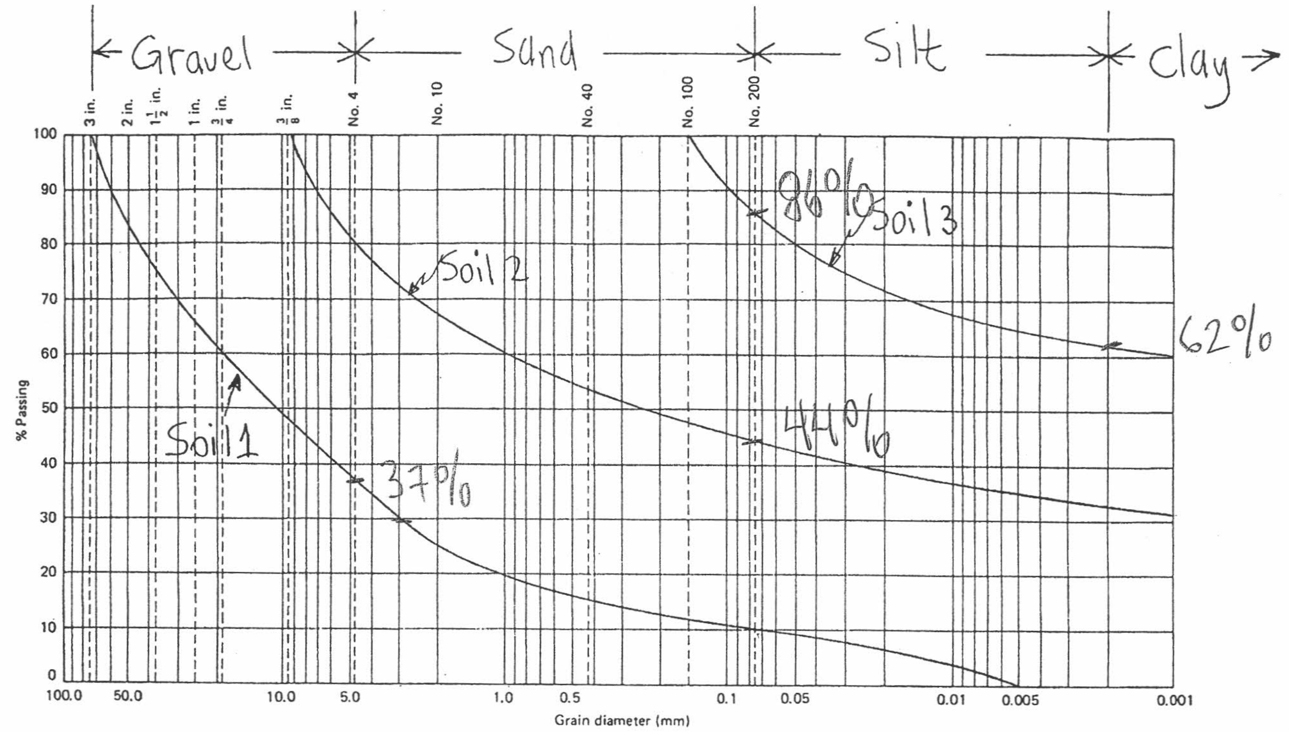
Solutions 10/10/14 /40

1) Given the particle size distribution curves for the three soils shown in the figure below. Answer the question below and the questions on the following page.



a) (2) Given that Soil 1 is non-plastic, the USCS group symbol for Soil 1 is GP-GM. Clearly show all of your work below.

% Passing # 200 sieve = 10% → coarse grained Soil

% Passing #4 Sieve = 37% → 63% G, 27% Sand

Gravel Soil → Dual symbols required

$C_u = \frac{D_{60}}{D_{10}} = \frac{19\,mm}{0.075} = 253$, $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(3.0)^2}{0.075 \times 19} = 6.3$

both criteria not met for GW → GP

non-plastic → plots below A-Line → GM

GP-GM

b) (1) The percentage of silt sizes in Soil 3 is:

- [✓ 24%]
- 14%
- 86%
- 62%
- 60%

86 - 62
= 24%

c) (1) Because Soil 2 is a coarse grained soil, it would be classified according to the USCS using its C_u and C_z values. True or [✓ False.]
Draw a circle around the correct answer.

