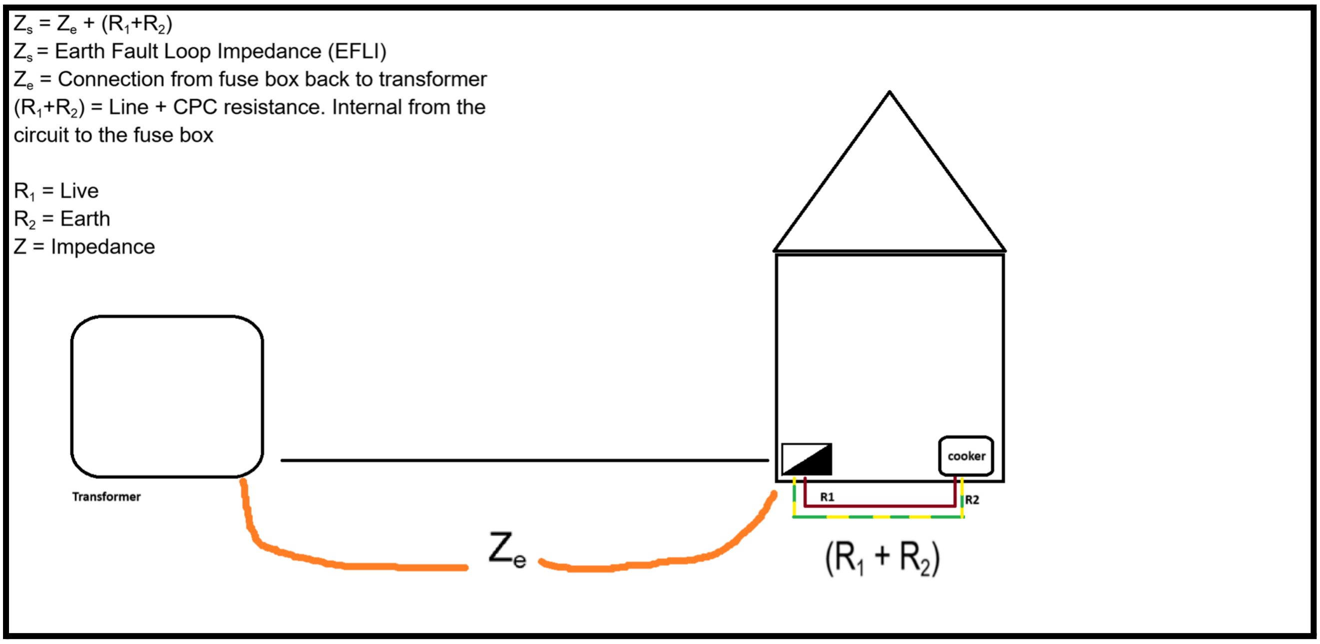
Theory section

Introduction

I_b - Design current
I_n - Protective size
I_z - current-carrying capacity (with all corrections)
I_t - current-carrying capacity.

$Z_s = Z_e + (R_1 + R_2)$



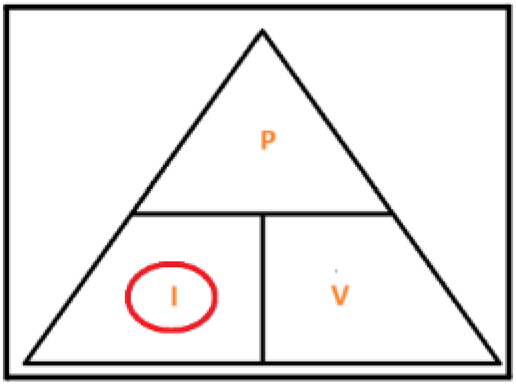
Question:

A 230 V 4kW load is to be wired in non-armoured single-core 70°C thermoplastic insulated copper conductors wired in steel conduit installed on the surface some 25 metres from the distribution board. **Three other similar circuits are installed in the same conduit which passes through an** area where the ambient temperature reaches 40°C. Calculate the cross-sectional area of cable required if protection is by a BS288-2 fuse. Show all working.

