[ENG13]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATIONS 2021/2022

GROUND AND WATER STUDIES 1

MODULE NO: CIE4020

THIS IS AN OPEN-BOOK EXAM

Date: Wednesday 18th May 2022 **Time: 14:00 – 17:00**

INSTRUCTIONS TO CANDIDATES:

There are TWO Sections; A and B.

You will be supplied with TWO Answer Booklets by the Invigilator. Answer Section A in ONE Answer Booklet, and Section B in the OTHER.

Section A: contains TWO questions: you should answer BOTH questions. Each of these questions is worth 20 marks.

Section B: contains THREE questions: you should answer ALL THREE questions. Each of these questions is worth 20 marks.

Marks for parts of questions are shown in brackets.

This assessment carries 100 marks.

All working must be shown.

A formula sheet is included.

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BEng (Hons) Civil Engineering
Semester Two Examination 2021/22
Ground and Water Studies 1
Module No. CIE4020

Section A – Water (Answer BOTH Questions in this Section)

Question 1

(a) Two parallel pipes carrying freshwater and seawater are connected to each other by a double U-tube differential manometer, as shown in **Figure Q1**,

(i) Determine the pressure difference between the two pipelines.

(**5 marks**)

(ii) What would be the pressure difference between the two pipes if the oil in the manometer is replaced by air and all other heights remain the same?

(**2 marks**)

Take the density of seawater at that location as 1035 kg/m^3, the fresh water as 1000 kg/m^3, the mercury as 13600 kg/m^3 the air as 1.1213 kg/m^3 and the specific gravity of the oil as 0.72. Assume all fluids are incompressible. The heights in the double tube are measured as follows: h_w = 0.5m, h_{Hg} = 0.1m, h_{oil} = 0.75m and h_{sea} = 0.2.5m.

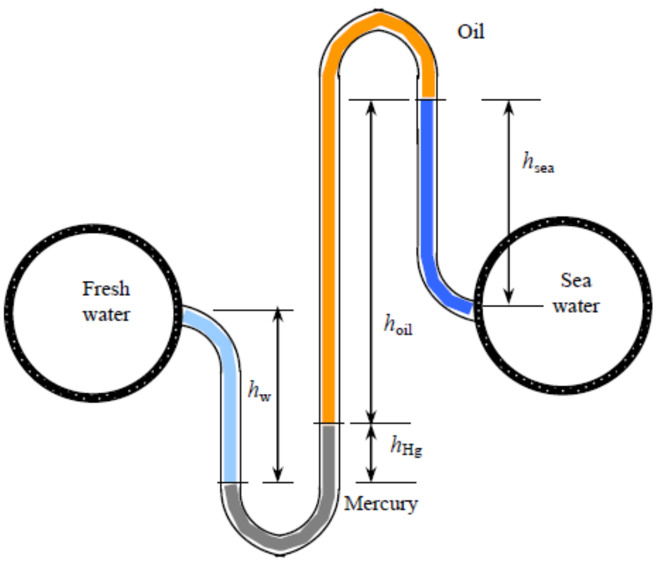

Figure Q1

Question 1 continues over the page….

