Isambard WA - lesson 9 - class date: Sunday 6th July 2025

Introduction

I_b = design current
I_n = Protective/fuse rating breaker size
I_z = Cable rating

NOTE: I stands for current. I_b I_n and I_z are all current based.

$$\boxed{Ib \le In \le Iz}$$

Simple example:

- Heater has a design current of 5
- needs to have a fuse of 6
- and a cable rating of 7.2.

Tutor aside: Always have leeway when it comes to **I_b**, **I_n** and **I_z**. For example, it says "less than or equal to". make sure it is always greater than. As shown in this example.

I_b – Design current: The actual current that the load is expected to draw under normal operation.

I_n – Nominal current: of the protective device: The rated current of the circuit breaker or fuse (e.g., a 16 A MCB).

I_z – Current-carrying capacity:(ampacity) of the cable or conductor, under the given installation conditions.

START FIRST PRACTISE

Question:

If we run a cable in a 30 degree room.
With a Twin and Earth 70 degrees.
Grouped with 7 cables with 320mm insulation
And a **32 A** breaker.

Workings out:

$$\boxed{I_b \leq I_n \leq I_z}$$

I_b = design current
I_n = Protective/fuse rating breaker size
I_z = Cable rating

The **first step** is to calculate the design current => I_b.
I_b = ??

The **second step** is to calculate the breaker size => I_n
I_n = **32 A** breaker.

The **third step** is to calculate I_z => cable rating;

- The pre-requisite is to calculate I_t => current carrying capacity.

$$\boxed{I_t \leq \frac{I_n}{C_a \cdot C_g \cdot C_i \cdot C_f}}$$

- The base formula to deduce $\mathbf{I_t}$ => current carrying capacity.

C_a => ambient temperature

$$\boxed{I_t \leq \frac{I_n}{1 \cdot C_g \cdot C_i \cdot C_f}}$$

- **C_a** - The ambient temperature is deduced as 1 from **Table F1** on **page 168**.

C_g => grouping

$$\boxed{I_t \leq \frac{I_n}{1 \cdot 0.71 \cdot C_i \cdot C_f}}$$

- **C_g** - is deduced as 0.71. Because there are seven cables in the wall. So this additional cable makes 8.

C_i => thermal insulation

$$\boxed{I_t \leq \frac{I_n}{1 \cdot 0.71 \cdot 0.51 \cdot C_f}}$$

- **C_i** - is deduced as 0.51. Because the question states "320mm insulation" which, when rounded up to 400. Corresponds to 0.51 Derating factor (C_i).

C_f => account for 3036 fuse box

$$\boxed{I_t \leq \frac{I_n}{1 \cdot 0.71 \cdot 0.51 \cdot 1}}$$

- **C_f** - is deduced as 1. As the on guide site states "for all other devices **C_f = 1**. "

I_n => represents the current at which the protective device is designed to operate in order to protect the circuit from damage.

$$\boxed{I_t \leq \frac{32\ A}{1 \cdot 0.71 \cdot 0.51 \cdot 1}}$$

- **I_n** - The question gives us the breaker size as **32 A**

Therefore **I_t**,

$$\boxed{\begin{gathered} I_t \leq \frac{32}{1 \times 0.71 \times 0.51 \times 1} = \frac{32}{0.3621} \approx 88.39\ A \\ \\ I_t \leq 88.39\ A \end{gathered}}$$

END FIRST PRACTISE

START SECOND PRACTISE

Question:

$\mathbf{I_n}$ is 45. The total answer is 63.

A shower is running through **100mm insulation**. Which has a **70 degree** thermoplastic cover. The cable is fitted into an enclosed wall with 6 circuits. The shower requires **7.2 kW** to run and uses **230 volts**.

The temperature of the bathroom is **25 degrees**.

Finally, Sam's fuse box has not been updated in a while and is **version 3036**.

