2018/2019 SEMESTER ONE EXAMINATION

Diploma in Electrical and Electronic Engineering (DEEE)
2nd Year Full-Time (DEEE)
Diploma in Energy Systems and Management (DESM)
2nd Year Full-Time (DESM)

ELECTRICAL INSTALLATION DESIGN Time Allowed: 2 hours

Instructions to Candidates:

1. The examination rules set out on the last page of the answer booklet are to be complied with.

2. This paper consists of TWO sections:

   Section A: 6 Short Questions, 10 marks each.
   Section B: 2 Long Questions, 20 marks each.

3. **ALL** questions are **COMPULSORY**.

4. All questions are to be answered in the answer booklet. Start each question in Section A and Section B on a new page.

5. This examination paper consists of 4 pages with another 6 pages of Extracts from CP5 Tables making a total of 10 pages.

SECTION A : [10 Marks Each]

1(a) A terrace house needs 22kVA of electricity at power factor of 0.8. State the voltage, frequency and number of wires that Singapore Power Services Limited will provide. What type of earthing system will be used? Calculate the maximum current that can be drawn from Singapore Power. (7 marks)

1(b) Sketch a single-phase electrical installation adopting the TNS earthing system, clearly labelled all parts. (3 marks)

2 Socket Outlet Assembly (SOA) are mandated for use in Temporary Electrical Installations.

(i) State the four areas where SOA is compulsory.

(ii) State the requirements relating to the enclosure of the assembly and type of protective devices used for the SOA.

(iii) State the maximum length for flexible cables used for handheld equipment when connecting to SOA.

(iv) Explain whether it is correct to loop from an existing industrial socket outlet fitted on the SOA to two 13A switched socket outlets.

(10 marks)

3(a) Determine the size (diameter) for the conduit as in Figure Q 3(a) needed to accommodate the following circuits. (Using the cable factor method.) (6 marks)

- 1 numbers of single-phase circuit using 2.5 mm^2 single core PVC-insulated stranded cables with 1.5mm^2 single core PVC insulated cables for the protective conductors
- 1 number of three-phase 3-wire circuit using 4.0 mm^2 single core PVC-insulated stranded cables with 2.5mm^2 single core PVC insulated cables for the protective conductors.

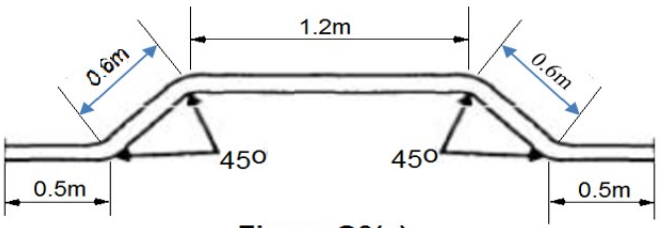


Figure Q3(a)

3(b) Can an ohmmeter be used to measure insulation resistance for electrical installation? The overall insulation resistance of the electrical installation with a total of 200 points (lighting and socket outlets) is 0.3 MΩ. Does the overall insulation resistance value comply with CP5:1998? (4 marks)

4 Design a manual traffic light control circuit which has the following operations.

The green light will always be on until the single push button is pressed.

Upon the pressing of the push button the green light will goes off after 10 seconds, the red light will be on for 25 seconds and then goes off and the green light on again.

The system will then be ready for the pressing of the push button again. (10 marks)

5 Refer to the single line diagram in Figure Q5 below:

(i) Determine the corresponding tripping time for the I_n Type C MCB and the $2xI_n$ Type B MCB when a current of $4xI_n$ flows in Load A and briefly explain whether discrimination is achieved. State the tripping mechanism(s) that will operates the MCBs under this condition. (6 marks)

(ii) If I_n = 20A determine the minimum cable size for load A and load B. Assume that ambient temperature is 30°C, no grouping and no thermal insulation. Multicore PVC insulated copper cable is to be used in surface conduit. (4 marks)

(Only Type C MCB Time/current characteristic graph is provided)

