Mechanical and Electrical Systems
24CVC121

Semester 2 2025 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 **3 from 4** questions.

All questions carry equal marks.

Continues/…

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1. a) Apart from the two issues that relate to syphonage in drainage systems, describe the two other issues that can have undesirable consequences. Use sketches to explain and describe preventative measures.

[6 marks]

b) Table 1a details the frequency factors used in sizing soil stacks for drainage systems within buildings. Using the data in Table 1a, what type of building is a soils stack in if the waste-water flow rate was calculated to be. 9.9 l/s given a load coming from 100 WCs at 2.0 Demand Units per WC?

[7 marks]

Table 1a: Typical Frequency Factors

Usage of appliances	*K*
Intermittent use, e.g. in dwelling, guesthouse, office	0,5
Frequent use, e.g. in hospital, school, restaurant, hotel	0,7
Congested use, e.g. in toilets and/or showers open to public	1,0
Special use, e.g. laboratory	1,2

c) Name two health and safety issues related to the temperature of domestic hot water storage and delivery at the faucet. Explain with diagrams where necessary how these issues are treated to ensure safe supply in building domestic hot water supply.

[7 marks]

2. a) Transmission lines are used to transport electricity over long distances, at voltages of 275 or 400 kV. Final distribution of electricity to domestic customers is at 230 V. Explain why different voltages are used in different parts of the electricity system.

[2 marks]

b) Figure Q2a depicts a Separated Extra Low Voltage (SELV) transformer. State two ways in which this type of transformer keeps users safe and give one instance of where this type of transformer could be used.

[3 marks]

Question 2 continues/…

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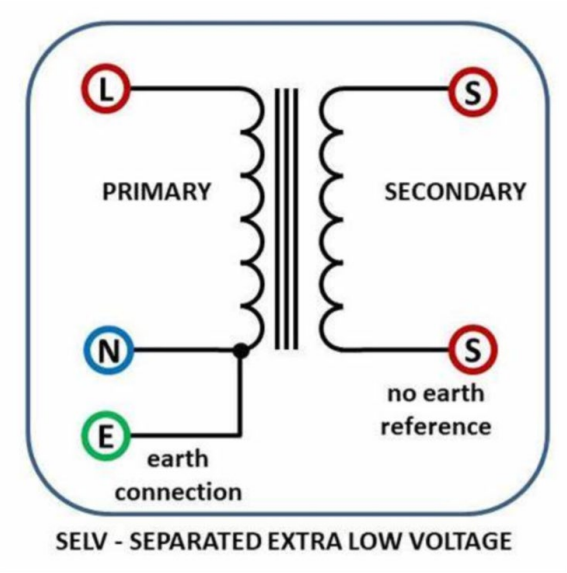


Figure Q2a

c) The transformer shown in Figure Q2a has 5000 turns on the primary winding and 1000 on the secondary winding. The primary winding is connected to single-phase 230 V. Calculate the voltage in the secondary circuit.

[2 marks]

d) Figure Q2b presents a diagram of a 11 kV/400 V transformer is shown below.

i) State whether the primary windings are connected in star or delta.
ii) State whether the secondary windings are connected in star or delta.
iii) State the relationship between V_{AB} and $V_{A.}$

[3 marks]

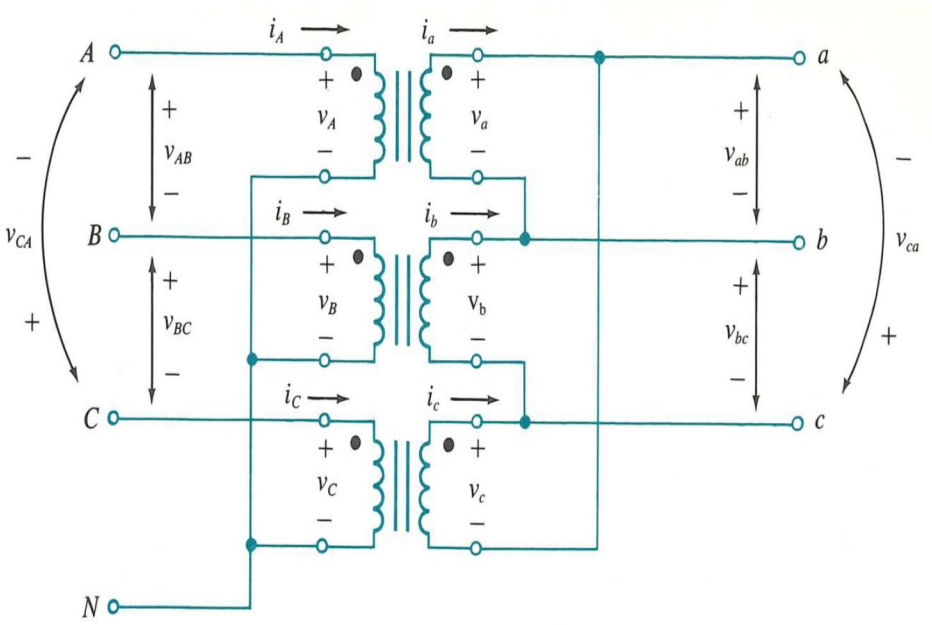


Figure Q2b

Question 2 continues/…

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e) For the transformer considered in part d), the apparent power is 2 MVA and the secondary current is 1500 A. Calculate the primary current.