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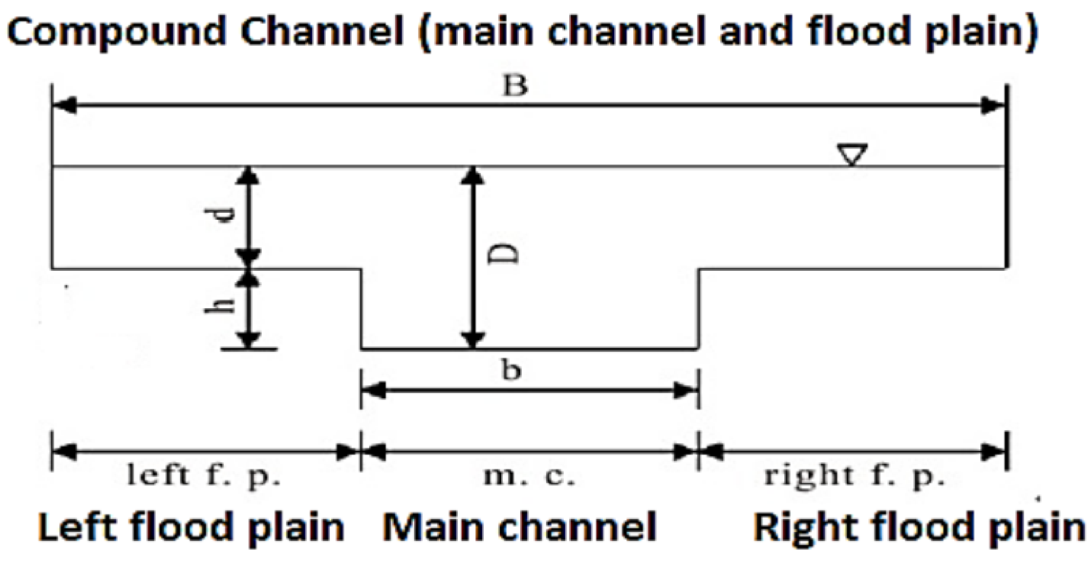
Question 1 continued….

(b) Water flows through an open channel of rectangular section, which is 4 m wide, bed slope is 0.0004, roughness coefficient (n) is 0.025 and discharge is 8 m^3/s. Determine the depth of water.

(**3 marks**)

(c) The compound channel section **(Figure 2b)** has a roughness coefficient (n) equals 0.023, slope = 0.0005. Find (1) the discharge and (2) the flow velocity. Assume that **the velocity is not uniform across the whole compound section** of the channel. Consider the following dimensions:

Top width (B) = 8m
Bottom width (b) = 2.5m
Depth of water (D) = 2.5m
h = 0.5 m



(Figure 2b)

(**10 marks**)

Total 20 marks

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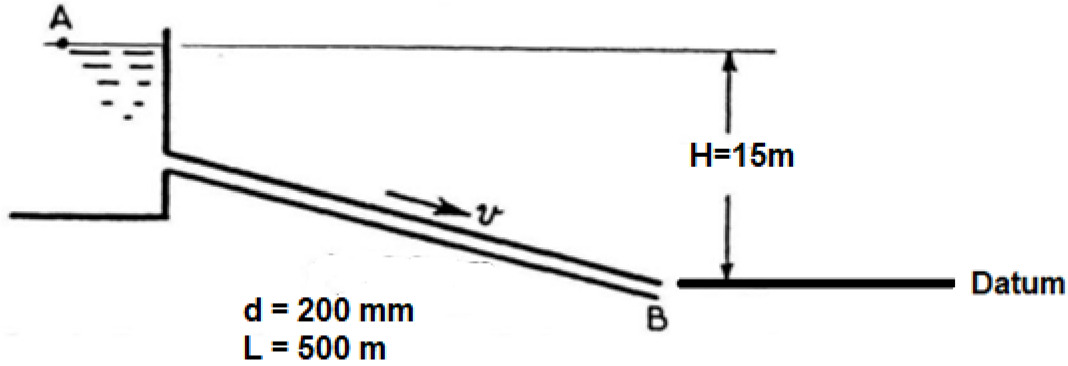
Question 2