Working out:

Voltage (V) - informs us what kind of circuit or power supply is needed
Kilowatts (kW) - informs us of how much power is consumed or required
(Used ChatGPT to get these definitions)

1) **I_b -> design current**



I = P/V
4,000/230 = 17.39 A

We do not calculate the diversity rule because the full load is not specified.
I_b = 17.39 A

2) I_n -> Protective device

I_n = 20 A

3) I_t - Current carrying capacity

$$\boxed{I_z \Rightarrow I_t \geq \frac{I_n}{C_a \times C_g \times C_i \times C_f} \quad \Rightarrow \quad \frac{I_n}{C_a \times C_g}}$$

C_a => Ambient temperature.

$$\boxed{I_z \Rightarrow I_t \geq \frac{I_n}{C_a \times C_g \times C_i \times C_f} \quad \Rightarrow \quad \frac{I_n}{0.87 \times C_g}}$$

The ambient temperature is defined as the air temperature surrounding a particular object or area. The question states that "the ambient temperature reaches 40 °C". The questions also states "thermoplastic 70°C insulated copper conductors"

	Insulation			
			Mineral	
Ambient temperature	70°C thermoplastic	90°C thermosetting	Thermoplastic covered or bare and exposed to touch 70°C thermoplastic	cBare and not exposed to touch 105 °C
25	1.03	1.02	1.07	1.04
30	1.00	1.00	1.00	1.00
35	0.94	0.96	0.93	0.96
40	0.87	0.91	0.85	0.92

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Table F1 Page 168

Therefore, using the table the answer for C_a is 0.87.

C_g => grouping

“Three other similar circuits are installed in the same conduit …”

Number of circuits or multi-core cables											
Arrangement (cable touching)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**12**	**Applicable reference method for current-carrying capacities**
Bunched in air, on a surface, embedded or enclosed	1.0	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	A to F
Single layer on wall or floor	1.0	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.7	C
Single layer multicore on a perforated horizontal or vertical cable tray system	1.0	0.8 8	0.8 2	0.7 7	0.7 5	0.73	0.7 3	0.72	0.72	0.72	E
Single layer multicore on a cable ladder system or cleats etc	1.0	0.8 7	0.8 2	0.8 0	0.8 0	0.79	0.7 9	0.78	0.78	0.78	E

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<u>I_t = 37.37 A (Current carrying capacity without corrections)</u>

$$I_t \geq \frac{I_n}{C_a \times C_g \times C_i \times C_f} \Rightarrow \frac{20\ A}{0.87 \times 0.65} = 35.37\ A$$

When you see the voltages 230V or 400v just remember:
- 230V - single phase systems
- 400V - three phase systems.

Conductor cross-sectional area	Reference method A (enclosed in conduit in thermally insulating wall, etc.)		Reference method B (enclosed in conduit on a wall or in trunking, etc.)		Reference method C (clipped direct)		Reference method F (in free air or on a perforated cable tray horizontal or vertical)				
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	Touching			Spaced by one cable diameter	
							2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat	
										horizontal	vertical
1	2	3	4	5	6	7	8	9	10	11	12
mm^2	A	A	A	A	A	A	A	A	A	A	A
1	11	10.5	13.5	12	15.5	14					
1.5	14.5	13.5	17.5	15.5	20	18					
2.5	20	18	24	21	27	25					
4	26	24	32	28	37	33					
6	34	31	41	36	47	43					

