Loughborough University

Mechanical and Electrical Systems
23CVC121

Semester 2 2024 In-Person Exam Paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **THREE** questions.

All questions carry equal marks.

Continues/…

1. a) Describe the two issues that relate to syphonage in drainage systems. Describe the causal factors using sketches and describe preventative measures.

[10 marks]

b) A new office building has five floors, and on each floor a cold-water feed rises from the mains supply up through the building to serve 2 basins and 2 WC's, in the arrangement depicted in Figure Q1a. The pipework is to be copper. Provide a labelled sketch of the system and size the pipework in accordance to BS EN 806-3. In addition, estimate the maximum flow rate in the system, stating your estimate, where it would occur in the system and any observations you make regarding your answer. Use Table Q1a and Q1b as needed.

[10 marks]

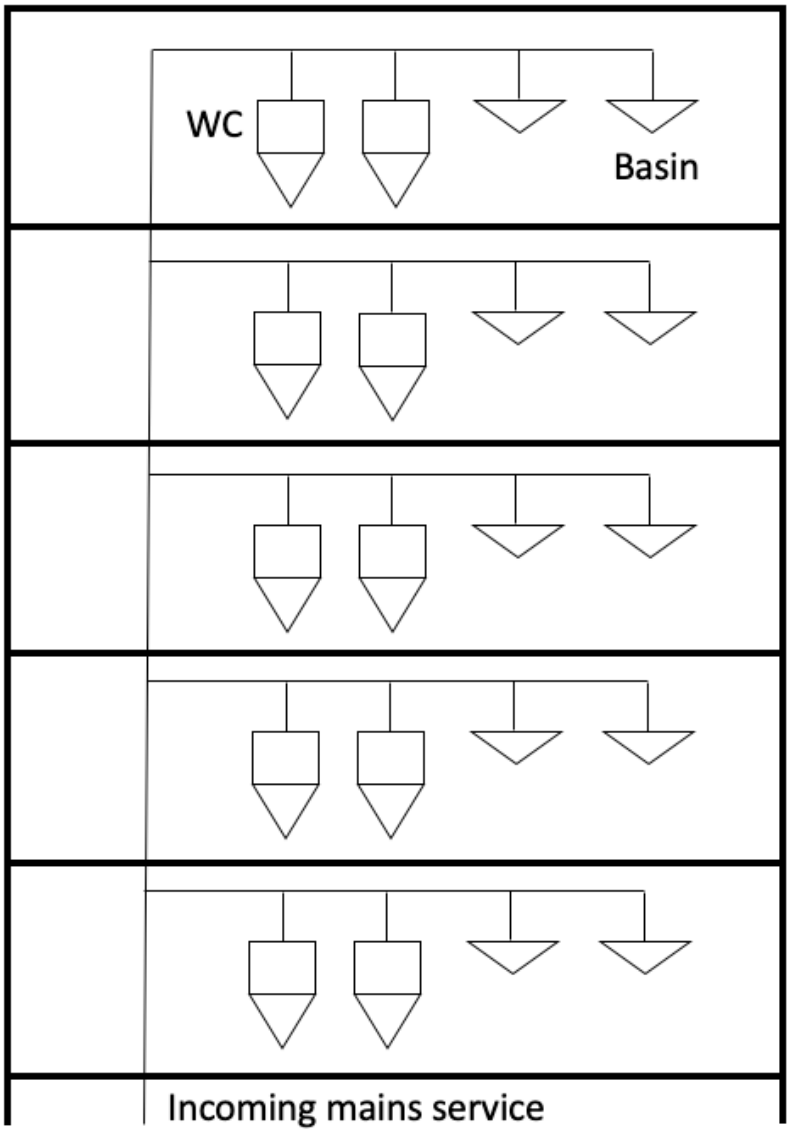


Figure Q1a

Question 1 continues/…

Tables Q1a

Draw-off flow-rates Q_A , minimum flow-rates at draw-off points Q_{min} and loading units for draw-off points

Draw-off point	Q_A	Q_{min}	Loading units
	l/s	l/s	
Washbasin, handbasin, bidet, WC-cistern	0,1	0,1	1
Domestic kitchen sink, - washing machine [a], dish washing machine, sink, shower head	0,2	0,15	2
Urinal flush valve	0,3	0,15	3
Bath domestic	0,4	0,3	4
Taps /garden/garage)	0,5	0,4	5
Non domestic kitchen sink DN 20, bath non domestic	0,8	0,8	8
Flush valve DN 20	1,5	1,0	15

[a] For non domestic appliances check with manufacturer.