> 12% Passing #200 - classify according to plasticity characteristics only

2) (1) A soil classified as a CL can **NOT** have the following characteristic:

- contain 3% gravel and 46% sand sizes → 51% Passing #200 sieve - fine grained soil ok
- contain more silt sized particles than clay sized particles
- [✓ a plasticity index of 6] must be CL-ML or ML
- a liquid limit of 30%

3) (1) A residual soil is a soil which was formed by:

- deposition of soil particles along or at the base of a slope by gravity
- deposition within a lake
- [✓ erosion and weathering of parent materials in place]
- deposition by flowing water in a stream or river

4) (1) Clay mineral particles attract water molecules to their surfaces because:

- they usually have a dispersed (parallel) structure
- [✓ of net negative electrical charges on their surfaces]
- of gravitational forces
- hydrated anions are ~~attracted~~ repelled to their surfaces

5) (2) Compacting a cohesive, clayey soil on the dry side of optimum moisture content contrasted with the wet side of optimum moisture content will give the soil:

- a lower hydraulic conductivity because the clods/aggregates can be easily remolded in the dry state
- lower shear strength
- [✓ higher potential for swelling]
- [✓ higher stiffness (i.e. higher slope of the stress-strain curve)]

Draw a circle around the bullets of the two best answers

6) (1) The relationship between zero air voids dry unit weight and moisture content:

- is linear on a graph of dry unit weight versus moisture content
- is the theoretical maximum dry unit weight for a given degree of saturation
- [✓ depends on the mineralogy of the soil]
- depends on the compactive effort applied to the soil

→ depends on G_s

$\gamma_d = \frac{G_s \gamma_w}{1 + w G_s}$ for ZAV curve

7) (1.5) A compacted fill is to be constructed with a total volume of 10,000 m^3. The fill is to be compacted to a dry unit weight of 20.0 kN/m^3 and a moisture content of 10%. Soil in the borrow area has a dry unit weight of 19.0 kN/m^3 and a moisture content of 8%. How many m^3 of water will need to be hauled in to meet the specification?

- 200 m^3
- [✓ 408 m^3]
- 545 m^3
- 2,000 m^3

borrow

$\gamma_d = 19.0 \frac{kN}{m^3}, W = 8.0\%$

fill

$V_T = 10,000 m^3, \gamma_d = 20.0 \frac{kN}{m^3}, W = 10\%$

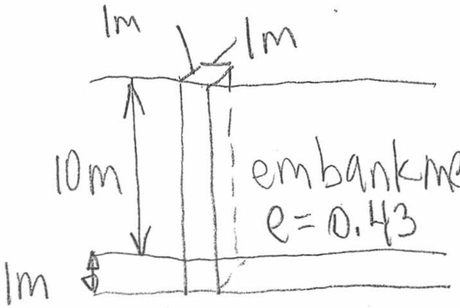
fill $\rightarrow \gamma_d = \frac{W_s}{V_T} \rightarrow W_s = \gamma_d \times V_T = 20.0 \frac{kN}{m^3} \times 10,000 m^3 = 200,000 kN$

$W = \frac{W_w}{W_s} \rightarrow W_w = WW_s = 0.10 \times 200,000 kN = 20,000$ kN water

borrow $\rightarrow W_s = 200,000 kN \rightarrow W_w = 0.08 \times 200000 = 16,000$ kN water

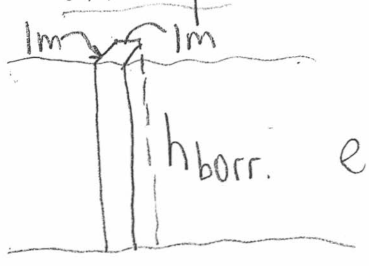
require $\rightarrow 20,000 - 16,000 = 4000 kN$; $V_w = \frac{W_w}{\gamma_w} = \frac{4000 kN}{9.81 kN/m^3} = 408 m^3$

8) (1.5) An airport runway is being extended and requires a 10 m high embankment. Analyses indicate that the embankment will settle 1 m due to consolidation of the underlying clay. The sand used to build the embankment is taken from a pit where the sand has a void ratio of 0.58. When compacted to specification, the sand will have a void ratio of 0.43. Considering unit areas for the pit and the embankment volumes, what height of sand must be taken from the borrow pit so that a long time after completion, the top of the embankment will be 10 m above the initial grade before construction?