[3 marks]

f) A single-phase motor has the following specifications:
- Real power - 11 kW
- Apparent power - 14.1 kVA

i) Calculate the power factor.

[2 marks]

ii) Explain what is meant by “power factor correction” and state one advantage of using it.

[2 marks]

iii) Power factor correction of 4 kVAr is added to the motor. Calculate the new power factor.

[3 marks]

3. A customer requires a new polyphase supply to be installed between their existing industrial facility to a new office building. The new office has a floor area of 1,200m^2 and its power factor is assumed to be 0.88. (The new office building does not have its own transformer).

a) For the new office building, 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 (apparent power) and thus calculate the current per phase (I_b).

[6 marks]

b) Within the existing switch panel in the industrial facility, there is a spare 200A fuse available (i.e. 200 A per phase). A new 70^{o}C thermosetting armoured sub-main cable is to be installed within an existing naturally ventilated combined services trench, in a perforated cable tray (not directly buried). This cable will be grouped with 4 other existing sub-mains cables and maximum temperature within the trench will not exceed 35^{o}C. The maximum cable distance is 65 metres.

i) Based on your answer to part a), state whether the spare fuse available in the switch panel is large enough for connecting the new supply.

[1 mark]

ii) Using the appropriate correction factors from tables Q3a and Q3b, calculate tabulated current capacity of cable (I_t).

[2 marks]

iii) Select suitable cable size using table Q3c.

[2 marks]

Question 3 continues/…

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iv) The maximum allowable voltage drop is 4% of nominal supply voltage. Using table Q3d, calculate the voltage drop (V_d) in the cable and state whether this meets the requirement for maximum voltage drop.

[4 marks]

c) State what is meant by maximum fault current and give one reason why it is important to calculate this.

[2 marks]

d) Explain what is meant by "touch voltage" and thus explain why equipotential bonding is beneficial in reducing this.

[3 marks]

Table Q3a

TABLE 4B1 – Rating factors (C_a) for ambient air temperatures other than 30 °C

Ambient temperature[a] °C	Insulation				
				Mineral[a]	
	60 °C thermosetting	70 °C thermoplastic	90 °C thermosetting	Thermoplastic covered or bare and exposed to touch 70 °C	Bare and not exposed to touch 105 °C
25	1.04	1.03	1.02	1.07	1.04
30	1.00	1.00	1.00	1.00	1.00
35	0.91	0.94	0.96	0.93	0.96
40	0.82	0.87	0.91	0.85	0.92
45	0.71	0.79	0.87	0.78	0.88
50	0.58	0.71	0.82	0.67	0.84
55	0.41	0.61	0.76	0.57	0.80
60	–	0.50	0.71	0.45	0.75
65	–	–	0.65	–	0.70
70	–	–	0.58	–	0.65
75	–	–	0.50	–	0.60
80	–	–	0.41	–	0.54
85	–	–	–	–	0.47
90	–	–	–	–	0.40
95	–	–	–	–	0.32

a For higher ambient temperatures, consult manufacturer.

Question 3 continues/…

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Table Q3b

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	

Table Q3c

4D4A – Multicore armoured 70 °C thermoplastic insulated cables

Ambient temperature: 30 °C
Ground ambient temperature: 20 °C
CURRENT-CARRYING CAPACITY (amperes): Conductor operating temperature: 70 °C

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
(mm²)	(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	-	-

Question 3 continues/…

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Table Q3d

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

4. a) Describe the main differences between GB electricity system around the start of the 21st century, and the electricity system that will be needed by the middle of the 21st century, including the mix of electricity generation technologies and their spatial distribution.

[5 marks]

b) Compare the actual half-hourly electricity prices in 2020 to the predicted half-hourly electricity prices in 2050. Explain the reasons for the differences, and some possible consequences.

[4 marks]

c) State two alternatives to gas boilers which may be widely used for domestic heating in future. Describe the advantages and disadvantages of these two technologies.

[6 marks]

d) Consider two possible locations where PV might be used. Describe the advantages and disadvantages of these two locations.

[5 marks]

R Buswell
S Watson

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