Table Q1b

Loading units for determination of pipe diameters

Table 3.1 — Hot-dip galvanised steel													
Max. load	**LU**	**6**			**16**			**40**	**160**	**300**	**600**	**1 600**	
Highest value	LU	4			15								
DN		**15**			**20**			**25**	**32**	**40**	**50**	**65**	
d_i	mm	16			21,6			27,2	35,9	41,8	53	68,8	
Max length of pipe	m	10			6								

Table 3.2 — Copper													
Max. load	**LU**	**1**	**2**	**3**	**3**	**4**	**6**	**10**	**20**	**50**	**165**	**430**	**1 050**	**2 100**
Highest value	LU			2			4	5	8					
d_a x s	mm	**12** x 1,0			**15** x 1,0			**18** x 1,0	**22** x 1,0	**28** x 1,5	**35** x 1,5	**42** x 1,5	**54** x 2	**76,1** x 2
d_i	mm	10,0			13,0			16,0	20,0	25	32	39	50	72,1
Max length of pipe	m	20	7	5	15	9	7							

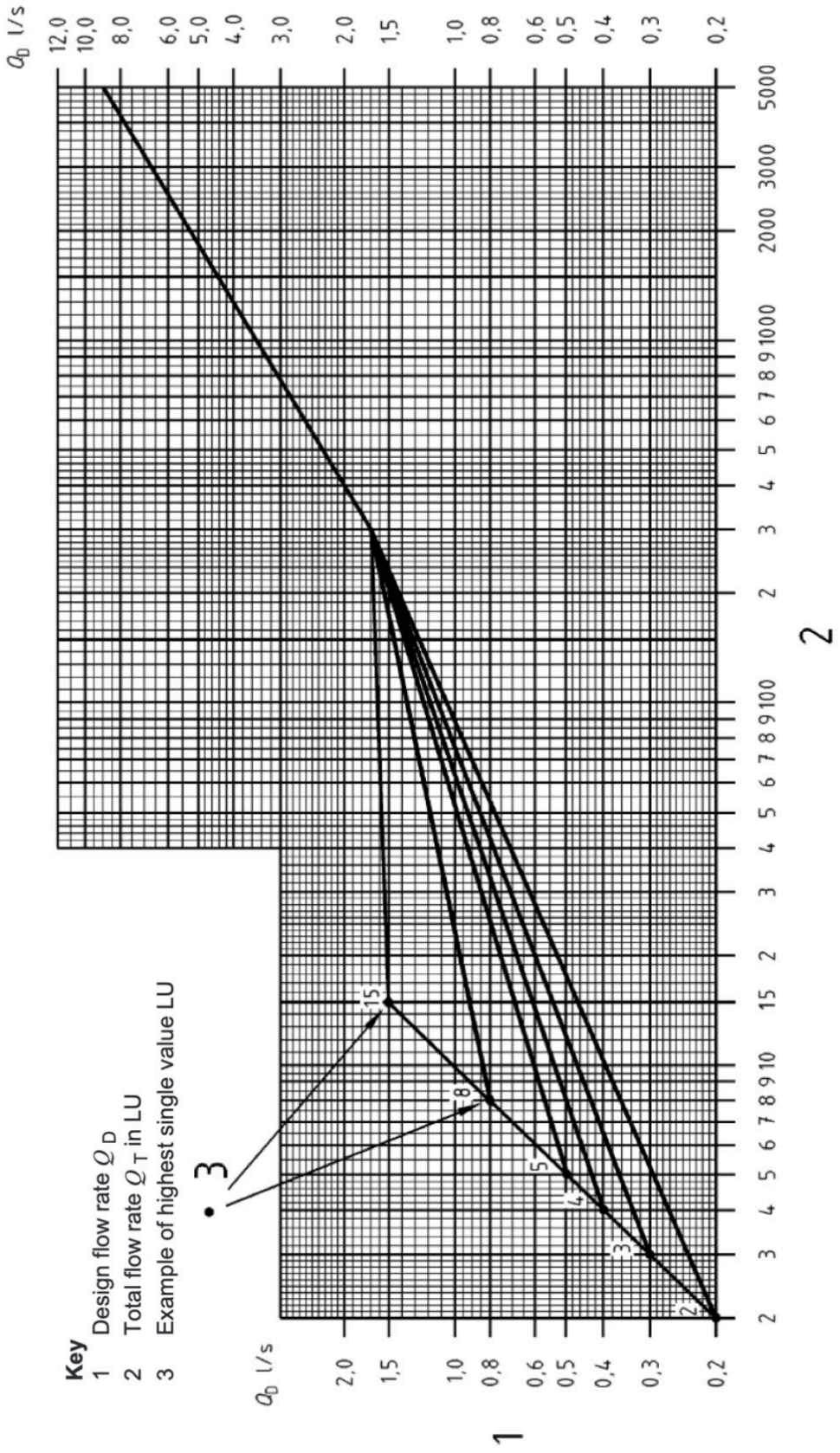
Table 3.3 — Stainless steel											
Max. load	**LU**	**3**	**4**	**6**	**10**	**20**	**50**	**165**	**430**	**1 050**	**2 100**
Highest value	LU			4	5	8					
d_a x s	mm	**15** x 1,0			**18** x 1,0	**22** x 1,0	**28** x 1,2	**35** x 1,5	**42** x 1,5	**54** x 1,5	**76,1** x 2
d_i	mm	13,0			16,0	19,6	25,6	32	39	51	72,1
Max length of pipe	m	15	9	7							

