The Open University of Sri Lanka
Diploma in Technology
ECX4234-Electrical Installation
Final Examination 2012/2013

Date 28/07/2013 **Time:9.30-12.30 hrs.**

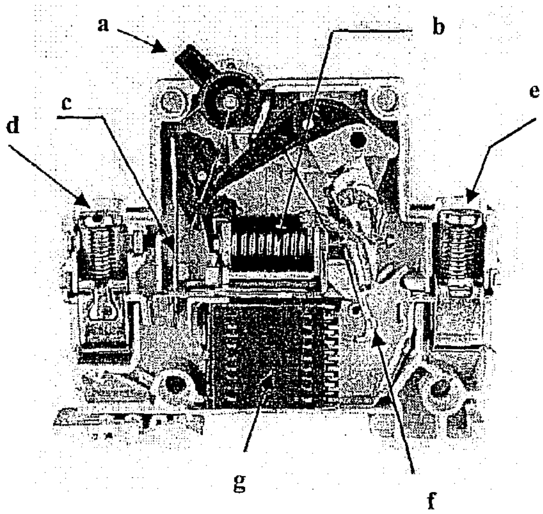
This paper contains 8 questions in 4 pages. Pages 5 to 11 contain tables and appendices required for answering the questions. Answer only five (5) questions.

1. a) State what is meant by the term "Electrical Installation" ? [2.5]
b) What would be the maximum current carrying capacity of 1/1.38 (1.5 mm^2) **p.v.c.** cable (in conduit) used in domestic wiring? [2.5]
c) State the colour code and size of the earth wire used in domestic wiring? [2.5]
d) In the equation $S = \frac{\sqrt{I^2 t}}{k}$ what is "S" and give its units? [2.5]
e) What would be the value of constant "k" given in **1.d** for copper cables? [2.5]
f) What is **mcb, rccb, rcd** and **rcbo** stands for and under what conditions the said equipments operates? [2.5]
g) What is the sensitivity of domestic **rccb** and state the time duration within which it should operate? [2.5]
h) State the maximum percentage voltage drop you would allow in a circuit from its distribution board in a domestic electrical Installation as per the IEE regulations? [2.5]

2. a) You are given a conduit occupied by two 1/1.13 wires running in a circuit. For how long the wire can run if the maximum current allowed is 5 Amperes. [2.5]
b) How many 1/1.13 single core cables that can be occupied in a 16 mm **p.v.c.** conduit pipe in a straight-run (with out bends) domestic wiring? [2.5]
c) What is the permissible earth fault loop impedance value for a protection of fixed equipment operating at 240 V & protected by a 16 A Type C **rcbo** to BS EN 61009? [2.5]
d) Between what terminals, the insulation test of a domestic electrical installation is done? [2.5]
e) What are the initial steps that you would take before carrying out the insulation test of a domestic electrical installation? [2.5]
f) State the name of the instrument used for the above (d) test? [2.5]
g) What voltage you apply for the above test if the operating voltage is 110 V? [2.5]
h) State the insulation resistance value you would expect for a good domestic electrical installation? [2.5]

3. a) What would be the size of the cable and rating of **mcb** used in domestic ring circuits? [5.0]
b) If you do not have the grouping factor table published by the IEE regulation for domestic wiring as a reference, what percentage of an area would you allow as a free space in domestic conduit wiring? [2.5]
c) What is **XLPE** stands for? Is it thermo setting or thermo plastic? [2.5]
d) You are requested to connect a 100 kVA, 400V, 3-phase ac generator to a distribution point located approximately about 85 m away from the generating point using XLPE multi-core non-armoured cable. Calculate the size of the cable for the above wiring if the cable is laid on a cable tray (free air)? Assume that the allowable voltage drop is 3% [10.0]