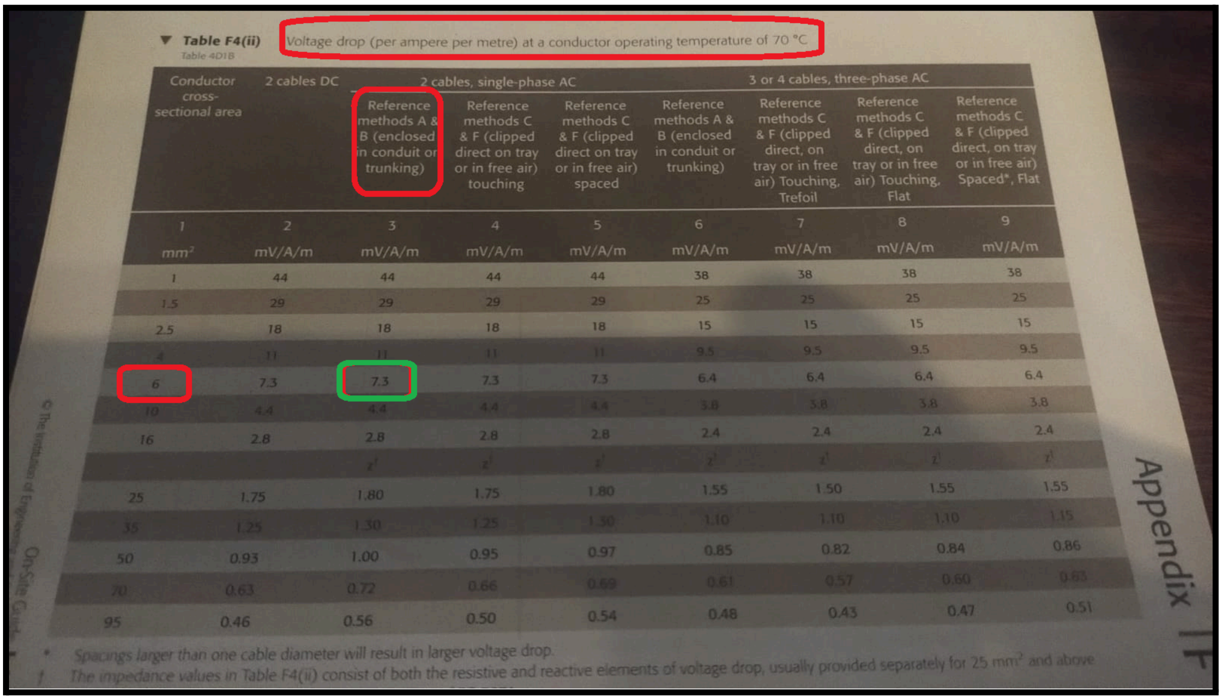
Appendix | F

Table F4(i) - page 171

We used the above table to deduce the I_z value.
Remember that we deduced I_t to be **35.37 A**.
If we round this up, 41 is the next number (circled in red above)
The question states **230V** - which means it is a **single phase system**
The question states “enclosed into the same conduit” “..installed onto the surface”.
The answer highlighted in **green**, shows that we need a **6mm^2** cable size. **6mm^2** cable corresponds to a **41 A** which is enough.

I_z = 6 mm^2

Voltage drop



▼ Table F4(ii) Voltage drop (per ampere per metre) at a conductor operating temperature of 70 °C
Table 4D1B

Conductor cross-sectional area	2 cables DC	2 cables, single-phase AC			3 or 4 cables, three-phase AC			
		Reference methods A & B (enclosed in conduit or trunking)	Reference methods C & F (clipped direct on tray or in free air) touching	Reference methods C & F (clipped direct on tray or in free air) spaced	Reference methods A & B (enclosed in conduit or trunking)	Reference methods C & F (clipped direct, on tray or in free air) Touching, Trefoil	Reference methods C & F (clipped direct, on tray or in free air) Touching, Flat	Reference methods C & F (clipped direct, on tray or in free air) Spaced*, Flat
1	2	3	4	5	6	7	8	9
mm^2	mV/A/m	mV/A/m	mV/A/m	mV/A/m	mV/A/m	mV/A/m	mV/A/m	mV/A/m
1	44	44	44	44	38	38	38	38
1.5	29	29	29	29	25	25	25	25
2.5	18	18	18	18	15	15	15	15
4	11	11	11	11	9.5	9.5	9.5	9.5
6	7.3	7.3	7.3	7.3	6.4	6.4	6.4	6.4
10	4.4	4.4	4.4	4.4	3.8	3.8	3.8	3.8
16	2.8	2.8	2.8	2.8	2.4	2.4	2.4	2.4
		$z^{\dagger}$	$z^{\dagger}$	$z^{\dagger}$	$z^{\dagger}$	$z^{\dagger}$	$z^{\dagger}$	$z^{\dagger}$
25	1.75	1.80	1.75	1.80	1.55	1.50	1.55	1.55
35	1.25	1.30	1.25	1.30	1.10	1.10	1.10	1.15
50	0.93	1.00	0.95	0.97	0.85	0.82	0.84	0.86
70	0.63	0.72	0.66	0.69	0.61	0.57	0.60	0.63
95	0.46	0.56	0.50	0.54	0.48	0.43	0.47	0.51