Table 3.4 — PE-X												
Max. load	**LU**	**1**	**2**	**3**	**4**	**5**	**8**	**16**	**35**	**100**	**350**	**700**
Highest value	LU					4	5	8				
d_a x s	mm	**12** x 1,7		**16** x 2,2			**20** x 2,8	**25** x 3,5	**32** x 4,4	**40** x 5,5	**50** x 6,9	**63** x 8,6
d_i	mm	8,4		11,6			14,4	18,0	23,2	29	36,2	45,6
Max length of pipe	m	13	4	9	5	4						

Question 1 continues/…

…/question 1 continued

Figure Q1b



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2. a) A customer requires a new polyphase supply to be installed between their existing factory to a new office building. Within the existing switch panel, there is a 300A BS88-2 gG fuse available (spare way). The new 70^{o}C thermosetting armoured sub-main cable is to be installed within an existing naturally ventilated combined services trench (not directly buried) which contains LTHW pipework, process nitrogen gas, HV/LV cables, communications cables and steam mains. This cable will be grouped with 7 other existing sub-mains cables and maximum temperature within the trench will not exceed 35^{o}C. The maximum cable distance is 65 metres. With relation to the new low voltage (LV) supply, identify the following requirements:

   i) State three relevant UK standards/regulations which are applicable to this installation.

   [3 marks]

   ii) State three primary electrical supply characteristics required to assess sub-mains cable sizing in accordance with BS7671.

   [3 marks]

   iii) In accordance with BS7671, what cable correction factors would you consider for this installation?

   [2 marks]

   b) For the new office building mentioned in part a), calculate the baseline lighting (12 W/m^2), small power (25 W/m^2) and air conditioning electrical power demand (29 W/m^2) in KVA and amperes per phase (I_b). The office building mentioned in part a) has a floor area of 2,500m^2. The new building power factor is assumed to be 0.89 Cos Ø.

   [6 marks]

   c) Based on the calculated values from sections a) and b), and using Tables Q2a, Q2b, Q2c and Q2d, complete the following:

   i) Calculate tabulated current capacity of cable (I_t). [2 marks]
   i) Select suitable cable size (I_z). [2 marks]
   ii) Calculate voltage drop (V_d). [2 marks]

Question 2 continues/…

Table Q2a

4B2 – Rating factors (C_a) for ambient ground temperatures other than 20 °C

Ground temperature °C	Insulation	
	70 °C thermoplastic	90 °C thermosetting
10	1.10	1.07
15	1.05	1.04
20	1.00	1.00
25	0.95	0.96
30	0.89	0.93
35	0.84	0.89
40	0.77	0.85
45	0.71	0.80
50	0.63	0.76
55	0.55	0.71
60	0.45	0.65
65	–	0.60
70	–	0.53
75	–	0.46
80	–	0.38

Table Q2b

4C1 – Rating factors for one circuit or one multicore cable or for a group of circuits, or a group of multicore cables, to be used with current-carrying capacities of Tables 4D1A to 4J4A

Item	Arrangement (cables touching)	Number of circuits or multicore cables												To be used with current-carrying capacities, Reference Method
		1	2	3	4	5	6	7	8	9	12	16	20	
1.	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	A to F
2.	Single layer on wall or floor	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.70	0.70	0.70	C
3.	Single layer multicore on a perforated horizontal or vertical cable tray system	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72	0.72	0.72	0.72	E
4.	Single layer multicore on cable ladder system or cleats etc.	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78	0.78	0.78	0.78	