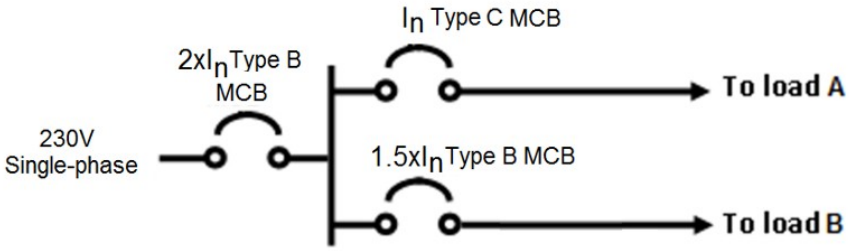


Figure Q5

6(a) Give a brief explanation of Direct contact, Indirect contact and Electrical Separation in the context of electrical installation. (6 marks)

6(b) Determine the earth fault loop impedance of the circuit in Figure Q6 (b) at the 13A switched socket outlet. (4 marks)

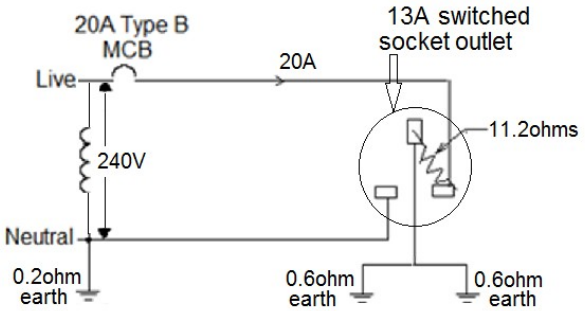


Figure Q6(b)

SECTION B : [20 Marks Each]

B1 An office unit is supplied by three-phase 400V/230V 50 Hz supply. It has the following electrical loads:

- 40 nos. 2 x 18W fluorescent lamps with 2x9W loss ballast pf =0.8
- 15 nos. of 50W, 50V tungsten halogen down lights
- **5 radial circuits** connected to 100 nos. 13A switched socket outlets, each protected by a 20A MCB (Estimated demand of each circuit is 3,000W)
- 2 nos. storage water heaters, each rated 1.5 kW
- 2 nos. of MULTI SPLIT air-conditioning units where the electrical load can be considered to be a three-phase motor, each rated 9.0 kW with an efficiency of 90% and a power factor of 0.85 running all the time at the same time.

Using the diversity factor given in Table 4B, draw a load list table as per sample below. (1 mark)

Description	Connected Load	D.F.	Current Demand

Hence calculate:

(i) the **three phase** maximum demand
(ii) the suitable size of the main circuit breaker, assuming 10% spare capacity is allowed for future expansion

(Standard circuit breaker rating: 30A, 40A, 50A, 63A, 80A, 100A). (19 marks)

B2(a) A 3-phase, 400V motor control centre(MCC) has an estimated power of 32kW at power factor of 0.85. The length of the cable is 40m from the main switchboard and it is to be wired in multi-core PVC insulated copper cables sharing a trunking with one other similar circuits. The ambient temperature is 39°C. Determine:

(i) The design current of the MCC, hence the nominal rating of a suitable Type C MCB (Standard MCB rating: 15A, 20A, 25A, 30A, 40A, 50A, 63A)
(ii) A suitable size of cable for the MCC.
(iii) The actual voltage drop and check whether the cable size selected can meet the CP5 requirement. Re-select cable size if necessary.

(11 marks)

B2(b) A single-phase 230V, induction motor is wired in single-core 2.5mm^2 PVC insulated copper conductor and 1.5mm^2 PVC insulated copper conductor for circuit protective conductor (CPC). The circuit is protected by a 32A BS88 fuse with a thermal overload device set at 20A, the circuit length is 30 meters long. The value of Z_E is given as 0.8 Ω.

(i) Determine if the given size of CPC meets the requirement for shock protection, resize the CPC if necessary. (5 marks)

(ii) Calculate the actual earth fault loop impedance for the size of CPC selected and determine the earth fault current. Hence check whether the CPC selected can withstand the earth fault current. (Given k =115.) (4 marks)

" ******* End of Paper ******* "

(Extracts from CP5 Tables pages 5 to 10)

Table 12C

Cable factors for long straight runs or runs incorporating bends

(Single core PVC cables)

Type of Conductor	Conductor cross-sectional area (mm2)	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 Table 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								

TABLE 4C1

Correction factors for ambient temperature where protection is not a semi-enclosed fuse to BS3036