* Spacings larger than one cable diameter will result in larger voltage drop.
† The impedance values in Table F4(ii) consist of both the resistive and reactive elements of voltage drop, usually provided separately for 25 mm^2 and above

Appendix

Table F4(ii) page 173

$$Volt\ Drop\ (Vd) = \frac{\langle mV|A|m\rangle \times Ib \times L}{1000}$$

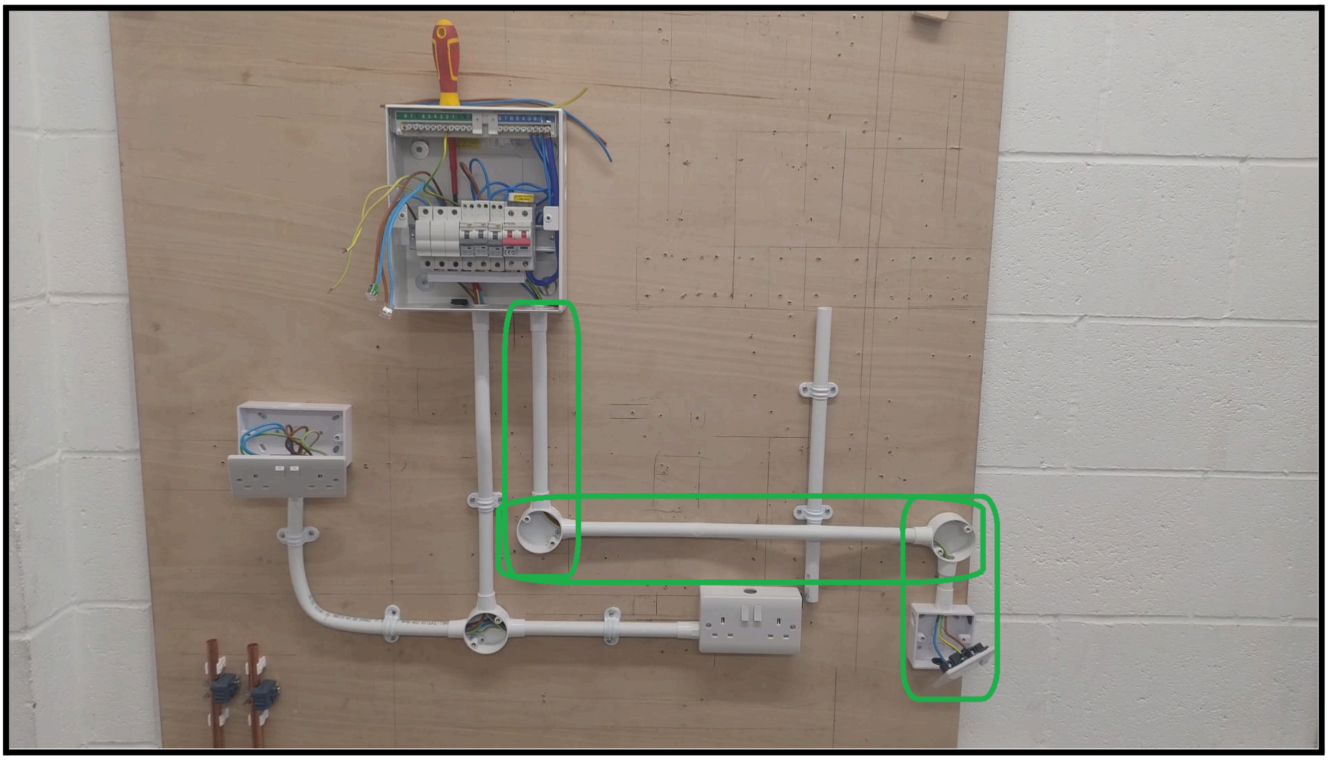
$$\text{Voltage Drop} = \frac{7.3 \times 17.39 \times 25}{1000} = 3.17\,\text{V}$$

<u>Practical section</u>

📌 **Important Clarification:**

Display	What it Means	Continuity?
`0.5 Ω`	Very low resistance (good path)	✅ Yes
`50 Ω`	Some resistance, might still beep	⚠️ Maybe (depends)
`>200 Ω` / `OL`	Too much resistance (open circuit)	❌ No

In the board below we also installed a radial circuit - which is highlighted in green.