Question 2 continues/…

Table Q2c

4D4A – Multicore armoured 70 °C thermoplastic insulated cables

Ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	21	18	22	19	22	18
2.5	28	25	31	26	29	24
4	38	33	41	35	37	30
6	49	42	53	45	46	38
10	67	58	72	62	60	50
16	89	77	97	83	78	64
25	118	102	128	110	99	82
35	145	125	157	135	119	98
50	175	151	190	163	140	116
70	222	192	241	207	173	143
95	269	231	291	251	204	169
120	310	267	336	290	231	192
150	356	306	386	332	261	217
185	405	348	439	378	292	243
240	476	409	516	445	336	280
300	547	469	592	510	379	316
400	621	540	683	590	-	-

Table Q2d

4D4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1.5	29	29			25		
2.5	18	18			15		
4	11	11			9.5		
6	7.3	7.3			6.4		
10	4.4	4.4			3.8		
16	2.8	2.8			2.4		
		r	x	z	r	x	z
25	1.75	1.75	0.170	1.75	1.50	0.145	1.50
35	1.25	1.25	0.165	1.25	1.10	0.145	1.10
50	0.93	0.93	0.165	0.94	0.80	0.140	0.81
70	0.63	0.63	0.160	0.65	0.55	0.140	0.57
95	0.46	0.47	0.155	0.50	0.41	0.135	0.43
120	0.36	0.38	0.155	0.41	0.33	0.135	0.35
150	0.29	0.30	0.155	0.34	0.26	0.130	0.29
185	0.23	0.25	0.150	0.29	0.21	0.130	0.25
240	0.180	0.190	0.150	0.24	0.165	0.130	0.21
300	0.145	0.155	0.145	0.21	0.135	0.130	0.185
400	0.105	0.115	0.145	0.185	0.100	0.125	0.160

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3. a) A new open plan office refurbishment design is being completed and a revised lighting design is required. The room is 20m (l) by 10m (w) by 2.7m (h). The surface reflectance's are 70% Ceiling, 50% walls and 20% floor cavity. The height of the desks is 0.75m. The 600 x 600mm recessed modular LG3 luminaires have a luminous flux of 1,500 lumens and contain two fluorescent T5 lamps. Using Table Q3, determine the following:

   i) Room index value [2 marks]
   ii) Utilisation factor [2 marks]
   iii) The number of luminaires achieving 500 lux at the working plane with a maintenance factor of 0.8. [2 marks]

   b) Expand and explain, giving examples of the following artificial lighting terms for the following:

   i) UGR. [2 marks]
   ii) Stroboscopic effects. [2 marks]

   c) Explain the concepts of circadian rhythm and expand on how lighting design can be adapted to incorporate into interior spaces.
   [6 marks]

   d) All buildings shall have emergency lighting in accordance with BS5266-1: 2016. Choose two options from the list below and state the minimum outputs required to ensure compliance with this standard:
   [4 marks]

Table Q3

A typical utilisation factor table

Surface	Reflectance value								
Ceiling	0.8	0.8	0.8	0.7	0.7	0.7	0.5	0.5	0.5
Walls	0.7	0.5	0.3	0.7	0.5	0.3	0.7	0.5	0.3
Floor cavity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Room index	**Utilisation factor for stated reflectance value and room index**								
0.60	0.69	0.57	0.50	0.67	0.57	0.50	0.65	0.56	0.49
0.80	0.80	0.70	0.63	0.79	0.69	0.62	0.76	0.67	0.61
1.00	0.88	0.78	0.71	0.86	0.77	0.71	0.83	0.75	0.70
1.25	0.94	0.85	0.79	0.92	0.84	0.78	0.88	0.82	0.77
1.50	0.98	0.90	0.85	0.96	0.89	0.84	0.92	0.87	0.82
2.00	1.03	0.96	0.91	1.00	0.94	0.90	0.96	0.91	0.87
2.50	1.06	1.00	0.95	1.03	0.98	0.94	0.99	0.95	0.91
3.00	1.07	1.02	0.98	1.05	1.00	0.96	1.00	0.97	0.93
4.00	1.10	1.06	1.02	1.08	1.04	1.00	1.03	1.00	0.97
5.00	1.12	1.08	1.05	1.09	1.06	1.03	1.04	1.02	0.99

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4. a) Significant progress has been made in decarbonising the GB electricity system to date. State the main changes in GB electricity generation mix that have occurred over the past 15 years, and explain how this has resulted in decarbonisation.

[3 marks]

b) The intention is to achieve full decarbonisation of the GB electricity system by 2035. State the changes in electricity generation mix that will be needed to achieve full decarbonisation, and discuss the challenges likely to be encountered. Explain how energy storage and flexibility (especially in buildings) could help alleviate these challenges.

[6 marks]

c) Discuss the use of solar PV and/or wind on-site renewable electricity generation in a domestic or non-domestic context. Explain how the technology operates, and thus describe the factors contributing to successful implementation.

[11 marks]

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S Watson