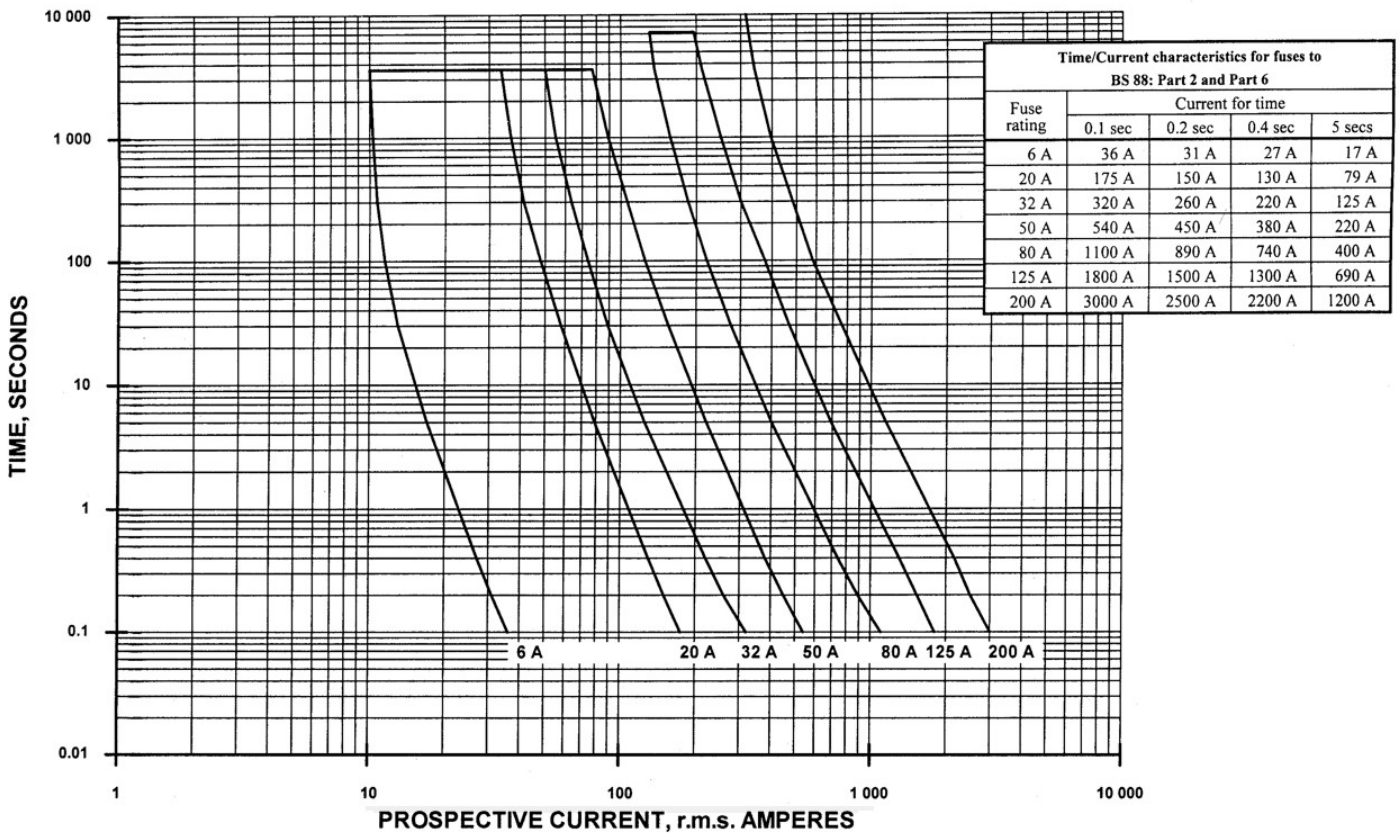
Type of insulation	Operating temperature	Ambient temperature (°C)														
		25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Rubber (flexible cables only)	60°C	1.04	1.0	0.91	0.82	0.71	0.58	0.41	-	-	-	-	-	-	-	-
General purpose pvc	70°C	1.03	1.0	0.94	0.87	0.79	0.71	0.61	0.50	0.35	-	-	-	-	-	-
Paper	80°C	1.02	1.0	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45	0.32		-	-	-
Rubber	85°C	1.02	1.0	0.95	0.90	0.85	0.80	0.74	0.67	0.60	0.52	0.43	0.30	-	-	-
Heat resisting pvc *	90°C	1.03	1.0	0.97	0.94	0.91	0.87	0.84	0.80	0.76	0.71	0.61	0.50	0.35	-	-
Thermosetting	90°C	1.02	1.0	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58	0.50	0.41	0.29	-	-
Mineral	70°C sheath	1.03	1.0	0.93	0.85	0.77	0.67	0.57	0.45	0.31	-	-	-	-	-	-
	105°C sheath	1.02	1.0	0.96	0.92	0.88	0.84	0.80	0.75	0.70	0.65	0.60	0.54	0.47	0.40	0.32