height must be 11m to accomodate settlement

borrow pit



e = 0.58

$V_{emb.} = 11m \times 1m \times 1m = 11 m^3$

$V_{borr} = h_{borr} \times 1m \times 1m$

$\gamma_{demb} = \frac{W_s}{V_{Temb.}}$ $\quad \gamma_{dborr} = \frac{W_s}{V_{Tborr}} \Rightarrow W_{semb} = W_{sborr} \rightarrow$ remains constant

can also say $\gamma_{demb} = \frac{W_s}{1+e_{emb}}$ and $\gamma_{dborr} = \frac{W_s}{1+e_{borr}}$

$\frac{\gamma_{dborr}}{\gamma_{demb}} = \frac{\frac{W_s}{1+e_{borr}}}{\frac{W_s}{1+e_{emb}}} = \frac{1+e_{emb}}{1+e_{borr}} = \frac{V_{Temb}}{V_{Tborr}}$; $V_{Tborr} = \frac{V_{Temb} \times (1+e_{borr})}{1+e_{emb}}$

4a

$$V_{T\,borr} = \frac{11\,m^3 \times (1 + 0.58)}{1 + 0.43}$$

$$= 11\,m^3 \times 1.105$$

$$= 12.15\,m^3$$

$$\therefore h_{borr} = \frac{12.15\,m^3}{1m \times 1m} = \underline{\underline{12.15m}}$$

or

$$V_{Temb} = V_s + V_{v\,emb.}$$

$$e = \frac{V_v}{V_s} \longrightarrow V_v = eV_s$$

$$\therefore V_{Temb} = V_s + 0.43V_s = 1.43V_s = 11\,m^3$$

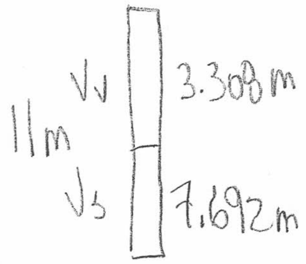
$$V_s = \frac{11\,m^3}{1.43} = 7.692\,m^3 \quad (V_v = 3.308\,m^3)$$

$V_{T\,borr} = V_s + 0.58\,V_s$ (V_s remains the same)

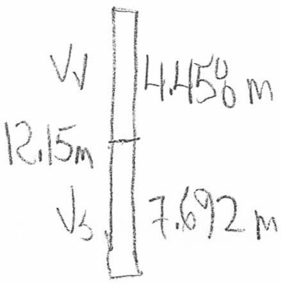
$$V_{T\,borr} = 7.692 + 0.58(7.692)\,m^3 = 12.15\,m^3$$

$$h_{borr} = \frac{12.15\,m^3}{1m \times 1m} = \underline{12.15m} \quad (V_v = 4.458)$$

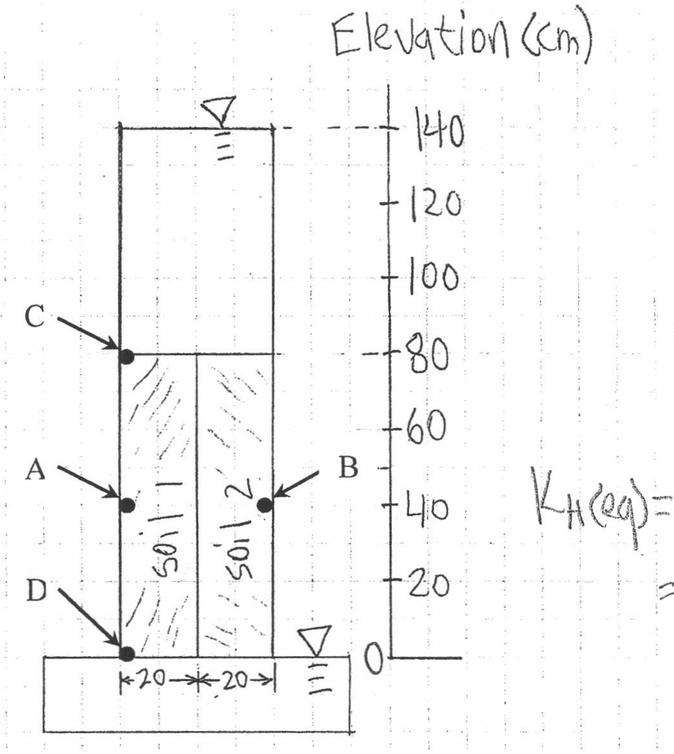
embankment ($e = 0.58$)



borrow pit ($e = 0.43$)