Workings out:

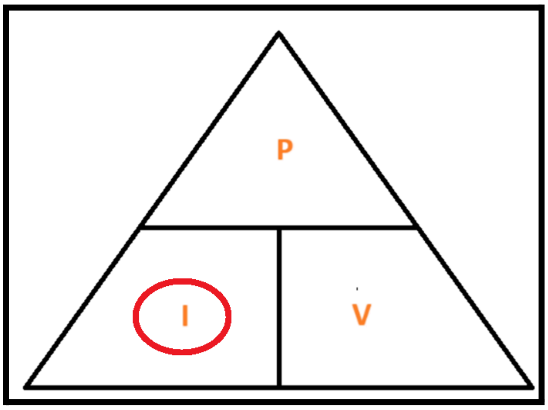
$$\boxed{I_b \leq I_n \leq I_z}$$

- **I_b = design current**
- **I_n = Breaker Size**
- **I_z = cable rating**

The **first step** is to calculate the design current => **I_b**.

$$\boxed{I_b \leq I_n \leq I_z}$$

- To calculate the design current (**I_b**) we use the **PIV formula triangle**;
- The answer for **I_b** will be measured in amps.



PIV formula triangle

- I = P / V or
- Current = Power / Voltage;
- 7.2 kW / 230 volts = 31.30 amps.
- 7,200 / 230 = 31.30 A

Diversity rule check

A | Appendix

The use of other methods of determining maximum demand is not precluded where specified by the installation designer. After the design currents for all the circuits have been determined, enabling the conductor sizes to be chosen, it is necessary to check that the limitation on voltage drop has been met.

▼ **Table A1** Current demand to be assumed for points of utilization and current-using equipment

Point of utilization or current-using equipment	Current demand to be assumed
Socket-outlets other than 2 A socket-outlets and other than 13 A socket-outlets See NOTE 1	Rated current
2 A socket-outlets	At least 0.5 A
Lighting outlet See NOTE 2	Current equivalent to the connected load, with a minimum of 100 W per lampholder
Electric clock, shaver supply unit (complying with BS EN 61558-2-5), shaver socket-outlet (complying with BS 4573), bell transformer, and current-using equipment of a rating not greater than 5 VA	May be neglected for the purpose of this assessment
Household cooking appliance	The first 10 A of the rated current plus 30 % of the remainder of the rated current plus 5 A if a socket-outlet is incorporated in the control unit
All other stationary equipment	British Standard rated current, or normal current

NOTES:

1 See Appendix H for the design of standard circuits using socket-outlets to BS 1363-2 and BS EN 60309-2 (BS 4343).

2 Final circuits for discharge lighting must be arranged so as to be capable of carrying the total steady current, which is made up of the lamp(s) and any associated controlgear and also their harmonic currents. Where more exact information is not available, the demand in volt-amperes (VA) is taken as the rated lamp watts multiplied by not less than 1.8. This multiplier is based upon the assumption that the circuit is corrected to a power factor (PF) of not less than 0.85 lagging, and takes into account controlgear losses and harmonic current.

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- **For I_b (the design current) check if the appliance appears on table A1 on page 136;**
- **If yes, apply the diversity calculation;**
- **In this instance a shower does not appear on the table;**
- **So I_b = 31.30 amps.**

The **second step** is to calculate the breaker size => I_n

$$\boxed{I_b \leq I_n \leq I_z}$$

- To calculate I_n read the Header row on **Table B1** (page 140);
- We must calculate the right sized breaker to use;

B | Appendix

Table B6 gives the maximum measured Z_S for circuits protected by circuit-breakers to BS 3871-1 and BS EN 60898 and RCBOs to BS EN 61009.

NOTE: The impedances tabulated in this appendix are lower than those in Tables 41.2, 41.3 and 41.4 of BS 7671 as the impedances in this appendix are measured values at an assumed conductor temperature of 10 °C while those in BS 7671 are design figures at the conductor maximum permitted operating temperature. The correction factor (divisor) used is 1.25. For smaller section conductors the impedance may also be limited by the adiabatic equation of Regulation 543.1.3. A value of k of 115 from Table 54.3 of BS 7671 is used. This is suitable for PVC insulated and sheathed cables to Table 4, 7 or 8 of BS 6004 and for thermosetting (LSHF) insulated and sheathed cables to Table 3, 5, 6 or 7 of BS 7211. The k value is based on both the thermoplastic (PVC) and LSHF cables operating at a maximum temperature of 70 °C.