NOTES:

1. Correction factors for flexible cords and for 85oC or 150oC rubber-insulated flexible cables are given in the relevant table of current-carrying capacity
2. This table also applies when determining the current-carrying capacity of a cable
3. * These factors are applicable only to ratings in columns 2 to 5 of Table 4D1

TABLE 4B1:Correction factors for groups of more than one circuit of single-core cables, or more than one multicore cable

Reference method of installation (see Table 4A)		Correction factor (C_g) Number of circuits or multicore cables													
		2	3	4	5	6	7	8	9	10	12	14	16	18	20
Enclosed (Method 3 or 4) or bunched and clipped direct to a non-metallic surface (Method 1)		0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.48	0.45	0.43	0.41	0.39	0.38
Single layer clipped to a non-metallic surface (Method 1)	Touching	0.85	0.90	0.75	0.73	0.72	0.72	0.71	0.70	-	-	-	-	-	-
	Spaced*	0.94	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Single layer *multicore* on a perforated metal cable tray, vertical or horizontal (Method 11)	Touching	0.86	0.81	0.77	0.75	0.74	0.73	0.73	0.72	0.71	0.70	-	-	-	-
	Spaced*#	0.91	0.89	0.88	0.87	0.87	-	-	-	-	-	-	-	-	-
Single layer *single-core* on a perforated metal cable tray, touching (Method 11)	Horizontal	0.90	0.85	-	-	-	-	-	-	-	-	-	-	-	-
	Vertical	0.85	-	-	-	-	-	-	-	-	-	-	-	-	-
Single layer multicore touching on ladder supports (Method 13)		0.86	0.82	0.80	0.79	0.78	0.78	0.78	0.77	-	-	-	-	-	-



Time/Current characteristics for fuses to BS 88: Part 2 and Part 6

Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
6 A	36 A	31 A	27 A	17 A
20 A	175 A	150 A	130 A	79 A
32 A	320 A	260 A	220 A	125 A
50 A	540 A	450 A	380 A	220 A
80 A	1100 A	890 A	740 A	400 A
125 A	1800 A	1500 A	1300 A	690 A
200 A	3000 A	2500 A	2200 A	1200 A