4. Answer the following questions with reference to the figure Q4a and figure Q4b shown below:



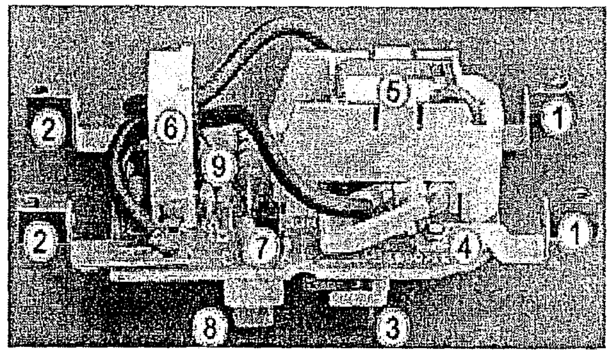


Figure Q4a **Figure Q4b**

a) i. Name the equipment shown in figure Q4a [3.5]
   ii. Identify the assembly of components **a-g** [1.5]
   iii. Draw the characteristics curve of component **c** [1.0]
   iv. Draw the characteristics curve of component **b** [1.0]
   v. From (iii) and (iv) deduce the equipment characteristics curve and explain its performance [2.0]

b) i. Name the equipment shown in figure Q4b [4.5]
   ii. Identify the assembly of components **1-9** [1.5]
   iii. State briefly under what condition the equipment operates [2.0]
   iii. How do you test this equipment after installing it in a domestic electrical installation (with out using its own test button) [3.0]

5. a) Give standard symbols for 10 electrical equipments used in domestic electrical installation works: [10.0]

   b) Draw the single line diagram for a fluorescent circuit (consisting of two tubes) to be installed in an industrial type of installation, showing the connection of all the associated equipments. What size of a capacitor you would normally use for such circuits? Describe the purpose of this capacitor. [10.0]

6. A 230 V single-phase circuit is run in two-core (with **cpc**) 70^0C **p.v.c** insulated sheathed cable having copper conductors of 4.0 mm^2 for the live and 2.5 mm^2 for the protective conductors. If the length of the path is 40 m, earth fault loop impedance external to the installation is 1.2 Ω and the circuit is protected by a 30 mA **rccb**, check whether the circuit is satisfying the adiabatic equation as per IEE regulation #543-01-03 [10.0]

   (Assume k=115 and rccb to operate within 0.04 s at a residual current of 5 $I_{\Delta n}$ Amps.)

   Also calculate the maximum time the conductor can withstand as per the adiabatic equation, if one wish to introduce an internal time delay for the **rccb**. [10.0]

7. a) State the factors on which the capacity of a conduit to carry cables depends? **[5.0]**

b) State the factors on which the capacity of a cable conductor depends? **[5.0]**

c) It is intended to run four, three and two single-core **p.v.c.** insulated similar cables with cross sections of 2.5 mm^2, 4 mm^2 and 6 mm^2 respectively in a conduit in an industrial electrical installation. The estimated length of the conduit run is about 5 meters and the run include 3 bends. Determine the minimum size of the conduit that can be used for this purpose? Also, estimate the minimum radius of the conduit bends to be used in the above installation. **[10.0]**

8. a) In order to determine the earth fault loop impedance of a "spur" on a ring circuit, strictly it is necessary to estimate the fractional distance of that spur from the origin of the circuit. If the fraction is denoted by *'y'* as shown in figure Q8, prove that the earth fault loop impedance at the remote end of spur is given by:

$$Z_S = \lfloor Z_E + y(1-y)(R_{1T} + R_{2T}) + R_{1S} + R_{2S} \rfloor \text{ Ohm}$$ **[7.5]**

Where:

R_{1T} = Total resistance of the phase conductor of the ring circuit in Ohm.
R_{2T} = Total resistance of the protective conductor of the ring circuit in Ohm.
R_{1S} = Resistance of the phase conductor of the spur in Ohm.
R_{2S} = Resistance of the protective conductor of the spur in Ohm.
Z_E = Earth fault loop impedance external to the installation in Ohm.