▼ **Table B1** Semi-enclosed fuses. Maximum measured earth fault loop impedance (in Ω) at ambient temperature where the overcurrent protective device is a semi-enclosed fuse to BS 3036

i **0.4 s disconnection (final circuits not exceeding 32 A in TN systems)**

Protective conductor (mm²)	Fuse rating			
	5 A	15 A	20 A	30 A
1.0	7.3	1.9	1.3	NP
≥ 1.5	7.3	1.9	1.3	0.83

ii **5 s disconnection (final circuits exceeding 32 A and distribution circuits in TN systems)**

Protective conductor (mm²)	Fuse rating			
	20 A	30 A	45 A	60 A
1.0	2.3	NP	NP	NP
1.5	2.91	1.6	NP	NP
2.5	2.91	2.0	1.0	NP
4.0	2.91	2.0	1.2	0.85
≥ 6.0	2.91	2.0	1.2	0.85

NOTE: NP means that the combination of the protective conductor and the fuse is Not Permitted.

Protective Conductor (mm2)	20 A	30 A	**45 A**	60 A
1.0	2.3	NP	NP	NP
1.5	2.91	1.6	NP	NP
2.5	2.91	2.0	1.0	NP
4.0	2.91	2.0	1.2	0.85
16.0	2.91	2.0	1.2	0.85

Extract of Table B1 from page 140 BS:7671:2018+A2:2022

- The design current (I_b) has been calculated as **31.30 amps** - as deduced in the **first step**;
- Round up to the nearest value in the header row table **Table B1** (page 140);
- From the table we can conclude that the right breaker size is **45 A** for a design current (I_b) of **31.30 amps**;

- 30 A and 20 A are too small. 60 A is too large
- Note that we highlighted **“protective device is a semi-enclosed fuse to BS 3036”**

The **third step** is to calculate $\mathbf{I_z}$ => cable rating;

$$\boxed{I_b \leq I_n \leq I_z}$$

- To calculate $\mathbf{I_z}$ => cable rating;
- We must first calculate $\mathbf{I_t}$ => current carrying capacity .

I_t => current carrying capacity formula

$$\boxed{I_t \geq \frac{I_n}{C_a \cdot C_g \cdot C_i \cdot C_f}}$$

- The above formula is used to calculate $\mathbf{I_t}$;
- From $\mathbf{I_t}$ we can deduce the value of $\mathbf{I_z}$;
- Use **page 167** to calculate $\mathbf{C_a}$, $\mathbf{C_g}$, $\mathbf{C_i}$ **and** $\mathbf{C_f}$

C_a => ambient temperature

$$I_t \geq \frac{I_n}{1.03 \; C_g \cdot C_i \cdot C_f}$$

- Calculate **C_a** first;
- We know that the Ambient template is 25 degrees and the insulation is 70 degrees;
- Hence, in **Table F1** on **page 168** the answer is 1.03.

C_g=> grouping

$$I_t \geq \frac{I_n}{1.03 \cdot 0.54 \; C_i \cdot C_f}$$

- We calculate **Cg** because of the **Table F3** on **page 170**;
- The question states 6 cables already situated into the wall;
- Therefore this additional cable will make it **seven**.

C_i => thermal insulation

$$I_t \geq \frac{I_n}{1.03 \times 0.54 \times 0.78 \times C_f}$$

- **C_i** is deduced from **Table F2** on **page 169**;
- **C_i** - factors in how insulation around a cable can affect its ability to dissipate heat and thus impact on the maximum amount of current that it can safely carry;
- The text informs us that the length of the insulation is 100mm this equates to 0.78.

C_f=> account for 3036 fuse box

$$I_t \geq \frac{I_n}{1.03 \times 0.54 \times 0.78 \times 0.725}$$

- **C_f** is deduced from **page 167** at the bottom of the page;

- The answer is 0.725;
- This number is deduced from the text “a semi-enclosed fuse to BS 3036”.

