UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) IN CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

GROUND AND WATER STUDIES II

MODULE NO: CIE5005

Date: Tuesday 21st May 2019 **Time: 10:00 – 13:00**

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 : Q1 to Q4 (Answer THREE Questions from four).

Section B : Q5 to Q7 (Answer TWO Questions from three).

Formulae and Definitions are provided.

Lined Graph Paper and Supplementary Answer Sheets are available for your use.

Ensure that you write your Candidate Number or Desk Number on each Figure, Supplementary Sheet or Sheet of Graph Paper you use to answer the selected questions.

All questions carry equal marks.

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Marks for parts of questions are shown in brackets.

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SECTION A – Answer THREE questions

1. a) Figure 1a below shows part of a storm drainage system. Identify the section(s) that could potentially cause hydraulic issues during the design phase, explaining the hydraulic conditions that are not being met and how the problem could be resolved.

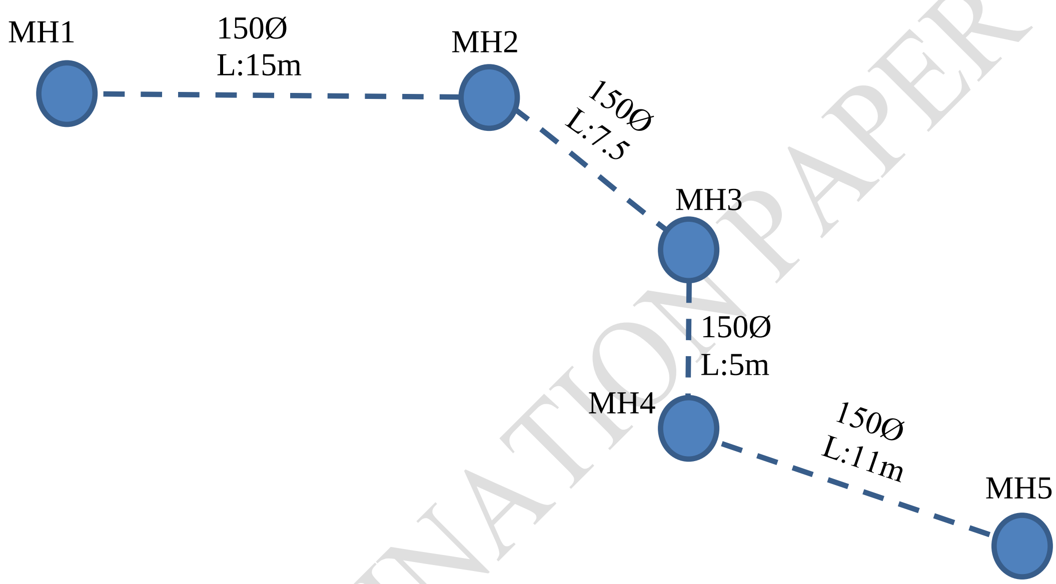

Figure 1a

(8 marks)

b) Water flows through a 225mm diameter pipe at a rate of 48 litres/sec. The pipe is 600m long and has a Darcy friction factor λ of 0.027. It is proposed to increase the flow through the pipeline to 65 litres/sec, without increasing the friction loss, by the addition of a parallel pipeline of the same diameter and λ value as the existing pipeline. Determine the length of pipe required.

(12 marks)

Total 20 marks

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2. a) Briefly outline the general design and construction criteria which is used for separate foul and storm drainage systems. **(7 marks)**

   b) Using the Rational Method, check the adequacy of the storm water sewerage system detailed in Table Q2b. The system is to withstand a 1 in 10 year event and has a time of entry of 4 minutes. HRS tables and a rainfall table are provided.

(13 marks)

Total 20 marks

3. a) Sketch out the general shape of the Moody diagram for flow through pipes and briefly explain the factors which affect the value of the Darcy friction factor λ in each of the zones.

(10 marks)

   b) Water, with a coefficient of dynamic viscosity μ of 1.12 x 10^{-3} kg/ms, flows from a storage tank to a service reservoir through a 300mm diameter pipeline at a rate of 70litres/sec. The water level in the storage tank is 310m AOD. The pipeline is 670m long and has a surface roughness k_s of 1.7mm. Determine the value of the Darcy friction factor λ and determine the water level in the reservoir.

(10 marks)

$$h_f = \frac{32\mu L v}{\rho g d^2} \qquad \frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{k_s}{3.7d} + \frac{2.51}{Re\sqrt{\lambda}}\right)$$

$$\frac{1}{\sqrt{\lambda}} = -2\log\left[\frac{k_s}{3.7d} + \frac{5.1286}{R_e^{0.89}}\right]$$

Total 20 marks

PLEASE TURN THE PAGE….

4. a) Briefly explain the procedures required to determine flows in a loop network using the Hardy Cross method.

(7 marks)

b) Determine the approximate flows in each of the pipes in the network shown in Fig Q4 and Table Q4. Perform no more than three iterations in table Q4a is provided.

(11 marks)

c) If the total head at node A is 245m determine the available head at node C if it has an elevation of 130m.