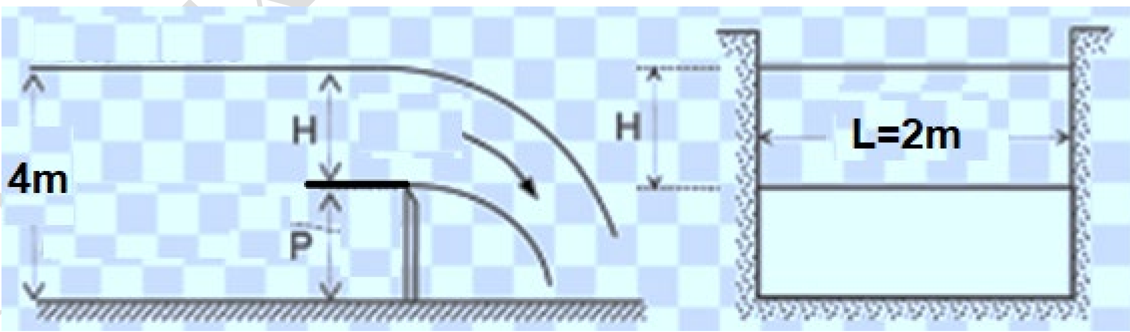
(a) Water flowing from a large reservoir to atmosphere **(Figure 3a)** through a 200mm diameter pipe 500m long. The entry from the reservoir to the pipe is a sharp-edged entrance and the outlet is 15m below the surface level in the reservoir. Taking friction factor (f) = 0.05 in the Darcy-Weisbach formula, calculate the discharge passing through the pipe.



(Figure 3 a)

(**10 marks**)

(b) A rectangular channel 2m wide carries water with a discharge of 10 m^3/s. A rectangular weir **(Figure 3 b)** is to be installed across the canal to raise the water level 4m above the channel floor. Calculate the required height of the weir (P) if the weir is suppressed. Assume ($C_d = 0.6$)



(Figure 3b)

(**10 marks**)
Total 20 marks

END OF SECTION A

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Section B – Ground (Answer ALL THREE Questions in this Section)

Question 3

(a) Sketch a "soil model" diagram clearly showing the solids, water and air components annotated with conventional symbols to allow development of 'soil property' equations.

(5 marks)

(b) An undisturbed sample of clayey soil is found to have a wet weight of 285 N, a dry weight of 250 N, and a total volume of 14×10^3 cm^3, if the specific gravity of soil solids is 2.70. Determine:

(i) The water content (**2 marks**)

(ii) Void ratio (**2 marks**)

(iii) Porosity (**2 marks**)

(iv) Degree of saturation (**2 marks**)

(v) The air content (**2 marks**)

(c) What would be the bulk unit weight and water content if the soil in (b) were fully saturated at the same void ratio as in its natural state?

(5 marks)

Total 20 marks

Section B continues over the page….

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Section B continued….

Question 4

(a) Define the term soil compaction and explain three of its applications in civil engineering

(**5 marks**)

(b) The results of a standard compaction test for a soil having a value of (**Gs** =**2.5**) are shown in the table below.

Water Content (%)	6.2	8.1	9.81	11.5	12.3	13.2
Bulk Unit Weight (kN/m^3)	16.9	18.7	19.5	20.5	20.4	20.1

(i) Plot the compaction curve and obtain the maximum dry unit weight (γ_d in kN/m^3) and the optimum water content.

(**5 marks**)

(ii) On the same axes, draw the γ_d vs w curves for 0%, 5% and 10% air content and determine the air content for the maximum dry unit weight.

(**5 marks**)

(iii) Determine the corresponding void ratio and degree of saturation reached for the maximum dry unit weight.

(**5 marks**)

Total 20 marks

Section B continues over the page….

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Section B continued….

Question 5

(a) Use the percentages of minerals given in the **Table Q5.1** to determine the missing values and the name of the soil texture using the soil texture triangle.