Deduce that under the worst case scenario, the above computed value would be:

$$Z_S = \lfloor Z_E + 0.25(R_{1T} + R_{2T}) + R_{1S} + R_{2S} \rfloor \text{ Ohm}$$ **[2.5]**

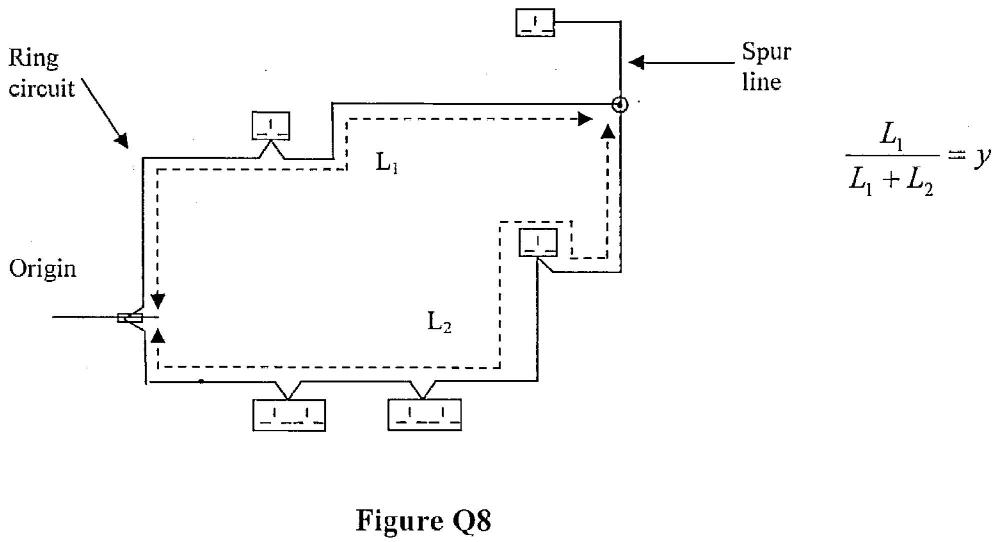
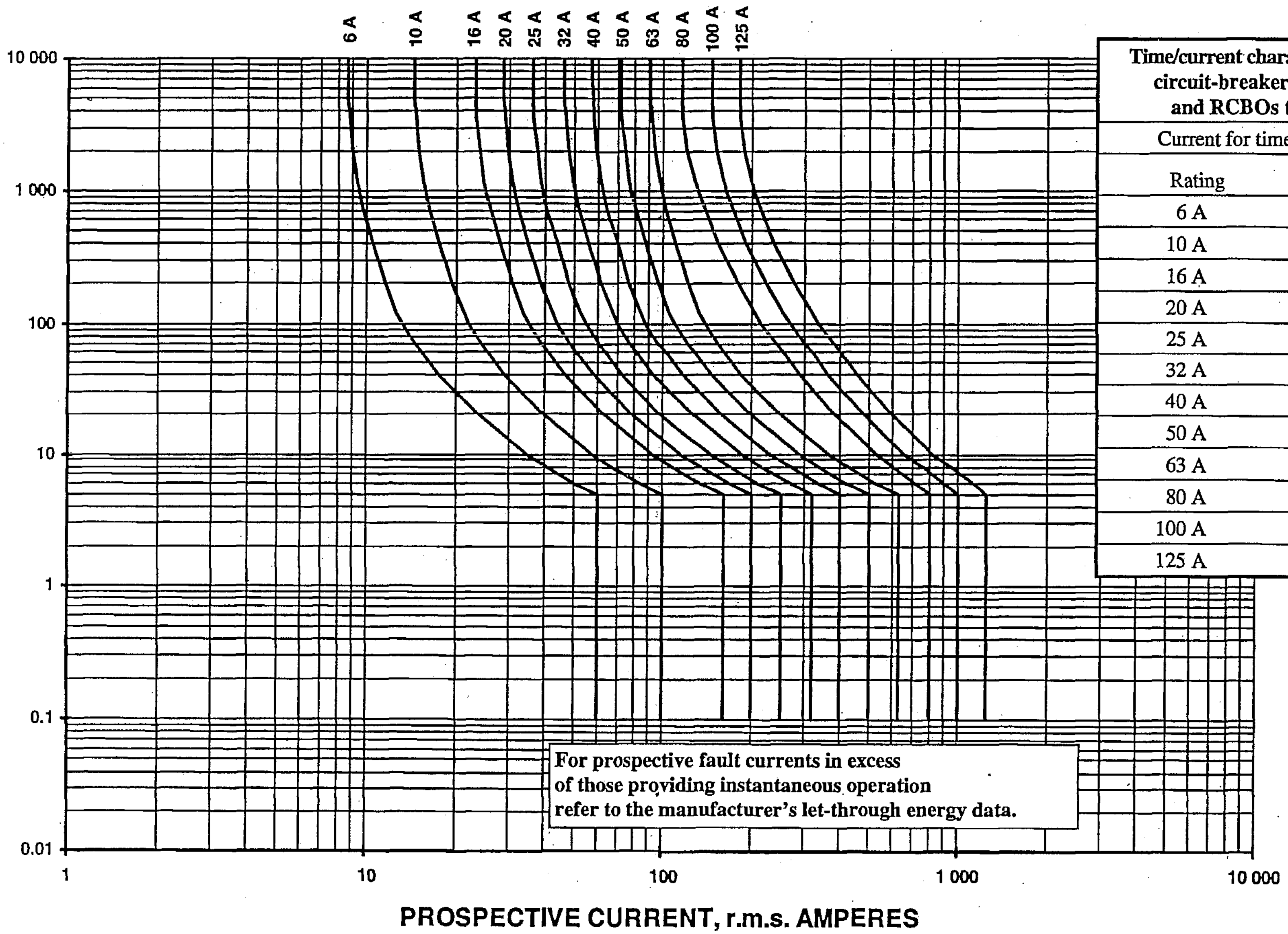


