2017/2018 SEMESTER TWO 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 shopping complex needs 4000kVA of electricity. State the voltage, frequency and number of wires that Singapore Power Services Limited will provide. What type of earthing system will be used? Determine the power that can be drawn from Singapore Power at **2000**kVA and power factor of 0.80 lagging. (6 marks)

1(b) Sketch a three-phase electrical installation adopting the TNS earthing system, clearly labelled all the parts. (4 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 colours used for 110 volts and 230 volts industrial plugs.
(iv) State the Inspection frequency required of Temporary Electrical Installations at Construction Worksite.

(10 marks)

3(a) Determine the size (diameter) of a 4.6m long conduit with one 90^o bend needed to accommodate the following circuits. (Using the cable factor method.) (6 marks)

- 2 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 4-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.

3(b) The overall insulation resistance of the electrical installation in Block 14, Singapore Polytechnic is 0.4 MΩ. The electrical installation has a total of 150 points (lighting and socket outlets). Does the overall insulation resistance value comply with CP5:1998? (4 marks)

4 Design a motor control circuit which has the following operations.

There are two motors to be started in sequence:

Motor 1 and a white light is started together by operating a start push button.

Motor 2 will start up automatically together with a green light 10 minutes after Motor 1 is started.

Overload relay protection for both motors shall be included in the design.

The operation of a stop push button will stop the running of the two motors and also light up a red lamp. (10 marks)

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

(i) Determine the corresponding tripping time for the 32A Type B MCB and the 50A Type B MCB when a current of 100A flows in Load B and briefly explain whether discrimination is achieved. State the tripping mechanism(s) that operates the MCB. (8 marks)

(ii) Determine the disconnection time for the 15A Type C MCB when the circuit for Load A is shorted to neutral with a short circuit current of 150A. (2 marks)

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

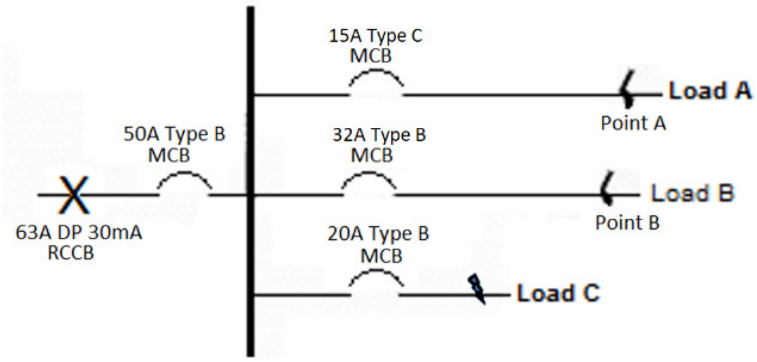

Figure Q5

6(a) In the circuit below, the value of Z is 50, the impedances are connected to a 400V/231V three phase supply. Determine V_2, V_5, I_1 and I_2. (7 marks)

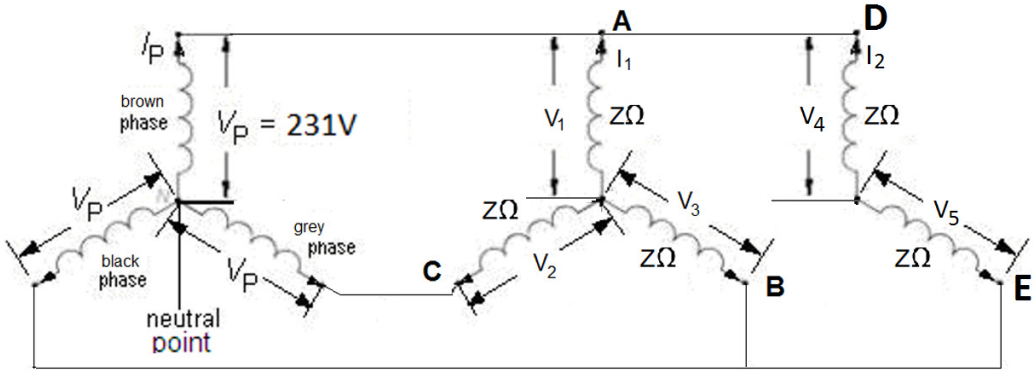

Figure Q6

6(b) Other than the insulation resistance test, name any 3 other tests which must be completed prior to the energisation of any electrical installation. (3 marks)

SECTION B : [20 Marks Each]

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

- 18 nos. 2 x 18W fluorescent lamps
- 10 nos. of 50W, 50V tungsten halogen down lights
- **3 radial circuits** connected to 36 nos. 13A switched socket outlets, each protected by a 20A MCB (Estimated demand of each circuit is 3000W)
- 5 nos. instantaneous water heaters, each rated 2.5 kW
- 8kW cooker connected to cooker control unit with 13A switched socket outlet
- a 1000W side by side refrigerator connected to a 13A switched socket outlet
- 1 nos. of MULTI SPLIT air-conditioning units where the electrical load can be considered to be a three-phase motor, rated 9.0 kW with an efficiency of 90% and a power factor of 0.85.

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 20% 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 13.5kW induction motor is delta-connected. The efficiency and the power factor of the motor are 90% and 0.80 respectively. The length of the cable is 50m from the distribution board 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 45^0 C. Determine:

(i) The line current, hence the nominal rating of a suitable Type B MCB (Standard MCB rating: 15A, 20A, 25A, 30A, 40A, 50A, 63A)
(ii) The starting current if the windings are connected in star for starting
(iii) A suitable size of cable for the delta connected motor.
(iv) The actual voltage drop and check whether the cable size selected can meet the CP5 requirement. Re-select cable size if necessary.