(2 marks)

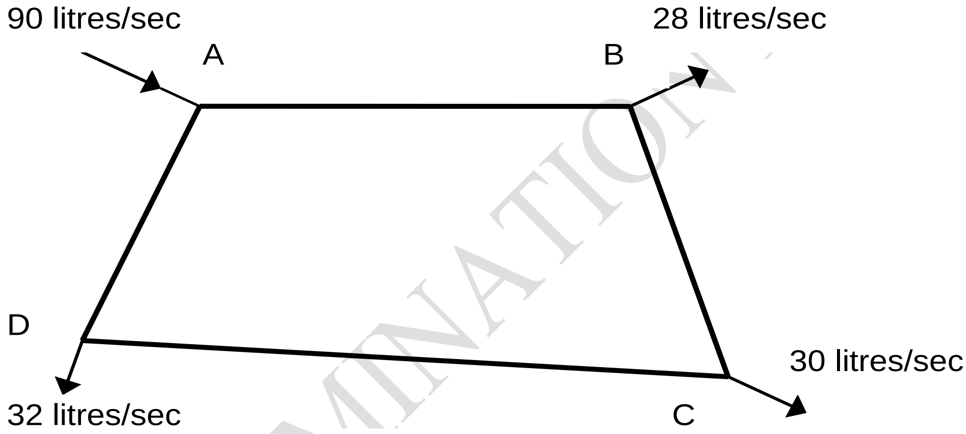

Fig Q4

Pipe	Length (m)	Diameter (mm)	Darcy Friction Factor (λ)
A - B	600	225	0.023
A - D	400	250	0.02
B - C	450	150	0.03
C - D	350	200	0.024

Table Q4

Total 20 marks

Pipe length ref No	Pipe Length (m)	Pipe gradient (1 in)	Vel (m/s)	Time of flow (min)	Time of Conc. (min)	Rate of rainfall i (mm/hr)	Imp. Area (ha)	Cumulative Imp. Area A_P (ha)	Flow Q (l/s)	Pipe dia. (mm)
1.0	70	80					0.06			150
1.1	78	91					0.15			225
2.0	64	83					0.10			150
2.1	55	59					0.12			225
1.2	75	53					0.23			300

Table Q2b. **To be handed in with answer book** **Student ID No** ....

Pipe	Length	Diameter	**1st estimate**			**2nd estimate**			**3rd estimate**		
	(m)	(mm)	**Q1 (litre/s)**	**h_f across Pipe (m)**	**h_f/Q1**	**Q2 (litre/s)**	**h_f across Pipe (m)**	**h_f/Q2**	**Q3 (litre/s)**	**h_f across Pipe (m)**	**h_f/Q3**
A - B	600	225									
A - D	400	250									
B - C	450	150									
D - C	350	200									

Table Q4a **To be handed in with answer book** **student ID No ……………………………….**

ks = 0·600mm
i = 0·00015 to 0·004

ie hydraulic gradient =
1 in 6667 to 1 in 250

Water (or sewage) at 15° C
full bore conditions.

velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00075	0.123	0.165	0.172	0.201	0.235	0.266	0.295	0.322	0.348	0.373	0.397	0.421
1/ 1333	0.242	0.728	0.867	1.582	2.881	4.695	7.088	10.119	13.846	18.323	23.600	29.728
0.00080	0.128	0.171	0.178	0.208	0.243	0.275	0.305	0.333	0.360	0.386	0.411	0.435
1/ 1250	0.250	0.753	0.897	1.637	2.980	4.856	7.329	10.463	14.316	18.943	24.397	30.731
0.00085	0.132	0.176	0.184	0.215	0.251	0.284	0.314	0.344	0.371	0.398	0.424	0.449
1/ 1176	0.259	0.778	0.926	1.690	3.076	5.011	7.563	10.797	14.771	19.544	25.170	31.703
0.00090	0.136	0.181	0.190	0.222	0.258	0.292	0.324	0.354	0.383	0.410	0.436	0.462
1/ 1111	0.267	0.802	0.954	1.741	3.169	5.162	7.791	11.120	15.213	20.128	25.921	32.647
0.00095	0.140	0.187	0.195	0.228	0.266	0.300	0.333	0.364	0.393	0.422	0.449	0.475
1/ 1053	0.275	0.825	0.982	1.791	3.260	5.309	8.012	11.435	15.643	20.696	26.651	33.566
0.00100	0.144	0.192	0.201	0.234	0.273	0.309	0.342	0.374	0.404	0.433	0.461	0.488
1/ 1000	0.282	0.848	1.009	1.840	3.348	5.453	8.227	11.742	16.062	21.249	27.363	34.461
0.00110	0.151	0.202	0.211	0.246	0.287	0.324	0.359	0.393	0.424	0.455	0.484	0.512
1/ 909	0.297	0.891	1.061	1.934	3.518	5.729	8.643	12.334	16.869	22.315	28.734	36.186
0.00120	0.158	0.211	0.221	0.258	0.300	0.339	0.376	0.411	0.444	0.475	0.506	0.535
1/ 833	0.311	0.933	1.110	2.024	3.681	5.993	9.040	12.899	17.641	23.335	30.045	37.835
0.00130	0.165	0.220	0.230	0.269	0.313	0.353	0.392	0.428	0.462	0.495	0.527	0.558
1/ 769	0.325	0.973	1.158	2.110	3.837	6.246	9.421	13.441	18.382	24.313	31.303	39.416
0.00140	0.172	0.229	0.239	0.279	0.325	0.367	0.407	0.444	0.480	0.514	0.547	0.579
1/ 714	0.338	1.012	1.204	2.193	3.988	6.490	9.788	13.963	19.094	25.254	32.513	40.938
0.00150	0.178	0.237	0.248	0.289	0.337	0.381	0.422	0.461	0.498	0.533	0.567	0.600
1/ 667	0.350	1.049	1.248	2.273	4.133	6.725	10.142	14.467	19.782	26.162	33.680	42.407
0.00160	0.185	0.246	0.257	0.299	0.348	0.393	0.436	0.476	0.514	0.551	0.586	0.620
1/ 625	0.362	1.085	1.291	2.351	4.273	6.953	10.484	14.954	20.447	27.041	34.810	43.828
0.00170	0.191	0.253	0.265	0.309	0.359	0.406	0.450	0.491	0.530	0.568	0.605	0.640
1/ 588	0.374	1.120	1.332	2.426	4.409	7.173	10.816	15.427	21.092	27.892	35.905	45.205
0.00180	0.196	0.261	0.273	0.318	0.370	0.418	0.463	0.506	0.546	0.585	0.622	0.658
1/ 556	0.386	1.154	1.373	2.499	4.541	7.388	11.158	15.886	21.718	28.719	36.968	46.542
0.00190	0.202	0.269	0.281	0.327	0.381	0.430	0.476	0.520	0.562	0.601	0.640	0.677
1/ 526	0.397	1.187	1.412	2.570	4.670	7.596	11.451	16.332	22.327	29.523	38.002	47.843
0.00200	0.208	0.276	0.288	0.336	0.391	0.441	0.489	0.534	0.576	0.617	0.657	0.695
1/ 500	0.408	1.219	1.450	2.639	4.795	7.799	11.757	16.767	22.921	30.307	39.010	49.110
0.00220	0.218	0.290	0.303	0.353	0.410	0.463	0.513	0.560	0.605	0.648	0.689	0.729
1/ 455	0.429	1.281	1.524	2.773	5.036	8.190	12.346	17.605	24.064	31.817	40.952	51.553
0.00240	0.228	0.303	0.317	0.369	0.429	0.485	0.537	0.586	0.633	0.678	0.721	0.762
1/ 417	0.449	1.340	1.594	2.900	5.267	8.565	12.908	18.405	25.157	33.261	42.808	53.887
0.00260	0.238	0.316	0.331	0.385	0.447	0.505	0.559	0.610	0.659	0.706	0.751	0.794
1/ 385	0.468	1.397	1.662	3.023	5.488	8.923	13.448	19.174	26.206	34.646	44.588	56.126
0.00280	0.248	0.329	0.343	0.400	0.465	0.525	0.581	0.634	0.684	0.733	0.780	0.825
1/ 357	0.486	1.452	1.727	3.140	5.701	9.269	13.967	19.913	27.215	35.978	46.301	58.281
0.00300	0.257	0.341	0.356	0.414	0.481	0.543	0.602	0.657	0.709	0.759	0.807	0.854
1/ 333	0.504	1.505	1.789	3.254	5.907	9.602	14.469	20.626	28.189	37.264	47.954	60.360
0.00320	0.266	0.352	0.368	0.428	0.498	0.562	0.622	0.679	0.733	0.784	0.834	0.882
1/ 313	0.521	1.556	1.850	3.364	6.106	9.925	14.953	21.316	29.131	38.507	49.553	62.371
0.00340	0.274	0.363	0.380	0.442	0.513	0.579	0.641	0.700	0.756	0.809	0.860	0.910
1/ 294	0.538	1.605	1.909	3.471	6.298	10.237	15.423	21.985	30.044	39.713	51.103	64.320
0.00360	0.282	0.374	0.391	0.455	0.528	0.596	0.660	0.720	0.778	0.833	0.886	0.937
1/ 278	0.555	1.653	1.966	3.574	6.486	10.540	15.880	22.635	30.930	40.883	52.608	66.212
0.00380	0.290	0.385	0.402	0.468	0.543	0.613	0.679	0.741	0.800	0.856	0.910	0.963
1/ 263	0.570	1.700	2.022	3.675	6.668	10.836	16.324	23.267	31.792	42.022	54.072	68.053

Coefficient for part-full pipes:

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continued

ks = 0·600mm
i = 0·004 to 0·1
ie hydraulic gradient =
1 in 250 to 1 in 10

Water (or sewage) at 15° C
full bore conditions.
velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm:											
	50	75	80	100	125	150	175	200	225	250	275	300
0.00400	0.298	0.395	0.413	0.480	0.558	0.629	0.697	0.760	0.821	0.879	0.934	0.988
1/ 250	0.586	1.746	2.076	3.773	6.845	11.123	16.756	23.882	32.632	43.131	55.498	69.846
0.00420	0.306	0.405	0.423	0.493	0.572	0.645	0.714	0.779	0.841	0.901	0.958	1.013
1/ 238	0.601	1.790	2.129	3.868	7.018	11.404	17.178	24.482	33.451	44.213	56.888	71.595
0.00440	0.313	0.415	0.434	0.504	0.586	0.661	0.731	0.798	0.861	0.922	0.981	1.037
1/ 227	0.616	1.834	2.180	3.962	7.187	11.678	17.589	25.068	34.251	45.269	58.246	73.303
0.00460	0.321	0.425	0.444	0.516	0.599	0.676	0.748	0.816	0.881	0.943	1.003	1.061
1/ 217	0.630	1.876	2.231	4.053	7.352	11.945	17.992	25.641	35.033	46.301	59.574	74.973
0.00480	0.328	0.434	0.454	0.527	0.612	0.691	0.764	0.834	0.900	0.964	1.025	1.084
1/ 208	0.644	1.918	2.280	4.142	7.514	12.207	18.386	26.202	35.798	47.312	60.873	76.606
0.00500	0.335	0.443	0.463	0.539	0.625	0.705	0.780	0.852	0.919	0.984	1.046	1.106
1/ 200	0.658	1.958	2.328	4.230	7.672	12.464	18.772	26.751	36.548	48.301	62.145	78.206
0.00550	0.352	0.466	0.486	0.566	0.656	0.740	0.819	0.894	0.965	1.033	1.098	1.161
1/ 182	0.691	2.057	2.445	4.441	8.054	13.084	19.704	28.078	38.358	50.692	65.218	82.071
0.00600	0.368	0.487	0.509	0.591	0.686	0.774	0.856	0.934	1.008	1.079	1.147	1.213
1/ 167	0.723	2.151	2.557	4.644	8.420	13.676	20.595	29.345	40.088	52.976	68.155	85.765
0.00650	0.384	0.507	0.530	0.616	0.715	0.806	0.892	0.973	1.050	1.124	1.195	1.263
1/ 154	0.753	2.241	2.664	4.837	8.770	14.244	21.449	30.561	41.748	55.167	70.972	89.307
0.00700	0.399	0.527	0.550	0.640	0.742	0.837	0.926	1.010	1.090	1.167	1.241	1.312
1/ 143	0.783	2.328	2.767	5.024	9.108	14.791	22.271	31.731	43.344	57.276	73.682	92.716
0.00750	0.413	0.546	0.570	0.663	0.769	0.867	0.959	1.046	1.129	1.208	1.285	1.358
1/ 133	0.811	2.411	2.866	5.204	9.433	15.319	23.064	32.860	44.885	59.310	76.298	96.005
0.00800	0.427	0.564	0.589	0.685	0.794	0.896	0.991	1.081	1.166	1.248	1.327	1.403
1/ 125	0.838	2.492	2.962	5.378	9.748	15.829	23.832	33.952	46.375	61.278	78.828	99.187
0.00850	0.441	0.582	0.608	0.706	0.819	0.924	1.022	1.114	1.203	1.287	1.368	1.447
1/ 118	0.865	2.571	3.056	5.547	10.053	16.324	24.576	35.011	47.820	63.185	81.280	102.270
0.00900	0.454	0.599	0.626	0.727	0.843	0.951	1.052	1.147	1.238	1.325	1.409	1.489
1/ 111	0.891	2.647	3.146	5.711	10.349	16.804	25.298	36.038	49.223	65.037	83.660	105.264
0.00950	0.466	0.616	0.643	0.747	0.867	0.977	1.081	1.179	1.272	1.362	1.448	1.530
1/ 105	0.916	2.721	3.234	5.870	10.638	17.271	26.000	37.038	50.587	66.838	85.976	108.176
0.01000	0.479	0.632	0.660	0.767	0.890	1.003	1.109	1.210	1.306	1.397	1.485	1.571
1/ 100	0.940	2.793	3.320	6.025	10.918	17.726	26.684	38.012	51.915	68.593	88.231	111.013
0.01100	0.503	0.664	0.693	0.805	0.934	1.053	1.164	1.270	1.370	1.466	1.559	1.648
1/ 91	0.988	2.933	3.485	6.325	11.459	18.604	28.003	39.889	54.477	71.975	92.579	116.480
0.01200	0.526	0.694	0.725	0.842	0.976	1.100	1.217	1.327	1.432	1.532	1.629	1.722
1/ 83	1.033	3.066	3.643	6.611	11.977	19.442	29.263	41.682	56.924	75.206	96.734	121.705
0.01300	0.548	0.723	0.755	0.877	1.016	1.146	1.267	1.382	1.491	1.595	1.696	1.793
1/ 77	1.076	3.193	3.795	6.885	12.473	20.246	30.472	43.402	59.272	78.306	100.718	126.716
0.01400	0.569	0.751	0.784	0.910	1.055	1.189	1.315	1.434	1.548	1.656	1.760	1.861
1/ 71	1.117	3.316	3.941	7.149	12.950	21.019	31.635	45.057	61.531	81.288	104.553	131.538
0.01500	0.590	0.777	0.812	0.943	1.093	1.232	1.362	1.485	1.602	1.715	1.823	1.927
1/ 67	1.158	3.435	4.081	7.404	13.410	21.766	32.758	46.655	63.710	84.166	108.252	136.191
0.01600	0.609	0.803	0.839	0.974	1.129	1.273	1.407	1.534	1.655	1.771	1.883	1.990
1/ 62	1.196	3.549	4.218	7.650	13.856	22.488	33.843	48.199	65.819	86.950	111.831	140.691
0.01700	0.628	0.829	0.865	1.004	1.164	1.312	1.451	1.582	1.707	1.826	1.941	2.052
1/ 59	1.234	3.660	4.349	7.889	14.288	23.188	34.895	49.697	67.862	89.647	115.299	145.052
0.01800	0.647	0.853	0.891	1.034	1.198	1.351	1.493	1.628	1.757	1.880	1.998	2.112
1/ 56	1.271	3.768	4.478	8.121	14.707	23.867	35.917	51.151	69.846	92.267	118.667	149.287
0.01900	0.665	0.877	0.916	1.063	1.232	1.388	1.535	1.673	1.805	1.932	2.053	2.170
1/ 53	1.306	3.873	4.602	8.347	15.115	24.528	36.911	52.565	71.776	94.815	121.942	153.406
	Coefficient for part-full pipes:											
	25	40	40	50	60	80	90	100	120	130	140	150