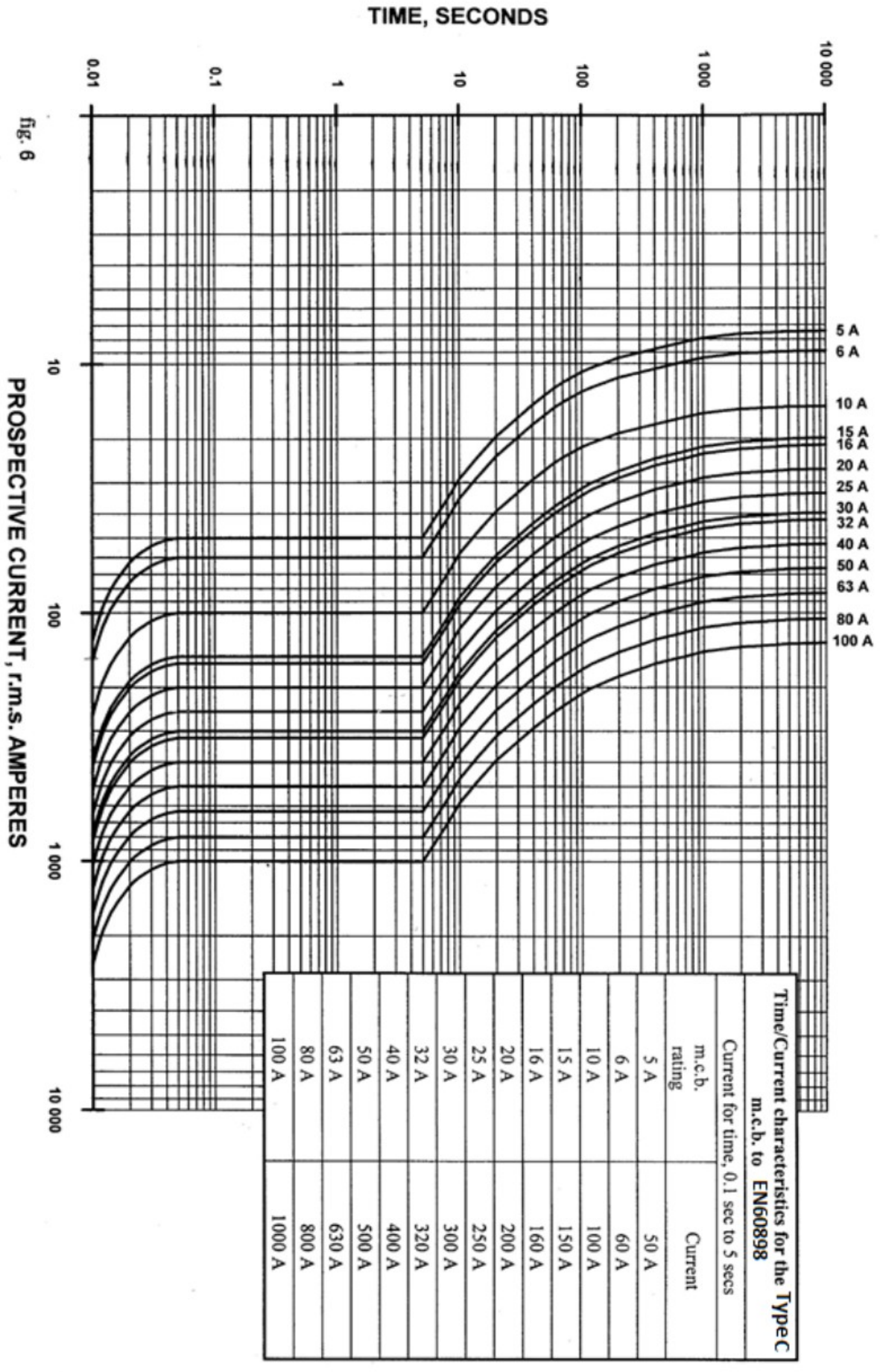


fig. 6

Time/Current characteristics for the Type C m.c.b. to EN60898	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	50 A
6 A	60 A
10 A	100 A
15 A	150 A
16 A	160 A
20 A	200 A
25 A	250 A
30 A	300 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

TABLE 4D2A

Multicore pvc insulated cables, non armoured (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes)

Ambient temperature 30° C
Conduuctor operating temperature 70 ° C

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 core cable* or 1 single phase a.c. or d.c.	1 two core cable*, single phase a.c. or d.c.	1 three core cable* or 1 four core cable, three phase a.c.	1 two core cable* single phase a.c. or d.c.	1 three core cable* or 1 four core cable, three phase a.c.	1 two core cable*, single phase a.c. or d.c.	1 three core cable* or 1 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	11	10	13	11.5	15	13.5	17	14.5
1.5	14	13	16.5	15	19.5	17.5	22	18.5
2.5	18.5	17.5	23	20	27	24	30	25
4	25	23	30	27	36	32	40	34
6	32	29	38	34	46	41	51	43
10	43	39	52	46	63	57	70	60
16	57	52	69	62	85	76	94	80
25	75	68	90	80	112	96	119	101
35	92	83	111	99	138	119	148	126
50	110	99	133	118	168	144	180	153
70	139	125	168	149	213	184	232	196
95	167	150	201	179	258	223	282	238
120	192	172	232	206	299	259	328	276
150	219	196	258	225	344	299	379	319
185	248	223	294	255	392	341	434	364
240	291	261	344	297	461	403	514	430
300	334	298	394	339	530	464	593	497
400	-	-	470	402	634	557	715	597