(12 marks)

B2(b) A single-phase 230V, 13A switched socket outlets circuit is wired in single-core 4.0mm² PVC insulated copper conductor and 1.5mm^2 PVC insulated copper conductor for circuit protective conductor. The circuit is protected by a 32A Type B MCB, the circuit length is 29 meters long. The value of Z_E is given as 0.75 Ω.

(i) Determine if the given size of circuit protective conductor (CPC) meets the requirement for shock protection, resize the CPC if necessary. (4 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	-	-	-	-	-	-

TABLE 41B2 (L)

Maximum earth fault loop impedance (Z_s) for miniature circuit-breakers, for disconnection times of both 0.4 s with U_o of 230 V (see Clause 413-02-11) **and 5 s** (see Clauses 413-02-12 and 413-02-14)

(e) Type 1 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	9.58	5.75	3.59	2.87	1.80	1.43	1.15	0.91	0.57	$57.50/I_n$

(f) Type 2 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	5.47	3.28	2.05	1.63	1.02	0.82	0.66	0.52	0.33	$230/(7I_n)$

(g) Type B miniature circuit-breakers to SS 359

Rating (amperes)	6	10	16	20	32	40	45	50	63	100	I_n
Z_s(ohms)	7.67	4.60	2.87	2.30	1.43	1.15	1.02	0.92	0.72	0.46	$46/I_n$

(h) Type C miniature circuit-breakers to SS 359 and Type 3 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	3.83	2.30	1.44	1.15	0.72	0.57	0.46	0.36	0.23	$23/I_n$

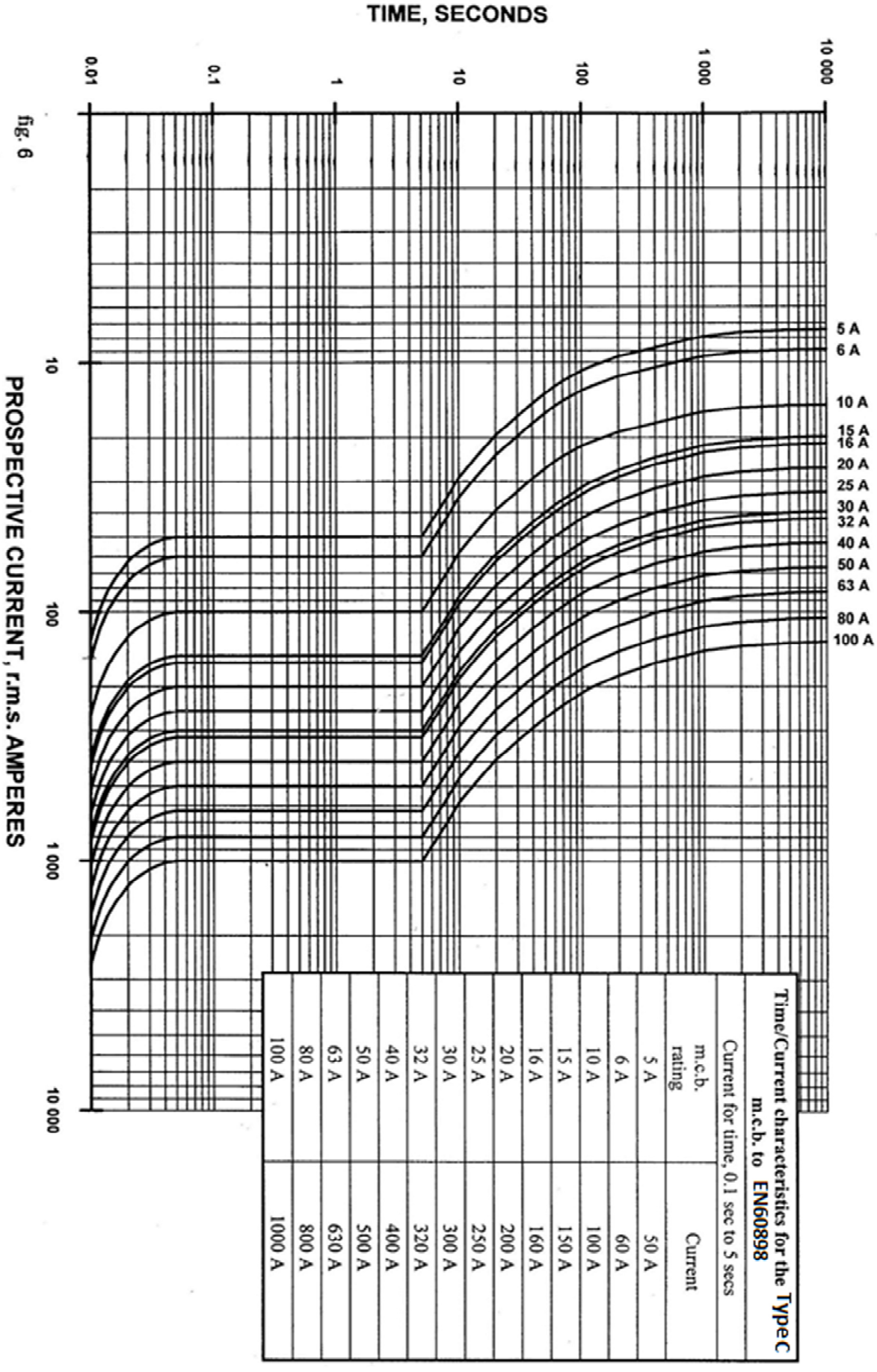

fig. 6

Time/Current characteristics for the Type C m.c.b. to EN60898

m.c.b. rating	Current for time, 0.1 sec to 5 secs
	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 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.