Figure Q8

b) A single-phase ring circuit is run in 2.5 mm^2 70 ^{0}C p.v.c-insulated and sheathed flat cable to BS 6004 with the protective conductor being 1.5 mm^2. Measured length of the ring circuit is about 80 m. A spur taken from the ring is run in the same cable and the length of the spur being 12 m. If it is estimated that the spur is taken from the ring 30 m from the origin and $Z_E = 0.35$, what is the earth fault loop impedance for the spur? **[5.0]**

c) Explain the variation of the calculated value in **8.b** if the point where the spur is taken from the ring circuit varies around the circuit? To get a pessimistically high result for you to be on the safe side, what would be the highest value of the earth fault loop impedance you would estimate for the spur in above ring circuit? **[5.0]** fig 3.5 **Type C circuit-breakers to BS EN 60898 and RCBOs to BS EN 61009**



Time/current characteristics for Type C circuit-breakers to BS EN 60898 and RCBOs to BS EN 61009

Current for time, 0.1 sec to 5 secs

Rating	Current
6 A	60 A
10 A	100 A
16 A	160 A
20 A	200 A
25 A	250 A
32 A	320 A
40 A	400 A
50 A	500 A
63 A	630 A
80 A	800 A
100 A	1000 A
125 A	1250 A

COPPER CONDUCTORS

TABLE 4E2A

Multicore 90 °C thermosetting insulated cables, non armoured
(COPPER CONDUCTORS)

Ambient temperature: 30 °C
Conductor operating temperature: 90 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method 4 (enclosed in an insulated wall, etc.)		Reference Method 3 (enclosed in conduit on a wall or ceiling, or in trunking)		Reference Method 1 (clipped direct)		Reference Method 11 (on a perforated cable tray) or Reference Method 13 (free air)	
	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.
1	2	3	4	5	6	7	8	9
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	14.5	13	17	15	19	17	21	18
1.5	18.5	16.5	22	19.5	24	22	26	23
2.5	25	22	30	26	33	30	36	32
4	33	30	40	35	45	40	49	42
6	42	38	51	44	58	52	63	54
10	57	51	69	60	80	71	86	75
16	76	68	91	80	107	96	115	100
25	99	89	119	105	138	119	149	127
35	121	109	146	128	171	147	185	158
50	145	130	175	154	209	179	225	192
70	183	164	221	194	269	229	289	246
95	220	197	265	233	328	278	352	298
120	253	227	305	268	382	322	410	346
150	290	259	334	300	441	371	473	399
185	329	295	384	340	506	424	542	456
240	386	346	459	398	599	500	641	538
300	442	396	532	455	693	576	741	621
400	-	-	625	536	803	667	865	741