9) Given the permeameter system below with **steady state flow** through soil layer 1 and soil layer 2 Soil layer 1 has a hydraulic conductivity value ten times greater than soil layer 2 (i.e. $k_1 = 10k_2$). The cross section of the permeameter is 40 cm wide x 20 cm deep into the paper.



z	h_p	h
140	0	140
80	60	140

$$K_{H(eq)} = \frac{1}{40}(K_1 \times 20 + 0.1K_1 \times 20) = \frac{22K_1}{40} = 0.55K_1$$

(4) Draw a **circle around the bullets** of **four** of the following statements below that are **TRUE**.

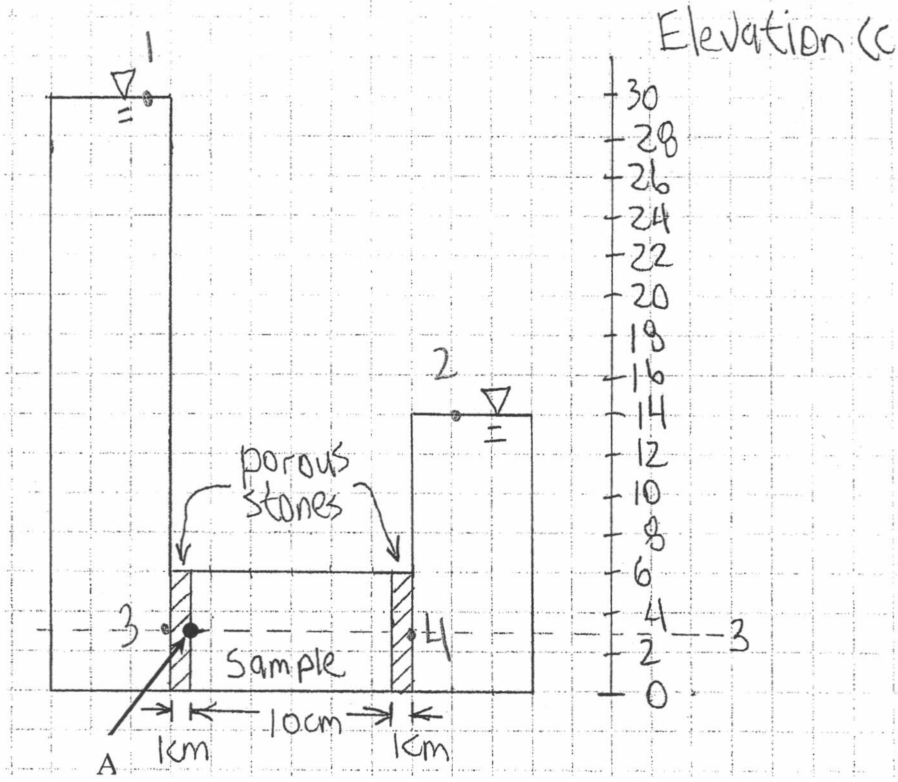
- The total head at point A is ten times less than the total head at point B.
- The flow rate through soil layer 1 is the same as the flow rate through soil layer 2.
- The hydraulic gradient across soil layer 1 is ten times less than the hydraulic gradient across soil layer 2.
- [✓] The flow rate through soil layer 1 is ten times higher than the flow rate through soil layer 2.
- [✓] An equivalent hydraulic conductivity for the two layers combined = $0.55k_1$
- The total head loss through the system is equal to ~~80~~ cm. 140
- [✓] The pressure head at point A is the same as the pressure head at point B.
- If the datum for this problem is changed to coincide with the headwater elevation, the total head at points A and B will not change.
- [✓] The pressure head at Point D is 0 cm.
- The pressure head at Point C is 140 cm.

flow parallel to layering $\rightarrow$ $i_1 = i_2 = i$ & $q_1 + q_2 = q_{perm\ system}$