Isambard W-A Class date: Sunday 13/07/2025

GENERIC SCHEDULE OF TEST RESULTS Certificate/Report No.: ....

Distribution board details

DB reference: .... Z_{db} .... Ω I_{pf} .... kA

Confirmed: Correct polarity ☐ Phase sequence ☐

SPD: Operational status confirmed¶ ☐ N/A ☐

Details of test instruments used (serial and/or asset numbers)

Multifunction: ....

Continuity: ....

Insulation resistance: ....

Earth fault loop impedance: ....

RCD: ....

Earth electrode resistance: ....

TEST RESULT DETAILS

	Continuity (Ω)					Insulation resistance				Z_s (Ω)	RCD		AFDD	**Remarks** Include details of circuits and/or installed equipment vulnerable to damage when testing (continue on a separate sheet if necessary)
	Ring final circuit			$(R_1 + R_2)$ or R_2										
17 Circuit number	18 r_1 (line) (Ω)	19 r_n (neutral)	20 r_2 (cpc)	21 $(R_1 + R_2)$	22 R_2	23 Test voltage (V)	24 Live - Live (MΩ)	25 Live - Earth (MΩ)	26 Polarity#	27 Maximum measured	28 Disconnection time (ms)**	29 Test button operation	30 Manual test button operation	31
				0.05		500	>200	>200	✓					

Tested by name (Capitals): ....

Signature: .... Date: ....

¶ Not all SPDs have visible functionality indication.
# An 'X', denoting incorrect polarity, cannot be entered on to this schedule when issued with an Electrical Installation Certificate.
** RCD effectiveness is verified using an alternating current test at rated residual operating current ($I_{\Delta n}$).

Test for a Radial circuit

Step One - test for Continuity (Ω)

(R_1 + R_2)
R_1 = Live and **R_2 = Earth**

A) Set-up electrical tester for continuity test:

- Set the dial on the electrical tester to the "**continuity**" setting;
- Plug the tester socket into the plug;
- Attach the probes into the **Live** and **Earth** socket pins.

B) In terms of the Fuse board:

- Put the Earth wire into position two of the connector block;
- This is because the circuit that we wish to test is on the second RCD;
- The live wire can go anywhere in the connector block.

As a result of following **part A** and **part B** we create a loop in the circuit. A loop in which the electrical current flows down the **brown live wire** and back through the **green and yellow earth wire**.

C) <u>Hit the test button on the electrical tester - interpret the result:</u>

- First reading was **0.05 Ω (Ohms)**
- Second reading of **0.07 Ω (Ohms).**

- This means that there is very little resistance in the circuit.
- When there is little resistance this means there is a good flow of current.
- Continuity checks if there is a connection between two points.

>200 Ω or there around - means no continuity or an open circuit. Resistance is too high to even measure.

Insulation resistance

Step Two - Test voltage (V)

Set the test voltage to 500 on the machine.
Write 500 on the test sheet because this is the voltage level.

Step Three - Live - Live (MΩ)

Means we test the **brown live wire** and the **blue neutral wire**.
We scored > 200Ω Ohms.
This test means that the **brown live wire** and the **blue neutral wire** do not touch each other in the radial circuit.
Does this score mean that because there is so much resistance the wires (**brown live wire** and the **blue neutral wire**) simply cannot be touching. Because if they were touching the resistance would be lower as there would be more current flow.

Step four - Live - Earth (MΩ)

Test the brown live wire and the earth wire. We got **>200 Ω (Ohms)** which means the wires are not touching.

Step five - Polarity is ticked because we got a reading in Part One subsection D.