NOTES:

1. **Where the conductor is to be protected by a semi-enclosed fuse to BS 3036, see item 6.2 of the preface to this appendix.**
2. Where a conductor operates at a temperature exceeding 70 °C it shall be ascertained that the equipment connected to the conductor is suitable for the conductor operating temperature (see Regulation 512-02).
3. * With or without a protective conductor.
4. For cables in rigid pvc conduit the values stated in Table 4D2 are applicable (see Regulation 521-05).
5. Where cables in this table are connected to equipment or accessories designed to operate at a temperature not exceeding 70 °C, the current ratings given in the equivalent table for 70 °C thermoplastic (pvc) insulated cables (Table 4D2A) shall be used (see also Regulation 523-01-01).
6. Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

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TABLE 4E2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Two-core cable, d.c.	Two-core cable, single-phase a.c.			Three- or four-core cable, three-phase a.c.		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	46	46			40		
1.5	31	31			27		
2.5	19	19			16		
4	12	12			10		
6	7.9	7.9			6.8		
10	4.7	4.7			4.0		
16	2.9	2.9			2.5		
		r	x	z	r	x	z
25	1.85	1.85	0.160	1.90	1.60	0.140	1.65
35	1.35	1.35	0.155	1.35	1.15	0.135	1.15
50	0.98	0.99	0.155	1.00	0.86	0.135	0.87
70	0.67	0.67	0.150	0.69	0.59	0.130	0.60
95	0.49	0.50	0.150	0.52	0.43	0.130	0.45
120	0.39	0.40	0.145	0.42	0.34	0.130	0.37
150	0.31	0.32	0.145	0.35	0.28	0.125	0.30
185	0.25	0.26	0.145	0.29	0.22	0.125	0.26
240	0.195	0.200	0.140	0.24	0.175	0.125	0.21
300	0.155	0.160	0.140	0.21	0.140	0.120	0.185
400	0.120	0.130	0.140	0.190	0.115	0.120	0.165

TABLE 8D

Values of $(R_1 + R_2)$ per metre for p.v.c.-insulated copper conductors

Cross-sectional area, mm²		$(R_1 + R_2)$ ohms/metre
Phase conductor	Protective conductor	
1	1	0.055
1.5	1	0.046
	1.5	0.037
2.5	1	0.039
	1.5	0.030
	2.5	0.022
4	1.5	0.026
	2.5	0.018
	4	0.014
6	2.5	0.016
	4	0.0116
	6	0.0092
10	4	0.0098
	6	0.0074
	10	0.0055
16	6	0.0064
	10	0.0045
	16	0.0035

APPENDIX 12

CABLE CAPACITIES OF CONDUIT AND TRUNKING

Introduction

This appendix describes a method which can be used to determine the size of conduit or trunking necessary to accommodate cables of the same size, or differing sizes, and provides a means of compliance with Regulation 529–7.

The method employs a 'unit system', each cable size being allocated a factor. The sum of all factors for the cables intended to be run in the same enclosure is compared against the factors given for conduit or trunking, as appropriate, in order to determine the size of the conduit or trunking necessary to accommodate those cables.

It has been found necessary, for conduit, to distinguish between –

1. straight runs not exceeding 3 metres in length, and
2. straight runs exceeding 3 metres, or runs of any length incorporating bends or sets.

The term 'bend' signifies a British Standard 90° bend, and one double set is equivalent to one bend.

For the case 1, each conduit size is represented by only one factor. For the case 2, each conduit size has a variable factor which is dependent on the length of run and the number of bends or sets. For a particular size of cable the factor allocated to it for case 1 is not the same as for case 2.