$q_1 = k_1 i_1 A_1$ (20x20) $\quad q_2 = k_2 i_2 A_2$ (20x20) $\rightarrow k_2 = 0.1k_1$

$q_1 = k_1 i \, 400\,cm^2 \quad q_2 = 0.1k_1 i \, 400\,cm^2 \rightarrow \frac{q_1}{q_2} = 10$

10) Given the permeameter system below with a **steady state** flowrate of 1.62 cm^3/s. The permeameter cross section is 6 cm x 6 cm and identical porous stones are on the ends of the sample as shown below. The hydraulic conductivity of the soil sample is 4.5 x 10^{-2} cm/s. Answer the following questions – part b) is on the next page.



	Z	hp	h
1	30	0	30
2	14	0	14
3	3	27	30
4	3	11	14

a) (2) Determine the hydraulic conductivity of the porous stones in cm/s.

$q = kiA = 1.62 \frac{cm^3}{s}$

flow perpendicular to layering – 1) $q_{ps1} = q_{sample} = q_{ps2} = q$

2) $\Delta h_{ps1} + \Delta h_{sample} + \Delta h_{ps2} = \Delta h_{system} = 16 cm$

$q_{sample} = 1.62 \frac{cm^3}{s} = K_s i_s A_s = 4.5 \times 10^{-2} \frac{cm}{s} \times i_s \times (6cm \times 6cm)$

$i_{sample} = \frac{1.62 \frac{cm^3}{s}}{4.5 \times 10^{-2} \frac{cm}{s} \times 36 cm^2} = 1.0 \, cm/cm \Rightarrow \Delta h_{samp} = i_{samp} \times L_{samp}$

$= 1.0 \frac{cm}{cm} \times 10 cm = 10 cm$

Since porous stones are identical $\Delta h_{ps1} = \Delta h_{ps2} = \Delta h_{ps}$

$\boxed{6a}$

$$\therefore \quad \Delta h_{ps} + 10\,cm + \Delta h_{ps} = 16\,cm$$

$$2\,\Delta h_{ps} = 6\,cm$$

$$\Delta h_{ps} = \frac{6\,cm}{2} = 3\,cm$$

$$i_{ps} = \frac{\Delta h}{L_{ps}} = \frac{3\,cm}{1\,cm} = 3\,\frac{cm}{cm}$$

$$q_{ps} = 1.62\,\frac{cm^3}{s} = K_{ps}\,i_{ps}\,A_{ps}$$

$$= K_{ps} \times 3\,\frac{cm}{cm} \times 36\,cm^2$$

$$K_{ps} = \frac{1.62\,\frac{cm^3}{s}}{3\,\frac{cm}{cm} \times 36\,cm^2} = \underline{1.5 \times 10^{-2}\,\frac{cm}{s}}$$

$\underline{\text{or}}$ $\quad q = K_{eq}\,i_{eq}\,A \quad - \quad i_{eq} = \frac{16\,cm}{12\,cm} = 1.33\,\frac{cm}{cm}$

$$K_{eq} = \frac{1.62\,\frac{cm^3}{s}}{1.33\,\frac{cm}{cm} \times 36\,cm^2} = 0.03375\,\frac{cm}{s}$$

$$K_{eq} = \frac{12\,cm}{\frac{2\,cm}{K_{ps}} + \frac{10\,cm}{4.5 \times 10^{-2}\,\frac{cm}{s}}} = 0.03375\,\frac{cm}{s}$$

$$\frac{2\,cm}{K_{ps}} = \frac{12\,cm}{0.03375\,\frac{cm}{s}} - \frac{10\,cm}{4.5 \times 10^{-2}\,\frac{cm}{s}} = 133.33\,s$$

$$K_{ps} = \frac{2\,cm}{133.33\,s} = \underline{0.015\,\frac{cm}{s}} = \underline{1.5 \times 10^{-2}\,\frac{cm}{s}}$$

b) (1) Determine the pressure head in cm at Point A (at the interface between the porous stone and the sample).