ks = 0·600mm   i < 0·1

	RETURN PERIOD (YEARS)						
DURATION	1	2	5	10	20	50	100
2.0 MINS	85.6	93.4	120.5	138.3	158	187	213
2.5 MINS	76.5	87.5	113.4	130.4	149	177	202
3.0 MINS	66.3	82.3	107.2	123.4	141	168	192
3.5 MINS	62.8	77.8	101.7	117.3	135	161	184
4.0 MINS	59.6	73.8	96.8	111.8	128	154	176
4.1 MINS	59.1	73.1	95.9	110.8	127	152	174
4.2 MINS	58.5	72.3	95.0	109.8	126	151	173
4.3 MINS	57.9	71.6	94.1	108.8	125	150	172
4.4 MINS	57.4	71.0	93.2	107.9	124	149	170
4.5 MINS	56.9	70.3	92.4	106.9	123	148	169
4.6 MINS	56.3	69.6	91.6	106.0	122	146	168
4.7 MINS	55.8	69.0	90.8	105.1	121	145	166
4.8 MINS	55.3	68.3	90.0	104.2	120	144	165
4.9 MINS	54.8	67.7	89.2	103.4	119	143	164
5.0 MINS	54.3	67.1	88.5	102.5	118	142	163
5.1 MINS	53.9	66.5	87.7	101.7	117	141	162
5.2 MINS	53.4	65.9	87.0	100.9	116	140	160
5.3 MINS	53.0	65.4	86.3	100.1	115	139	159
5.4 MINS	52.5	64.8	85.6	99.3	115	138	158
5.5 MINS	52.1	64.3	84.9	98.5	114	137	157
5.6 MINS	51.7	63.7	84.2	97.8	113	136	156
5.7 MINS	51.2	63.2	83.5	97.0	112	135	155
5.8 MINS	50.8	62.7	82.9	96.3	111	134	154
5.9 MINS	50.4	62.2	82.3	95.6	110	133	153
6.0 MINS	50.0	61.7	81.6	94.9	110	132	152
6.2 MINS	49.3	60.7	80.4	93.5	108	130	150
6.4 MINS	48.5	59.8	79.2	92.2	107	129	148
6.6 MINS	47.8	58.9	78.1	90.9	105	127	146
6.8 MINS	47.1	58.0	77.0	89.6	104	125	144
7.0 MINS	46.4	57.2	75.9	88.4	102	124	143
7.2 MINS	45.8	56.4	74.9	87.3	101	122	141
7.4 MINS	45.2	55.6	73.9	86.1	100	121	139
7.6 MINS	44.5	54.8	72.9	85.0	99	119	138
7.8 MINS	44.0	54.1	71.9	84.0	97	118	136
8.0 MINS	43.4	53.4	71.0	82.9	96	117	135
8.2 MINS	42.8	52.7	70.1	81.9	95	115	133
8.4 MINS	42.3	52.0	69.3	81.0	94	114	132
8.6 MINS	41.8	51.4	68.4	80.0	93	113	131
8.8 MINS	41.2	50.7	67.6	79.1	92	112	129
9.0 MINS	40.8	50.1	66.8	78.2	91	110	128
9.2 MINS	40.3	49.5	66.0	77.3	90	109	127
9.4 MINS	39.9	49.0	65.3	76.4	89	108	125
9.6 MINS	39.4	48.4	64.6	75.6	88	107	124
9.8 MINS	39.0	47.9	63.8	74.8	87	106	123
10.0 MINS	38.6	47.4	63.1	74.0	86	105	121
10.5 MINS	37.6	46.1	61.5	72.1	84	102	118
11.0 MINS	36.7	44.9	59.9	70.2	82	100	116
11.5 MINS	35.8	43.8	58.4	68.5	80	97	113
12.0 MINS	35.0	42.8	57.0	66.9	78	95	111
12.5 MINS	34.2	41.8	55.7	65.4	76	93	108
13.0 MINS	33.4	40.8	54.4	64.0	75	91	106
13.5 MINS	32.7	39.9	53.3	62.6	73	89	104
14.0 MINS	32.0	39.1	52.1	61.3	72	87	102
14.5 MINS	31.4	38.3	51.0	60.0	70	86	100
15.0 MINS	30.8	37.5	50.0	58.8	69	84	98
16.0 MINS	29.6	36.1	48.1	56.6	66	81	94
17.0 MINS	28.6	34.8	46.3	54.6	64	78	91
18.0 MINS	27.6	33.5	44.7	52.7	62	76	88

END OF SECTION A

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SECTION B – Answer TWO questions

5. a) A quick 'UU' triaxial compression test is to be carried out on a cylindrical clay sample. Show how Mohr's stress circles will be used to characterise the clay behaviour. Ensure that you label all axes and key points on the Mohr's stress circles you sketch. Also sketch the cylinder of clay showing the direction of all key stresses involved on key planes.