VOLTAGE DROP (per ampere per metre)

TABLE 4D2B

Conductor operating temperature:

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		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	44	44			38		
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

TABLE 41B1 (L)

Maximum earth fault loop impedance (Z_s) for fuses, for 0.4s disconnection time with U_o of 230 V (see Clause 413-02-10)

(a) General purpose (*gG*) fuses to BS 88 Parts 2 and 6

Rating (amperes)	6	10	16	20	25	32	40	50
Z_s (ohms)	8.51	5.10	2.70	1.77	1.43	1.04	0.82	0.60

TABLE 41D (L)

Maximum earth fault loop impedance (Z_s) for 5 s disconnection time with U_o 230 V (see Clauses 413-02-13 and 413-02-14)

(a) General purpose (*gG*) fuses to BS 88 Parts 2 and 6

Rating (amperes)	6	10	16	20	25	32	40	50
Z_s(ohms)	13.51	7.41	4.17	2.91	2.30	1.84	1.35	1.04

Table 4B
Allowance for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	**Type of premises**		
	Individual household installations, including individual dwellings of a block	**Small shops, stores, offices and business premises**	**Small hotels, boarding houses, guest houses, etc.**
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Heating and power (but see 3 to 8 below)	100% f.l. of total demand up to 10A + 50% of any current demand in excess of 10A	100% f.l. of largest appliance + 75% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
3. Cooking appliances	10A + 30% f.l. of connected cooking appliances in excess of 10A + 5A if socket outlet incorporated in unit	100% f.l. of largest appliances + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances	100% f.l. of largest appliances + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
Motors (other than lift motors which are subject to special consideration)		100% f.l. of largest motor + 80% f.l. of 2nd largest motor + 60% f.l. of remaining motor	100% f.l. of largest motor + 50% f.l. of remaining motor
5. Water heater (instantaneous type)	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances
6. Water heater (thermostatically controlled)	No diversity allowable		
7. Floor warming installations	(Reserved for future use)		
8.Thermal storage space heating installations	(Reserved for future use)		
9. Standard arrangement of final circuits (13A switched socket outlets)	100% of current demand of largest circuit + 40% of current demand of every other circuit	100% of current demand of largest circuit + 50% of current demand of every other circuit	
10. Socket outlets other than include in 9 above and stationary equipment other than those listed above	100% of current demand of largest point of utilisation + 40% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every point in main rooms (dining rooms, etc) + 40% of current demand of every other point of utilisation

Table 17A
Values of resistance/metre for copper and aluminium conductors and of (R1 + R2)/metre at 20°C in milliohms/metre

Cross-sectional area (mm^2)		Resistance/metre or ($R_1 + R_2$)/ metre	
Phase conductor	Protective conductor	Plain copper (mΩ/m)	Aluminium
1	-	18.10	
1	1	36.20	
1.5	-	12.10	
1.5	1	30.20	
1.5	1.5	24.20	
2.5	-	7.41	
2.5	1	25.51	
2.5	1.5	19.51	
2.5	2.5	14.82	
4	-	4.61	
4	1.5	16.71	
4	2.5	12.02	
4	4	9.22	
6	-	3.08	
6	2.5	10.49	
6	4	7.69	
6	6	6.16	
10	-	1.83	
10	4	6.44	
10	6	4.91	
10	10	3.66	
16	-	1.15	1.91
16	6	4.23	-
16	10	2.98	-
16	16	2.30	3.82
25	-	0.727	1.2
25	10	2.557	-
25	16	1.877	-
25	25	1.454	2.4
35	-	0.524	0.868
35	16	1.674	2.778
35	25	1.251	2.068
35	35	1.048	1.736

Table 17B - Multipliers to be applied to Table 17A

Insulation Material	p.v.c.	85^0 C Rubber	90^0 C Thermosetting
Multiplier	1.38 (1.30)	1.53 (1.42)	1.60 (1.48)
Note : The values in brackets are applicable to the resistance of circuit protective Conductors where Table 54B applies.			

The multipliers given in Table 17B are based on the simplified formula given in BS 6360 for both copper and aluminium conductors namely that the resistance temperature coefficient is 0.004 per °C at 20°C.