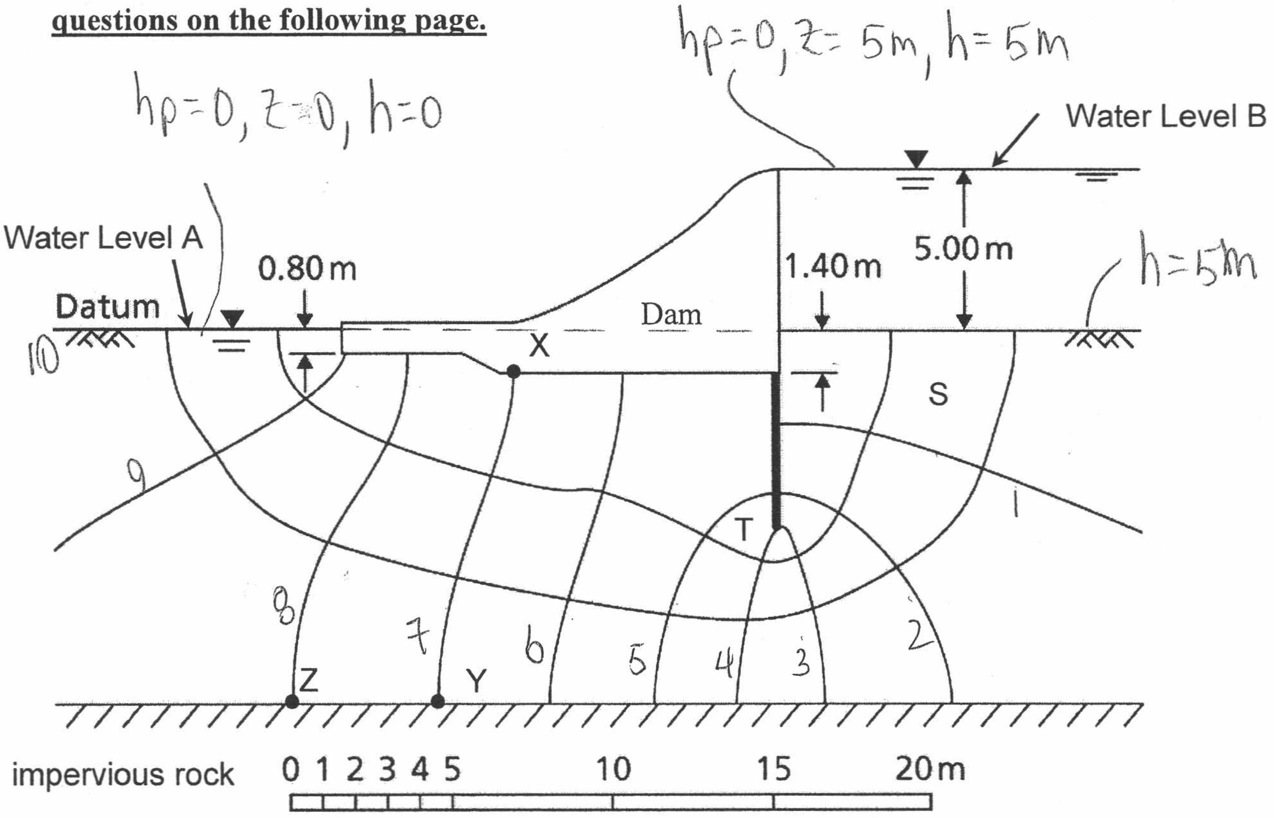
h @ pt. A = h @ pt. 3 − Δh_{ps}

= 30 cm − 3 cm = 27 cm

z @ pt A = 3 cm

$h_p = h - z$ = 27 cm − 3 cm = 24 cm

11) Given the flow net for the masonary dam. All flow net elements are curvilinear squares. Note that a sheet pile cutoff extends below the right hand side of the dam (i.e. the heavy black vertical line). The hydraulic conductivity of the sand soil is 3.0 x 10^{-5} m/s. **Answer the questions on the following page.**



a) (2) Given the flow net on the previous page, calculate the quantity of flow beneath the dam per meter length of dam (perpendicular to the page) in m^3/s.

$q = k H \frac{N_f}{N_d} \times 1m$ $N_f = 3, \; N_d = 10, \; H = 5.0m$

$q = 3.0 \times 10^{-5} \frac{m}{s} \times 5.0m \times \frac{3}{10} \times 1m$

$q = 4.5 \times 10^{-5} \frac{m^3}{s}$

b) (1) Determine the pore pressure in kN/m^2 at point "X".