For trunking each size of cable has been allocated a factor, as has been each size of trunking.

Because of certain aspects, such as the assessment of reasonable care of pulling-in, acceptable utilisation of the space available and the dimensional tolerances of cables, conduit and trunking, any method of standardizing the cable capacities of such enclosures can only give guidance on the number of cables which can be accommodated. Thus the sizes of conduit or trunking determined by the method given in this appendix are those which can be reasonably expected to accommodate the desired number of cables in a particular run using an acceptable pulling force and with the minimum probability of damage to cable insulation.

Only mechanical considerations have been taken into account in determining the factors given in the following tables. As the number of circuits in a conduit or trunking increases, the current-carrying capacities of the cables must be reduced according to the appropriate grouping factors in Appendix 9. It may therefore be more attractive economically to divide the circuits concerned between two or more enclosures.

This appendix deals with the following four cases:

- Single-core p.v.c.-insulated cables in straight runs of conduit not exceeding 3m in length.
- Single-core p.v.c.-insulated cables in straight runs of conduit exceeding 3m in length, or in runs of any length incorporating bends or sets.
- Single-core p.v.c.-insulated cables in trunking.
- Other sizes and types of cable in trunking.

For other cables and/or conduits not covered by the tables, advice on the number of cables which can be accommodated should be obtained from the manufacturers.

Single-core p.v.c.-insulated cables in straight runs of conduit not exceeding 3m in length.

For each cable it is intended to use, obtain the appropriate factor from Table 12A.

Add all the cable factors so obtained and compare with the conduit factors given in Table 12B.

The conduit size which will satisfactorily accommodate the cables is that size having a factor equal to or exceeding the sum of the cable factors.

TABLE 12A

Cable factors for short straight runs

Type of conductor	Conductor cross-sectional area mm^2	Factor
Solid	1	22
	1.5	27
	2.5	39
Stranded	1.5	31
	2.5	43
	4	58
	6	88
	10	146

TABLE 12B

Conduit factors for short straight runs

Conduit dia mm	Factor
16	290
20	460
25	800
32	1400

Single-core p.v.c.-insulated cables in straight runs of conduit exceeding 3m in length or in runs of any length incorporating bends or sets.

For each cable it is intended to use, obtain the appropriate factor from Table 12C.

Add all the cable factors so obtained and compare with the conduit factors given in Table 12D, taking into account the length of run it is intended to use and the number of bends and sets in that run.

The conduit size which will satisfactorily accommodate the cables is that size having a factor equal to or exceeding the sum of the cable factors.

TABLE 12C

Cable factors for long straight runs, or runs incorporating bends

Type of conductor	Conductor cross-sectional area mm^2	Factor
Solid or stranded	1	16
	1.5	22
	2.5	30
	4	43
	6	58
	10	105

TABLE 12D

Conduit factors for runs incorporating bends

Length of run m	Conduit diameter, mm																			
	16	20	25	32	16	20	25	32	16	20	25	32	16	20	25	32	16	20	25	32
	Straight				One bend				Two bends				Three bends				Four bends			
1	Covered by Tables 12A and 12B				188	303	543	947	177	286	514	900	158	256	463	818	130	213	388	692
1.5					182	294	528	923	167	270	487	857	143	233	422	750	111	182	333	600
2					177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529
2.5					171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474
3					167	270	487	857	143	233	422	750	111	182	333	600				
3.5	179	290	521	911	162	263	475	837	136	222	404	720	103	169	311	563				
4	177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529				
4.5	174	282	507	889	154	250	452	800	125	204	373	667	91	149	275	500				
5	171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474				
6	167	270	487	857	143	233	422	750	111	182	333	600								
7	162	263	475	837	136	222	404	720	103	169	311	563								
8	158	256	463	818	130	213	388	692	97	159	292	529								
9	154	250	452	800	125	204	373	667	91	149	275	500								
10	150	244	442	783	120	196	358	643	86	141	260	474								