I_n => represents the current at which the protective device is designed to operate in order to protect the circuit from damage

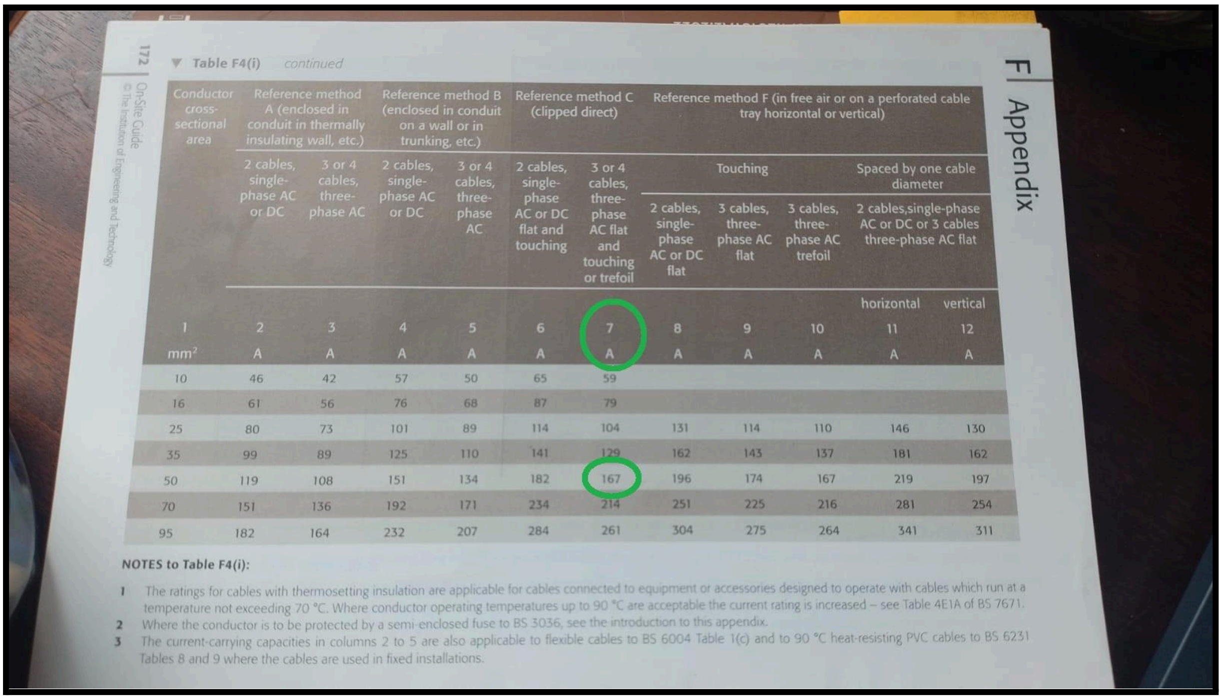
$$I_t \geq \frac{I_n}{C_a \times C_g \times C_i \times C_f} = \frac{45}{1.03 \times 0.54 \times 0.78 \times 0.725}$$

- **I_n** has been deduced from the **second step** to be **45 A**;
- Because, we deduced the breaker size **(I_n)** based on the design current **(I_b)**;
- If the current exceeds **45 A** then the breaker device will operate.

I_t = 143.1A

$$I_t \geq \frac{45}{0.3145} \approx 143.1\ A$$

I_z - Cable size. We need a cable size that can carry a **143.1 A** current flow.
As mentioned in the question. We already have **6 circuits**. With this addition, **there will be 7 circuits.**



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F Appendix

▼ Table F4(i) *continued*

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)				
							Touching			Spaced by one cable diameter	
	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	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
10	46	42	57	50	65	59					
16	61	56	76	68	87	79					
25	80	73	101	89	114	104	131	114	110	146	130
35	99	89	125	110	141	129	162	143	137	181	162
50	119	108	151	134	182	167	196	174	167	219	197
70	151	136	192	171	234	214	251	225	216	281	254
95	182	164	232	207	284	261	304	275	264	341	311