$h @ pt X = 5.0m - \left(\frac{5.0m}{10 drops}\right) \times 7 drops = 1.5m$

$z @ X = -1.4m \longrightarrow h = h_p + z \Rightarrow h_p = h - z$

$h_p @ X = 1.5m - (-1.4m) = 2.9m$ $u = h_p \gamma_w = 2.9m \times 9.81 \frac{kN}{m^3}$

$\underline{u = 28.4 \frac{kN}{m^2}}$

c) (3) Draw a circle around the bullets for the correct **three** answers.
If standpipes were installed with their ends open at points X, Y and Z:

- the water level in standpipe Y would rise to a higher elevation than level B
- the pressure head at Point X is the same as the pressure head at Point Y
- [✓ the water level in standpipe X would rise to the same elevation as standpipe Y]
- the water level in standpipe Z would rise to a higher elevation than standpipe X
- the water level in standpipe Z would rise to the same elevation as level A
- all standpipes would have water levels higher than water level B and lower than water level A
- [✓ the water level in standpipe Y would rise to a lower elevation than level B]
- [✓ the water level in standpipe Z would rise to a higher elevation than level A]

d) (2) Given the flow net on the previous page. Draw a circle around the bullets for the correct **two** answers.

- the hydraulic gradient across the element marked S is greater than the hydraulic gradient across the element marked T
- the total head loss across the element marked T is lower than the total head loss across the element marked S because the equipotential lines are closer together for element T than element S
- [✓ the flow rate through the element marked T is the same as the flow rate through the element marked S]
- the flow rate through the element marked S is higher than the flow rate through the element marked T because the flow channel at element S is wider than at element T
- [✓ the total head loss across the element marked T is the same as the total head loss across element marked S]

12) (12) Indicate T for true or F for false answers to the questions below **by drawing a circle around the selected letter**.

T [✓ F] A soil with a liquidity index close to ~~1.0~~ 0 is likely heavily overconsolidated.

[✓ T] F For clays, as specific surface area increases, the liquid limit increases.

T [✓ F] Given a thin walled tube sample of clay collected from 5 m below the groundwater table and given that the sample has a water content of 40% and specific gravity of soil solids of 2.72. Additional information is needed to calculate the void ratio of this clay sample.

$WG = Se$

$S = 100\ \%$

$e = WG$

T [✓ F] Given a standard Proctor compaction curve. If a modified Proctor test was carried out on the same soil both the optimum moisture content and the maximum dry unit weight would increase.

$WG = Se \quad e = \frac{WG}{S} = \frac{0.2 \times 2.7}{0.9} = 0.6$

T [✓ F] A soil has a water content of 20%, degree of saturation of 90% and specific gravity of soil solids of 2.70. The porosity of this soil is 0.6.

$\Rightarrow e = 0.6$

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

[✓ T] F The absolute permeability of a soil does not depend on the viscosity and unit weight of the permeating fluid.

[✓ T] F In steady state downward seepage, the pressure head at any point in a uniform saturated soil mass is less than that for the hydrostatic, no flow condition.

T [✓ F] Seepage velocity is determined by dividing the discharge velocity by the void ratio of the soil because the solid soil particles are impermeable.

$V_s = \frac{ki}{n} = \frac{v}{n}$

T [✓ F] For anisotropic hydraulic conductivity conditions, the flow net is drawn in a transformed section with the vertical scale compressed relative to the horizontal scale because the horizontal hydraulic conductivity is typically less than the vertical hydraulic conductivity.

$h = h_p + z = \text{constant}$

[✓ T] F In a flow net for seepage through an embankment dam on an impermeable foundation, $\Delta h_p = -\Delta Z$ along an equipotential line.

h is constant $- \Delta h = 0$

$\Delta h_p + \Delta Z = 0$

$\Delta h_p = -\Delta Z$

[✓ T] F In a flow net for seepage through an embankment dam on an impermeable foundation, the sloping upstream face of the dam is an equipotential line with total head equal to the elevation head of the reservoir (headwater) level.

[✓ T] F In a flow net for seepage through an embankment dam on an impermeable foundation, at every point on the top flow line the total head is equal to the elevation head.