(5 marks)

b) A series of 'quick' unconsolidated undrained triaxial tests were conducted on a sample of clay with the results obtained being as follows:

Test Number	1	2	3
Cell Pressure (kN/m^2)	100	200	400
Vertical Stress at Failure (kN/m^2)	207	311	512

Using Figure Q5b and constructing Mohr's stress circles, determine the shear strength parameters of the soil sample. Using these values describe the clay soil being tested in geotechnical terms.

(8 marks)

c) State three shear strength testing methods available for sands in the field and/or in the laboratory, briefly describing limitations and advantages for each

(4 marks)

d) Explain what you would expect to occur when carrying out a shear box test on a dense sand, using sketch diagrams, as appropriate, to explain why this behaviour is expected.

(3 marks)

Total 20 marks

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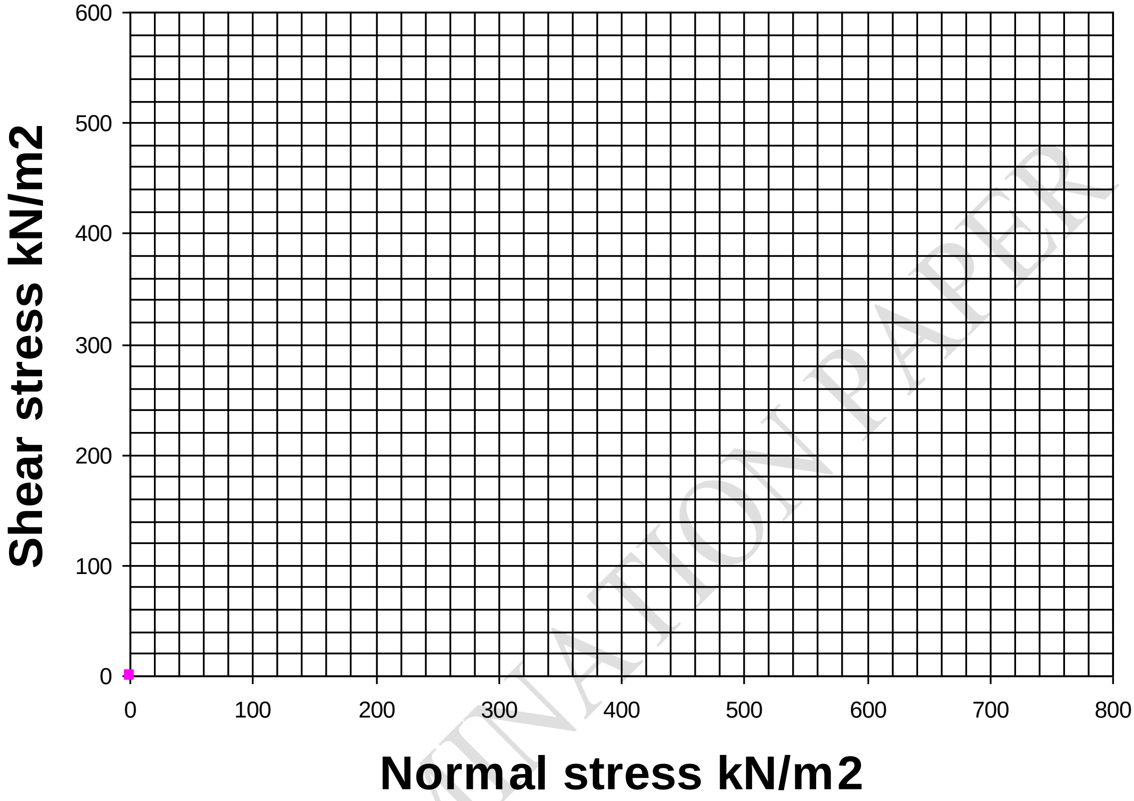

Figure Q5b

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6. a) A flexible foundation of length 3m and breadth 2m is to exert a uniform pressure of 120kN/m^2 on the surface of a 8m layer of soil. Using Figure Q6a, determine the immediate settlement under the centre of the foundation if the elastic soil stiffness (E) is assumed to be 4MN/m^2.

(6 marks)

b) A flexible foundation of length 3m and breadth 2m is to exert a uniform pressure of 120kN/m^2 on the surface of a layer of soil of assumed infinite thickness. Using Figure Q6b, determine the total stress at a depth of 5m beneath a corner of the foundation.

(5 marks)

c) The following results were obtained from an oedometer test on a specimen of saturated clay:

Applied Stress (kN/m^2)	0	25	50	100	200	400	800
Void Ratio	0.970	0.935	0.896	0.865	0.818	0.769	0.723

i) Determine the value of m_v for an effective stress range from 20kN/m^2 to 120kN/m^2.

(6 marks)

ii) Calculate the consolidation settlement for a 4m thick layer of this clay, when the effective stress changes from 20kN/m^2 to 120kN/m^2.