No	Percentage (%)			
	Gravel	Sand	Silt	Clay
1	0	55		15
2	15	25	30	
3	0		45	20
4	10	50	10	
5	0		75	10

Table Q5.1

(**10 marks**)

(b) **Figure Q5** below shows a soil profile consists of three layers with properties shown in **Table Q5.2** (Page 8). Calculate the following:

(i) The equivalent coefficient of permeability along the x-direction
(ii) The equivalent coefficient of permeability along the z-direction
(iii) The ratio of coefficients in two direction

(**10 marks**)

[Total 20 marks]

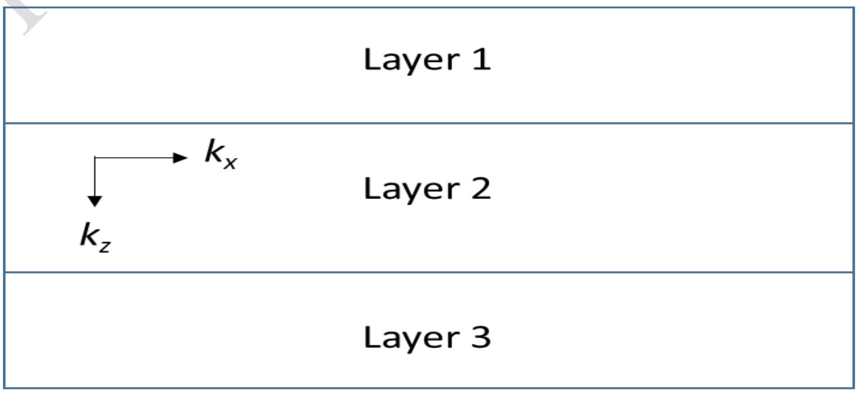

Figure Q5

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Section B Question 5 continued….

Layer	Thickness (m)	kx (m/s)	kz (m/s)
1	2.5	2.0x10-6	1.0x10-6
2	5.0	5.0x10-8	2.5x10-8
3	2.5	3.0x10-5	1.5x10-5

<u>Table Q5.2</u>

END OF SECTION B

END OF QUESTIONS

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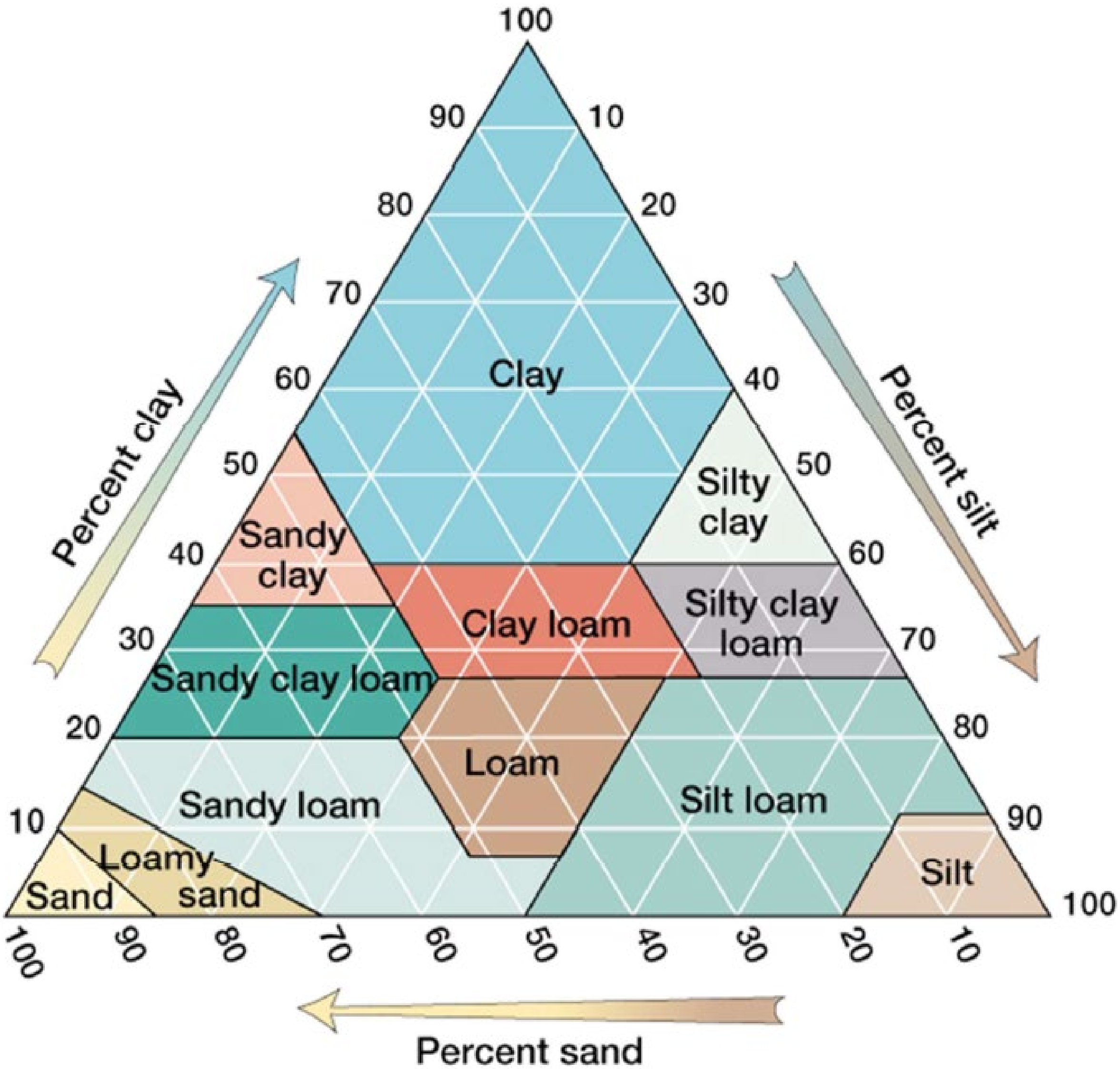
USDA Soil Triangle