NOTES to Table F4(i):

1 The ratings for cables with thermosetting insulation are applicable for cables connected to equipment or accessories designed to operate with cables which run at a temperature not exceeding 70 °C. Where conductor operating temperatures up to 90 °C are acceptable the current rating is increased – see Table 4E1A of BS 7671.
2 Where the conductor is to be protected by a semi-enclosed fuse to BS 3036, see the introduction to this appendix.
3 The current-carrying capacities in columns 2 to 5 are also applicable to flexible cables to BS 6004 Table 1(c) and to 90 °C heat-resisting PVC cables to BS 6231 Tables 8 and 9 where the cables are used in fixed installations.

END SECOND PRACTISE

Voltage drop

Introduction

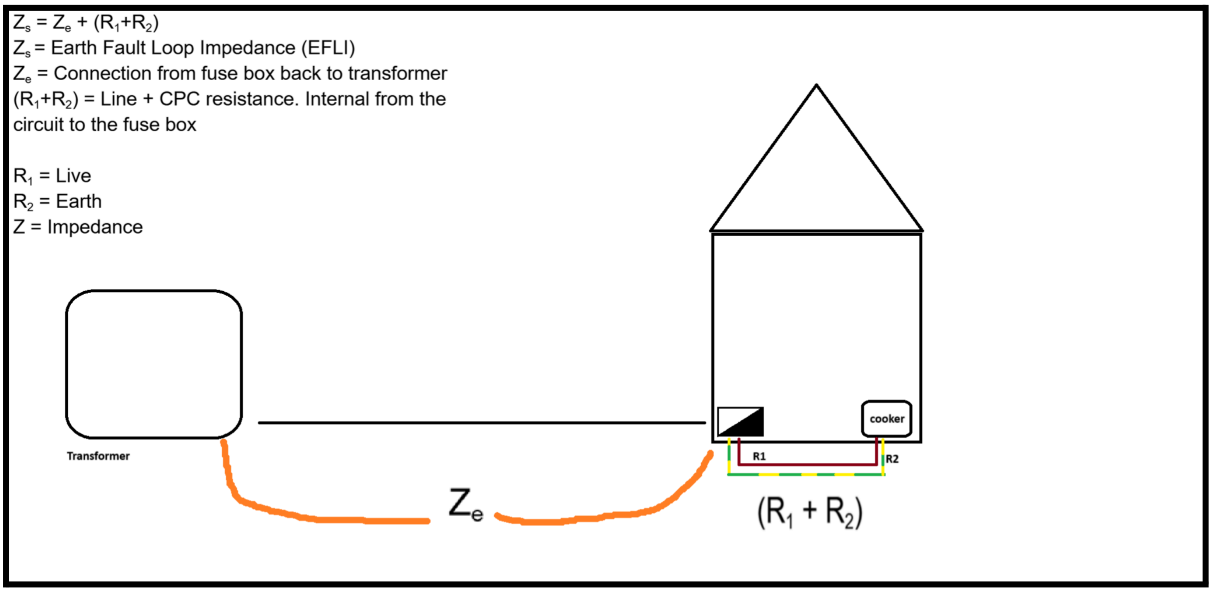
$Z_s = Z_e + (R_1+R_2)$

Z_s = Earth Fault Loop Impedance (EFLI)
Z_e = Connection from fuse box back to transformer
(R_1+R_2) = Line + CPC resistance. Internal from the circuit to the fuse box

R_1 = Live
R_2 = Earth
Z = Impedance

$(R_1 + R_2)$

Question



Working out

$$\text{Voltage drop} = \frac{(\text{mv/A/m}) \times I_b \times L}{1000}$$

$$\boxed{\frac{6.44 \times 28 \times 1.2}{1000}}$$

= 0.22 Ω

=> $Z_s = Z_e + (R_1 + R_2)$
=> 0.22 + 0.09
=> 0.31 Ω

230 / 0.31 = 741.94 A (will flow in an event of a fault)