(3 marks)

Total 20 marks

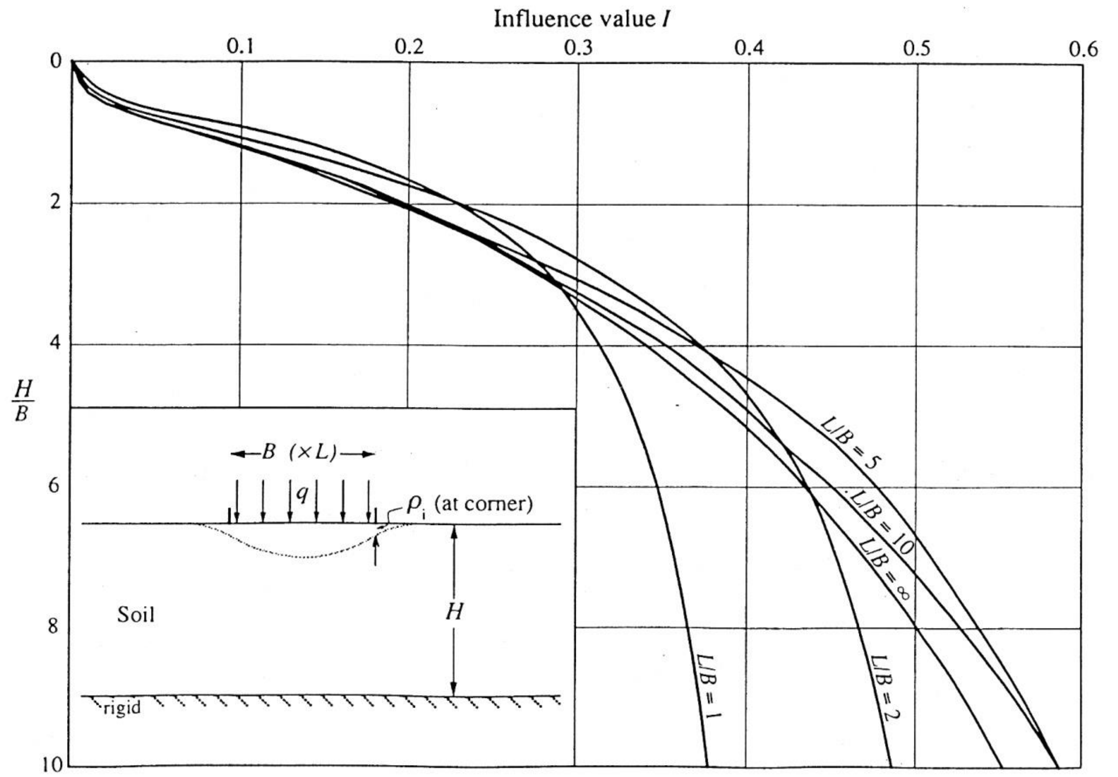

Figure Q6a

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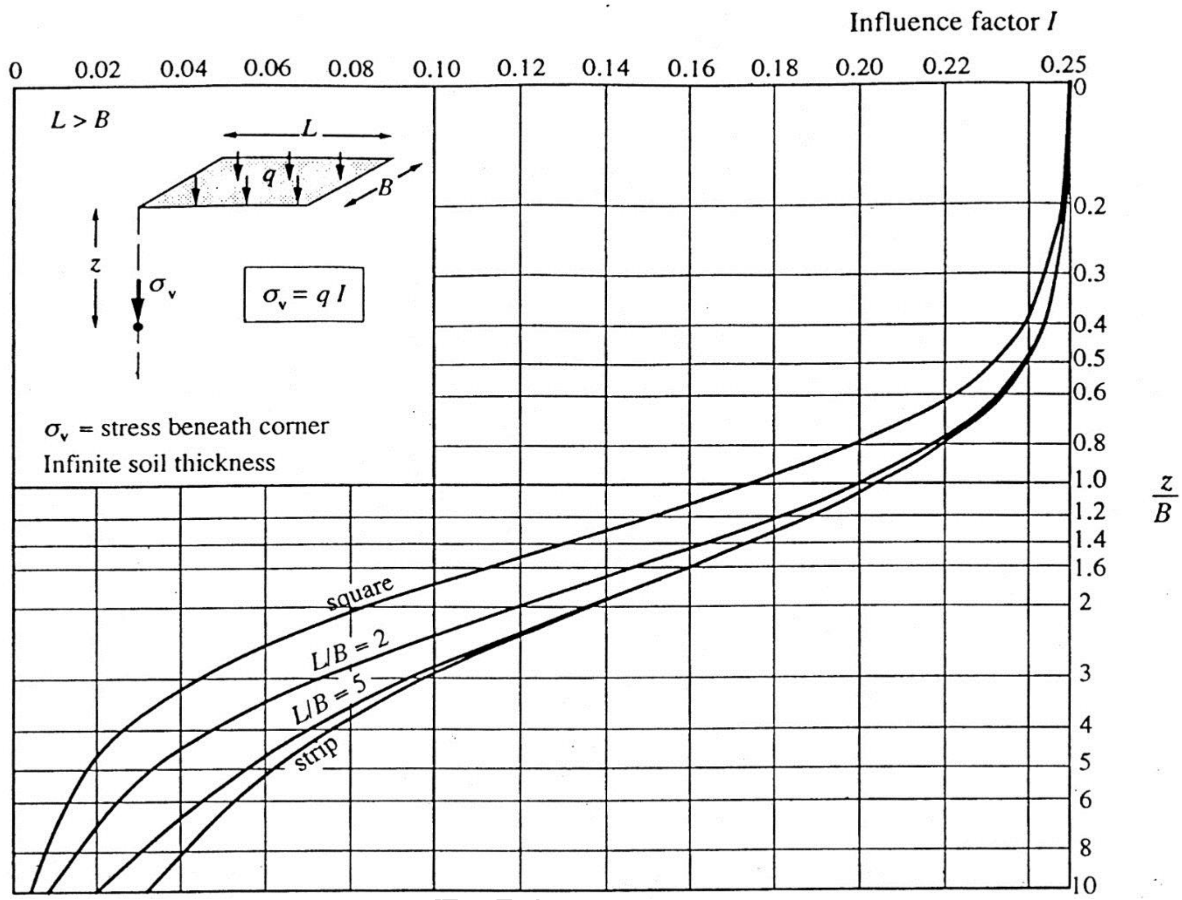