Useful Formulae
Soil Part

TERMINOLOGY, SYMBOLS AND UNITS

Term	Symbol	Units
Volume		m^3
Mass		kg
Gravity	g	9.81 m/sec^2
Weight		kN = (kg x 9.81)/1000
Total volume	V	m^3
Volume of air	V_A	m^3
Volume of water	V_W	m^3
Volume of voids	V_V	m^3
Volume of Solids	V_S	m^3
Mass of water	M_W	kg
Mass of solids	M_S	kg
Total mass	M	kN
Specific gravity	G_s	None
Density of water	ρ_w	1000kg/m^3
Unit weight of water	γ_w	9.81 kN/m^3
Void ratio	e	None
Degree of saturation	S_r	None
Moisture content	w	None
Porosity	n	None
Soil Bulk density	ρ_b	kg/m^3
Dry density	ρ_d	kg/m^3
Saturated density	ρ_{sat}	kg/m^3
Soil Bulk unit weight	γ_b	kN/m^3
Dry unit weight	γ_d	kN/m^3
Saturated unit weight	γ_{sat}	kN/m^3

Coefficient of Permeability	k	m/s
Soil Layer Thickness	H	m

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DEFINITIONS

Term	**Expression**	
Density of water, ρ_w		
Unit weight of water, γ_w		
Specific gravity, G_s	$\frac{\text{density of solids}}{\text{density of water}}$	$\frac{\rho_s}{\rho_w}$
Water content, w	$\frac{\text{mass of water}}{\text{mass of solids}}$	$\frac{M_w}{M_s}$
Void ratio, e	$\frac{\text{volume of voids}}{\text{volume of solids}}$	$\frac{V_v}{V_s}$
Degree of saturation, S_r	$\frac{\text{volume of water}}{\text{volume of voids}}$	$\frac{V_w}{V_v}$
Porosity, n	$\frac{\text{volume of voids}}{\text{total volume}}$	$\frac{V_v}{V}$
Bulk density, ρ_b	$\frac{\text{total mass}}{\text{total volume}}$	$\frac{M}{V}$
Dry density, ρ_d	$\frac{\text{mass of solids}}{\text{total volume}}$	$\frac{M_s}{V}$
Saturated density, ρ_{sat}	$\frac{\text{total saturated mass}}{\text{total volume}}$	$\frac{M}{V}$
Bulk unit weight, γ_b	$\frac{\text{total weight}}{\text{total volume}}$	$\frac{W}{V}$
Dry unit weight, γ_d	$\frac{\text{weight of solids}}{\text{total volume}}$	$\frac{W_s}{V}$
Saturated unit weight, γ_{sat}	$\frac{\text{total saturated weight}}{\text{total volume}}$	$\frac{W}{V}$
Air voids, A_v	volume of air	V_a

total volume V

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$$\rho_b = \frac{(G_s + S_r e)\rho_W}{1 + e}$$

BASIC PROPERTIES Formulae:

Void space relationship from soil model $w\, G_s = S_r\, e$

Bulk Density

$$\rho_b = \frac{\rho_W\ G_s(1 + w)}{1 + e}$$

Dry Density

$$\rho_d = \frac{\rho_W\ G_s}{1 + e}$$

$$\rho_d = \frac{\rho_b}{1 + w}$$

$$\rho_d = \frac{\rho_{sat}}{1 + w_{sat}}$$

Theoretical Dry Density

$$\rho_d = \frac{\rho_W\, G_s\, (1 - A_v)}{1 + w\, G_s}$$

Porosity

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

Air voids $A_v = n\,(1 - S_r)$

Soil Coefficient of Uniformity $C_u = \frac{D_{60}}{D_{10}}$

Soil Coefficient of Curvature $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

$$Constant\ head\ permeability, k = \frac{V_w L}{Aht}$$

$$Falling\ head\ permeabilit, k = \frac{2.303\ a\ L}{At} \log \frac{h_1}{h_2}$$

$$k_H = \frac{1}{H}(k_{H1}xH_1 + k_{H2}xH_2 + \ \ldots\ldots\ldots\ldots + k_{Hn}xH_n)$$

$$k_v = \frac{H}{(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3} + \ \ldots\ldots\ \ + \frac{H_n}{k_n})}$$

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Hydraulics Part

Principles of Flow in Pipes

Reynold Number: $\boldsymbol{R_e = \frac{\rho VD}{\mu} = \frac{VD}{v}}$

Darcy-Weisbach Friction Head Loss: $\boldsymbol{h_f = \frac{fL}{D}\frac{V^2}{2g} = \left(\frac{8fl}{\pi^2 gD^5}\right)Q^2}$

Hagen-Poiseuille Friction Head Loss: $\boldsymbol{h_f = \frac{32\mu LV}{\rho gD^2}}$

Minor Head Loss: $\boldsymbol{h_l = K\frac{V^2}{2g}}$

Minor Head losses equation for sudden expansions: $\boldsymbol{\frac{(V_1 - V_2)^2}{2g}}$

Principles of Flow in Open Channels

Steady Uniform flow Equations:

Chezy velocity: $\boldsymbol{V = C\sqrt{RS_0}}$;

Manning velocity: $\boldsymbol{V = \frac{1}{n}R^{2/3}S_0^{1/2}}$

Flows over Weirs:

$\boldsymbol{Q = \frac{2}{3}C_d L\sqrt{2g}H^{3/2}}$ (*General flow over Weir*)

$\boldsymbol{Q = \frac{2}{3}C_d\sqrt{2g}LH^{3/2}}$ (*Suppressed Rectangular Weir*)

$\boldsymbol{Q = \frac{2}{3}C_d\sqrt{2g}(L - 0.2H)H^{3/2}}$ (*Unsuppressed Rectangular Weir*)

$$Q = \frac{8}{15} C_d Tan\frac{\theta}{2}\sqrt{2g}H^{5/2}$$ (*Triangular (or V-notch) Weir*)

$$Q = \frac{2}{3} C_d L\sqrt{2g}H^{3/2} + \frac{8}{15} C_d Tan\frac{\theta}{2}\sqrt{2g}H^{5/2}$$ (*Trapezoidal Weir*)

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