Fig Q6b

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7. a) Explain the difference between 'compaction' and 'consolidation' using geotechnical reference to void ratio, pore water pressure, soil mineralogy and the most appropriate "stress state" (and any other parameters you deem relevant). You must provide a detailed description of the process of consolidation in your answer to obtain maximum marks.

(5 marks)

b) Using Figure Q7c determine the total stress, pore water pressure and effective stress at each strata change and at the location of the water table and hence plot a graph to illustrate their variation with depth from ground surface to a depth of 16m below ground level. The water table is located at a depth of 5m below ground level within a 9m thick deposit of sandy gravel overlying 7m of clay.

(15 marks)

Total 20 marks

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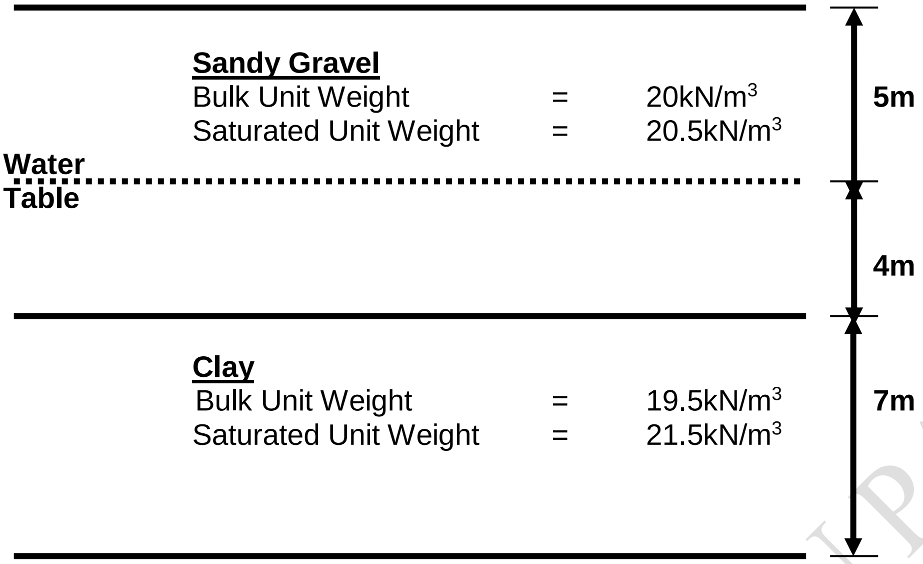

NOTE: Assume that Unit Weight of Water = 9.81kN/m^3

Figure Q7c

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Formulae

$$\rho_i = \frac{qB}{E_u} \cdot I \qquad q = \frac{k\,h \cdot N_f}{N_d}$$

$$\Delta e = \frac{\Delta H}{H} \cdot (1 + e_o) \qquad m_v = \frac{\Delta e}{\Delta\sigma} \cdot \frac{(1)}{(1 + e_o)}$$

$$\sigma_v = \sigma_v' + u \qquad \Delta H = m_v\, \Delta\sigma_v'\, H$$

$$\sigma_v = q\, I$$

$R = 0.564\, S$ (square grid)

$(1 - U) = (1 - U_r)(1 - U_v)$

$T_r = (c_h\, t) / (4 R^2)$

$T_v = (c_v\, t) / d^2$

END OF QUESTIONS

Terminology, symbols, units and formula sheets over the page….

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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	$1000 kg/m^3$
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

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DEFINITIONS

Term	Expression	
Density of water, ρ_w	$\frac{\text{mass of water}}{\text{volume of water}}$	$\frac{M_w}{V_w}$
Unit weight of water, γ_w	$\frac{\text{weight of water}}{\text{volume of water}}$	$\frac{W_w}{V_w}$
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	$\frac{\text{volume of voids}}{\text{total volume}}$	$\frac{V_v}{V}$
Soil 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}	$\frac{\text{total saturated mass}}{\text{total volume}}$	$\frac{M}{V}$
Soil 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}	$\frac{\text{total saturated weight}}{\text{total volume}}$	$\frac{W}{V}$

Please turn the page

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BASIC PROPERTIES Formulae:

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

Bulk Density

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

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

Dry Density

$$\rho_d = \frac{\rho_w\,G_s}{1 + e}$$

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

Porosity

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

END OF PAPER